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Sea Cage Gateway - A Distributed Sensor Management Network in ActorFrame

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Master of Science in Communication Technology

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Problem Description

The Sea Cage Gateway (SCG) project is about remote management, administration, and surveillance of offshore fish-farming facilities. Each facility consists of many sea cages and, usually, an adhering feed barge. Several factors are changing in the traditional location for these facilities. Amongst these are the environmental threats that sea cages can pose for a delicate, coastal environment. When such installations are moved further offshore, the need for remote management will increase. A certain degree of autonomy and self-control is required by the sea cage installation. The basis for this will be the use of sensors connected to the sea cages which report in to a computational device on each sea cage and further towards land.

This thesis studies how sensors can be integrated into the system in a flexible and dynamic way. The system will require a variety of sensors and sensor data. Some examples of sensor data are temperature, current, position, sea cage status, light, etc. The analysis should consider these requirements. Furthermore, due to the isolated position of the sea cages combined with rough conditions, alternative communication links may be necessary. This must also be considered in the analysis.

The analysis should result in the design of a system-framework which connects all the elements of the SCG-domain together to perform the necessary tasks. If possible, principles from mobile grid and other comparable technologies shall be considered. The ActorFrame-framework shall be used to develop a demonstrator showing how a sensor (GPS-receiver) connected to a sea cage may be realized in the framework.

Assignment given: 13. March 2006
Supervisor: Rolv Bræk, ITEM

Summary

This master thesis has been written in connection with the ongoing Sea Cage Gateway (SCG) project, a project investigating the possibility of remotely administering fish farming facilities. These facilities consist of sea cages placed offshore and connected to the mainland through wireless communication technologies. The sea cages all contain a number of sensors optimizing production and increasing safety. Not only must this sensor data be read, it must also be transported, collected, interpreted, handled, saved and retrieved. In addition, it is necessary to provide backup communication links in case of failures in the main communication systems. The system should be as autonomous as possible, allowing it to be unmanned for longer periods of time.

This thesis has further investigated the possibility of remotely controlling and administering a fish farm through distributed nodes over wireless communication links. As a basis for this thesis domain descriptions from previous master theses written in connection with the SCG-project have been used. This thesis has also aimed to collect inspiration from other domains and concepts which have similarities with the SCG-project. With the increasing numbers of nodes and communication links present at the fish farm installations, areas such as grid computing and sensor networks have many applicable principles for the SCG-system. These principles have been integrated into the system design to give the basis for further such functionality in the SCG-domain.

In addition to the areas of grid computing and sensor networks, the current and latest wireless communication technologies available for providing the services required by the SCG-system have been presented. The communication links also influence the system design since their connection types must be handled by the SCG-system elements.

The SCG-system proposed has been designed and implemented with ActorFrame. The implemented system has functioned as a demonstrator for the main principles presented in the design. It has incorporated a GPS-receiver and a GPRS-modem to represent a sensor on a sea cage and a redundant communication link. The system implemented reports GPS-data to a central unit and issues alerts upon sensor data deviations (sea cage out of position). Furthermore, the demonstrator can detect a failed communication link and switch to the backup GPRS-modem, generate alarms, and continue to provide basic services. All elements and their status are reported and registered in a database and are presented through a dynamic web interface.

The demonstrator has shown that ActorFrame can be utilized to provide the necessary functionality the SCG-domain requires. A few improvements are proposed for the framework to increase the flexibility and performance of the system, especially in the area of handling the distribution of actors on independent nodes and how the heterogeneous network technologies present in SCG-system require a higher-level of network-awareness on behalf of the application. This thesis has also suggested several possible extensions and future areas of work.

Preface

This master thesis has been written for the Norwegian University of Science and Technology, Department of Telematics, in the period March 2006 to August 2006.

The basis for this thesis is the Sea Cage Gateway project. This project aims to examine the possibilities of wireless remote sensor administration of fish sea cages. These cages are to be placed further offshore than current practice is, thus creating new demands on surveillance principles and communication technologies. In addition, it is a goal to keep the elements as low cost as possible to secure maximum deployment and utilization for as many actors as possible.

This thesis has been an interesting and informative task. It has taken me through many fields of my education, and provided a perfect mix of both practical and theoretical elements.

I would like to thank my fellow students Frank Paaske and Jon Arne Grødal for much help and advice. I would also like to thank Geir Melby, Haldor Samset and Frank Kramer for always answering my questions. Furthermore, the World Cup and Tour de France deserve a mention for their many distratctions. Finally, I would like to thank my supervisors Rolv Bræk and Frode Flægstad for much understanding, help, patience and feedback throughout the duration of this thesis.

Trondheim, August 2006

Jens Askgaard

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Abbreviations

AJAX	Asynchronous Javascript and XML
API	Application Program Interface
BCS	Backup Communication System
CDMA	Code Division Multiple Access
CS	Control Station
CSS	Cascading Style Sheet
DOM	Document Object Model
ECS	Emergency Communication System
EDGE	Enhanced Data for GSM Evolution
FCS	Failure Communication System
FK	Foreign Key
GPRS	General Packet Radio System
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technology
IM	Instant Messaging
IP	Internet Protocol
IPv6	Internet Protocol version 6
JNI	Java Native Interface
JSP	Java Server Pages
LAN	Local Area Network
MAC	Media Access Control
MCS	Main Communication System
MS	Management Station
NAT	Network Address Translation
OS	Operating System
PCS	Primary Communication System
PHP	PHP: Hypertext Preprocessor
PK	Primary Key
PPP	Point-to-Point Protocol
SCG	Sea Cage Gateway
SCS	Sea Cage Station
SDL	Specification and Description Language
SMS	Short Message Service
SOAP	Simple Object Access Protocol
SQL	Structured Query Language
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
UDP	User Datagram Protocol
UML	Unified Modelling Language
UMTS	Universal Mobile Telecommunications system
WAP	Wireless Application Protocol
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WSDL	Web Services Description Language
XML	eXtensible Markup Language

"In pisciculture, as in every other form of extravagance, however, it was Lucullus who set the most dazzling standards of notoriety. His fishponds were universally acknowledged to be wonders, and scandals, of the age. To keep them supplied with salt water, he had tunnels driven through mountains; and to regulate the cooling effect of the tides, groynes built far out into the sea. The talents that had once been devoted to the service of the Republic could not have more spectacularly, or provocatively, squandered. "*Piscinarii*", Cicero called Lucullus and Horetensius – "fish fanciers". It was a word coined half in contempt and half in despair."

- excerpt from the Tom Holland book "Rubicon – The triumph and tragedy of the Roman Republic"

1. Introduction

In this chapter the background and motivation for this thesis are presented. In addition, the scope of the project, its assumptions and constraints, and an outline are given.

1.1. Background

This project is part of the Sea Cage Gateway project which is an ICT-system currently researching the possibilites for remote control, management, and monitoring of offshore installations in the aquaculture environment. This system is dependent on wireless technologies to provide the connections necessary. Due to changing and varying needs in the industry, the possibility of moving such installations from the safe harbours of fjords and near-coastal areas to offshore locations is currently being reviewed.

The advantages of relocating fish-farm installations offshore are many. Among these, one can mention factors such as larger-scale production, protection of vulnerable coastal areas, freeing up over-populated fjords, and the ability to install fish-farms in previously inaccessible areas. This project also focuses on making such technology as cheap and accessible as possible, allowing it to be utilized on smaller installations. The technology and design decisions keep this in mind, maintaining a focus on non-proprietary hardware and open-source software. Low introduction costs are hoped to make the technology easily accessible and enable many potential actors in the market.

What kinds of communication technology and system design principles are necessary to meet the requirements needed for such a venture?

A heightened awareness to the possibilities introduced by new technology could improve both production and add value and services to the entire value chain, giving an edge in a competitive market. Through the coordinated use of sensors and sensor data, production can be optimized and production costs could be reduced. An example of this is the amount of fish feed needed. Over-feeding results in both a waste of resources and is a source of pollution. In addition, making sensor-data available throughout the life-cycle of a fish, control and administration can be greatly improved.

The SCG-project incorporates a number of different areas. From the system principles and architecture itself, to the handling of data, to the utilization of the system nodes, to the communication technology required and so forth.

1.2. Scope

The focus area for this thesis is developing an architecture supporting the main principles required for the Sea Cage System. This architecture is to be implemented and demonstrated to show the principles in action. The design of the system should allow for later extensions and utilization. The technology available to provide the services will be briefly presented, but the demonstrator presented will be based on the available equipment. The resulting system will not be a fully-functional SCG-system, but provide a possible basis for the development of one, either through the use of concepts presented, or as a further development of the system itself.

The system is to be designed and implemented in the ActorFrame-framework, utilizing the Ramses tool suite where possible.

1.3. Assumptions and constraints

The basis for the system development in this thesis is the domain descriptions presented in the master theses "Sea Cage Gateway – Fish Farm Control Station" [1] and "Sea Cage Gateway - Management System" [2]. Issues such as reliability and security will not be explicitly explored; neither will the utilization of sensor data or context beyond that of the available sensor. This thesis does not consider context and utilization of sensor data, or how they should be administered. However, it does consider the need for such issues, and relevant suggestions are made.

The demonstrator is restricted to the equipment available. This equipment consists of three computers with varying characteristics, one GPRS-modem, and one GPS-receiver.

1.4. Project outline

In chapter 2, a brief introduction to the field of aquaculture is given and current trends and related technology are presented.
In chapter 3, the Sea Cage Gateway system is presented in its current status, and the domain that this thesis is based on is presented.
In chapter 4, sensors and sensor networks are presented. There are many similarities between sensor networks and webs which can improve and inspire the design of the SCG-system.
Chapter 5 presents grid computing and mobile grids. As with sensor networks, grid computing can provide inspiration for utilizing all elements available in the SCG-domain.
In chapter 6, the communication technologies currently available for handling the communication links of the system are presented and discussed.
Chapter 7 introduces the modelling framework that is to be used, and tools supporting this framework.
Chapter 8 presents the system design and functionality based on a domain analysis and the inspiration collected from the previous chapters.
Chapter 9 presents the hardware used for developing and testing the system. It describes how specific elements of the system have been implemented, and contains a summary of the tests conducted on the system. It also presents all the external elements which have been included to realize the design.
Chapter 10 summarizes the experiences from deployment, and discusses design decisions, possible extensions and features, and suggests areas of future work.
In chapter 11, a conclusion to this thesis is given.
Chapter 12 contains the references for this thesis.
In the following appendixes details of elements in the thesis are presented.

2. Aquaculture

Aquaculture[1] is the marine counterpart to agriculture. The principle is controlled breeding and harvesting of marine life. Although the concept of aquaculture is not novel, the field has undergone several major changes in the past decades. From being a fringe industry, often used in varying forms in underdeveloped countries, aquaculture has become an area of large social and economic focus. From feeding the world to maintaining the coastal culture, the possibilities available through aquaculture are many.

2.1. The history of aquaculture

The history of aquaculture goes back at least 4000 years. [3] Unlike agriculture, which has been the main source of food for generations and partially held responsible for the appearance of civilization, aquaculture has contributed far less to the overall food consume. Although the principle of rearing and harvesting fish and other aquatic food sources have been available for a considerable time, the industry has been more concerned with improving classic hunter/gatherer techniques to obtain food from the oceans. Reasons for why agriculture and aquaculture took such different paths are mentioned in [3]; among those is the apparent abundance of aquatic food combined with lacking knowledge of a foreign environment such as the marine one.

Recently the world demand for fish has superseded the amount available through traditional capture fishery. After experiencing a steadily growing demand after World War II, the production peeked in 2000 at 95 million tonnes. [3] Despite this, the available amount of fish, not inluding the production in China, has not changed much since the mid-1980s. This gap has to be covered through aquaculture fisheries, and a prognosis yields that fish production will equal, or surpass, traditional captures fishery production within the first quarter of the 21st century. [3]

In addition to responding to increasing demands for fish, fish production also offers a cheaper source of vital proteins for many groups of the human population. Proteins are a high-value source of nutrition not always easily accessible in under-developed areas.

2.2. Factors affecting aquaculture production

There are many variables affecting the efficiency of aquaculture and the amount of biomass that can be extracted. In Figure 2-1 the main elements and there co-dependencies are shown.

[1] Actually, in the SCG-domain the word pisciculture would be more accurate as this relates to the cultivation of fish. Aquaculture is a more general term, including all forms of marine life. Aquaculture will nonetheless be used for the remainder of this thesis.

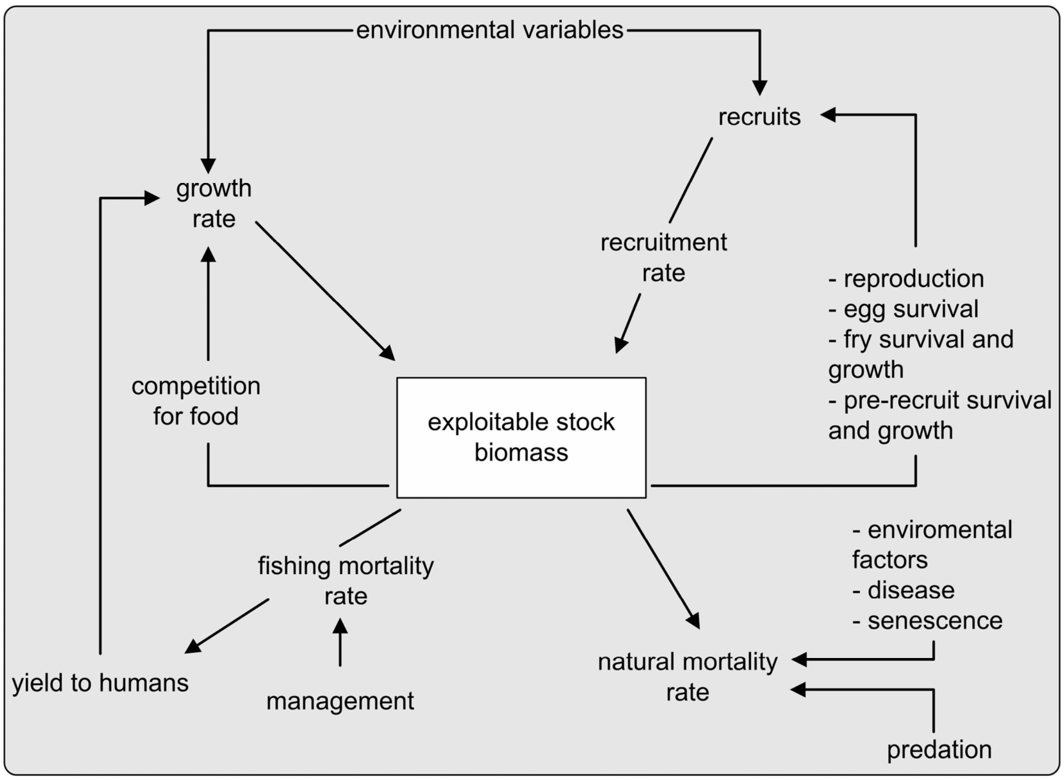


Figure 2-1: Factors affecting exploitable stock (redrawn and slightly modified from [3])

As shown, there are many factors affecting the efficiency of fish-stock rearing. From the fish are fry until they are ready for harvest, many growth environment conditions affect their development. Improving these conditions to maximize production is of great interest for the industries, and the use of sensor data and efficient exploitation of them could optimize breeding conditions.

2.3. Cage techniques

The initial goal of holding fish was to keep captured stock alive until it could be sold at the market. This was probably done through simple cages and fish traps. The actual culture of fish, where fish were kept for longer periods of time and gained weight have references back to the Han dynasty of China, almost 2200 years ago. [3] These cages consisted only of cloth with bamboo sticks for support. Since then several types of aquaculture facilities have been developed and defined. The most common types are:

- Enclosure is where the shoreline is the natural boundary on all sides but one.
- Pen is an enclosure where all sides of the structure are man-made, except the bottom.
- Cage is an enclosure where all sides of the structure are man-made, a floating device.

The most used in the context served in Norway, and in offshore locations, are cages. There are several sub-categories of cages, all with different capabilities. In Figure 2-2 a rigid sea cage is shown. Rigid sea cages are, as the name implies, a rigid construction. This gives great platform stability and easy access on onboard walkways for fish-farm personnel. Unfortunately, such construction can not withstand rough conditions due to their stiff design.

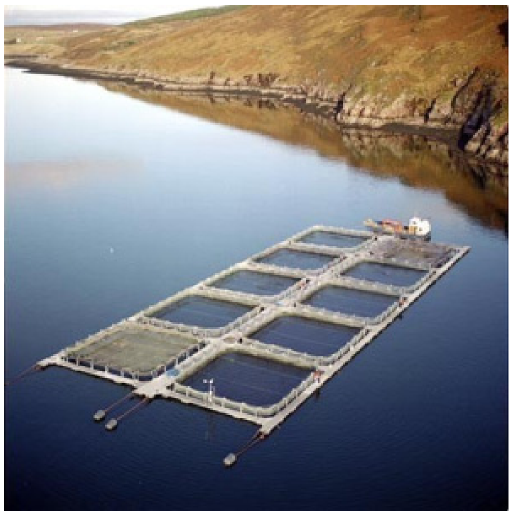


Figure 2-2: A rigid sea cage [4]

A flexible sea cage is shown in Figure 2-3. As shown, these constructions differ in many ways from the rigid design. There is a lack of personnel access, and the construction is not stable. Although this reduces user-accessibility, there are many advantages with this form of design, and it is the most common construction used.

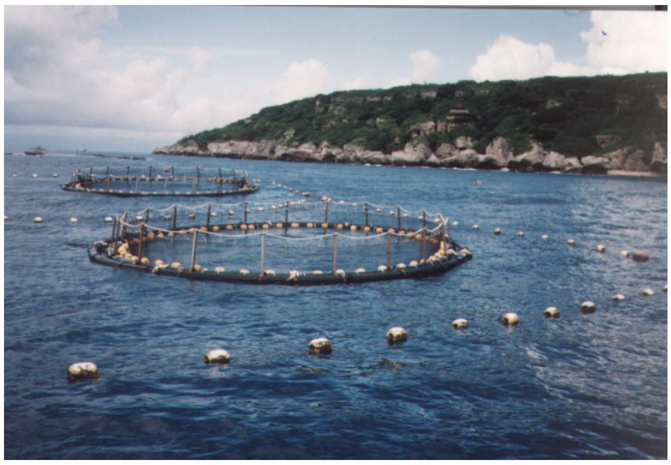


Figure 2-3: A flexible sea cage [5]

The flexibility of the design enable the construction to withstand rough conditions, conditions often experienced in the offshore waters of coastal Norway. The construction is also lightweight and cheap. These factors affect both the economic side, but also allow for simpler logistics and delivery in isolated areas.

Sea cages also vary between being a floating cage or submersible. As the name implies, a submersible cage is enclosed in all directions and can be sunk below the seas surface when needed. This can be an advantage during rough conditions, protecting the cage itself, the environment and its contents.

Sea cages are provided feed through the use of feed barges spraying food into the enclosure at regular intervals, or through fixed pipes mounted to the cages attached to a central feed unit. A mobile feed barge is shown in Figure 2-4.

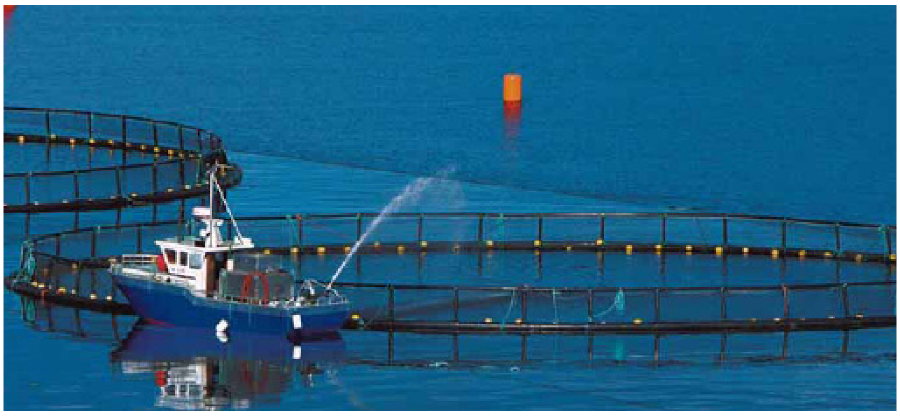


Figure 2-4: A mobile feed barge by a sea cage [6]

Although sea cages present a good way of rearing fish, there are problems related to their use. Among the factors that can be considered problematic for sea cages are currents, the spread of disease in a confined area, vulnerability to drifting objects, fouling and wastes from fish and feed, exposure to weather and climate, ice, light, predators/scavengers, etc. They also occupy large areas of attractive coastal areas, may alter the behaviour of local animals, and can contribute to the spreading of sea lice.

2.4. Aquaculture in the future

As previously mentioned there are several changes occurring within the aquaculture industry. Previously, when production was relatively low, the rearing facilities were few and far between. With an increase of production these facilities increased in both size and numbers, moving from inland facilities to coastal. This represents a challenge for the environments currently supporting aquaculture instalments. Not only will there not be enough room in calm coastal waters, but the pressure on the local environment will be large, depleting the conditions for not only the reared fish but also other species dependent on the local conditions. Pollution and waste from fish farms have already been mentioned. Larger-scale aquaculture production may also aid to relieve pressure on over-fished populations/species, i.e. cod. With offshore production facilities these factors can be relieved due to stronger currents, deeper waters and space, allowing for problems experienced in coastal areas to be naturally reduced.

As a curiosity, another motivation for enabling systems for fish-farming offshore is available in the United States of America. Here each state controls the sea out to five miles offshore. Beyond this border, restrictions are fewer and the local authorities' power is reduced, making it a very attractive area for producers. [7] This may not be the most ethical reason for pursuing such a system, but it is a potential market nonetheless.

2.5. New demands from markets

With increasing focus on origin and quality of food products, new demands have appeared for suppliers. Not only is price the main focus for the consumer, but traceability and ecological production also influence the choice of product. This requires efficient logging of all aspects of the aquatic products life-cycle, from the origin of the fry, to conditions experienced during rearing, to methods used for cultivation, etc. By efficiently logging the same factors used to optimize production and providing traceability of fish back to a certain cage, it enables a consumer or supplier to see what conditions the product has experienced. So the information collected by sensors need not only be beneficiary to the producer, but also to the market, consumer, and in research.

2.6. Current related technology used in aquaculture and aquatic environments

There currently exist systems for monitoring fish farms and sensors specifically designed for the purpose. A large actor in the fish-farm technology market is AKVAsmart. [8] They offer monitoring and data analysis equipment in addition to the sensors themselves. These systems are proprietary, and do not incorporate wireless technologies for long-distance remote-control and administration of fish farms. AKVAsmart are involved with the SCG-project with the intent to incorporate such technology into their current product portfolio.

Another system using many of the same components is the SeaWatch-system. [9] The SeaWatch-system incorporates many similar functions, only their focus is more on marine conditions in general, rather than a sea cage specific application area. A system overview is shown in Figure 2-5.

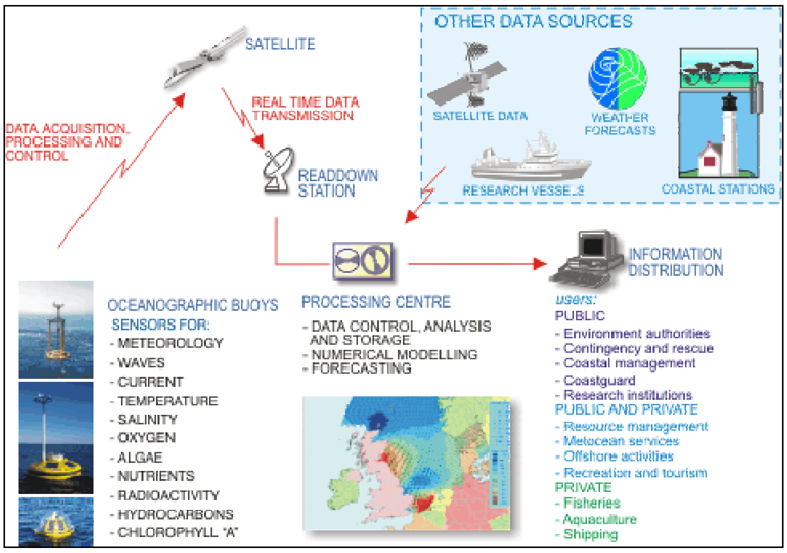


Figure 2-5: The SeaWatch system overview [9]

SeaWatch is an international marine surveillance and warning system, and collects both oceanographic and metrological data. The concept of sensor data and networks connected to autonomous systems with self-contained power supplies provides many of the same basic functions that the SCG-system will need and include. The system uses satellite communication for its remote operations, whilst utilizing cable and telephone lines for communication with fixed-locations installations.

An application area for the SCG-system is the detection of drifting cages via GPS. Projects aiming at remotely determining fish cage positions, and identifying drifting cages have been conducted. An example is the use of Radarsat F5 (radar images) for detecting and positioning fish cages. [10] As an alternative to satellite imagery, radar images are not hampered by bad weather or cloudy conditions. The radar images used are shown in Figure 2-6.

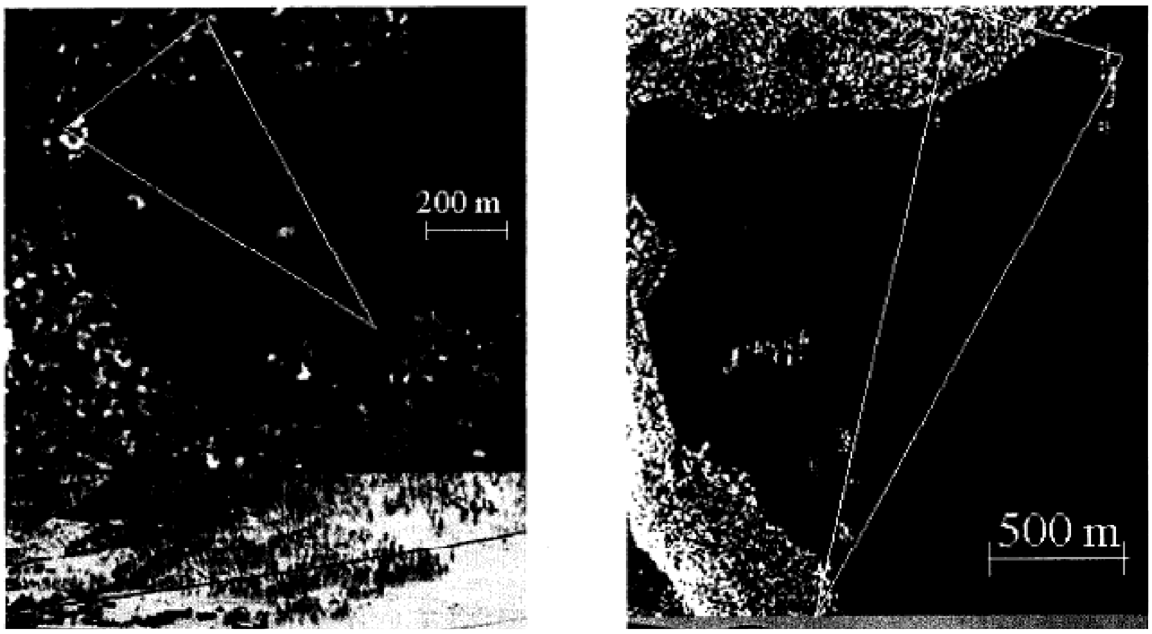


Figure 2-6: Radar images used for detecting and positioning fish cages [10]

Although the results of this project concluded that this technique did allow for the detection and positioning of fish cages, it is a somewhat extensive process. This can probably easily be replaced by installing GPS-recivers with adequate monitoring systems on sea cages as part of the SCG-system.

3. The Sea Cage Gateway project

The Sea Cage Gateway is a project researching how to best control and administrate offshore and remote fish-farming facilities. The focus of the project is the use of wireless communication technologies to provide a flexible and adaptable framework for developing and implementing services for the system.

3.1. Domain description

In [1] a domain description has been provided as a basis for the system architecture. The main components of the Sea Cage Gateway system have been defined as three main nodes, sensors, and four alternative communication schemes. A high-level overview is given in Figure 3-1.

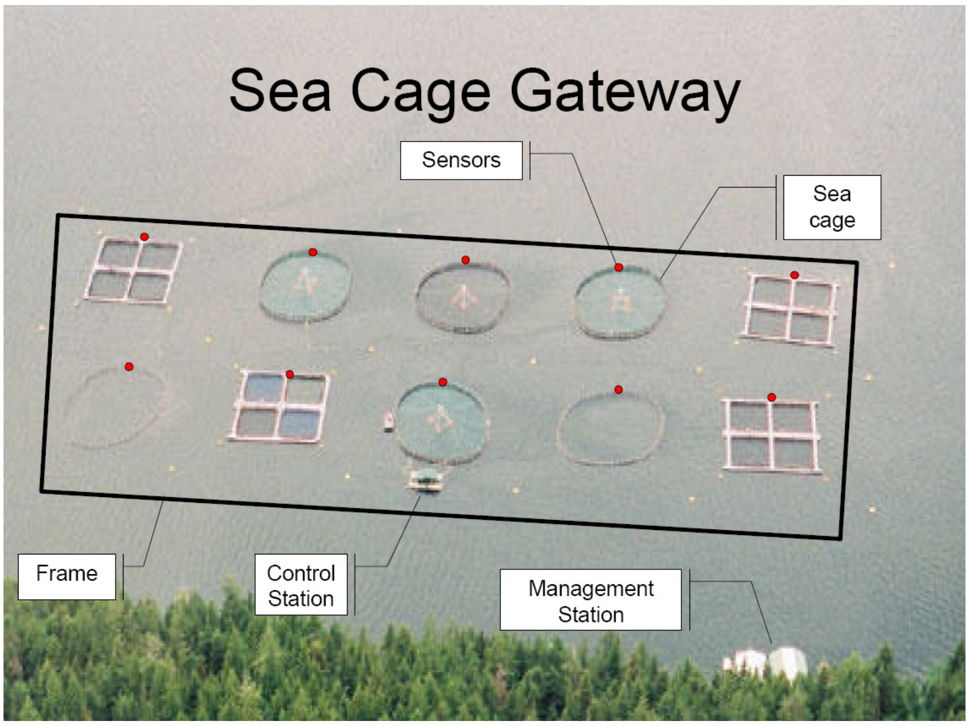


Figure 3-1: An overview of the Sea Cage Gateway-system elements [1]

The main features are shown and described in Table 3-1.

Table 3-1: The elements of the Sea Cage Gateway system

Feature	Description
Management station (MS)	The management station is the land-based administrative station for all control stations. All information collected by the elements in the Sea Cage Gateway system are handled and distributed by the management station.
Control Station (CS)	The control station is the controlling agent of all the sea cages in a single frame. The control station administers the sea cages, represents the frame in the system and provides, amongst other services, the feed necessary for the fish. Sensors may be attached to

	the control station.
Frame	The frame is a boundary around the sea cages, and keeps the cages together whilst yielding some protection against the elements. A frame contains up to ten sea cages all which reside under the same control station.
Sea cage station (SCS)	The Sea Cage station is the node directly attached to each individual sea cage. Each sea cage controls and administers the sensors connected to it, and reports sensor data and deviating values to the rest of the system.
Sensors	Sensors form the basis of the system. All sea cages consist of a basic array of sensors in addition to specialized sensors which are distributed among each farm. Sensors are used to collect information for both optimizing breeding conditions, in addition to surveillance and control of the sea cage status.

The size of a frame is minimum 500 x 200 metres, which gives a sense of the range communications will have to traverse. [1]

In addition to the nodes of the system, a wireless communication scheme has been developed. It consists of two primary broadband communication links, the Primary Communication System (PCS) and the Main Communication System (MCS), combined with two narrowband backup systems, named as the Emergency Communication System and the Failure Communication System (ECS and FCS). These elements are shown in Figure 3-2.

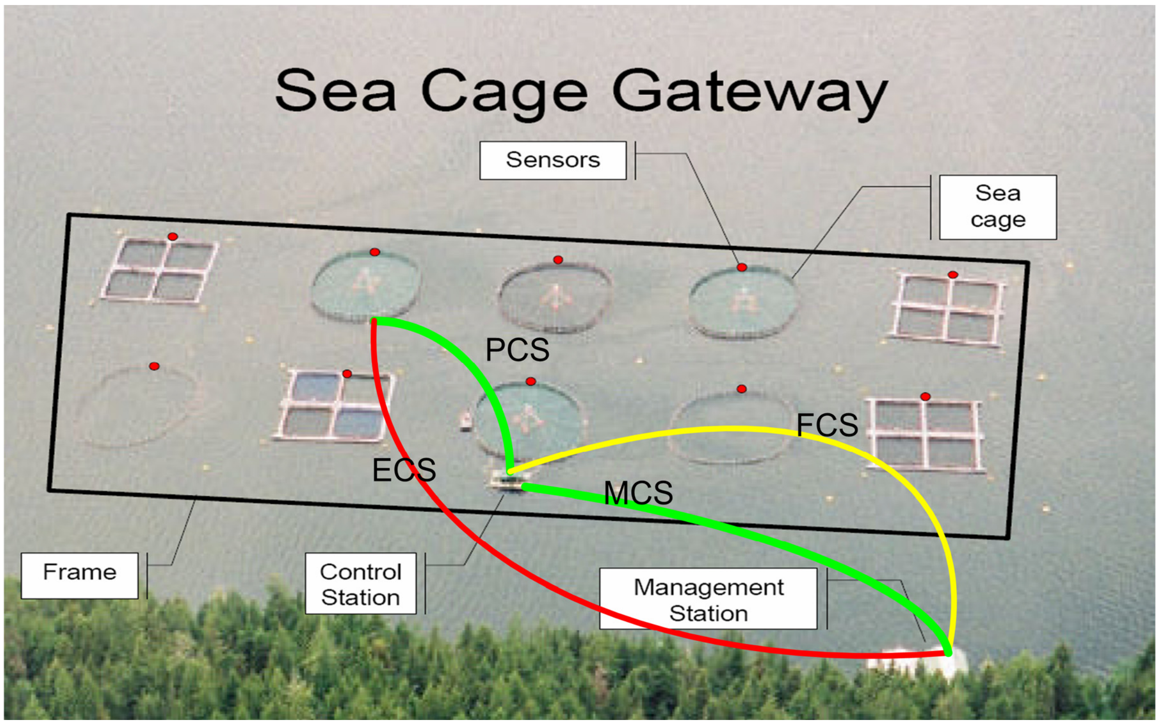


Figure 3-2: Communication schemes of the Sea Cage Gateway

The features of the communication schemes are shown in Table 3-2.

Table 3-2: The proposed communication links of the Sea Cage Gateway System

Communication link	Description
Main Communication System (MCS)	The MCS is the primary broadband communication technology connecting the CS to the MS.
Primary Communication System (PCS)	The PCS is the primary broadband communication technology connecting the SCS to the MS.
Failure Communication System (FCS)	The FCS is a backup narrowband communication technology which goal is to maintain communications between the MS and CS in the event of a MCS failure. This technology should provide other characteristics then the MCS technology.
Emergency Communication System (ECS)	The ECS is a backup communication system which provides communication in the event of a failure in the PCS between the SCS and CS. It also provides a backup in the event of a complete communications failure in SCG, which is a complete failure of both the FCS and PCS.

Since the backup communication schemes have different characteristics than the primary communication technology, an extra redundancy is implemented in the system. However, this also implies that the information flow sent in the two cases cannot be the same. In the event of a primary link failure the system must detect this, and adjust the data distributed to the available communication technology. An example of this is if the ECS is the current communication link. In this case all other communication links are down, implying an urgent need for repairs in the system. In addition, only critical information should be broadcast over this backup link, for instance large deviations in the position of the sea cage. Such deviations may indicate a possible moorage breaking.

3.1.1. Scenario

To form a basis for the system to be developed and to base some functional requirements and design objectives on, a simple scenario has been defined. These are based on the domains descriptions provided in [1] and have been supplemented with the initial desired setup of such a system.

With the new low-cost SCG-system Nils Nilsen has decided to invest his life savings into a fish farm of his own. In his remote coastal community times are hard, and jobs even harder to come by. FishFarmAS[2] already provide the MS[3]-node necessary for superior administration of the system. This means that he only needs to invest in the

[2] This element could also have been provided by the owner himself. It is just to show that automatic sevice-configuration allows for many actors to be part of the SCG-domain.
[3] For the remainder of this thesis the physical entity of a system element will be referred to by its abbreviation, sometimes followed by –node. To improve readability the –node appendage will not always be used.

CS-node, frame, and SCS-nodes, in addition to providing a land-link and sea-link for wireless communication.

After placing the nodes in their designated position the system is initiated. Upon initiation, the CS automatically registers with the MS, and the MS-node automatically assigns the resources necessary for administering this node, and sends the data the CS-node needs to function optimally under current conditions. Furthermore, when each corresponding SCS-node is connected, these also automatically register with the CS-node, and receive correct operating parameters if necessary. The CS automatically updates the MS with its new capabilities. Sensors which are subsequently connected to each SCS are also automatically detected, reported and initiated for use.

Since the system is largely autonomous, the CS needs only to be manned for a few hours every day. Otherwise the system controls itself, either through self-management, or through parameters sent from shore. When a SCS detects that it is out of its default position an alarm is issued so personnel can be sent to investigate. The boundaries for this are shown in Figure 3-3.

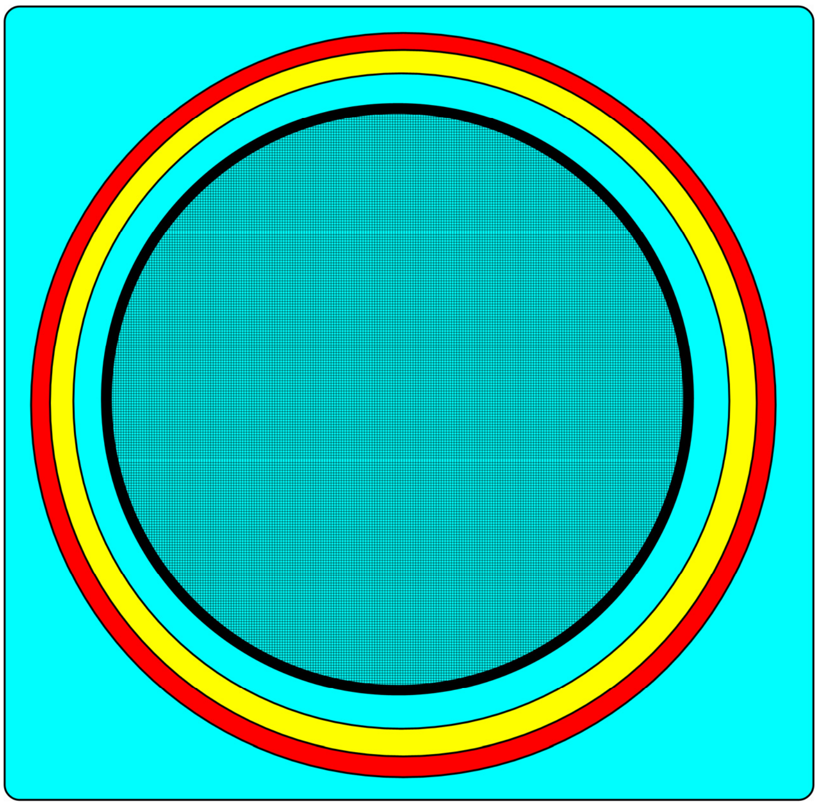


Figure 3-3: The drifting boundaries for a sea cage

The sea cage is represented by the meshed circle in the middle. The yellow boundary indicates a boundary where a considerable strain on the moorings is necessary to achieve such a position. Within the yellow boundary is the natural position of the sea cage, where room to move with the current and tide has been given. Finally, the red boundary indicates that one or more moorings have broken, and that there is a possibility of the cage being adrift. The boundaries will have to be adjusted to the positioning of the GPS-receiver on the sea cage as it is unlikely that the receiver will be mounted in the centre. The alarm generated may take many forms and several could be used at once. This could be e-mail, SMS, call-up function, WAP-Push, application alarm, to mention a few.

In the event of a communication failure, the system will detects and handle the break, and gives an alarm so a maintenance crew can be sent. Meanwhile, the system continues to operate and monitor the fish farm taking into the consideration the new situation the SCS-node is in.

The main keywords are self-configuration, ease-of-use, autonomy, sensor handling, self-monitoring, and fault-tolerance.

3.2. Previous work on the SCG

As mentioned, there have been projects concerning the SCG-system previously. These have explored and described the domain in question, and demonstrated some possible functions. [1] proposed, and used, a client-server architecture between the nodes and utilized Web Services for providing GPS-data reporting and handling. Another project has considered the use of a context-manager for handling aquaculture sensor data to a maximum degree, the so-called FiFaMos-project. [11]

4. Sensors

The main building blocks of the SCG-system are the sensors mounted on the sea cages and control station. These sensors provide the data for optimization of production and provide the information necessary for security and maintenance services. Handling the different sensors to perform the tasks required is a crucial goal for a SCG-system. In addition, the type of sensors used on an installation must be power-optimized, reliable, and robust enough to withstand the rough conditions experienced in an offshore environment.

4.1. Sensor types

There are many different types of sensors available, all with varying detection methods and sensor interfaces. The type of sensors can be optical, acoustic, thermal, chemical, mechanical, electromagnetic, etc. The means of sensor data transmission can be continuous or discrete, digital or analogue, and can require continuous monitoring or can be handled with an interval-based polling technique. Sensors may have some of the resources necessary to process some data or allow for a certain degree of configuration, whilst others simply transmit a raw stream of measurements. In general, sensors do not parse or log data, but simply read them and supply them to a proxy for handling. [12] The proxy is generally the machine the sensor has been connected to, and one proxy will likely administer multiple sensors.

In general, limited resources capability is an attribute to almost all sensors. This adheres to processing power, memory, bandwidth limitation, and above all battery capacity. Battery capacity is the limit to which all other limits succumb, with bandwidth being the largest consumer of energy.

4.2. Sensors related to aquaculture

Sensors available for aquaculture are many, and are currently increasing. The need for all of these sensors may not be necessary, but support for the majority should be provided. Some of these sensors may only be needed on a simple SCS in a frame, and this information then can apply for all SCS-nodes local to that frame.

[3] lists the following areas as of interest for utilizing sensors to detect the required parameters; weather, current, temperature, salinity, oxygen, algae, nutrients, biosensors, radioactivity, heavy metals, hydrocarbons, pH. In addition, sensors monitoring the equipment in use, the food consumption and current position of the sea cage can provide the functionality and support required. Many of these sensors can be related to the factors influencing the exploitable stock, as shown in Figure 2-1.

Several of these sensors are available from AKVAsmart [8], and a selection of their assortment is displayed in the subsequent figures.

The AkvaSensor camera shown in Figure 4-1 is a camera for visually monitoring the sea cage stock. The camera is adjustable for both depth and position, and provides high-resolution video for fish and feed surveillance. [13]

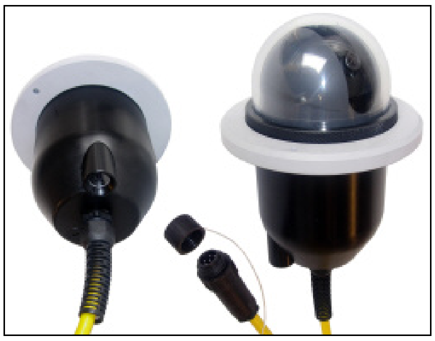


Figure 4-1: The AKVAsmart AkvaSensor Camera - SmartEye [13]

The AkvaSensor Biomass Estimator equipment is shown in Figure 4-2. This system utilizes camera images to estimate the biomass in the sea cage based on biomass distribution knowledge. [14]

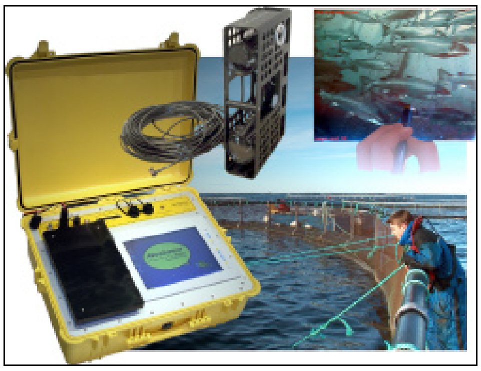


Figure 4-2: The AKVAsmart AkvaSensor Vicass Biomass Estimator [14]

The AkvaSensor Oxygen equipment is shown in Figure 4-3. This sensor is used to monitor oxygen conditions in the sea cage. [15]

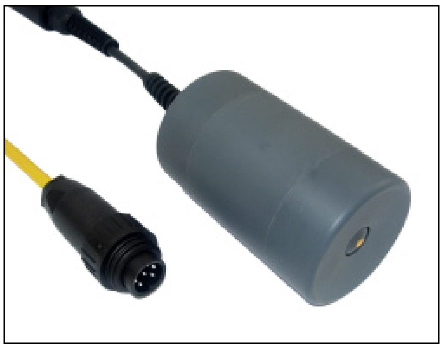


Figure 4-3: The AKVAsmart AkvaSensor Oxygen [15]

There are, of course, many other sensors and producers of equipment. This is just meant as an introduction to the variety of sensors a SCG-system must be able to incorporate and utilize to their full potential.

4.3. Sensor networks

A sensor network is a computer network consisting of many distributed sensors all registering and reporting data, either to each other or to a centralized computing unit. A sensor network consists of three elementary parts; sensing, communication and computation. [16]

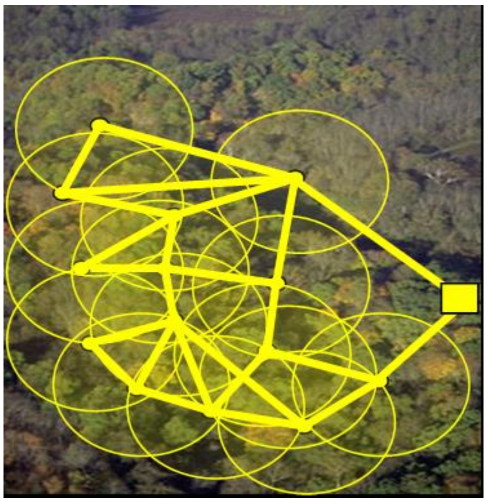


Figure 4-4: A sensor network [17]

Sensor networks are currently being utilized in several application areas, such as traffic surveillance, air traffic control, cars, robotics and environmental monitoring. Their application domain is steadily increasing, mostly due to the constant development of cheap, low-energy, high-capability sensors.

There are many challenges concerning the use and deployment of sensor networks. The limiting factors of a sensor network are energy-conservation, limited computational and memory resources, and bandwidth requirements. In light of these issues several types of sensor networks are implemented, with three main categories; proactive, reactive and hybrid. [18] Note that these sensor networks are assumed to be made up of homogeneous sensors. Although this is not the case for the SCG-system, which will incorporate many different sensors, the theory of sensor handling still applies.

- *Proactive*

  In a proactive sensor network, sensors sense and send their data at pre-determined intervals of time. These sensor networks are often used in areas were periodic examination is the area of interest. The interval between transmissions can be manipulated according to needs. A longer interval will translate into fewer transmissions and lower power use. However, the information density will be correspondingly poorer. With a shorter polling interval, the power consumption will increase, but so will the information amount retrieved. [18]

  This type of sensor data attainment could be of interest for several sensors on the SCG-system, especially sensors used to analyze environment variables such as temperature conditions.

- *Reactive*
  In a reactive sensor network, sensor nodes continuously/periodically sense the environment and transmit only information when threshold values are violated. If the sensor data does not incriminate the pre-defined threshold values no information is transmitted. A drawback is that sensor values are unknown if no threshold value is broken. This method saves battery by not transmitting information regularly, but leads to an unknown status of environment in which the sensor is operating. [18]

  Such a function could be of interest for the GPS-positioning sensor, since the position is not of interest unless the sea cage positioning data is indicating that the sea cage is drifting.

- *Hybrid*
  A hybrid sensor network incorporates elements from both the reactive and the proactive realms. In this form the network polls information regularly, but at a lower frequency then common in a proactive sensor network. The hybrid network, however, also transmits data when threshold values are exceeded. This adds flexibility to the system and incorporates the best of the other sensor network types. Values such as polling intervals, threshold values and parameters can all be adjusted to suit the area of application. However, this network form is more complex, and requires more processing and bandwidth resources, with a corresponding increase of battery power use. [18]

  This type of sensor network is very versatile, allowing for both regular logging of sensor data, whilst assurance is given that abnormal values are immediately reported when detected. For the SCG-system this scheme could be applied to several sensors, especially those monitoring environment variables which can be met with counter-measures. An example of this could be a sensor monitoring the algae-levels in the sea-cage. A complete log of the algae-levels in the cage could be desirable for research purposes, but simultaneously, immediate notification of hazardous levels is necessary in order to handle the situation.

Choosing how to handle the sensors of the SCG-system depends on several factors. What are the real-time requirements of the variable being monitored? Is it time-critical or non-time critical? What type of information is being monitored? What kind variable is being monitored? Is the sensor attaining the values for a log, for a control function, or both? Does battery consumption come second to attaining as much data as possible?

4.3.1. Mobile ad-hoc sensor networks

An extension of the standard sensor network is the mobile ad-hoc sensor network. They are characterized by a dynamic topology and wireless communication, and addresses how this affects sensor-handling and routing decisions. [19] The ad-hoc connecting of sensors in a SCG-gateway environment is beyond the scope of this thesis, but issues within mobile-ad-hoc sensor networks can be applicable to the domain in question. The main challenges with low-energy sensors in ad-hoc wireless networks are mainly the same as in sensor networks; energy-conservation, limited computational and memory resources, and bandwidth requirements. In addition, mobile ad-hoc sensor networks must handle wireless communication within a dynamic topology.

One area of research is the data-link layer utilized in a mobile ad-hoc sensor network. Focus is on using contention-free protocols, such as TDMA, to reduce power consumption at sensor-nodes. [19] The range a node transmits its data can also be adjusted; ensuring that the node does not exaggerate the distance it sends its information, thus preserving energy. Another focus area is balancing the trade-off between sensor computations on data, or sending data to another node for computation. The main power drain for a wireless sensor node is the transmission of data, so in some cases a few extra cycles of the CPU uses far less energy then transmitting the data. It is also less energy intensive to receive a wireless transmission than to broadcast one. [18]

For the SCG-system this can provide some guidelines. Although the data-link layer used is not part of this thesis, avoiding contention to the wireless medium could to a degree be handled by the application. By querying, for instance, the individual SCS one at a time in a round-robin fashion for reports contention for the wireless medium is avoided, thus reducing interference. However, signals should still be sent when reporting incriminated threshold values.

The routing theories of mobile ad-hoc sensor networks could be of interest for handling inter-node communication protocols between individual SCS-nodes, but this is beyond the scope of this thesis.

4.3.2. Sensor Webs

An extension of the mobile ad-hoc sensor networks, a sensor web incorporates more functionality in the sensor network, mobile or fixed. A sensor web, as defined by NASA, "*consists of a system of intra-communicating, spatially distributed sensor pods that can be deployed to monitor and explore new environment*". [20]

A sensor web can consist of several sensors and platforms, these can be orbital (remember, this is NASA's definition), terrestrial, fixed or mobile. This is shown in Figure 4-5.

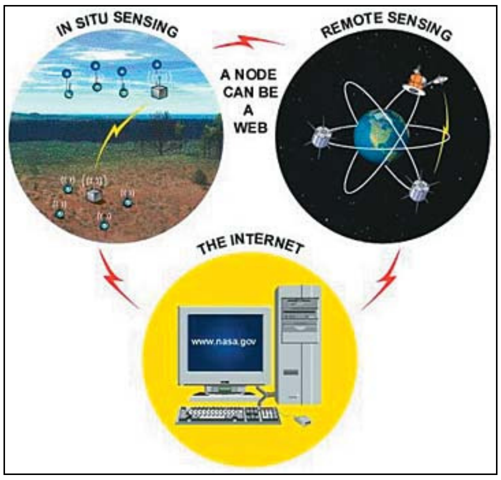


Figure 4-5: The generalized concept of sensor web [21]

The ability to create functioning sensor webs are due to the continuing progress of high-performance, low-cost mobile sensor units.

Information collected by sensors are not simply sent to end users, but propagated through the sensor web to all other integrated nodes. This sharing of information is the source of the rich functionality achieved in a sensor web. The web itself is one of the end users of the sensor web. Information collected and utilized by the sensor web enables dynamic and efficient sensor configuration, sensor web management, and adaptability.

For the SCG-system this could be of interest in many areas. If one node registers an increase in wind speed beyond the normal values, it can alert the other SCS-nodes of this, and these could increase the polling frequency on the GPS-position since the weather is expected to worsen. Or an increase in algae-levels could cause all SCS-nodes to increase the frequency of reading these sensors. This can also work the other way around by reducing the polling frequency of a GPS-reciever when conditions are calm, saving battery power. Taking it a step further, this could handle sensor loads and configuration by adding context and load information. [12]

4.4. Utilization and distribution of sensor information

The vast amount of sensor information standing to be acquired through the wide-spread use of a system such as the SCG-system can be of use for many parties beyond the fish farm company itself. Such factors can affect what type of data could be of interest, and influence the way the sensors are set up, both in regard to the information retrieved and the way it is handled.

Some interested parties and their possible areas of interest are listed in Table 4-1. [3]

Table 4-1: Interested parties in sensor data from the SCG-system

Party	Area of interest
Public authorities	Authorities could follow-up on legal restrictions and laws on fish food production and quality.
Consumers	Consumers who are ecologically aware could be interested in

	tracking their fish-product to its origin and receive data on the conditions experience by their product.
Aquaculture	The aquaculture industry in general could collect and utilize sensor data for research and development.
Commercial fishing	Could utilize sensor data on conditions in the offshore ocean areas.
Tourist industry	Weather conditions.
Research institutes	Oceanographic studies
Navy coastguard	Enforcement, security, rescues.
Offshore industry	Safety
Ship traffic	Safety. Constant updates to onboard GPS-map with the current position of sea cages, or generating drifting sea cage alerts could help avoid accidents.

The sensor data collected could be made available to many institutions listed in the table above and provides a valuable basis for research and testing, in addition to administrating and optimizing the fish farm production. As an example, the onboard GPS-map systems of large vessels can be automatically updated on the presence of new sea cages in addition to the position of previously deployed cages.

5. Grid computing

With constantly increasing bandwidth, capacity, and connected nodes, the border between remote and local entities are becoming blurred. The possibility of accessing other resources on a network has led to the development of new techniques and architectures, utilizing the availability of processing power and storage capacity. This is often referred to as grid computing. There are many different definitions of what grid computing really is. One definition is given by [22]:

"Grid is a type of parallel and distributed system that enables the sharing, selection, and aggregation of geographically distributed "autonomous" resources dynamically at runtime depending on their availability, capability, performance, cost, and users' quality-of-service requirements."

The utilization of resources connected to a network has been exploited in several projects over the last decade, taking advantaged of unused capacity present on idle connections. Large, complex tasks are split into small, independent work tasks, and are distributed among the participants of the grid. This has been used to compute results on protein folding, financial modelling, earthquake simulation, and climate and environment analysis. [23]

A vision of the future of grid computing draws parallels to today's power grids, an inspiration which actually coined the term. Electricity is a readily available product to an almost ubiquitous degree, and factors such as point of origin, production and transportation methods are completely transparent to the user. The final product, however, is a commodity. Such is the vision for processing and storage resources. In addition, utilizing the enormous amount of latent processing power for research is an area of many opportunities. One could eventually see all connected computer resources as one enormous virtual computer with virtually unlimited processing power and resources.

For the SCG-system such visions are far off. However, grid principles can be included as to increase the power of the implemented architecture. The SCG-system will be comprised of many sensors and many computer nodes. These elements vary in characteristics and power. If the combined resources of these resources could be tapped, the SCG-system could become even more autonomous. Although there are many issues to be handled in order to utilize the resources of a distributed system, the system design should provide a basis for providing such functionality. By building a hierarchy of increasingly more powerful computer nodes, whilst making all nodes aware of all other nodes, the building blocks for distributing and requesting resources from others are laid. All nodes should have the knowledge and capability to communicate with other nodes.

Grid computing also introduces other issues which must be attended to, such as scheduling, and software and consistency management, but this is beyond the scope of this thesis.

5.1. Mobile Grid

Since the introduction of grid computing the network technology has been constantly changing and improving. This has lead to two major changes. The first is the dimension of mobility introduced by wireless communication; the other is the abundance of heterogeneous communication links. Furthermore, the introduction of small, handheld devices, such as the PDA and the smart phone, represent terminals which can really appreciate the services of grid computing. Previously, the environments for grid computing were considered relatively homogenous, stable and centralized to a certain degree. [24] Now, even a low-end mobile phone provides at least GSM and GPRS, often Bluetooth and IrDA, and increasingly more common, 3G and WLAN.

With the advent of these new technologies, the extended grid, the mobile grid, poses many challenges. The wireless communication technology is currently unreliable compared to fixed links. The resources of the new wave of mobile terminals are very limited compared to the standard desktop-computer. Applications aiming at utilizing grid principles on mobile terminals must be able to handle heterogeneous network connections with varying characteristics, different types of mobile terminal, network disconnections, and be conscious of power consumption and battery levels. [24] In other words applications must be terminal-aware, network connection-aware, and power-aware.

This has many parallels to the conditions the SCG-system will experience. The SCS-nodes have limited resources, both processing- and power-wise, the communication links of the system can be of several types and characteristics, disconnections will probably occur, mobile nodes can be introduced and there can be different operating systems and different computers implemented on nodes. All these elements must be considered and attended to, meaning that the system must be aware and take advantage of them.

6. Communication technologies

In this chapter a variety of the possible communication technologies for enabling communication among the nodes in the system are presented.

UMTS is not considered as it does not have, and will not likely achieve, the coverage necessary to offer the connections required. Although EDGE only requires an update to current base stations, and thus in theory has the same potential coverage as GPRS, current coverage is still poor and it is therefore not included.

GPRS, WLAN and WiMax are presented in [1] and [2], but satellite communication, CDMA450, and VHF-Data are not. To set these technologies up against each other all of them are presented here.

Bluetooth and ZigBee are also presented in this section. These are not alternatives for the communication links presented earlier, but represent communication technologies which can incorporate other functionality relative to the SCG-system.

6.1. GPRS

GPRS (General Packet Radio Service) is considered a 2.5G (G for Generation) technology with GSM being 2G, and the aforementioned UMTS being 3G. To use GPRS a mobile terminal or modem supporting it is required, and an operator subscription including GPRS is necessary. GPRS provides data rates of up towards 160 Kb/s, and the coverage map for Telenor GPRS in Norway is shown in Figure 6-1.

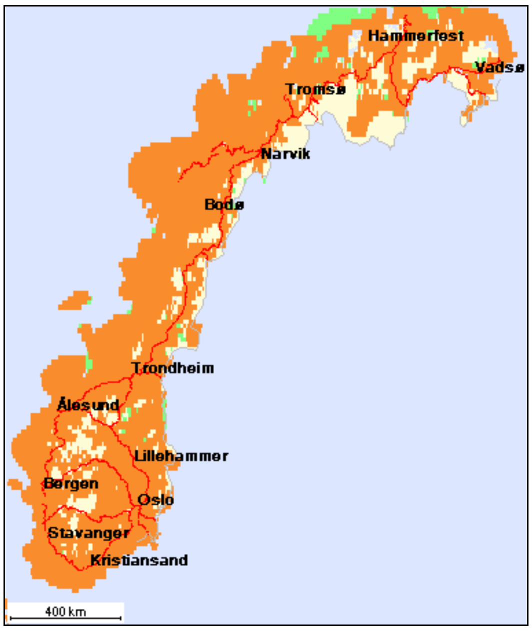


Figure 6-1: Coverage map for Telenor GPRS [25]

As can be seen, GPRS does cover many near-coastal areas (the orange areas), and in certain areas it also covers offshore areas, enabling the technology to be implemented at certain locations. GPRS operates on restricted frequencies and requires locally installed infrastructure. An improvement over the traditional GSM-data is that GPRS is packet-based and payment is for the data sent, not the time connected.

In the SCG-system, GPRS is an alternative for the narrowband ECS and FCS communication links. The stability and latency of a GPRS-connection can be varying and pose a challenge for the application.

6.2. CDMA450

CDMA450 is a new technology utilizing the old NMT-network in Scandinavia, and is provided by ICE AS in Norway. [26] This service has just recently been opened for public and commercial use, and provides services such as mobile and portable broadband to remote districts where such services have previously been unavailable. Due to the lower radio frequency used by this technology, the coverage is equal to, or greater than, other comparable technologies, and the data rate is larger. The coverage provided with the portable broadband modem is shown in Figure 6-2, and provides a theoretical maximum capacity of up towards 2 Mbit/s.

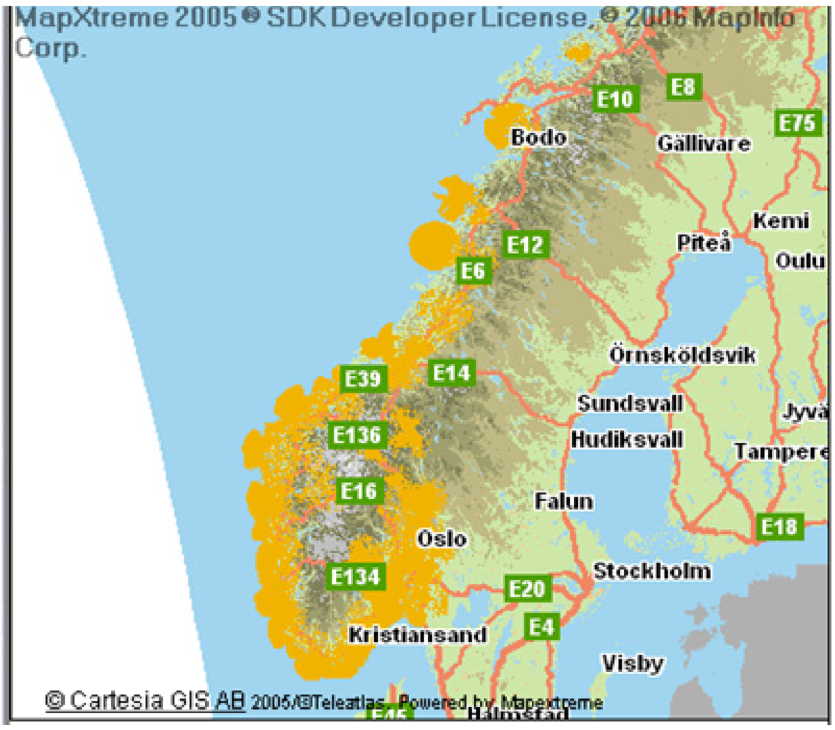


Figure 6-2: Coverage map for CDMA450 for the portable broadband modem [27]

Although the initial data rate is larger than for instance GPRS/EDGE, the capacity is reduced when there are many simultaneous users connected to the same access point. As with GPRS, CDMA450 uses licensed frequencies, and require a vendor-delivered infrastructure. In addition, the current payment model only allows up to 2GB of data transmissions per month. [26]

CDMA450 could primarily be considered for the ECS and FCS, but with the data rate offered, it could also function as a PCS or MCS. This is dependent on the amount of data transferred on the communication link, an amount currently difficult to predict without further study.

6.3. WLAN

WLAN is an abbreviation for "Wireless Local Area Network", and is the more common term for the 802.11x standard for wireless radio communication between nodes and access points. [28] The standard is currently available in three versions, 802.11a, 802.11b and 802.11g. The different versions operate at different frequencies and have different range and bandwidth capabilities.

The range of a WLAN-signal from an access point depends on many factors. Obstacles, interference and power are critical factors which determine possible range. Range can be boosted with added power, or through the use of relay points. The data rate for the 802.11g standard has, for instance, a theoretical maximum of 54 Mbit/s, but in reality it operates between 10 and 20 Mbit/s.

To set up WLAN-zone for communications, one needs a wireless router/access point and a terminal needs a WLAN client device. The client automatically detects WLAN presence, and can automatically set up a connection if the user wishes to.

As an alternative for the PCS, WLAN is a clear potential candidate. A WLAN-network could be installed on each sea-cage installation, with a wireless router placed on the CS. The wireless network is easily configured and setup, data rates are high, equipment is cheap, and it is a well-tested communication scheme. The range depends on the equipment used and the power applied. Standard wireless routers provide up towards 100 metres, somewhat short of what is necessary. Range can be improved by boosting antenna power, or using relay points for re-amplifying the signal. Theoretical tests have yielded ranges of up to, and over, several kilometres by using more advanced antennas. The cost of such equipment is of course higher, but this can then be utilized as the MCS as well.

WLAN is the suggested MCS and PCS of [1]. As an MCS, WLAN will quickly become the restricting factor for how far offshore the sea cages can be placed.

6.4. Satellite communication

Satellite communication is available throughout the world, providing connectivity at any given location. Telenor Satellite [29] provides a satellite service at sea called SeaLink. [30] This technology can provide "always-on" internet connectivity, and coverage is shown in Figure 6-3.

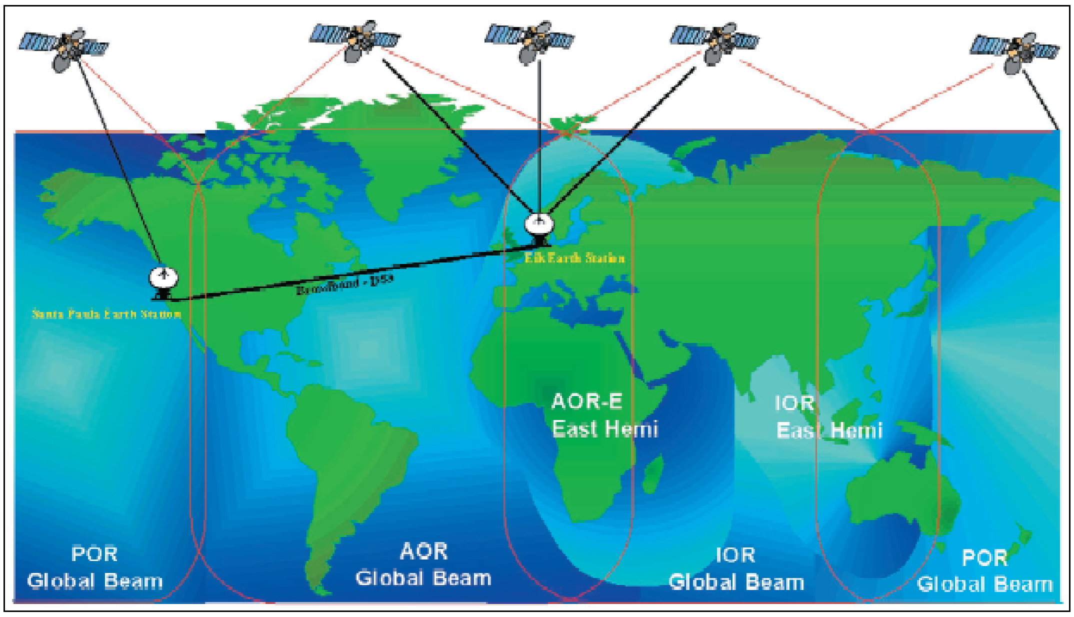


Figure 6-3: Expected coverage for Telenor Sealink [30]

The SeaLink service offers data rates from 64 kb/s to 8 Mb/s. [31] Issues such as power consumption and cost are difficult to estimate, but the range provided by satellite communication is unmatched.

For a SCG-system incorporating such a communication technology, sea cages can be placed almost anywhere in the world. It can function as both a narrowband and broadband technology for the SCG-system and, in a global perspective, it is independent of the local communication infrastructure.

6.5. VHF-Data

VHF-Data uses released frequencies within the VHF-radio system to provide a data carrying service. Telenor Maritime Radio offer two versions of VHF-Data, a narrowband and a broadband version. [32] The capacities are set to 21 kb/s and 140 kb/s respectively. These capacities are for compressed data, so actual data transmission is higher, for instance it is stated that the 21 kb/s link equals a 100 kb/s link. [33] Current coverage is the southern coast of Norway, but full coverage up to Kirkenes is expected by the end of 2006. The system reaches up to 70 km out from the coast. VHF-Data has always-on connectivity, and incorporates a standard IP/Ethernet interface in the radio for simple connection to existing networks.

As VHF-data rollout has been quite recent, only time will tell how the actual implementation works under field conditions. However, it is absolutely as an interesting candidate for providing ECS and FCS connections.

6.6. WiMAX

WiMAX is the more common name for the 802.16 standard and is an acronym for "Worldwide Interoperability for Microwave Access". It is generally considered as a future wireless alternative to cable and DSL. The technology provides a range of up to

50 km, with a theoretical data rate of 70 Mb/s, but more likely between 500 kb/s to 2 Mb/s. [34]

WiMAX delivers great range and great capacity, a combination which is unmatched. This technology would be a natural choice for the MCS of the SCG-system.

It should be noted that field tests in Chile with WiMAX transmissions over the ocean surface have not been promising. The links are very unstable, which to a large degree is due to transmission interference because of reflection of the signals from the sea. These factors can also affect the range of the similar WLAN-technology. An improvement has been achieved by placing the transmitting and receiving antennas higher up in the air, thus changing the angle of which the radio waves hit the sea surface. [35]

6.7. Bluetooth

Bluetooth is a wireless radio standard with focus on low energy consumption. It currently exists in three standards, with communication ranges from 10 cm up to 100 metres, and it can support communication speeds up towards 2.1 Mbit/s. It is able to discover other Bluetooth units in their vicinity through the use of a Service Discovery Protocol. [36] Whilst WLAN is considered a wireless version of wired Ethernet LAN's, Bluetooth's area of application has been considered to replace cables currently used between a computer and its accessory units.

Bluetooth is included here not as an alternative for either the narrowband or broadband communication, but because of its Service Discovery protocol. This property is of value when it is necessary to automatically discover the presence, services and capabilities of nodes. This could be a function to ease the implementation of mobile nodes interacting directly with the closest SCS-node. It could also provide a wireless connection to installed sensors. ActorFrame is currently being extended to support Bluetooth Service Discovery and communication. [37] [38]

6.8. ZigBee

ZigBee is a relatively new wireless communication technology with a focus on low power consumption, aimed primarily at sensor applications and remote control. [39] It is based on the IEEE 802.15.4-standard, with a theoretical range of up to 100 metres. The bandwidth is set to be between 20 and 250 kb/s. As for the battery lifetime, this can be from several hundred days, to over one thousand. [40]

ZigBee nodes can automatically construct ad-hoc networks upon need, using an Ad-Hoc On-demand protocol.

This technology could be used to allow for wireless connections of sensors to an SCS, enabling the entire Sea Cage Gateway System to be wireless.

6.9. Summary

The main characteristics of the communication technologies currently available are shown in Table 6-1. The licensed spectrum column implies whether an existing infrastructure is necessary by vendors with license permissions, which can translate into a cost-penalty on the amount of data transmitted. Elements such as range and data rate are difficult to pinpoint exactly. Varying environments and elements can greatly alter these characteristics, and field tests are probably necessary to establish correct parameters.

Table 6-1: Communication link characteristics and areas of application

Communication technology	Range	Licensed spectrum	MCS	PCS	ECS	FCS	Data rate (max)
GPRS	High	YES	No	No	Yes	Yes	160 kb/s
CDMA450	High	YES	Yes	No	Yes	Yes	2 Mb/s
WLAN	Low	NO	Yes	Yes	No	No	20 Mb/s
WIMAX	Medium	YES	Yes	Yes	Yes	Yes	2 Mb/s
VHF-Data	High	YES	Yes	No	Yes	Yes	140 kb/s
Satellite communication	Global	YES	Yes	No	Yes	Yes	8 Mb/s

When considering the suitability of a communication technology to the requirements of the four links defined for the SCG-domain, range and data rates are the most obvious characteristics. The PCS requires least range, but may require larger capacity due to the amount of communicating nodes present. The ECS requires the largest range of all. This is not only because it is the element farthest from land, but because it must also provide communications in the case of a moorage breaking. This can quickly bring the sea cage far out to sea. The FCS and MCS are supposed to cover the same distance, assuming that the CS-node, the frame, and all the SCS-nodes do not begin to drift.

Most technologies are easily interconnected with WLAN through an Ethernet-connection. For PCS, WLAN is the obvious choice. For the other connections there are no clear technologies which stand out above the rest. In addition, several more factors about the data rate, capacity and latency requirements of the SCG-system must be determined. As the ECS, satellite communication may be the best alternative due to the possible drifting of sea cages. For MCS perhaps CDMA450 is the preferred choice, with FCS being VHF-Data. In time, WiMax should be able to compete as being the primary choice for MCS.

7. Framework and modelling concepts

In this chapter the ActorFrame-framework and adhering concepts are introduced. UML2.0 is presented as this is the modelling language used by ActorFrame. UML2.0 is also used for implementing the design into the Ramses tool suite, also presented in this chapter.

7.1. UML2.0

UML2.0 is the modelling language used for Ericsson Service Development Framework presented in the following sections. UML is defined for object-oriented development processes in [41] as:

"The Unified Modelling Language (UML) is a general-purpose visual modelling language that is used to specify, visualize, construct, and document the artefacts of a software system."

UML2.0 is the continuance of UML, and addresses the problems and shortcomings of the previous standard. It also represents a convergence between computer and telecommunication architectural concepts. Several of UML2.0 concepts are used for modelling ActorFrame-based applications. The most relevant elements are listed in [42]. These are *Parts*, *Ports*, *Connectors*, *State Machines*, *Composite State* and *Profile*.

UML2.0 captures both the static structure of the system and its dynamic behaviour.

7.1.1. Inner structure

In UML2.0, the definition Part enables the description of the internal structure of a class. A part can contain other parts, and may create and kill inner parts during its lifetime. Parts have multiplicities in the form [n…m]. A class with internal structure, ports, connectors and multiplicities is shown in Figure 4-2.

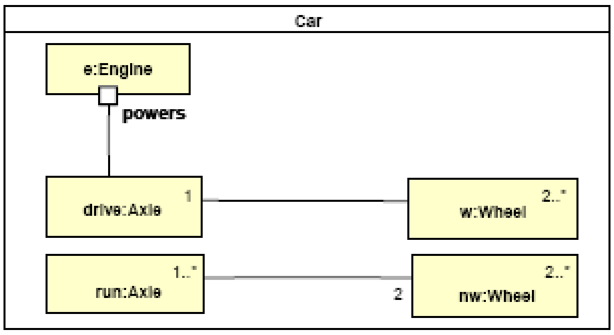


Figure 7-1: A class in UML2.0 with internal structure, ports and connectors [42]

Ports define a formal connection between parts, and can provide an interface between the class and the environment. Ports can either be directly connected to its part, or delegate signals to inner parts. These are known as behaviour ports and delegation ports respectively. [42] Unfortunately, these do not have separate notations in UML2.0.

Connectors specify links between parts to enable communication. They can either be connected to a port, or directly to a part. [42] When a connector is connected directly to a part from a port, a form of one-way communication arises. The part with the port may send a signal to the connected part, but the connected part cannot utilize the connector to specify a receiver. To respond it must use a specific address or answer to the signals originator.

Profiles can be used to make new concepts for a model. In ActorFrame the stereotype <<Actor>> is used on parts. The extensions of this can only be applied on instances of the metaclass Actor. [42]

7.1.2. State machines

UML2.0 offers increased support for modelling state machines and the encapsulation of behaviour in composite states. State machines function by accepting triggers in states, performing an action, and then changing states. Sometimes a state change results in the previous state. Triggers can be messages, timeouts, value change, or procedure calls. [42]

7.2. Ericsson's service creation architectures

ActorFrame is a Java framework providing a high level of abstraction for creating services. It is part of Ericsson's development framework, shown in Figure 7-2, and is based on UML2.0 modelling concepts for inner structure and state machines.

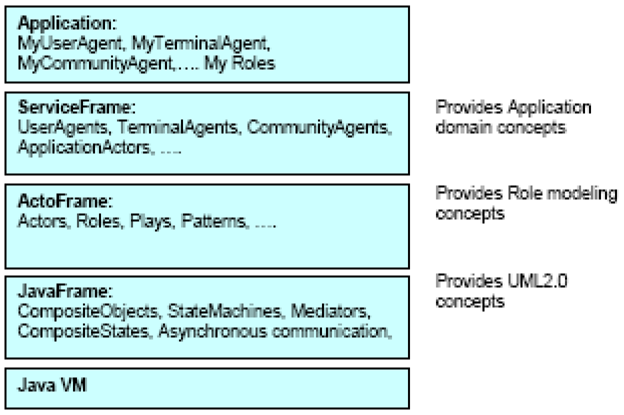

Application:
MyUserAgent, MyTerminalAgent, MyCommunityAgent,.... My Roles
ServiceFrame:
UserAgents, TerminalAgents, CommunityAgents, ApplicationActors, ...
Provides Application domain concepts
ActoFrame:
Actors, Roles, Plays, Patterns, ...
Provides Role modeling concepts
JavaFrame:
CompositeObjects, StateMachines, Mediators, CompositeStates, Asynchronous communication,
Provides UML2.0 concepts
Java VM

Figure 7-2: Ericsson's development framework [42]

The main motivation of these architectures and frameworks is to release the designers from the trivial tasks of handling non-service specific technicalities, allowing them to focus fully on service functionality. [42]

As is shown in the figure, ActorFrame is based on JavaFrame, and provides support for the higher levels of abstraction of ServiceFrame.

The frameworks build on concepts familiar from telecom-domains, with terminals and users wishing to communicate with each other. In such a sense, the SCG-system is slightly different, but that does not mean that it cannot provide modelling concepts for this domain..

7.2.1. JavaFrame

JavaFrame provides a framework for implementing UML2.0 concepts, such as state machines and composites, in Java. It also offers asynchronous message passing in Java. By providing predefined classes for UML2.0 design concepts, a model can be directly implemented using Java. It also supports asynchronous messaging, mechanisms such as identifying the sender of signals, and applies the save concept known from SDL. By using an underlying Scheduler, JavaFrame simulates concurrency of Active objects.

It should be noted that the state machines of JavaFrame can only trigger transitions through the reception of signals (this includes timers), and does not support triggers such as changed values or method calls. [42]

The main classes provided in JavaFrame are *StateMachine*, *Composite* and *Mediators*. For more information about JavaFrame, see [43] and [44].

7.2.2. ActorFrame

ActorFrame is based on the JavaFrame-framework which, amongst others, provides support for message-passing and state machines. ActorFrame incorporates role-modelling for creating applications, based on the concepts of roles, actors and plays. ActorFrame also provides distribution functionality which enables easy distribution of actors through the use of an ActorRouter-instance.

In addition to providing a framework for modelling services, the ActorFrame-framework provides possibilities for easy modularity. With state machines as a core component, distribution is easier, and verification is simpler to achieve, both manually and with tools supporting such functionality. It also provides a certain degree of structural documentation.

The Ramses tool-suite allows for model driven service engineering with ActorFrame and provides automatic code generation from models. It also supplies trace functions, and input consistency check functions, and is continuously being extended and improved.

7.2.2.1. Actors, roles and plays

The building block of a play in ActorFrame is the actor. An actor is in essence a state-machine capable of receiving and sending actor messages, and can contain several inner actors. The structure of an actor in ActorFrame shown in UML2.0 notation is shown in Figure 7-3.

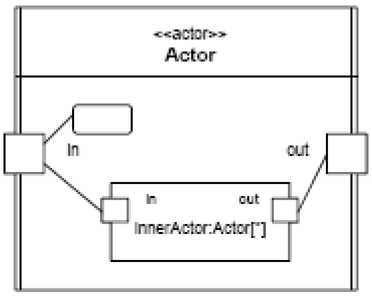


Figure 7-3: The Actor class [42]

The basis for ActorFrame-modelling is the play-annotation incorporated. A play can be compared to a service, provided by actors playing roles to achieve a performance. These collaborations last as long as the service is needed. As with a play, an actor can play several roles and be a part of several plays. This is shown in Figure 7-4.

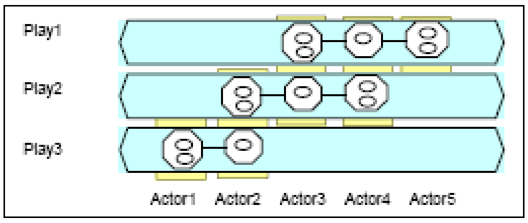


Figure 7-4: The elements of a play [42]

To set up a service, the *RoleRequest*-protocol provided by the framework is used. This consists of a *RoleRequest*-message sent to the actor incorporating the role required. This can either be the actor itself, or from one of its inner actors. If the role can be performed, a *RoleConfirm*-message is sent to the originator of the *RoleRequest*-message, and the role can be used. The protocol is shown in Figure 7-5.

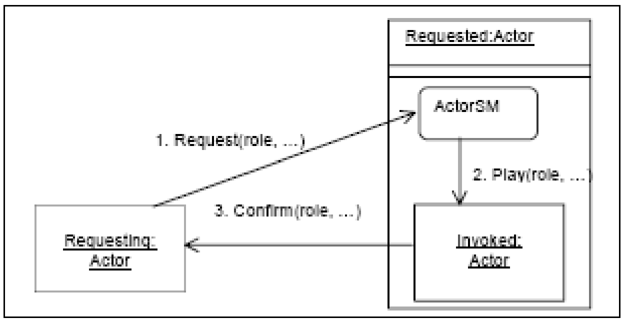


Figure 7-5: The RoleRequest-protocol [42]

When a role is no longer necessary in a service, or the service itself is discontinued, a *RoleReleaseMsg*-signal can be issued to the actors participating. The *RoleReleaseMsg*-message removes not only the actor which receives the signal, but any other actors who have been request by that actor, and so on. The response to a *RoleReleaseMsg*-signal is *RoleRemovedMsg*-signal.

As mentioned in section 7.1.1, UML2.0 does not provide separate notations for behaviour and delegation ports. In this thesis, however, behaviour ports will be symbolised with a white square, whilst delegation ports are shown with filled (black) squares. This is shown in Figure 7-6.

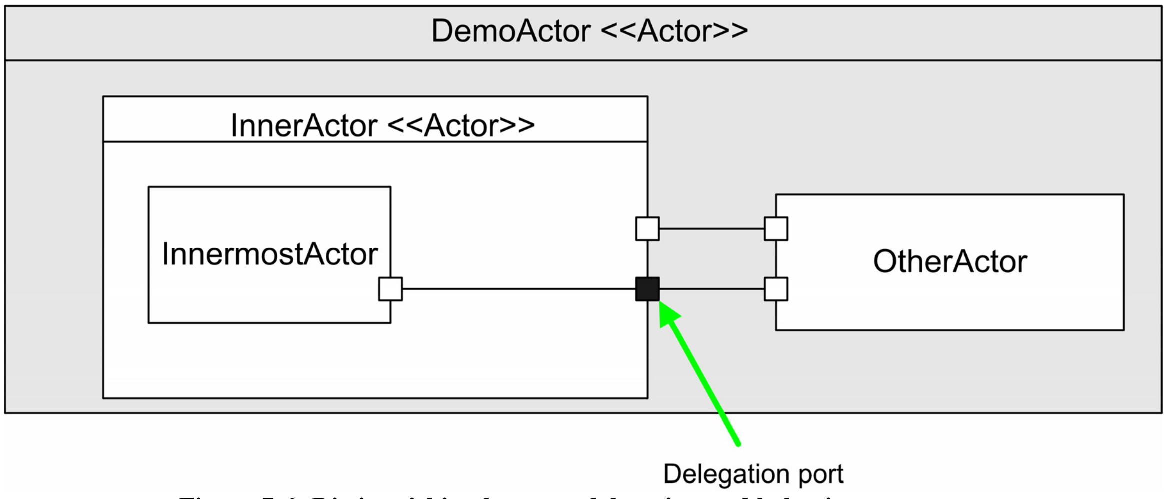


Figure 7-6: Distinguishing between delegation and behaviour ports

The filled port indicated by the green arrow is a delegation port enabling the *InnerMostActor*-actor to connect directly to the *OtherActor*.

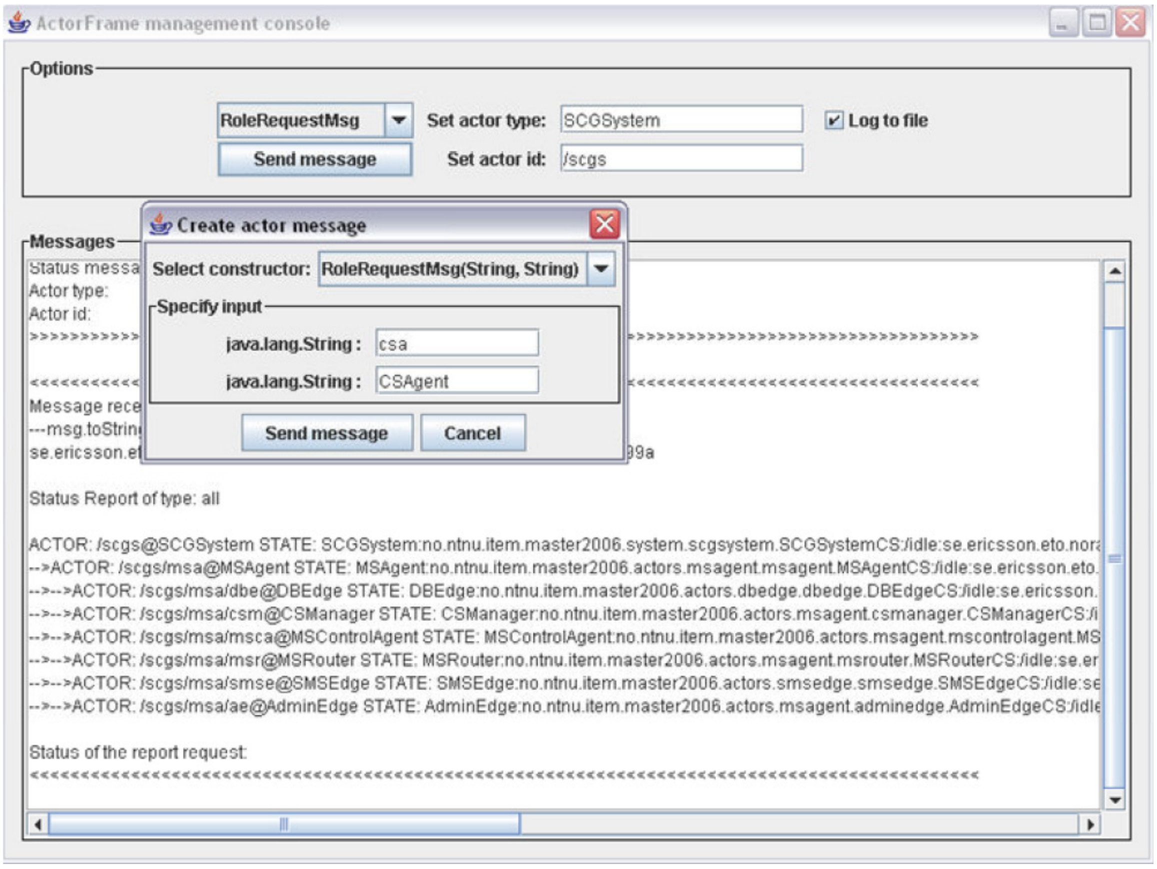
The full functionality of ports is somewhat unclear in ActorFrame. What kind of behaviour occurs when several instances are connected to same port is uncertain. Therefore ports in this system are only used in one-to-one relationships of static actors, and only connectors are used when connecting a dynamic instance to a static actor.

In the SCG-system the service-modelling through the use of the play-analogy may not be all that obvious. Mainly, the *RoleRequest*-protocol is intended to be used to provide a level of self-configuration of the nodes in the system. Actors will represent entities of the system, and interact to provide the services required by the system through signal-passing and by dynamically adding and removing actors and roles. The plays will largely consist of interacting actors placed on the nodes of the system. The framework provides the addressing, ports and connectors used for the system and handles message passing.

7.2.2.2. ActorFrame standalone app and management console

An ActorFrame standalone version has been released to enable quicker development and execution of services. In essence, this implies that developers do not have to use J2EE servers to execute services. This is an advantage, as dealing with J2EE servers can be a quite complex and heavy process. [42] It should be noted that one can switch to a J2EE platform at a later stage. [42]

ActorFrame also provides a management console which can be initiated upon service execution. The management console provides many options, from requesting the state of any actor, to the sending of any signal available in the system. In this project the management console has mainly been used for testing and debugging the system created. A screenshot of the management console is shown in Figure 7-7.



RoleRequestMsg

Set actor type: SCGSystem

✓ Log to file

Set actor id: /scgs

Select constructor: RoleRequestMsg(String, String)

Specify input

java.lang.String : csa

java.lang.String : CSAgent

```
Status messa
Actor type:
Actor id:
>>>>>>>>>>>                                   >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

<<<<<<<<<<<                                   <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
Message rece
---msg.toStrin
se.ericsson.e                                 99a

Status Report of type: all

ACTOR: /scgs@SCGSystem STATE: SCGSystem:no.ntnu.item.master2006.system.scgsystem.SCGSystemCS:/idle:se.ericsson.eto.nor
-->ACTOR: /scgs/msa@MSAgent STATE: MSAgent:no.ntnu.item.master2006.actors.msagent.msagent.MSAgentCS:/idle:se.ericsson.eto.
-->-->ACTOR: /scgs/msa/dbe@DBEdge STATE: DBEdge:no.ntnu.item.master2006.actors.dbedge.dbedge.DBEdgeCS:/idle:se.ericsson.
-->-->ACTOR: /scgs/msa/csm@CSManager STATE: CSManager:no.ntnu.item.master2006.actors.msagent.csmanager.CSManagerCS:/i
-->-->ACTOR: /scgs/msa/msca@MSControlAgent STATE: MSControlAgent:no.ntnu.item.master2006.actors.msagent.mscontrolagent.MS
-->-->ACTOR: /scgs/msa/msr@MSRouter STATE: MSRouter:no.ntnu.item.master2006.actors.msagent.msrouter.MSRouterCS:/idle:se.er
-->-->ACTOR: /scgs/msa/smse@SMSEdge STATE: SMSEdge:no.ntnu.item.master2006.actors.smsedge.smsedge.SMSEdgeCS:/idle:se
-->-->ACTOR: /scgs/msa/ae@AdminEdge STATE: AdminEdge:no.ntnu.item.master2006.actors.msagent.adminedge.AdminEdgeCS:/idle

Status of the report request:
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
```

Figure 7-7: The ActorFrame management console

This screenshot shows the creation of a *RoleRequestMsg*-signal to the *SCGSystem*-actor, requesting a *CSAgent*-actor, named "*csa*". The current status of the "*/scgs*"-instance of the *SCGSystem*-actor can be seen in the background. The design of the *SCGSystem*-actor is shown in section 9.5.

7.2.2.3. ActorFrame routing system - ActorRouter

ActorRouter[4] is part of the ActorFrame-framework, and provides support for the transparent distribution of actors. Unfortunately, no official documentation currently exists on how ActorRouter works or which services it supplies, so the following description is given strictly from observing its behaviour and through a black-box interpretation (with elements of a trial-and-error process).

The ActorRouter requires the setting of a public IP address and a default gateway address. The public IP address is necessary since ActorRouter uses application-level routing. This implies that the IP-address of the sending party is included in the messages and not read from the IP-header. This requires that designers (or users) must have more knowledge about their network connection and topology than usual. For

[4] ActorRouter is sometimes referred to as Actor router. In this thesis it has been named ActorRouter so it is not to be confused with *Router*-actors.

instance, if one is residing behind a NAT with private addresses, then the port-forwarding scheme must be known. The default gateway is the IP-address where messages-recipients not present on the local node are sent.

An ActorRouter-instance, upon request, resides on each node where actors exist. An actor is made visible to ActorRouter by calling the method:

```
setVisible(true);
```

in the actors state machine (*ActorSM*-class), which allows for a local actor to be registered by ActorRouter. The default is that an actor is not visible. After a set time interval (by default, 40 seconds), each actor reports to their ActorRouter, and then the ActorRouter reports to a default gateway which actors reside on its domain. This is shown in Figure 7-8.

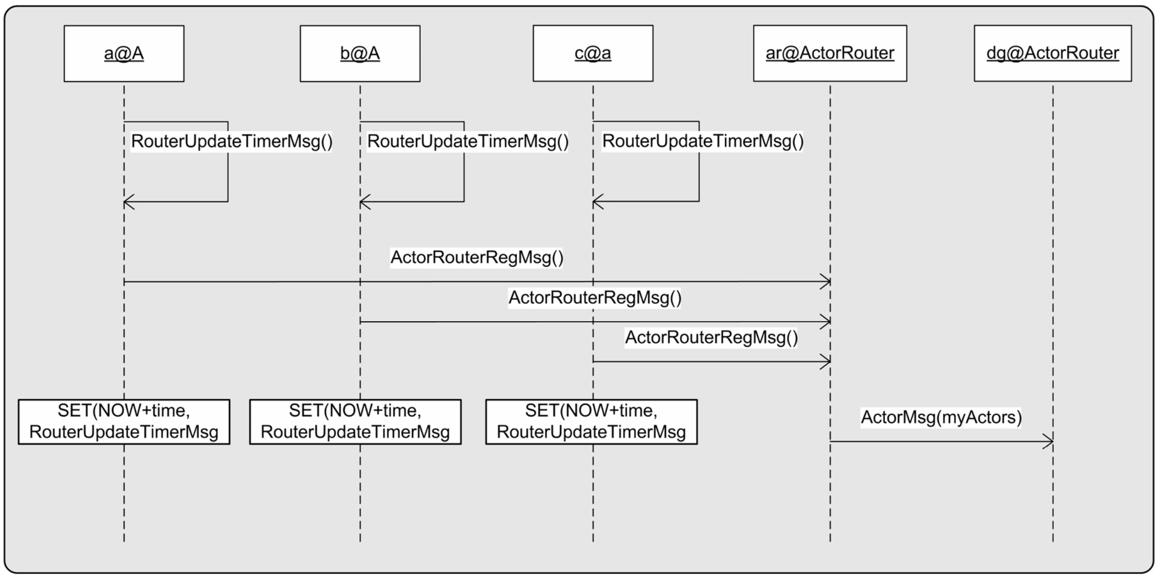


Figure 7-8: An informal sequence diagram illustrating ActorRouter-protocol

After receiving the *ActorRouterRegMsg*-signals from all actors, the ActorRouter reports to its default gateway every ten seconds (not shown).

When a local actor sends a message to an actor not present on the node the signal is sent to the local ActorRouter. Here the forwarding table is checked to see if the recipient has been registered, and if not present, than ActorRouter sends the message to its default gateway. The ActorRouter-table residing on the default gateway address then handles the message. If it is not present here, the signal is resent to its default gateway. Eventually the recipient is found, or the message is discarded. No notice of a discarded message is given by ActorRouter. The process is shown in Figure 7-9. Note that the process presented assumes that the residing actors on a node have not been reported to the default gateway, so the ActorRouter-table of ActorDomain B does not yet contain those of ActorDomain A.

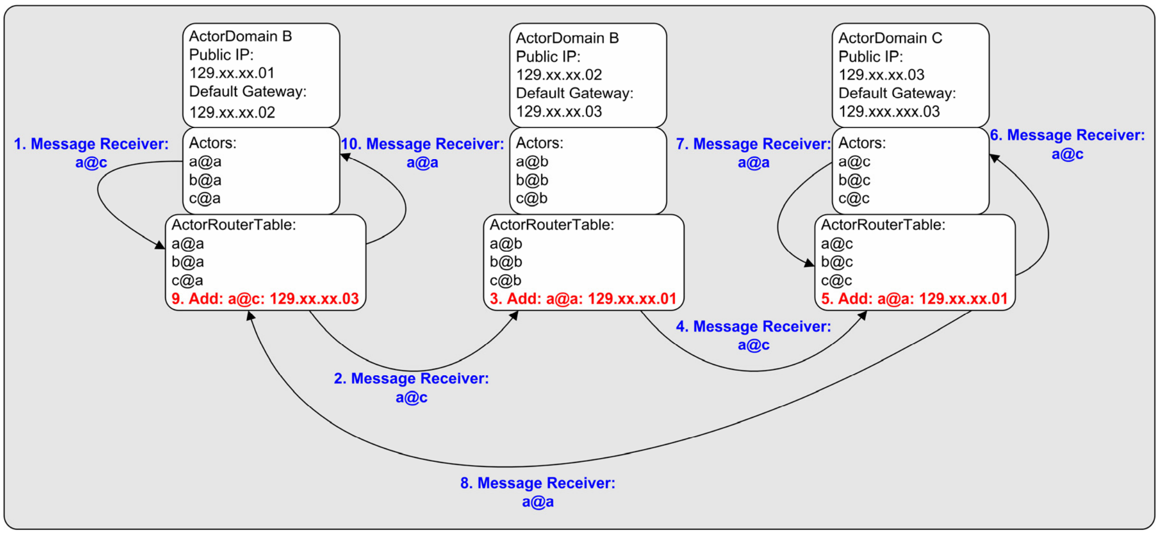


Figure 7-9: The workings of ActorRouter

Upon receiving messages from foreign actors, ActorRouter registers their origin and adds it to the local routing-table. When the actor "a@c" receives the message in action six, it replies to the sending actor. As can be seen from the figure, the local ActorRouter now has this actor in its forwarding table, and the signal is sent directly to the correct domain (action 8). These entries are removed after a certain time-period if no more signals are sent or received.

The messages sending the visible, resident actors of an ActorRouter are sent over a UDP-connection, whilst other messages are sent over a TCP-connection. ActorRouter is currently being extended to support Bluetooth interaction. [37] [38]

ActorRouter does not support ports or connectors over distributed entities.

7.2.3. ServiceFrame

ServiceFrame is an application of ActorFrame, designed to increase the abstraction level of service design. The main objective, as stated in [45] is:

"The main objective of the ServiceFrame project has been to address the principal underlying problems seeking to provide sound and viable solutions that enable rapid development of advanced, hybrid and personalized services without sacrificing the quality."

In other words, the goal is to be able to design, develop and offer advanced, hybrid services in the shortest time possible. With hybrid services, the paper refers to services provided across different networks by different service providers. [45]

This is done by focusing on the application domain of the service. The generic application domains considered in ServiceFrame are shown in Figure 7-10.

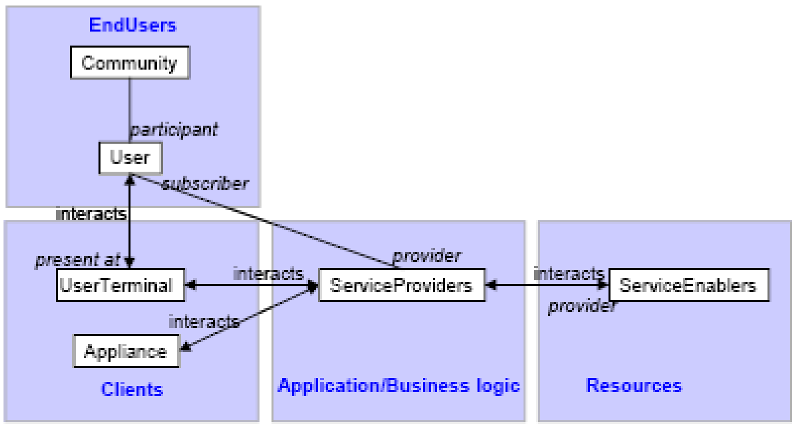


Figure 7-10: The application domain incorporated by ServiceFrame [45]

The key design principles used for ServiceFrame are conceptual abstraction, environment mirroring, role modelling, service-centred architecture and the use/reuse of frameworks and patterns. For more information on ServiceFrame, see [45].

The SCG-system may not appear to be in the domain of ServiceFrame at first glance. How can a sensor administration and retrieval system fit in here? Who are the users? Who are the communities? What are the terminals? In a sense, all of the above are present in the SCG-system. The users are the nodes themselves, in addition to the human users of the system. The communities can be all similar nodes; such as all SCS- and CS-nodes, local or global, in addition to the administration, rescue teams or other interested parties. The terminals are the node-hardware and operating systems, and user-introduced elements (PDA, laptop, smart phone). The nodes, with sensors, can be seen as service providers, service enablers and service cutsomers. These are some possible suggestions for modelling the SCG-system in ServiceFrame.

7.2.4. MidletFrame

MidletFrame is a stripped down version of ActorFrame implemented in J2ME. This opens for using ActorFrame concepts on small mobile devices, and allows interaction with standard ActorFrame actors.

MidletFrame incorporated on smart phones could be used for mobile terminals interacting with nodes on site. These can incorporate Bluetooth for service discovery and node presence. This allows for the smart phone to directly and seamlessly interact with the ActorFrame-elements already present.

7.3. Ramses

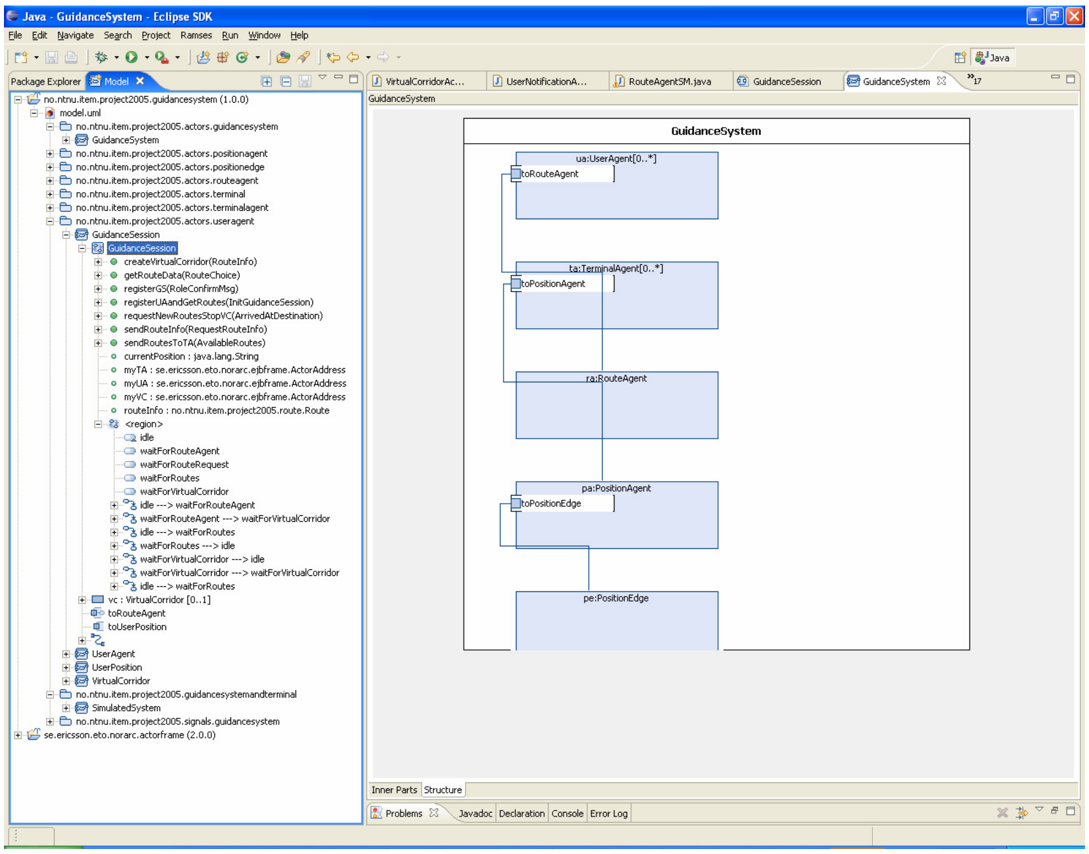
Ramses is a system development tool, created at the Department of Telematics at NTNU. It consists of a series of plug-ins for the Eclipse platform [46]. Ramses offers model editors, code generators, model checks and runtime trace support. The tool is based on the UML2.0 specification, as shown in Figure 7-11.

Editors
Inspectors
UML 2.0
Generators
Trace Viewers

Figure 7-11: The Ramses tool suite [47]

The editor allows for the design of the system using the elements from UML2.0. The inspectors provide means to check and validate the design. The trace viewers show message sequences for testing and error-detection. The generator translates the system design into code.

Ramses has been used to implement and check the SCG-system designed in this thesis. A screenshot demonstrating the model view used by Ramses is shown in Figure 7-12.



```
no.ntnu.item.project2005.guidancesystem (1.0.0)
  model.uml
    no.ntnu.item.project2005.actors.guidancesystem
      GuidanceSystem
    no.ntnu.item.project2005.actors.positionagent
    no.ntnu.item.project2005.actors.positionedge
    no.ntnu.item.project2005.actors.routeagent
    no.ntnu.item.project2005.actors.terminal
    no.ntnu.item.project2005.actors.terminalagent
    no.ntnu.item.project2005.actors.useragent
      GuidanceSession
        GuidanceSession
          createVirtualCorridor(RouteInfo)
          getRouteData(RouteChoice)
          registerGS(RoleConfirmMsg)
          registerUAandGetRoutes(InitGuidanceSession)
          requestNewRoutesStopVC(ArrivedAtDestination)
          sendRouteInfo(RequestRouteInfo)
          sendRoutesToTA(AvailableRoutes)
          currentPosition : java.lang.String
          myTA : se.ericsson.eto.norarc.ejbframe.ActorAddress
          myUA : se.ericsson.eto.norarc.ejbframe.ActorAddress
          myVC : se.ericsson.eto.norarc.ejbframe.ActorAddress
          routeInfo : no.ntnu.item.project2005.route.Route
          <region>
            idle
            waitForRouteAgent
            waitForRouteRequest
            waitForRoutes
            waitForVirtualCorridor
            idle ---> waitForRouteAgent
            waitForRouteAgent ---> waitForVirtualCorridor
            idle ---> waitForRoutes
            waitForRoutes ---> idle
            waitForVirtualCorridor ---> idle
            waitForVirtualCorridor ---> waitForVirtualCorridor
            idle ---> waitForRoutes
        vc : VirtualCorridor [0..1]
        toRouteAgent
        toUserPosition
      UserAgent
      UserPosition
      VirtualCorridor
    no.ntnu.item.project2005.guidancesystemandterminal
      SimulatedSystem
    no.ntnu.item.project2005.signals.guidancesystem
se.ericsson.eto.norarc.actorframe (2.0.0)
```

Figure 7-12: Screenshot of the Ramses model view in Eclipse

For more information on the Ramses system development tool, see [47].

8. Design of the Sea Cage Gateway system

In this chapter the design of the Sea Cage Gateway system based on ActorFrame is presented. First the elements, environments and task of the nodes comprising the system are identified and described. The actual design based on the elements identified so far in this thesis is presented, and is followed by sequence- and communication diagrams describing the actions and functionality of the system in different modes of operation.

8.1. Design goals and considerations

This thesis is to utilize the ActorFrame-framework for providing the desired functionality of the SCG-system. In addition, the design considers issues such as multiple communication links, as well as looking to sensor networks and mobile grid for inspiration.

The system design is also inspired by many design principles listed in [48]. Although these principles are mainly directed at the SDL-domain, they give many sound guidelines for modelling in the ActorFrame-domain, which resembles SDL in many ways. Among the principles followed are; describe the environment, mirror the environment behaviour, mirror the environment knowledge, analyze the behaviour, look for similarities, and analyse the variability. [48] These principles have all been applied to a varying degree.

In Figure 8-1, the distribution of the different nodes is shown and how the nodes forming the basis of the SCG-system are meant to be interconnected. An actor will represent each node of the system. This implies that a *SCSAgent*[5]-actor will reside on the SCS-node, a *CSAgent*-actor on the CS-node, and so forth. The use of the agent name of actors is a ServiceFrame-concept, extending the actor-concept a step further. In ServiceFrame agents are an Actor-class which publicly represents actors. Agents automatically register themselves with a *NameServer*-actor for easy discovery. This will not be implemented here, only the naming-paradigm is used.

With a basis of utilizing all the nodes in the fashion of sensor webs or in grid computing, the possibility of connecting all nodes to each other is an option that should be considered in the system design. The vision is that all the SCS-nodes are interconnected through their CS, and all CS-nodes are interconnected through their MS. The elements are not physically interconnected directly, but the connections are made possible through the distribution of node presence, address, status and knowledge throughout the system.

[5] For the remainder of this thesis all ActorFrame-actors and signals will be represented in an italic font.

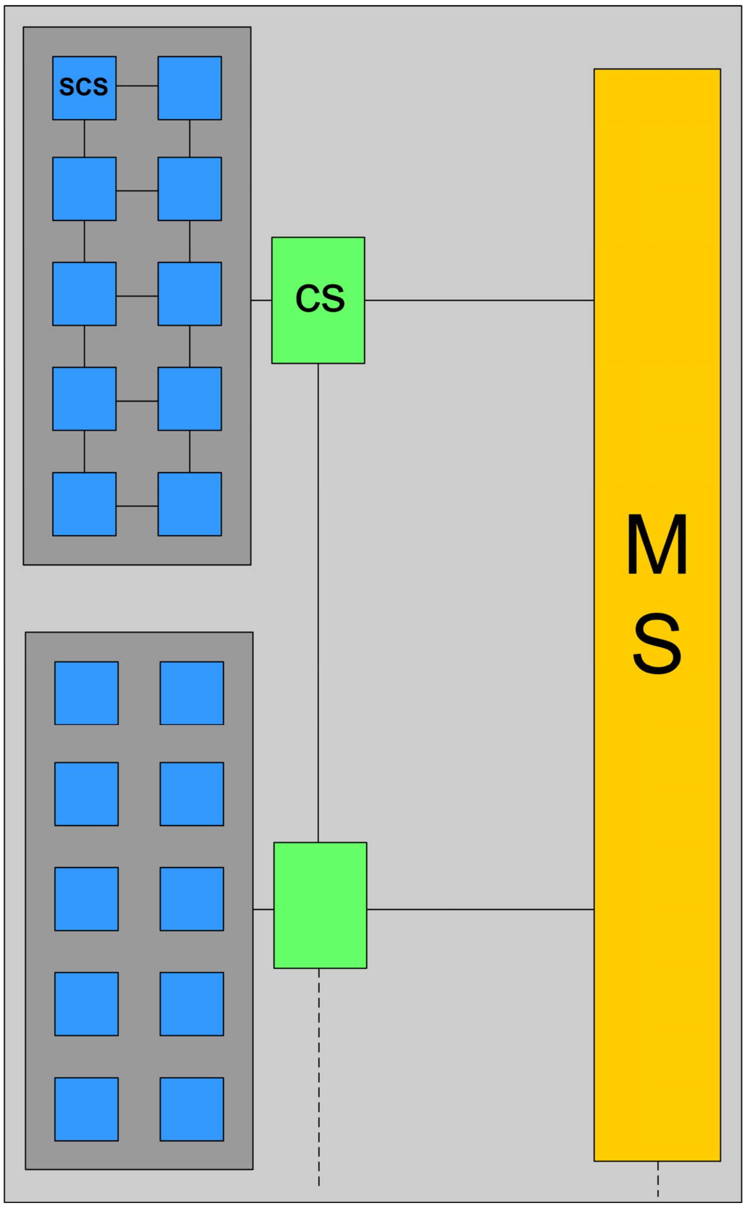


Figure 8-1: Interoperability between nodes, mobile grid

To enable a scalable solution to the addressing issues, the grid/web is built up as a hierarchy, using the natural hierarchy already implemented in the relations between the nodes. The cardinalities of these relations are shown Figure 8-2.

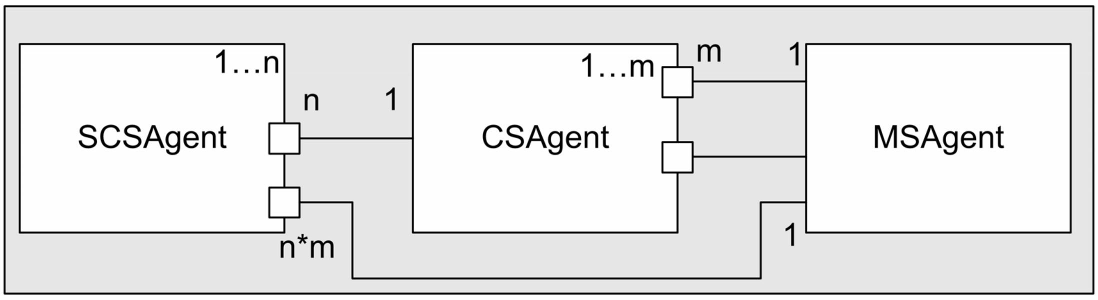


Figure 8-2: System cardinality and connections

Here the relative connections implied by the proposed communication schemes are illustrated. These relations have a significant influence on system design, and come up again when analyzing the environments of the system elements.

As a basis for design, the system also assumes a certain setup sequence. As shown in Figure 8-3, the MS-node with its *MSAgent*-actor is the first node to be set up. Then the CS-node is set up, and when the *CSAgent*-actor is initiated it proceeds to register itself with its *MSAgent*.

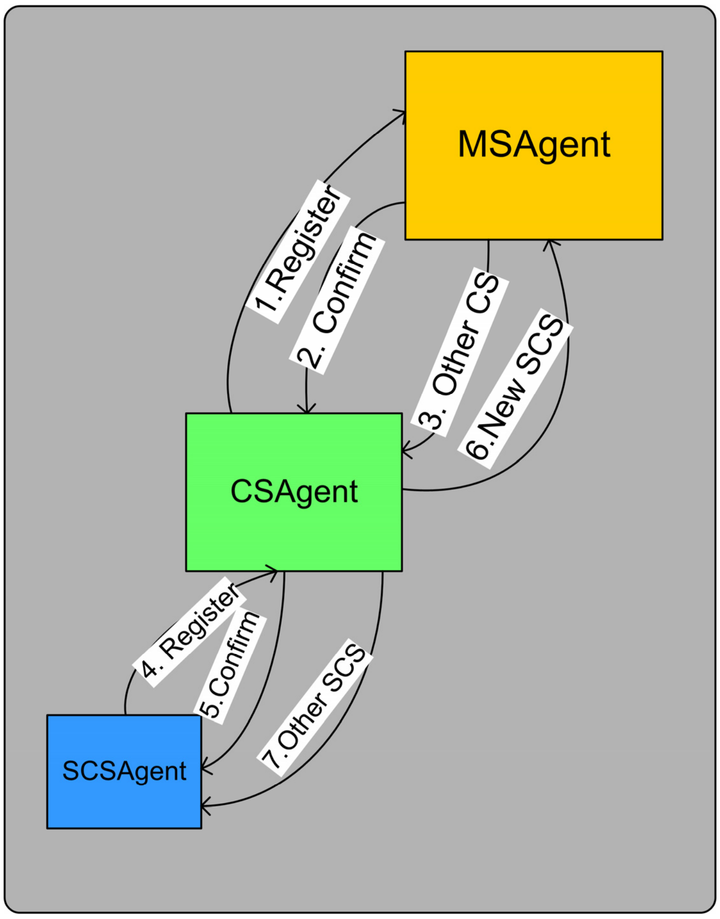
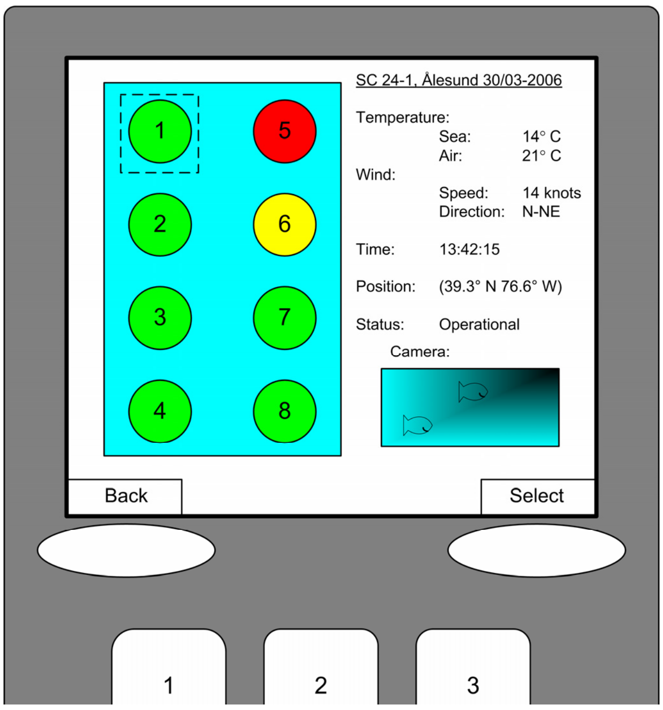


Figure 8-3: How the SCG-system is created

Finally, the *SCSAgents* are created and register with their *CSAgent* who, in turn, reports the presence of a new SCS-node to its MS-node. It is therefore assumed that a MS-node exists before a CS-node is initiated. The Register-Confirm procedure corresponds to the *RoleRequest*-protocol of ActorFrame.

The SCG-system should allow for extensions to be added with a fair amount of ease, incorporating additional services with new actors and roles. An example of this is shown in Figure 8-4, where a mobile device receives SCG-information and could provide control functions for the systems administration.



SC 24-1, Ålesund 30/03-2006

Temperature:
Sea: 14° C
Air: 21° C
Wind:
Speed: 14 knots
Direction: N-NE

Time: 13:42:15

Position: (39.3° N 76.6° W)

Status: Operational

Camera:

Figure 8-4: Preliminary illustration of mobile application interface

Interaction for such an application could be achieved in a variety of ways. This application could connect through a standard GPRS-connection to the MS-node or connect via Bluetooth as a part of an ad-hoc network at the actual facilities (at an SCS- or CS-node).

An alternative way of access for system interaction could be through the use of a web browser which allows for a standard and easy way to access information. The use of web browser interfaces is steadily increasing, with the advantage of a standardised and highly distributed interface. However, if the user is on-location, and wishes to retrieve information directly from a SCS or a CS, this might be impractical. This is due to the fact that if the CS is connected via a pay per data technology this could incur increased, and unnecessary, costs for the supplier.

Some possible functions will be illustrated in the design presented in the following sections but will not be implemented in the demonstrator for this project. These functions are to illustrate further areas of application, whilst the demonstrator is the focus for the implemented elements.

8.1.1. A basic set of functional requirements

In order to aid the design and testing process of the SCG-system, some basic functional requirements for the system as a whole have been defined. The functional requirements presented can also be viewed as design goals for the system. These requirements are based on the keywords presented in the scenario in section 3.1.1, and on the sensor network and mobile grid concepts discussed in sections 4.3 and 5.1. These are listed in Table 8-1.

Table 8-1: Some basic functional requirements for the SCG-system

R	SR	Description	Priority
1.		**The system must allow for automatic configuration and registration of new nodes (CS and SCS).**	**High**
	a	The system must make information about new nodes available to other nodes.	Medium
	b	The new nodes must receive information about the other nodes in the system.	Medium
	c	The SCG-system must register all nodes.	High
2.		**The system must allow for information to be propagated throughout the system.**	**High**
	a	Parameters must be available upon initiation.	High
	b	Basic parameters must be possible to update upon initiation.	High
3		**The system must detect and handle communication link failures.**	**High**
	a	If MCS fails between CS and MS, FCS must be used.	Low
	b	If PCS fails between CS and SCS, ECS must be used.	High
	c	If MCS, PCS and FCS fail, ECS must be used.	Low
	d	Upon failure maintenance team must be notified	High
	e	Upon alarms, rescue team must be notified	**High**
5		**The system must collect and store sensor data**	**High**
	a	Data must be available for retrieval at a later occasion.	High
6		**The system must utilize sensor data to issue warnings about abnormal sensor readings.**	**High**
	a	The system must issues warnings regarding deviations in the GPS-readings against pre-defined threshold values.	High
	b	The system must issues warnings regarding failed communication links and nodes.	High

Points one and two are partly inspired by mobile grid concepts by providing all nodes with access to all other system nodes through the distribution of address lists. Through these lists mobile nodes can interact and gain access to the systems capabilities. Inspiration from the sensor-network architecture is used for minimizing energy use and resource consumption among distributed nodes, and although the utilization of sensor data among other nodes is beyond the scope of this thesis, the architecture is to provide a basis for incorporating the principles. These points also imply a certain-level of self-configuration on initiation of SCG-elements

Point three deals with the fault redundancy element of the system and point four includes the possibility of complete node failure. Point five addresses the issues of data handling, and point six provides definitions of a few ways to handle sensor data, slightly inspired by sensor networks.

Being only some functional requirements of a system with limited functionality, most of the requirements have a high priority. One exception is the node-presence distribution, as this does not directly affect the services required. They simply lay the foundation for more advanced services. The other exception is the handling of link failures between the CS- and MS-node. As the equipment necessary for such functionality is lacking in the demonstrator their priorities have been set to low. This is to focus on the issues at hand with the equipment available.

This is not an exhaustive list of requirements, simply a foundation for displaying the requirements and design goals the rest of the system can be built on and utilize. This is the case for requirements 1 & 2 where the propagation of information and actors provide the possibility for both self-configuration techniques and mobile-grid functionality.

8.1.2. Non-functional requirements

After establishing the functional requirements, the nature of the non-functional requirements must be identified and specified. Issues such as delay, reliability, user interaction, ease of use, cost, maintenance and more, are all aspects to be considered when designing a system. As the system being implemented in this thesis is simply for simulation and demonstration purposes, the non-functional requirements are often set simply for stream-lining the test procedures. As complex a system as the SCG-system can become, especially if providing full mobile grid computing in addition to sensor web functionality, will inevitably provide many challenges in establishing the ideal non-functional requirements.

Amongst non-functional requirements of the SCG-system demonstrator to be designed and implemented, a few are displayed in Table 8-2

Table 8-2: Some non-functional requirements

Non-functional requirement	Description
Sensor update interval	How often should sensor readings be performed? This will probably vary from sensortype to sensortype and in different scenarios. If the SCS-node begins drifting a higher frequency for polling the GPS-receiver could be necessary.
SCS status update interval	How often should the status and sensor reports be collected from the SCS?
CS status update interval	How often should the status and sensor reports be collected from the CS?
PCS latency maximum	What is the maximum round-trip delay allowed for the PCS-link?
MCS latency maximum	What is the maximum round-trip delay allowed for the MCS-link?
PCS status check interval	How long should it take between checking the PCS-status? What is the maximum time window given before a reply is required? This is again dependent on the link latency.
MCS status check interval	How long should it take between checking the MCS-status? What is the maximum time window given before a reply is required? This is again dependent on the link latency.
GPS-deviation maximum	How far should a position be from a pre-defined are before alarms are generated?

There are many elements not listed in the table above, as the ECS- and FCS-links will require attention in the same areas as the MCS- and PCS-links. The requirements can also change depending of the state of the system.

The issues of privacy and security for this system have not been considered.

The purpose of this thesis is to create a demonstration of such a system. Although non-functional requirements are an integrated part of the design, they have not been given priority. The above discussion serves as an example of issues related to this system.

8.2. Overview of the system elements

Before designing the actors and elements needed to provide the architecture for the SCG-system the elements of the system must be analyzed. Determining the environment in which a node is to operate in addition to determining its task, enables a design which can effectively handle the scenarios expected from it. Note that there may well be more tasks or environmental variables then those identified in the following sections, but the system designed in this thesis will be based on the elements presented here.

The entire SCG-system infrastructure is illustrated in Figure 8-5, and the distribution of the agent-actors is shown.

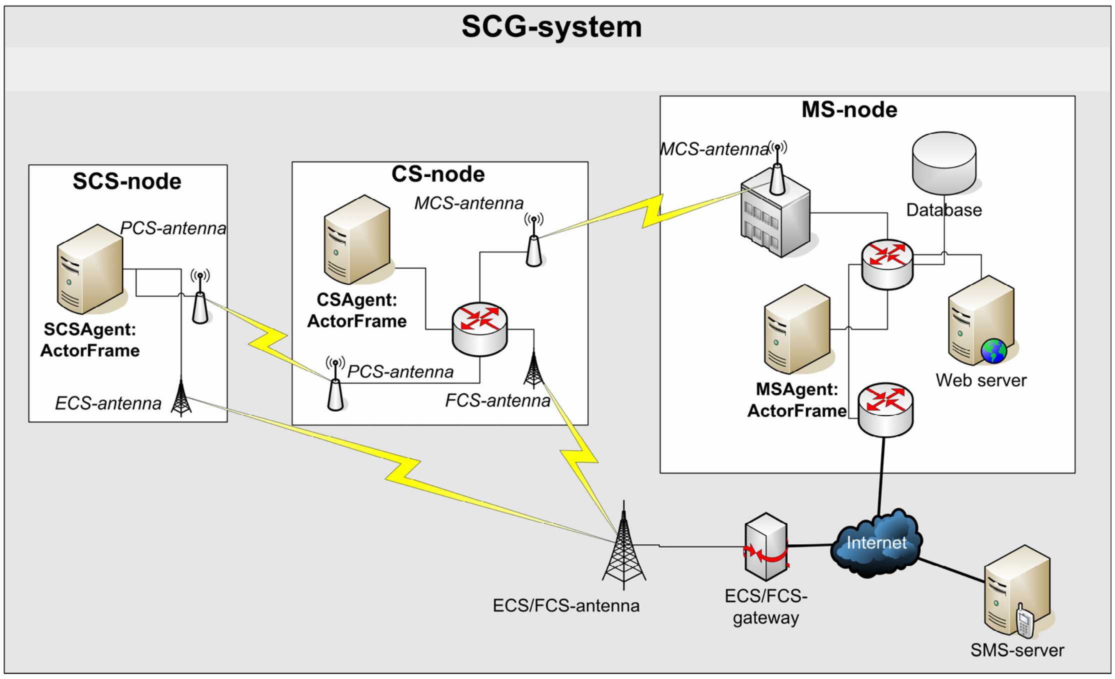


Figure 8-5: The SCG-system elements, nodes and deployed actors

As mentioned and displayed, each node will be represented in the SCG-system with a dedicated actor. In this thesis MCS and PCS are WLAN (LAN), and ECS is GPRS. A FCS is not available, but design considerations do take it into account.

8.2.1. The SCS-node

The SCS-node represents the hardware on location mounted to each sea cage. This node is directly connected to the sensors, and provides interaction with the rest of the system through its GPRS- and WLAN-capabilities. It's surrounding environment and interfaces are shown in Figure 8-6.

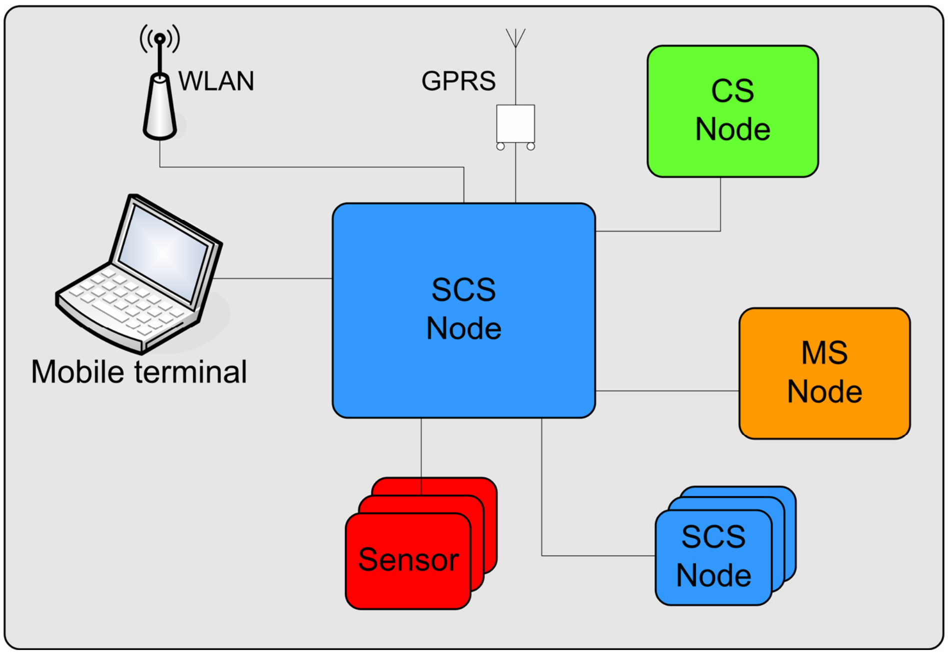


Figure 8-6: The SCS-environment

As shown, the following elements are present in the environment for which the SCS-node must provide interaction for. They are described in Table 8-3.

Table 8-3: SCS-node environment descriptions

Environment element	Description
Sensors	Each SCS-node must provide sensor interaction and information retrieval.
MS-node	In the case of a communications failure, the SCS-node must communicate with the MS-node directly.
CS-node	Each SCS-node will have a designated CS-node to which it will report sensor data and other relevant information.
SCS-node	The SCS-node may have to be aware of the other SCS-nodes under the same CS-node to enable further functionality such as resource sharing or additional redundancy.
PCS	The PCS must be handled by the node. This includes both the initiation of the link, and the checking of its status.
ECS	The node must be aware of its ECS, and have the ability to initialize it and utilize it. It must also be aware of the link characteristics, and adjust to these accordingly. One such characteristic could be data rate, another could be latency.
Mobile terminal	Each SCS-node should provide the possibility for a direct connection via a mobile terminal present at the SCS.

The communication schemes should, in essence, be transparent for the application running on the SCS-node, and the type of communication link should only affect which entity the node contacts (MS or CS). Unfortunately, this is not the case, as a switch in communication link also yields a new connection with a new assigned IP-address. Since ActorRouter uses application-level routing, this will be handled by the node under the different failure modes. A change of communication link also leads to a change in the recipient of signals as these are now supposed to be sent to the MS-node.

In addition to handling the environment, the node must perform a minimum of certain tasks to ensure proper, flexible and correct operation. The minimum set of tasks necessary for the SCS-node to perform is given in Table 8-4.

Table 8-4: SCS-node tasks

Node tasks	Description
Parameter storage	To ensure proper operations certain parameters must be held by the SCS-node and these must also be adjustable. These values could be sensor-polling-intervals, threshold values etc. Each individual sensor will also maintain a more detailed configuration set for operations.
Parameter control	Elements of the data received, both from the sensors and the rest of the system need to be controlled against the current parameter settings. An example of this could be the control of current GPS-data against pre-determined values based on ideal GPS-position. A breach of the set parameters indicates a possible failure in the system, a situation requiring immediate attention.
Data storage	Sensor data retrieved must be stored for later utilization and distribution, but not to the extent of implementing a database. Data is ordered as they are still in the possession of their respective sensors.
OS-manipulation	The system requires that the application running on each node can interact on the operating system it resides on. Elements requiring the use of the operating system can be, amongst others, battery-level status, initiating/checking network connections and possibilities, putting the system in a suspend modus for battery conservation, etc.
Sensor Detection	In keeping with the goal of a self-configuring, self-contained system, a separate process for checking for new sensors should be implemented. This could also be handled by the OS-handling entity, but to focus on the task this been kept as a separate process. Allowing sensor-attachment to be a plug-and-play process in regards to the system architecture is an important feature.

These tasks will be incorporated into the system design of the *SCSAgent*-actor.

8.2.2. The CS-node

The CS-node resembles the SCS-node in many ways, and its environment is shown in Figure 8-7. Although the functionality of different processes may vary, the basic environment and tasks are the same. The one major difference is that the CS-node must handle all the SCS-nodes operating beneath it in the SCG-hierarchy.

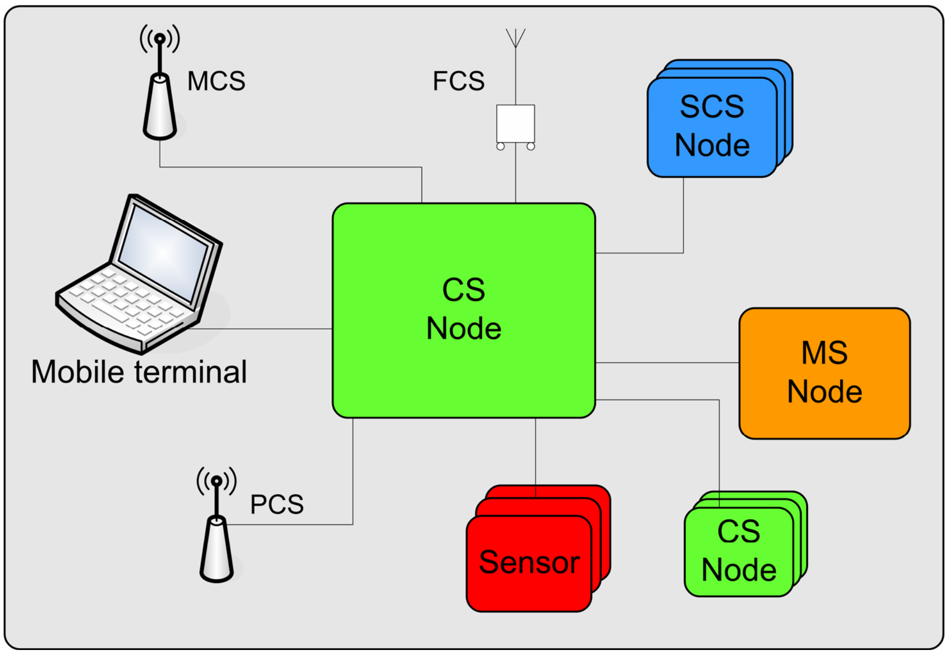


Figure 8-7: The CS-environment

The handling of the SCS-nodes and the more direct connection with the MS-node are the major extensions compared to the SCS-node. The elements present in the CS-node environment are listed in Table 8-5.

Table 8-5: CS-node environment descriptions

Environment element	Description
Sensors	Each CS-node must provide sensor interaction and information retrieval.
SCS-node	The CS-node administrates and controls all SCS-nodes contained within the frame of the CS-node.
CS-node	The CS-node may have to be aware of the other CS-nodes under the same MS-node to enable further functionality such as resource sharing or additional redundancy.
MS-node	The CS-node interacts frequently with the MS-node, and generated reports and alarms are sent to this node.
PCS	The PCS must be handled by the node. This includes both the initiation of the link, and the checking of its status.
MCS	The CS-node must also maintain and supervise the MCS-link with the MS-node.
FCS	The node must be aware of its FCS, and have the ability to initialize it and utilize it. It must also be aware of the link characteristics, and adjust to these accordingly. One such characteristic could be data rate, another could be latency.
Mobile terminal	Each SCS-node should provide the possibility for a direct connection via a mobile terminal present at the SCS.

The CS-node tasks are largely similar to the SCS-node tasks listed previously. Besides these, the CS-node may need to provide larger database requirements. The CS-node may also require interoperability with more equipment, for instance the feeding technology. For the time being this function is regarded as one of the sensors.

8.2.3. The MS-node

The MS-node represents the main computing environment of the SCG-system, and represents the SCG-system to the environment through a variety of interfaces. The operating environment of the MS-node is shown in Figure 8-8.

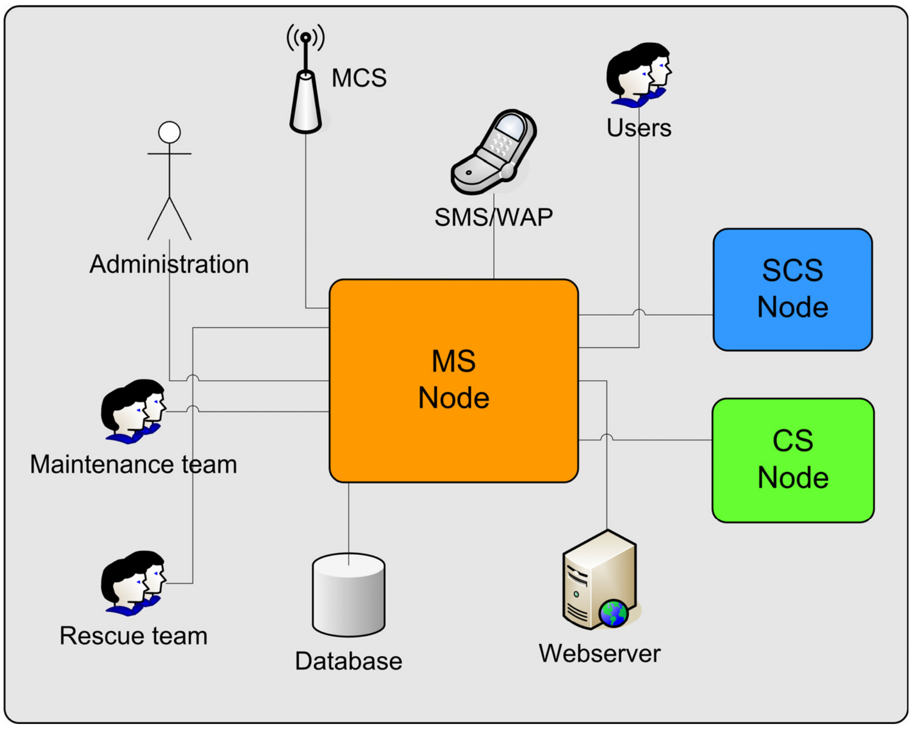


Figure 8-8: The MS-environment

As seen in the figure, the environment of the MS-node represents many external entities and participants. This is the main area of interaction for the SCG-system. The elements present in the environment of the MS-node are described in Table 8-6.

Table 8-6: MS-node environment descriptions

Environment element	Description
CS-node	The CS-node represents a collection of sea cages, and provides the data retrieved from these, as well as forwarding commands for the MS-node.
SCS-node	Under the failure of some of the communication links, the SCS-node will interact directly with the MS-node.
Database	All information retrieved from all the sea cages must be systemized and stored in a database for later retrieval and use.
MCS	Although the MS-node cannot handle any failure in a

	communication link, it must be aware of it so it can alert maintenance teams.
Web server	Providing information to a web server for easy access will greatly increase the accessibility to the system.
Administration	Access to systems settings, such as for instance changing the report frequency from the CS-nodes, must be implemented. This will give many possibilities for fine-tuning the system, as well as defining the correct data for group access and allowing direct interaction to the system.
WAP/SMS/IM	To provide transparent access to means of interaction with outside actors of the system. System alerts regarding drifting sea cages can be given to the rescue teams and administration through an SMS-message
Groups	There are certain essential groups necessary for maintaining the SCG-system operable. The ones shown in Figure 8-8 are the rescue team and maintenance team. These are subsequently a sea cage retrieval team, and a node and communication link repair team. The right individuals must be notified for the correct incidence. This can be achieved through the WAP/SMS previously described.
Users	Users interacting with the system either through a dedicated application, web server or mobile terminal.

The MS-node environment could also consist of other MS-nodes, but this has not been considered here.

In addition to handling the entities in the environment the MS-node needs to perform additional tasks. These are similar to the ones listed earlier and are displayed in Table 8-7.

Table 8-7: The MS-node tasks

Node tasks	Description
Parameter control	The node must be able to control parameters or variables reported in to it.
Parameter storage	Parameters for nodes must be stored in order to be distributed to new nodes which are connected.
Parameter settings	Centralized parameters regarding threshold values for sensors can be one example. Another example is that of update intervals of sensor at the SCS- and CS-nodes.
Data storage	The accumulated sensor data generated by the SCG-system must be stored for analysis and use.
Data retrieval	The data stored must be accessible in many formats, all providing support for both different forms of interaction with the data, and presentation of it.
Warning/repair activities	The node must provide the necessary information for correct warning and repair activities to be initiated.

Again, this is not an exhaustive list of possible MS-node tasks, simply an example of possible ones, and the ones used as basis for the *MSAgent*-actor design.

8.2.4. Failure modes

In this section different failure modes which can occur in the SCG-domain and the related actions taken for each of them are presented. Elements that can fail are the MCS, PCS, FCS and ECS, in addition to the failure of the nodes themselves. This is based on the description given in section 3.1. These will be described more thoroughly later, with sequence and collaboration diagrams when they are handled in the system design process. The links involved and their adhering system nodes are shown in Figure 8-9.

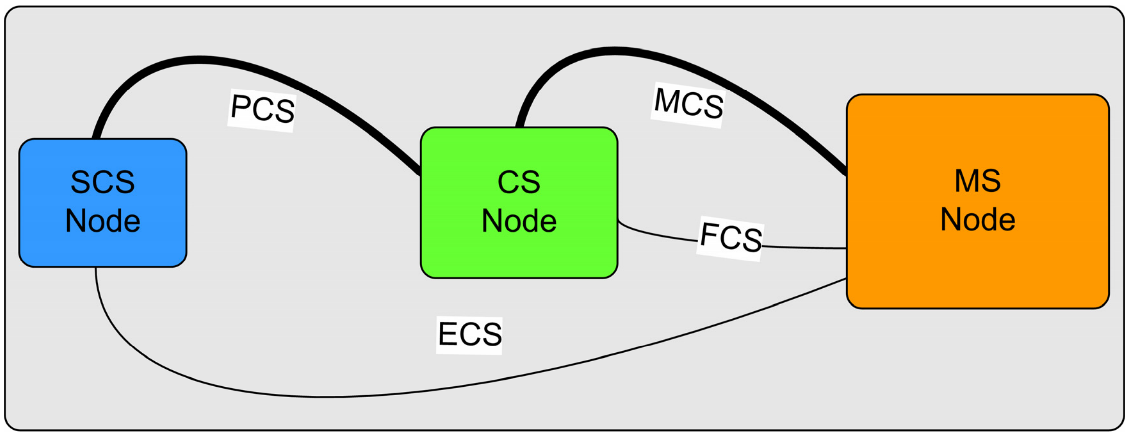


Figure 8-9: The communication schemes of the SCG-system

There are two ways in which a broken communication link can be detected, one from either side of the link. In this system only one side can initiate the reserve communication technology. If the PCS between the SCS and CS is down, only the SCS can handle this by initiating the ECS. The CS may detect that it has lost contact with a SCS, but can do nothing more than report this to the MS-node and request a repair team. It is therefore important that both sides of the collaboration implement link connectivity awareness. The above also applies for the link between the CS and MS.

In addition to the failure of links, the nodes may also fail. This will not be considered in this thesis, but the response will be quite similar to that of a servered communication link, only that an additional test of node-existence is conducted.

For all signals traversing communication links, timers will be incorporated due to the asynchronous nature of the signals. The timers can either initiate a second attempt at sending the signal, or trigger a fail mode operation. Care should be taken and timers should be set long enough to ensure that duplicated signals do not arrive at the destination. Although these could simply be ignored and have no impact, there is a possibility that duplicate signals can cause inconsistencies.

The actions taken for each scenario of a communication link failure (not the FCS-failure) are shown in an informal sequence diagram shown in Figure 8-10.

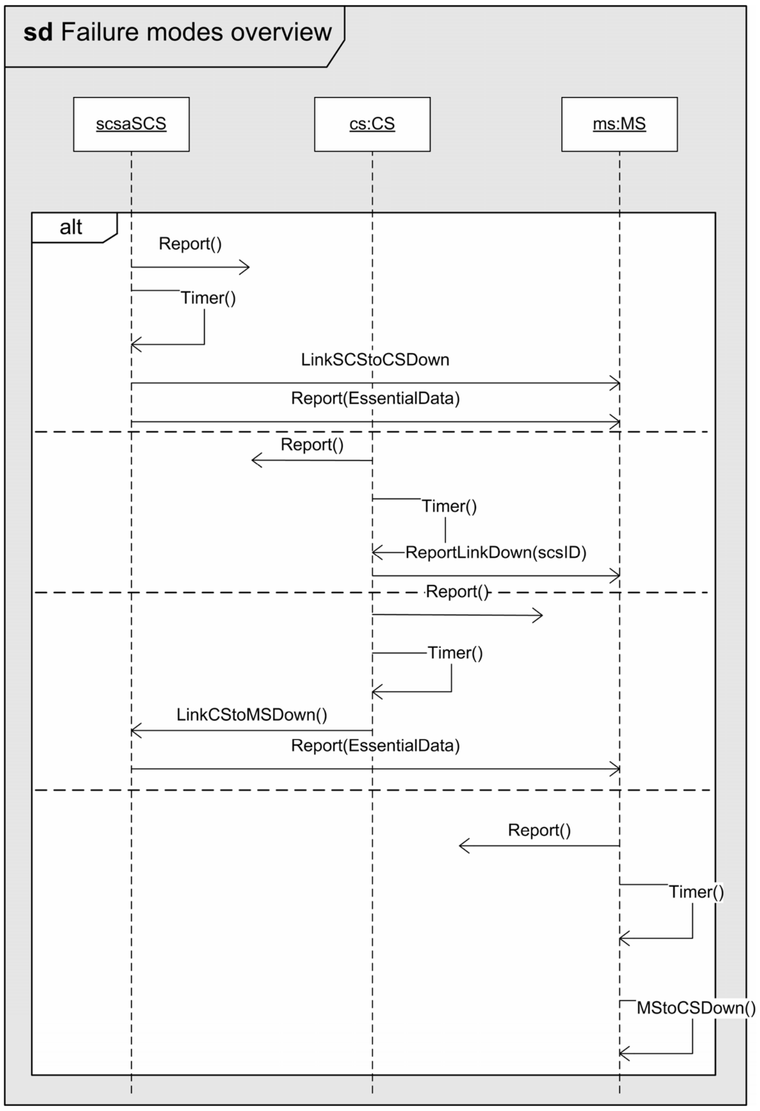


Figure 8-10: A sequence diagram showing failure of different communication links

In the first alternative of the sequence diagram, a failed PCS between the SCS and CS results in a switch to ECS and a report is made to the MS-node.

Since the communication links are in essence transparent, link failures only manifest themselves in the system as a change of addressing the recipient of a signal. This applies only to the SCS-node, where a primary link failure leads to an alternative addressing node, and signals are sent to the MS-node. Another problem does arise though. Upon initiating a new communication link, the node will receive a new IP-address from the connection. This must also be considered, especially with the application-level routing used by the ActorFrame ActorRouter. The actions taken upon link failure are summarized in Table 8-8.

Table 8-8: SCG-system failure modes and corresponding actions

Failure	Actions
PCS detected by SCS	ECS is initiated and the CS-node and MS-node are notified. The CS-node is notified through the MS-node. Alarms are generated.

PCS detected by CS	The MS-node is notified, and alarms are generated.
MCS detected by MS	Alarms are generated.
MCS detected by CS	FCS is initiated and the MS-node is notified.
FCS detected by MS	Alarms are generated.
FCS detected by CS	The SCS is notified and ECS is initiated. SCS then notifies the MS and alarms are generated.
Nodes	A node failure will manifest as a communication link failure and be detected through the same routines with some few additions.

When all communication schemes fail, the sea cage constellation is completely isolated. The rest of the system will detect this, and the correct actions will be taken. The sea cages could upon failure of all communications take turns, in a round-robin style, registering sensor data and testing communication links. When systems are restored the rest of the SCS-nodes return to a normal operating modus again. Such functionality is beyond the scope of this thesis, but is an interesting area to develop further.

8.3. Generic design of the system

Here a generic design of the system is presented and described. The implementation will use parts of this, in addition to specialized actors of the generic concepts presented here. An example of this will be given for the SensorAgent-actor presented in the next section. The actors and their inner actors are shown and functionality is presented with sequence and communication diagrams[6]. The bases for the design are the elements identified in the previous chapter, combined with the functional requirements, domain description, and sensor network and grid computing influences.

The design process has been an iterative process, with more than one change applied during implementation. Subsequently, the designs presented have evolved compared to the original drawings.

Several of the designs presented include elements which have not been implemented, and are shown only to illustrate further areas of function for the SCG-system. These functions are considered beyond the scope of this thesis or unnecessary for the implementation of the demonstrator. Where the design differs from implementation, the actor-name is surrounded by parenthesis and it is commented in the particular section.

Ports and connectors have not been used between distributed actors due to the lack of support for this in ActorRouter. As mentioned in section 7.2.2.1, ports are also used with caution within a class.

[6] UML2.0 Collaboration diagrams

The *Edge*-appendage used on certain actors is to describe and underline that these actors interact with elements beyond the ActorFrame-framework. These actors provide transparency and levelling between the ActorFrame-domain and external services.

The default ports of the actors have been omitted, as have port names on implemented ports. The port names generally follow the naming convention "*FromIdToWhoId*" and are presented with each corresponding state machine in Appendix G.

8.3.1. SCSAgent

The *SCSAgent*-actor is the actor which will represent the SCS-node in the system, and its structure is shown in Figure 8-11. Its tasks have been defined to the acquisition of sensor data, use of certain vital sensor data (such as GPS), handle sensor data and internal parameter settings, and maintain communications with the CS and MS. Simultaneously, this actor runs the system, manipulates the operating system, discovers and registers new sensors and handles eventual grid activities. This includes not only maintaining both the available services and topology but also allowing access to the *SCSAgent* from a mobile terminal. This fits in to the visions of mobile grid presented earlier.

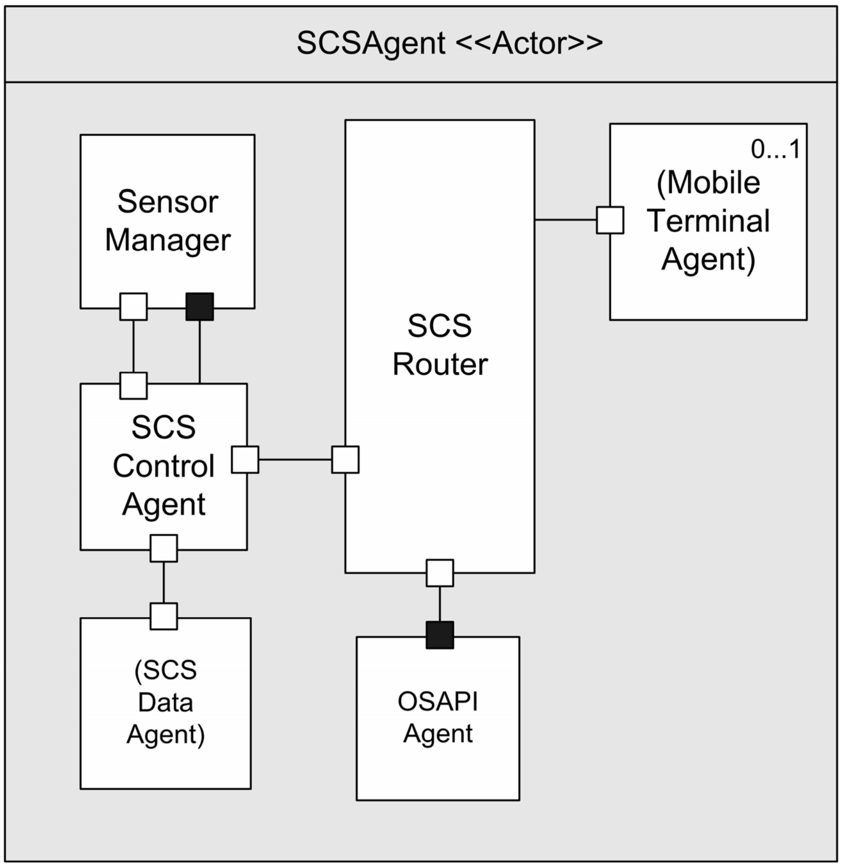


Figure 8-11: The SCSAgent-actor design

The connected mobile terminal will then have access to all the SCS-node's capabilities and, if desired, the rest of the Sea Cage Gateway system. Access could for several reasons be restricted, amongst others for security issues.

The *SCSAgent*-actor contains five inner actors which are:

- *SCSControlAgent-actor*
The *SCSControlAgent*-actor represents the main logic of the *SCSAgent*-actor. This actor handles sensor-input, parameter distribution, and handles the essential data from sensors such as position alerts. It also reports and answers to its superiors in the SCG-hierarchy.

- *SCSDataAgent-actor*
The *SCSDataAgent* handles the shared, persistent data required in the SCS-node. This could be any way of storing data. It is only available through the *SCSControlAgent* so that a certain level of access control can be implemented. If necessary, this actor can function towards a database. Since only a GPS-receiver is used in this system, there is no need for a *SCSDataAgent*-actor for the demonstrator, and it has therefore not been implemented.

- *OSAPIAgent-actor*
The *OSAPIAgent*-actor handles interaction with the local operating system and provides a layer from the residing operating system and the rest of the actors. Examples of interaction with the local OS could be to set the node to sleep, or to obtain system information such as battery level or connection status (initiate GPRS upon WLAN-disconnection). There should be implemented several actors for several operating systems, a minimum for Linux and Windows. For this system only a *WindowsAPIEdge* has been implemented, but other operating system edges can easily be added. The inner structure is shown in Figure 8-12.

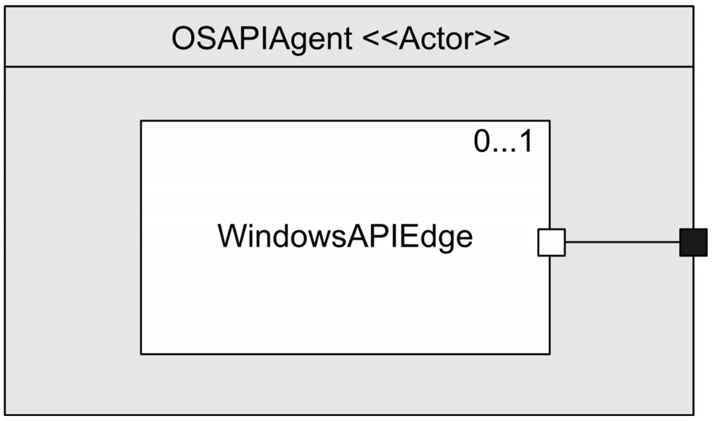


Figure 8-12: The OSAPIAgent-actor design

The *WindowsAPIEdge*-actor is directly available to the *SCSRouter* through a delegation port. The actor for the specific operating system will always connect to this port.

- *SCSRouter-actor*

The *SCSRouter*-actor handles addressing issues for the actors of the *SCSAgent*-actor. In addition to handling local addressing between actors not connected by ports, it also handles the sending and receiving of messages to and from the other distributed actors of the system. This provides a level of layering between the actors of the SCS-node and those on the CS-node, MS-node and eventually the other SCS-nodes.

The advantages of having a single point of interaction with the rest of the system are many. First and foremost, the use of a designated actor to handle distributed communication enables an easier control of link failures. The *SCSRouter*-actor uses timers for distributed communication, and can easily discover lacking responses and hopefully take care of this. Compared to allowing all actors control their own timers when sending messages to other actors, this method reduces complexity but increases the workload of the *Router*-actor.

- *MobileTerminalAgent-actor*

The *MobileTerminalAgent* is the terminal agent for a mobile terminal wishing to interact with the system. This actor could function as a bridge to the CS or MS should the native communication scheme fail. This actor has not been implemented since it is beyond the scope of this thesis.

8.3.1.1. SensorManager

The *SensorManager*-actor in the system represents the sensors connected to a SCS-node. This provides a layering from the SCS to the sensors, and handles the sensors in a dedicated process. The *SensorManager*-actor contains two types of inner actors, a *SensorDetectionEdge*-actor and *SensorAgent*-actors.

The structure of the *SensorManager*-actor is shown in Figure 8-13.

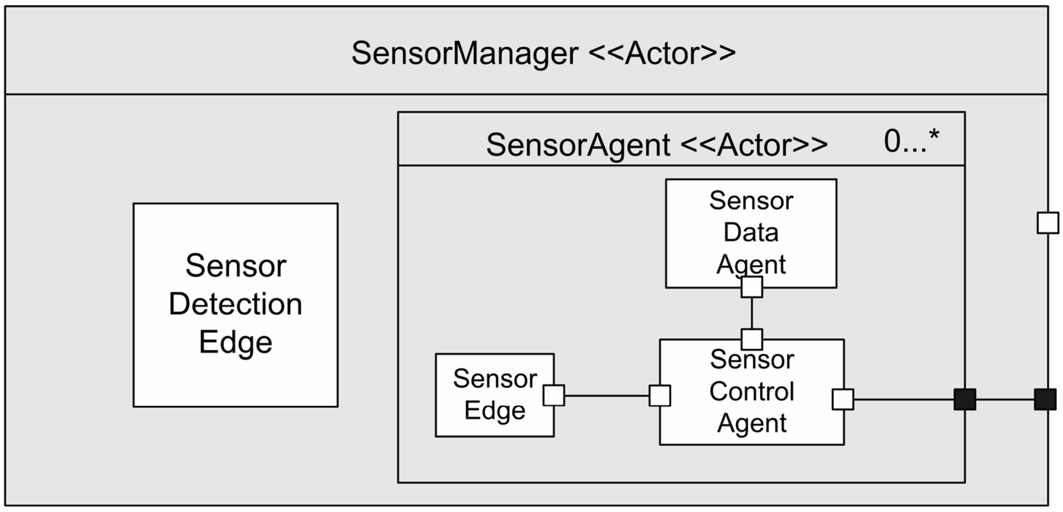


Figure 8-13: The SensorManager-actor design

As can be seen, the *SensorManager* contains the following five inner-actors:

- *SensorDetectionEdge-actor*

  The *SensorDetectionEdge* handles new sensors connected to the system. It listens to the communication ports and reacts when a new sensor is connected by requesting a new *SensorAgent* for that specific type of sensor. The *SensorDetectionEdge*-actor could, in essence, be considered to be part of the *OSAPIEdge*, since it does require interaction with the residing OS. In this case, it has been considered to be more bound to the *SensorManager*-actor, and has been placed here.

- *SensorAgent-actor*

  The *SensorAgent* represents the independent sensors to be supported by the SCG-system. There will be specialized entities of this actor for each sensor type.

- *SensorControlAgent-actor*

  The *SensorControlAgent* is responsible for administering and controlling the sensor. It can control sensor polling intervals, as well as detect sensor value threshold deviations.

- *SensorDataAgent-actor*

  The *SensorDataAgent* records data collected from the sensor. Upon request a report can be generated from the *SensorControlAgent* on current and historical status. This function is most likely to be limited to recent events due to the restrictions imposed on the SCS-node. Logging may be only to the extent of writing to a text-file. If the sensor does not require the storage of sensor data, the *SensorDataAgent* is not needed.

- *SensorEdge-actor*

  The *SensorEdge*-actor handles the direct interaction with the sensor. This could require different types of interfaces and is separated from the rest of the system to provide transparency.

In this system only a GPS-sensor is attached to the SCS-node. The *GPSSensorAgent*-actor implemented is shown in Figure 8-14.

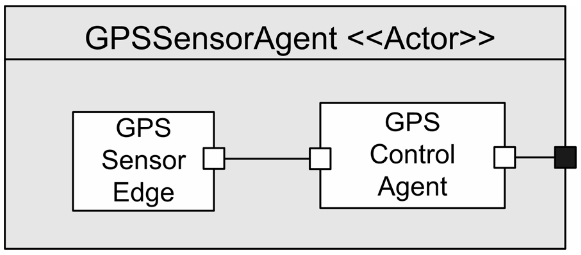


Figure 8-14: The GPSSensorAgent-actor design

As can be seen the *GPSSensorAgent*-actor consist only of the inner actors *GPSSensorEdge*-actor and *GPSControlAgent*-actor. The *SensorDataAgent* has not been implemented here due to the lack of need for a log of former GPS-positions. The *GPSControlAgent* only compares the latest position to a default position, and reacts only upon deviation larger than a certain pre-defined threshold. Therefore no form of data storing agent has been implemented beyond that of the latest position received and the default position. The *GPSControlAgent*-actor is directly connected to the *SCSControlAgent* through ports and connectors, providing a direct line of interaction when necessary. One example is in the case of an alarm situation.

8.3.2. CSAgent

The *CSAgent*-actor represents the CS-node of the Sea Cage Gateway-system. Its structure can be seen in Figure 8-15. As earlier described, its structure and functionality is quite similar to the *SCSAgent*. The actors represented in this actor are therefore the same as for the *SCSAgent*-actor, although their tasks differ slightly. In addition, the *CSAgent*-actor has a *SCSManager*-actor for administering, controlling and interacting with the *SCS*-nodes deployed in the system.

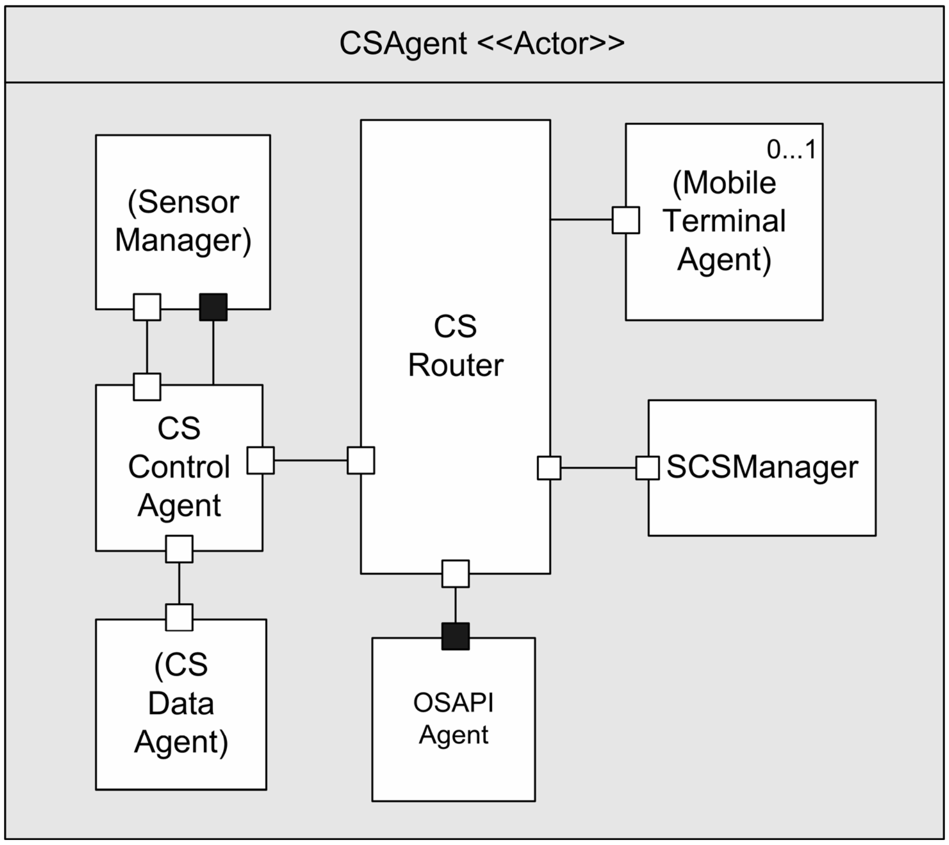


Figure 8-15: The CSAgent-actor design

The *CSAgent*-actor consists of seven inner actors. The *CSDataAgent*, *CSRouter*, *MobileTerminalAgent*, *SensorManager* and *CSControlAgent* represent the same functions as in the *SCSAgent*-actor, although there features may be slightly different or extended. The reasoning for their existence corresponds with those presented under the *SCSAgent*-section. Since there are no sensors attached to the CS-node for the demonstrator, no *SensorManager* has been implemented in the *CSAgent*.

The *SCSManager* is responsible for handling all SCS-nodes attached to its CS. This is done by assigning a *SCSSession*-actor to each connected SCS. This is shown in Figure 8-16

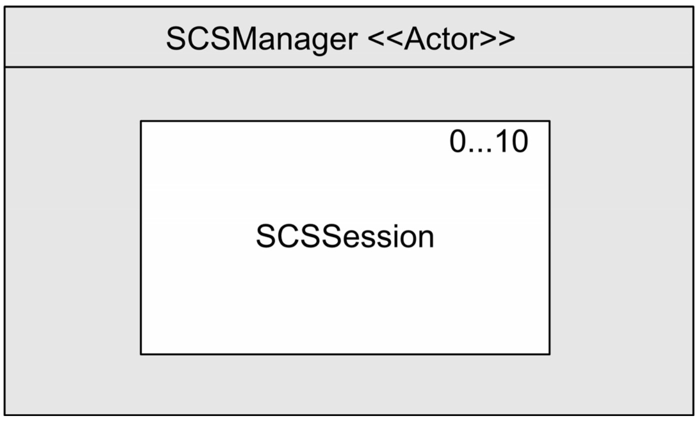


Figure 8-16: The SCSManager-actor design

The *SCSSession*-actor handles interaction with its specific *SCSAgent* throughout the period the SCS is connected to the CS. This provides dedicated actors handling each SCS connected to the CS, and provides a layer between the CS and its SCS-nodes.

8.3.3. MSAgent

The *MSAgent* represents the MS-node of the system. Its structure is shown in Figure 8-17. As presented in section 8.2.3, a possible set of tasks for the *MSAgent*-actor have been established. This list could of course be extended; a context handler could be added to the system for instance. Alternatively, such functions and others could be performed directly on the database residing on the MS-node. All of the inner actors represent a task to be performed or interaction with the environment.

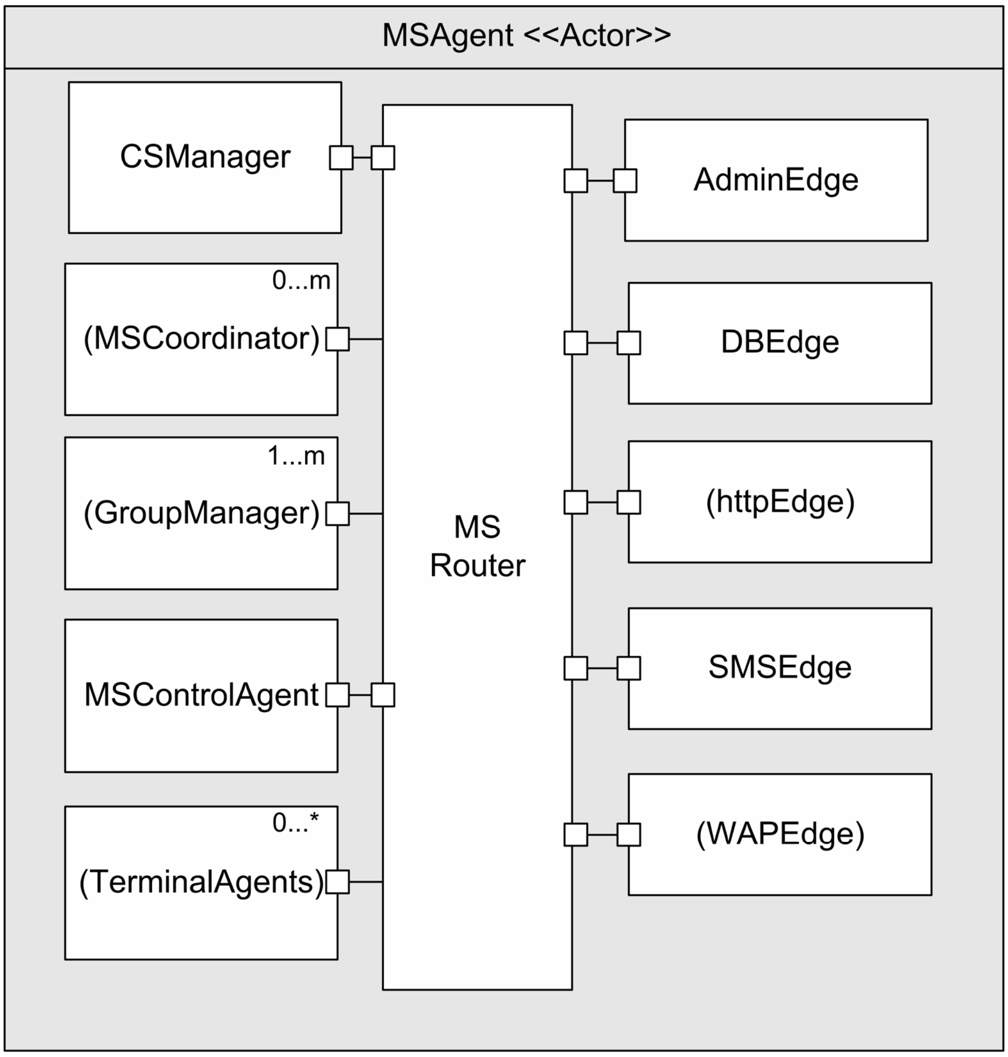


Figure 8-17: The MSAgent-actor design

The *MSAgent*-actor initially consists of the following nine inner actors:

- *CSManager-actor*
  The *CSManager*-actor is similar to the *SCSManager*-actor, shown in Figure 8-18 and performs the same task/role. As the *SCSManager*-actor, the *CSManager*-actor has an inner *CSSession*-actor to control and interact with each individual CS-node. The internal structure of the *CSManager* is shown in Figure 8-18.

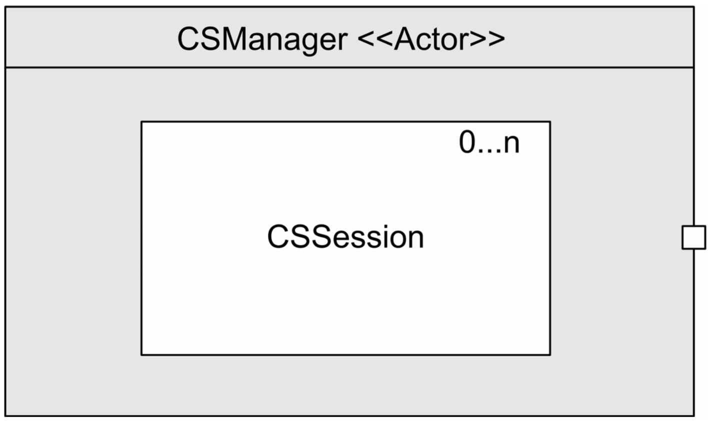


Figure 8-18: The CSManager-actor design

In addition, the *CSSession* must be able to handle SCS-nodes when the PCS fails. This can be done by incorporating a *ReserveSCSSession*-actor as an inner actor of *CSSession*. This is shown in Figure 8-19.

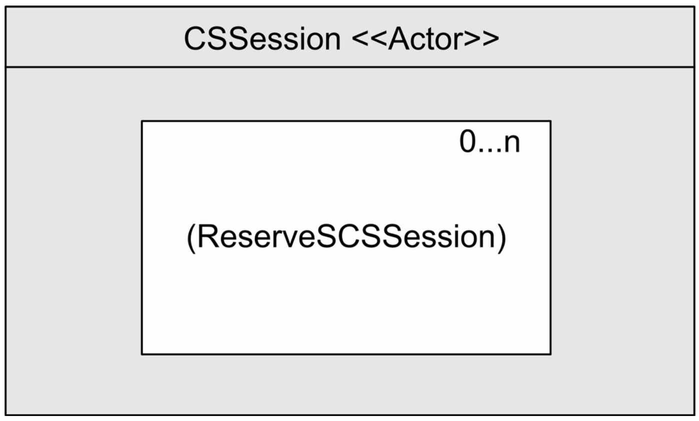


Figure 8-19: The CSSession-actor design

When a SCS loses its connection to its CS, it requests a *ReserveSCSSession*-actor from its CS-node's *CSSession*-actor. As there is only one SCS-node using the ECS in the demonstrator system, the *CSSession* can handle the communication for this SCS, and the *ReserveSCSSession*-actor has not been implemented.

- *GroupManager-actor*

To handle the two essential group's defined in [1], maintenance and rescue, these have been assigned to the *GroupManager*-actor. This is shown in Figure 8-20.

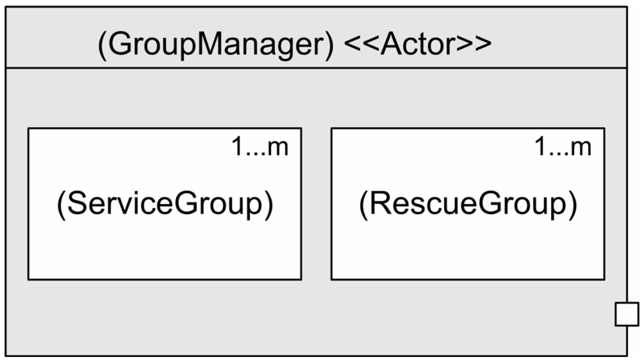


Figure 8-20: The GroupManager-actor design

These have not been implemented in the system as their functions have not been completely determined.

- *MSControlAgent-actor*

This actor is similar to the control agents introduced in the *SCSAgent* and *CSAgent*. This actor controls MS-necessary operations. With further research into the workings and desired functions of the MS-node, this actor's functions may be distributed to other actors, or it may not be necessary at all.

- *DBEdge-actor*

The *DBEdge*-actor registers collected sensor-data and other information in a database for storage and later retrieval.

- *SMSEdge-actor*

The *SMSEdge* provides an edge to an SMS-server for enabling the possibility of, for instance, generating alarms to rescue groups or providing status information. The possibility of handling incoming SMS to retrieve information or adjust settings could also be implemented.

- *WAPEdge-actor*

The *WAPEdge*-actor provides an edge to a WAP-gateway to enable WAP-specific functions, much like those of the *SMSEdge*-actor. This edge has not been implemented as the alarm function is sufficiently demonstrated with the *SMSEdge*.

- *httpEdge-actor*

This actor holds a reference to a web-server for interaction with web-users through a web interface. The advantages of using web interfaces for user- and control-interaction are many. Through the use of web-pages, web-browsers can access the information from anywhere, and to a certain extent remove the necessity of local applications residing on user machines. To handle the statelessness of the http-protocol, *httpSession*-actors are implemented as an inner actor of the *httpEdge*-actor, as demonstrated in [49]. This actor has not been implemented as this form of interaction is not the focus of the design.

- *AdminEdge-actor*
  In order for an administrator to adjust/change parameters and functionality of the system an actor provides an edge against a user interface, most likely a GUI. The *AdminEdge* is for providing an interface to system for users. In this system it will be limited, simply providing the possibilities for testing some functionality of the system

8.4. Sequence and communication diagrams

Here the main functionality and interaction patterns of the system are described with corresponding sequence and communication diagrams. Not all of these sequence diagrams have been implemented, and in some of the diagrams generic signal names are used. This is commented in the subsequent sections. A full list of signals and parameters can be found in Appendix H.

8.4.1. Setting up the system

Before being able to provide the services necessary for the Sea Cage Gateway system, the system must be set up and the nodes must be connected. The system set-up is designed with two main objectives; the distribution of the necessary addresses for interaction and to allow for easy configuration and set-up for new nodes attaching to the current system. The setup also establishes the hierarchy of inter-communicating actors. The actors involved in collaborations between the distributed nodes are shown in Figure 8-21.

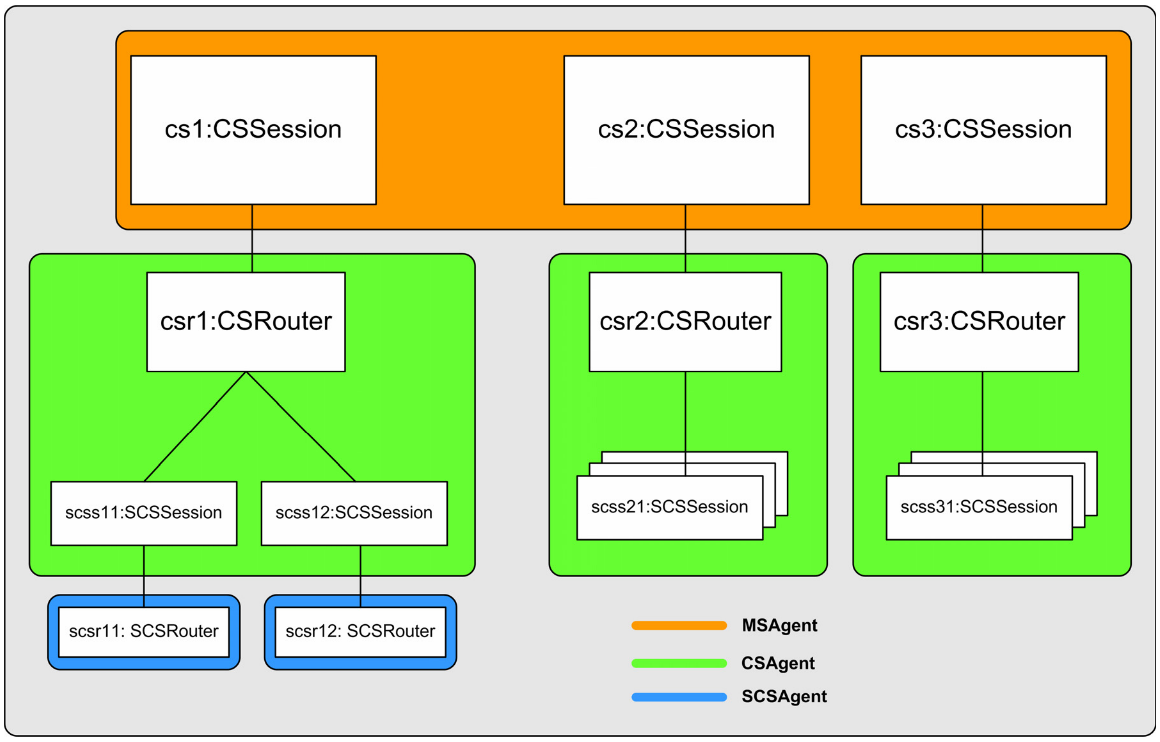
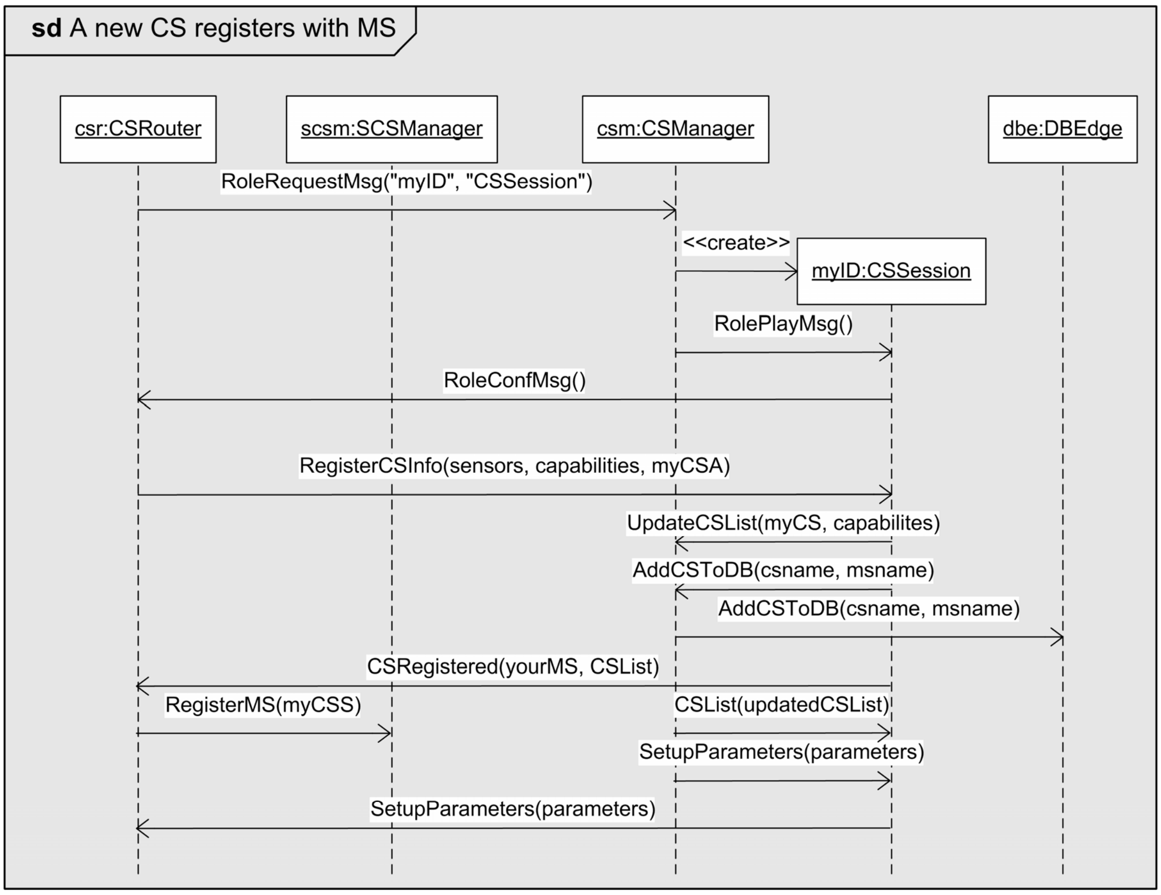


Figure 8-21: The intercommunicating actors of the SCG-system

To allow for easy configuration, the SCG-system is assumed to be set-up with the *MSAgent* first, with subsequent CS-nodes attaching later. This also applies to the SCS-nodes later connected to their CS-node. This is shown in Figure 8-3. Finally, sensors are attached to the SCS-node.

8.4.1.1. Initiating the connection between a new CS and the MS

The first step of setting up the system is for a new CS-node to contact and register with its MS-node. A *RoleRequestMsg*-signal[7] is therefore sent from the *CSRouter*-actor of the CS-node to the *MSAgent* inner actor *CSManager* and requests a *CSSession*-actor to coordinate further interaction with. The sequence diagram for this procedure is shown in Figure 8-22.


sd A new CS registers with MS
csr:CSRouter
scsm:SCSManager
csm:CSManager
dbe:DBEdge
RoleRequestMsg("myID", "CSSession")
<<create>>
myID:CSSession
RolePlayMsg()
RoleConfMsg()
RegisterCSInfo(sensors, capabilities, myCSA)
UpdateCSList(myCS, capabilites)
AddCSToDB(csname, msname)
AddCSToDB(csname, msname)
CSRegistered(yourMS, CSList)
RegisterMS(myCSS)
CSList(updatedCSList)
SetupParameters(parameters)
SetupParameters(parameters)
Figure 8-22: The sequence diagram for a new CS registering with MS

Upon reception of the *RoleConfMsg*-signal, the *CSRouter*-actor registers with its designated *CSSession*-actor with the *RegisterCSInfo*-signal, a signal containing information about the CS. In the demonstrator this signal is empty. *CSSession*, in turn, adds the new CS-node to the list of current CS-nodes by sending the *UpdateCSList*-signal to its parent, the *CSManager*-actor. The *CSManager*-actor updates its list of CS-nodes and sends the updated list of CS-nodes to all of its children (inner actor) *CSSessions* (not shown). *CSSession* then forwards the list to their designated

[7] Signal and message are used as synonyms in this thesis.

CSAgent-actor, more precisely the *CSRouter*-actor which handles all communication with higher placed nodes in the SCG-hierarchy. Finally, and if necessary, a set of basic parameters are sent out to the *CSRouter*, which forwards these to *CSControlAgent*-actor (not shown). This allows for basic parameter setting directly and automatically from the MS if the default values aboard the current CS are obsolete or unavailable. There are no such parameters included in the demonstrator.

To clearly see the messages being passed between the SCG-nodes, a high-level communication diagram is shown in Figure 8-23.

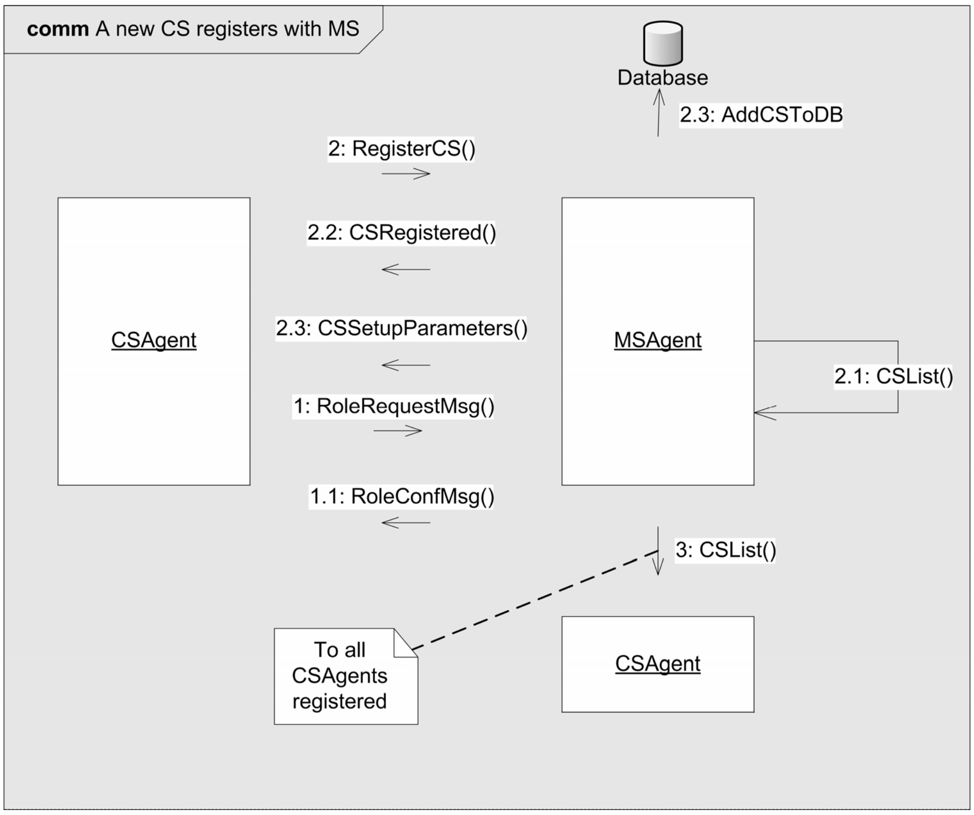


Figure 8-23: A high-level communication diagram for a new CS registering with MS

The communication 2.1 refers to the distribution of the new, update list of CS-nodes via the signal *CSList* among the *CSSession*-actors in the *MSAgent*-actor. These sessions subsequently distribute the new list to their CS-nodes. The *CSList* is distributed to the latest CS in *CSSetupParameters*-signal as previously shown in Figure 8-22

8.4.1.2. Initiating the connection between a new SCS and a CS

The procedure for connecting a new SCS-node to its CS-node, shown in Figure 8-24, is very similar to connecting a new CS-node to the MS-node.

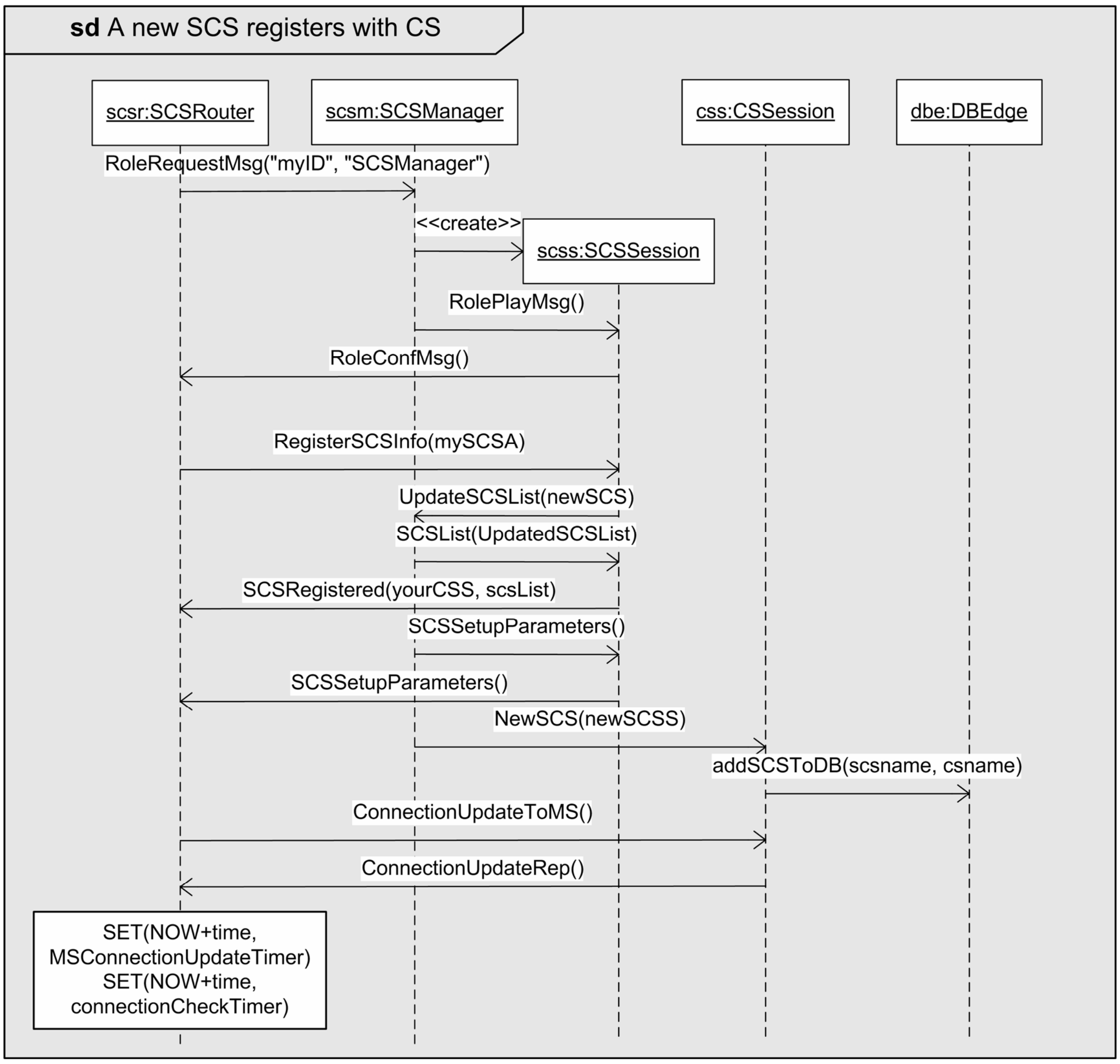


Figure 8-24: The sequence diagram for a new SCS registering with CS

The main difference is that the *SCSSession*-actor reports to the *CSAgent's CSSession*-actor that a new SCS-node has been installed. The *SCSRouter* receives a list of the other SCS-nodes represented by their *SCSRouters* under the same CS-node. In addition, the *SCSRouter*-actor sends a *ConnectionUpdateToMS*-signal to its *CSAgent*-actors *CSSession*-actor. This is due to the functionality of the ActorFrame ActorRouter. The routing table of the *SCSAgent* must contain the *MSAgent*-address in order for messages to be sent to the *MSAgent* when the PCS goes down. When the PCS is unavailable, the default gateway otherwise used is unavailable. Therefore the *SCSAgent* must regularly receive messages from *CSSession*. This interval is specified by the *MSConnectionUpdateTimer*-timer. A *ConnectionCheckTimer*-timer is also set; this timer specifies the intervals in which the *SCSRouter* checks the PCS link-status to the *SCSSession*.

A high-level communication diagram displaying messages sent between the top-level distributed actors is shown in Figure 8-25.

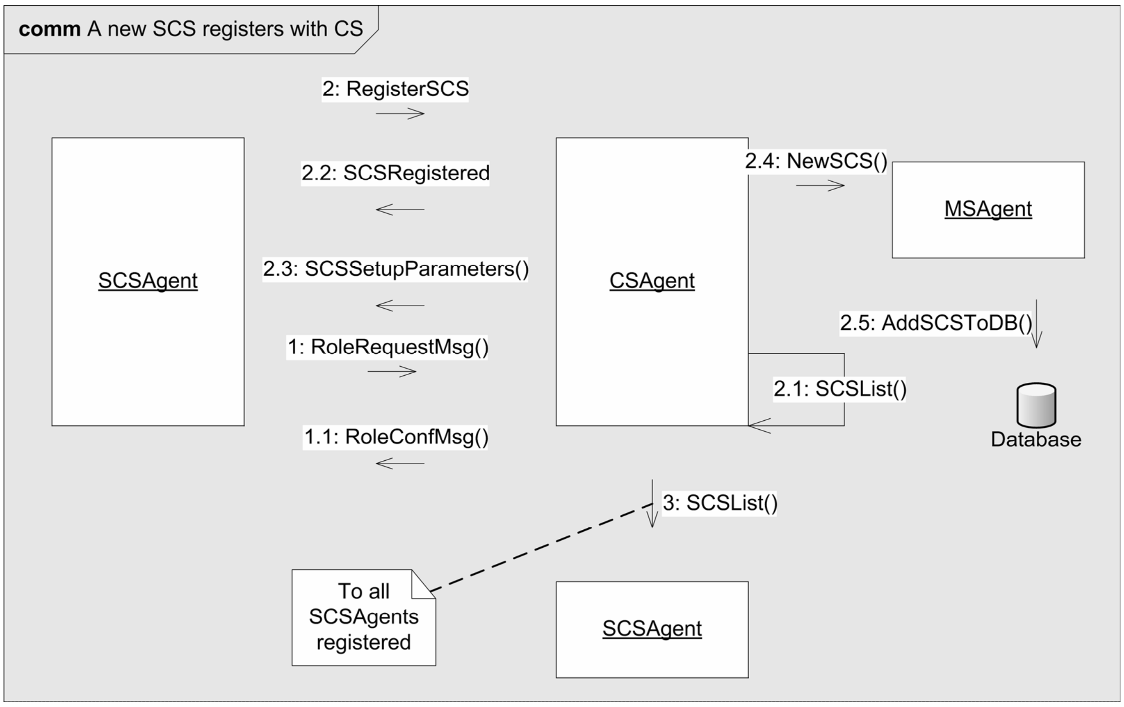


Figure 8-25: A high-level communication diagram for a new SCS registering with CS

Again, this is a very similar pattern as the one connecting a CS to a MS. The main difference is, as previously mentioned, the update of the SCS-capability to the *CSAgent* and the *MSAgent*. The *ConnectionUpdateToMS*-signal from the *SCSAgent* to the *MSAgent* is not shown in this communication diagram, as it would degrade the readability of the figure.

8.4.1.3. Initiating the connection between a new sensor and its SCS

To achieve a high level of self-configuration and automation, new sensors should be automatically discovered and integrated into the system. The sequence diagram for this is shown in Figure 8-26.

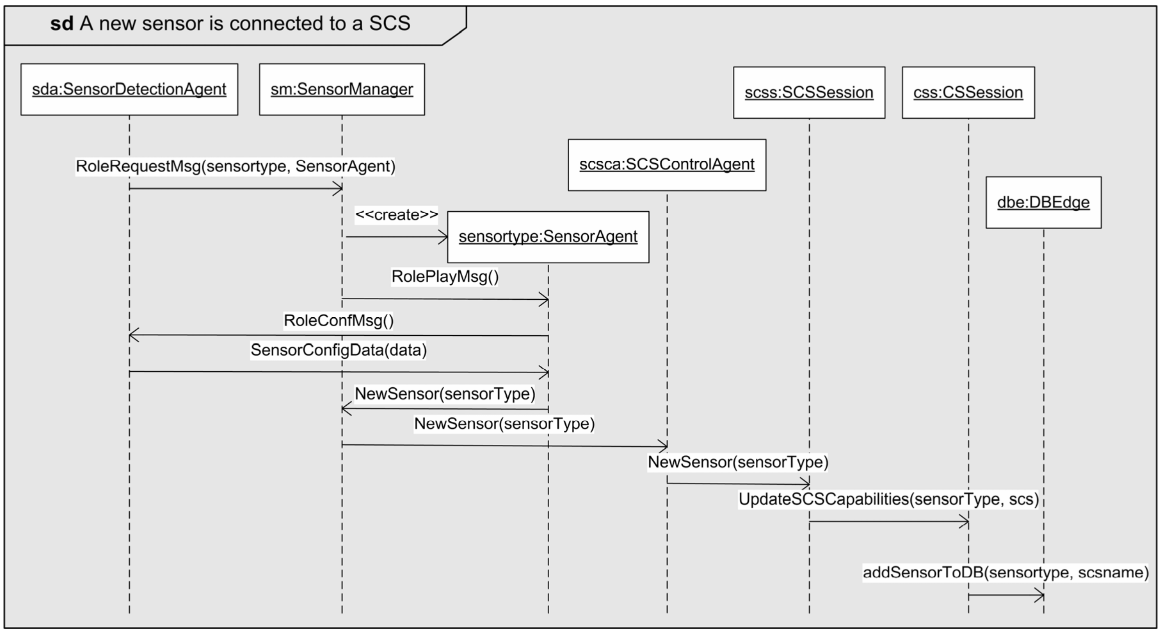


Figure 8-26: The sequence diagram for connecting a new sensor to a SCS

The *SensorDetectionAgent*-actor continually searches for new sensors by, for instance, scanning all available COM-ports. When it detects a new sensor, it identifies its type, and sends a *RoleRequestMsg*-signal for a *SensorAgent* for this type of sensor. The *SensorAgent* for this sensor then handles input and control of the new sensor. The *SensorManager* then informs the *SCSControlAgent*-actor about the new sensor, and the *SCSControlAgent*-actor informs the *SCSSession*-actor (via *SCSRouter*, not shown), and the *SCSSession*-actor propagates the information on to its *CSSession* (via *CSRouter*, not shown). Information of the new sensor is thus propagated throughout the system automatically. If, for instance, preferred parameter settings for a certain sensor have been altered since deployment of the *SCSAgent*, the *SCSSession* or *CSSession* can send new operating parameters back to the *SensorAgent*-actor. These parameters can be anything from polling intervals to threshold values.

A high level communication diagram for this collaboration is shown in Figure 8-27.

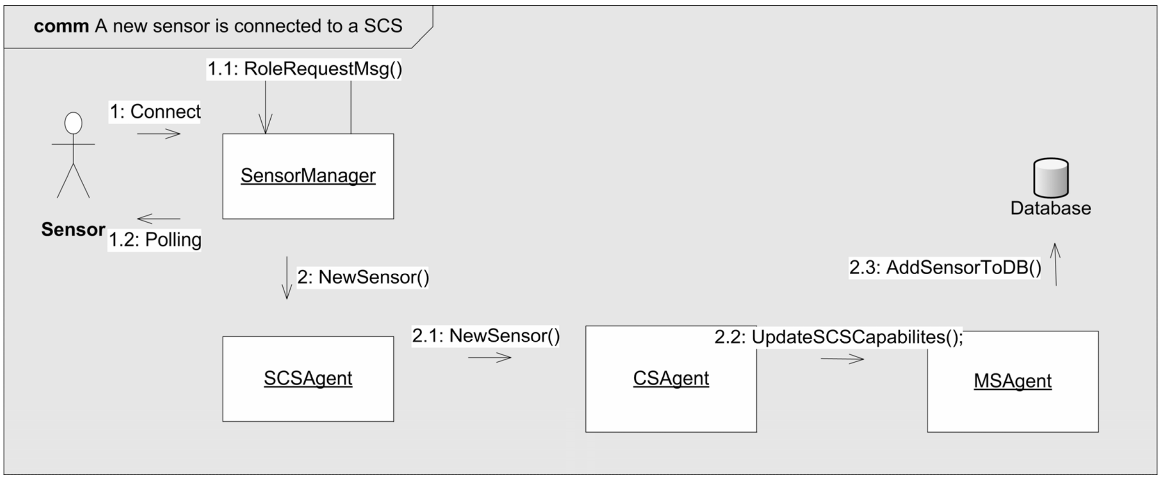


Figure 8-27: A high-level communication diagram for a new sensor being connected to a SCS

In this communication diagram, the *Sensor* is presented as an actor outside the system. This is not to be confused with the actor-terminology used in ActorFrame. The connection of a sensor generates an automatic *RoleRequestMsg*-signal, and the sensor is consequently queried. The information of a new sensor is then propagated among the nodes of the SCG-system and added to the database.

As shown in section 8.2.2, sensors may also be connected to the *CSAgent*-actor. This will be handled similarly as the sequence diagram, except that it will be the CS-capabilities that will be updated.

8.4.2. Communications for sensor data retrieval under normal operation

In the following section interaction between the different nodes under normal operating conditions are shown. The interactions for this section have been limited to the acquisition of sensor data from lower-level nodes. There will be other forms of interaction during operations of the SCG-system, such as distributing new parameters through the system, but the focus here is sensor-data-retrieval. This system only implements timer-based sensor data collection. The discussion assumes that all communication links are functioning properly, and that all nodes are active.

The process of retrieving sensor data has taken a two-level design. As will be shown in the following section, each node updates and retrieves its own sensor data with pre-determined intervals defined with timers. Each node also requests sensor data from a lower-level node with a pre-defined frequency. The interval is shortest for the *SCSAgent*, larger for the *CSAgent* and the longest interval is the *MSAgents*. When receiving a query for updated sensor data, the queried node retrieves the latest data from their data agent, and sends this to the requesting party. The principle with involved actors is shown in Figure 8-28.

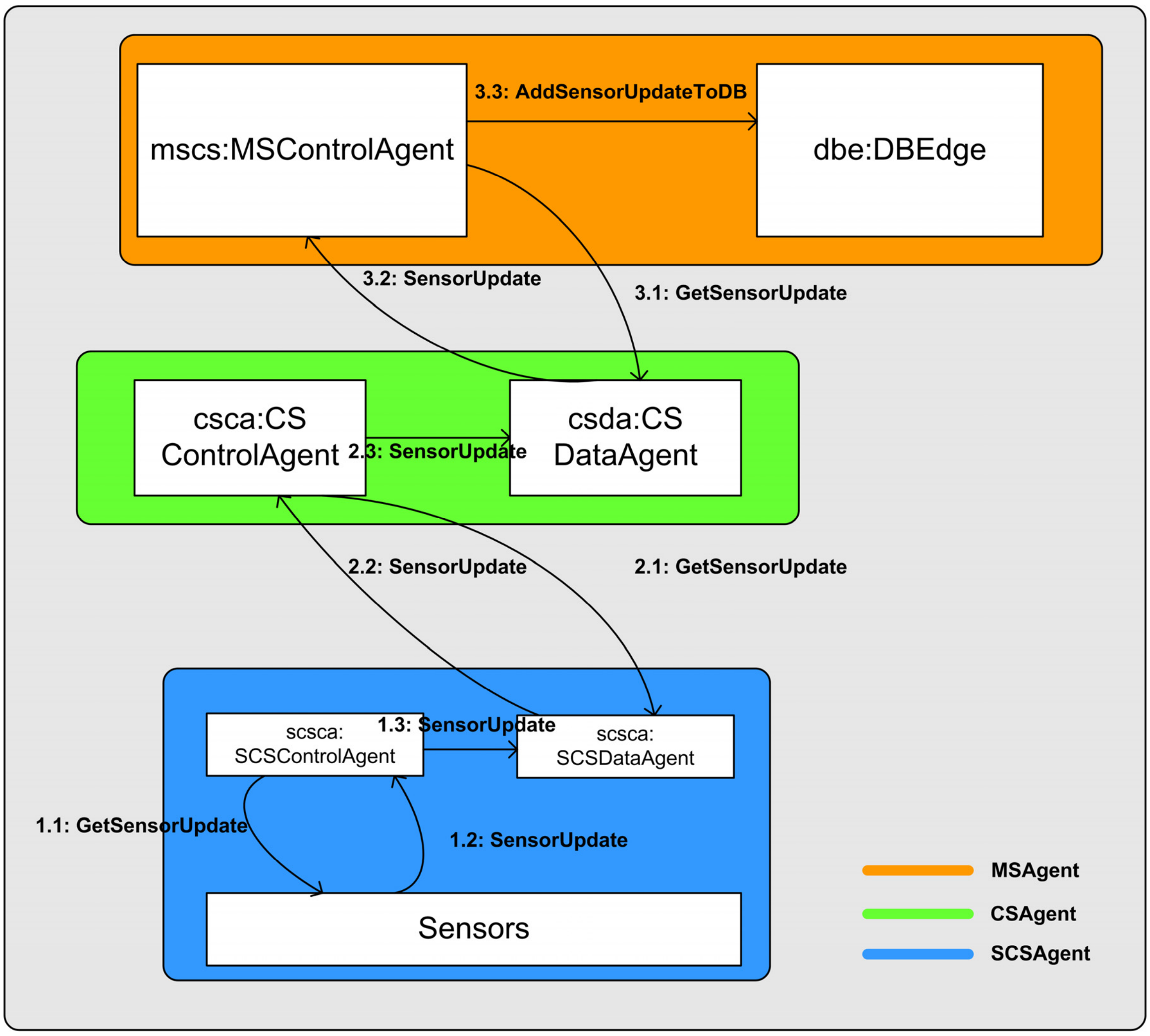


Figure 8-28: How sensor data is retrieved from the nodes of the SCG-system

The reason for doing this instead of nodes retrieving sensor data upon request is both to assure more reliable response times, since the request does not propagate throughout the system, but also for ensuring up-to-date sensor data in each independent node. This is important in the case of communications failure. It also allows for data to be aggreagated at several natural levels before being reported further.

When the sensor data has been reported upwards in the SCG-hierarchy the local sensor data registry can be emptied, or perhaps stored in another format for backup reasons. This has not been considered here.

The sequence diagrams for the collaborations illustrated above are described in detail in the following sections.

8.4.2.1. Communication between MS and CS

Communications between the CS and MS can be initiated for a variety of reasons; due to an alarm, regular sensor data update, or upon request from a user. The request can be generated either by user through the *httpEdge*, through the *AdminEdge* or through a regular timer for retrieving the data from the SCG-system nodes. This in turn generates a *GetSensorUpdate*-signal to the *CSManager*-actor, who proceeds to query all its *CSAgents* for their sensor-data. The *CSAgents* are registered in a *csList,* which is an *ArrayList*. The sequence diagram for this is shown in Figure 8-29.

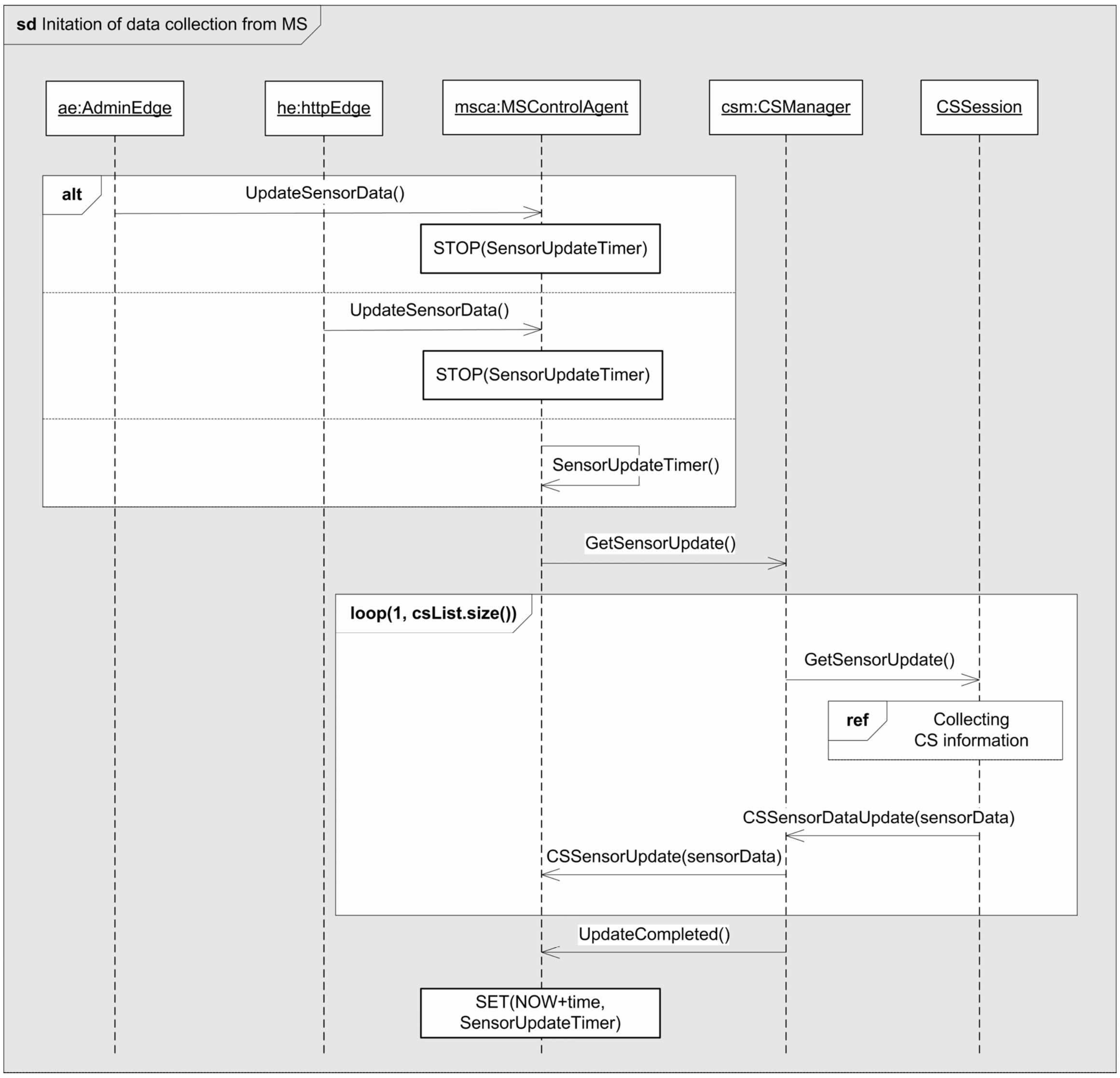


Figure 8-29: The sequence diagram for the collection of sensor data from the MS-node

When the *SensorDataUpdate*-signal is received the signal is sent both to the *MSControlAgent*-actor and to the *DBEdge*-actor (this is done automatically by the *MSRouter*-actor). The *DBEdge*-actor inserts the sensor data into the database. When all updates are finished the *MSControlAgent*-actor is notified of this through the *UpdateCompleted*-signal, and the timer for requesting sensor updates is reset. This timer is set for the first time when the SCG-system registers its first sensor.

A communication diagram illustrating the interactions between the distributed actors is shown in Figure 8-30.

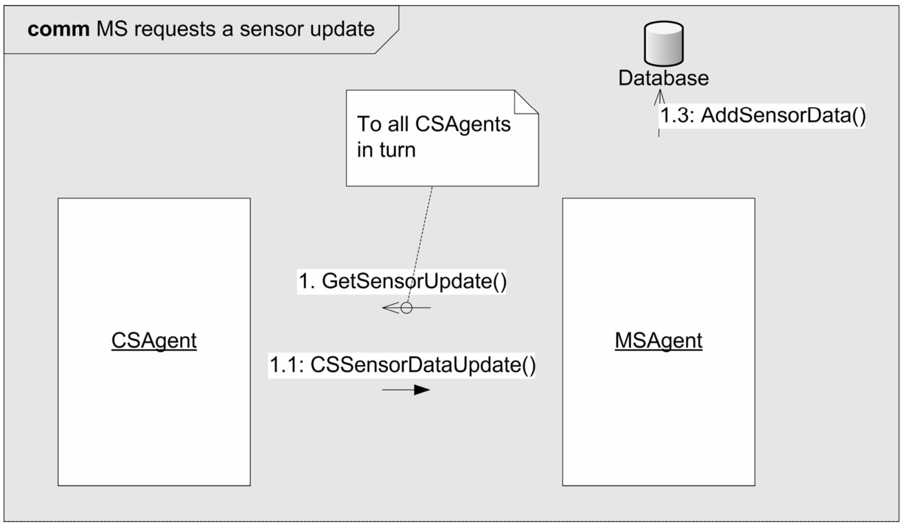


Figure 8-30: A high-level communication diagram for sensor data retrieval from the CS-nodes

The sequence diagram showing the interaction between the *CSSession*-actor and its *CSControlAgent* and *CSDataAgent* upon a sensor update request is shown in Figure 8-31.

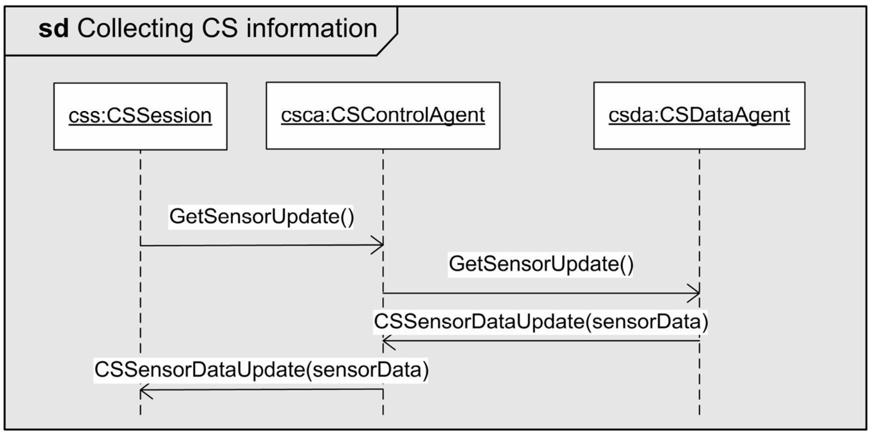

sd Collecting CS information
css:CSSession
csca:CSControlAgent
csda:CSDataAgent
GetSensorUpdate()
GetSensorUpdate()
CSSensorDataUpdate(sensorData)
CSSensorDataUpdate(sensorData)

Figure 8-31: The sequence diagram for the handling sensor update requests by the CS

The signals presented all go through the *CSRouter*-actor, but this is not shown.

8.4.2.2. Communication between CS and SCS

Asides from the case of abnormal sensor reading leading to the generation of an alert-signal, communications between the SCS and CS is generally initiated from the CS. The intervals between communications have to be set according to the sensor data required, and the capacity available on each SCS-node. Generally, communication between the CS and SCS is generated on three occasions. The first is the aforementioned alarm situation, the second is the regular polling conducted by the CS based on a timer-interval, third is on request from the MS. Under normal communications only the regular polling from the *CSAgent* has been implemented.

The sequence diagram for when a CS-node retrieves sensor data from its SCS-nodes is shown in Figure 8-32.

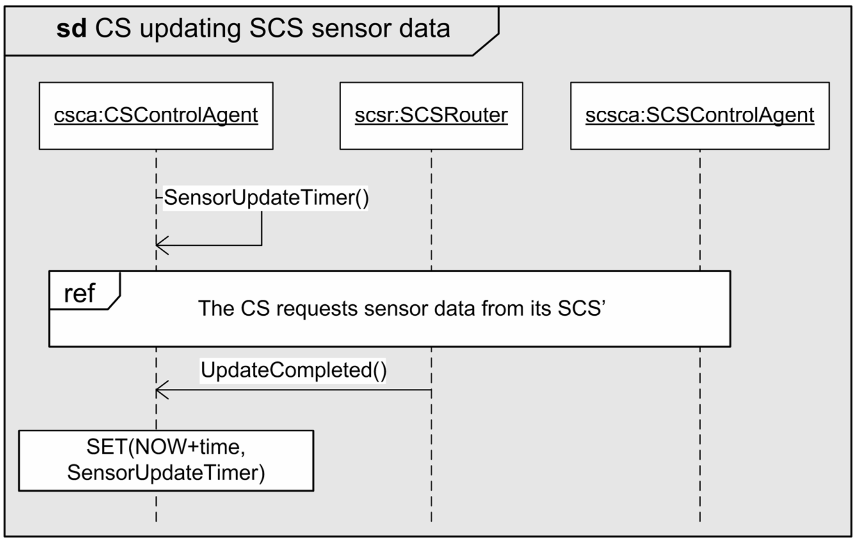

sd CS updating SCS sensor data
csca:CSControlAgent
scsr:SCSRouter
scsca:SCSControlAgent
SensorUpdateTimer()
ref
The CS requests sensor data from its SCS'
UpdateCompleted()
SET(NOW+time, SensorUpdateTimer)

Figure 8-32: The sequence diagram for a CS updating its sensor data

As with the *MSControlAgent*, the *CSControlAgent* sensor data retrieval procedure is timer-initiated. This timer is set for the first time when the CS is alerted of a sensor connected to a SCS-node. When all the SCS-nodes have reported their sensor data, the *CSControlAgent* is notified through the *UpdateCompleted*-signal.

When the *SensorUpdateTimer*-timer has been invoked, the *CSControlAgent* generates a request to its *SCSManager* to retrieve the sensor data from all SCS-nodes. The *SCSManager*, via the *SCSSession*-actors, continues to poll the SCS-nodes for sensor data one at a time using the *scsList*, similar to the *csList*. This is both to minimize the traffic and congestion on the PCS-link, reducing energy consumption, but this also makes it easier to maintain the status of all link and collaborating parties. The sequence diagram for this procedure is shown in Figure 8-33.

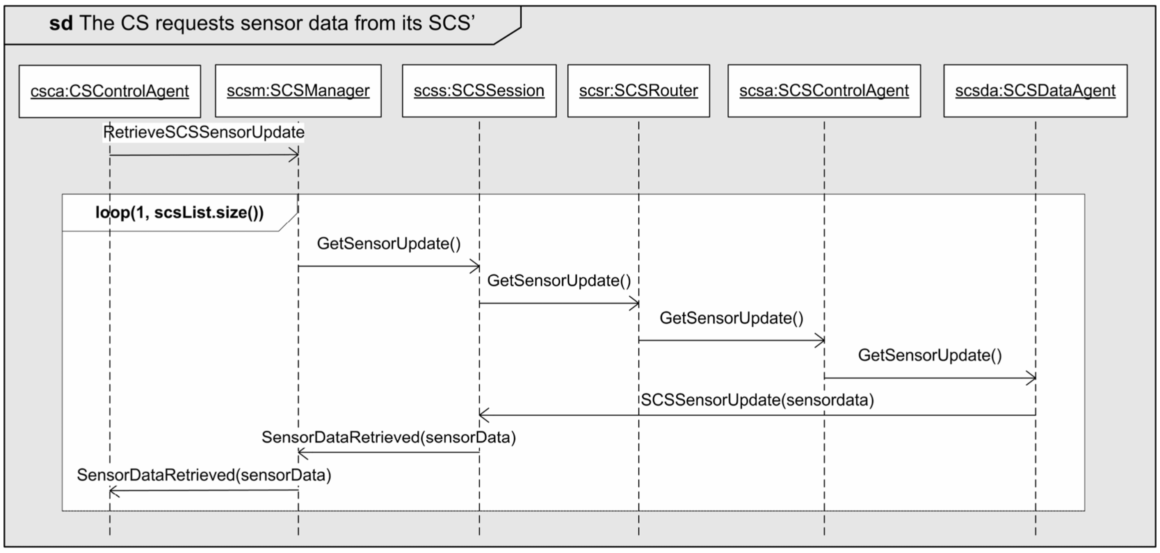


Figure 8-33: The sequence diagram for retrieving sensor data from a CS-node's SCS-nodes

This procedure is similar to the one where the *MSAgent* retrieves the sensor-data from its *CSAgents*. The *CSControlAgent*-actor forwards the sensor data received to the *CSDataAgent*-actor for storage.

A communication diagram showing the interactions between the distributed actors is shown in Figure 8-34.

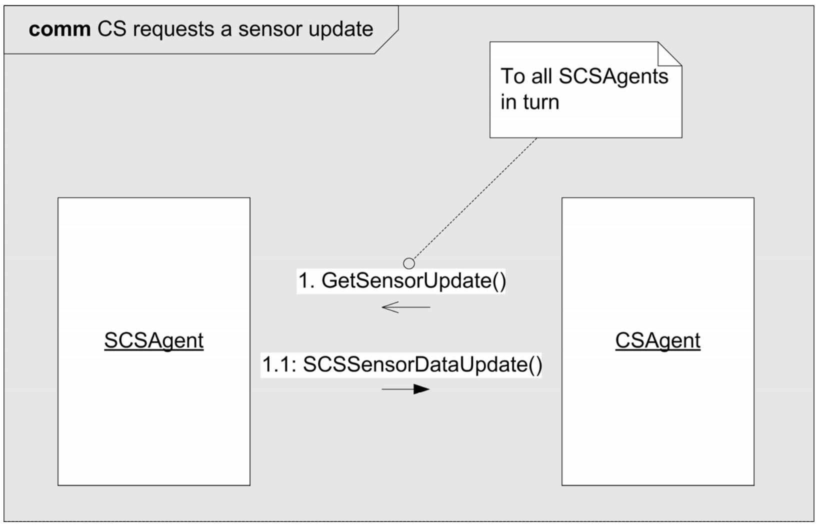


Figure 8-34: A high-level communication diagram for sensor data retrieval from SCS-nodes

This pattern is identical to the one used between the *MSAgent* and its *CSAgents*, except there is no update to an external database here. This could be implemented at a later stage if necessary.

8.4.2.3. Communication between SCS and sensors

A major part of this system is the acquisition, distribution and utilization of sensor data retrieved from the sensors installed at each SCS-node. A general sequence diagram for SCS-sensor interaction is shown in Figure 8-35. This sequence diagram is identical for sensors attached to CS-node.

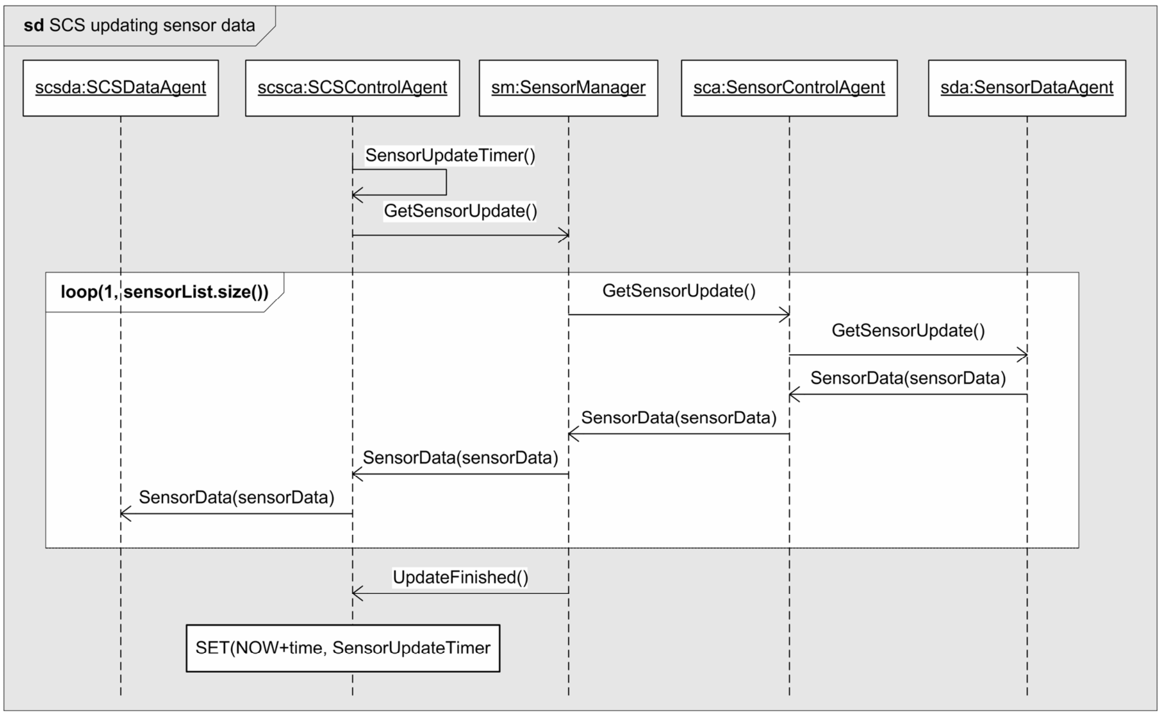


Figure 8-35: The sequence diagram for a SCS retrieving its sensors data

Again, the pattern for retrieving the sensor data is similar to that of the *CSAgent* and *MSAgent,* and the descriptions for those procedures apply here as well. An issue to be considered here is the format of the sensor data retrieved from the sensors. One option is to transport it in pre-defined, sensor-specific objects. These objects can preserve the data in its original format, allowing for the data to be handled by other entities. Such a scenario could be that of grid computing, sending sensor-data to the *CSAgent* for processing and analysis. Another option is to simply report the data as a *String*. In this way all sensor data could be comprised into a *String*, or defined in a XML-document, and reduce the number of signals and interactions necessary for sending sensor data. This is simpler, less bandwidth is required, but some of the data density may be reduced.

Whether the data should be sent in a sensor-specific signal or through a generic sensor-signal can also be discussed. It is good practice to branch on signal, and not a signal parameter value, but in the case of incorporating new sensors in the SCG-system using sensor-neutral signals can be an advantage. By adding the new sensor-data to a pre-existing *String* of data, this data can easily piggyback through the system back to the *MSAgent*. In such a scenario one does not have to implement a new signal throughout the system and state machines. In the demonstrator, with only one sensor, a sensor-specific signal has been implemented, the *GPSSensorData*-signal. This is an area applicable for further discussion, and distinctions between the sensor data in the system may be necessary.

The *SensorControlAgent*-actor regularly queries the sensors for data, both for threshold-value checks, as well as for logging purposes. The sequence diagram for this is shown in Figure 8-36.

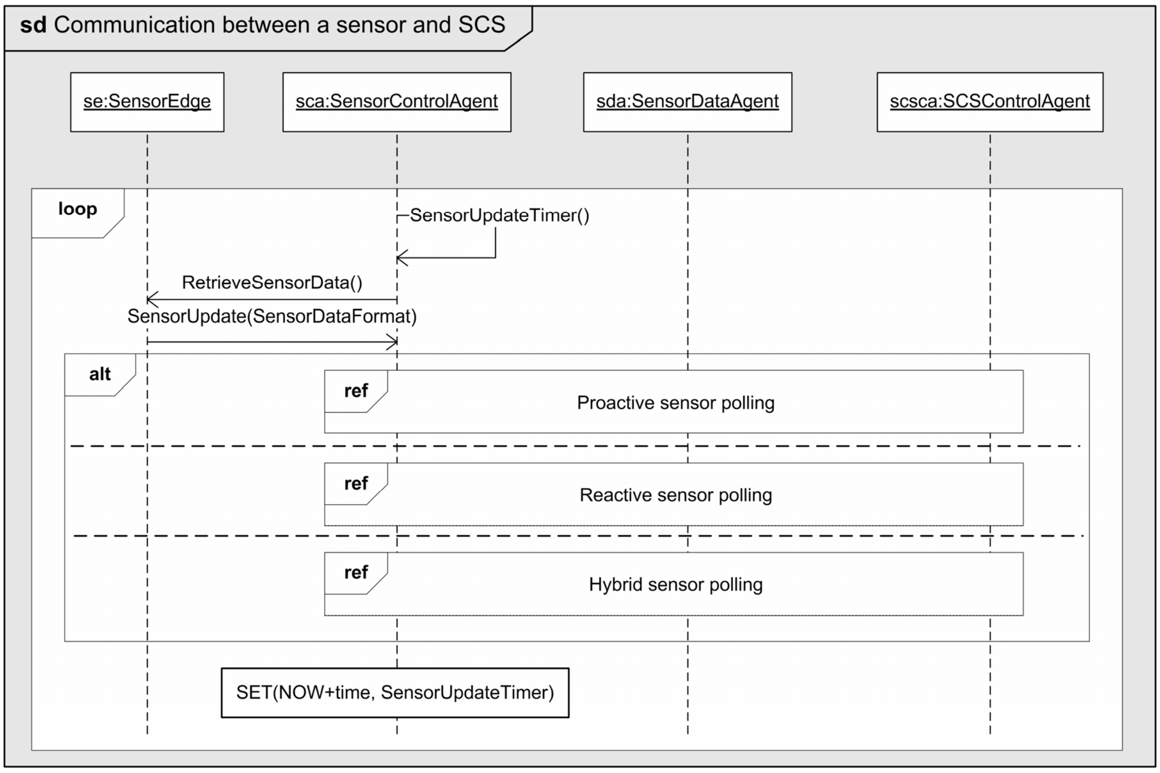


Figure 8-36: The sequence diagram for interaction between the SCS and its sensors

As shown the *SensorControlAgent*-actor retrieves sensor data by querying its *SensorEdge*-actor for sensor data. The interval at which this happens is determined by the timer parameters for this type of sensor. The *SensorEdge*-actor retrieves the current sensor reading and sends it back to the *SensorControlAgent*-actor. Alternatively the sensor data can be streamed directly to the control or data agent.

If the data is simply of interest for storage, the data is sent to the *SensorDataAgent* for storage until a request for a sensor report is received, initiated through the signal *RetrieveSensorData*. The required data is then sent, and if storage capacity is limited, the current data is erased. This is similar to proactive sensor handling, described in section 4.3. The simple sequence diagram for this is shown in Figure 8-37.

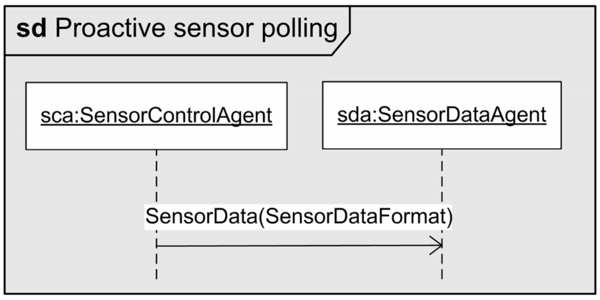


Figure 8-37: The sequence diagram for proactive sensor polling

If the sensor data is of a type that has threshold parameters concerning a range of normal operations, *SensorControlAgent*-actor will compare the collected data to these values. In the occurrence of a deviation, the *SCSControlAgent* is notified and appropriate action is taken. This is similar to the reactive sensor handling, described in section 4.3. The sequence diagram for reactive sensor handling is shown in Figure 8-38.

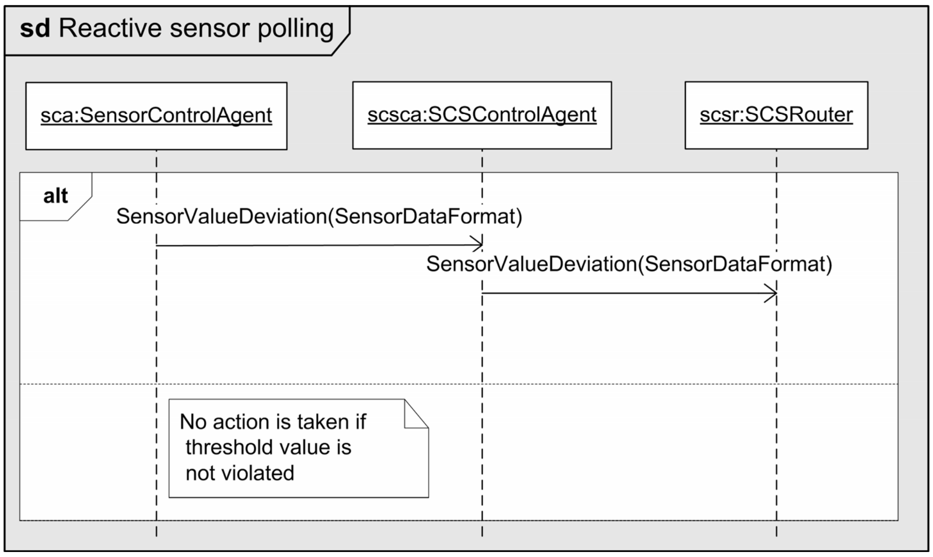

sd Reactive sensor polling
sca:SensorControlAgent
scsca:SCSControlAgent
scsr:SCSRouter
alt
SensorValueDeviation(SensorDataFormat)
SensorValueDeviation(SensorDataFormat)
No action is taken if threshold value is not violated

Figure 8-38: The sequence diagram for reactive sensor polling

Finally, there is the case where the data from the sensor is both to be checked and stored. This is similar to the hybrid sensor handling described in section 4.3. The *SensorControlAgent*-actor controls the sensor data against its defined parameters and issues an alert if the threshold is violated. If the data is within the boundaries set, it is simply stored. The sequence diagram for this is shown in Figure 8-39.

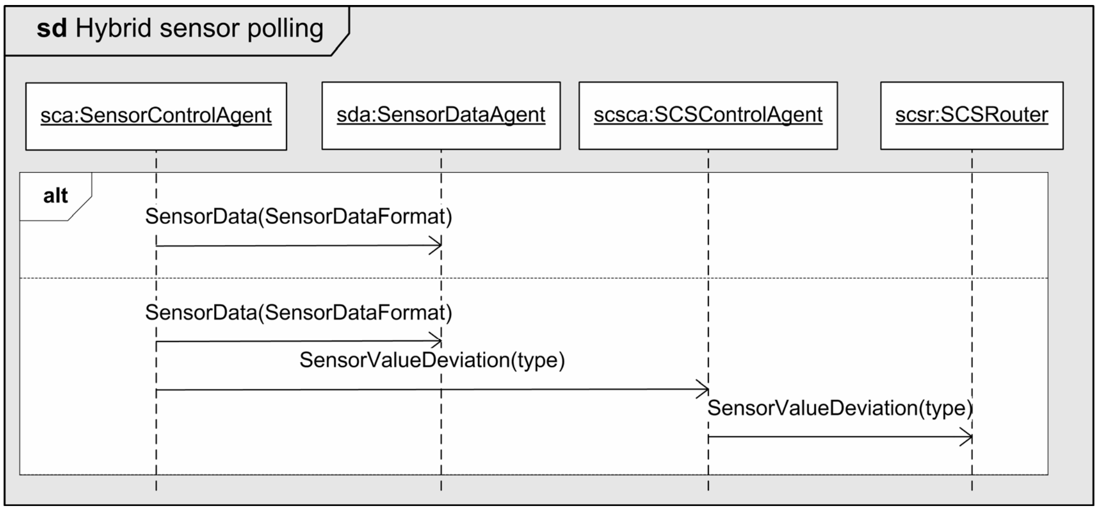

sd Hybrid sensor polling
sca:SensorControlAgent
sda:SensorDataAgent
scsca:SCSControlAgent
scsr:SCSRouter
alt
SensorData(SensorDataFormat)
SensorData(SensorDataFormat)
SensorValueDeviation(type)
SensorValueDeviation(type)

Figure 8-39: The sequence diagram for hybrid sensor polling

In the case of a threshold-breach on received sensor data, the *SensorValueDeviation*-signal is automatically propagated through the SCG-system up to the *MSAgent*. Here the relative alarms are issued and the status of the SCS is updated in the database.

The demonstrator to be implemented only has the use of a GPS-receiver. In the SCG-system domain itself, GPS is used mainly to detect sea cages drifting out of position. This would only require reactive sensor polling on the GPS-receiver to achieve its task. But seen in the light of both context information, and other parties interested in the GPS-position of sea cages, see Table 4-1, the GPS-sensor has been implemented with hybrid sensor polling. The generic signal *SensorData* has been replaced with *GPSSensorData* and the *SensorValueDeviation*-signal has been replaced with a *PositionAlert*-signal.

When the position received from the GPS-receiver violates the maximum position deviation threshold, a *PositionAlert*-signal is propagated throughout the SCG-system alerting all involved actors of the status, updating the SCS-status in the database, and SMS-alarms are generated to the rescue team. This is shown in the communication diagram presented in Figure 8-40.

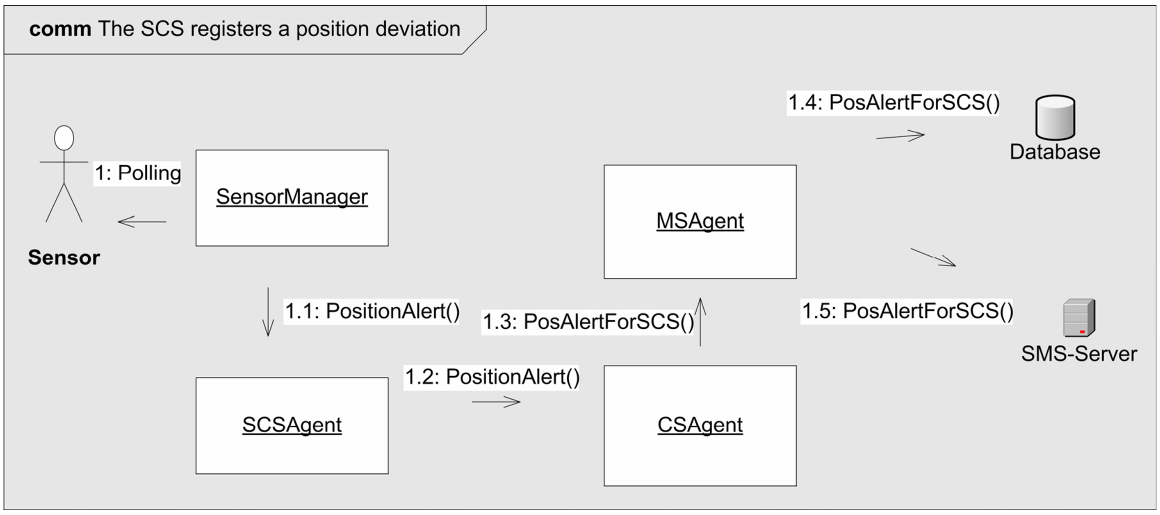


Figure 8-40: A high-level communication diagram for issuing position deviation alerts

If wished for, the SCS could issue subsequent position alerts in pre-determined intervals to allow for constant SMS-updates of the latest position to rescue teams attempting to locate and salvage the fish cage. This has not been implemented in this system, and only one SMS-warning is sent. The updated position, however, is still reported in to the MS and is available from the database.

8.4.3. Ensuring the detection of failures and appropriate actions

As described in section 8.2.4, there are several modes of communication link failure that the SCG-system must detect and handle. The system has been designed so that all communication traversing communication links is either handled by the respective *Router*-actors, or by the respective *Session*-actors. This reduces the number of interacting actors over distributed links, and makes it easier to detect and handle link failures.

When a message is sent from a *Session*-actor or a *Router*-actor a timer is set by the entity which makes a request. All requests require a response within a pre-defined time interval. Upon a timer-trigger the sending entity can either resend the signal or take other appropriate actions. This could either be initiating the reserve communication link, or issuing an alarm about a broken communication link depending on which side of the collaboration the actor is.

If the frequency of interactions between the distributed actors is rare, a heartbeat- or hello-signal could be implemented to regularly check communication link status. If the frequency of signal-interaction is sufficient then such a signal may not be necessary, it would simply drain power and bandwidth.

As shown under the normal operations section, the queries are often issued from the top-down in this system. This means that the CS requests a report periodically from its SCS-nodes, instead of the SCS-nodes themselves initiating reports. In exception cases, however, the SCS can send alarm messages to the MS or CS. A timer is set for every interaction by the initiating side.

The assumption is made that the management station is under surveillance and has backup routines for failure. The possibility that the MS fails should otherwise be considered.

In the implementation for the demonstrator only the case of a failed PCS-link discovered by the SCS has been implemented. Subsequently, no timers on messages are set except for those generated periodically by the *SCSAgent* to check PCS-status. The remaining sequence diagrams are suggested solutions and have neither been implemented nor tested, but their patterns are very similar to the one used in the demonstrator. They may function as a starting point for considering such functionality.

8.4.3.1. Failed PCS between SCS and CS

In the event of a failure between a SCS and its CS the SCS should switch to ECS as soon as possible. All messages sent between these entities should be replied to ensure reception. A timer is set by the router of a SCS to ensure that missing messages are detected. Although both the CS and SCS can detect failures, only the SCS can switch over to ECS communication. But the CS must also be able to detect the failure, both as to alert the MS and repair teams, but also in the event of a total failure of either the SCS-node itself, or of the ECS. In addition, the CS must be able to maintain state integrity when an expected signal fails to make its appearance.

The interval between the connection checks is defined as the *connectionCheckTimer*. When this timer is triggered, the *SCSRouter*-actor sends a *SCSConnectionCheck*-signal to its *SCSSession*-actor. This initiates a *connectionTimer*-timer which defines the interval in which a *SCSConnectionCheckACK*-signal is expected to be received. The sequence diagram for link-failure detection and handling is shown in Figure 8-41.

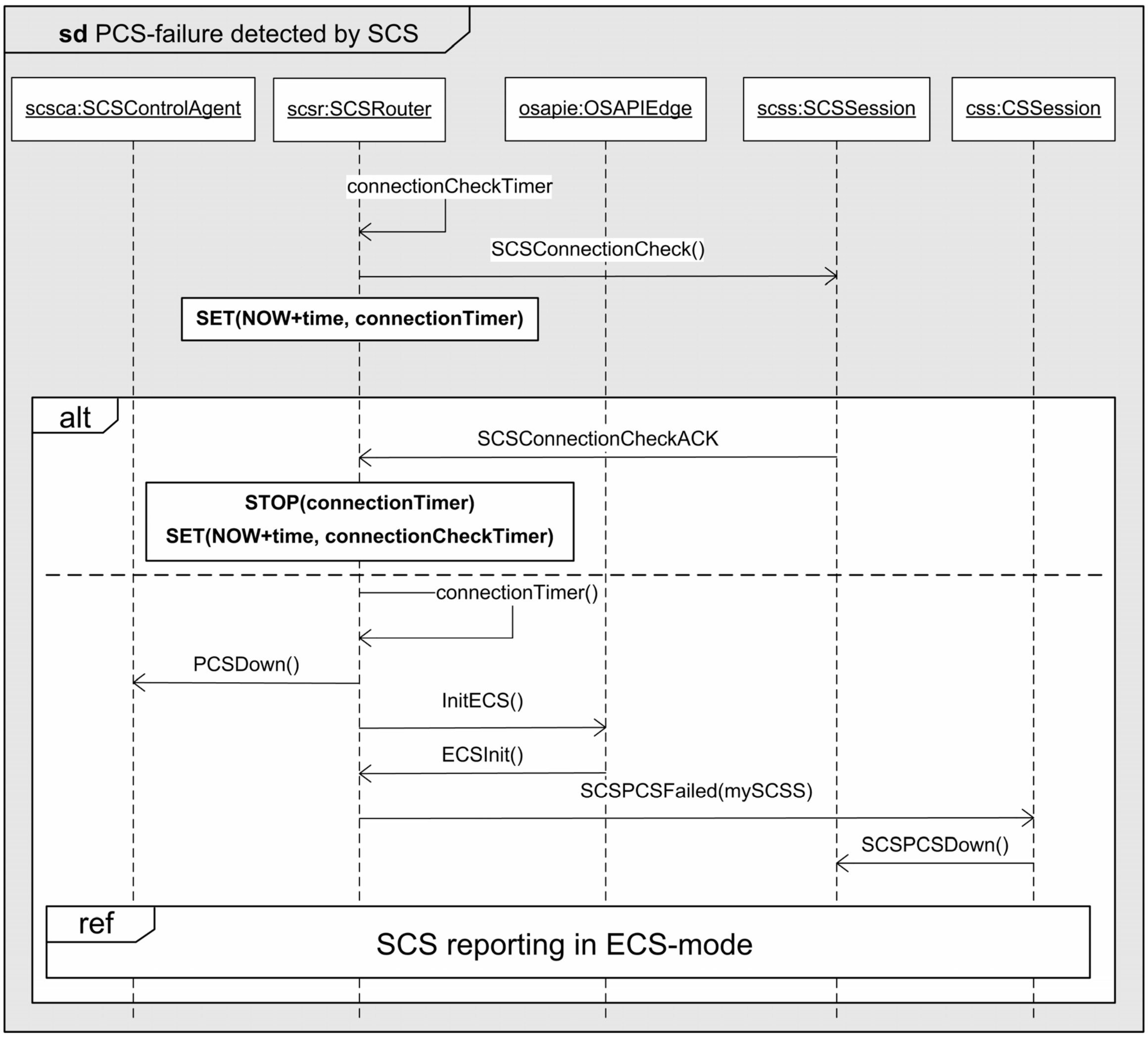


Figure 8-41: The sequence diagram for a failed PCS between a SCS and CS

A missed receipt signal is in this case interpreted as a communication failure. Alternatively, a failure could be interpreted as a certain number of missing receipts. Each time the *connectionTimer* was received a connection counter could be incremented, and at a certain counter value, the ECS could be assumed down. The failure of the link could affect the report status of the control agent, but if capacity of the new link is capable operations could continue as normal.

So if the *connectionTimer* expires before the *SCSReportReg*-signal is received, the *SCSRouter* assumes that the PCS-link is down. The *SCSRouter*-actor subsequently alerts the *SCSControlAgent*-actor of the failed link so it can adjust to the new status (shown later). *SCSRouter*-actor also sends a request to the *OSAPIEdge*-actor to initiate the reserve communication link through the signal *InitEcs*. Upon confirmation that the ECS has been initiated, *SCSRouter* sends the *SCSPCSFailed*-signal to its CS-node's *CSSession*, alerting that the PCS has failed. The *CSSession*-actor can then handle the further situation by both being a recipient of alarms from the SCS, alerting the *SCSSession* of the *CSAgent*, updating the database status and alerting the proper personnel to ensure swift repairs.

The messages exchanged between the distributed actors are also shown in the communication diagram presented in Figure 8-42.

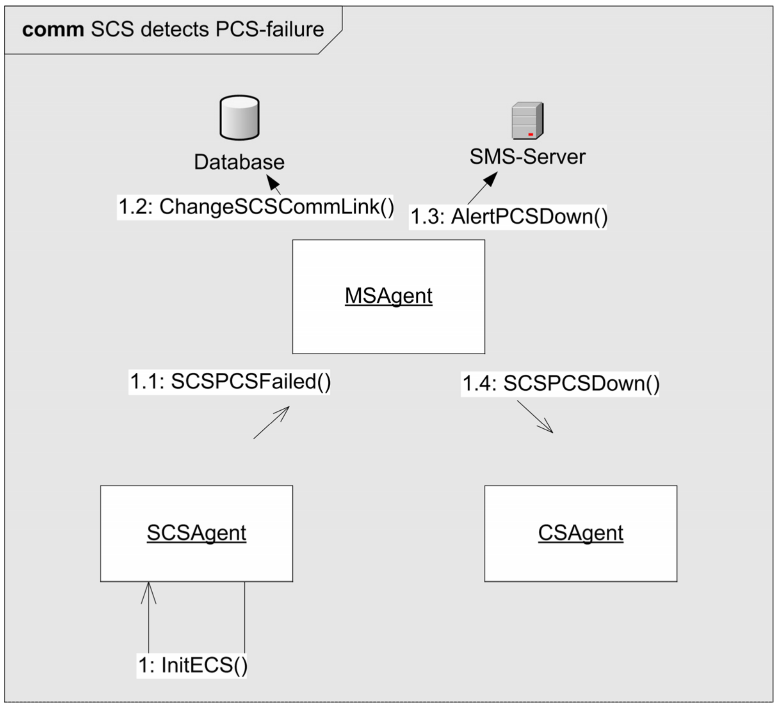


Figure 8-42: A high-level communication diagram for when a PCS fails

In the implementation the *CSSession*-actor handles all SCS-nodes under their CS-node when the PCS is down. As suggested in section 8.2.3, a *ReserveSCSSession* could be initiated to handle each SCS in ECS-status

The other possible scenario, the case of a detected failure from the CS side of the collaboration, is handled somewhat differently. The sequence diagram for this is shown in Figure 8-43.

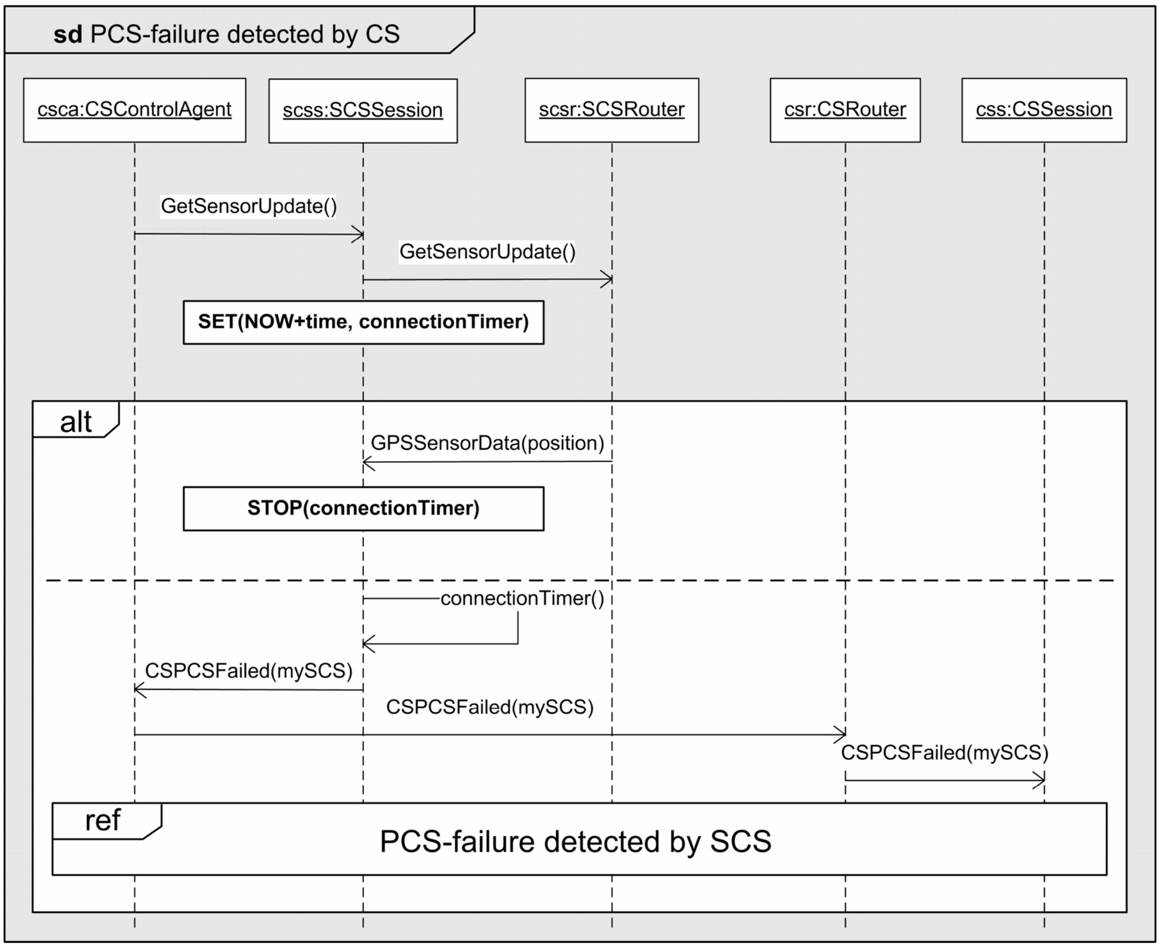


Figure 8-43: The sequence diagram for a failed PCS between CS and SCS

The *SCSRouter*-actor is the recipient of the *GetSensorUpdate*-signal generated by its corresponding *SCSSession*-actor. Since there is only one *SCSSession* per SCS, it is simpler to handle link failures due to the one-to-one relationship of inter-communicating actors.

If the *connectionTimer* expires before the *GPSSensorData*-signal is received the link between the CS and SCS is assumed to be down. The *SCSSession* report a link failure to the *CSControlAgent*, who in turn, via *CSRouter*, alerts its *CSSession*. The *CSSession* can then generate the alarms necessary to the correct personnel.

8.4.3.2. Failed MCS between CS and MS

In the event of a MCS-failure between the CS and MS, events are much similar to those of a failure between a SCS and its CS. The difference is that the recipient of the messages is still the same, meaning that the messages are still sent to *CSSession*. The sequence diagram for this scenario is shown in Figure 8-44.

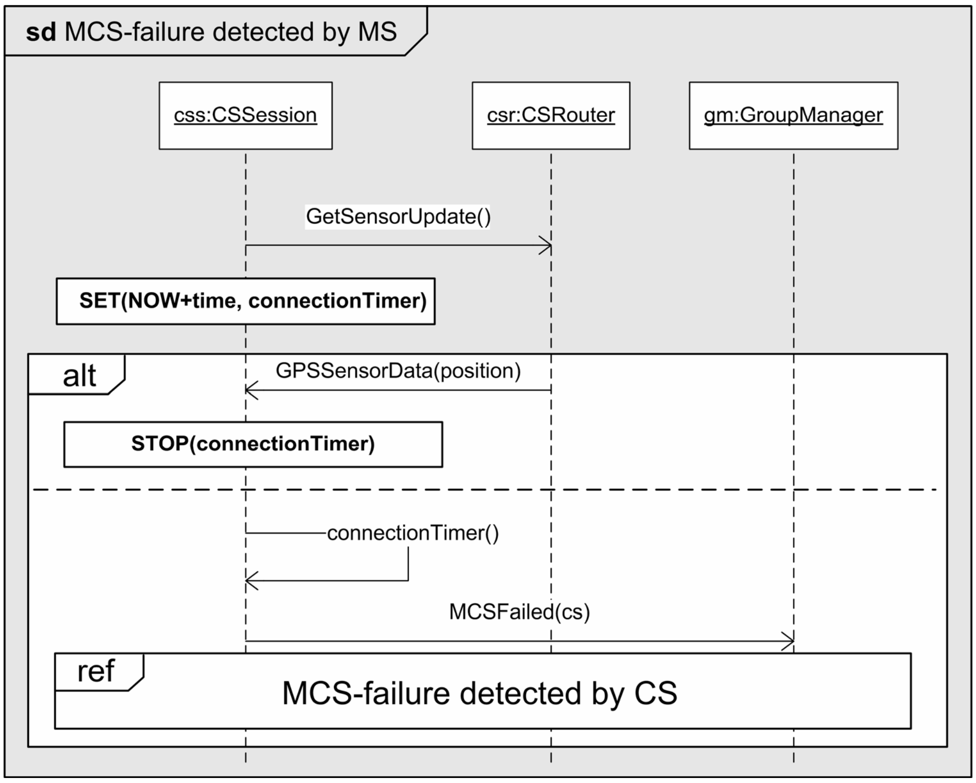


Figure 8-44: The sequence diagram for a failure of MCS between MS and CS

When the MS detects a failed communication link to a CS, it can do little more than alert the correct personnel about the failure. In order to restore communications the CS must itself become aware of the link failure and switch to FCS-communication. This is shown in Figure 8-45.

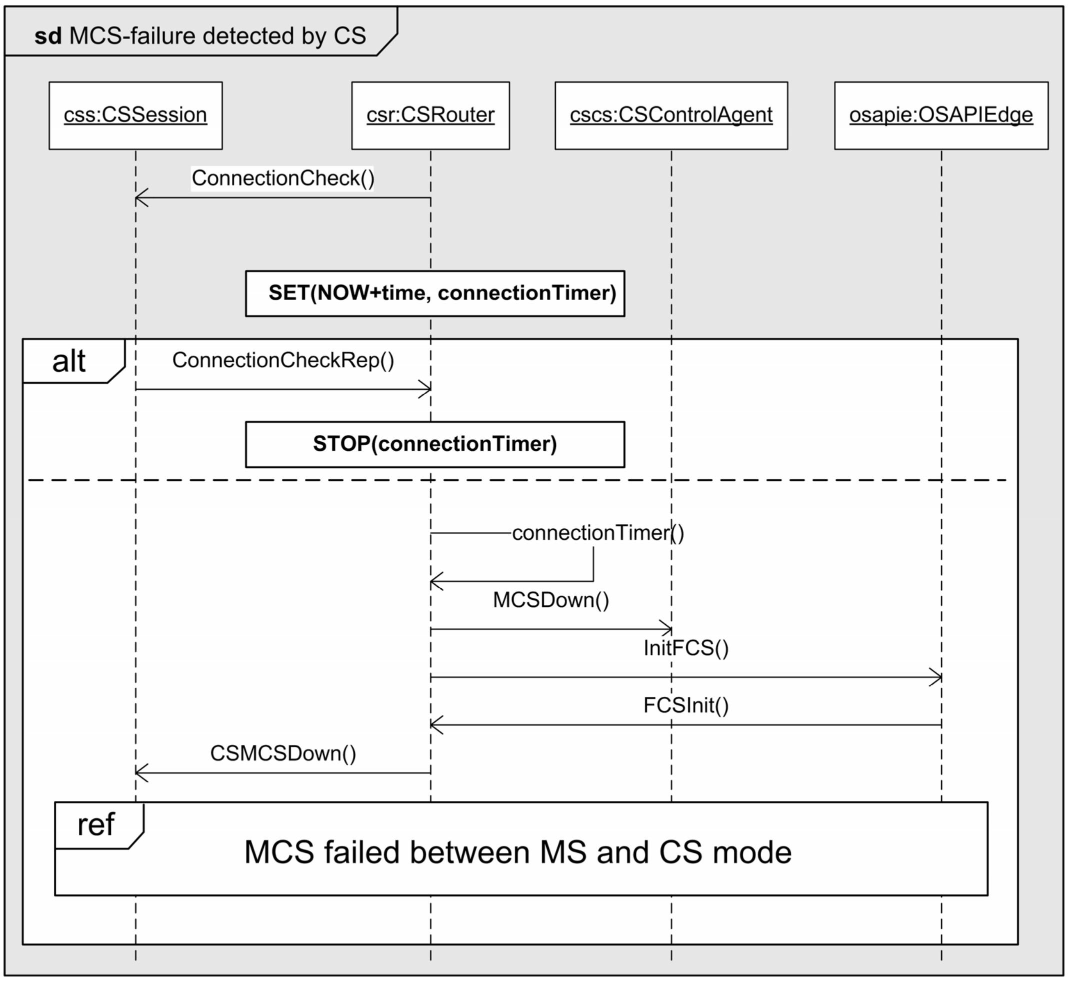


Figure 8-45: The sequence diagram for a failure of MCS between CS and MS

As previously mentioned, the procedure here is very similar to when a SCS switches to ECS. Here the initiation of the GPRS-link is done (if the FCS is GPRS), and a report of the situation is sent to the MS-node's *CSSession*, which will then take the appropriate measures for re-establishing the link.

8.4.3.3. Failed FCS between CS and MS

Another scenario is that of the FCS failing. If this happens the SCS-node must be alerted so it can initiate ECS to preserve communication capabilities until the FCS and MCS are repaired or restored.

Under the assumption that the MCS between a CS and its MS has failed and that the FCS is currently in use, the sequence diagram is shown in Figure 8-46.

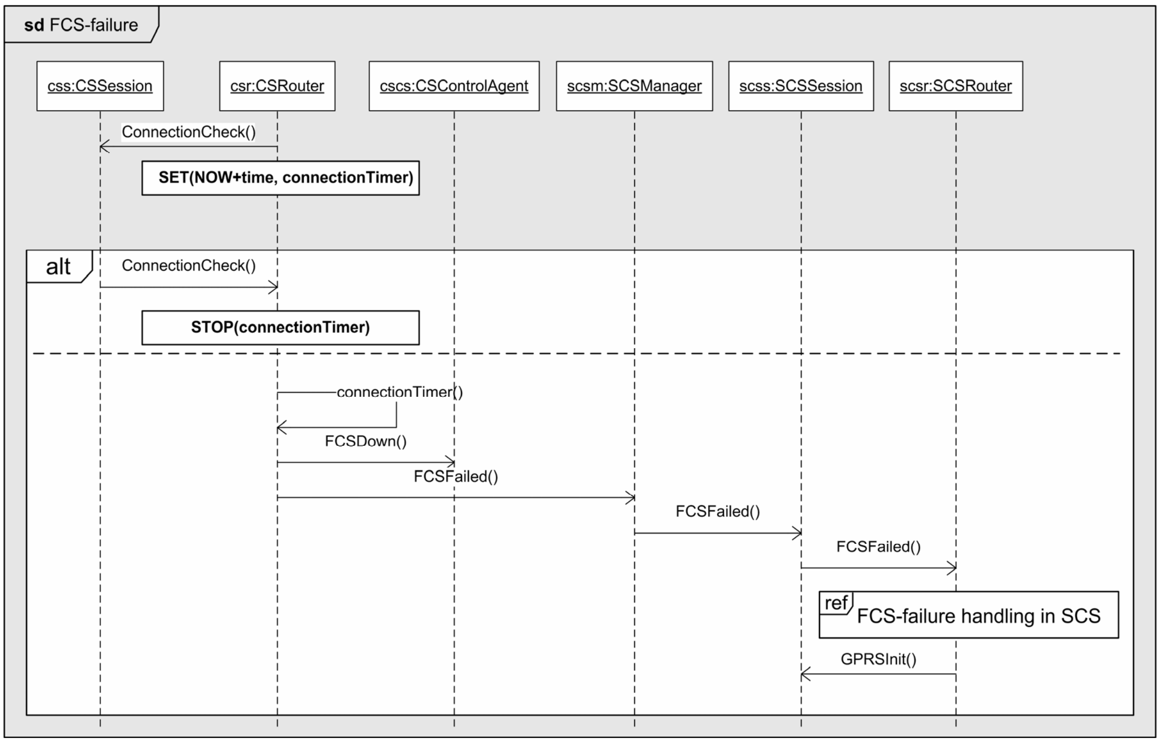


Figure 8-46: The sequence diagram for an FCS-failure

When the FCS fails, the only means of communication remaining is the ECS. When a FCS-failure is detected the *CSControlAgent*-actor alerts the *SCSManager* that the FCS is down. The *SCSManager*-actor, via its *SCSSession*-actors then alerts the SCS-nodes that they must switch to ECS to uphold communications.

When in ECS-mode, each SCS must establish its own connection to the MS to be able to send alert alarms that are vital for secure and safe operation of the fish farm. This is the same status as when the PCS between a SCS and CS is down. Since, in this scenario, the PCS between the SCS and CS is still operational, the SCS-nodes could continue to report to the CS. To simplify the situation, it is assumed this is not the case.

A high-level communication diagram illustrating the signals sent between the distributed actors is shown in Figure 8-47.

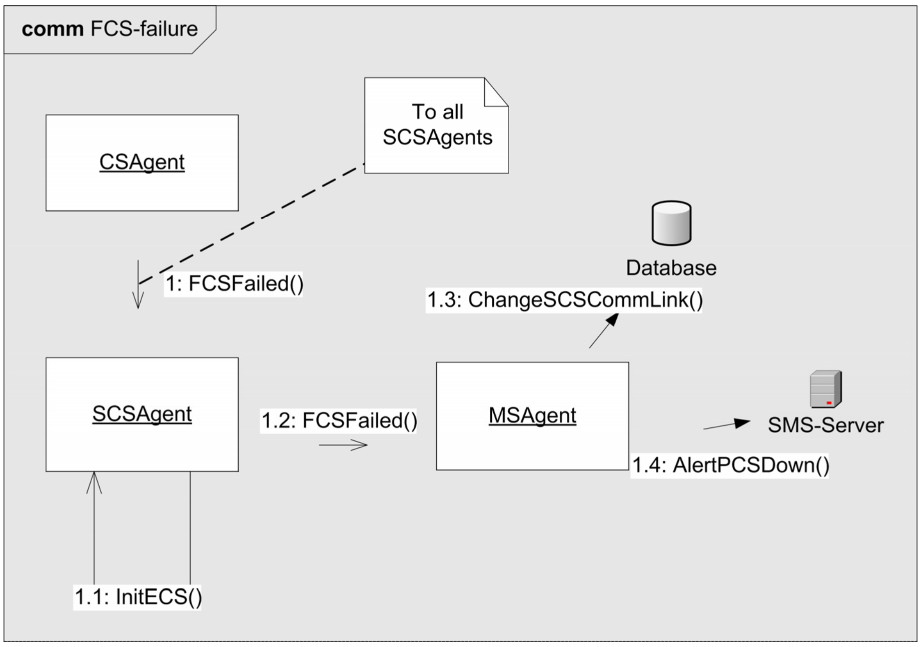


Figure 8-47: A high-level communication diagram for a failed FCS

The communication diagram essentially displays the same as the corresponding sequence diagram, but it also shows how the *MSAgent* updates the database through the *DBEdge*-actor, and issues SMS-warning through the *SMSEdge*-actor.

The sequence diagram reference "*FCS-failure handling in SCS*" has not been created, but will likely be quite similar to the sequence diagrams displayed and described in section 8.4.3.1.

8.4.4. Communications under ECS-operation

Since the system implemented is supposed to handle a failed PCS-link, functionality for how the SCG-system is supposed to interact has been implemented for this type of situation. The sequence diagram describing this interaction is shown in Figure 8-48.

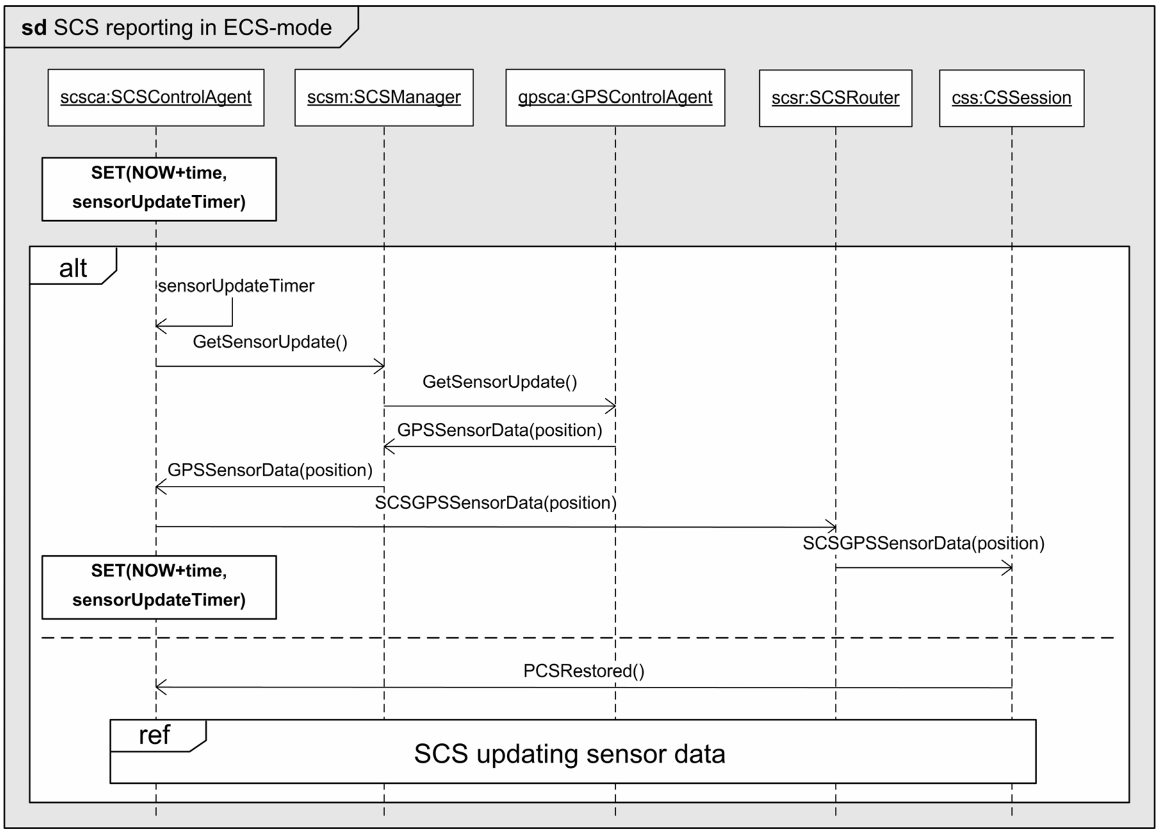


Figure 8-48: The sequence diagram for interaction between the SCS and MS in ECS-mode

As shown, the *sensorUpdateTimer*-timer is set at a new value. This is because the interval defined by this timer implicates how often the sensor data is retrieved and replaces the reporting function previously initiated from the *CSAgent*. This interval also serves to maintain the *CSSession*-address present in the ActorRouter-forwarding table, previously managed by the *ConnectionToMS*-signal. Both these issues must be considered when setting the timer interval.

The SCS-node now automatically generates position reports and sends these directly to its *CSSession*-actor. This is shown in the communication diagram presented in Figure 8-49.

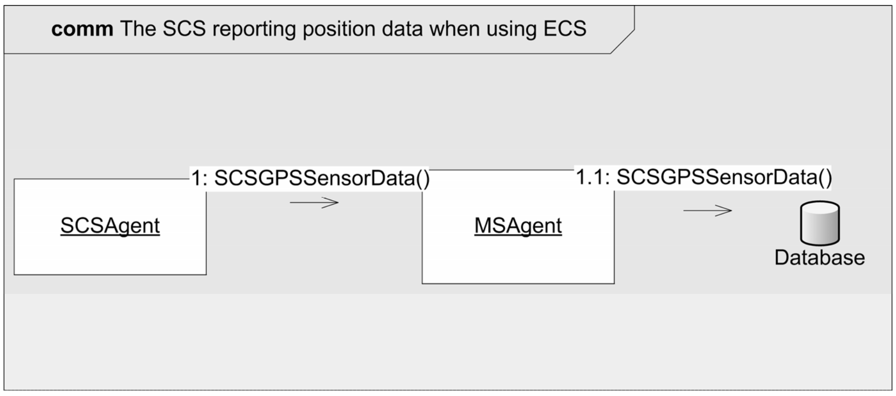


Figure 8-49: A high-level communication diagram for sensor reporting with ECS

The signal *GPSSensorData* has now been replaced with *SCSGPSSensorData* for reporting the SCS-node's current position. The reason for this is that part of the natural hierarchy used for signal distribution is gone so the signal sent by the *SCSAgent* requires more information than previously required under normal operations.

Subsequently, position deviations must now also be reported in to the *CSSession*-actor. This follows the same pattern as during normal operations, except that the CS-node is not involved, and that the SCS-node sends a *PosAlertForSCS*-signal instead of *PositionAlert*. This signal has been replaced for the same reason the *GPSSensorData*-signal was changed. A communication diagram for this procedure is shown in Figure 8-50.

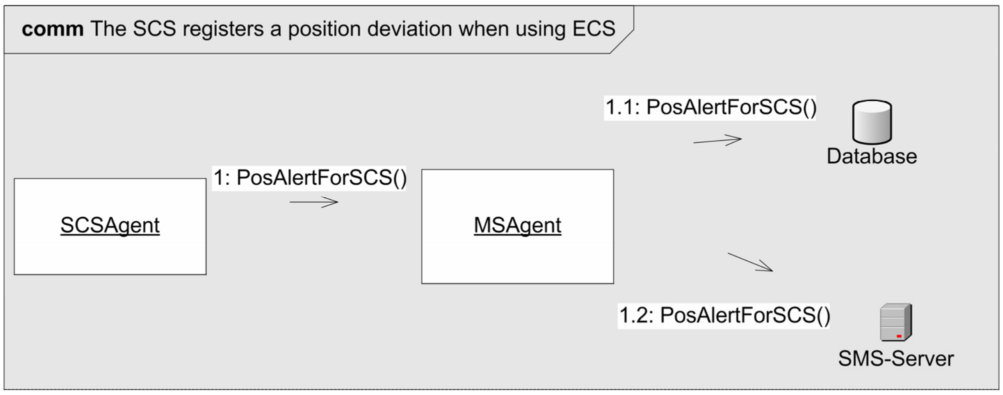


Figure 8-50: A high-level communication diagram for position alerts with ECS

The *CSAgent* could have been notified that one of its SCS-nodes may be drifting, especially if personnel are present at the time, but this has not been implemented for the demonstrator.

When the *SCSSession* of the SCS-node which is no longer available is asked to retrieve sensor data by the sensor manager, it simply replies with a *PCSDown*-signal. The *SCSManager* then moves on to the next *SCSSession*.

The *PCSRestored*-signal is generated from the *AdminEdge*-actor of the *MSAgent*. It is propagated through the system via the CS-node to the SCS-node, reinstating the normal mode of operations. The signal is finally received by the *SCSRouter*-actor who distributes it to both the *SCSControlAgent* and *WindowsAPIEdge*. This sets the status of the *SCSControlAgent* back to normal, and the *WindowsAPIEdge* disconnects the GPRS-modem connection. The prerequisite for these actions is that the SCS-node has regained PCS and been assigned the same IP-address as before the link went down. Otherwise the *SCSSession*-actor will not be able to deliver the *PCSRestored*-signal as the SCS-node will be unavailable (IP-address unknown).

It should be noted that the system itself could be enabled to detect when the PCS is back online. If the *SCSSession*-actor periodically sent a connection-check type signal to the *SCSRouter* then this signal will not be received by the *SCSRouter*-actor for the duration of the link failure. But when the PCS has been restored, again under the assumption of the SCS-node receiving the same IP-address, this signal will be received by the *SCSRouter*. This will indicate to the *SCSRouter* that the PCS is back online, and that the GPRS-connection can be taken down. It can subsequently produce a response signal to the *SCSSession*-actor, who in turn can notify the rest of the SCG-system that the link has been restored. This has not been implemented as it has been assumed that a service team is necessary for restoring link failures, thus the *PCSRestored*-signal is generated by this team. It is, however, an interesting concept for connections which can sometimes fall out without the link actually having failed.

9. Implementation and deployment

In the following chapter the implementation specific parts of the system are presented and described, and the deployment of the system is described. A test summary for the demonstrator is also given.

The system has been implemented on three different machines, emulating a CS-node, MS-node, and the SCS-node respectively. These machines vary in type, specifications, capabilities, and operating systems; from a modern laptop, via an industry computer, to an older machine running Linux. Since only one of the available machines has WLAN-capabilites, Ethernet connections will provide communication. This is transparent for the nodes compared to a WLAN connection.

9.1. Incorporated hardware

In this section the equipment used to demonstrate and test the SCG-system application is presented. The system is comprised of three computers, each simulating a node of the system. In addition, a GPS-sensor and GPRS-modem have been attached to the machine representing the SCS-node.

9.1.1. Node computers

The computer running the *MSAgent*-actor is a Netshop 259IEN laptop computer. It has a 2.0 GHz Pentium M processor with 1 GB of memory, and is running Windows XP. It is shown in Figure 9-1.

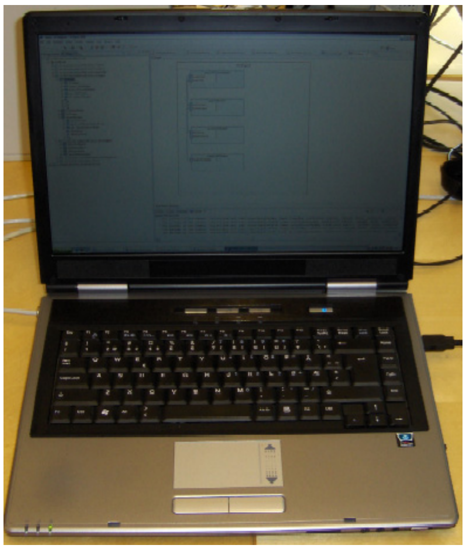


Figure 9-1: The MS-node computer

This computer also runs the MySQL-database, and the web-server (both are described later).

The computer simulating the CS-node and running the *CSAgent*-actor is a Compaq Deskpro, with a 733 MHz Pentium III processor with 384 MB of memory, running the Linux-based Ubuntu 6.06[8] operating system. It is shown in Figure 9-2.

Figure 9-2: The CS-node computer

The SCS-node with the *SCSAgent* is an Advantech ARK-3381 [50] embedded box computer with a 598 MHz Intel Celeron processor and 480 MB of memory, running Windows XP. This is the type of computer which might actually be deployed on a sea cage. It is shown in Figure 9-3.

Figure 9-3: The SCS-node computer

All machines have been installed with Eclipse 3.1.2, Ramses 2.0.0.M9003 plug-in tool, and ActorFrame 2.0.4. The ActorFrame standalone support, described in section 7.2.2.2 has been used for running the agents.

9.1.2. The GPS-receiver

In this SCG-system only one type of sensor is used, and this is a GPS-receiver connected to the SCS-node computer. The GPS-sensor used is a Haicom HI-204III GPS-receiver [51], and is shown in Figure 9-4.

[8] http://www.ubuntu.org

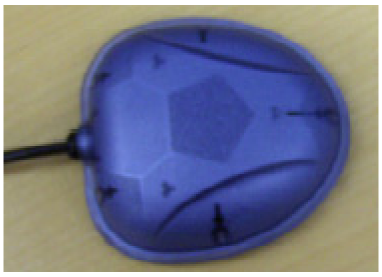


Figure 9-4: The Haicom GPS-receiver

The GPS-receiver outputs NMEA [52] messages which require parsing to be accessible for other entities. The NMEA-output format is defined by the National Marine Electronics Association, and the formats supported by the GPS-receiver are shown in Table 9-1.

Table 9-1: NMEA-messages supported by the GPS-receiver

NMEA-message	Description
GCA	Global Positioning System Fix Data
GLL	Geographic Position Latitude/Longitude
GSA	GNSS DOP and Active Satellites
GSC	GNSS Satellites in View
RMC	Recommended Minimum Specific GNSS Data
VTG	Course Over Ground and Ground Speed

All of these messages provide some unique information, whilst some information is present in several messages, such as longitude and latitude. An example of a received GCA-message is:

```
$GPGGA,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,M,<10>,M,<11>,<12>,*<13><CR><LF>
```

The fields correspond to the points displayed in Table 9-2.

Table 9-2: The data of the GCA-message [53]

Field	Example	Description
1	104549.04	UTC time in hhmmss.ss format, 000000.00 ~ 235959.99
2	2447.2038	Latitude in ddmm.mmmm format Leading zeros transmitted
3	N	Latitude hemisphere indicator, 'N' = North, 'S' = South
4	12100.4990	Longitude in dddmm.mmmm format Leading zeros transmitted
5	E	Longitude hemisphere indicator, 'E' = East, 'W' = West
6	1	Position fix quality indicator 0: position fix unavailable 1: valid position fix, SPS mode 2: valid position fix, differential GPS mode
7	06	Number of satellites in use, 00 ~ 12
8	01.7	Horizontal dilution of precision, 00.0 ~ 99.9
9	00078.8	Antenna height above/below mean sea level, -9999.9 ~ 17999.9

10	0016.3	Geoidal height, -999.9 ~ 9999.9
11		Age of DGPS data since last valid RTCM transmission in xxx format (seconds) NULL when DGPS not used
12		Differential reference station ID, 0000 ~ 1023 NULL when DGPS not used
13	5C	Checksum

For more information on NMEA-messages, see [52].

9.1.3. Reserve communication link

The primary communication link (MCS and PCS) for the SCG-system in this thesis is WLAN, although the system is actually using LAN-connections. As the means of communication technology for the ECS, GPRS has been chosen for demonstration and testing purposes. A GPRS-modem, shown in Figure 9-5, is connected to the SCS-node computer.

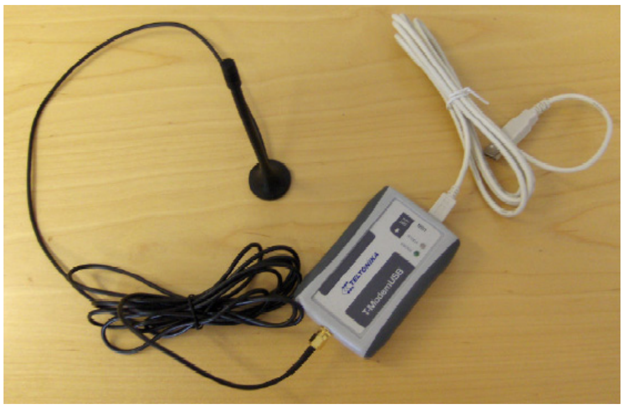


Figure 9-5: The Teltonika GPRS-modem

The GPRS-modem used is a Teltonika T-ModemUSB [54], with a USB2.0 connection and external antenna. This modem requires an operative SIM-card with a subscription that supports GPRS. To initiate the modem, the T-Modem control tool provided with the modem must be used. This program searches for the modem, authorizes the SIM-card, controls the PIN, and connects to the network. The APN (Access Point Name) of the GPRS connection is also specified here. Then the modem can be set up for use with a "Windows Dial-up Connection". [55] This connection needs only to be set up once. A dial-up connection called "Telenor GPRS" has been created for this system.

Since the ActorRouter of ActorFrame uses application-level routing, a public IP-address must be obtained from the service provider of the GPRS-connection. The default connection only provides a private address. For the subscription (Telenor) used for the demonstrator, the APN-connection must be set to:

```
internet.public
```

This gives the connected node a public IP-address.

9.2. Implemented elements

In the system described in the previous chapter, several edge-actors where presented. The implemented system contains five of these for demonstrational purposes. These are the *GPSSensorEdge*, *WindowsAPIEdge*, *DBEdge*, *SMSEdge* and *AdminEdge*. The *SensorDetectionEdge*-actor has also been implemented, but it only requests a *GPSSensorAgent* containing the *GPSSensorEdge* from the *SensorManager*.

9.2.1. GPSSensorEdge

The *GPSSensorEdge*-actor handles interaction with the GPS-sensor incorporated into this system. To be able to read and utilize the data generated by the GPS-sensor, several steps are required. First, the COM-port of the sensor must be established. Second, the data from the sensor must be read. Third, the data must be interpreted in order for it to be utilized.

9.2.1.1. Acquiring GPS-data

In order for data to be read from the GPS-sensor, a connection between the *GPSSensorEdge*-actor and the COM-port of the GPS-sensor must be made. To enable a connection to a COM-port via Java, an open source library has been used. As Sun no longer provides an open API for this purpose with Windows, an alternative library was incorporated. [56] This is the RXTX-library, which is a "*native lib providing serial and parallel communication for the Java Development Toolkit (JDK)*", available under the gnu LGPL[9] license. [57]

The *LoggingServer*-class which provides interaction to the GPS-receiver requires the COM-port that the GPS-receiver is attached to in order to open a connection. In this system this is done manually by specifying the COM-port to which the GPS-sensor is connected to. The *LoggingServer*-class diagram is shown in Figure 9-6.

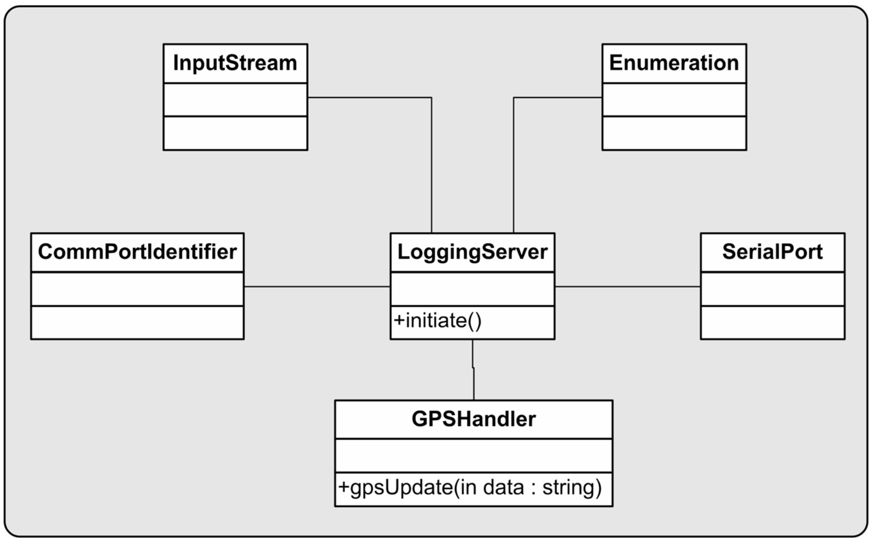


Figure 9-6: The class diagram for LoggingServer

[9] http://www.gnu.org/licenses/lgpl.html

The *LoggingServer* creates a connection to the specified COM-port, identified by *CommPortIdentifier*-class. When the COM-port is opened, a *SerialPort*-connection is created. The *InputStream*-class then represents the information received through the *SerialPort*-connection. This *InputStream* is then read, and presents the NMEA-messages from the GPS-receiver. When a full NMEA-message has been received the *LoggingServer*-class calls the *gpsUpdate*()-method of *GPSHandler*, with NMEA-*String* as parameter. The method *initiate*() opens a new *InputStream* to retrieve the latest reading from the GPS-receiver, and is called from the *GPSHandler*-class.

The code of the *LoggingServer*-class is presented in Appendix F.

9.2.1.2. Parsing and interpreting GPS-data

When a connection to the GPS-sensor has been established, the data received from it must be interpreted. To enable this, a NMEA-parser has been included. The classes *NMEA* and *GPSInfo* are from the open-source JavaGPS-package [58], and *LatLng* is from the JCoord-package, available under the gnu GPL license[10]. [59].

To provide interaction with the *LoggingServer*, and supply the necessary functions and classes, a simple *GPSHandler*-class has been written. The *GPSEdgeSM*-class creates a *GPSHandler*-class upon initiation, and this class then provides all the methods necessary for retrieving GPS-data from the receiver. The class diagram for the *GPSHandler* is shown in Figure 9-7.

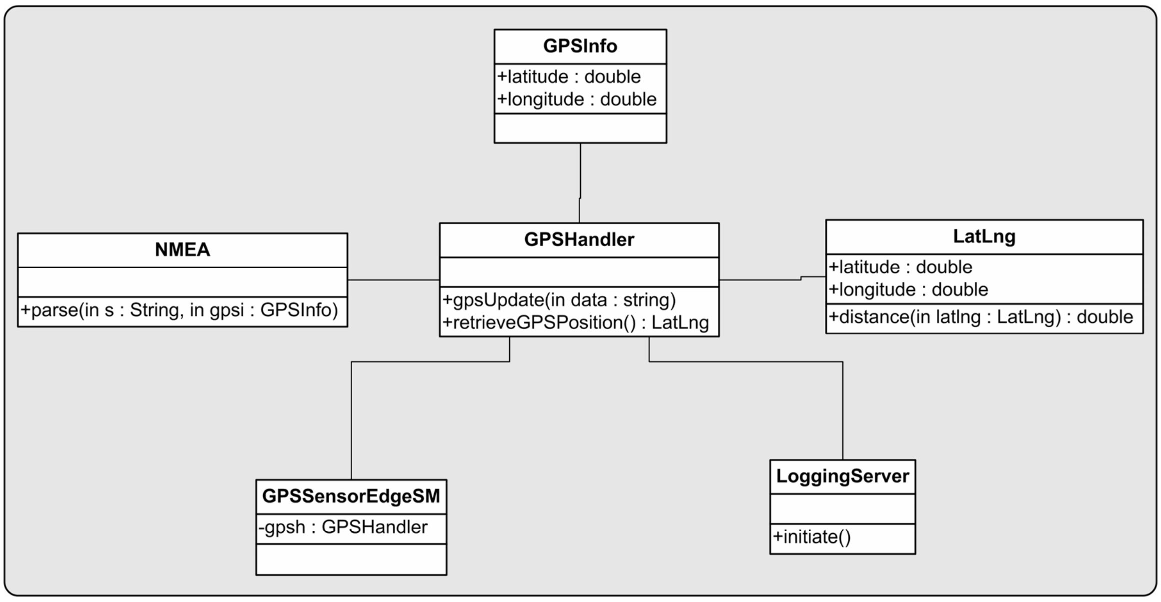


Figure 9-7: The class diagram for GPSHandler

The *NMEA*-class of the JavaGPS-package provides a parse method which parses NMEA-messages and stores the results in a *GPSInfo*-class. As mentioned in section 9.1.2, there are several types of NMEA-messages, all containing different information. To obtain the latitude and longitude only one type of NMEA-message

[10] http://www.gnu.org/licenses/gpl.html

would be necessary. However, it could be interesting to access more of the data retrieved from the GPS-receiver at a later occasion, and therefore all NMEA-messages are parsed. The *GPSInfo*-class contains more attributes then listed in the figure, but for this system only latitude and longitude are used.

From the *GPSInfo*-class, a *LatLng*-class is created, with the data from *GPSInfo*-class. The reason for using the *LatLng*-class is due to the provided distance-method. This method returns the distance from a provided position compared to its own position variable. This makes it possible to set a certain maximum distance away from a pre-defined point for the *GPSControlAgent*-actor to allow. For instance, considering the natural drifting of a cage, if a distance from the original position of over fourty metres is unusual, an alarm can be issued. This distance is just an example. The action-statement used in the *GPSControlAgentActions*-class is shown below:

```
public static void compareGPSPosition(GPSPositionUpdate signal,
GPSControlAgentSM asm){
                           asm.newLal = signal.lal;
                           double distance = asm.oldLal.distance(asm.newLal);
                    if(distance>=0.01 && distance<0.2){
                           asm.sendMessage(new PositionAlert(),
"GpscaToDel");
                    }
                    else if(distance>=0.2){
                           //Alarm. The red boundary has been violated.
                    }
                    asm.startTimer(new TimerMsg(), 10000, "gpsUpdate");
       }
```

The instances *newLal* and *oldLal* are of the type *LatLng*. The *oldLal*-instance is the default position to which subsequent position messages are compared to. The default for the demonstrator is set as the first position received after the *GPSControlAgent* has been created. The timer interval has been set to 10 seconds (in milliseconds). This interval can be altered according to needs.

When the *ReqGPSPosition*-signal is received by the *GPSSensorEdge*-actor, the actor simply calls the *retrieveGPSPosition*-method of the *GPSHandler*, receives a *LatLng*-class, and sends this back to the *GPSControlAgent*.

9.2.2. OSAPIAgent and WindowsAPIEdge

In this system, the *OSAPIAgent* handles the interaction with the operating system. Since Java is a platform-independent language it can be deployed on all machines running a JVM (Java Virtual Machine). Unfortunately in the SCG-system, a certain level of interaction with the operating system is necessary, and it is therefore important to identify the operating system the application is running on. Java can not directly interact with the operating system; this requires the use of wrappers and JNI[11] and can be a complicated process.

[11] Java Native Interface. This provides an interface between Java and the native Windows code.

The *OSAPIAgent* immediately checks upon initiation which type of platform it is running on. This is simply done through the *getProperty()*-method of *System* as shown below:

```
String s = System.getProperty("os.name");
```

The result of the *getProperty()*-method causes the generation of a *RoleRequestMsg*-signal specifying the required *OSAPIEdge*. This system currently only supports Windows XP through the *WindowsAPIEdge*-actor.

Once initiated, the *WindowsAPIEdge* handles all operating system-specific interaction. In the SCG-system implemented here it has only two tasks; initiating and terminating the reserve communication link. The reserve communication link is initiated by the *InitECS*-signal which triggers the following code:

```
Process p = Runtime.getRuntime().exec("rasdial \"Telenor GPRS\"");
p.waitFor();
```

The connection is disengaged when the *PCSRestored*-signal is received by the *WindowsAPIEdge* with:

```
Process p = Runtime.getRuntime().exec("rasdial \"Telenor GPRS\"/d");
p.waitFor();
```

The *waitFor()*-method ensures that the connection has been initiated or terminated before confirmation is sent to the adhering *SCSRouter*.

The application initiates the GPRS-connection "Telenor GPRS" through system commands executed by the *Runtime*-object. The command for initiating the pre-defined dial-up connection called "Telenor GPRS" is:

```
rasdial "Telenor GPRS"
```

This command initiates and connects the GPRS-modem to the service provider and alerts that the connection is up and running. This is shown in a screenshot presented in Figure 9-8.

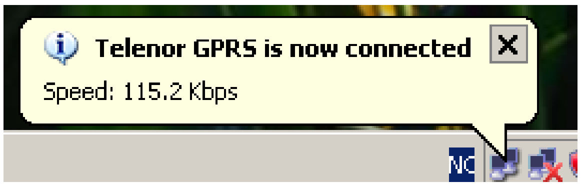

Telenor GPRS is now connected
Speed: 115.2 Kbps

Figure 9-8: Telenor GPRS has been initiated

For disconnecting the connection the following command is used:

```
rasdial "Telenor GPRS" /d
```

9.2.3. DBEdge

A *DBEdge*-actor has been implemented to show how ActorFrame can interact with databases. It also shows the flexibility achieved through the use of a database in this system; not only for registering sensor data, but also for registering system elements such as CS-nodes and SCS-nodes and their current status. In addition, database interaction support is available for many languages, and provides several options for the display, manipulation and insertion of information.

The database designed and implemented here is a very simple, relational database, created purely for the demonstrational purposes of this simulator. A far more detailed database-design is discussed and presented in [2]. The design for the database used in this system is shown in Figure 9-9.

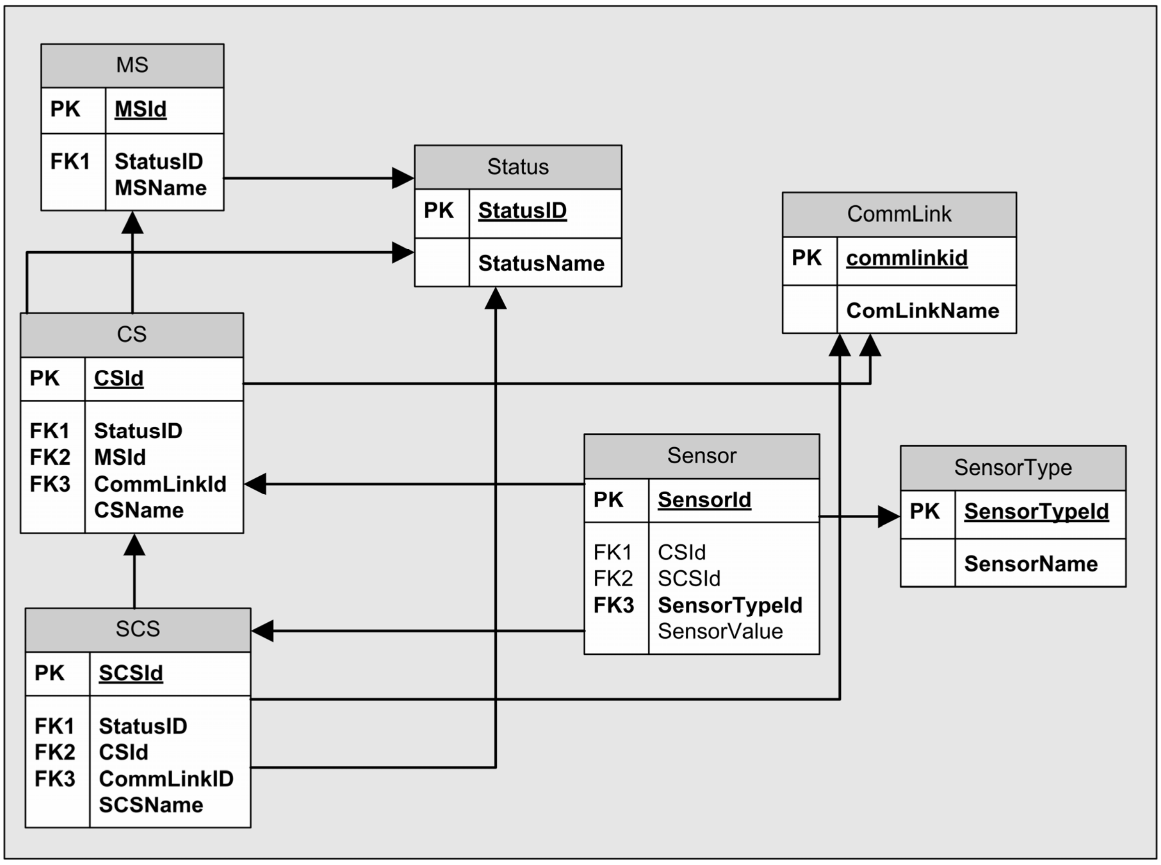


Figure 9-9: The SCG-database design

The arrows indicate a many-to-one relationship. The bold columns indicate a required field (not null), and PK and FK stand for “Primary Key” and “Foreign Key”.

The database designed has been implemented in a MySQL Server 5.0, Community Edition. [60] This is a freely downloadable database, available under the GPL License. For more information on the MySQL-database, [61] can be recommended.

The full specification of the database implementation is presented in Appendix C.

To access and manipulate the database from the Java-environment that ActorFrame operates in, an interface between them is necessary. The MySQL Connector/J driver provides this interface. As stated in [62]:

"MySQL Connector/J is a native Java Driver that converts JDBC calls into network calls into the network protocol used by the MySQL-database."

A *SQLInterface*-class has been written which provides some pre-defined methods for interacting with the implemented database. This class uses the MySQL Connector/J as the SQL-driver. The *SQLInterface*-class provides several pre-defined methods for updating and manipulating the database-values, and is created by the *DBEdgeSM*-class upon initiation. These methods are aimed at making database interaction as simple as possible seen from the ActorFrame application. The methods provided are shown in the simple class diagram in Figure 9-10 (method parameters have been left out).

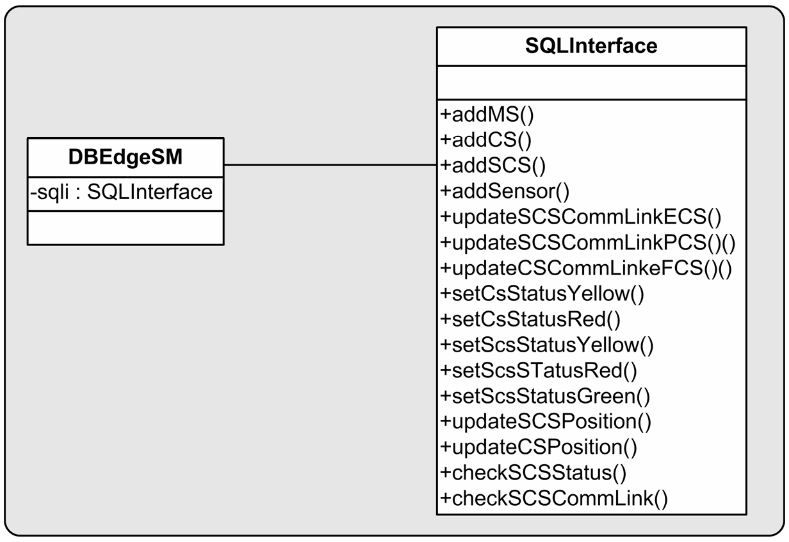


Figure 9-10: The class diagram for the DBEdgeSM

Not all of the methods provided have been used in this demonstration. The full code of the *SQLInterface* is available in Appendix D.

9.2.4. SMSEdge

The *SMSEdge*-actor provides an interface towards an SMS-server residing in the PATS-lab of Telenor R&D, Trondheim. The connection towards this SMS-server has been created through the use of Web Services, using the SOAP-protocol and a client generated from a WSDL-file created by Telenor. [63] An *SMS*-class using the generated web-service client which allows access to these services has been provided by Telenor R&D. This *SMS*-class provides the three methods necessary for setting a receiver, setting a message and sending an SMS. These are shown in the class-diagram in Figure 9-11.

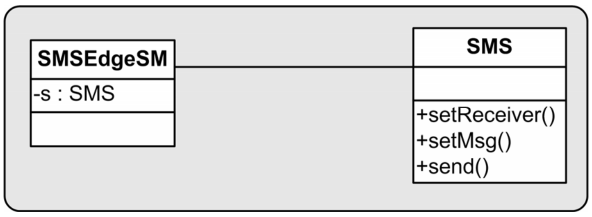


Figure 9-11: The class-diagram for SMSEdgeSM

The *SMSEdgeSM*-class instantiates a new *SMS*-class upon initiation and uses this to generate SMS-alerts when asked to by the system. The edge currently offers two types of SMS; one for position alerts and one for communication link failure. The message sent in an SMS contains the SCS-node that generated the warning, and the type of alert it is. The sent SMS are shown in Figure 9-12.

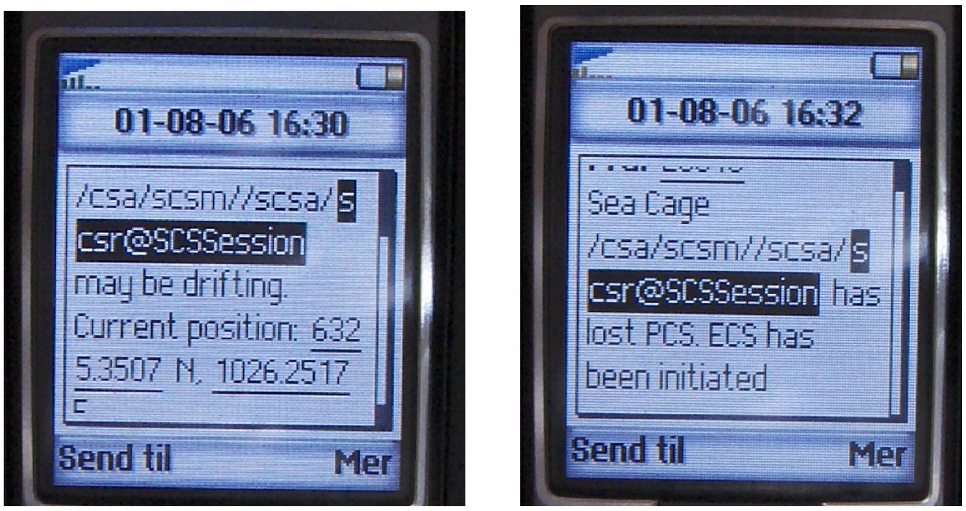


Figure 9-12: The SMS-warnings generated for GPS-position deviation (left) and link failure (right)

The message recipients and text have been specified by the *SMSEdge*-actor and are extended with the actor generating the alert, and in the case of a position alert, the current position of the sea cage.

9.2.5. AdminEdge

A simple *AdminEdge*-actor has been implemented to provide some interaction with the system for testing and simulation purposes. The function it provides is a GUI which allows for the user to send a message to re-instantiate the PCS-connection, and reset the default GPS-position. This simple GUI is shown in Figure 9-13.

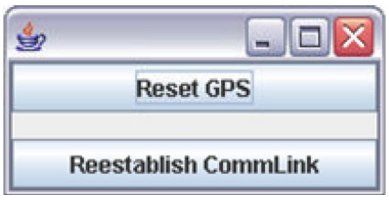


Figure 9-13: The AdminGUI

The GUI generates the *PCSRestored*-signal to the SCS and CS when “Reestablish CommLink”-button is pressed, and resets the default GPS-position of the *GPSControlAgent* upon pressing the “Reset GPS”-button.

9.2.6. ActorRouter setup

When setting up a distributed ActorFrame-system the default gateways must be set before initiation. How the default gateways are set up is important to ensure that messages are delivered to the correct recipients, whilst avoiding unnecessary transmissions over costly links. By setting up the default gateways properly it is also possible to a certain degree to create local islands of nodes, enabling some private addressing to be used in some situations (although this is not ideal). At the same time it must be assured that a recipient of signal can be reached independent of where the sending actor is residing. It is possible to specify the same default gateway for all actors in the system, but as mentioned previously, this will incur larger communication costs, both economical and resource costs, and the hierarchical advantages of the design will be reduced. A standard default gateway for all nodes could also be a bottleneck for the system, and will not be fault-tolerant. The default gateway setups of the SCG-nodes are shown in Figure 9-14.

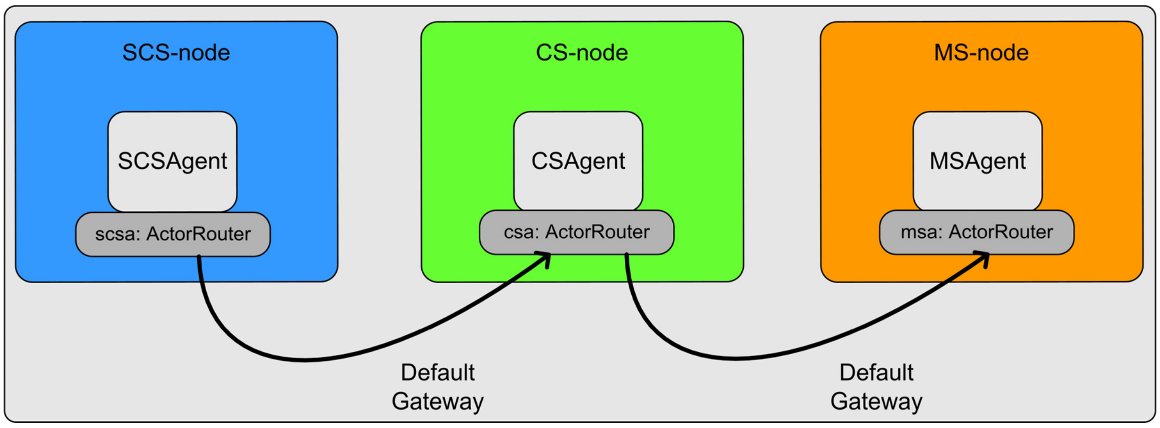


Figure 9-14: The assignment of the default gateway of ActorRouter

When connecting a CS-node to the MS-node the address of the *RoleRequestMsg*-signal is the *CSManager*-actor of the *MSAgent*-actor. Since the ActorRouter on the *CSAgent*-actor does not have any entries upon initiation, the only way for the *RoleRequestMsg-signal* to reach its recipient is if it resides on the default gateway. The default gateway of the *CSAgent*-actor is set to the IP-address of the *MSAgent*-actor. The same scenario is applicable for the *SCSAgent*-actor, and therefore the *SCSAgent*-actors default gateway is set to the *CSAgent*-actors IP-address. The *MSAgent*-actor’s default gateway is set to its own IP-address.

To minimize the amount of entries in the ActorRouter forwarding tables, only actors who must be available for other actors are set visible for the ActorRouter. This also reduces the amount of information sent between the ActorRouters, and provides a certain level of protection against unwarranted access to actors on distributed nodes.

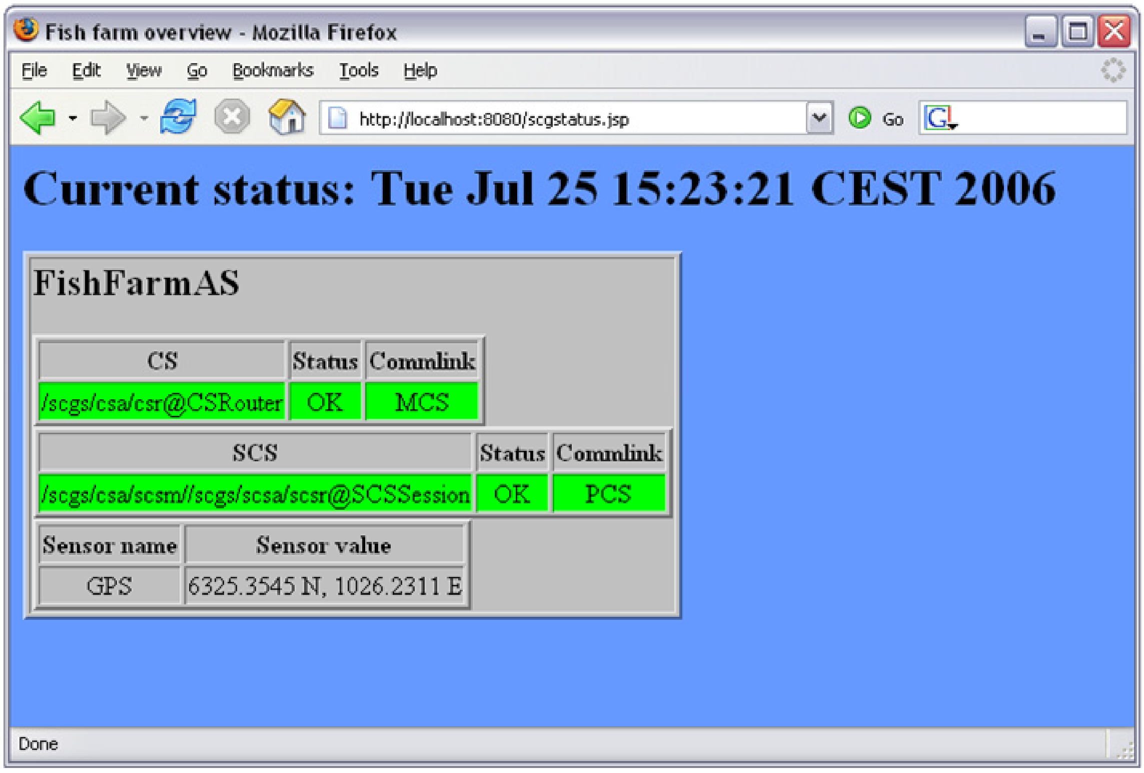
9.3. Web Interface

To display the changes of the members of the SCG-system and display the collected data values and node-status, a web interface has been implemented. This interface continuously reads data from the database and presents it on a web-page. This interface has been implemented in JSP (Java Server Pages), but both PHP (PHP: Hypertext Preprocessor) and AJAX (Asynchronous Javascript and XML) could have been used. JSP provides the possibility of incorporating Java-code with HTML-tags. For more information on JSP, see [64]. PHP is another high-level tool for creating dynamic web content. For more information on PHP, see [65]

AJAX represents a changing paradigm in web application development. It combines the existing web technologies JSP, DOM, CSS and XML to provide a richer user interface and experience, comparable to desktop applications. AJAX functions more as an application than a web-page on the client-machine. This application only retrieves information that is new to the browser when necessary, instead of reloading pages to register changes. For more information on AJAX, see [66]

The choice of JSP for implementing the web interface was largely due to the Java-element of JSP, thus using Java for both ActorFrame and JSP. The web interface could later be extended to interact with ActorFrame-classes if such functionality is wanted.

The web interface implemented regularly queries the database of the SCG-system, displaying the results in organized tables. Every ten seconds the interface searches through the database, and updates the web-page with new elements and data. Each registered MS-node has its CS-nodes under it, with each CS having their SCS-nodes displayed underneath them. Finally, the SCS-sensors and values are displayed with their corresponding values. A screenshot of the layout is shown in Figure 9-15.


Fish farm overview - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://localhost:8080/scgstatus.jsp
Go
Done

Current status: Tue Jul 25 15:23:21 CEST 2006

FishFarmAS

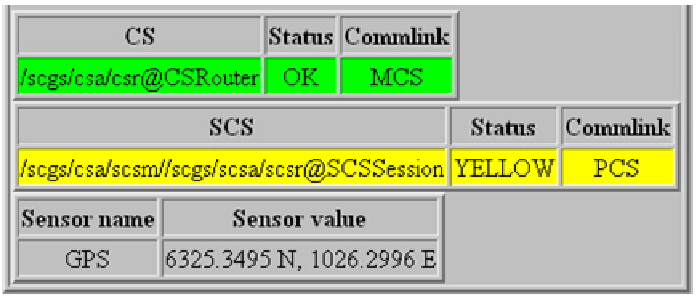
CS	Status	Commlink
/scgs/csa/csr@CSRouter	OK	MCS

SCS	Status	Commlink
/scgs/csa/scsm//scgs/scsa/scsr@SCSSession	OK	PCS

Sensor name	Sensor value
GPS	6325.3545 N, 1026.2311 E

Figure 9-15: A screenshot of the SCG-system web interface

This web interface also detects changes in the status of the SCS-node, and alters the colour of the element when the status indicates it. For this demonstration a deviation in the GPS-position sets the status of the SCS to yellow. This is shown in Figure 9-16.



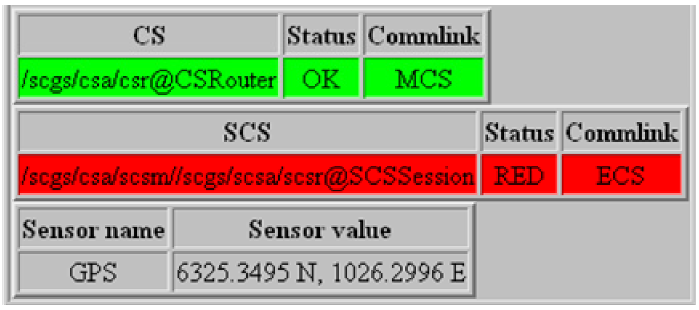
CS	Status	Commlink
/scgs/csa/csr@CSRouter	OK	MCS

SCS	Status	Commlink
/scgs/csa/scsm//scgs/scsa/scsr@SCSSession	YELLOW	PCS

Sensor name	Sensor value
GPS	6325.3495 N, 1026.2996 E

Figure 9-16: The SCS-status has been set to yellow

A PCS-failure with the corresponding ECS-initiation sets the SCS-status to red and updates the "CommLink"-field to ECS. This is shown in Figure 9-17.



CS	Status	Commlink
/scgs/csa/csr@CSRouter	OK	MCS

SCS	Status	Commlink
/scgs/csa/scsm//scgs/scsa/scsr@SCSSession	RED	ECS

Sensor name	Sensor value
GPS	6325.3495 N, 1026.2996 E

Figure 9-17: The SCS-status has been set to red and ECS has been initiated

Otherwise the status of the SCS has been set to green. Since there are no sensors connected to the CS in the demonstrator, and the CS does not experience any communication link failures, its status is by default always green. But the database does provide both alternative statuses and communication links for the CS as well.

The interface could have implemented much more information and functions, but as the purpose of it was purely for simulation and demonstration no more functionality was added.

The full code of the web interface, name "*scgstatus*.jsp", is available in Appendix E.

To run the web interface a web server has been set up. The web server used is the Blazix application server, which is freely available under their own license definitions. [67] This server is a high performance Java-based server, which can function both as a web server and as an EJB-server (application server). In other words, ActorFrame elements can be moved over to this server should the need arise. The choice of this server is mostly coincidental; there are many freely available servers that can be used. Blazix is a small, efficient Web Server suitable for this demonstration. That it is written in Java is not a disadvantage for the cross-platform interoperability. For more information on the Blazix-server, see [68]

9.4. Setting up the demonstrator

The node-computers were all connected to a LAN for testing. LAN is used only since two of the computers used for the demonstrator did not support WLAN. Compared to WLAN, the SCG-system will not behave any differently. In addition, it is easy to simulate a connection-failure; the Ethernet-cable is simply pulled out.

The demonstrator was setup in Telenors R&D Department in Trondheim. All node computers were attached to the same local network. An illustration of the setup is shown in Figure 9-18.

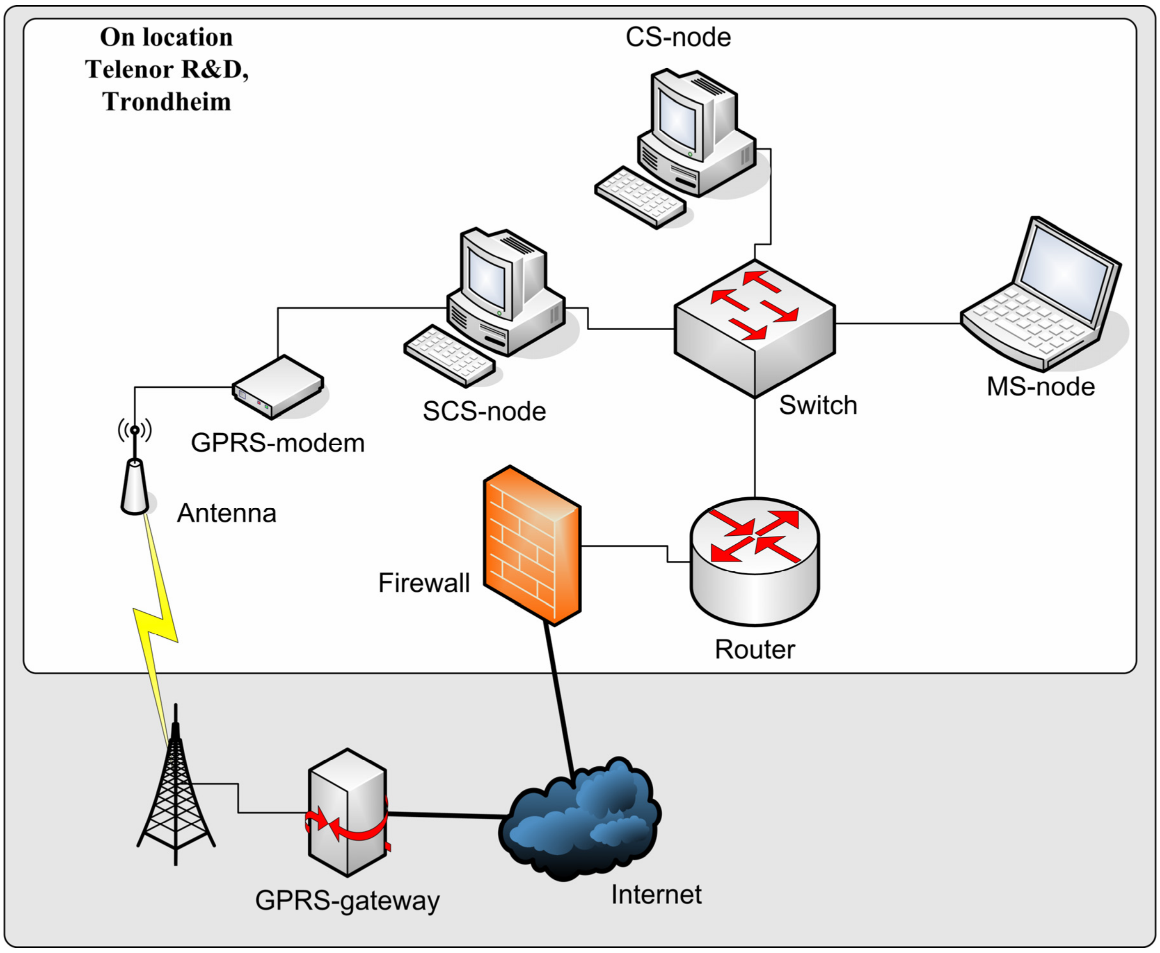


Figure 9-18: The demonstrator setup environment

A problem discovered during testing was that when the SCS-node used its GPRS-modem to communicate with the other nodes all signals originating from outside the local network were effectively stopped by the firewall protecting the LAN. The ports necessary for ActorFrame (5555-5557), were opened up for the MS-node computer, and the problem was solved.

A picture of the nodes, with the GPS-receiver and the GPRS-modem connected to the SCS-node is shown in Figure 9-19.

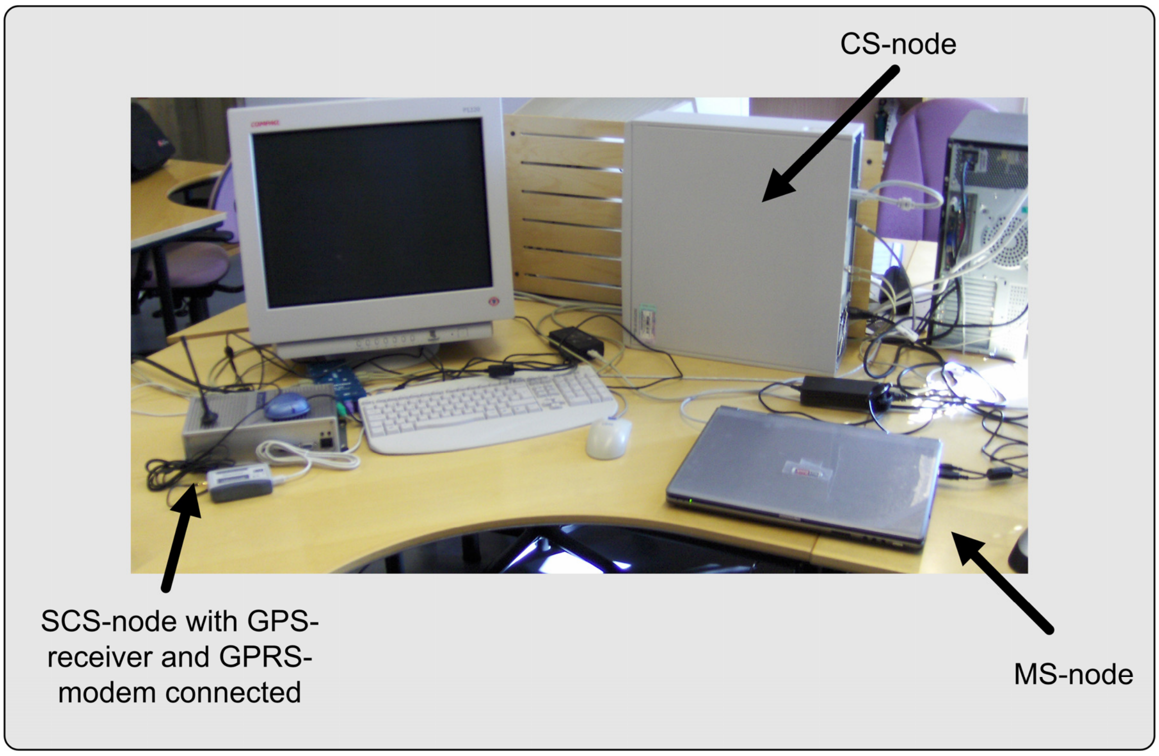


Figure 9-19: Picture of the testing elements

The agents were then initiated on their subsequent nodes with the Eclipse IDE in the standalone mode of ActorFrame.

9.5. Testing

During the process of implementing this system, tests of the functionality have been conducted continuously. Complete testing and analysis of, for instance, input consistency has not been done. However, the possibilities of inconsistency have been regarded, and that is why the amount of actors collaborating directly has sought to be reduced through a hierarchical and separated design. In addition, these tests were to test functionality under controlled circumstances, and are no guarantee for proper function when used outside this environment. They have inevitably failed for the first few iterations of development before all issues were resolved. It is also through this process that logical inconsistency and other unexpected or unforeseen elements were discovered and consequently attempted solved. In the following section the successful results are displayed, and elements that were not solved are commented. Largely, the tests correspond to the sequence and communication diagrams presented in section 8.4.

The tests were conducted by first administering them on the SCG-system simulated in an outer actor named the *SCGSystem*-actor. The design of this actor is shown in Figure 9-20.

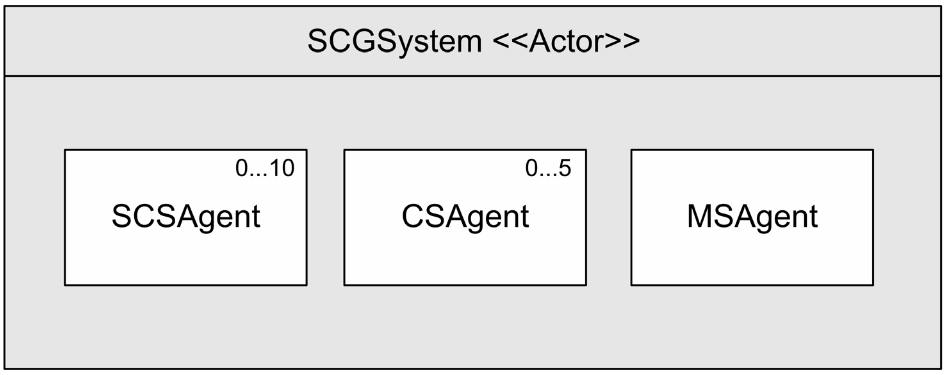


Figure 9-20: The SCGSystem-actor design

This allowed for testing all the elements on a local system before distributing the agents on their respective nodes. It also allowed for testing of several *CSAgents* and *SCSAgents* at once, which provided the basis for considering the distribution of addresses among actors. After the test was passed on the simulated SCG-system, the actors were distributed on the machines described in section 9.1.1, and the same procedure was repeated. The main difference in the setup of the distributed environment was the altering of the ActorAddresses in signals. For instance, in the simulated version the MSAgent-address used is *"/scgs/msa@MSAgent"*, which translates into *"/scgsystemid/msagentid@ActorType"*. But when the actors are distributed on their respective nodes the *SCGSystem*-actor no longer exists, so the *MSAgent*-actors address is *"/msa@MSAgent"*.

To generate the actors in the simulated system the ActorFrame management-console described in section 7.2.2.2 is used. Via this interface *RoleRequestMsg*-signals are sent to the *SCGSystem*-actor, and the requested actor is instantiated. First a *RoleRequestMsg*-signal for the actor "*CSAgent*" and instance "*csa*" is sent, then a *RoleRequestMsg*-signal requesting the actor "*SCSAgent*" and instance "*scsa*". The *RoleRequestMsg*-signal for the *GPSSensorAgent* is generated automatically upon a timer trigger in the *SensorDetectionEdge*-actor.

9.5.1. Test summary

A summary of the test results against the specifed functional requirements is shown in Table 9-3. The full tests for each area are available in Appendix B.

Table 9-3: Test results against functional requirements

R	SR	Description	Test result	
			Simulated	Distributed
1.		**The system must allow for automatic configuration and registration of new nodes (CS and SCS).**	**OK**	**OK**
	a	The system must make information about new nodes available to other nodes.	OK	Failed
	b	The new nodes must receive information about the other nodes in the system.	OK	Failed
	c	The SCG-system must register all nodes.	OK	OK
2.		**The system must allow for information to**	**OK**	**OK**

		be propagated throughout the system.		
	a	Parameters must be available upon initiation.	OK	OK
	b	Basic parameters must be possible to update upon initiation.	OK	OK
3		**The system must detect and handle communication link failures.**	**OK**	**OK**
	a	If MCS fails between CS and MS, FCS must be used.	Not implemented	Not implemented
	b	If PCS fails between CS and SCS, ECS must be used.	OK	OK
	c	If MCS, PCS and FCS fail, ECS must be used.	Not implemented	Not Implemented
4		**The system must issue alerts upon sensor value deviation or PCS-failure**	**OK**	**OK**
	a	Upon failure maintenance team must be notified	OK	OK
	b	Upon alarms, rescue team must be notified	OK	OK
5		**The system must collect and store sensor data**	**OK**	**OK**
	a	Data must be retrieved from sensors and provided to other nodes upon requests	OK	OK
6		**The system must utilize sensor data to issue warnings about abnormal sensor readings.**	**OK**	**OK**
	a	The system must issues warnings regarding deviations in the GPS-readings against pre-defined threshold values.	OK	OK
	b	The system must issues warnings regarding failed communication links and nodes.	OK	OK

As can be seen from the table, some elements were not implemented, mostly due to a lack of equipment, but some due to that the development platform became increasingly unstable as the SCG-system grew in size. In addition, it was discovered during deployment that ActorFrame uses its own serialization methods when sending ActorMessages over distributed links. Theses methods do not support *ArrayLists*, which were implemented as the means of registering lists of SCS-nodes and CS-nodes, and subsequently distributed to the other nodes. ActorFrame does support the serialization of Arrays, but support for creating arrays as signal-parameters or actor-variables seems to be lacking in Ramses.

9.5.2. Main experiences from testing

Several discoveries were made during the testing process in addition to those that had a direct implication on the functional requirements specified. In some cases this lead to the introduction of a new actor, in other cases the logic had to be redesigned. The main discoveries are briefly introduced below.

Initially it was intended to have the GPRS-link initiated all the time, and allow the operating system to use it when the LAN-connection disappeared. By appointing lower metrics in the routing table to the GPRS-link it was assumed that the operating system would prioritize the LAN-connection whilst active. Unfortunately, it soon became clear that this would not work. The reason for this was that the GPRS-connection uses a PPP-protocol. This protocol requires the specification of a default gateway for all traffic, overriding the metrics implemented in the routing table. Due to this factor an *OSAPIEdge*-actor was introduced to provide the administration of the GPRS-link. Another network issue uncovered during testing was the default private address allocation upon a GPRS-connection. This was solved by specifically requesting a public address through an alternative APN from the service-provider. It should be noted that although the GPRS-connection handled all outbound traffic from the SCS-node, the node can still receive data on both active connection addresses (LAN and GPRS) when they both are operational. This fact was used to restore the SCS to normal modus after a PCS-failure had been resolved.

Even after the GPRS-connection had received a public address, messages originating from the SCS-node were not received by the MS-node. At first it was thought that the GPRS-modem did not support the serialization method of ActorFrame, but the SCS-node was able to receive signals without problems. Finally it was revealed that the local firewall does not allow any traffic originating from the outside in to the local network. Ports in the firewall were then opened for the MS-node IP-address.

There was also a problem with signal-parameters being sent over distributed links. When the parameter was of the type *ActorAddress*, the content was null after being transmitted. But if the method *getSenderRole*() was applied on the received signal, the *ActorAddress* here was still valid. It was eventually discovered that Ramses does not seem to support the serialization of *ActorAddresses* which are contained as parameters in *ActorMessages*. ActorFrame, however, does support this, and this is why the *getSenderRole*()-method still worked. The additional code necessary was discovered by examining the framework. Thus, to allow for the serializaiton of ActorAddresses in ActorFrame, the following line of code must be included in the serialize-method of the generated signal class from Ramses:

```
dout.write(ActorAddressHelper.persist(actoraddress));
```

In the deserialize-method of the generated signal-class the following line of code must also be included:

```
actoraddress = ActorAddressHelper.resurrect(actoraddress);
```

It was then subsequently added manually to all signals generated by Ramses that were to be sent over communication links and contained *ActorAddresses* as parameters.

ActorFrame also generates inconsistencies in its way of addressing actors when distributed. Two methods often used to identify Actor-addresses are *getMyActorAddress* on *ActorSM's* and *getSenderRole*() on *ActorMsg's*. A typical address received from the first method is *"/csa/csr@CSRouter*". If, however, a message is sent from the aforementioned ActorAddress via ActorRouter to a distributed actor, where the method *getSenderRole*() is applied on the received signal, a different result is generated. Now the address is "*/IP-address/csa/csr@CSRouter*".

This quickly caused inconsistencies in the database and had to be considered and taken into account during the subsequent system design.

10. Discussion

In this chapter the content and experiences from this thesis are discussed and presented. New features and areas future work are also presented.

10.1. Experiences from deployment of demonstrator

During the design, implementation and testing of the SCG-system some problems were discovered and issues were unearthed. The following sections summarize the different aspects of the SCG-system and discuss some changes or adjustments that could be made to the system design, modelling tool and the ActorFrame-framework.

10.1.1. ActorFrame in the SCG-domain

ActorFrame provides state machines, signal interaction and play concepts to support the services required by the SCG-system. The plays given are system setup, system communication, alarm generation and link-failure handling, and together provide a distributed sensor data retrieval network with link redundancy for the SCG-system.

The demonstrator has shown that ActorFrame can provide the support for the system functionality. The basic functionality required was provided in an easy and clear manner. The keywords presented after the domain description and scenario in section 3.1.1 were self-configuration, ease-of-use, autonomy, sensor handling, self-monitoring, and fault-tolerance. All of these were provided using the ActorFrame-framework. The MS-node was aware of all of its CS-nodes and their capabilities, the CS-nodes were aware of all other CS-nodes, in addition to their own SCS-nodes and their capabilities. SCS-nodes were aware of all other SCS-nodes under the same CS-node. Interaction with non-ActorFrame elements such as the SMS-server and database were relatively easily integrated into the system through *Edge*-actors. In addition, ActorFrame provides modelling concepts and designs that are easily verified, validated, distributed, tested and extendable. The last point especially provides flexibility and adaptability necessary to handle new demands and technologies when these arise. But as shown through this thesis some elements of the systems functionality had to be handled specifically through application and system design due to shortcomings of the ActorFrame-framework.

Compared to the proposed use of client-server architecture with Web Services from [1], [2] there are advantages gained through use of ActorFrame. Although the system may be seen as more complex, documentation and testing is part of modelling process. The modularity of the design provides freedom for distribution and reuse. Providing a peer2peer relationship between the system entities allows for more flexible functionality. In the demonstrator, for instance, it allows for alarms and alerts to be generated by many parties, in addition to allowing the surveillance of communication links to be controlled by both sides. It could be said, however, that the system design implemented a certain level of client-server structure amongst peer2peer nodes, providing easier, more controllable, and more understandable interactions between nodes. This is most apparent in the hierarchy used, and the sensor data reporting and link status controlling functions. Beyond that, the possible grid computing and sensor web based functionality can possibly be integrated into the existing architecture. The design and implementation also allow for the distribution of actors to separate nodes, which can aid both fault-tolerance and enable load-sharing on potential bottle-neck actors and nodes.

There are, however, some extensions to the framework that could further improve the support it could give to the domain in question; distributed systems deployed over heterogeneous and changing networks technologies with dynamic node presence. The wired, fixed communication domain of ActorFrame does not suffice in the distributed, ad-hoc, wireless networks of the future. ActorFrame should be able to detect changes in the network connections, or at least allow the ActorFrame-application to detect these changes and pass these on to the ActorFrame-framework. An example from the demonstrator of this lacking flexibility of the framework is when the SCS-node switches to a GPRS-connection, thus receiving a new IP-address. ActorFrame does not appear to provide the possibility of updating the nodes IP-address in the ActorRouter. One option is to assume one-way communication until communication is restored; though this will greatly reduce the functionality of the system. This also makes the assumption that the IP-address received when the main communication link has been restored will be the same as the one registered earlier. This is not a situation that can be guaranteed for most systems.

The *CSAgent*-actor was run on a Linux-based operating system. The standalone ActorFrame application was slightly unstable on this platform. A regularly experienced problem was the instantiation of the actors and theirs action before the ActorRouter was ready. Thus the *RoleRequestMsg*-signal to the *MSAgent* was not sent. This often required several restarts before the initiation happened in a more correct order. A timer delay on the sending of the *RoleRequestMsg* could probably have reduced these problems, but this problem was not experienced on the MS- or SCS-node. If this is an ActorFrame, hardware or operating system problem is not clear.

The lack of flexibility for assigning the default gateway is also an area that can be extended. Due to possible communication link failures access to a default gateway may be lost. The possibility of assigning several default gateways, in weighted orders, would improve the redundancy handling of the system. In the demonstrator this has been solved by issuing time-interval generated messages to keep a fresh backup address present in the local ActorRouter's forwarding table.

During the testing phase of the demonstrator it was discovered that ActorFrame does not seem to support the sending of *ArrayLists* between distributed actors. Using its own serialization-method, *ArrayLists* are not one of the parameters supported for signals. This was unfortunate since *ArrayLists* were used to provide the lists of available *SCSAgents* and *CSAgents*. As commented earliar, ActorFrame does support *Arrays*, but it does not seem as Ramses supports the creation of *Arrays*; an unlucky combination. There are alternative means of distributing the lists of available actors, *Strings* could be written and parsed, XML could provide structurally ordered information, or a separate signal could be sent for each new actor, but such complexity should be easy to avoid.

The inconsistency of the ActorAddresses retrieved through different methods on distributed actors has already been commented in section 9.5.2. This should be attended to in order to ensure consistent addresses throughout the system. It may be that ActorFrame does not discriminate between the two forms of addressing, but it could pose a problem for external applications. In the demonstrator this caused problems with the database entries. This form of addressing actors may provide a possible way of dynamically specifying an actor's IP-address in an ActorMessage, but such a solution should probably be avoided.

One of the SCG-domain goals is to provide the cheapest solution possible. By using Java as a programming language, platform impendency of the residing operating system is achieved. This allows for the use of, for instance, Linux for the operating systems of the nodes in the system. Unfortunately, the system does not achieve full platform independency due to the fact that the application needs access to services only available through the native operating system. In the demonstrator this has been in relation with the connection of the GPS-receiver and GPRS-modem, both which have been given Windows-specific implementations. A sign of this lacking cross-platform independence is the introduction of the *OSAPIAgent*-actor into the system design to hide this from the rest of the ActorFrame-application. It is not feasible for ActorFrame to provide interaction with all operating systems, but in certain areas such functionality could be useful.

10.1.2. ActorRouter

The part of ActorFrame that binds distributed actors together is the ActorRouter. As described in section 7.2.2.3, ActorRouter handles the forwarding of messages which are not addressed to any actors in the current actor domain. In addition, ActorRouter maintains forwarding tables and reports its local actors to a default gateway. The method of routing is application-level, which means that the IP-networking is disregarded (headers are not read by ActorFrame).

The ActorRouter's application-level routing is simple and does not require much processing power. It does not provide any form of route-optimization and is in many essences completely cut-off from the actual networking technology it uses. Due to this, the system designer and implementer must know more about the network topology than is traditional. In the ideal internet paradigm, where all addresses are public with end-to-end transparency, and with the implementation of IPv6 providing the address space necessary for all-public addresses and can mask alternating connection points through mobile-IP, these issues may be of less importance. But for the time being the reality is a myriad of connections and connection types with constantly new and re-assigned IP-addresses. When an actor domain is instantiated, the IP-address this node is to be represented with has to be known. This can be difficult in cases of random initiated network connections generated during the lifetime of the actors, such as the GPRS-connection of the demonstrator. During the period of time which the SCS-node is using the GPRS-connection, only one-way communication was possible. If the SCS-node does not receive the same IP-address when the PCS comes back online this situation will not change. This is not a preferable option. This can also pose problems when the node-computer is behind a firewall or NAT, demanding knowledge of the port-forwarding scheme implemented. One extension could be to allow ActorRouter to read IP-headers on received *ActorMessage* packages.

As mentioned in the previous section, these issues can to a certain degree be handled by the ActorFrame-application, but this requires access to the ActorRouter-settings in runtime. An example of this is identifying and updating the IP-address of the SCS-node when it switches to the GPRS-connection of the ECS, enabling the MS-node to send messages to the SCS. It would also be interesting to be able to specify several default gateways, both to improve reliability through redundant gateways and to provide several alternate options when links fail.

The issue of firewalls blocking requests for TCP- and UDP-connections from outside the LAN was also a problem. One option is to maintain the established TCP- and UDP-sessions beyond that of sending a single signal. If the initial request is made by the node residing behind the firewall all responses will be allowed to return. This does however require that the one node always makes the first initiative, but it does enable firewall-traversal.

These proposed extensions will to a certain extent remove the transparency to networking issues otherwise provided by ActorRouter. The increasing variety of network connections and technologies, with mobile nodes constantly re-establishing connection points, makes it difficult to make the network layer completely transparent. Since this is difficult for a framework to handle, the application layer must be aware of network layer and aid in the process of handling this. This is an unfortunate measure, but necessary to explore in order to fully utilize the potential of full mobility and heterogeneous network technologies.

10.1.3. Ramses

The Ramses tool suite has been used for implementation of the system designed. It provides the possibility for inserting the design directly into the tool, and then automatically generating the code. This has greatly simplified the implementation process, making it both quicker, ensuring correctness, and providing support for testing. In the domain of model-driven development, Ramses is a tool which greatly improves and aids such a system development process.

Still, there are some are some possible areas of improvement and extensions that would increase the Ramses tool suite efficiency. One area is providing the possibility of using inheritance concept on the state machines of the system. Easy extendibility and reuse through the use of inheritance is one of the advantages state machines offer. The ability to use pre-defined modules of well-proven, designed and tested elements, and then extend these for specific tasks is a great advantage. Ramses does, for the time being, not support the concept of inheritance. For the system implemented in this thesis, many actors share the same basic functionality, such as the *CSManager* and *SCSManager* to mention a few. The design and implementation of these could have benefited from inheritance.

Another element discovered during testing of the system was the lacking support in Ramses for arrays. As mentioned in the previous section, ActorFrame does not provide support for distributing *ArrayLists*. It does, however, support *Arrays*. Unfortunately, Ramses does not support the creation of *Arrays*. The only *Array* that can be created is the *ArrayList*. This is an unfortunate situation, which prevented the distribution of actor addresses in the SCG-system, a basic element of possible grid computing and node-to-node independent interaction. In addition, Ramses does not seem to support the serialization of *ActorAddresses* as parameters in signals. ActorFrame does support the serialization of *ActorAddresses*, but Ramses has not implemented this. Such an element should be supported by Ramses as it is not uncommon to want to distribute ActorAddresses, either by specifying the target or originator of a signal which must traversed other actors before reaching its destination.

It would also be interesting to see if Ramses could provide the possibility to set a signal reception to all existing states. A scenario where this could be useful is the event of a link-failure or when a sea cage is drifting when priority messages must always be handled.

As one of the nodes of the SCG-system was run on a Linux-platform, Ramses was run on this platform. Although initially platform independent, there were problems with using Ramses on Linux. This was solved by creating a */tmpactordir/* in the root directory.

Finally, it was experienced that Ramses development tool became increasingly unstable when the system generated increased in size and complexity. This grew to such an extent that further implementation and some design changes went unimplemented. It is for the time being unclear if the problem was due to Ramses, ActorFrame, Eclipse, the development computer, or any of the plug-ins which Ramses utilizes.

10.1.4. Redundant communication link

The redundant communication link for the demonstrator was provided by a GPRS-modem. This modem was set up at a speed of 115,2 Kb/s. The data rate provided was more than adequate to provide the communications necessary, and the link could be initiated and disconnected upon request. A slight increase in latency was experienced, but no more than expected and not enough to present any problems.

10.2. Design decisions

There are many possible ways of designing a system such as the SCG-system. But before looking into the design itself, a comment is given on the basic domain description presented in [1], [2]. As used throughout this thesis, the SCG-domain has had four independent communication systems; MCS, PCS, ECS, FCS. This was meant to provide a certain level of redundancy in the case of communication failures, taking into account the relative instability of today's wireless communication technologies compared to wired solutions.

When implementing such a solution a possible scalability problem arises. When the PCS fails, SCS-nodes are intended to communicate directly with the MS-node. The load on the MS-node can become large in periods of large network instability, depending on the amount of sea cages in the SCG-system. This may not be necessary. For the actors residing on the SCS-node the CS-node is still available, independent of the communication link. This allows for direct communication with the CS-node, and only slightly changing the status of the system compared to operations under normal modus. This so-called BCS (Backup Communication System) is shown in Figure 10-1.

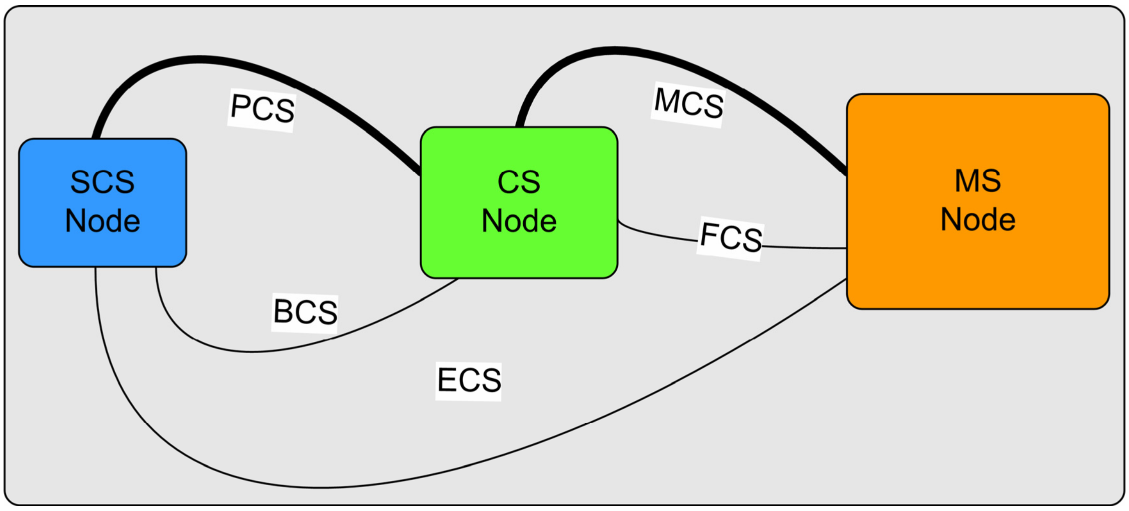


Figure 10-1: Alternative communication links

The messages are simply sent over the same link as the ECS, only to the CS-node. This reduces the load on the MS-node in the event of a large-scale PCS-failure. In the case of an FCS-failure, ECS is used as previously suggested. The BCS-solution is dependent on the type of address the CS-node has (private or public), and how much of a cost is put on the MCS-link. But it is an addition to be considered.

Otherwise an optional design of the *SCSAgent* and *CSAgent* can be considered. The alternative design is shown in Figure 10-2.

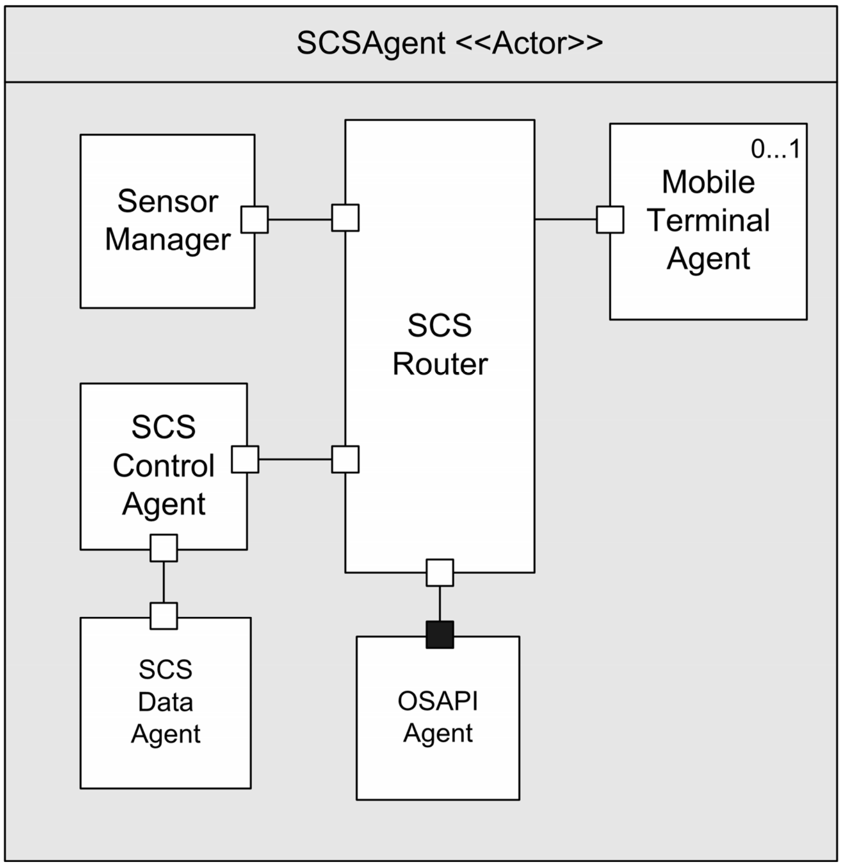


Figure 10-2: Alternative SCSAgent-design

Here the *SensorManager*-actor is no longer connected to the *SCSControlAgent*-actor, but directly to the *SCSRouter*-actor. This design maintains the patterns of the higher-level actors (*CSAgent* and *MSAgent*) where there lower-level actors are independently connected to the router-actor on the node (*CSManager*-actor and *SCSManager*-actor) relieving the *ControlAgent*-actor of some signal traffic and providing easier access to the elements of the system. The change shown in Figure 10-2 also applies for the *SensorManager*-actor of the *CSAgent*-actor.

The issue of providing globally (amongst the SCG-elements) unique addresses for the actors of the system has not been addressed. To provide full node access and interoperability all actors should have a unique address. But since the amount of nodes is dynamic it is difficult to provide such addresses through the provided framework. One possible solution is creating an outer actor for the already specified actors aiming to provide such a service. The structure of such an actor for the *SCSAgent* is shown in Figure 10-3.

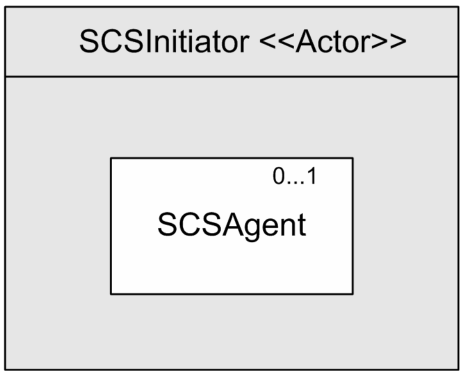


Figure 10-3: The SCSInitiator-actor design

The *SCSInitiator* handles the task of assigning a globally unique id to its inner actor *SCSAgent*. This can be done in at least three ways. The *SCSInitiator*-actor may upon creation prompt the user for a globally unique address. Another option is for the *SCSInitiator*-actor to contact an Address-actor for the SCG-system which subsequently provides the actor with a unique id for the *SCSAgent*. Finally, the *SCSInitiator*-actor may itself create a unique id for the inner *SCSAgent*-actor by using, for instance, the MAC-address of the local computer to generate a unique key. The id received from any of these methods is then used in a *RoleReqMsg*-signal sent from the *SCSInitiator* to itself requesting a *SCSAgent* with this id. The same procedure will apply for the *CSAgent*- and *MSAgent*-actors.

There are many potential additional actors that have been proposed in the system designs in section 8.3 which have not been implemented. The inclusion of these actors is a natural extension for an SCG-system incorporating more sensors and agents.

It should also be noted that no functionality for removing node-actors has been implemented; this would be a natural extension to a fully-functional system enabling nodes to be removed and re-installed in different settings.

The setup of the ActorRouter default gateways can also be discussed, especially in light of the functionality currently offered. A dedicated node running an ActorRouter entity functioning as a default gateway for all nodes provides a single point of interaction for the entire system, ensuring that all actors can be located. This solution does also present several drawbacks. This node can become a bottleneck, it is a single-point-of-failure, and all registering actors must present publicly accessible addresses.

The design and implementation has been done to provide a demonstrator for this system. Being a demonstrator it also provides limited functionality. This aside, the implemented demonstrator will be able to provide the services required from a single sea cage with a GPS-receiver and a GPRS-modem.

10.3. New features and extensions

As presented throughout this thesis, the current design and implementation have been made for creating a demonstrator of the system. The design has also looked ahead and attempted to provide the building blocks for future extensions to the degree of potential mobile grid computing elements. The road to actual implementations of such functionality is long and complex, with many additional issues to consider providing the basis for many possible theses.

An interesting basis scenario could be the introduction of new actors to the SCG-domain, actors which are mobile in nature. The SCG-domain can be extended to contain many new, outside, parties interested in both the data generated and in direct interaction with the system. An example of this is if the fish collection boat which harvests the biomass produced in the sea cage is handled by an outside party. This party is then to gain access directly to the current SCS, preferably automatically and seamlessly. One step has been taken by proposing a *MobileTerminalAgent*-actor residing on each distributed node. The intention for this actor is to provide support for roaming actors wishing to interact with this particular *SCSAgent*. An assumption has been made of no more than one mobile terminal per agent per time, therefore a form of *UserAgent* has not been considered. Not to say that a type of *UserAgent* may not be necessary. This *MobileTerminalAgent* will provide access to the entire SCG-system through the *SCSAgents* knowledge of the domain it is in, in addition to knowing the other nodes capabilities and capacity. The nature of the actors wishing to interact could be outside the traditionally considered actors, and these actors can wish interaction with the SCG-system without ever having been considered during the design and implementation. Some potential actors are shown in Figure 10-4.

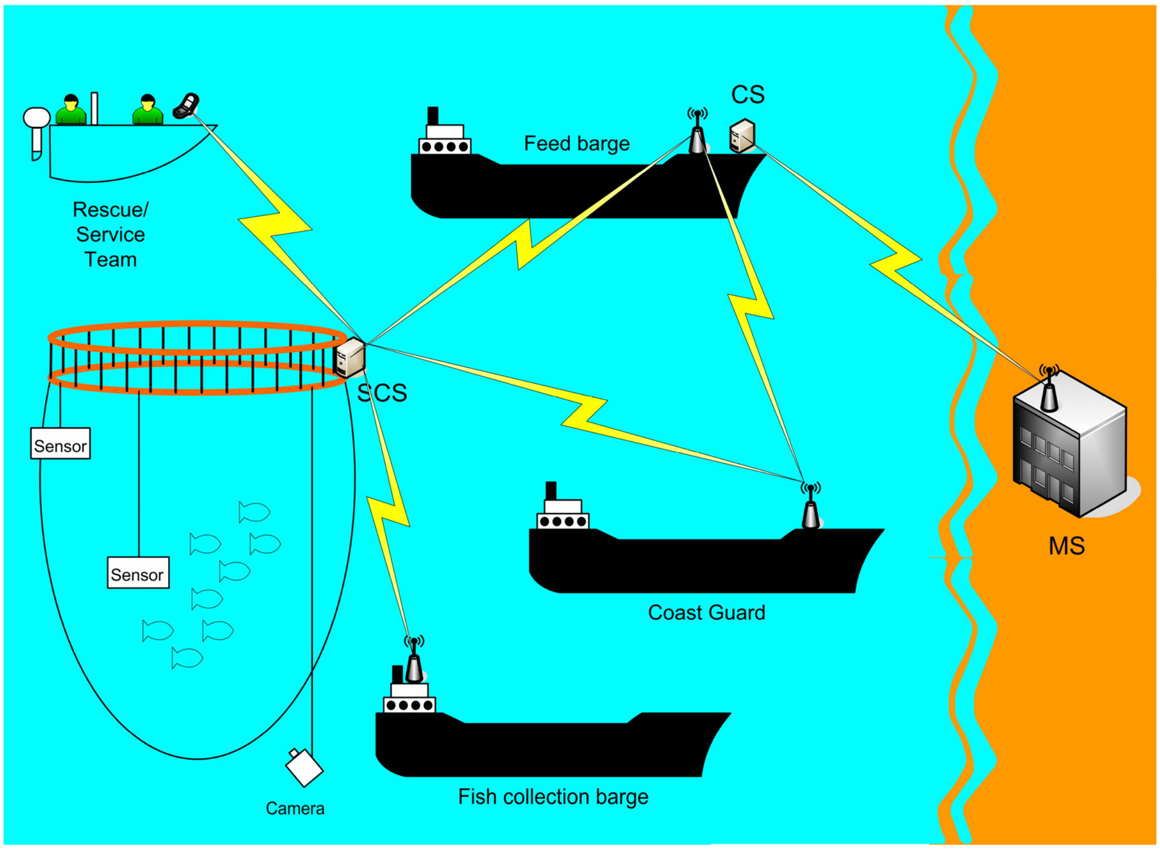


Figure 10-4: Potential actors in an extended SCG-domain

As shown, both the fish collection barge arriving to harvest the produced biomass and the coast guard which may be enforcing local law, may be interested in access to the

SCG-system and specific nodes. The fish collection barge could be interested in accessing the SCS-nodes GPS-data to automate the procedure of connecting with the sea cage. How should this be achieved? How general does the design have to be to allow for unknown actors to easily and seamlessly interact with the system? Some standard interfaces and access methods must be implemented in addition to publicised. Perhaps this can be handled by a central *SystemAccessEdge*-actor, which further interacts with a services- and registry-actor. Or could it be simpler and more efficient if each system node could provide access capabilities to enquiring actors. Yet another option could be for the mobile actors to provide their own interface for the system to utilize, simply demanding a generic interface-handler on behalf of the application? Perhaps the integration of Bluetooth-support into the ActorFrame-framework can take advantage of the Service Discovery protocol native to Bluetooth.

Besides that, there are many further unexplored areas in the SCG-domain. Extending functionality to provide further services and implementing the unimplemented design proposals presented here are just a few of them. The handling of the SCS-nodes during ECS-operation, here simply handled by the CSSession-actor could be further discussed, and the solution of a *ReserveSCSSession* as an inner actor of the *CSSession* as presented in section 8.3.3 could be considered. Also, how to assign groups of rescue and service teams to each CS-node and its SCS-nodes is another area that should be further explored. The automatic assigning of rescue and service teams upon a new node-connection would extend the self-configuration aspect of the system even further.

The handling of sensor data, and in what format it should be kept in, is also an area for discussion. In this system, the position data has been handled by a position-specific object locally in the SCS-node, and is later reported in as a simple *String*. This depletes the original sensor-reading when sent beyond the SCS-node. Sending the position data in the original *LatLng*-class, or any other GPS-oriented object, allows for the CS-node or MS-node to perform operations on the data. An example is the case of detecting if a sea cage is drifting. If this were a complex operation, to large for the SCS-node computer, it should be sent to the CS-node for handling. Sending the data as an object, such as the ones described, enables easy handling for the CS-node. Sending it simply as a String may result in information loss. Since ActorFrame probably does not support the serialization of foreign objects the transport of these can, at least for the time being, be tricky. Alternatives are representing information in ordered *Strings* or using XML, requiring the recipient to use parsers to recreate the objects. Other issues include bandwidth requirements of the different alternatives.

Further work on the grid-computing/mobile-grid concept of the SCG-system is also an interesting area of possible research. In the demonstrator, the presence and addresses of all nodes are propagated through the system when an element is added. This knowledge of system entities has not yet been utilized to provide further services. There are many possible application-areas of such an extension, amongst others task-sharing and resource-handling. Such services could further improve the autonomy of the SCG-system by extending redundancy, self-healing and self-configuring abilities. When sensors, nodes or links go down the system entities can work together in reassigning the work loads, taking turns to perform tasks to lengthen battery life time without reducing the amount of work done. The tasks usually handled by the *CSAgent* can be redistributed amongst the remaining SCS-nodes, forming a type of virtual *CSAgent*, minimizing the affect of such a failure on the rest of the system.

Another interesting area is work on improving data sharing amongst the nodes of the SCG-system, the sensor web inspired functionality. Providing the ability to interpret sensor data collected from other entities to improve operating parameters for the node and equipment itself. As already mentioned, registered occurrences or sensor readings warranting an increase in the polling frequency of the sea cage position could be of interest. Increases in wind speeds or currents, drops in pressure or increased sea cage velocity, are all elements which can trigger the SCS-node to reconfigure the settings of its *GPSControlAgent*-actor. Another interesting application area is that of poisonous algae. If one sea cage detects an increase in the algae amount in its vicinity, this information can immediately be sent to the MS-node, CS-node, and all other local SCS-nodes. This can allow, if the sea cages are submersible, for SCS-nodes to adjust there buoyancy of their sea cage and retreat to depths clear of the algae. A quick reaction to such threats could save enormous values. The possibilities and scenarios for this are next to endless.

It could also be interesting to implement further edges to improve accessibility to the system. One such edge could be towards Web Services, others could be connecting the SCG-system for system initiation, self-configuration, node-connection and sensor data retrieval to the context-manager developed in [11], allowing the division of tasks between specialized and optimized entities.

In addition to the basic scenarios this thesis and demonstrator have been based on, there are other services that the SCG-domain may require support for. One example of this is the delivery of a camera-feed to the mainland for visual surveillance of the fish stock. The transport of streaming video data is not a task for ActorFrame, but it could perhaps be utilized in discovering and providing access to such functionality. The application could provide the necessary data for an external application to setup the data stream.

New features and extensions have already been proposed for the ActorFrame-framework and Ramses in section 10.1, and are not repeated here.

10.4. Future work

The demonstrator provided here is simply the first step in realizing an SCG-system in the ActorFrame-framework. If the system is not further implemented in ActorFrame there should be some principles that may apply which have been uncovered here. Still, there are still many areas of future work applicable to what has been presented here. These topics vary over a vast majority of areas.

The new features and extensions proposed in previous section can all be considered as possible areas of future work and consideration. There are also many other topics springing out from the SCG-system which could provide a basis for further study. This is both in the SCG-domain itself and adjourning areas discussed in this thesis.

A full economic study of all aspects of the SCG-domain, from the hardware incorporated, via communication links, to sensors and software should be conducted. This requires a basis for the characteristics of the equipment needed, which again requires defining the needs of the system. An example of this is determining the bandwidth requirements of the SCG-system elements, both for primary operation modus, and for the redundant communication links. Specifying the resource needs of the node-hardware is another example. These are both are areas of further study.

With distributed nodes connected through an unstable network connection there are cases in which the nodes will be cut of from each other. Both the nodes themselves and the communication links may fail. This can present many challenges. How does an actor handle a missing signal due to a communication failure? This has already been considered partially in this thesis, both in reducing the number of directly inter-communicating actors, but also regarding link failure detection on signals expecting responses. Still, this has not been implemented and tested and are therefore simply suggestions. In addition, the case of synchronizing data and states when previously disconnected nodes regain contact. Ensuring the propagation of correct and up-to-data information must also be handled. In the implemented demonstrator this is relatively simple as no log is kept over the GPS-positions of the sea cage. But if the *CSAgent* is to keep an updated log of sensor values in periods in which it has no connection with the SCS-node there may arise inconsistencies.

As mentioned in the previous section, further investigating and exploring the grid computing potentials of the SCG-system are of interest. Many mobile grid computing elements can be studied, such as task-scheduling, status-distribution, energy-awareness, network-awareness and consistency management.

With the system design as it is, all possible sensors must have defined *SensorAgents* capable of handling their sensor input. This implies that if a new sensor is introduced in the aquaculture domain, all SCS- and CS-nodes must be reinstated with a new and updated SCG-system application. This can be quite a large task, especially when the system is well-functioning before update. It could be interesting to see if new actor specifications could be implemented and installed during run-time of the current actors. Such dynamic class configuration could greatly simplify the introduction of new sensors into the system. But the introduction of a new actor could quickly affect the whole system in several ways. If new signals, variables and parameters must be introduced for the new *SensorAgent,* this will imply updating several actors to handle these and send them. As mentioned previously in section 8.4.2.2, using a generic signal for transporting sensor data in primitive types could be a way around this. Such dynamic class configuration and its repercussions are both areas for future study.

As seen in this thesis, when a node can have several network connections it is important for the application to be aware of this. The previous environment for service development consisted of relatively similar nodes, connected via a relatively standard network interface. This environment for an ActorFrame-application between two distributed entities is shown in Figure 10-5.

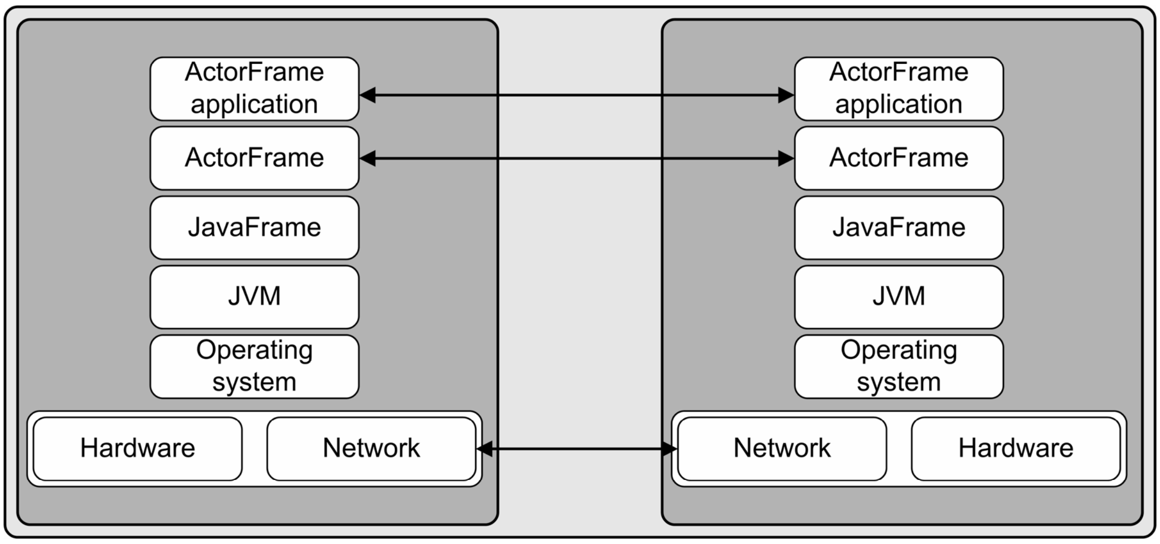


Figure 10-5: The former environment for ActorFrame applications

Providing network transparency, both in the traditional end-to-end transparency of the internet, but also the separation of the application from the network layer, is growing increasingly more difficult. Not only must an application be aware of its own status, hardware and network capabilities, it must also consider the other collaborating actors capabilities. The potential is limited by the weakest link. The new and future environment for both ActorFrame and other development frameworks will be similar to that shown in Figure 10-6.

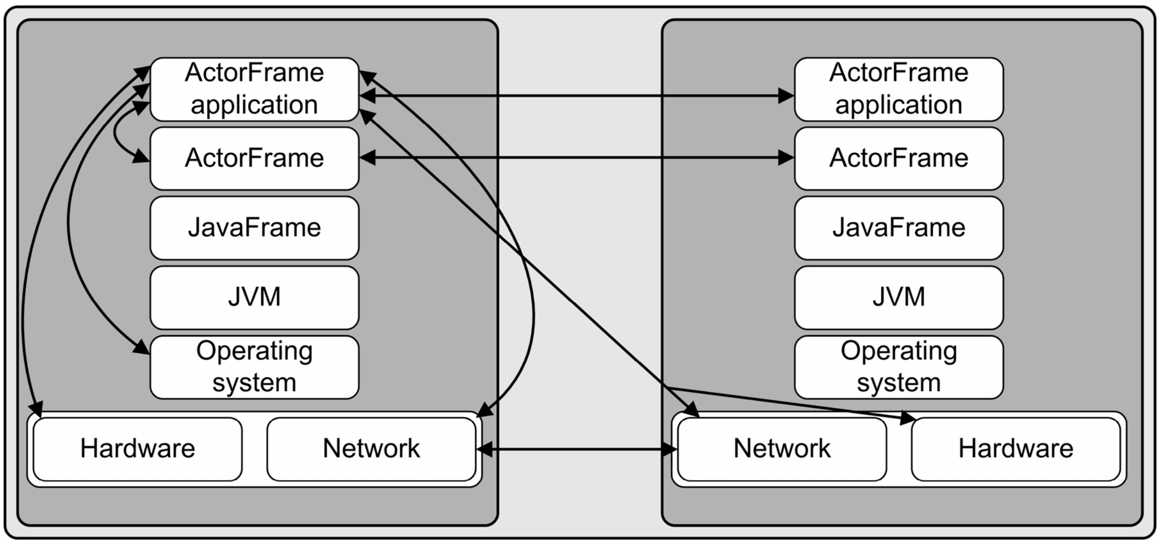


Figure 10-6: The future environemnt for ActorFrame application development

The amount of elements to be considered is much larger and more complex than before. With the current layering architecture this requires the application to be aware of, and handle, more and more factors. This will require that the application and services development will become increasingly more complicated, incurring longer and more complex development. How to provide a certain level of transparency from these issues, allowing designers to continue to focus on developing and designing services independent of these issues, should be an area of future interest and study.

The weakness of only having a single default gateway has also been mentioned previously. It could be interesting to examine possible ways of adding redundancy and flexibility to the routing scheme of ActorRouter. An option may be the use of anycast-addresses, or perhaps using redundant servers masked through another Java-framework such as JGroup. [69]

Section 10.3 also mentions the topic of allowing dynamic access from mobile agents to parts of or all of the SCG-system data and resources. This fits in with a new area currently under research named “Mobile Dynamic Virtual Organization” (MDVO). The name refers to the traditional understanding of virtual organizations, extending to more recent scenarios with dynamic and undefined organizations with constantly varying access points. This is a very recent area of research, and an interesting one as such.

Finally, two issues should be mentioned. One is considering the amount of functionality necessary to provide the services required by the SCG-domain. Whilst grid computing and mobile environment adaptation may provide a great number of services and possiblilites, they may introduce more complexity than is needed. From a research point of view the SCG-domain presents numerous possibilities within these fields, all of which can probably enhance the SCG-system, but careful consideration should be taken as to when enough is enough. The other issue is that technology today is improving at a fantastic rate, both within computers and communication technologies. Although one should not take for granted that this kind of development will continue there are currently no signs of it slowing down. This should be taken into account and kept in mind when developing a system for the future, a system such as the SCG-system.

11. Conclusion

This thesis has investigated the use of distributed inter-communicating state machines designed and applied with the play analogy of ActorFrame to the SCG-domain. This domain consists of interconnected independent computers interacting to provide self-contained and self-configuring remote sensing and control of offshore sea cage installations. In addition, the design has been inspired by areas such as sensor networks, webs, and grid computing, providing some simple building blocks and principles for further development.

The steady increase in wireless, long range, high capacity communication technologies make it more and more plausible to implement many of the visions of the SCG-system. The amount of possible technologies has grown to the point where not only one, but several links can be established from each node. It should be noted that some of these technologies have only just been released for commercial interests, and there is still some doubt to how well they will perform beyond the theoretical domain. Still, there currently exist technologies that will suffice to the basic needs of the SCG-system. The abundance of communication links and technologies also challenge former network transparency issues, making the network more visible to applications than before.

A demonstration system has been designed and implemented with the ActorFrame-framework, aided by the model-driven design tool Ramses. This has aided in keeping the distance from design to implementation very short. The demonstration system has provided the possibility to prove and test basic principles and logic. The results have been encouraging. Support for automatic system set up, sensor reporting, and alarms generated when a communication link has been severed or a sensor value is incorrect have all been provided through ActorFrame. Although giving support for a number of areas, the ActorFrame-framework is slightly out of its application domain in the SCG-system, and its original focus of fixed, homogeneous network connections is apparent.

Working with ActorFrame in the SCG-domain has provided many possible areas of future work. These are not only related to the actual SCG-system and ActorFrame, but also to other areas representing challenges for further service development frameworks. Some key words are mobility, heterogeneous networks, network- and terminal-awareness and transparency, multiple connection types, service discovery and service utilization.

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Appendix A. User manual

Here instructions on how to test the simulated system are described[12]. The implementation of the system can be found in the zip-file uploaded with this thesis. This user manual assumes the use of the same GPS-reciever and GPRS-modem with the same subscripition (Djuice).

1. In order to try/test the demonstration, or eventually perform changes, one needs to download the Eclipse Platform (version 3.1.2) from:

   http://www.eclipse.org

2. Following the instructions for installing Ramses from the Ramses Wiki, available from:

   http://www.item.ntnu.no/lab/pats/wiki/index.php/Ramses_User_Page

3. Choose Import -> Existing Projects into Workspace, and import the zip-file (no.ntnu.item.master.2006) on the accompanying zip-file, specified in Appendix I. It is usually a good idea to restart the work area at this point.

4. The projects imported and their project and external JAR-dependencies are show in Table A-1.

Table A-1: System projects with dependencies

Project	Description	Dependencies	
		Projects	**JAR**
no.ntnu.item.master2006	Contains the files generated through the system design tool.	no.ntnu.item.master2006.ext.GPSHandler no.ntnu.item.master2006.ext.mySQLHandler no.ntnu.item.master2006.ext.smsHandler se.ericsson.eto.norarc.actorframe	adminGUI.jar javagps.jar jcoord-1.0.zip
no.ntnu.item.master2006 .ext.GPSHandler	Contains the classes for interaction with the GPS-receiver.	(none)	javagps.jar jcoord-1.0.zip RXTXcomm.jar
no.ntnu.item.master2006 .ext.mySQLHandler	Contains the classes for interaction with the MySQL-database.	(none)	mysql-connector-java-3.1.13-bin.jar
no.ntnu.item.master2006 .ext.simpleAdminGUI	Contains the classes for the GUI.	no.ntnu.item.master2006 se.ericsson.eto.norarc.actorframe	(none)
no.ntnu.item.master2006 .ext.smsHandler	Contain the classes for interaction with the SMS-server	(none)	axis.jar commons-discovery-0.2.jar commons-logging-1.0.4.jar jaxrpc.jar sms.jar saaj.jar wsdl4j-1.5.1.jar
se.ericsson.eto.norarc.actorframe	Contains ActorFrame.	(none)	actorframe2.0.0.2.jar

[12] If problems are encountered, please do not hesitate to send an e-mail about it to *jens@askgaard.com.*

scsagent	Contains the generated code for the *MSAgent*-actor.	no.ntnu.item.master2006 no.ntnu.item.master2006.ext.GPSHandler no.ntnu.item.master2006.ext.mySQLHandler no.ntnu.item.master2006.ext.simpleAdminGUI no.ntnu.item.master2006.ext.smsHandler se.ericsson.eto.norarc.actorframe	jcoord-1.0.zip RXTXcomm.jar
csagent	Contains the generated code for the *CSAgent*-actor.	no.ntnu.item.master2006 no.ntnu.item.master2006.ext.GPSHandler no.ntnu.item.master2006.ext.mySQLHandler no.ntnu.item.master2006.ext.simpleAdminGUI no.ntnu.item.master2006.ext.smsHandler se.ericsson.eto.norarc.actorframe	jcoord-1.0.zip RXTXcomm.jar
scsagent	Contains the generated code for the *SCSAgent*-actor.	no.ntnu.item.master2006 no.ntnu.item.master2006.ext.GPSHandler no.ntnu.item.master2006.ext.mySQLHandler no.ntnu.item.master2006.ext.simpleAdminGUI no.ntnu.item.master2006.ext.smsHandler se.ericsson.eto.norarc.actorframe	jcoord-1.0.zip RXTXcomm.jar
simulation	Contains the generated standalone application simulation.	no.ntnu.item.master2006 no.ntnu.item.master2006.ext.GPSHandler no.ntnu.item.master2006.ext.mySQLHandler no.ntnu.item.master2006.ext.simpleAdminGUI no.ntnu.item.master2006.ext.smsHandler se.ericsson.eto.norarc.actorframe	jcoord-1.0.zip RXTXcomm.jar

All JARs are provided in the *systemjars.zip*-file, part of Appendix I. In addition to the mentioned items, the projects which use the GPSSensorEdge must add the files *rxtxParallel.dll* and *rxtxSerial.dll* to the same folder. These are used to interact with the Windows operating system. These are also part of the *systemjars.zip*-file.

5. Initiate the database as described in Appendix C.

6. Download and run a web-server. Place the *scgstatus.jsp* file in the *webfiles*-folder of the web server. This file is available from Appendix I.

7. Install the GPS-receiver. Ensure that this is connected to "COM12".

8. Initiate the GPRS-modem.

9. Run the simulation by right-clicking on default-package in the simulation-project. Select Run AS -> Java Application.

10. The ActorFrame-management console should appear. Select *RoleRequestMsg* from the drop-down menu, specify the recipient as actor type "SCGSystem", actor id "/scgs".

11. First a request *CSAgent* by setting the first parameter as "csa", and the second parameter as "CSAgent"

12. Repeat the same steps only use “scsa” and “SCSAgent” as parameters to request a *SCSAgent*.

13. The simulation should now be up and running. By moving the GPS-receiver an alarm should be generated. By altering the code of the *SCSSession*-actor responses to the *connectionCheck*-signal can be disengaged and the PCS-link is assumed down.

14. The status of the system can be viewed at the address of the web server. Assuming that the port has been set to 8080, the address is:

    http://localhost:8080/scgstatus.jsp

For testing the distributed system the projects *scsagent*, *csagent*, and *msagent* must be imported to their respective nodes. The GPS-receiver and the GPRS-modem must be installed and setup on the SCS-node. The public addresses and default gateways of the actors must be specifed in the *AFProperties.properties*-files present in each actor-project. Start the *msagent* first, doing the same as in step 8. Then initiate the *csagent* and *scsagent* respectively.

If several tests are run, it can be an advantage to clear out the database before re-initiating the system. This is done through the SQL-command:

```
mysql>DELETE FROM table;
```

The tables which need to be cleared are *ms*, *cs*, *scs* and *sensor*. See Appendix C.

Appendix B. System testing

In this section the test procedures and tests are shown and commented. They are related to the functional requirements stated in Table 8-1 and the sequence and communication diagrams in section 8.4.

a. Testing the system setup

This test was conducted for testing the sequence and communication diagrams depicted in section 8.4.1, which also correspond to functional requirements one and two. The results are shown in Table B-1.

Table B-1: Test of the system setup functionality

	Function tested	**Expected behaviour**	**Result**	
			Simulated	**Distributed**
1	A *CSAgent* is instantiated.	a) A *RoleRequestMsg* is sent to the *CSManager*	OK	OK
		b) A *CSSession*-actor is created and responds to the *CSAgent*.	OK	OK
		c) All *CSAgents* receive notification of the new CS.	OK	Failure
		d) The new *CSAgent* receives setup parameters and a list of CS'.	OK	Failure
		e) The database is updated with the new CS.	OK	OK
2	A *SCSAgent* is instantiated.	a) A *RoleRequestMsg* is sent to the *SCSManager*	OK	OK
		b) A *SCSSession*-actor is created and responds to the *CSAgent*.	OK	OK
		c) All *SCSAgents* receive notification of the new SCS.	OK	Failed
		d) The new *SCSAgent* receives setup parameters and a list of SCS'	OK	Failed
		e) The *CSSession*-actor receives notification of the new *SCSAgent*.	OK	OK
		f) The database is updated with the new SCS	OK	OK
3	A GPS-receiver is connected to the SCS.	a) The sensor is detected and a *SensorAgent* is initiated.	Failure – not implemented	Failure – not implemented
		b) The sensor receives a specific *SensorAgent*, and polling of data is initiated.	OK	OK
		c) The *SCSAgent* is notified of the new sensor.	OK	OK

		d) The *CSAgent* is notified of the new sensor and initiates a timer.	OK	OK
		e) The *MSAgent* is notified of the new sensor and initiates a timer.	OK	OK
		f) The database is updated with the new sensor.	OK	OK

As seen in point three of the table, the *SensorDetectionEdge*-actor does not provide automatic sensor detection as of yet, and thus cannot provide the service expected. The *SensorDetectionEdge*-actor implemented does nothing more than wait a determined time interval before reporting a gps-receiver detected on port "COM12".

b. Testing sensor updates

This test was conducted for testing the sequence diagrams in section 8.4.2 and corresponds to the functional requirement five. The results are shown in Table B-2

Table B-2: Test of the sensor update functionality

	Function tested	**Expected behaviour**	**Result**	
			Simulated	**Distributed**
1	The *GPSControlAgent* requests sensor data from *GPSSensorEdge*	a) Upon a timer-initiative a *ReqGPSPosition* is sent to the *GPSSensorEdge.*	OK	OK
		b) The *GPSSensorEdge* retrieves position data from the sensor and puts this in the *GPSPositionUpdate*-signal.	OK	OK
		c) The *GPSControlAgent* receives the position update and can compares it to the default position.	OK	OK
		e) A new timer-interval is initiated.	OK	OK
2	The *SCSControlAgent* requests a sensor update from the *GPSControlAgent*	a) A *GetSensorUpdate* is sent to the *SCSManager* from the *SCSControlAgent* when the timer is set off.	OK	OK
		b) The *SCSManager* sends a *GetSensorUpdate* to the *GPSControlAgent.*	OK	OK
		c) A *GPSSensorData*-signal with the position is returned to the *SCSControlAgent.*	OK	OK
		d) A new timer is initiated.	OK	OK
3	The *CSControlAgent* requests a sensor	a) A *GetSensorUpdate*-signal is sent from the *CSControlAgent* when the timer is invoked.	OK	OK

	update from the *SCSControlAgent*	b)	The *SCSManager* consequently queries all SCS for sensor data (one).	OK	OK
		c)	The *SCSRouter* sends the request to the *SCSControlAgent.*	OK	OK
		d)	The *SCSControlAgent* returns the latest position in the *GPSSensorUpdate*-signal.	OK	OK
		e)	The *CSControlAgent* receives the latest position and stores this.	OK	OK
		f)	When the *UpdateFinished*-signal is received, a new timer is set.	OK	OK
4	The *MSControlAgent* requests a sensor update from the *CSControlAgent*	a)	A *GetSensorUpdate*-signal is sent from the *CSControlAgent* when the timer is invoked.	OK	OK
		b)	The *CSManager* sends the *GetSensorUpdate* to the *CSSessions* (one).	OK	OK
		c)	The *CSControlAgent* and the *DBEdge* receive the *GPSSensorUpdate*-signal.	OK	OK
		d)	The *DBEdge* updates the database, and the web interface registers the change.	OK	OK
		e)	The *CSManager* sends the *UpdateFinished*-signal when all CS have sent sensor updates.	OK	OK
		f)	The *SensorUpdate*-timer is reset.	OK	OK

c. Testing sensor and PCS-failure alarms

In the following table the results of the tests for sensor-deviation and PCS-failure are shown. For the simulated version the PCS-failure was initiated by discontinuing the replies of the *SCSConnectionCheck*-messages, and for the distributed test the Ethernet-cable was pulled out. The functional requirements corresponding to this functionality are three, four and six. The results are shown in Table B-3.

Table B-3: Test of the sensor deviation and PCS-failure detection and alarms

	Function tested		**Expected behaviour**	**Result**	
				Simulated	**Distributed**
1	The GPS-receiver is	a)	The position deviation is discovered by the	OK	OK

	moved beyond the boundaries set.	*GPSControlAgent.*		
		b) A *PositionAlert*-signal is sent.	OK	OK
		c) The *SCSAgent*, *CSAgent* and *MSAgent* are notified.	OK	OK
		d) An alarm is issued by the *SMSEdge.*	OK	OK
		e) The database is updated with the new position and SCS-status is set to yellow.	OK	OK
2	The PCS is disconnected.	a) The *SCSAgent* detects that the link is down.	OK	OK
		b) The ECS is initiated.	Failure	OK
		c) The *CSSession* is notified, which in turn notifies the *SCSAgent* via MCS.	OK	OK
		d) An alarm is issued by the *SMSEdge.*	OK	OK
		e) The database is updated with the new commlink, and the SCS-status is set to red.	OK	OK
		f) The *SCSAgent* sends position updates directly to the *CSSession.*	OK	OK
3	The GPS-receiver is moved beyond the boundaries set whilst the SCS-node is in ECS-node.	a) The position deviation is discovered by the *GPSControlAgent.*	OK	OK
		b) A *PositionAlert*-signal is sent to the *MSAgent.*	OK	OK
		c) An alarm is issued by the *SMSEdge.*	OK	OK
		d) The database is updated with the new position and SCS-status is kept red.	OK	OK

The failure in point two b is due to the fact that no GPRS-modem was installed on the computer that tested the simulated system.

d. Testing communication between SCS and MS under ECS

In this test the reporting and alert-generating functions whilst the SCS-node used the ECS-link were tested. This corresponds to functional requirement three. The results are shown in Table B-4.

Table B-4: Test of the sensor reporting and alert generation in ECS-mode

	Function tested	Expected behaviour	Result	
			Simulated	Distributed

1	Periodic messages with position updates are sent to *CSSession*.	a)	The *CSControlAgent* readjusts its sensor-update timers in this new status.	OK	OK
		b)	The *GPSSensorUpdate*-message is sent to the *CSSession* by *SCSRouter*.	OK	OK
2	The GPS-receiver is moved out of bounds	a)	The *GPSControlAgent* detects the threshold breach and immediately sends a *PositionAlert*-signal.	OK	OK
		b)	The *SCSRouter* sends the *PositionAlert*-signal to *CSSession*.	OK	OK
		c)	The *CSSession* is notified and in turn generates alarms and notifies the *MSControlAgent*.	OK	OK
		d)	An alarm is issued by the *SMSEdge*.	OK	OK
		e)	The database is updated with the position deviation.	OK	OK
3	The PCS is restored.	a)	The *PCSRestored*-signal is received by the *SCSRouter* and forwarded to *SCSControlAgent*.	OK	OK
		b)	*SCSRouter* returns to normal operation, routing signals to *SCSSession*, and issuing connection checks and maintaining the connection to the *MSAgent*.	OK	OK
		c)	*SCSControlAgent* returns to normal operation, readjusts the timer interval and discontinues direct reporting to the *CSSession*.	OK	OK
		d)	The database is updated with the new communication link, and the status is set to green given no other alarms are active.	OK	OK

Appendix C. Database setup

In this chapter the implementation of the database used in the SCG-system is presented.

a. The database columns and types

In Table C-1, the tables with their columns and column types are presented.

Table C-1: The scgdb-database design

scgdb Database, Finalized		
Column name	**Table**	**Column type**
msid	MS	SMALLINT(3) UNSIGNED NOT NULL
statusid	MS	SMALLINT(3) UNSIGNED NOT NULL
msname	MS	VARCHAR(30) NOT NULL
csid	CS	SMALLINT(3) UNSIGNED NOT NULL AUTO_INCREMENT
msid	CS	SMALLINT(3) UNSIGNED NOT NULL
statusid	CS	SMALLINT(3) UNSIGNED NOT NULL
csname	CS	VARCHAR(100) NOT NULL
scsid	SCS	SMALLINT(2) UNSIGNED NOT NULL AUTO_INCREMENT
csid	SCS	SMALLINT(3) UNSIGNED NOT NULL AUTO_INCREMENT
statusid	SCS	SMALLINT(3) UNSIGNED NOT NULL
scsname	SCS	VARCHAR(100) NOT NULL
statusid	Status	SMALLINT(3) UNSIGNED NOT NULL AUTO_INCREMENT
statusname	Status	VARCHAR(30) NOT NULL
sensorid	Sensor	SMALLINT(3) UNSIGNED NOT NULL AUTO_INCREMENT
sensortypeid	Sensor	SMALLINT(3) UNSIGNED NOT NULL
csid	Sensor	SMALLINT(3) UNSIGNED
scsid	Sensor	SMALLINT(3) UNSIGNED
sensorvalue	Sensor	VARCHAR(30)
sensortypeid	SensorType	SMALLINT(3) UNSIGNED NOT NULL AUTO_INCREMENT
sensorname	SensorType	VARCHAR(30) NOT NULL
commlinkid	CommLink	SMALLINT(1) UNSIGNED NOT NULL AUTO_INCREMENT
commlinkname	CommLink	VARCHAR(30) NOT NULL

b. Database query sentences

In this section the SQL-sentences used to initiate the tables of the *scgdb*-database are described. The sentences presented were run in the mySQL-client window.

To create the database:

```
mysql> CREATE DATABASE scgdb;
```

To create a user with read and write permissions from localhost:

```
mysql> GRANT * ON scgdb TO "user"@"localhost" IDENTIFIED BY "komtek";
```

This creates a user called "user" with all privileges on the *scgdb*-database with the password "komtek". This is used to access the database from the *SQLInterface*-class and the *scgstatus.jsp* web interface. Giving all privileges to a user is under normal circumstances not a good idea, but for a demonstration it makes access and interaction much easier. This user is the one used by the *SQLInterface*-class in Appendix D and the *scgstatus.jsp* class in Appendix E.

To create the ms-table:

```
mysql> CREATE TABLE ms (msid SMALLINT(3) UNSIGNED NOT NULL AUTO_INCREMENT,
statusid SMALLINT(3) NOT NULL, msname VARCHAR(30), PRIMARY KEY (msid));
```

To create the cs-table:

```
mysql> CREATE TABLE cs (csid SMALLINT(3) UNSIGNED NOT NULL AUTO_INCREMENT,
statusid SMALLINT(3) NOT NULL, msid SMALLINT(3) NOT NULL, csname
VARCHAR(100), PRIMARY KEY (csid));
```

To create the scs-table:

```
mysql> CREATE TABLE scs (scsid SMALLINT(3) UNSIGNED NOT NULL AUTO_INCREMENT,
statusid SMALLINT(3) NOT NULL, csid SMALLINT(3) NOT NULL, scsname
VARCHAR(100), PRIMARY KEY (scsid));
```

To create the status-table:

```
mysql> CREATE TABLE status (statusid SMALLINT(3) UNSIGNED NOT NULL
AUTO_INCREMENT, statusname VARCHAR(30) NOT NULL, PRIMARY KEY (statusid));
```

To create the sensor-table:

```
mysql> CREATE TABLE sensor (sensorid SMALLINT(3) UNSIGNED NOT NULL
AUTO_INCREMENT, sensortypeid SMALLINT(3) NOT NULL, csid SMALLINT(3), scsid
SMALLINT(3), sensorvalue VARCHAR(100), PRIMARY KEY (sensorid));
```

To create the sensortype-table:

```
mysql> CREATE TABLE sensortype (sensortypeid SMALLINT(3) UNSIGNED NOT NULL
AUTO_INCREMENT, sensorname VARCHAR(30) NOT NULL, PRIMARY KEY
(sensortypeid));
```

To create the commlink-table:

```
mysql> CREATE TABLE commlink (commlinkid SMALLINT(1) UNSIGNED NOT NULL
AUTO_INCREMENT, commlinkname VARCHAR(30) NOT NULL, PRIMARY KEY
(commlinkid));
```

If preferable the scgdb-database can be imported and is provided as part of Appendix I. To import the database write:

```
C:\MYSQLDUMP -U user -P scgdb < scgdb.sql
```

The remaining queries used for interaction with the scgdb-database can be seen in Appendix D and Appendix E.

Appendix D. The SQLInterface-class

This appendix presents the code of the *SQLInterface*-class used by the *DBEdgeSM*-class to provide interconnectivity with the installed database of Appendix C.

Each method creates its own connection to the database, and closes it when finished. This has been done to avoid connection-problems and overloads.

```
package no.sql;

import java.sql.*;

public class SQLInterface {

public void addMS(String msname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();

affected = stmt.executeUpdate("INSERT INTO ms values(null, 1,\""+ msname +
"\")");
// execute updates returns number of affected rows
if (affected == 1) {
System.out.println("A MS was added to the database");
} else {
System.out.println("A MS was not added");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void addCS(String csname, String msname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;
ResultSet rs = null;
int parent = 0;

try {
```

```
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
rs = stmt.executeQuery("SELECT msid from ms where msname =\""+ msname +
"\"");
while (rs.next()) {

parent = rs.getInt("msid");
System.out.println("MS-parent is: " + parent);
}
affected = stmt.executeUpdate("INSERT INTO cs values(null,"+ parent + ",
1,1,\"" + csname + "\")");
// execute updates returns number of affected rows
if (affected == 1) {
System.out.println("A CS was added to the database");
} else {
System.out.println("A CS was not added");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void addSCS(String scsname, String csname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;
ResultSet rs = null;
int parent = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
rs = stmt.executeQuery("SELECT csid from cs where csname =\""+ csname +
"\"");
while (rs.next()) {
parent = rs.getInt("csid");
System.out.println("CS-parent is: " + parent);
}
affected = stmt.executeUpdate("INSERT INTO scs values(null, "+ parent +
",1,2,\"" + scsname + "\")");
// execute updates returns number of affected rows
if (affected == 1) {
System.out.println("A SCS was added to the database");
} else {
System.out.println("A SCS was not added");
}
} catch (Exception e) {
```

```
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void addSensor(String csname, String scsname, String sensorname)
throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;
ResultSet rs = null;
int sensortype = 0;
int parent = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
rs = stmt.executeQuery("select sensortypeid from sensortype where sensorname
=\""+ sensorname + "\"");
while (rs.next()) {
sensortype = rs.getInt("sensortypeid");
System.out.println("The sensor to be added has id: "+ sensortype);
}
if (csname != null) {
rs = stmt.executeQuery("SELECT csid from cs where csname =\""+ csname +
"\"");
while (rs.next()) {
parent = rs.getInt("csid");
System.out.println("CS-parent is: " + parent);
}
affected = stmt.executeUpdate("INSERT INTO sensor values(null, \""+
sensortype + "\",null,\"" + parent+ "\",\"Pending values\")");
if (affected == 1) {
System.out
.println("A sensor of a CS was added to the database.");
} else {
System.out
.println("A sensor of a CS was not added to the database.");
}
}
else if (scsname != null) {
rs = stmt
.executeQuery("SELECT scsid from scs where scsname =\""+ scsname + "\"");
while (rs.next()) {
parent = rs.getInt("scsid");
System.out.println("SCS-parent is: " + parent);
}
affected = stmt.executeUpdate("INSERT INTO sensor values(null,"+ sensortype
+ ",\"" + parent+ "\",null,\"Pending values\")");
if (affected == 1) {
```

```
System.out
.println("A sensor of a SCS was added to the database.");
} else {
System.out
.println("A sensor of a SCS was not added to the database.");
}
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void updateSCSCommLinkECS(String scsname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
affected = stmt.executeUpdate("UPDATE SCS SET commlinkid = 3 where scsname =
\""+ scsname + "\"");
if (affected == 1) {
System.out.println("The SCS comm status has been updated.");
} else {
System.out.println("The SCS comm status has not been updated.");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void updateSCSCommLinkPCS(String scsname) throws Exception {
Connection con = null;
```

```
Statement stmt = null;
int affected = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
affected = stmt.executeUpdate("UPDATE SCS SET commlinkid = 2 where scsname =
\""+ scsname + "\"");
if (affected == 1) {
System.out.println("The SCS comm status has been updated.");
} else {
System.out.println("The SCS comm status has not been updated.");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void updateCSCommLinkFCS(String csname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
affected = stmt.executeUpdate("UPDATE CS SET commlinkid = 4 where csname =
\""+ csname + "\"");
if (affected == 1) {
System.out.println("The CS comm status has been updated.");
} else {
System.out.println("The CS comm status has not been updated.");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
```

```
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void setCsStatusYellow(String csname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
affected = stmt.executeUpdate("UPDATE CS SET statusid = 2 where csname =
\""+ csname + "\"");
if (affected == 1) {
System.out.println("The CS status has gone to yellow");
} else {
System.out.println("The CS status has not gone to yellow");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void setCsStatusRed(String csname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
affected = stmt.executeUpdate("UPDATE CS SET statusid = 3 where csname =
\""+ csname + "\"");
if (affected == 1) {
System.out.println("The CS status has gone to red");
} else {
System.out.println("The CS status has not gone to red");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
```

```
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void setScsStatusYellow(String scsname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
affected = stmt.executeUpdate("UPDATE SCS SET statusid = 2 where scsname =
\""+ scsname + "\"");
if (affected == 1) {
System.out.println("The SCS status has gone to yellow");
} else {
System.out.println("The SCS status has not gone to yellow");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void setScsStatusRed(String scsname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
affected = stmt.executeUpdate("UPDATE SCS SET statusid = 3 where scsname =
\""+ scsname + "\"");
if (affected == 1) {
System.out.println("The SCS status has gone to red");
} else {
```

```
System.out.println("The SCS status has not gone to red");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void setScsStatusGreen(String scsname) throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
affected = stmt.executeUpdate("UPDATE SCS SET statusid = 1 where scsname =
\""+ scsname + "\"");
if (affected == 1) {
System.out.println("The SCS status has gone to green");
} else {
System.out.println("The SCS status has not gone to green");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public int checkSCSStatus(String scsname) throws Exception {
Connection con = null;
Statement stmt = null;
ResultSet rs = null;
int status = 0;

try {
```

```
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();rs = stmt.executeQuery("SELECT statusid from
scs where scsname =\""+ scsname + "\"");
while (rs.next()) {
status = rs.getInt("statusid");
System.out.println("SCS-status is: " + commlink);
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}
return status;
}

public int checkSCSCommLink(String scsname) throws Exception {
Connection con = null;
Statement stmt = null;
ResultSet rs = null;
int commlink = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
rs = stmt.executeQuery("SELECT commlinkid from scs where scsname =\""+
scsname + "\"");
while (rs.next()) {
commlink = rs.getInt("commlinkid");
// String commname = rs.getString("commlinkname");
System.out.println("SCS-comm is: " + commlink);
}

} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}
return commlink;
}

public void updateSCSPosition(String scsname, String newpos)
throws Exception {
Connection con = null;
Statement stmt = null;
int affected = 0;
ResultSet rs = null;
int id = 0;
try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
rs = stmt.executeQuery("select scsid from scs where scsname = \""+ scsname +
"\"");
while (rs.next()) {
id = rs.getInt("scsid");
}
affected = stmt.executeUpdate("UPDATE SENSOR SET sensorvalue = \""+ newpos +
"\" where scsid = \"" + id+ "\" and sensortypeid = 1");
if (affected == 1) {
System.out.println("The SCS GPS has been updated");
} else {
System.out.println("The SCS GPS has not been updated");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}

public void updateCSPosition(String csname, String newpos) throws Exception
{
Connection con = null;
Statement stmt = null;
int affected = 0;
ResultSet rs = null;
int id = 0;

try {
String url = "jdbc:mysql:///scgdb";
Class.forName("com.mysql.jdbc.Driver").newInstance();
con = DriverManager.getConnection(url, "user", "komtek");
stmt = con.createStatement();
rs = stmt.executeQuery("select csid from cs where csname = \""+ csname +
"\"");
while (rs.next()) {
```

```
id = rs.getInt("scsid");
}
affected = stmt.executeUpdate("UPDATE SENSOR SET sensorvalue = \""
+ newpos + "\" where csid = \"" + id
+ "\" and sensortypeid = 1");
if (affected == 1) {
System.out.println("The CS GPS has been updated");
} else {
System.out.println("The CS GPS has not been updated");
}
} catch (Exception e) {
System.out.println("Problem: " + e.toString());
} finally {
if (stmt != null) {
try {
stmt.close();
} catch (Exception e) {
System.out.println(e.toString());
}
stmt = null;
}
if (con != null) {
try {
con.close();
} catch (Exception e) {
System.out.println(e.toString());
}
con = null;
}}}}
```

Appendix E. The web interface code

The code of the *scgstatus.jsp* web interface is presented here. This JSP-file interacts with the database specified in Appendix C. This file is also part of Appendix I.

scgstatus.jsp:

```
<html>
<head>
<META HTTP-EQUIV="refresh"
content="10;URL=http://129.241.219.178:8080/scgstatus.jsp">


<%@ page
import = "java.io.*"
import = "java.lang.*"
import = "java.sql.*"
%>
<title>
Fish farm overview
</title>
</head>
<body bgcolor="6699FF">
<h1>Current status: <% java.util.Date date = new java.util.Date();
out.println(date);%></h1>
<%
Connection dbconn;
ResultSet results;
ResultSet rs;
ResultSet scsresults;
ResultSet csresult;
ResultSet sensorresults;
Statement mssql;
Statement cssql;
Statement scssql;
Statement sensorsql;
int msid = 0;
int csid = 0;
int scsid = 0;

try
{
Class.forName("com.mysql.jdbc.Driver");
try
{
boolean      doneheading = false;
dbconn = (Connection)
DriverManager.getConnection("jdbc:mysql://localhost/scgdb",
"user", "komtek");

mssql = dbconn.createStatement();
cssql = dbconn.createStatement();
scssql = dbconn.createStatement();
sensorsql = dbconn.createStatement();
String query = "SELECT * FROM MS";
rs = mssql.executeQuery(query);%>
<TABLE BORDER = 2 bgcolor="silver"><%
while (rs.next()) {%>
<TD><%
String st = rs.getString("MSNAME");
msid = rs.getInt("MSID");
%><H2><%
out.println(st);
```

```
%></H2>
<%
query = "select csid, csname, statusname, commlinkname from
cs,status,commlink where cs.statusid = status.statusid and cs.commlinkid =
commlink.commlinkid and cs.msid= "+msid+"";
csresult = cssql.executeQuery(query);
while(csresult.next()){%>
<TABLE BORDER = 2 >
<TR>
<TH>CS</TH>
<TH>Status</TH>
<TH>Commlink</TH>
</TR><%
String s = csresult.getString("CSNAME");
String tcs = csresult.getString("statusname");
String rcs = csresult.getString("commlinkname");
%><TR bgcolor ="lime" align ="center"><TD><%
out.println(s);
%></TD><%
%><TD><%
out.println(tcs);
%></TD><TD><%out.println(rcs);%></TD></TR></TABLE><%
csid = csresult.getInt("csid");
String newQuery = "select scsid, scsname, statusname, commlinkname from
scs,status,commlink where scs.statusid = status.statusid and scs.commlinkid
= commlink.commlinkid and scs.csid= "+csid+"";
scsresults = scssql.executeQuery(newQuery);
while(scsresults.next()){%>
<TABLE BORDER = 2>
<TR>
<TH>SCS</TH>
<TH>Status</TH>
                        <TH>Commlink</TH>
</TR>
<%
String t = scsresults.getString("SCSNAME");
String status = scsresults.getString("STATUSNAME");
String comm = scsresults.getString("commlinkname");
scsid = scsresults.getInt("SCSID");

if(status.equalsIgnoreCase("OK")){%>
<TR bgcolor ="lime" size ="5" align ="center"><%}
else if(status.equalsIgnoreCase("yellow")){%>
<TR bgcolor ="yellow" size ="5" align ="center"><%}
else if(status.equalsIgnoreCase("red")){%>
<TR bgcolor ="red" size ="5" align ="center"><%}
%><TD><%
out.println(t);
%></TD><TD><%
out.println(status);%>
</TD><TD><%
out.println(comm);
%></TD></font>
</TABLE>
<%
String lastQuery = "select sensorname, sensorvalue from sensor,sensortype
where sensor.sensortypeid = sensortype.sensortypeid and
"+scsid+"=sensor.scsid";
sensorresults = sensorsql.executeQuery(lastQuery);%>
<TABLE BORDER = 2 >
<TR align  = "center">
<TH>Sensor name</TH>
<TH>Sensor value</TH>
</TR><%
while(sensorresults.next()){
String sname = sensorresults.getString("Sensorname");
String svalue = sensorresults.getString("sensorvalue");
%><TR align = "center"><TD><% out.println(sname);%></TD>
<TD><%out.println(svalue);%></TD></TR><%
}%></TABLE>
<P><%}
}%><%
rs.next();}

%></TD></TABLE><%


}
catch (SQLException s)
{
out.println("SQL Error<br>");
}
}
catch (ClassNotFoundException err)
{
out.println("Class loading error");
}
%>
</body>
</html>
```

Appendix F. The LoggingServer-class

In this appendix the *LoggingServer*-class which creates the connection to the GPS-receiver handles the sensor data is presented.

```
package no.gps;

import gnu.io.CommPortIdentifier;
import gnu.io.PortInUseException;
import gnu.io.SerialPort;
import gnu.io.UnsupportedCommOperationException;
import java.io.IOException;
import java.io.InputStream;
import java.util.Enumeration;

public class LoggingServer{

private Enumeration portIdents;
private CommPortIdentifier portInUse;
private SerialPort serialPort;
private InputStream inputStream;
private boolean running = true;
private GPSHandler gpsh;

public LoggingServer(GPSHandler gpsh){
this.gpsh = gpsh;
portIdents = CommPortIdentifier.getPortIdentifiers();
while (portIdents.hasMoreElements()) {
CommPortIdentifier port = (CommPortIdentifier) portIdents.nextElement();
if(port.getName().equalsIgnoreCase("COM12")){
portInUse = port;
}
}

try {
serialPort = (SerialPort)portInUse.open("LoggingServer", 2000);
serialPort.setSerialPortParams(4800,8,1,0);
} catch (PortInUseException e) {
e.printStackTrace();
} catch (UnsupportedCommOperationException e) {

e.printStackTrace();
}
initiate();
}

public void initiate(){
try {
boolean test = true;
inputStream = serialPort.getInputStream();
while(test){

int b = inputStream.read();


String s;
String data = "";
int q = 0;

while(b != -1) {
s= Character.toString((char)b);
if(s.equalsIgnoreCase("$")&&q>=1){
gpsh.gpsUpdate(data);
test = false;
data="";
}
data = data+s;
q++;
b = inputStream.read();
}
}
} catch (IOException e) {
e.printStackTrace();
}  finally {
try {
if(inputStream!=null)
inputStream.close();
} catch (IOException e) {
e.printStackTrace();
}
}
}
}
```

Appendix G. State machines

In this appendix the state machines of the SCG-system are presented. They are presented in a simple form and for more details please view the models generated by Ramses and their corresponding action methods. The parameters of the signals have been left out and these can be found in Appendix H. These state machines are influenced by the test and demonstrator nature of the SCG-system for this thesis. It should be noted that some choice-functionality of state machines has been handled by the action-statements as to provide greater flexibility during implementation and testing. In addition, the amount of states presented is in some cases fewer than would be natural for an actual implementation. This is to reduce the possibilities for input inconsistency to focus on application functionality and services.

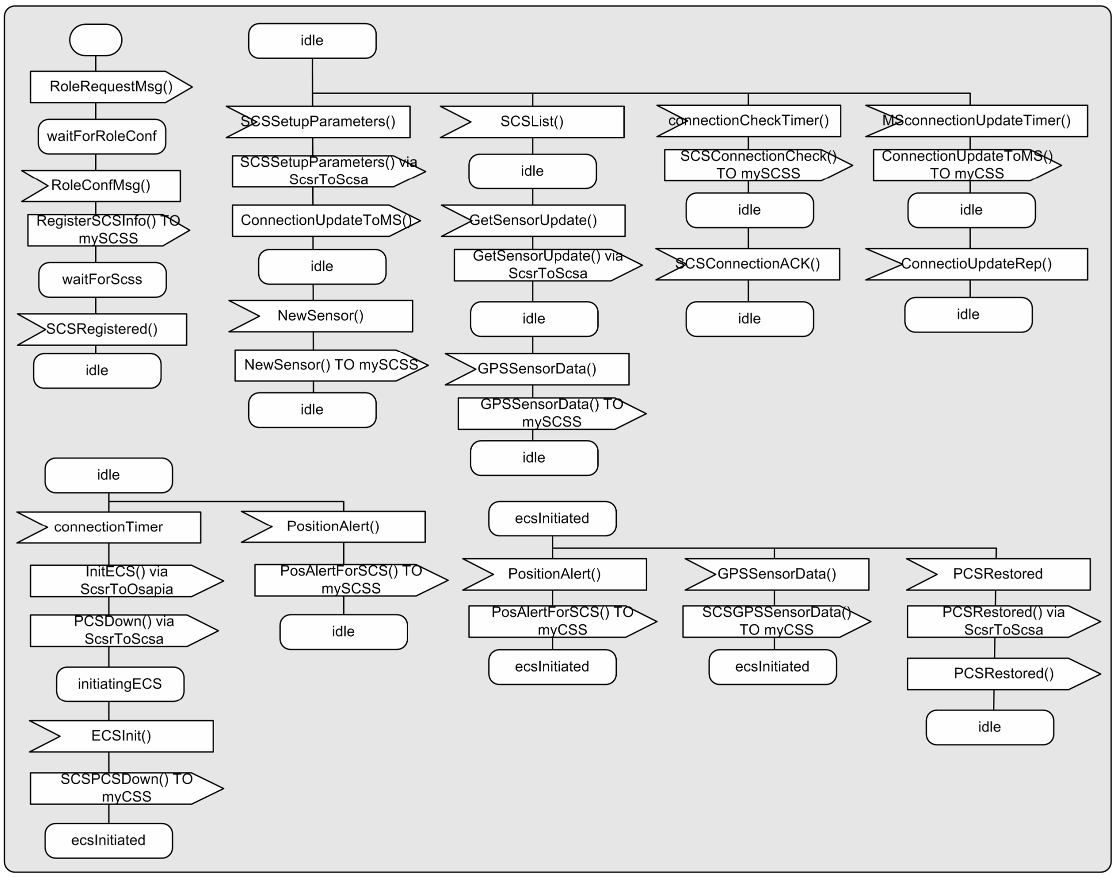
The state machines may also be seen in the *model*-view provided by Ramses.

a. SCSAgent

Here the state machines of the inner actors of the *SCSAgent* are presented.

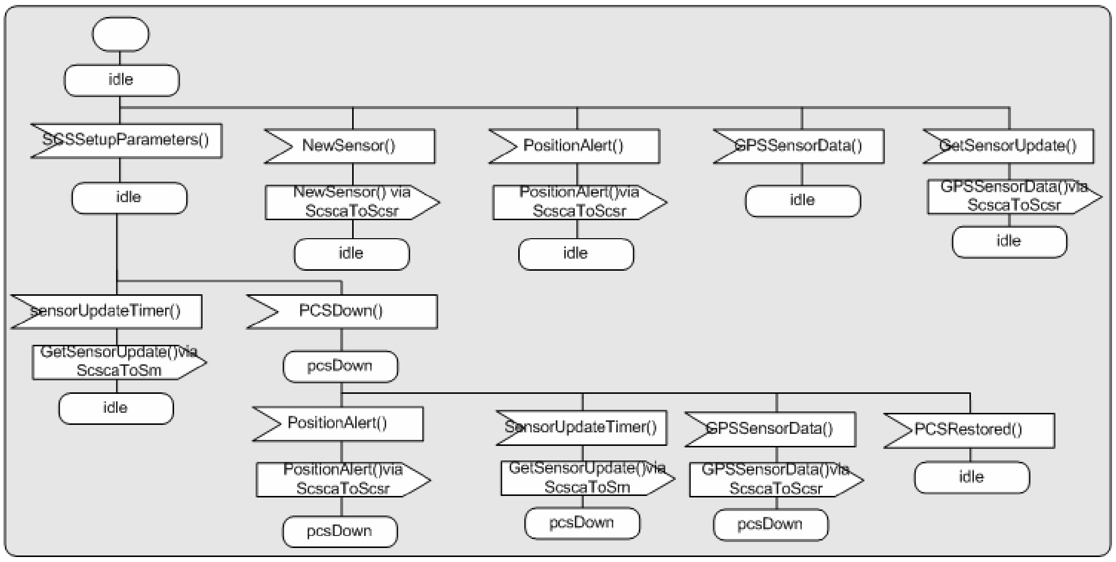
SCSRouter

The ports used by the *SCSRouter* are *ScsrToScsca* which is connected to the *SCSControlAgent* and *ScsrToOsapia* which is connected to the *OSAPIAgent*. The variables *mySCSS* and *myCSS* are ActorAddresses for the nodes *SCSSession* and *CSSession*.

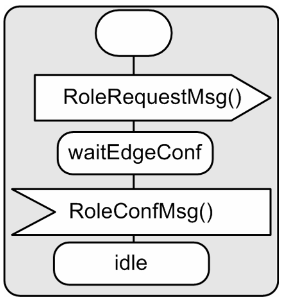


SCSControlAgent

The ports used by the *SCSControlAgent* are *ScscaToScsr* which is connected to the *SCSRouter* and *ScscaToSm* which is connected to the *SensorManager*.

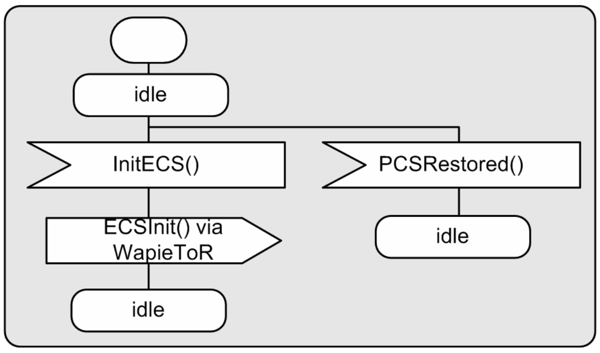


OSAPIAgent



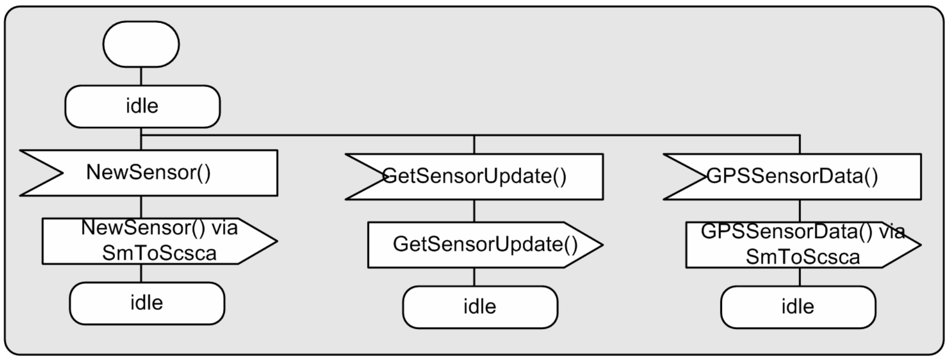
WindowsAPIEdge

The port *WapieToR* is connected to the *SCSRouter*.

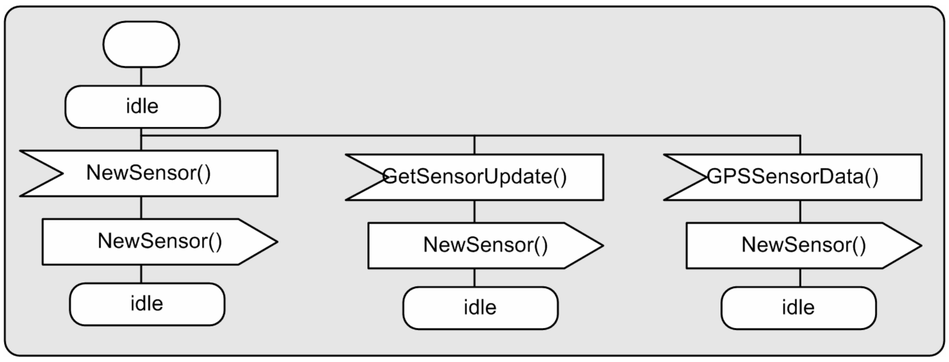


SensorManager

The port *SmToScsca* is connected to the *SCSControlAgent*.

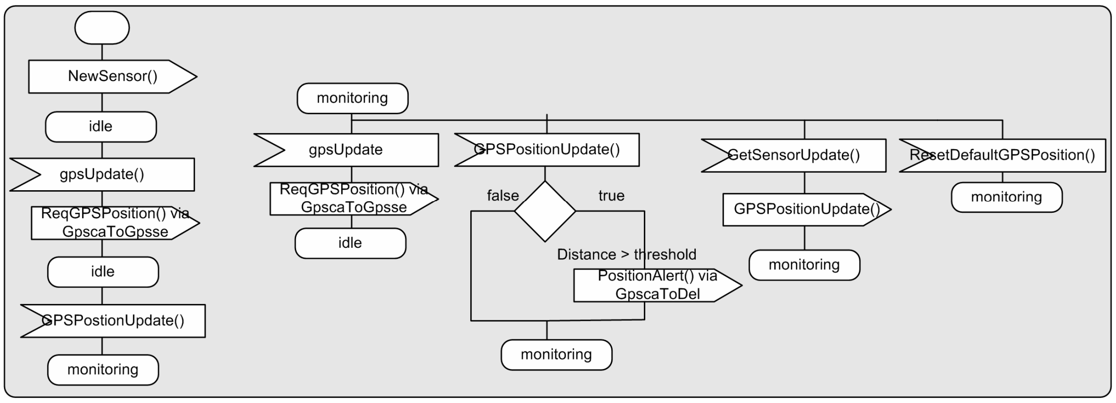


GPSSensorAgent



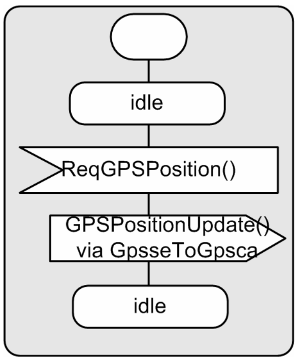
GPSControlAgent

The port *GpscaToGpsse* is connected to the *GPSSensorEdge*-actor and the port *GpscaToDel* is connected to the *SCSControlAgent*.



GPSSensorEdge

The port *GpsseToGpsca* is connected to the *GPSControlAgent*.

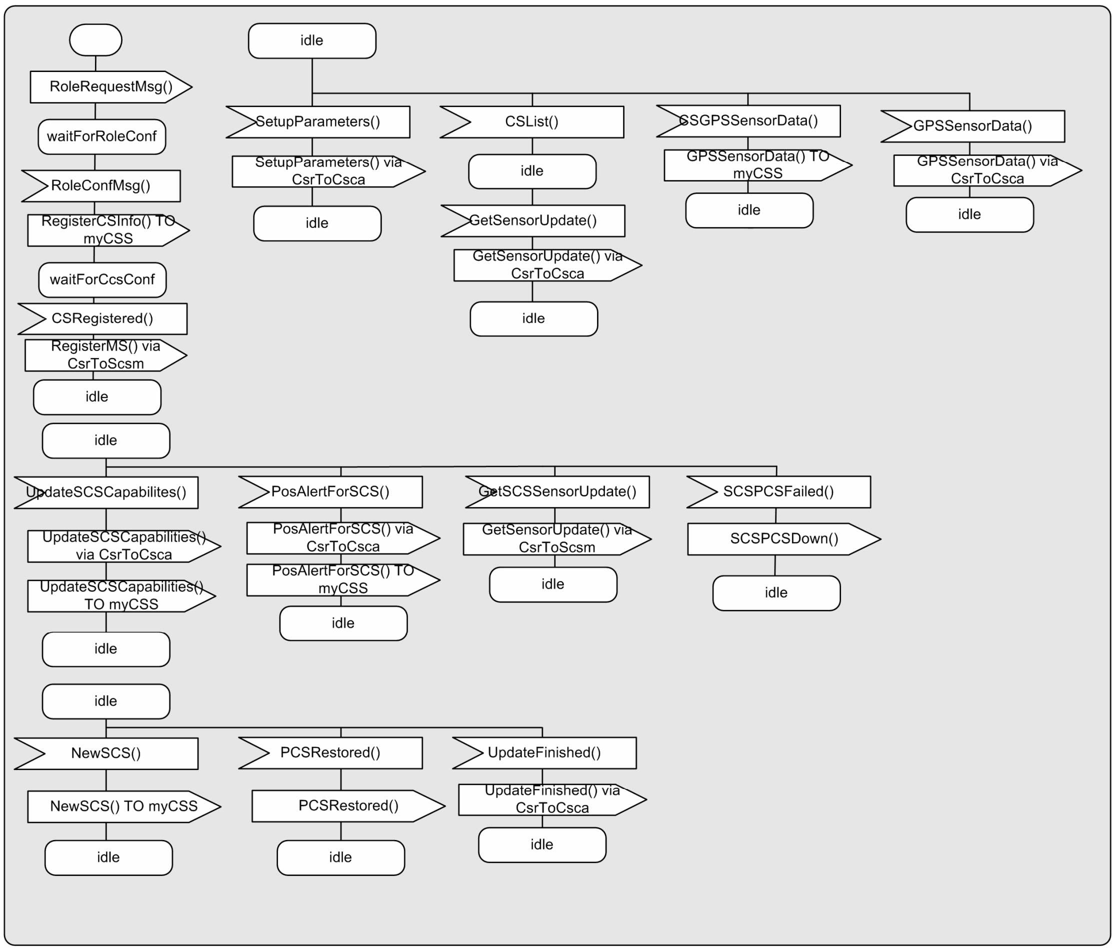


b. CSAgent

Here the state machines of the inner actors of the *CSAgent* are presented.

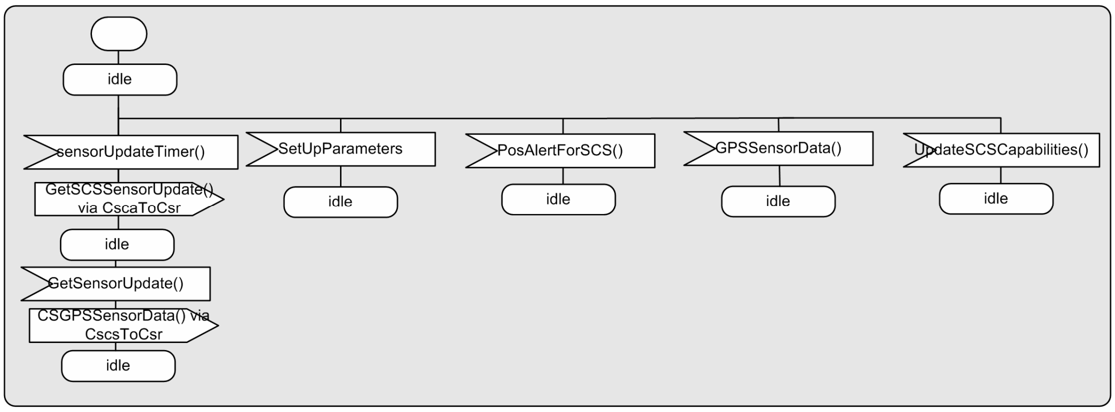
CSRouter

The port *CsrToScsm* is connected to the *SCSManager* and the port *CsrToCsca* is connected to the *CSControlAgent*. The variable *myCSS* is an ActorAddress for the nodes *CSSession*.



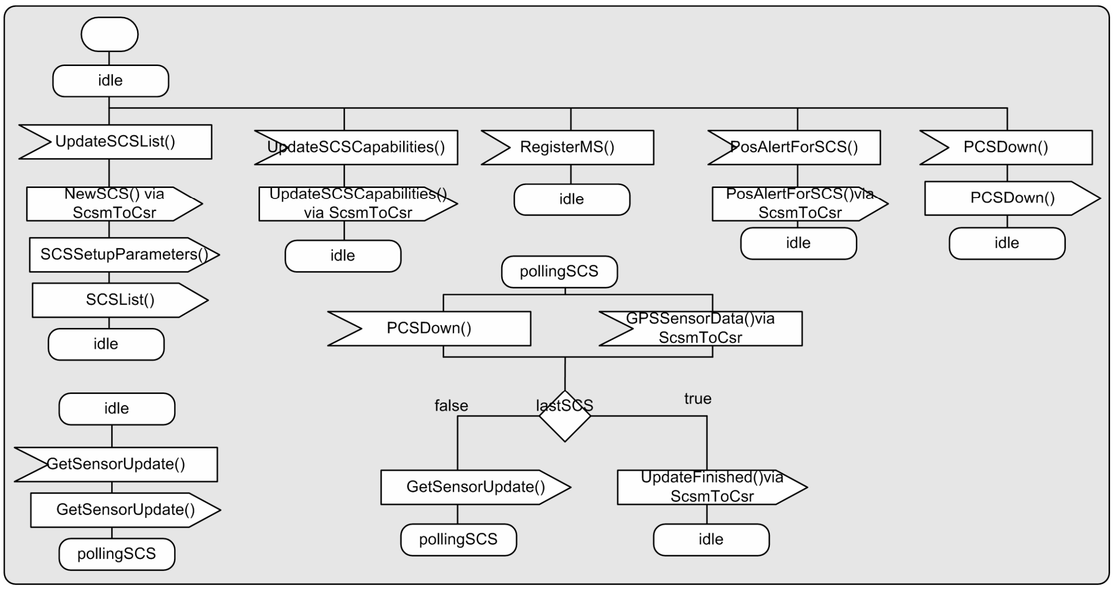
CSControlAgent

The port *CscaToCsr* is connected to the *CSRouter*-actor.



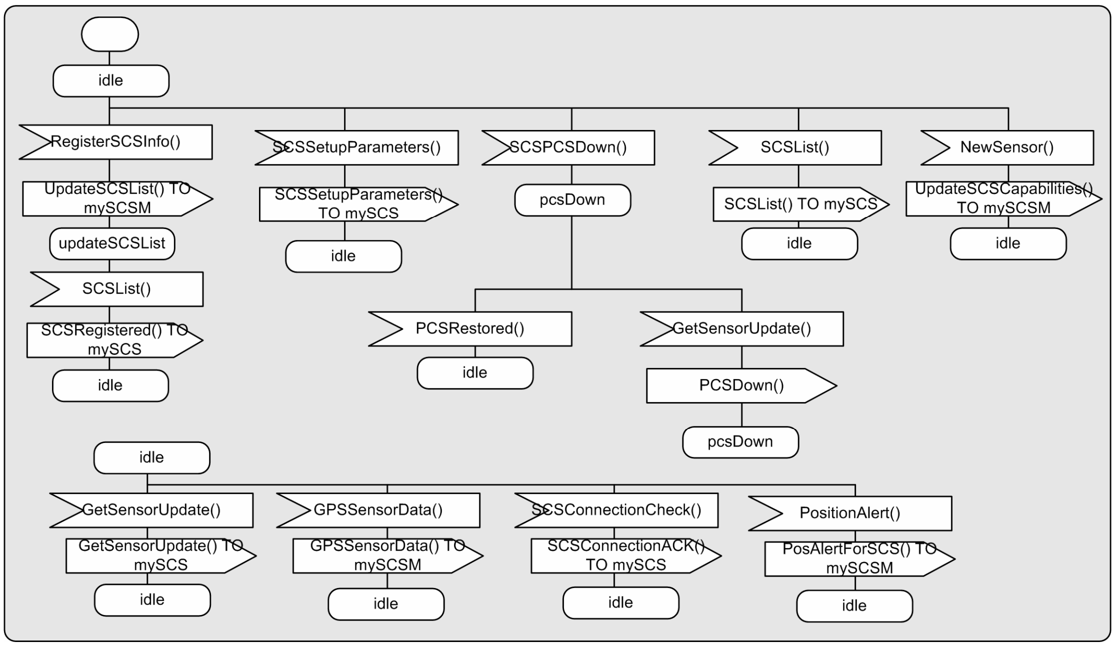
SCSManager

The port *ScsmToCsr* is connected to the *CSRouter*.



SCSSession

The variables *mySCS* and *mySCSM* are ActorAddresses for the *SCSSession's* SCS-node (*SCSRouter*) and *SCSManager*.

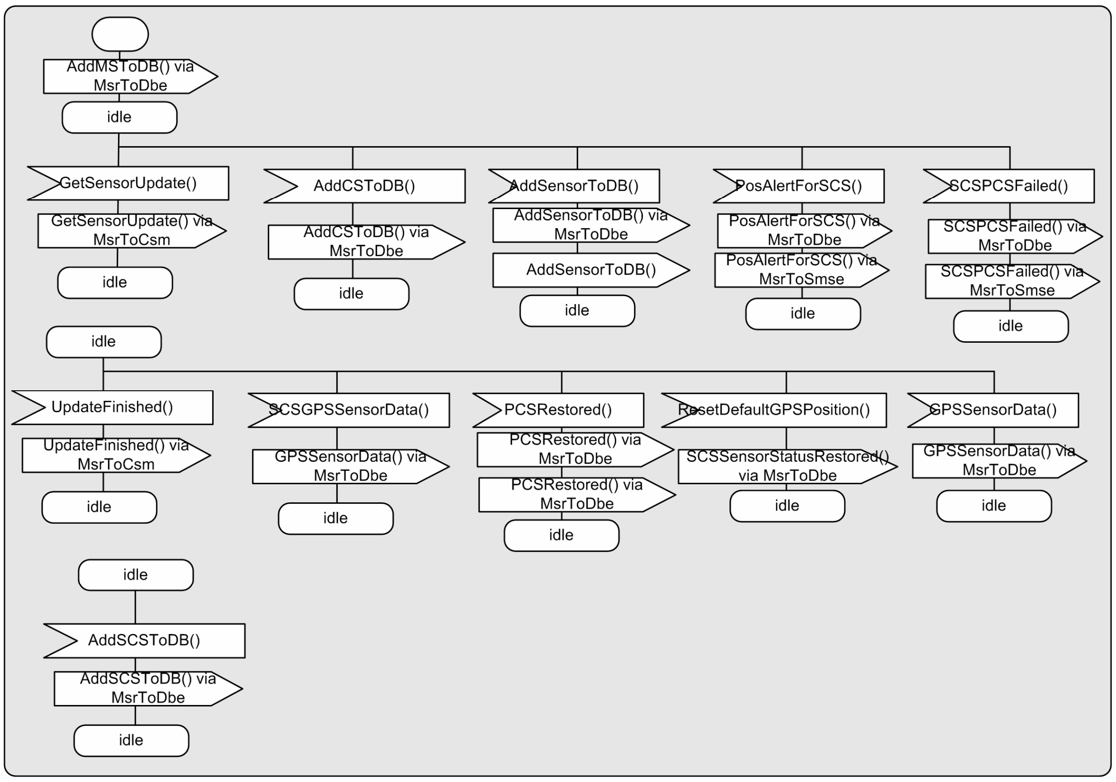


c. *MSAgent*

Here the state machines of the inner actors of the *MSAgent* are presented.

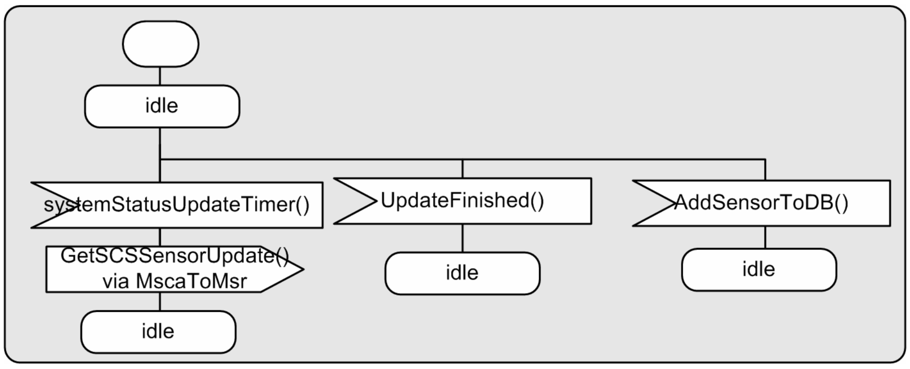
MSRouter

The port *MsrToCsm* is connected to the *CSManager*, the port *MsrToDbe* is connected to the *DBEdge* and the port *MsrToSmse* is connected to the *SMSEdge*-actor.


AddMSToDB() via MsrToDbe
idle
GetSensorUpdate()
GetSensorUpdate() via MsrToCsm
idle
AddCSToDB()
AddCSToDB() via MsrToDbe
idle
AddSensorToDB()
AddSensorToDB() via MsrToDbe
AddSensorToDB()
idle
PosAlertForSCS()
PosAlertForSCS() via MsrToDbe
PosAlertForSCS() via MsrToSmse
idle
SCSPCSFailed()
SCSPCSFailed() via MsrToDbe
SCSPCSFailed() via MsrToSmse
idle
idle
UpdateFinished()
UpdateFinished() via MsrToCsm
idle
SCSGPSSensorData()
GPSSensorData() via MsrToDbe
idle
PCSRestored()
PCSRestored() via MsrToDbe
PCSRestored() via MsrToDbe
idle
ResetDefaultGPSPosition()
SCSSensorStatusRestored() via MsrToDbe
idle
GPSSensorData()
GPSSensorData() via MsrToDbe
idle
idle
AddSCSToDB()
AddSCSToDB() via MsrToDbe
idle

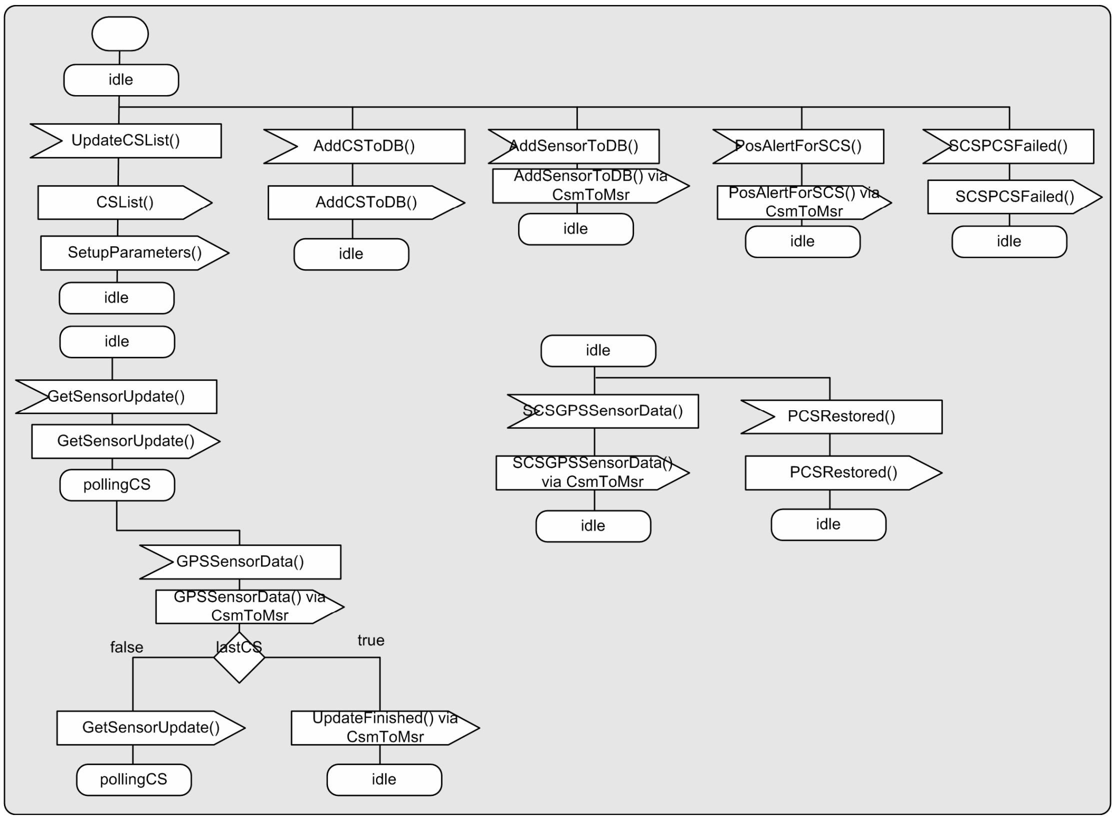
MSControlAgent

The port *MscaToMsr* is connected to the *MSRouter*-actor.



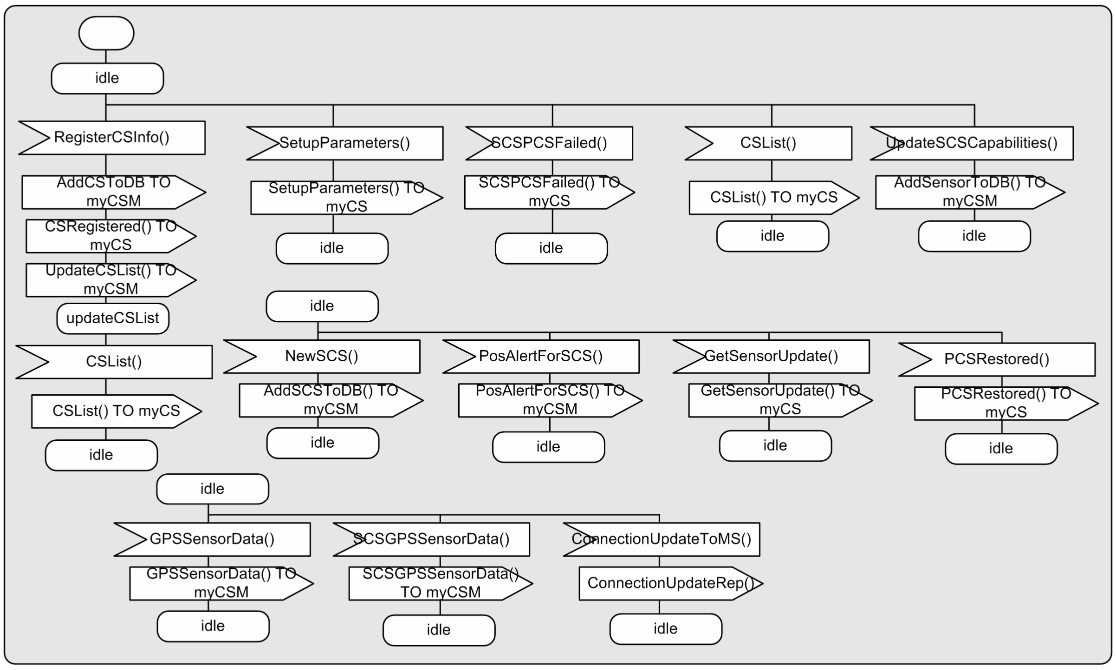
CSManager

The port *CsmToMsr* is connected to the *MSRouter*-actor.

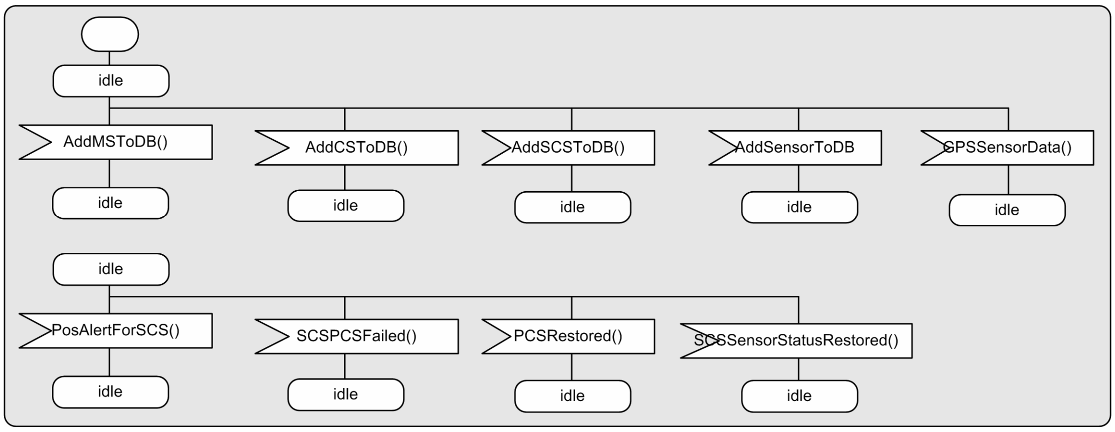


CSSession

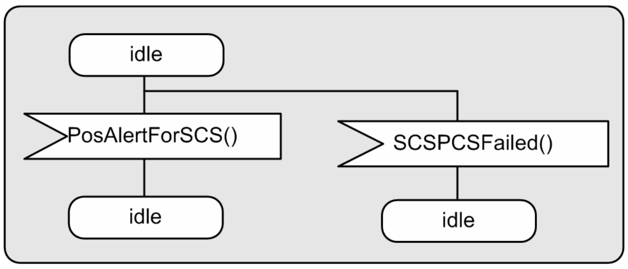
The variables *myCS* and *myCSM* are ActorAddresses for the *CSSession's* CS-node (*CSRouter*) and *CSManager*.



DBEdge



SMSEdge



Appendix H. List of signals

In Table H-1 the signals and their parameters used in the SCG-system demonstrator are listed. The code for manual alteration can be found in section 9.5.2.

Table H-1: List of signals in the SCG-system

Signal	Parameters	Requires manual alteration
AddCSToDB	csname: String msname: String	
AddMSToDB	msname: String	
AddSCStoDB	scsname: String csname: String	
AddSensorToDB	sensorname: String scsname: String	
CSGPSSensorData	position: String scs: ActorAddress	Add code for serialization of *scs*
CSList	otherCSList: ArrayList	
CSPCSDown		
CSRegistered	csList: ArrayList	
ConnectionUpdateRep		
ConnectionUpdateToMS		
ECSInit		
FCSInit		
GPSPositionUpdate	lal: LatLng	
GPSSensorData	position: String scs: ActorAddress	Add code for serialization of *scs*
GetCSSensorUpdate		
GetSCSSensorUpdate		
GetSensorUpdate		
InitECS		
InitFCS		
NewSCS	newSCSS: ActorAddress	Add code for serialization of *newSCSS*
NewSensor	sensorType: String	
PCSDown		
PCSRestored		
PosAlertForSCS	alertSCS: ActorAddress currentPos: String	Add code for serialization of *alertSCS*
PositionAlert	currentPos: String	
RegisterCSInfo		
RegisterMS	yourCSM: ActorAddress	
RegisterSCSInfo		
ReqGPSPosition		

ResetDefaultGPSPosition	scs: ActorAddress	
SCSConnectionACK		
SCSConnectionCheck		
SCSGPSSensorData	scs: ActorAddress position: String	Add code for serialization of *scs*
SCSList	scsList: ArrayList	
SCSPCSDown		
SCSPCSFailed	mySCSS: ActorAddress	Add code for serialization of *mySCSS*
SCSRegistered	yourMS: ActorAddress scsList: ArrayList	Add code for serialization of *yourMS*
SCSSensorStatusRestored	scs: ActorAddress	
SCSSetupParameters	yourCSS: ActorAddress	Add code for serialization of *yourCSS*
SetupParameters		
UpdateCSCommLinkStatus	csname: String commLinkStatus: String	
UpdateCSList		
UpdateFinished		
UpdateSCSCapabilities	sensorType: String scsname: ActorAddress	Add code for serialization of *scsname*
UpdateSCSCommLinkStatus	scsname: String commLinkStatus: String	
UpdateSCSList	newSCS: ActorAddress	
UpdateSCSStatus	scsname: String status: String	

Appendix I. Implementation

The implementation of the demonstrator is available on the *AppendixI.z*ip-file accompanying the delivery of this thesis. The contents of this file are shown in Table I-1.

Table I-1: The contents of Appendix I

File	Contents
no.ntnu.item.askgaard.master2006 .scgsystem.zip	*msagent* *csagent* *scsagent* *simulation* *no.ntnu.item.master2006* *no.ntnu.item.master2006.ext.GPSHandler* *no.ntnu.item.master2006.ext.mySQLHandler* *no.ntnu.item.master2006.ext.simpleAdminGUI* *no.ntnu.item.master2006.ext.smsHandler* *se.ericsson.eto.norarc.actorframe*
scgdb.sql	The scgdb-database
scgstatus.jsp	The web interface for the SCG-system

The *LoggingServer*-class can be found in the *no.gps*-package of the *no.ntnu.item.master2006.ext.GPSHandler*-project.

The *SQLInterface*-class can be found in the *no.sql*-package of the *no.ntnu.item.master2006.ext.mySQLHandler*-project.