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Composition of New Features into a Wireless Nurse Call System

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Problem Description

The use of a combined fixed and wireless nurse call system has the capability to increase nurse s awareness of the patient s needs and facilitate their work. St. Olav s hospital has such a system installed. Using former work by Professor Lill Kristiansen as a starting point several ways to improve the system s functionality have been identified. One way to implement these improvements would be to do it directly on the currently installed nurse call system (Imatis), but due to its non-open source nature some alternative means are going to be taken into consideration as well: Either reverse engineer the whole system using the Arctis modelling tool (UML based), or design a similar system from scratch using openSIPS.

The objective of this thesis is to have a wireless system with a suitable level of similarity to the one currently installed at St. Olav s hospital, to which the identified improvements can be implemented. Thus enabling us to compare the improved system with the original system at St. Olav s and show the system in its intended environment. Due to the time constraints criteria based on perceived usefulness and complexity of design derived from several sources including discussion with the supervisor will be used to determine which improvements will be implemented first.

Assignment given: 16. August 2010
Supervisor: Lill Kristiansen, ITEM

Preface

This thesis is the result of my work at the Department of Telematics (ITEM) at the Norwegian University of Science and Technology (NTNU).

I would like to thank my supervisor Lill Kristiansen and my co-supervisor Hien Nam Le, for their patience as well as all the guidance and feedback they have continually offered me. Thanks to both of them I've managed to learn a great deal during my stay in Norway.

Especially Lill Kristiansen who besides helping me feel more than welcome during my stay in Norway has offered me plenty of meaningful discussions and comments that have proven to be instrumental for the completion of this thesis.

I would also like to express my gratitude to the people at St. Olav's Hospital for letting me perform all the necessary tests on the nurse call system despite the noise, as well as for all the insight they have provided me with.

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Table of Contents

List of Figures

List of Tables

List of Tables

Acronyms

AACN: **A**uthentication, **A**uthorization, and **A**ccounting

CEPT: **C**onference of **E**uropean **P**osts & **T**elecommunications

CSCW: **C**omputer **S**upported **C**ooperative **W**ork

DECT: **D**igitally **E**nhanced **C**ordless **T**elecommunication

FDMA: **F**requency **D**ivision **M**ultiple **A**ccess

GSM: **G**lobal **S**ystem for **M**obile communication

GUI: **G**raphic **U**ser **I**nterface

HCI: **H**uman-**C**omputer **I**nteraction

ICT: **I**nformation **C**ommunications **T**echnology

IETF: **I**nternet **E**ngineering **T**ask **F**orce

ITU: **I**nternational **T**elecommunications **U**nion

MGPC: **M**edia **G**ateway **C**ontrol **P**rotocol

MOSSA: MObilbasert **S**yke**S**ignal**A**nlegg

OJS: **O**pen **J**ava **S**erver

PBX: **P**rivate **B**ranch e**X**change

POTS: **P**lain **O**ld **T**elephony **S**ervice. (It is the same as PSTN)

PSTN: **P**ublic **S**witched **T**elephone **N**etwork. (It is the same as POTS)

RAS: **R**egistration, **A**dmission and **S**tatus

RTP: **R**eal-time **T**ransport **P**rotocol

RTCP: RTP **C**ontrol **P**rotocol

SIMPLE: SIP for **I**nstant **M**essaging and **P**resence **L**everaging **E**xtensions

SIP: **S**ession **I**nitiation **P**rotocol

SMS: **S**hort **M**essage **S**ervice

SPACE: SPecification by **A**ctivities, **C**ollaborations, and **E**xternal state machines

TDMA: **T**ime **D**ivision **M**ultiple **A**ccess

TLA: **T**emporal **L**ogic of **A**ctions

TLC: **T**emporal **L**ogic model **C**hecker

UML: **U**nified **M**odeling **L**anguage

UI: **U**ser **I**nterface

URI: **U**niform **R**esource **I**dentifier

URL: **U**niform **R**esource **L**ocator

VoIP: **V**oice **o**ver **I**nternet **P**rotocol

WLAN: **W**ireless **L**ocal **A**rea **N**etwork

Definitions

Accepting a nurse call: Action performed by a nurse when an incoming nurse call is received on her mobile device and she acknowledges her intention to respond to it by pressing the accept button.

Active nurse call: Any nurse call that has not yet been responded to.

Assistance call: Special type of nurse call intended to be used only by healthcare personnel (usually by nurses); it should be used whenever they are with a patient and need assistance from a nurse, but the matter is not deemed critical or urgent enough to warrant the use of a heart arrest call instead.

Heart arrest call: Special type of nurse call delivered to all nurses in the same ward to procure an immediate response due to its critical and time sensitive nature. It is intended to be requested by healthcare personnel only (usually by nurses).

Normal nurse call: Term used along this text to differentiate between generic nurse calls and the special types of nurse calls.

Nurse call: A signal send from a patient's room usually to a nurse or group of nurse's in order to inform them that their presence is required in the patient's room. It is also used to refer to all types of nurse calls as a group.

Progressive care: *"Progressive care defines the care that is delivered to patients whose needs fall along the less acute end of the continuum of critical care"* (AACN 2008).

Request a nurse call: Actions done by a person that result in a nurse call being issued (e.g.: pulling the signal cord at St. Olav's Hospital).

Respond to a nurse call: Sequence of actions performed by a nurse when she activates the presence panel in a room with an active nurse call, deals with the patient's needs and deactivates the presence panel. After the presence panel has been activated an active nurse call is considered as "being responded to" until the presence panel has been deactivated, at which point it is considered to "have been responded to."

UI: Any input or output signals (acoustic, graphical, tactile, visual…) that enable a person to communicate with a system. E.g.: a phone making a beeping sound whenever a new call is received, or a patient pulling the signal cord to generate a normal nurse call.

Workaround: *"A procedural change in computer system use intended to compensate for a design flaw, typically a software behaviour that is perceived to be a flaw."* (Koopman 2003).

Abstract

Healthcare needs are evolving constantly, some of these needs are already being covered by current technology but some are still not. This thesis offers a critical review of former work relating to ICT and hospitals, evaluating the hospital needs from a communication point of view and examining the most relevant alternatives to provide wireless communication in healthcare. An analysis of the nurse call system currently in use at St. Olav's Hospital (Trondheim, Norway) is also provided along several viable alternatives to reengineer it.

The aforementioned system has been fully characterized and modeled from scratch using UML 2.3 and the resulting reengineered version has been discussed in detail. Two new features that could enhance the user's satisfaction with the system have been identified (assistance call and lunch break) and implemented into it in a way that minimizes the modifications made to the system, in order to facilitate a possible implementation on the existing system at St. Olav's Hospital.

One issue that remains to be solved are the delays: all the wireless communication options reviewed have them (from 20 seconds to 2 minutes, depending on the technology), which makes them unsuitable for emergency situations where time is of the essence. Although that doesn't mean that they are useless, it simply means that an alternate communication method is necessary for those situations, which can be used to complement the wireless system by adding a level of redundancy to it.

1   Introduction

1.1   Motivation

The general availability of wireless technologies have had a great impact on society, from something as basic as how people get in their cars, to how to conduct business and interact with each other. Mobile phones alone have drastically changed the way people behave (Srivastava 2005), solely stating that they allow people to more easily keep in touch with others while on the move would be to overly simplify their many uses. New communication technologies like IP telephony are a step further, by reducing costs and increasing functionality over POTS they have made many new applications possible.

One of such applications can be found in healthcare, where IP telephony and other technologies are used to ease the way staff members communicate with each other, and to increase the functionality of existing fixed nurse call systems, thus enabling them to increase their efficiency (Breslin, Graskovich et al. 2004; Kuruzovich and Angst et al. 2008).

Combined fixed and wireless nurse call systems are the result of merging an existing system (fixed nurse call system) with a wireless system, and although they provide new functionalities beyond the ones provided by the fixed system, they have not necessarily displaced it. St. Olav's Hospital offers a clear example as to how the use of both systems can enhance their separate usefulness as well as adding an important level of redundancy, which is paramount in healthcare (Kristiansen 2010a).

The perspective from the system's designers and its users are not usually the same, and while designers should expect users to adapt the system to their specific needs (Ackerman 2000), the way this adaptation is done might include some work-arounds that despite accomplishing their aim hadn't been taken into account by the designers. An example of such adaptation takes place at St. Olav's Hospital whenever a nurse takes the battery out of her wireless phone in order to avoid being disturbed by nurse calls during her lunch break (Kristiansen 2010a). Such workarounds are sometimes not as efficient as a genuine solution, in this particular instance by removing the battery a nurse is losing all the other functionalities provided by her wireless phone (she won't be able to receive any phone calls), instead of just ceasing to receive nurse calls, which was what prompted her to customize the system.

By examining the specific usage given to a system by a certain user group: what functionalities do they use the most and why, whether they use any workarounds or not, or whether they try to extend the system's functionality in one way or another (Koopman 2003), the system can be specifically tailored to their needs. Such tailoring might consist on modifying existing features to make them more user-friendly or designing new features based on its user's behaviour. In any case this tailoring and involvement will most likely improve the end user's satisfaction and increase the system's functionality (Baroudi, Olson et al. 1986; Shirani, Aiken et al. 1994).

1.2   Scope and limitations

Due to the limited amount of time available for the completion of this thesis only two improvements have been implemented:

- Lunch break
- Assistance call

The objective of this thesis is two-fold: to reengineer the wireless nurse call system (Imatis), and to add the aforementioned functionalities to it.
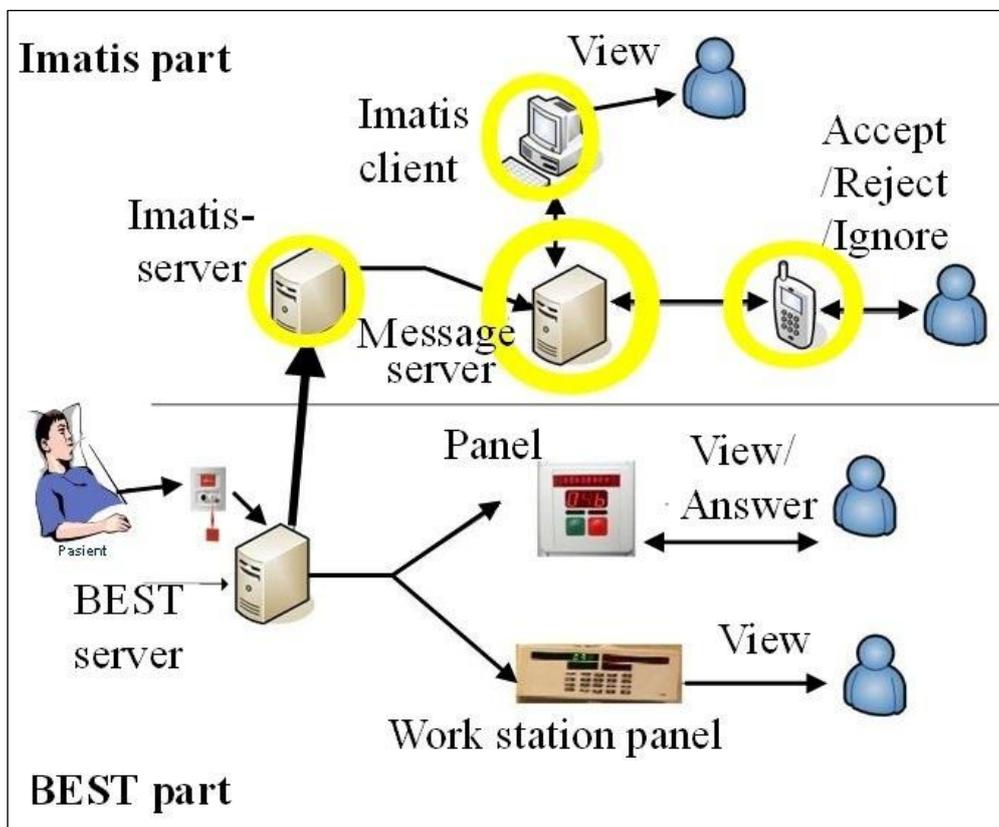
Figure 1.1: Contributions on the existing system (slightly modified from Kristiansen 2010a).

The components encircled in yellow on **Figure 1.1** indicate where the aforementioned objectives will take place, namely: the Imatis server, the message server, the Imatis client and the wireless phones. The BEST part of the system will not be modified in any way, so that it will work exactly as it did before any functionalities where added.

1.3   Outline

A brief description of each chapter is given below, in case the reader wishes to skip a certain chapter of this thesis:

- **Chapter 2: Former work on ICT and hospitals** offers an overview of the history and evolution of nurse calls, the specific needs of the different healthcare users, and how the different technologies affect each of them in a different way. It also introduces several technology alternatives for wireless communication available to healthcare as well as some former research on CSCW (ICT and organization issues).

- **Chapter 3: St. Olav's Hospital** deals with the current system installed at St. Olav's Hospital at the time this thesis was written.

- **Chapter 4: Enabling technologies and tools** offers an analysis of the different technologies and tools that could be used to achieve objectives of this thesis, namely: H.323, SIP and Arctis.

- **Chapter 5: Modeling St. Olav's nurse call system using UML** describes a reengineered version of the currently installed system at St. Olav's Hospital; this version tries to remain as similar as possible to the existing system.

- **Chapter 6: Modeling new features in the existing system** describes how new features could be modeled in the reengineered version of the existing system in a way that minimizes the modifications that have to be made to the system.

- **Chapter 7: Discussion of the results** analyses the results obtained and discusses how the previous research done in this thesis has influenced them.

- **Chapter 8: Lessons learned, conclusions and further work** concludes this thesis by adding a few personal notes, summarizing its achievements, and pointing out future work possibilities.

- **Appendices: Appendix A** shows the results and conclusions of a study conducted at St. Olav's Hospital and dwells further on the exact behaviour of the currently installed system; **Appendix B** offers a brief tutorial on UML syntax to facilitate the understanding of **Chapter 5** and **Chapter 6**.

1.4   Methods

During the writing of this thesis several methods have been used to acquire the needed information for its completion:

- Reading publications or studies has been the main method used to gather information.
- Reading training material from St. Olav's Hospital, as well as other documentation provided by Professor Lill Kristiansen.
- Attended a seminar at NSEP's on October the 13th 2010; a lot of feedback was given by the participants and notes were taken.
- Testing at an empty ward at St. Olav's Hospital was conducted on September the 9th 2010; its objective was to study how the system behaved in certain situations (for more information please refer to **Appendix A**).
- Experience acquired after working with the different enabling technologies and tools (Arctis/UML…) along the time it took to elaborate this thesis.
- Regular meetings and e-mail communications with Professor Lill Kristiansen and Doctor Hien Nam Le.

1.5   Notes about gender use

Along this text all healthcare personnel are referred to with the feminine grammatical gender while all other non-specific persons are referred to using the masculine one. This has been done to avoid an excessive use of the passive form and to make the text more approachable.

1.6   Notes about the cross-references in this document

This document is hyperlinked so that when the reader clicks on any part of the table of contents, the list of figures or the list of tables he'll be redirected to the appropriate point in the document. References encountered along the thesis are also hyperlinked in a similar manner, but the date of the reference has to be clicked for the redirection to happen (the author's names aren't hyperlinked). Lastly any text written in this style is also hyperlinked, so clicking on it will redirect the reader to the appropriate point in the document or the appropriate webpage if the hyperlink begins with http://.

In order to go back to where the reader was before clicking on a hyperlink simply press both "ALT" and "←" at the same time.

2 Former Work on ICT and Hospitals

2.1 Former work on organization's use of ICT

There is a large amount of research revolving around how members of different organizations interact and communicate with each other in different contexts in order to disseminate information. Some studies such as Ackerman (2000) and Grudin (1994) use a non-organization specific approach, while others such as Alpay, Toussaint et al. (2004) focus on specific domains. Despite their differences all of them agree that although incentives are critical for groupware they are not enough to guarantee its acceptance, and in order to improve ICT a better understanding of the user's needs and how the different contexts influence their decision making are needed.

2.2 History, evolution, and research of ICT in hospitals

The need for an efficient nurse call system arose when patients started to get moved into more private rooms instead of sharing a common space; this move limited the visual awareness nurses had of their patients, and thus created the need for other ways to perceive their patient's needs (Solumsmo and Aslaksen 2009).

Nurse call systems were invepted from such an awareness loss and have been in use in hospitals since the early part of the 20th century. Prove of this lies in the first patent for such a device, made in 1911 by Maurice Levison; in that patent Levison stated *"My invention relates to improvements in signalling systems and more particularly to signalling systems adapted for installation in hospitals [...]"* (Levinson 1911). Because the patent makes reference to existing systems already installed in hospitals and because it was written in 1911, it can be concluded that such systems were already in place before 1911; regrettably it has been impossible to determine at which date those systems where first installed due to the lack of any reliable sources that dealt with the matter.

The importance given by patients to privacy has risen considerably in recent times (Bäck and Wikblad 1998), this fact added to a recent trend to focus on patients as customers are prompting hospitals to change their structure and make single-rooms the norm (Halvorsrud and Sund 2005; van de Glind 2007; Solumsmo and Aslaksen 2009). This recent shift from multiple-bed to single-bed rooms has further increased the need of a reliable system to handle nurse calls, as increased privacy for patients often brings a decrease in awareness for nurses (Solumsmo and Aslaksen 2009).

It was from early signalling systems such as the one invented by Levinson that modern nurse call systems evolved from. Since the inception of nurse call systems the needs of hospitals have increased, and needs such as the ability to effectively coordinate staff or to be able to reach a certain person at a certain time have become paramount.

For quite a long time fixed nurse call systems and overhead paging[1] had been the chosen method of communication to supply those needs, but as new technologies were developed those chosen methods were replaced by pagers and fixed phones, which have been replaced in turn by newer technologies. Maturity has not yet been reached in his field and new or improved technologies are expected to appear and replace or complement the old ones as time goes by. One of such technologies are wireless phones, which once properly configured may ease communication among healthcare personnel allowing them to contact each other with greater ease, thus increasing coordination and facilitating consultations (Bruun Jensen 2006).

Hospitals could use two separate systems: one to deal with nurse calls and the other one to deal with the hospital's need for staff intercommunication and coordination. But with current technologies both systems can be integrated into one. An example of such integration can be seen at St. Olav's Hospital where the fixed nurse call system has been merged with the wireless phones; with this merge the wireless part of the system gives mobility and increased accessibility while the fixed part of the system ensures redundancy and offers a certain amount of context awareness. If part of responding to a nurse call includes pressing a button inside the patient's room, then the presence of a nurse inside the aforementioned room can be assured as long as the nurse call has been responded to (Kristiansen 2010a); whereas if a nurse call could be responded to remotely via a wireless device there would be no way to ascertain that a nurse had been present in the room at all (Østhus, Kristiansen et al. 2006).

One might think that this would be a great improvement over previous technologies, but the reality is not as simple as that; increased availability means increased chance of interruption, and because healthcare personnel needs to be able to concentrate in order to effectively perform their job, the interests of the interrupting party are often in conflict with those of the

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[1] Despite fixed nurse call systems being the chosen method in Norway, some countries such as the United Kingdom, the United States and Spain relied mostly on overhead paging instead.

interrupted one. While the first wishes access to a certain human resource as fast as possible, the later might not wish to be disturbed because she is in the middle of something of a delicate nature (informing a patient of his prognostic), or that requires a lot of attention (taking a complicated history from a patient; Scholl, Hasvold et al. 2007; Gundersen, Lello et al. 2009). As stated by a certain doctor: *"My pager has gone off five times in the past 15 minutes, while I've been trying to take Mr Jones's history. I can't keep his complicated history straight."* (Kristiansen 2010c).

2.3   User groups

First of all it should be noted that in Norwegian hospitals the role of operations associate found in US hospitals (Taylor, Coakley et al. 2004) and the roles of patient services manager and patient services coordinator do not exist; while most of their functions are being done by nurses, some are not needed at all since in Norway patients are not allowed to call nurses directly (they have to request a nurse call and wait for the nurse to come to them). Also in Norwegian hospitals the functions performed by patient care aids (orderlies) in Canadian hospitals: being the first ones to respond to nurse calls and contacting a nurse afterwards if they deem it necessary (Bruun Jensen 2006) are handled in a different manner altogether, as orderlies don't deal with nurse calls at all (they don't even receive them); nurse calls in Norwegian hospitals are handled in its entirety by nurses.

Taking into account the aforementioned peculiarities of Norwegian hospitals, users within them can then be divided into two user blocks, that besides often competing with each other for resources[2], have different needs (Grudin 1994; Bardram 2000) as well as different perceptions (e.g.: different assessments of importance and urgency; Coiera and Tombs 1998).

  - Doctors
  - Nurses

This is a very simplistic division that only deals with healthcare personnel (patients and support staff are not included) and doesn't really take into account the complex realities of modern hospitals: the existence of surgery clinics which often work as parallel organizations to departments and wards (Wagner 1993), the different needs of each department…. But that at the same time takes into consideration that there are different hierarchies within a hospital

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[2] Resources in this case refer more to time and availability than to physical resources per se.

and that the value of the staff's time varies accordingly. This division ignores the lower echelons (cleaning assistance, hospital porters and patients) because their time is inexpensive compared to the other echelons (Bardram 2000).

Halvorsrud and Sund (2005) point out that healthcare personnel in a hospital setting don't have the same needs as healthcare personnel working in an outpatient nursing centre; thus it can be concluded that the type of healthcare institution can be used to further refine a division in user groups.

2.3.1 Doctors

The use of role based phones has become commonplace among doctors (Scholl, Hasvold et al. 2007) as it eliminates the need to identify the individual occupying a certain role, which was often the cause of unnecessary interruptions in the past (Coiera and Tombs 1998). A further evolution is presented by IP telephony based phones which offer the possibility to integrate an individual phone and one or several role based devices into the same one.

It should be noted that doctors are a very hierarchical group, with those at the top often presenting further availability problems; this hierarchical structure might cause a shift in doctors' communication preferences as they rise within (Scholl, Hasvold et al. 2007).

Although most doctors agree that a wireless phone gives them certain advantages, some use it only to place on-going calls in order to better control their interruptibility. There still are some doctors that prefer pagers because they cause a lesser interruption than a call, and allow them to call back at their leisure *"with a phone it is easier to take the call and explain that you will call back later. I think I would do so, if I have a phone. So, that could be a disadvantage with the phone; that you may get interrupted and allow yourself to get interrupted. You get more easily interrupted by a phone than a pager. [Resident - B]"* (Scholl, Hasvold et al. 2007).

2.3.2 Nurses

In hospitals where a wireless nurse call system has been installed, the purpose of a nurse's wireless phone is twofold: the first use would be as either a complement or a complete replacement of an existing fixed nurse call system, on which case the wireless phone would be used to receive nurse calls, while the second would be as an ordinary wireless communication device, which could be used to reach or be reached by colleagues and doctors from anywhere in the hospital (Bruun Jensen 2006). This differs from the aforementioned

usage given to wireless phones by doctors, because due to the hierarchical structure of hospitals (Wagner 1993) most nurses lack the luxury of being able to use it as a one-way communication device and need to be available at all times.

Nurses often have a very different perception than doctors and often view having an individual wireless phone as an advantage over a common fixed phone, since it allows for a much more focused delivery of calls and offers a reduction on the overall noise level (Scholl, Hasvold et al. 2007). As for the increased availability, it doesn't seem to bother them or turn into a deal breaker as it does for doctors. Despite that, most nurses would indeed like to be able to deactivate parts of the system whenever they needed (e.g.: being able to deactivate nurse calls while still being able to receive calls from colleagues or doctors while on lunch break or in a meeting; Kristiansen 2010a).

2.4   Existing Technology

2.4.1 Paging Systems[3]

Initially developed by Charles F. Neergard, a hospitalized radio engineer who found the constant use of overhead paging[4] to page doctors intolerable; soon after that paging found widespread usage in healthcare: its small operation cost coupled with the small size and long battery life of pagers conspired to quickly turn paging into the most widespread communication systems in use in hospitals (Yi-Bing 1997).

At the beginning a paging system consisted in a small device (pager) with a dedicated phone number that sounded an alert tone when its number was dialled, these type of pagers are known as tone pagers. From this early state they acquired a small LCD screen which enabled them to display a string of digits (normally the caller's phone number), this type of pagers are the so called numeric pagers; a further improvement consisted in a larger screen and the capability to display alphanumerical strings hence making those pagers known as alphanumerical pagers (Yi-Bing 1997).

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[3] Telenor ceased offering paging services to the general public in Norway on September 2003 (Telenor 2001).

[4] Overhead paging refers in this case to the use of public address speakers.

Albeit there have been further improvements in paging technology they have not managed to replace the aforementioned one-way paging systems. From now on the aforementioned one-way paging systems will be referred to as conventional paging systems. One attempt to replace conventional paging systems with newer technology was made by Ighani, Kapoor et al. (2008), who conducted a study in an academic ophthalmology department in Houston (Texas) that compared a one-way alphanumerical paging system with a two-way text paging system, namely Motorola's Unication P900 (ArchWireless 2006) based on inFLEXion[5].

The aforementioned study consisted on one week of training, followed by a month of unstructured paging, and one month of structured paging. The difference between them is that in the structured paging a particular character was manually added at the end of the page following a hyphen, depending on the time frame on which a call back or a response was needed, or if a confirmation of receipt was needed (e.g. *"let's talk about our research project-4," "meet me at the clinic at 4:00 PM today-k")*.

One important downside of the two-way paging system which the aforementioned study didn't give much importance to was the increased transfer time introduced by the new system, which had an average delivery time per page of two minutes instead of the average 20 seconds that the conventional system had. Although two minutes might not be very important depending on the circumstances they constitute an unacceptable delay in emergency situations. In situations where a few seconds could mean the difference between success and failure this system would become totally useless. A possible solution for those scenarios might be to have a complementary communication system that could ensure the necessary healthcare personnel were informed within an acceptable timeframe.

After the study was concluded no significant statistical differences were found between the results of the unstructured and structured paging systems, and both of them seemed to appease the participants equally. On the other hand as **Figure 2.1** illustrates there was a substantial difference in overall satisfaction between the two-way paging system and the

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[5] The text incorrectly states FLEX instead of inFLEXion, but since voice mail support is specified as a feature in the text, the technology used couldn't have been FLEX because it doesn't have voice mail support and its only capable of one-way paging; the only FLEX family protocol that is capable of voice mail is inFLEXion (Mangione-Smith 1995).

conventional paging system, with the former being preferred by most users, as well as offering a substantial reduction on the perceived number of interruptions, which could often lead to a reduction in the number of medical errors committed (McGillis Hall, Pedersen et al. 2010). In addition to the above most users agreed that the ability to send and receive messages offered by the two-way paging system was a very welcome feature that saved them a lot of time.
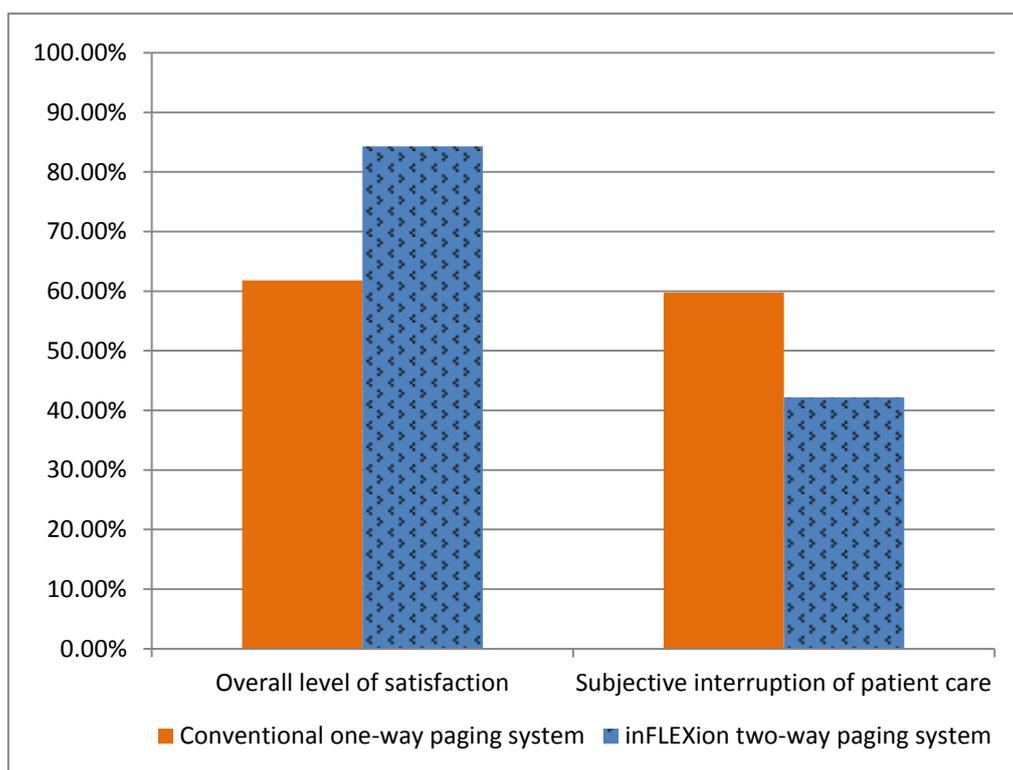
Figure 2.1: Results derived from the participant's feedback (chart made using data from Ighani, Kapoor et al [2008]).

2.4.2 IP-DECT based systems

Although DECT wasn't incepted until 1988 its origins can be traced to the 1980s when the European cordless handset market was about to be flooded by imported units. In response to that threat CEPT CT1 was established as a standard throughout most of Europe (except France and the UK). Due to two rival approaches (FDMA and TDMA) available at the time, the next evolution gave birth to two standards: CT2 and DECT, with the later offering a much better performance (bit rate of 1152 Kbits/s compared to the 72 Kbits/s of CT2), and a much wider range of applications with the setback of being much more expensive than the other one (Howett 1992).

While traditional IP doesn't support host mobility, the advent of Mobile IP complemented its capabilities by offering automatic reconnection, thus compensating the lack of inherent host mobility. That fact along the similarities between DECT micromobility management and Mobile IP macromobility made merging the two technologies possible, and IP-DECT became a reality (Baiocchi 2001; Gyasi-Agyei 2001). Nowadays creating an IP-DECT system is a simple matter of combining a DECT based system with an IP PBX system which would then allow access to IP telephony. Some vendors like Ascom (2008) have gone further and have advertised that IP-DECT is the easiest way to convert an existing DECT infrastructure to VoIP, and that it can be done seamlessly by reusing old legacy PBX and DECT base stations. Even though this might sound like an overstatement at first glance, the similarities between DECT and IP-DECT are such that this is unlikely to be the case (Gyasi-Agyei 2001).

Recently Solvoll, Fasani et al. (2010) decided to evaluate the capabilities of a similar system (Ascom/trixbox) for context sensitive communication in hospitals, the study used a trixbox CE 2.6 (an Asterisk based IP PBX), the Ascom Unite System (an amalgam of hardware components sharing a common communication platform which integrates the trixbox CE and with the wireless part of the system), and the wireless part of the system (a combination of IP-DECT base stations, handhelds and location detection devices).

The study concluded that the system provided a voice quality similar to that of a land line and ensured the delivery of alarms (equivalent of St. Olav's nurse call) even in the event of a saturation of the base stations. But the latency in which data were send over the DECT network (further study of the data provided gives an average transfer speed of 60 to 90 characters per second, depending on the number of messages and their length) limited its usage in context sensitive applications, and went as further as stating that "*the DECT framework is not suitable for data applications.*"

This last statement is very strong and in direct contradiction to other sources (Baiocchi 2001; Gyasi-Agyei 2001), and although DECT might not be suited for large data intensive applications such as real time location awareness, it is still suitable for other data applications such as text messaging. The fact that the expert team in the study consisted of only one person and the unexplained fact that sometimes the tests took only ¼ of the usual time to complete, doesn't help to give weight to such an statement. On the other hand when the results obtained with DECT are compared with those obtained with inFLEXion (which had delays of up to two minutes per page according to Ighani, Kapoor et al. [2008]) it's easy to

see that the DECT framework offers a much better performance regarding message delivery rates.

2.4.3 Vocera communications system

Breslin, Graskovich et al. (2004) and Kuruzovich, Angst et al. (2008) talk in depth about the Vocera communications system which consists of the Vocera B2000 communications badge (Vocera 2008) shown on **Figure 2.2** combined with a software package. The system uses a combination of WLAN, VoIP and voice recognition to allow *"hands-free communication;"* the communications badge accepts voice activated commands enabling the user to respond to calls using only her voice, and to make calls by pressing one button only.

Figure 2.2: Vocera B2000 communications badge (Vocera **2008**).

A study conducted at St. Agnes Healthcare by Breslin, Graskovich et al. (2004) concluded that the average nurse saved 24 minutes every 8 hour shift by using Vocera when compared to the conventional paging system and overhead paging system they were using before[6], Vocera was also responsible for an average decrease on overhead pages of 94%.

The abovementioned study was made in a healthcare facility that relied mostly on the use of overhead pages to locate personal within the hospital, thus the reduction in overhead pages might have been achieved as well with an increased use of the conventional paging system.

The St. Agnes study was directed mainly at the nursing staff; once Vocera was properly configured it allowed nurses to page someone using a name, title or role instead of having to

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[6] The study doesn't mention what type of fixed nurse call system was being used before Vocera, or whether they were using one at all.

spend time searching for phone number. By paying close attention to the data provided by the study it can be inferred that the time saved by the nurses could be divided into two categories: time saved because nurses didn't have to look for the person who was occupying a certain role at a certain time (which could have been saved by using role based pagers as well), and time saved by being able to make and receive pagers and calls while on the move.

Breslin, Graskovich et al. (2004) carefully avoid mentioning the impact Vocera had on the increased availability of doctor's and their interruptibility, and entirely dodge questions that might arise from the conflict of interests between the two user groups (doctors and nurses) like the called prisoner's dilemma (Grudin 1994).

A second study conducted by Lyons (2008) at The Indiana Heart Hospital, revealed an average decrease in response time by nurses of 37% (from 100 seconds to 63), when comparing Vocera with Rauland-Borg Responder IV. The decreased response time could be attributed to the fact that the nurses had the Vocera communications badges on them at all times, and thus received nurse calls wherever they were. The aforementioned study also neglected to mention whether there was a significant delay time between the time a nurse call was received by the Rauland-Borg Responder IV (fixed part) and the Vocera communications badges (wireless part), thus not allowing for a real calculation of the decrease in response time. Although given that what really matters from a patient's perspective is the total response time not that much importance should be given to this specific detail.

It is also worth mentioning that Lyons (2008) restricted his results and conclusions to the nurse call part of the system, ignoring the other effects the integration might have on its users, like the detrimental effect increased availability has on interruptions, which are increased by the indiscriminate use of wireless communication devices and will most likely result in an increased number of medical errors (Scholl, Hasvold et al. 2007; McGillis Hall, Pedersen et al. 2010). This last fact is given further importance because the study was conducted in the progressive care unit of the hospital where safety should be paramount (Haghenbeck 2003).

The limited scope of the data provided coupled with the fact that a decrease in response time is not often considered the best way to measure good nursing, much less if it is used as a single criteria, further limits the utility of the conclusions derived by Lyons (2008).

2.4.4 Standard mobile phones

With the recent tendency to lift the ban on mobile phone usage in hospital settings (Halvorsrud and Sund 2005) there have been several initiatives to introduce mobile phones in healthcare, like the Vocera application for iPhone[7] or MOSSA.

MOSSA (Halvorsrud and Sund 2005; Bygdås, Kileng et al. 2005) arose from the cooperation between Ringerike Hospital, Telenor R&D and Ascom Tateco, and it was designed to deliver nurse calls to a standard mobile phone (the phone used for the prototype was a Sony Ericsson P900 [Sony Ericsson 2003]).

The MOSSA system consists of five components which are depicted on **Figure 2.3** and described in further detail below.
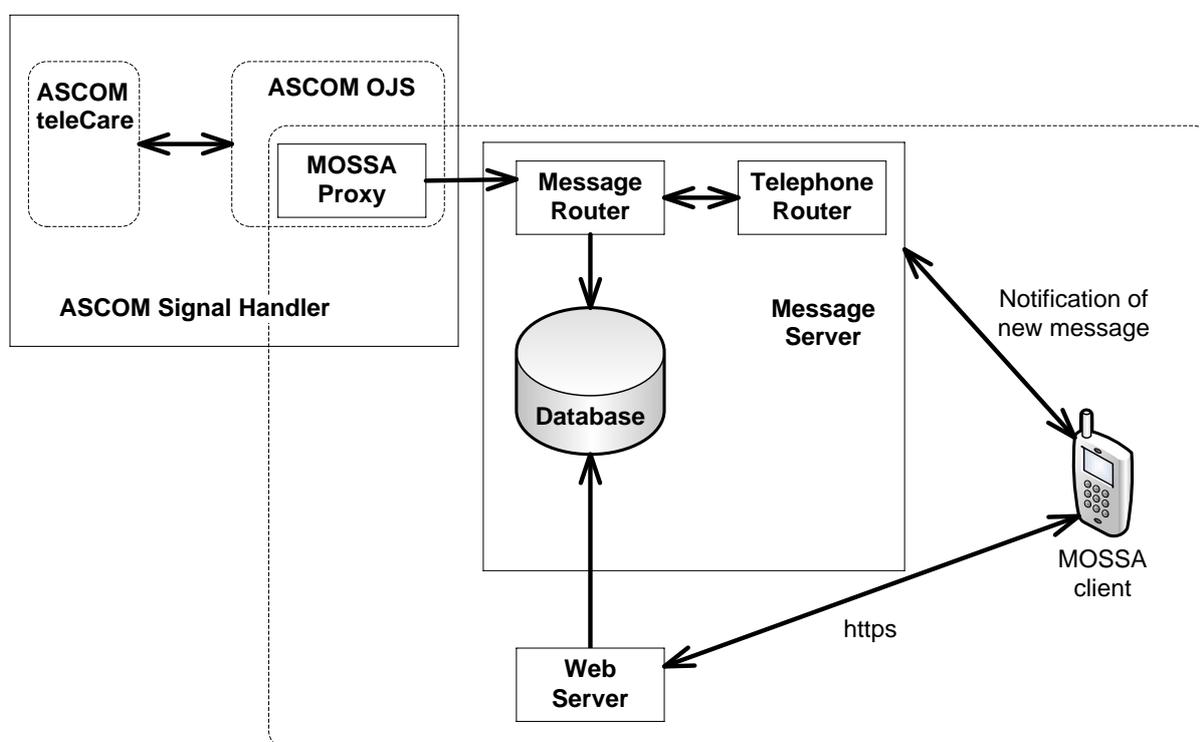
Figure 2.3: Overview of the MOSSA system (translated and redrawn from Bygdås, Kileng et al. 2005).

- Ascom teleCare: handles the dispatching of the nurse call.
- MOSSA Proxy: runs on Ascom OJS and is in charge of intercepting nurse calls and forwarding them to the message server.

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[7] The Vocera application for iPhone is an extension of the Vocera communications system that substitutes the communications badge for an iPhone running an specific application (Vocera 2010).

- Message server: identifies which phone should receive the nurse call and then proceeds to send a message to the MOSSA client on identified the phone.
- MOSSA client: acts as a GUI by "filtering" the content of the message, so that a webpage containing all of the nurse's active nurse calls is displayed. On the aforementioned webpage the nurse has the option of doing nothing about the nurse call, which will mean accepting it after 3 minutes, calling the patient or rejecting the nurse call, on which case the system will redirect the message to the next nurse.
- Web server: where the aforementioned webpages are hosted.

As stated beforehand MOSSA requires an "active reject" from the user and has a "passive accept" time-out of three minutes (if a nurse is busy and cannot answer the phone for more than three minutes MOSSA will behave as if she had accepted the call). This represents an opposite approach from the one used by the system at St. Olav's (**Appendix A**) which requires an "active accept" and has a "passive reject" time-out of 15 seconds.

The "passive reject"/"active accept" approach offers more flexibility to nurses because it doesn't accept any nurse calls without active action from them, on the other hand with the "passive accept"/"active reject" approach a nurse that has been unable to reach her phone (e.g.: her hands were busy, she had left her phone in another room…) will be accepting all her incoming nurse calls; given that she might be unable to respond for a prolonged period of time, the time the patient will have to wait for a nurse to respond to his call will be increased. It should also be taken into account that in order to respond to a nurse call, a nurse needs to know which room the call is coming from, which means that she needs to interact with her phone, at which point she should be able to make a decision regarding the call anyway.

The main advantage of MOSSA is that any mobile device can be chosen as long as it complies with its functional requirements (being a class A terminal among others). Using the GPRS/UMTS network is both a blessing and a curse for MOSSA, by using it the need for a specialized infrastructure is eliminated, but the system acquires its vulnerabilities (Xenakis, Apostolopoulou et al. 2008), and its lack of availability in certain critical scenarios (Tataranni, Porcarelli et al. 2001).

An study on MOSSA was conducted by Bygdås, Kileng et al. (2005) for a period of two weeks on two nurses who had been previously using a DECT system. Once the study was concluded both nurses expressed their satisfaction with MOSSA, especially with the ability to call the patient directly. It should be noted that this functionality was already available on the

DECT system and it wasn't being given much use by nurses due to their preference of visiting patients directly instead of calling them. The rest of the feedback provided by the two nurses included complains about the mobile device chosen, which didn't seem robust enough for hospital use and suffered interruptions of data transfers during voice communications. These interruptions were caused because the device chosen for the prototype didn't comply with one of MOSSA's requirements: it lacked continuous IP connectivity even during voice calls i.e. it wasn't a class A terminal.

Bygdås, Kileng et al. (2005) didn't go into details about the delays experienced by the system if any, or on how to handle urgent communications which are a necessity in healthcare. Given the delicate nature of healthcare an alternative system for delivering nurse calls should be in place in order to backup MOSSA in times of network outage and to ensure a timely delivery of urgent communications.

3 St. Olav's Hospital[8]

For more information about the exact behaviour of the currently installed nurse call system please refer to **Appendix A**.

3.1 Introduction

Located in central Trondheim, St. Olav's is a health enterprise and university hospital that serves a local population of 200,000 inhabitants and provides specialized care for a regional population of 660,000 inhabitants (the Central Norway region: counties of Møre og Romsdal, Sør-Trøndelag and Nord-Trøndelag; Solumsmo and Aslaksen 2009).

3.1.1 Development plan[9]

The new hospital is being built with a "build-move-demolish" approach, so that the new hospital is replacing the old one as its being build; this approach allows the hospital to stay operational during the whole construction process and offers an added level of flexibility.

Phase one of construction was completed on 2006 and consisted on building new centres alongside the old hospital, once this was done a section of the old hospital was vacated by moving it into these new buildings which were then demolished, thus freeing the necessary space for phase two.

One major drawback of this approach is the time it will take to complete, since recent planning extensions put the finishing date at 2020, at which time the hospital will occupy a total area of 223.000 m^2, with 55.000 m^2 of those being used for teaching purposes.

3.1.2 Structure[10]

St. Olav's is in this last incarnation a disaggregated hospital, designed as multiple buildings connected via sky bridges and underground service tunnels with free areas and green zones in between.

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[8] This chapter has been written using references from Kristiansen (2010a) and Sletten (2009).

[9] This section has been written using references from Solumsmo and Aslaksen (2009).

[10] This section has been written using references from Solumsmo and Aslaksen (2009) and Smith (2009).

The hospital buildings have been designed to melt into an extension of the streets of Trondheim and simulate normal housing blocks thus reintroducing the underlying urban street grid that had been interrupted by the old hospital. The aforementioned distribution of space can be seen in detail on **Figure 3.1**.
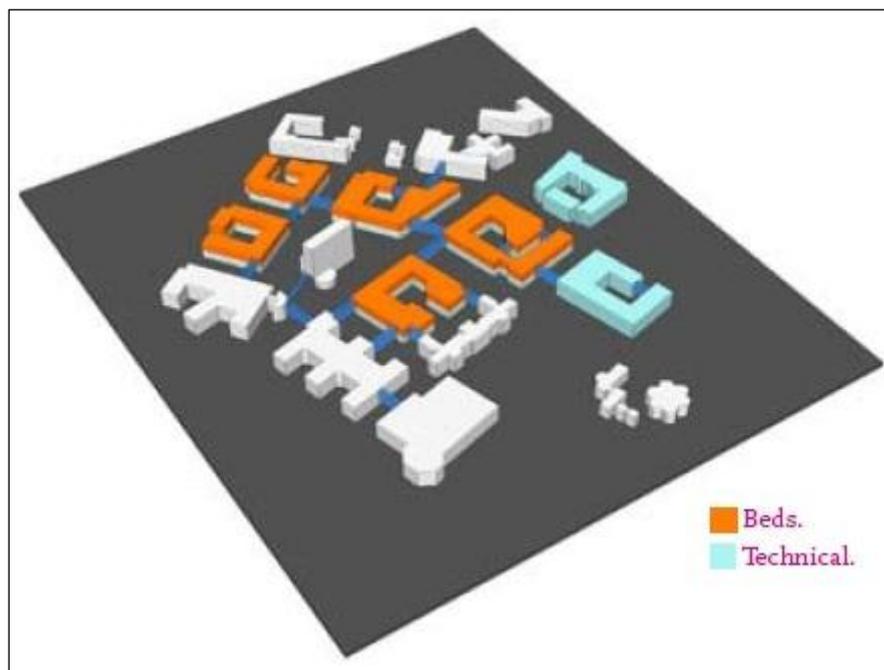
Figure 3.1: Organizational structure of St. Olav's Hospital (Smith 2009).

The aforementioned structure is supposed to help change the user's perception so that the crushing feeling of being in a gargantuan institution is replaced by a much calmer one of being in a familiar place. A further refinement of this technique relies on the unique architectural feel each building has, a fact enhanced by each building having an individualized entrance lobby and reception desk; this has the added benefit of giving each building its own support facilities.

This redundancy of support facilities might seem like a waste of resources, but it's in this redundancy where one of the greatest strengths of St. Olav's lies, as it offers an almost limitless flexibility for growth and change, turning expansion into a simple matter of acquiring and converting new housing blocks.

3.2 Combined nurse call system

The nurse call system installed is in fact a combination of three connected systems: a fixed nurse call system (BEST), a wireless nurse call system (Imatis) and an IP telephony system (Cisco).

IP telephony allows for the integration of fax, voice and data applications, enabling the same system to handle voice communication between the different parties as well as the requirements of the nurse call system, which can be considered a data application. (Hassan, Nayandoro et al. 2000).

3.2.1 Old Wards

A quick look at **Figure 3.2** should illustrate the underlying fact that the old wards weren't designed to provide visual awareness to the nurses; the old hospital was built over a century ago (Solumsmo and Aslaksen 2009), at which time visual awareness might not have been as important a feature as it is nowadays. The old wards consist of a long corridor with rooms on both sides and the duty room more or less in the middle; this offers nearly no visual awareness to nurses in the duty room, or to other nurses regarding the duty room.
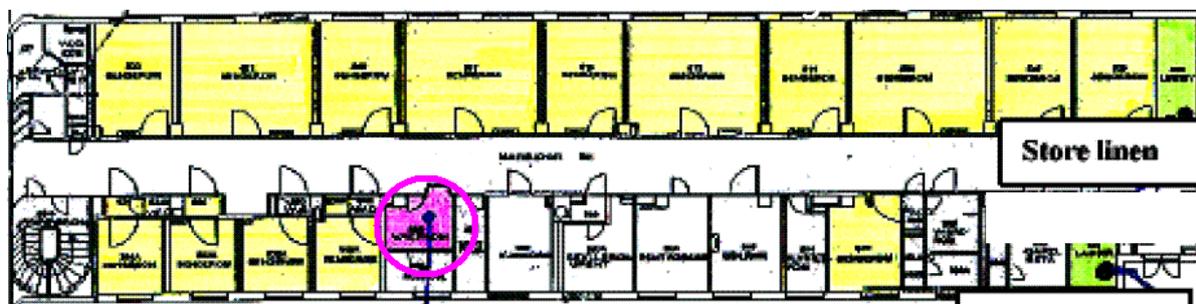
Figure 3.2: Floor plan of an old ward (Kristiansen 2010a).

In the old wards nurses have no wireless phones and only the fixed part of the system is used, forcing the nurses to rely on the wall mounted displays (**Figure 3.3**) in the duty rooms, and the various ceiling displays stationed along the corridor, where all active nurse calls in the ward are displayed.

Figure 3.3: Wall mounted display located in the duty rooms (Sletten 2009).

In addition to the aforementioned displays, the presence panels inside each room (shown on **Figure 3.4**) display new nurse calls once a nurse has registered as present in the room (by activating the presence panel). These presence panels will announce new nurse calls with a short audible sound that will cease shortly, followed by a blinking light on the display that will remain active for as long as the nurse call hasn't been responded to.

Figure 3.4: Presence panel located on the door frame of every patient's room (Kristiansen 2010a).

Finally a whiteboard is used to display any planned meetings and formal responsibilities, such as the ones a physician might need to know.

3.2.2 New Wards

The new hospital wards have been designed to provide maximum visual awareness to nurses from their station; following this principle each ward has been divided into three separate bed courts, each of them with its own work station for the nurses, with direct line of sight to the nearby ones as depicted on **Figure 3.5**.
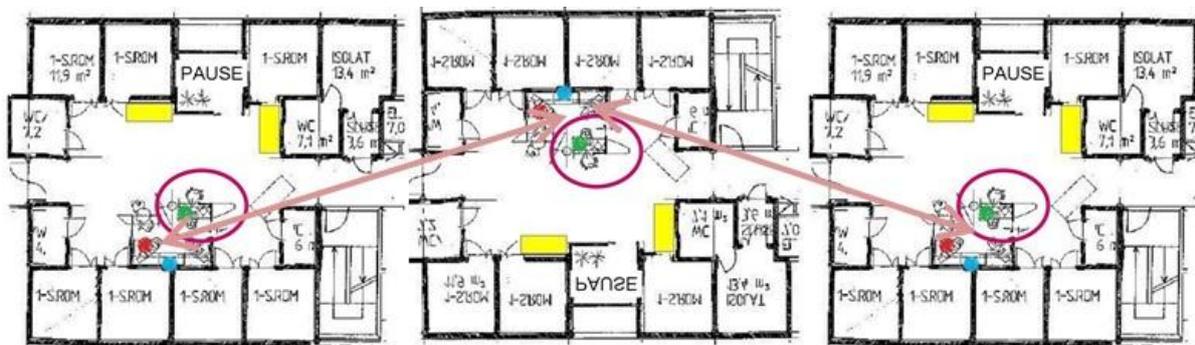
Figure 3.5: Line of sight between work stations in the new wards (Kristiansen 2010b).

This direct line of sight was the architect's intent, but in reality, poor placement of printers and other devices often obstructs this intended line of sight, eliminating some of the enhanced awareness the new wards would have otherwise provided nurses with.

Nurses have access to the wireless system in addition to the aforementioned fixed system (with the exception of the inexistent ceiling displays of the new wards). Each work station has a Cisco Unified IP Phone 7960G (Cisco 2008), which is a fixed IP-phone, and a computer running the Imatis client on which nurses can modify room responsibilities after having logged in.

3.2.3 Imatis client

The Imatis client is used for nurses to allocate or eliminate room responsibilities, in order to do that a nurse has to log in using her id card, once this has been done she can assign room responsibilities among the nurses that are currently logged in their wireless phones. Up to two nurses might be assigned to each room (one of them being the primary responsible nurse and the other one the secondary). Besides assigning nurses to rooms some nurses (up to three) can be set as generally available (Disp1, Disp2 and Disp3 in **Figure 3.6**) so that they are taken into account for the round robin (usually a nurse set this way is not assigned to any rooms).
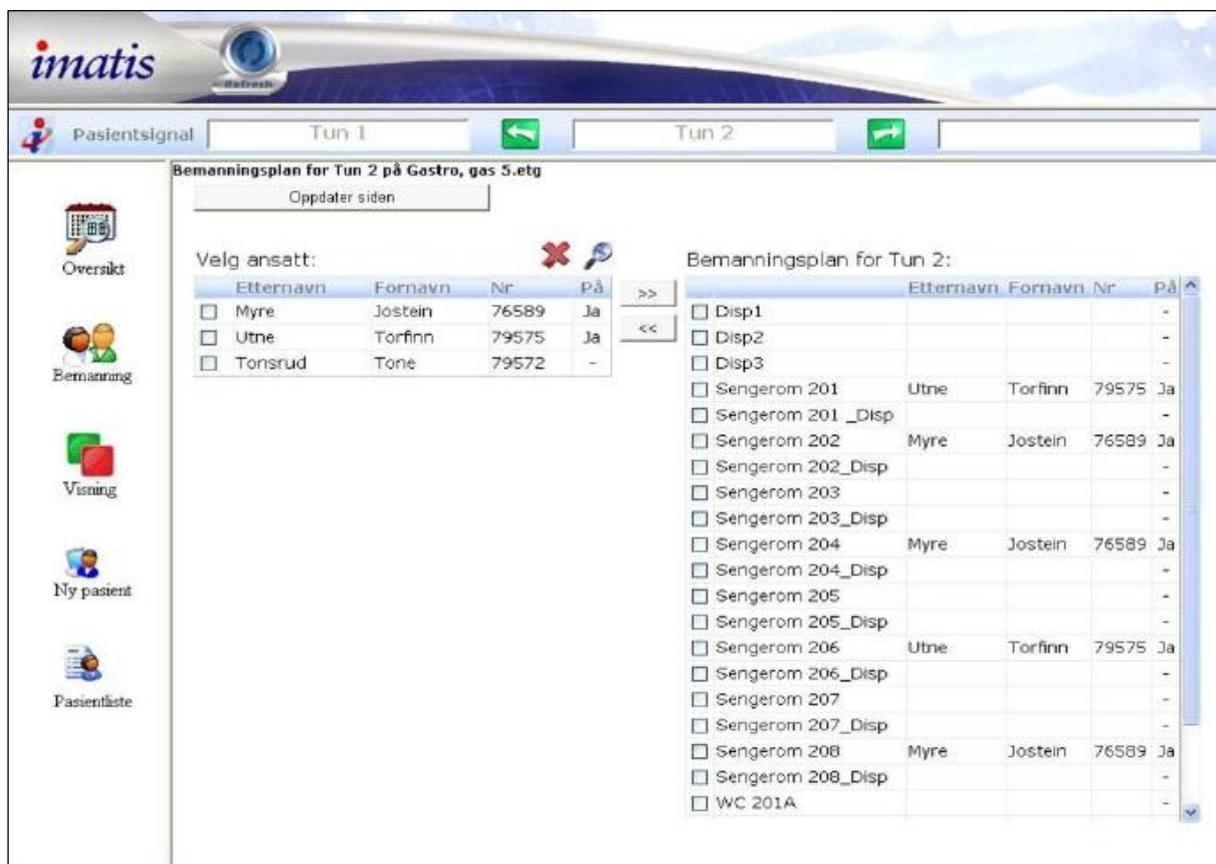
Figure 3.6: View of the Imatis client when allocating room responsibilities (doesn't reflect a real call plan; St. Olav's 2009).

3.2.4 Wireless phones

Each nurse has a Cisco Unified Wireless IP Phone Model 7921G (Cisco 2009) which can be seen on **Figure 3.7**, where she logs in at the start of the day and logs out before leaving.
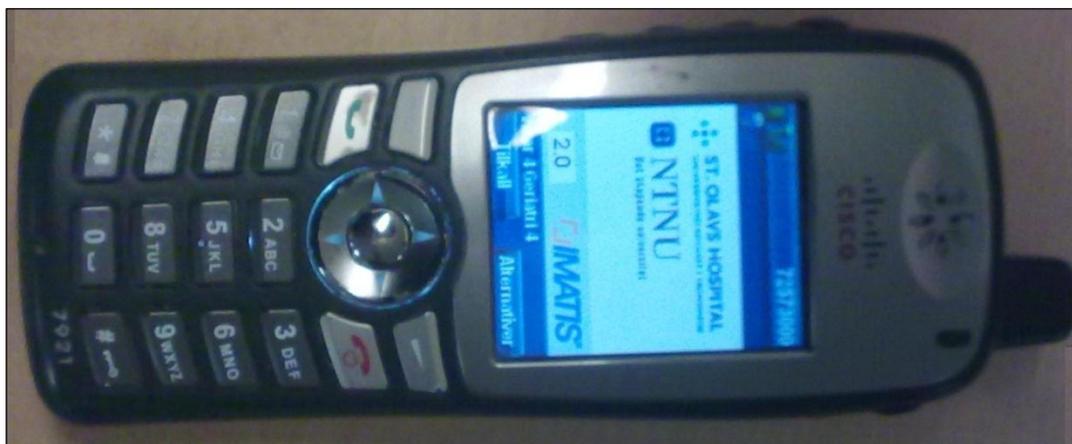
Figure 3.7: Cisco Unified Wireless IP Phone 7921G (image taken by the author).

The aforementioned phone in addition to being used for receiving and replying to nurse calls can also be used to make and receive normal phone calls, or to send text messages, just like a regular IP-phone. Despite this apparent flexibility it has several drawbacks (for more details please refer to **Appendix A.14**), like not having been specially designed for hospital use.

3.2.5 Nurse Calls

There are currently two types of nurse calls: normal nurse calls which can be generated from the patient terminal, the presence panel or by pulling the signal cord, and heart arrest calls which are generated by pressing the red signal button.

When a normal nurse call is generated the system contacts the primary responsible nurse for that room first (if any); if there isn't one or if she doesn't respond or rejects the call the system contacts the secondary nurse (if any); if there isn't a secondary nurse, or if she doesn't respond or if she rejects the call the system initiates the round robin.

Because a nurse is normally working on several things at the same time the system was designed with an "active accept"/"passive reject" approach in mind so that upon receiving a nurse call a nurse would have three available options:

- Accept the call by pressing the accept button; doing this declares intent from the nurse to deal with the call within a given timeframe, which might vary from one department to another.

● Reject the call by pressing the reject button; doing this redirects the call to the following nurse: either the secondary nurse assigned to the room or the next nurse in the round robin.

● Do nothing; if a nurse has her hands busy or is otherwise unable to reach her phone, she can ignore the call, once this has been going on for 15 seconds the call is redirected to the next nurse as if it had been rejected.

In a heart arrest call, instead of contacting nurses one by one, the system sends the heart arrest call to all nurses on the call plan at once. After receiving the heart arrest call a nurse doesn't have the option of rejecting or accepting it, the phone just keeps ringing until the presence panel in the room where the heart arrest call was generated is activated.

3.2.6 Interaction of the fixed and the wireless system

The wireless system has been designed to be used in conjunction with the fixed system and it has been integrated with it as shown on **Figure 3.8**. Despite some simplifications having been
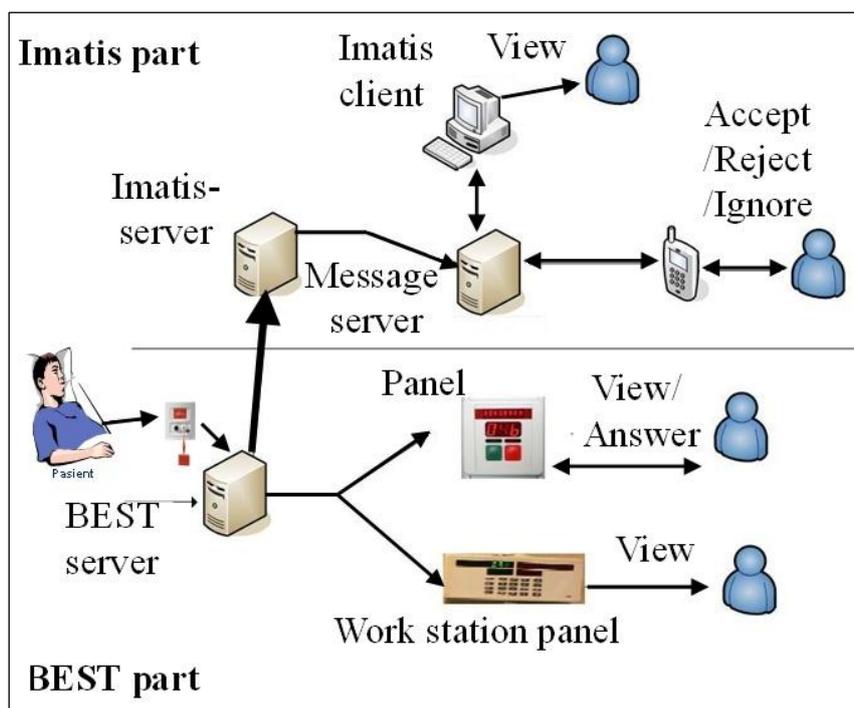
Figure 3.8: Relationship between the fixed and wireless system (slightly modified from Kristiansen 2010a).

made to the aforementioned figure, the main idea behind it remains that the BEST part has been integrated with the Imatis part in a one way fashion, so that while the Imatis part (wireless) doesn't send anything to the BEST part (fixed), it does receive something from it. Once a nurse call has been generated the BEST part informs the Imatis part of the type of

nurse call generated as well as the room it was generated from; in a way the Imatis server acts as a one way liaison with the BEST server.

This one way integration allows the fixed system to operate independently to the wireless part of the system in case of need, thus acting as a backup system in case the wireless system fails. In such a situation the fixed system should work in a similar way as it currently does in the old wards.

4 Enabling Technologies and Tools

4.1 Introduction

This chapter focuses on reviewing the different technologies and tools that could allow the currently installed wireless nurse call at St. Olav's to be reengineered, and enhanced with new functionalities. But to accomplish such a thing the technical needs of the system must be taken into account first.

Normal nurse calls are somewhat similar to text messages, the receiving terminal receives an interactive text message (some options are available upon receipt as stated on **section 3.2.5**), but instead of being "fire and forget" like an SMS they require a response from the receiving terminal[11]. They are also time sensitive and their delivery needs to be ensured in some way. The system needs to be reliable enough so that once send, normal nurse calls can be assured a delivery within a timely fashion; ideally this timely fashion would be immediately after being send (the current system has a 32 second delay, please refer to **Appendix A** for further information).

Heart arrest calls on the other hand do not require a reply from the receiving terminal (they keep ringing until they are responded to), but are especially time sensitive, since they usually involve emergency situations (the current delay is of 32 seconds can a handicap in these situations).

Since receiving terminals treat both types of nurse calls differently they need to be able to tell them apart; "tagging" them from origin allows them to be told apart and enables receiving terminals to treat each of them according to a specific structure (normal nurse calls require a response within a time-frame while hear arrest calls do not require a response from the receiving terminal at all, but cannot be turned off).

Because the objective of this thesis is to have a system as similar as possible to the one currently installed, IP telephony has been chosen as the enabling technology; but before going into details about the different paths available to accomplish the aforementioned objective using IP telephony, let's take a closer look at what IP telephony really is.

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[11] Receiving terminal refers to a nurse's wireless phone each nurse when she is receiving a nurse call.

4.1.1 IP telephony

IP telephony means integration of data, fax and voice; it's sometimes used interchangeably with VoIP which strictly refers to *"passing phone calls over a packet data network"* (Soares, Neves et al. 2008). IP telephony uses VoIP technology for the voice and video part of the system. These are grabbed in digital form, split into little pieces and then transferred through the network as packets, which are then reassembled at the other end of the conversation. All this should be done as seamlessly as possible so that the parties involved in the conversation wouldn't notice any difference between a conversation had over IP telephony and one had over POTS (Soares, Neves et al. 2008).

Although they are many protocols that enable IP telephony the two most widespread ones are H.323 and SIP (Ansari, Khan et al. 2009). The rest of the available protocols are of a proprietary nature and it's because of this nature conflicting with the objective of this thesis that they won't be taken into consideration, nonetheless and for the sake of completion the most relevant ones are listed here: Skype (Skype Limited), JAJAH (Telefónica; Reuters 2009), Skinny Client Control Protocol (Cisco), CorNet IP (Siemens) and MiNET (Mitel Networks; Ansari, Khan et al. 2009).

Some complementary protocols exist: MGCP and H.248/Megaco, but because both of them need to be used in conjunction with either SIP or H.323 (Ansari, Khan et al. 2009) they won't be taken into consideration on their own.

4.2   H.323[12]

H.323 was developed by the International Telecommunications Union in February 1996; its latest version available at the time this thesis was finished being v6 (approved in 2006). H.323 consists of several different protocols each of which defines a specific part of H.323 as depicted on **Figure 4.1**. G.7xx consist of audio processing protocols, H.26x video processing protocols, H.225 defines registration, admission, status and call signalling, H.245 controls multimedia communications and T.120 data conferencing, while RTP and RTCP provide media transportation.

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[12] This subchapter has been written using references from Soares, Neves et al. (**2008**) and Ansari, Khan et al. (**2009**).
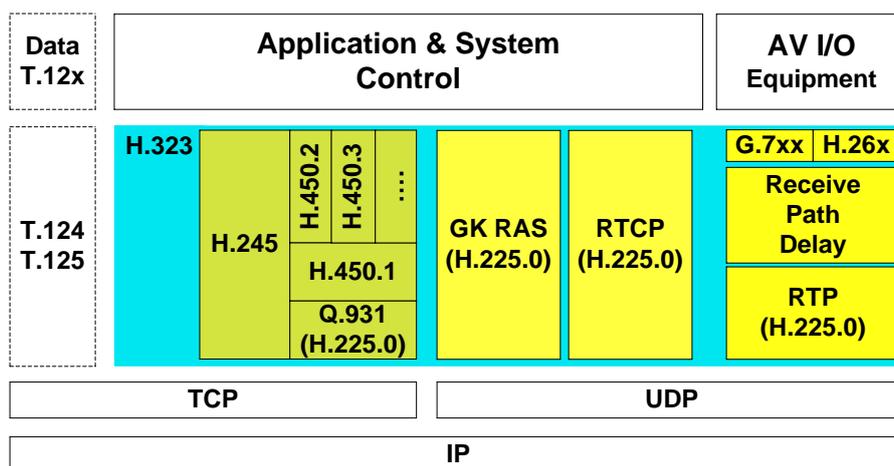
Figure 4.1: H.323 Protocol Suite (redrawn from Glasmann, Kellerer et al. [2003]).

An overview of the H.323 architecture can be seen on **Figure 4.2** which might be useful to put the reader into perspective.
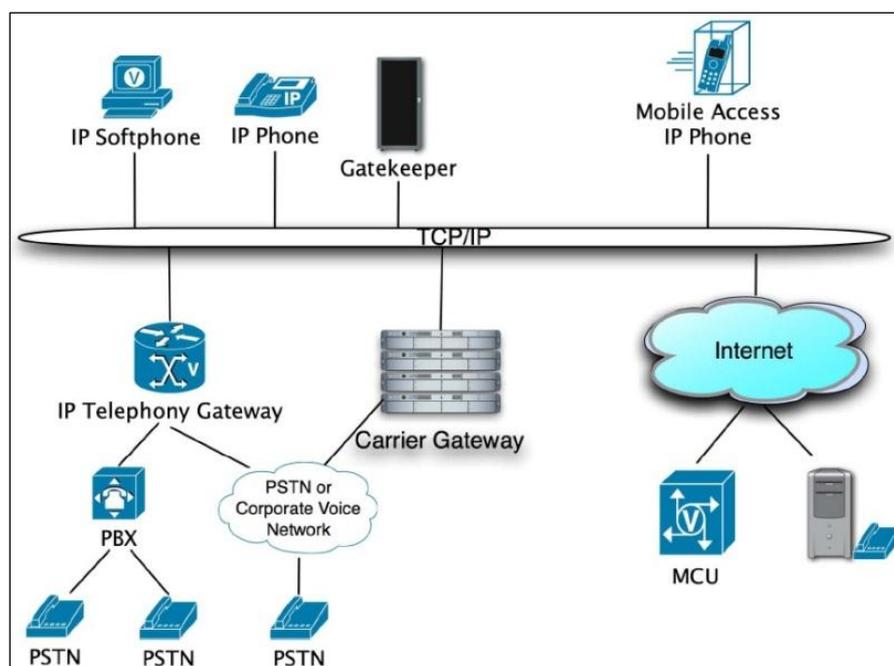
Figure 4.2: H.323 Architecture (Soares, Neves et al. 2008).

H.323 was designed with the requirements of multimedia communications in mind and defines a unified system to perform these functions; it also offers a high level of scalability since it allows extensions by the standards community without affecting existing features, and it also allows for non-standard features to be safely added by specific vendors (thanks to unique global identifiers). It can be easily integrated with PSTN (by using gateways) and allows a call to be placed from end point to end point, thus skipping the gatekeeper (although most devices still use it for registration and address resolution).

Two of the main advantages of H.323 are its ability to support any audio or video codec independently of whether it's proprietary or not, and its ability to convey both data and video conferencing (with lip synchronization of audio and video streams). Apart from that H.323's messages are binary encoded making them more suitable for narrowband communications, although that makes them unsuitable for humans to read; furthermore H.323 supports several addressing mechanisms (URI, e-mail addresses and E.164 numbers), its able to recover from connection failures and has load balancing capabilities.

All in all, H.323 is quite a robust system with a high level of interoperability that is widely used for VoIP and videoconferencing.

4.3   SIP[13]

The Session Initiation Protocol was developed by the Internet Engineering Task Force in 1999; its latest version available at the time this thesis was finished being v2.0 RFC 3261 (approved in 2002). It was initially conceived to setup a generic session between multiple points which initially consisted of voice communication only, but that expanded over the years to include video, instant messaging, presence, and application sharing among others. Given SIP's lack of strict guidelines regarding functionalities these expanded services transform SIP from a simple protocol to a more complex one with interoperability issues (Glasmann, Kellerer et al. 2003; Guillet, Serhrouchni et al. 2008). Both audio and video signalling are independent from SIP session signalling, and as shown on **Figure 4.3**, the SIP core protocol is quite small when compared to the whole protocol suite.
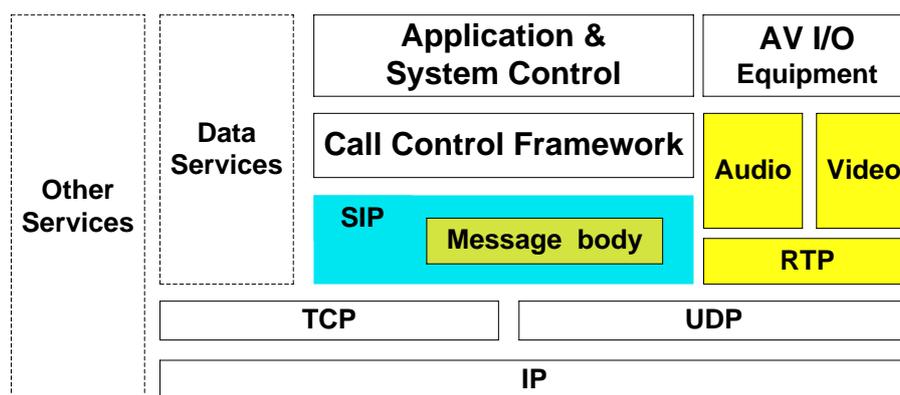
Figure 4.3: SIP protocol suite (redrawn from Glasmann, Kellerer et al. [2003]).

[13] This subchapter has been written using references from Soares, Neves et al. (2008) and Ansari, Khan et al. (2009).

Some notable facts about SIP are its lack of native PSTN support (although it might be integrated with SIP as part of "other services") and its ability to support any audio or voice codec as long it has been agreed upon by both parties. SIP has very specific addressing requirements (URI must be used), lacks sophisticated load balancing capabilities (uses trial and error), and has only limited support for video conferencing (doesn't have lip synchronization). SIP messages are encoded in ASCII in order to make them more readable to humans; this codification increases their size considerably and makes SIP less suitable for narrowband communications. SIP is highly scalable because extensions can be added by the standards community without affecting existing features (they are not always backwards compatible), and non-standard features can be incorporated by specific vendors (they incorporate them as they see fit, creating a potential risk of interoperability problems).

On one hand SIP has some interoperability issues (Glasmann, Kellerer et al. 2003; Guillet, Serrhrouchni et al. 2008) and less technical capabilities than H.323, but on the other hand SIP remains simpler and has a much wider range of applications; in the end is more a matter of preference as both protocols have advantages and disadvantages.

4.3.1 SIP's Presence: SIMPLE[14]

The SIMPLE architecture represents an application of SIP's event notification model, in the standard event notification model the person who wants to be aware of another's presence (referred to as *"watcher"*) subscribes to the presence agent, while the person who wants his presence to be known (referred to as *"presentity"*) registers to the SIP proxy and publishes his presence into the aforementioned presence agent as depicted on **Figure 4.4**.
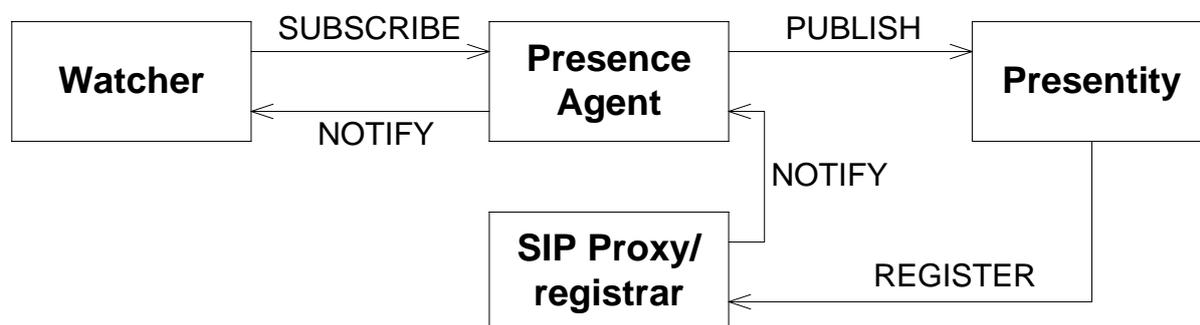
Figure 4.4: SIP's presence components (redrawn from Schulzrinne [2006]).

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[14] This subchapter has been written using references from Schulzrinne (2006).

According to Schulrinne (2006) a working presence system requires more than subscribe, publish and notify operations, because users need to be able to customize the system to their own needs (e.g.: decide who can "watch" them, filter the notified content…)

SIMPLE's presence architecture conveys much more information than the classical presence application which only allows for "available" and several degrees of "unavailable;" SIMPLE allows multiple sources to contribute presence information to the whole (phone status, calendar information, position…) and combines them into one view which is then delivered to the watchers. Although with multiple sources comes the risk of conflicting information, which instead of being filtered is delivered as a whole to the watchers (e.g.: a user's calendar might state that he is in a meeting, but his phone might list his location as "at home").

Besides allowing users to indicate a much wider range of presence options SIMPLE allows users to choose between different sets of privacy modes (e.g.: home, work, holiday…), which can be used to better tailor their privacy settings (e.g.: when on work mode a user would not be interrupted by incoming calls unless they were from work or from certain preselected contacts, while when on holiday mode he would not be interrupted by work calls).

Despite possible privacy issues, scaling problems and failing to address calls made by strangers, the SIMPLE presence architecture is likely to reduce interruptions Schulrinne (2006).

4.4 Arctis[15]

Arctis[16] is a UML based tool for service engineering designed as an Eclipse plug-in and currently under development at NTNU.

4.4.1 SPACE

Arctis is based on the SPACE engineering approach. This approach uses UML 2.x collaborations as main specification units, in addition to UML activities which are able to express collaborative behaviour in a visual form. By using them as joint compositions a complete description of the system's behaviour "global behaviour" is achieved.

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[15] This subchapter has been written using references from Kraemer (2008, 2009 and 2010).

[16] The last version of Arctis used was 1.0.0.M0341 which had been released on 2010-11-29.

Model checking of the compositional properties of the collaborations and their compositions is used by SPACE to ensure their correctness. Afterwards a multi-model approach is used to synthesize a component-oriented model (one model decomposes the system into its components while the other decomposes the collaborations) by means of an automated model transformation.

4.4.2 Arctis editor

The Arctis editor is a combination of graphical and textual edition that allows the creation of building blocks; it has been integrated with Eclipse's Java Development Tools as a plug-in and as depicted on **Figure 4.5** offers users of Eclipse and Java a "familiar" work environment.
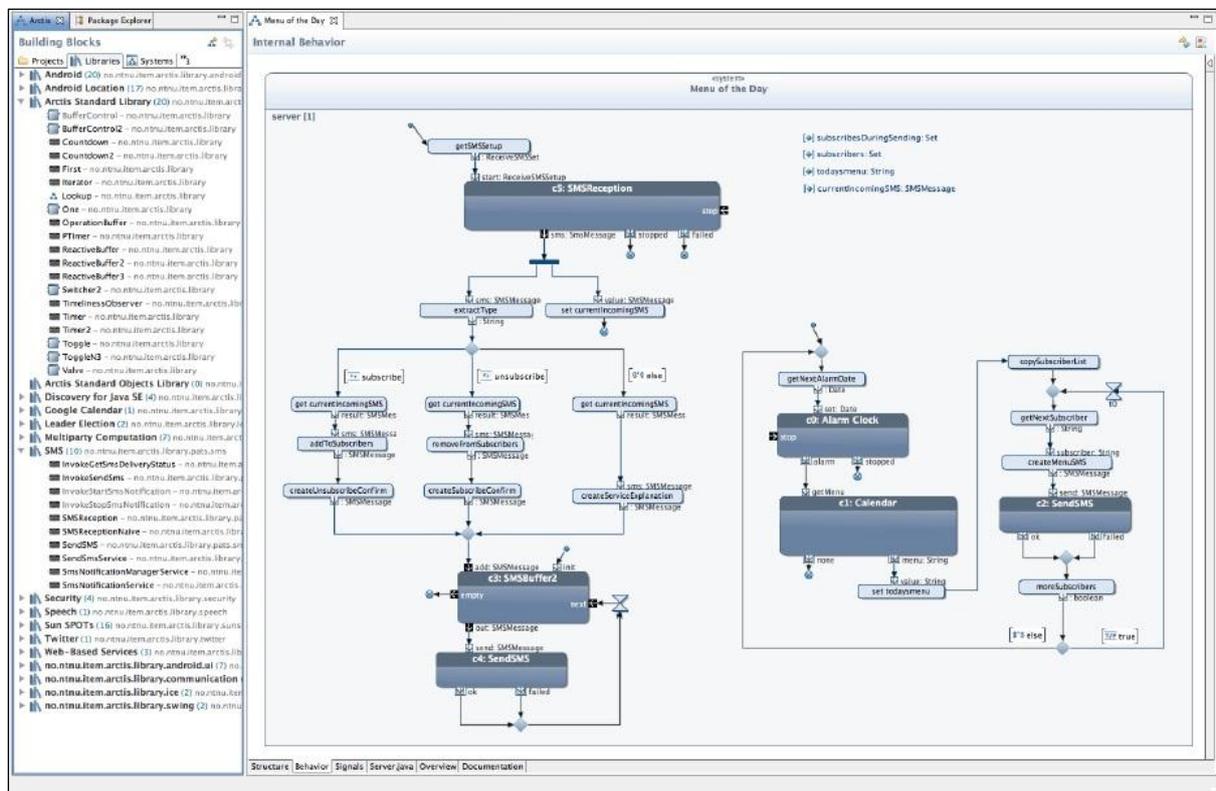
Figure 4.5: Sample view of the Arctis editor (Kraemer 2010).

The Arctis editor has been designed with a simple idea in mind: to save time; it manages to accomplish such a thing by reducing the task of creating an application to combining self-contained building blocks which can either be created from scratch or taken from existing libraries, and which can afterwards be reused for other applications.

Creating Android applications is also possible via the Arctis editor once the Android software development kit and the Android development tools have been installed. From the engineers

point of view it shouldn't be very different from creating java based applications, it is once again a question of selecting and combining self-contained building blocks.

4.4.3 Arctis analyser

The Arctis analyser picks the building blocks and checks them for errors, after it has detected any errors some suggestions as to how to fix them are be offered. In some events after analysing the system some suggestions as to how to improve it might be offered in a similar manner.

4.4.4 Arctis compiler

The Arctis compiler takes the building blocks and generates executable code from them, the process depicted on **Figure 4.6**, begins by taking the building blocks and editing them into
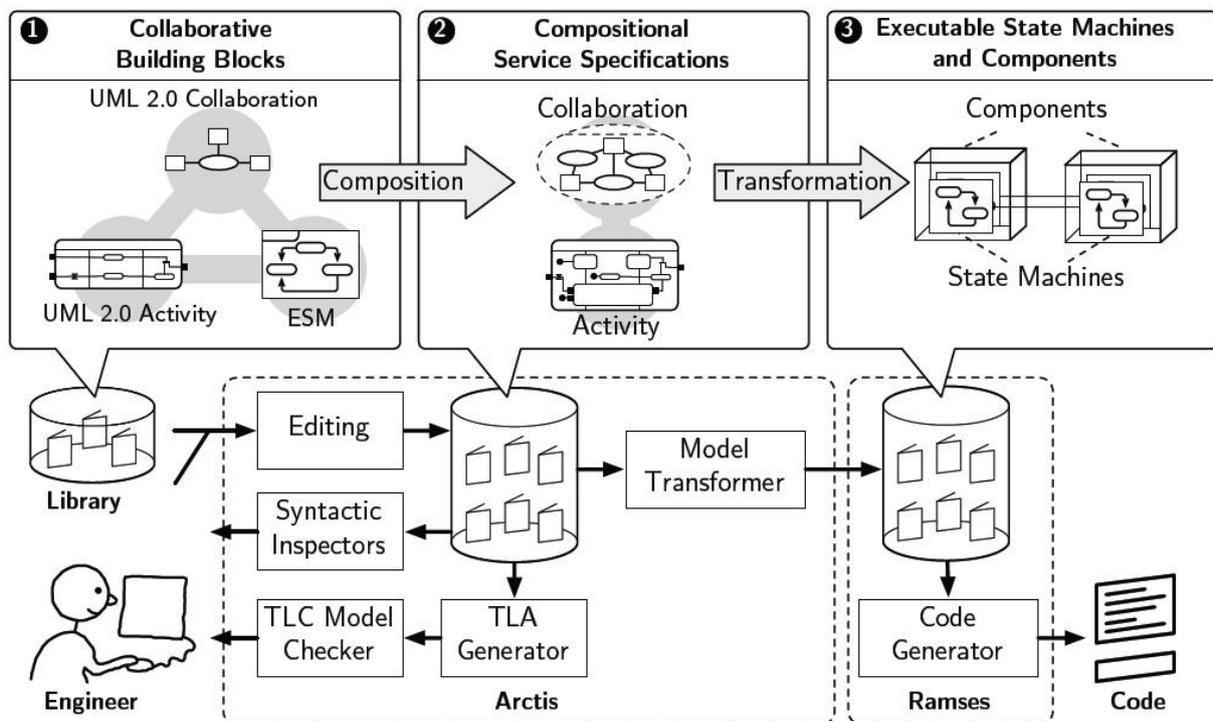
Figure 4.6: How Arctis turns building blocks into executable code (Kraemer 2008).

compositions (which is done by the engineer), afterwards Arctis uses the SPACE engineering approach to turn those compositions into executable state machines via automated model transformation, and finally Ramses (the code generator) implements these executable state machines into actual executable code.

4.4.5 Building blocks

Building blocks are the units used by the specifications: they can be designed, analysed, and reused individually (i.e.: they are self-contained). Their structure is described using UML 2.X collaborations, and their behaviour using UML activities, so that once those are combined the resulting building blocks are characterized completely.

There are three types of building blocks depending on the number of participants and other factors: *system collaborations* which cannot be decomposed in other building blocks, *service collaborations* which comprise two or more participants and can be decomposed in other building blocks, and *activity blocks* which consist of only one participant and thus have no UML collaborations.

4.4.6 Conclusions

By using Arctis the current system at St. Olav's Hospital can be reengineered to work with Android based phones. In order to accomplish this goal, the system would be first modeled using UML activities and collaborations, and then by making use of existing Android libraries and creating all the necessary building blocks, existing functionalities like normal nurse calls and heart arrest calls could be emulated.

4.5   Choosing the most adequate tools and technologies

With the requirements of St. Olav's nurse call system in mind, and given the fact that neither video nor data conferencing are required H.323 is not a better option than SIP. In fact given than SIP's open source project (OpenSIPs) seems simpler to implement than H.323's one (H.323+), SIP would be the better choice between the two of them. But taking into account that OpenSIPs is undergoing a radical change of design (from 1.6 to 2.0), engineering a system using an about to be out-dated protocol might not be the best choice (OpenSIPs 2010).

Whereas despite still being under development Arctis offers many more benefits regarding expansion and scalability. It also allows the system to be modelled with UML first and then be implemented with Arctis, so that if time didn't allow for a complete implementation a model of the entire system would still have created. UML diagrams could also be used to further the understanding of the currently installed system by St. Olav's Hospital IT personnel; this could help generate some feedback which could in turn be used to further improve and refine the system, and thus increase end user's satisfaction.

5 Modeling St. Olav's Nurse Call System Using UML

5.1 Introduction

This reengineered version of the currently installed system at St. Olav's Hospital (plese refer to **Figure 3.8** for an overview of the system) only focuses on the Imatis part of the system and not the BEST one, which is only used as a triggering mechanism to generate the nurse calls.

5.1.1 Terminology

Because of the possible misunderstanding of the nurse call "term", nurse calls have been divided into two groups: normal nurse calls and heart arrest calls, this is simply a naming convention made in order to prevent possible misunderstandings.

"Respond" has been chosen instead of "answer" because some existing systems like MOSSA allow nurses to call the patient when they receive a nurse call in addition to accepting or rejecting the nurse call; this added to the fact that "answering" is commonly associated with phone conversations might let to some confusion about what "answering a nurse call" was referring to.

5.1.2 Non implemented features

The existing escalation feature of the nurse call system has not been implemented; this fact will have very minor implications on the end result, since the only change will be that nurse calls won't be redirected to neighbouring wards if no one is accepting them after a certain amount of time has passed; one of the reasons for such a choice has been the lack of suitable information on the exact behaviour of the aforementioned escalation feature.

Heart arrest calls lack a task list (in the current system they have a task list similar to the one normal nurse calls have), the logic behind this decision lies in the fact that such a task list is not really needed and instead of adding a functionality it adds an unnecessary level of cumbersomeness to the system; a nurse will still be able to see the history of any nurse calls received in her phone, so no functionality has been lost.

5.1.3 UML syntax

The modeling described in this chapter has been done using UML 2.3 which was released on May 2010 (OMG 2010). A quick tutorial about the UML syntax is available in **Appendix B**; in order to facilitate a better understanding of the UML diagrams presented in **Chapter 5** and

Chapter 6 it is recommended that the reader familiarizes himself with it before proceeding further into these two chapters.

5.2   Nurse call overview
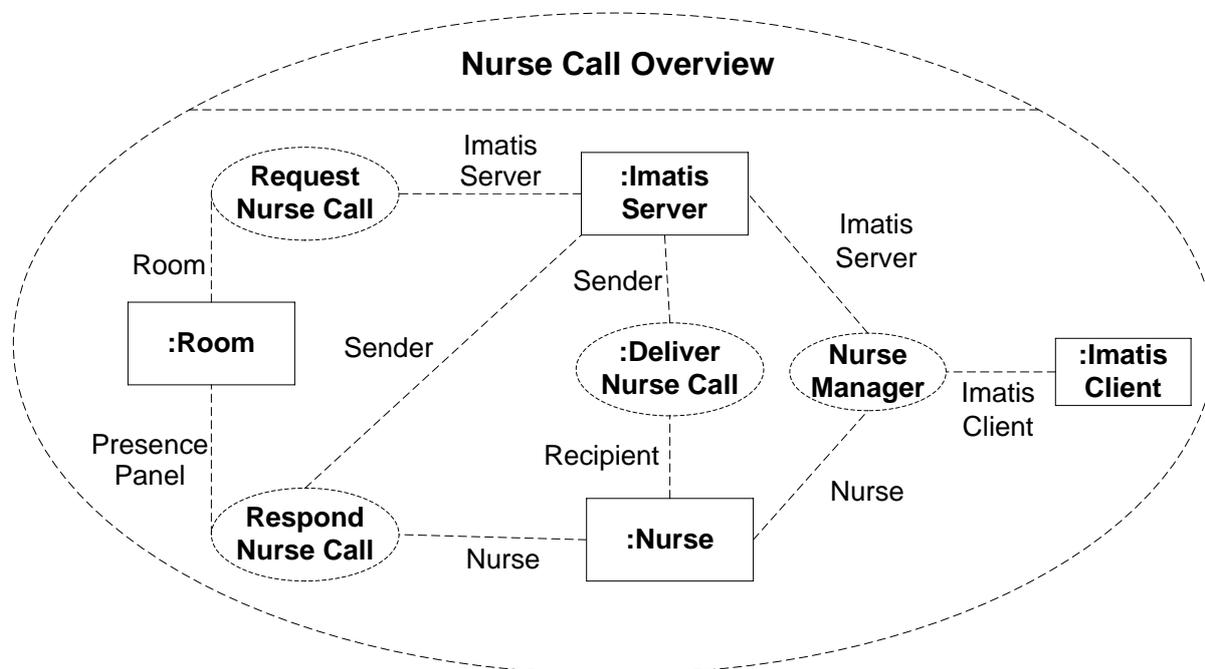
Figure 5.1: Nurse call overview collaboration diagram.

As seen on **Figure 5.1** a nurse call is initiated by being requested from a room, afterwards the aforementioned nurse call is processed by the Imatis server which delivers it to a nurse. Once a nurse has accepted the nurse call she has to go to the room to respond to it, once there she has to activate the presence panel, at which point the nurse call will enter a "waiting phase" until the presence panel has been deactivated which will conclude the nurse call.

Independently from this main sequence of events the nurse manager allows nurses to interface with the Imatis client and the Imatis server.

Each of the sub-collaborations presented here are explained in further detail in their respective sub-chapters and sections.

5.3   Nurse manager
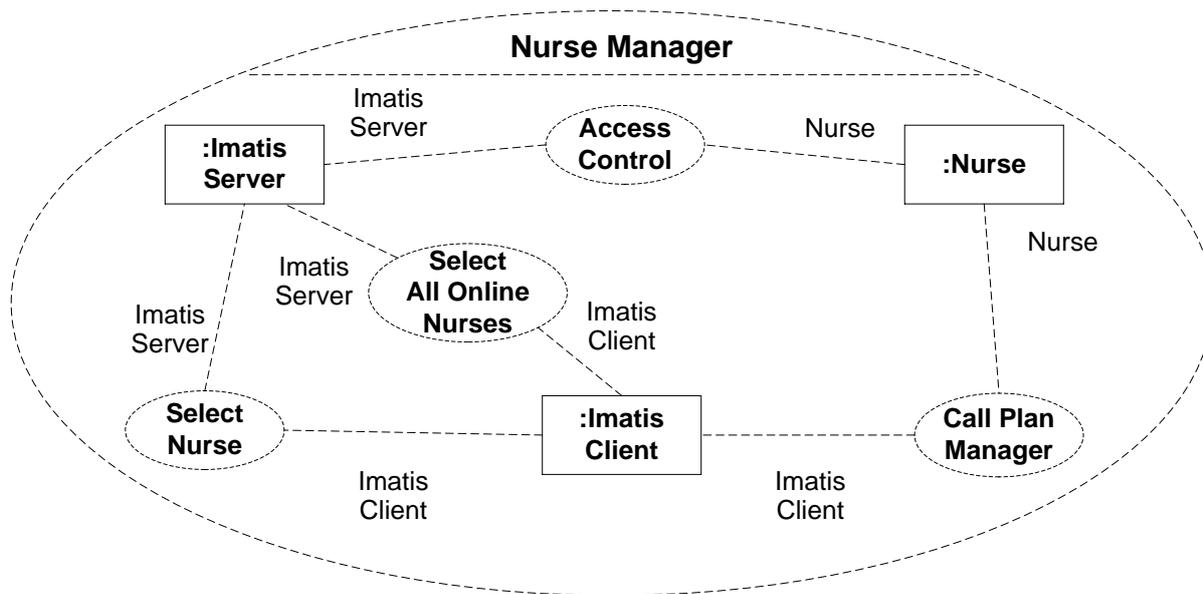
Figure 5.2: Nurse manager collaboration diagram.

The *nurse manager* sub-collaboration modeled on **Figure 5.2** consists of two sub-collaborations that are "invisible" to nurses, as they are not directly involved in them: *select nurse* and *select all online nurses*. The rest of the sub-collaborations are *not* "invisible" to nurses: *access control* which allows nurses to log in and out of the Imatis server via their phones, and *call plan manager* which allows them to log in and out of the Imatis client with their ID cards, as well as allowing them to manage room responsibilities in the call plan.

5.3.1 Access Control
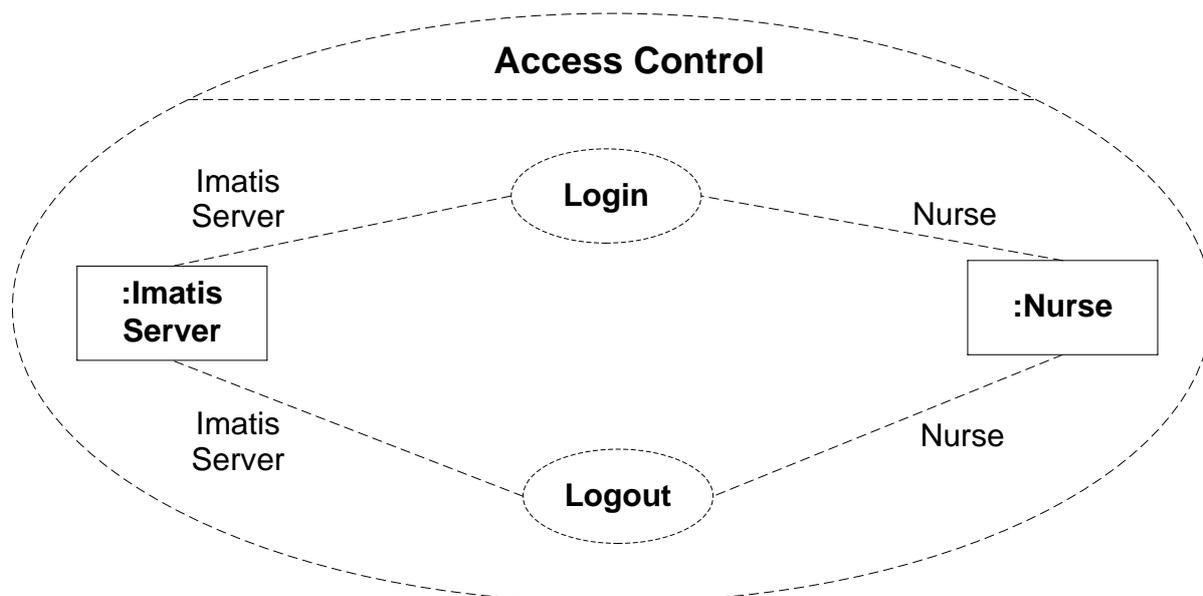
Figure 5.3: Access control collaboration diagram.

The *access control* sub-collaboration modeled on **Figure 5.3** consists of the *login* and *logout* elementary collaborations; its modeled behaviour shown on **Figure 5.4** might not be exactly the same as in the currently installed system, this is due to the lack of detailed knowledge about how Imatis handles logins (it might take place via Cisco and an external AAA server).
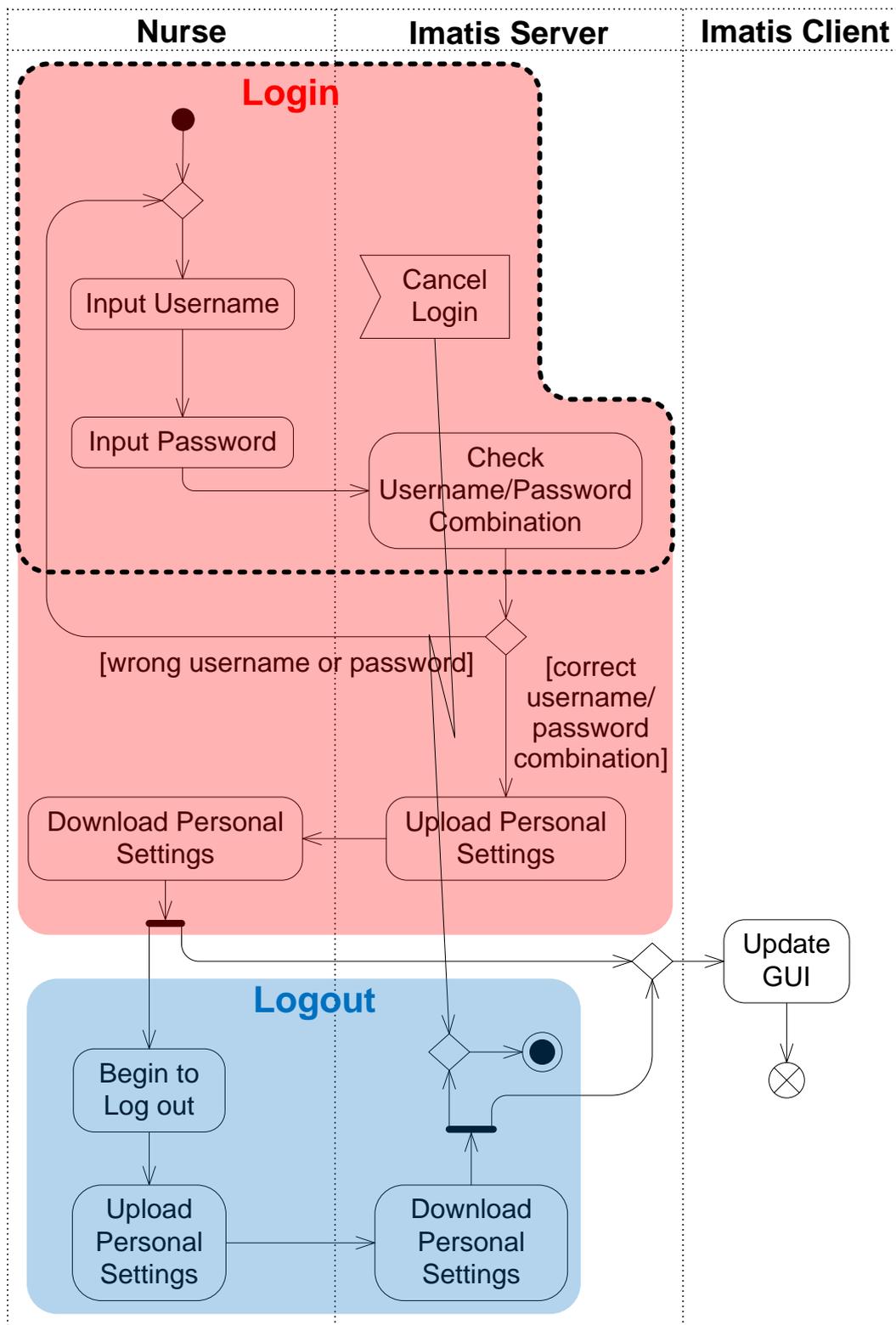
Figure 5.4: Access control activity diagram.

The *login* activity as currently modeled allows nurses to log into their accounts by inputting their username and password into any available IP phone, once these have been verified by the Imatis server no further input from the nurse is required; the system automatically download her personal settings from the Imatis server to her phone (these include text messages, address book, call history… but do *not* include sound profiles or specific configurations of the phone itself) so that a nurse can pick a different IP phone every day and keep her personal data. Once the log in process has finished the Imatis client updates its GUI to show that the nurse is now "online," at this point the system will "wait" until the nurse decides to log out. Once this happens the phone uploads her personal settings to the Imatis server (so that they can be retrieved the next time she logs in), and finally after she has logged out the Imatis client updates its GUI to show that the aforementioned nurse is now "offline."

The interruptible region allows a nurse to cancel the login procedure at any point before the phone has begun uploading her personal settings, once this has begun she has to wait for it to finish before she can log out.

5.3.2 Call plan manager
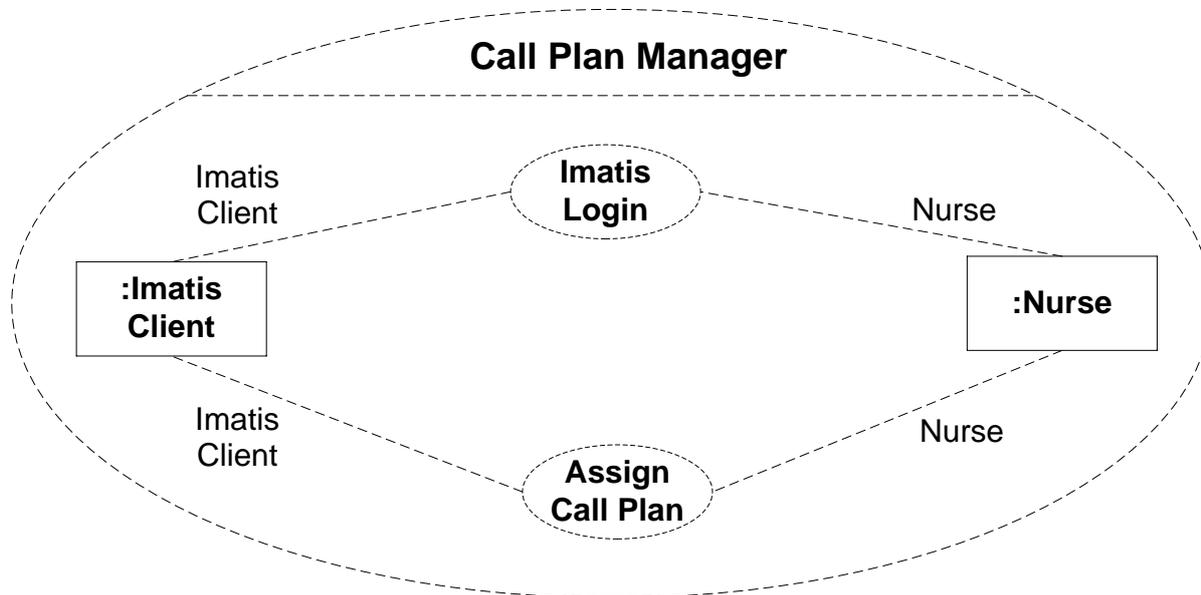
Figure 5.5: Call plan manager collaboration diagram.

The *call plan manager* sub-collaboration modeled on **Figure 5.5** consists of the *Imatis login* and *assign call plan* elementary collaborations; for the same reasons as in the *access control* sub-collaboration from **Figure 5.3** its modeled behaviour shown on **Figure 5.6** might not be exactly the same as in the currently installed system.
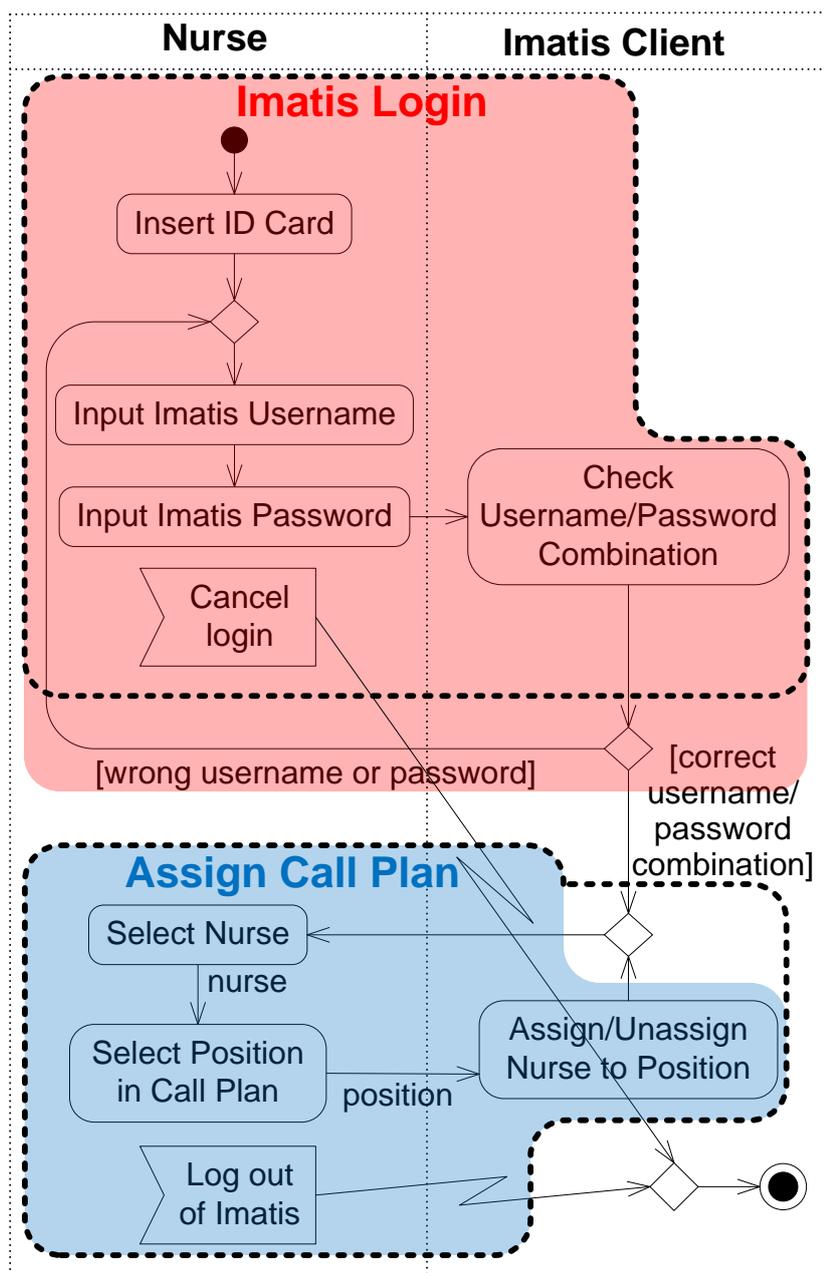
Figure 5.6: Call plan manager activity diagram.

After inserting her ID card into the keyboard slot of a computer running the Imatis client and inputting her username and password, the *Imatis login* activity will log a nurse into the Imatis client, and allow her to manage responsibilities in the call plan using the assign *call plan activity*. In order to update the call plan a nurse must be selected followed by the desired position in the call plan, if the nurse was already assigned to this position she'll be unassigned otherwise she'll be assigned to it.

The call plan is never "done" since the information is always partial and can be updated at any time, so once a nurse has been assigned or unassigned to a position in the call plan the

system will wait for another nurse to be selected until the nurse logs out of the Imatis client; at that time the activity will conclude. In a similar manner as in the *access control* activity a nurse might cancel the login procedure before logging in the Imatis client.

5.4   Request nurse call
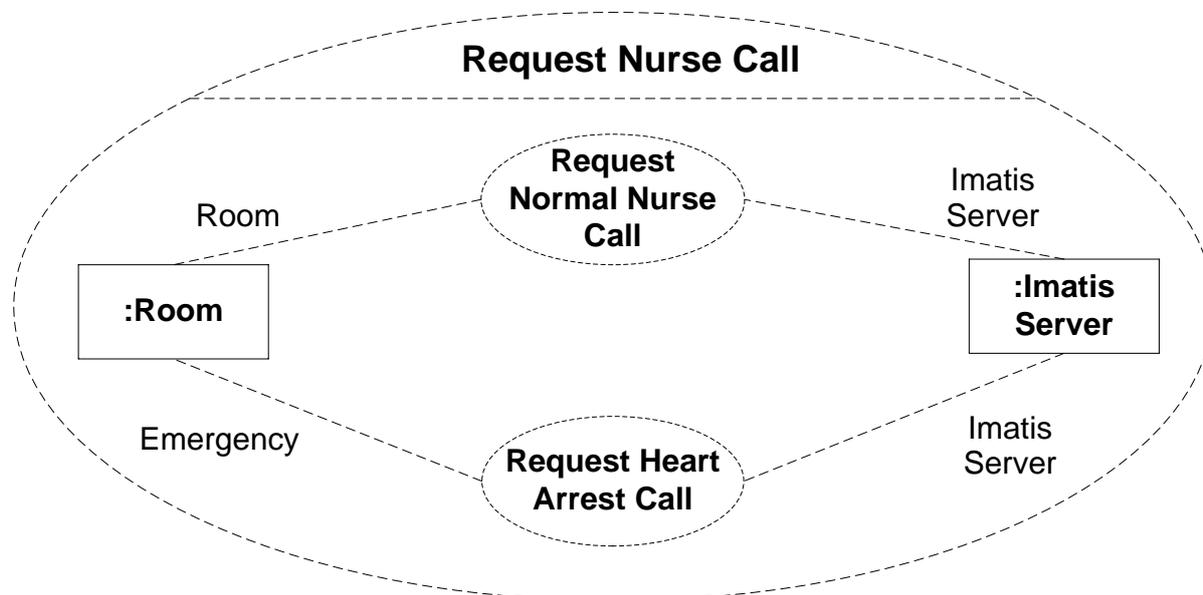
Figure 5.7: Request nurse call collaboration diagram.

The *request nurse call* sub-collaboration modeled on **Figure 5.7** consists of the *request normal nurse call* and *request heart arrest call* elementary collaborations. This division is due to nurse calls being requested differently depending on their type, but because the currently installed system doesn't differentiate between a call requested by pulling the signal cord, a call requested by using the patient terminal, and a call requested via the presence panel, this context information can't be used to infer who requested the nurse call (nurses tend to use the presence panel while patients use the other two); so at this point all normal nurse calls are considered to be requested from a room, without specifying by who.

Due to the sensitive nature of heart arrest calls and despite the fact that most fact that most heart arrest calls in some departments are not genuine (a patient might inadvertently press the red signal button), the system always treats them as emergencies and lets human intervention determine whether the heart arrest call was genuine or not.

5.5   Deliver nurse call
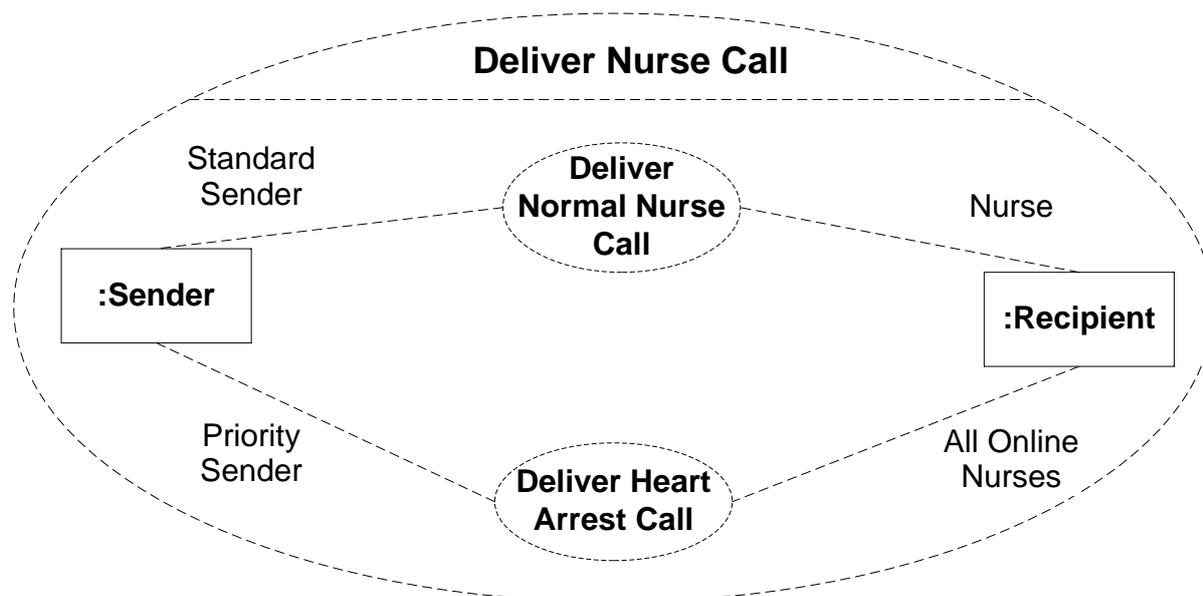
Figure 5.8: Deliver nurse call collaboration diagram.

The *deliver nurse call* sub-collaboration modeled on **Figure 5.8** consists of the *devilver normal nurse call* and *deliver heart arrest call* elementary collaborations. As seen previously on **Figure 5.1** after a nurse call has been requested it is delivered, but because not all calls are requested with the same priority they are delivered differently as well; heart arrest calls are delivered by "priority sender" (the Imatis server acting with priority) while normal nurse calls are delivered by "standard sender" (the Imatis server acting without priority). The other difference at this point is that normal nurse calls are delivered to nurses one at a time while heart arrest calls are delivered to all online nurses at once.

5.6   Respond nurse call
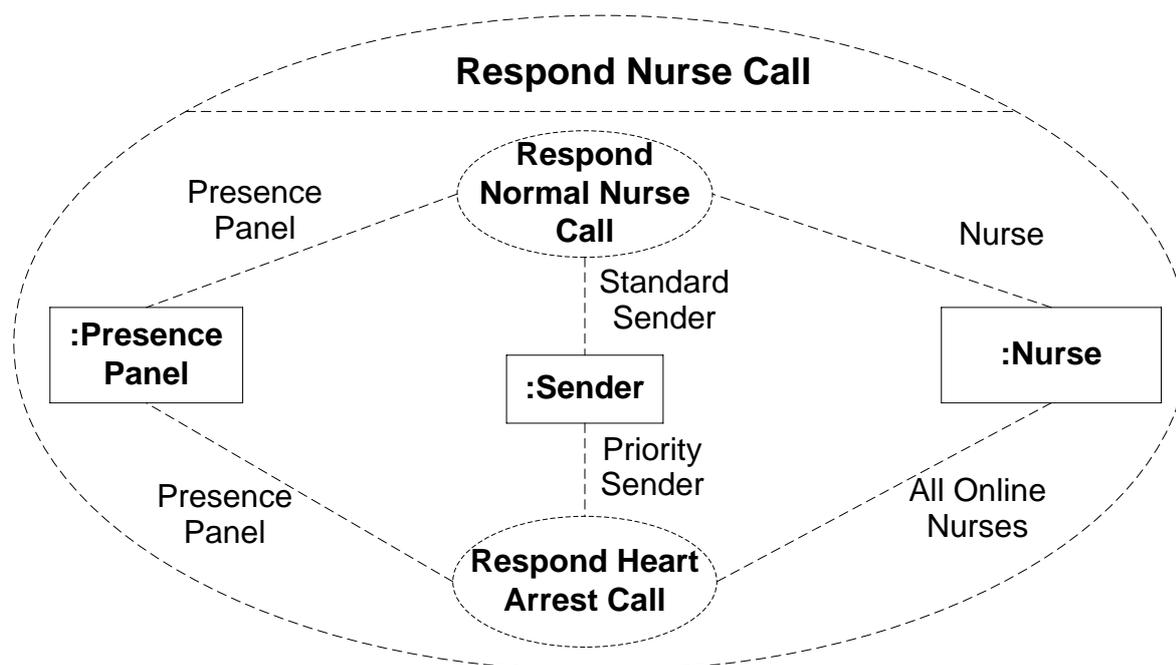
Figure 5.9: Respond nurse call collaboration diagram.

The *respond nurse call* sub-collaboration modeled on **Figure 5.9** consists of the *respond normal nurse call* and *respond heart arrest call* sub-collaborations. Nurse calls are also responded differently depending on their type; while normal nurse calls are generally responded to by only one nurse, heart arrest calls are responded to by multiple nurses (since all nurses set as online receive the call they might all respond to it). Since the different types of calls are delivered with different levels of priority they are continued to be treated with the same priority within the *respond nurse call* part of the system.

5.7   Behaviour of normal nurse calls

The behaviour of normal nurse calls has been modeled on **Figure 5.10**; normal nurse calls begin by being requested from a room, once that happens the Imatis server checks which room the nurse call has originated from (this action is done without priority, which is why it belongs to the "standard sender"). Once the room has been identified the Imatis client's GUI is updated and a nurse is requested (see **section 5.7.1** for further information), once a nurse has been obtained the nurse call is send to her IP phone.

Upon receiving the nurse call a nurse has 15 seconds to decide whether to accept or reject the call, and in the event that the nurse call wasn't delivered or that a response wasn't received

within the aforementioned timeframe the system will treat the nurse call as rejected and will request another nurse to send the nurse call to.
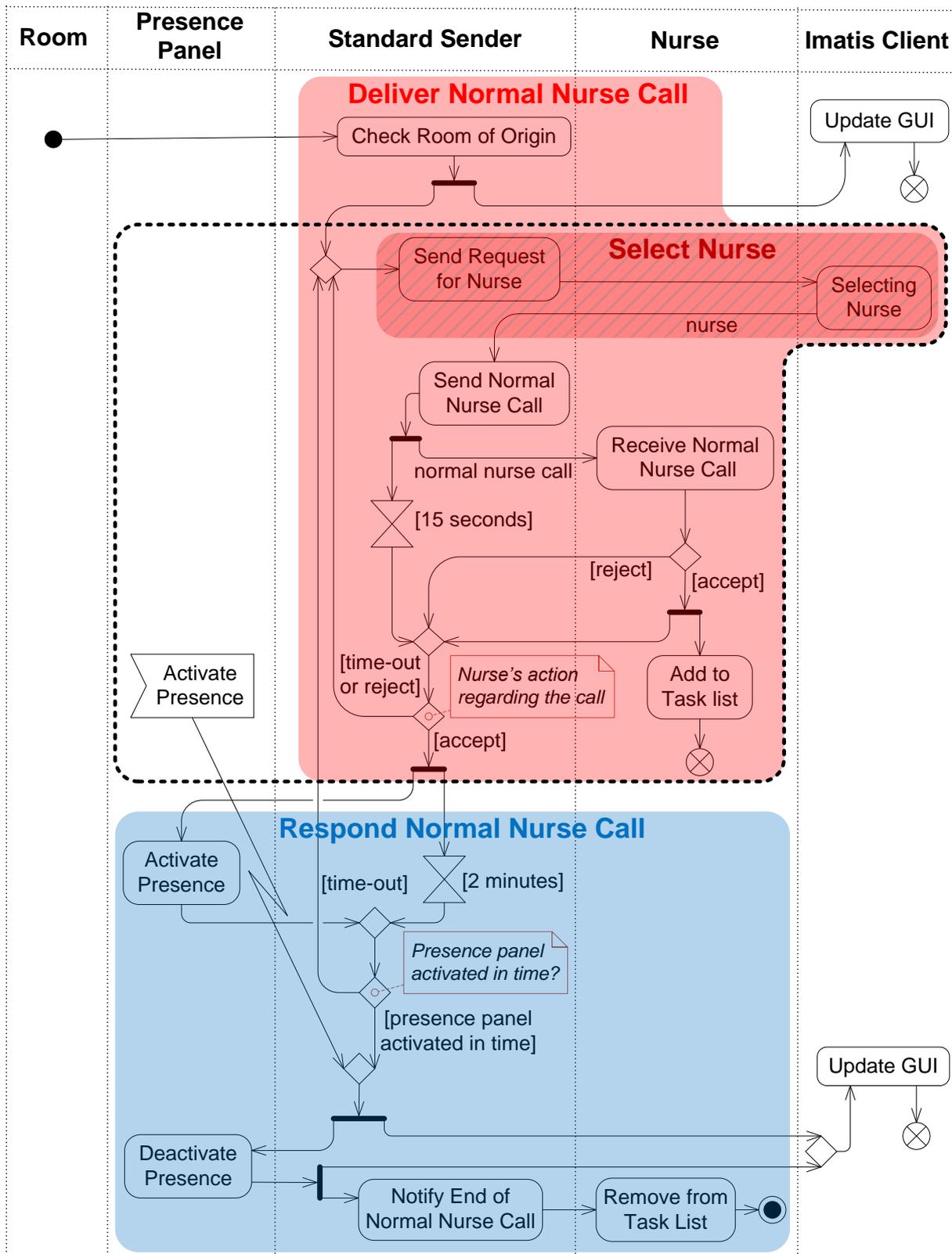
Figure 5.10: Normal nurse call activity diagram.

Once a nurse has accepted the call it is added to her task list locally (it can only be seen from her IP phone) and she has 2 minutes to activate the presence panel inside the room (the system can't tell who activates the presence panel, so as long as someone activates it within the given timeframe no further action will be taken), otherwise the system will request another nurse to send the nurse call to and wait for the call to be accepted again.

This represents the expected "call flow," but to accommodate the fact that the presence panel might be activated at any time, as soon as the presence panel is activated the system abruptly exits the *deliver normal nurse call* activity and enters the *respond normal nurse call* activity (which might result in the delivery of a nurse call being terminated before the 15 seconds time-out having been exhausted). At this point the Imatis client updates its GUI accordingly and the system proceeds to wait until the presence panel has been deactivated (the nurse is assumed to be dealing with the patient during this time, and hence the nurse call is still considered as being responded to); once the presence panel has been deactivated the nurse call is removed from nurse's the task list and the nurse call is considered to have been responded to; concurrently the Imatis client's GUI clears the room's status.

5.7.1 Select nurse

The *select nurse* activity has been modeled on **Figure 5.11** to be as similar as possible to the existing system, but as mentioned before an escalation feature hasn't been implemented, so *select nurse* will always select nurses within the same ward where the nurse call was issued.

Select nurse is independent for each nurse call, so it only takes into account which nurses have already been contacted for the nurse call that issued the *select nurse* activity.

In case of this being the first request issued for a nurse within this nurse call, the nurse assigned in the call plan to the room where the nurse call was requested from is chosen, if the room wasn't assigned a primary nurse then the nurse most directly below the room is chosen first (i.e.: the secondary nurse, or in her absence of the round robin starts).

If the chosen nurse is online then she is selected and set as contacted (this is an "inner" flag not visible anywhere outside this activity of which no log is kept once the nurse call has been responded to), the system then checks if all online nurses have already been set as contacted, and if that is the case they are all set as "not contacted" to prevent a possible "infinite loop" (in such a loop the system wouldn't be able to check any of the online nurse's because they had already been previously contacted, and wouldn't be able to set them as not contacted

because there was an offline nurse that hadn't been contacted which could not be set as contacted because she was offline); after this last check the *select nurse* activity concludes.
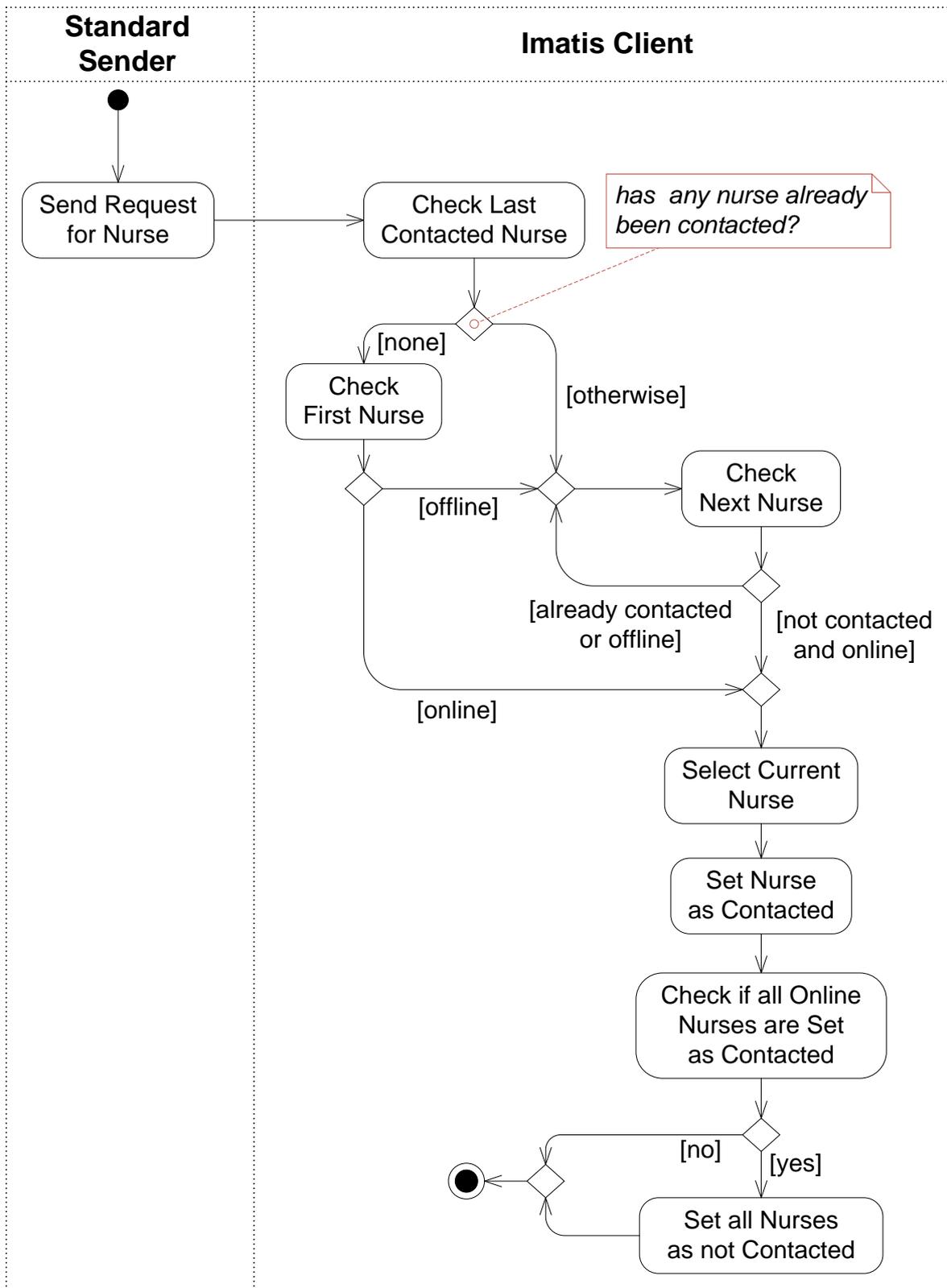
Figure 5.11: Select nurse activity diagram.

In case the chosen nurse is offline the nurse below her in the call plan is chosen instead and if she is online and hasn't been set as contacted (this has to been done in such a way because when the system enters the round robin a nurse can't be contacted again until all other nurses have already been contacted as many times as she has) she is then selected following the same procedure that has been described before.

This process will continue until an online nurse that hasn't been set as contacted is found, at which point she is chosen and the system checks whether all online nurses have already been contacted and acts accordingly, afterwards the activity concludes.

If this has not been the first request for a nurse within this nurse call, the nurse below the last nurse to have been selected will be chosen first according to the same procedure that has already been explained; thus the system follows the round robin protocol.

It should be noted that even though it might seem unlikely this implementation will select the same nurses as the currently installed system in *all* cases, even in situations such as the one depicted in **Table 5.1** that would "test" the system (the following call plan may easily exist on some wards).

Table 5.1: Example call plan that tests round robin compliance.

	Surname	Name	Nr	Online
Disp 1	Geriatri 4	Vikar 2	35141	Yes
Disp 2				
Disp 3				
Sengerom 43				
Sengerom 43_Disp				
Sengerom 44	Geriatri 4	Vikar 3	35132	Yes
Sengerom 44_Disp				
Sengerom 45				
Sengerom 45_Disp				
Sengerom 46	Geriatri 4	Vikar 4	35133	Yes
Sengerom 46_Disp				
Sengerom 50	Geriatri 4	Vikar 2	35141	Yes
Sengerom 50_Disp				
Sengerom 56	Geriatri 4	Vikar 2	35141	Yes
Sengerom 56_Disp				

In the currently installed system the nurses would be contacted in the following order: Vikar 3, Vikar 4, Vikar 2 [Repeat Cycle] (please refer to **Appendix A** for further details).

Whereas on the implemented system one might think that nurses would be contacted in the following order instead: Vikar 3, Vikar 4, Vikar 2, then Vikar 2, Vikar 3, Vikar 4, then Vikar 2, Vikar 3, Vikar 4... But that is not the case, because after all nurses have already been contacted they are set as not contacted and thus the system would "reset itself" and start with the primary nurse once again.

In case of no nurse in the call plan being online the system will "wait" (in reality it will keep looking for an online nurse) until one is; this has been implemented as a safety measure to ensure that no nurse calls will be lost due to no nurses in the call plan being online.

This model is based on a simple solution that emulates both the round robin and the secondary nurse while keeping the system as simple as possible.

5.8   Behaviour of heart arrest calls

The behaviour of heart arrest calls has been modeled on **Figure 5.12**; heart arrest calls begin by being requested in an emergency, once that happens the Imatis server checks which room the heart arrest call has been requested from (this action is done with priority, which is why it belongs to the "priority sender"). Once the room has been identified the Imatis client's GUI is updated and all online nurses are requested (see **section 5.8.1** for further information), once the nurses have been obtained the heart arrest call is send to their IP phones.

Once the heart arrest call has been received the IP phones won't stop ringing until the presence panel in room where the heart arrest call was requested has been activated; once this happens the heart arrest calls will cease to be delivered (the IP phones will stop receiving the heart arrest calls or if they hadn't begun to receive them yet they won't begin to do it). At this point the heart arrest is considered to still being responded to, and the system will wait until the presence panel has been deactivated (which should mean that the situation has been handled); once the presence panel has been deactivated the heart arrest call is considered to have been responded to and the Imatis client's GUI clears the room's status.
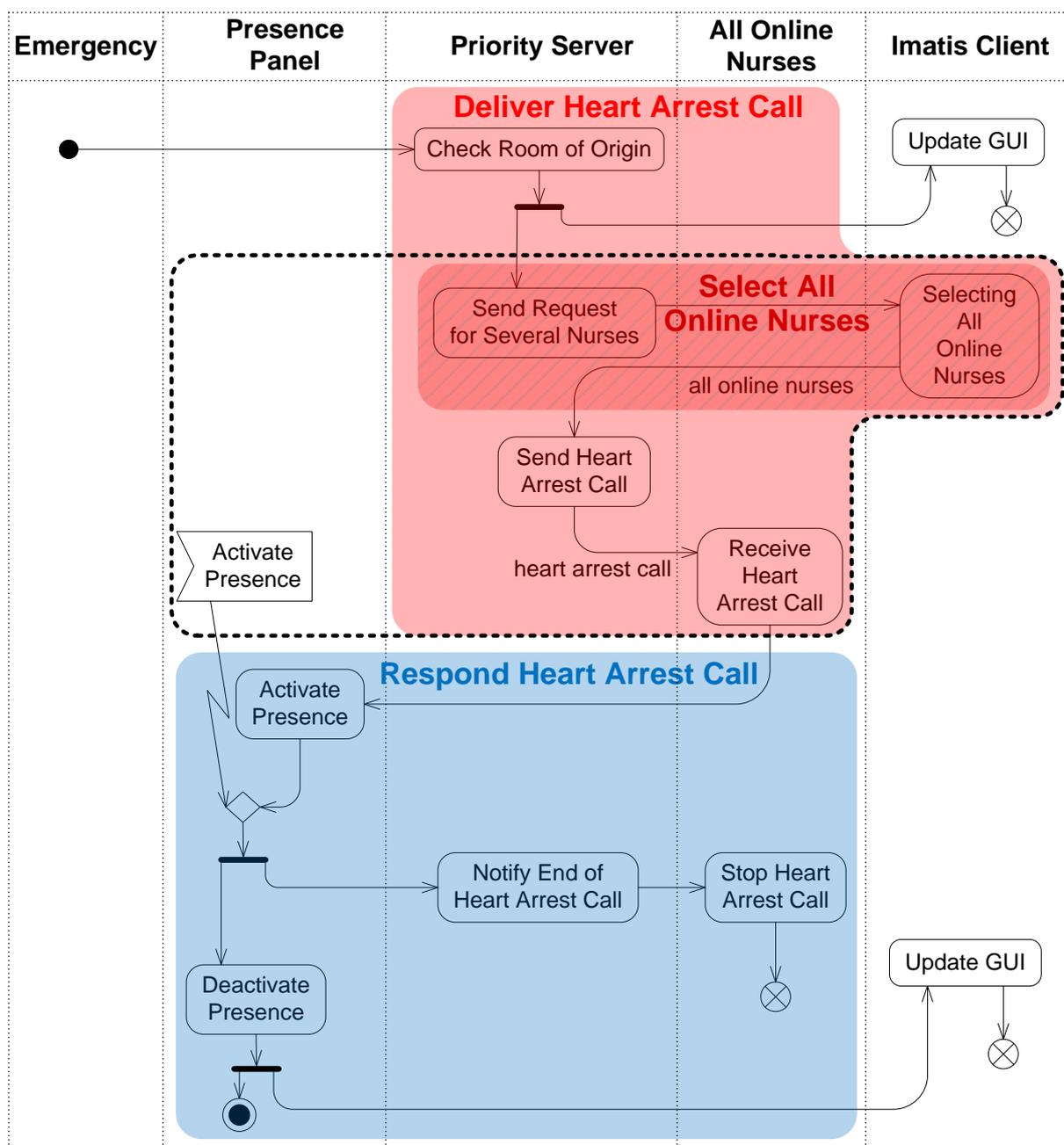
Figure 5.12: Heart arrest call activity diagram.

5.8.1 Select all online nurses

The *select all online nurses* activity has been modeled on **Figure 5.13** and despite appearances its behaviour is simpler than the one of the *select nurse* activity from **Figure 5.11**. Once a request for multiple nurses has been issued, the Imatis client simply checks all nurses in the call plan one by one to see if they are online and selects all those who are. Once this has been accomplished the *select all online nurses* activity concludes.
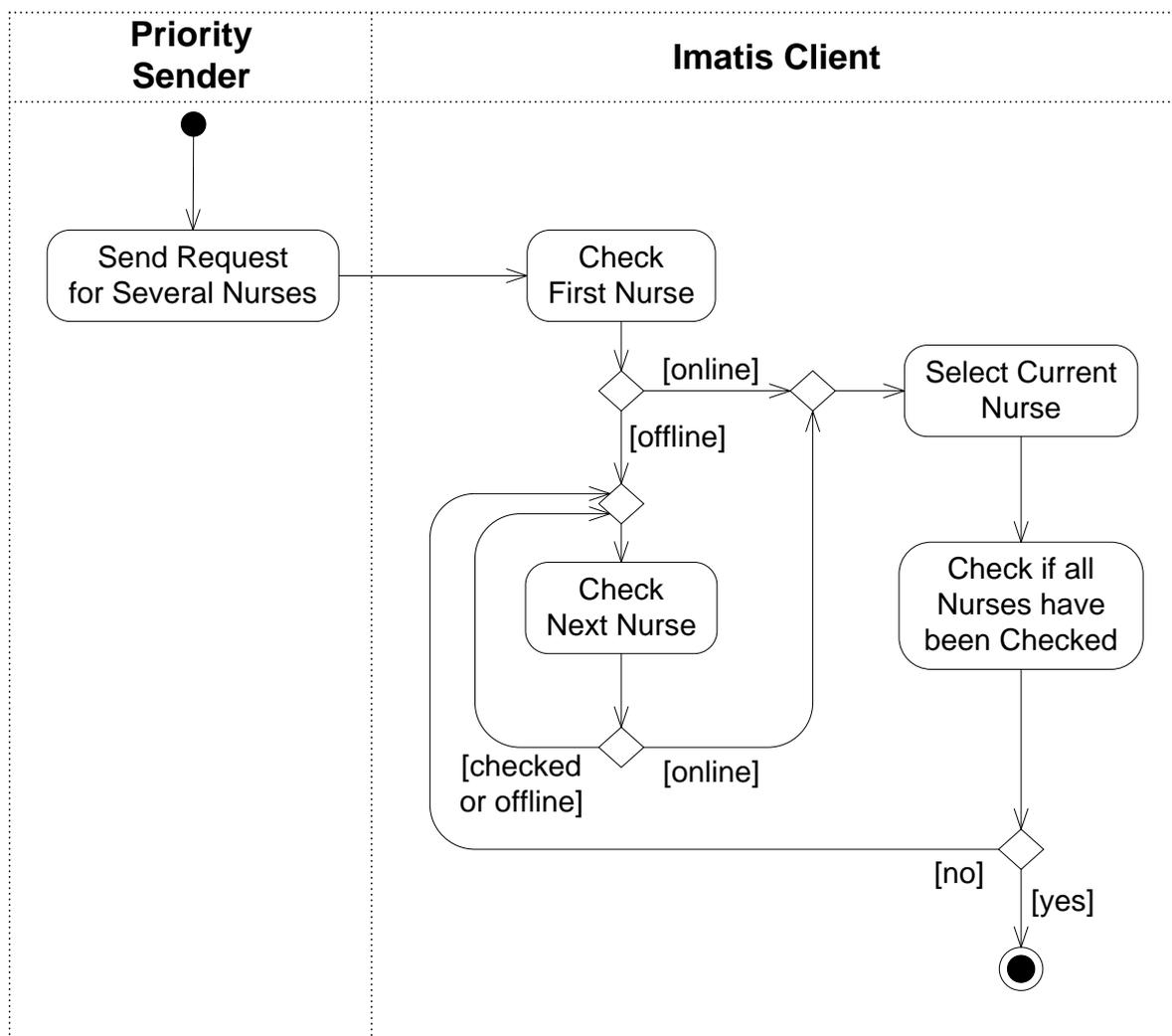
Figure 5.13: Select all online nurses activity diagram.

6 Modeling New Features in the Existing System

6.1 Introduction

Once the reengineered version has been modeled it's time to add the new features, which have been determined to be the *lunch break* and the *assistance call*.

6.1.1 Lunch break

The *lunch break* feature acts as an additional availability field, so that a nurse can be set as either available or not; in the latter case she won't any receive normal nurse calls or assistance calls, which should reduce the interruptions she suffers during her lunch break. The decision of having heart arrest calls delivered independently of a nurse's availability was made because of the sensitive nature of heart arrest calls, and due to the fact that most nurses have lunch in the ward or on the same floor.

Although it would have been possible to implement the lunch break so that it could be set by the nurses from their IP phones directly it was deemed better not to do so and "force" nurses to do it from the Imatis client instead. In order to facilitate the use of the *lunch break* feature the availability of any nurse can be changed from the call plan as shown on **Figure 6.1**, so

Figure 6.1: Example call plan with new availability field on the leftmost column (modified from St. Olav's 2009).

that any nurse can change any other nurse's availability; this could act as a "control mechanism" by prompting nurses to either go to the work station and change their availability status themselves or ask another nurse to change it for them.

If a nurse is available she'll be listed with a "Ja" (Norwegian for yes) on the availability field, otherwise there will be a "-" in the field, in the same way as the Imatis client displays whether a nurse is online or not.

On a side note, whenever a nurse logs in her phone, her availability is reverted back to "available," so instead of going to the Imatis client she can always log out and back in from her IP phone to change her availability from "not available" to "available" (given the time it currently takes a nurse to log in and out of her IP phone (please refer to **Appendix A.11** for further information) this way of changing availability is not expected to be used a lot, and has only been implemented as a way to ensure that in case a nurse inadvertently logs out of the system while being "not available," she will be available the next time she logs in.

Since the Imatis client is already being consulted by the Imatis server regarding the call plan, and in order to minimize how the lunch break feature affects the system as a whole, the Imatis client has been chosen to host this new availability field instead of adding an external presence server (in the latter case SIMPLE could be used as an external presence server, please refer to **section 4.3.1** for further information).

Some proper control mechanism could be added by limiting the lunch break duration (i.e.: using a timed lunch break as discusses by Sletten [2009]) or by limiting the number of times it could be activated each day (e.g.: setting a maximum of 2 lunch breaks per day), but it has been deemed more appropriate to see how the end users use the "standard" lunch break feature before modifying it further.

6.1.2 Assistance call

An assistance call is generated by pressing the red presence button on the presence panel while the presence panel is deactivated, and is intended to be used by nurses when they need help from another nurse. This modification also implies that whenever a normal nurse call is generated the patient will be more likely to have generated it that what was previously the case (please refer to **Appendix A.5** for further detail about how the fixed system differentiates between nurse calls requested via the presence panel or by pulling the signal cord).

It should be noted that the similarities between the way the *assistance call* has been modeled here and a workaround currently used by nurses whenever they need assistance with a patient (they deactivate the presence panel and request a nurse call with it immediately afterwards) are intentional, and should make assistance calls more approachable and user friendly to nurses, since they are already using a similar "workaround" in place (Koopman 2003).

With this implementation whenever a nurse receives an assistance call on her IP phone, the message displayed is distinctly different than those from normal nurse calls (albeit with the same options); this difference should easily make a nurse aware of the fact that another nurse is requesting help. Some models of IP phones, but *not* the one currently used by nurses would also allow themselves to be configured to play a different ringtone upon receipt of an assistance call (please refer to **Appendix A.14** for further information).

The Imatis client GUI has also been changed to show a "blue A" icon on a room where an assistance call has been generated to help differentiate them from other types of nurse calls, as depicted on **Figure 6.2**.

Figure 6.2: Imatis client GUI with a yet to be responded to assistance call on room #204 (slightly modified from Sletten 2009).

Since the fixed system is already able to differentiate between an assistance call and a normal nurse call it can be customized to treat them differently (different display messages, blink

codes, sounds...). Thus nurse calls generated from the presence panel (i.e.: assistance calls) could be changed with no further implementation needed (by selecting a different option from the BEST configuration settings) to play a different sound in order to be easily identifiable by nurses; they could also be changed to display a message that meant "assistance" on the display panels instead of the current one (this is less important since they display a different message than other nurse calls, but it might help nurses in training get acquainted with how the system works).

 A possible alternative to this proposed *assistance call* would be to allow it to be issued from the IP phones directly, in order to do that the task list could be modified so that once a nurse call was added to it, there would be an option to ask for further assistance, that way the system would already know where the assistance was needed. The downside of this method is that if a nurse visits a patient without having accepted a nurse call from that room she would be unable to use it to request an *assistance call*.

6.1.3 Similarities

Some of the collaborations and activities are exactly the same as in the reengineered version of the current system from **Chapter 5** so they won't be repeated in this chapter: *nurse call overview*, *select all online nurses* and *heart arrest calls*.

6.2   Nurse manager
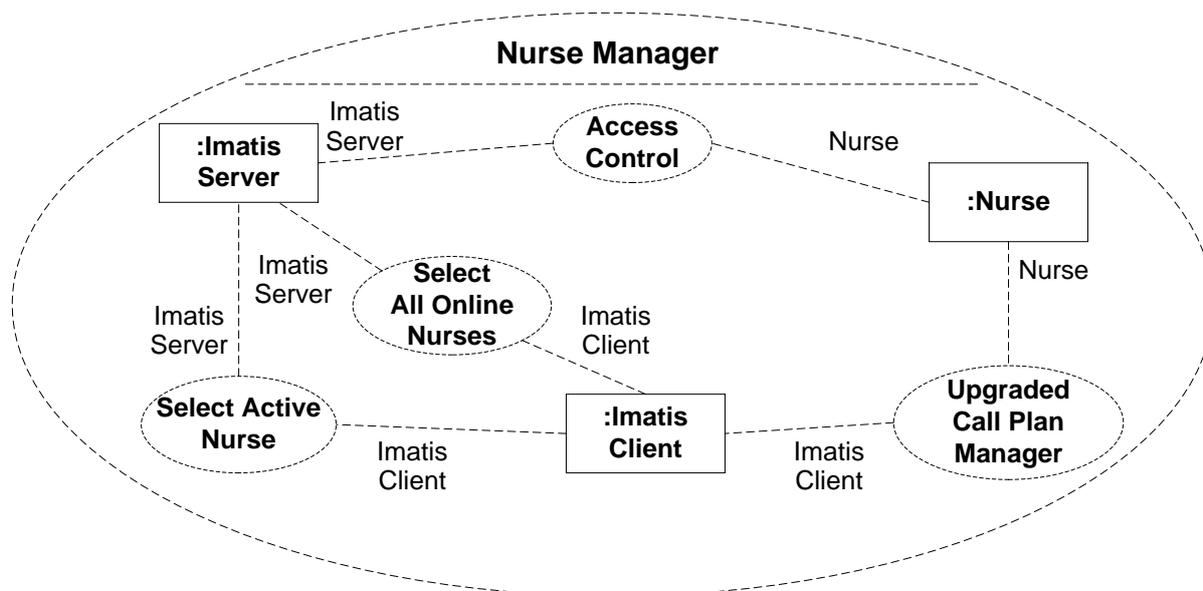
Figure 6.3: Nurse manager collaboration diagram.

The nurse manager modeled on **Figure 6.3** is very similar to the one from **Figure 5.2** with a change on two of the sub-collaborations, namely *call plan manager* is replaced by *upgraded call plan manager* and *select nurse* is replaced by *select active nurse* in addition to a small change on how the Imatis client treats the *access control* sub-collaboration. Although the name change might suggest otherwise the actual change in the behaviour of the replacing sub-collaborations has been minimized as much as possible and is examined in further detail in their respective sub-chapters and sections.

6.2.1 Access control

The *access control* sub-collaboration model is the same as the one from **Figure 5.3** and its modeled behaviour is also the same as the one shown on **Figure 5.4**; the only change is in how the Imatis client deals with the "update GUI" action. In this section in addition to setting the nurse as "online" once she has logged in, she will also be set as "available." This has been done to prevent nurses from inadvertently leaving themselves as "not available".

6.2.2 Upgraded call plan manager
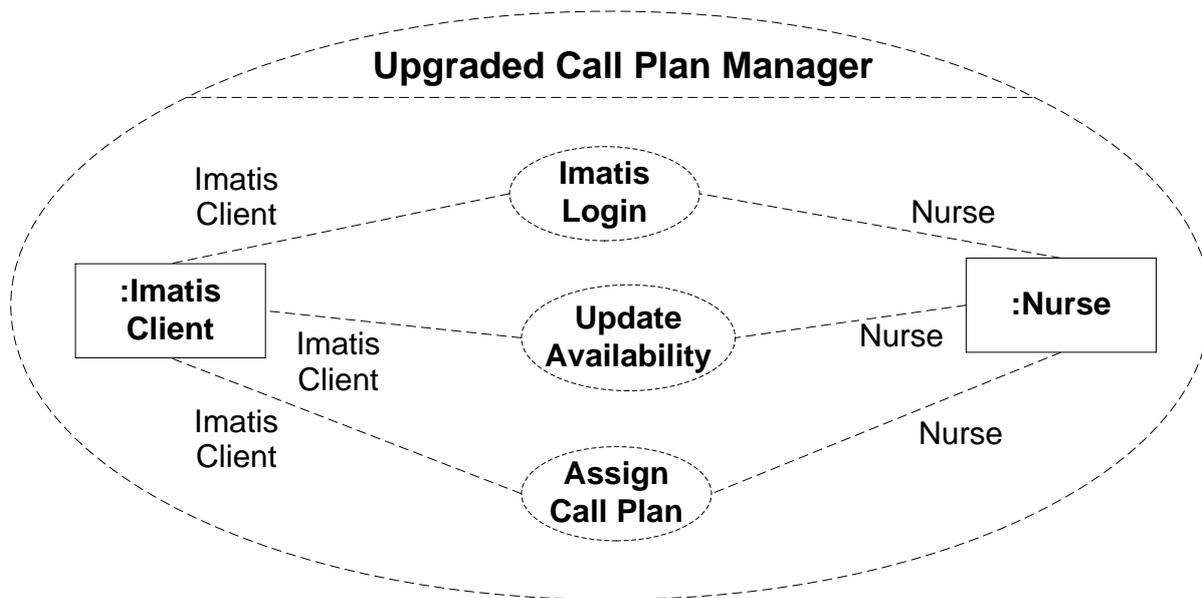
Figure 6.4: Upgraded call plan manager collaboration diagram.

The *upgraded call plan manager* sub-collaboration modeled on **Figure 6.4** is similar to the one from **Figure 5.5** with the addition of the *update availability* elementary collaboration; its modeled behaviour shown on **Figure 6.5** is similar to the one from **Figure 5.6**, with the inclusion of the *update availability* action. In this case after a nurse has logged in the Imatis client she'll have the option of changing her availability from "available" to "not available" or vice versa in addition to managing the call plan. This new option is the core of the new

lunch break feature; in order to change a nurse's availability, once a nurse is on the same screen where the call plan allocation takes place, she simply selects a nurse and the desired level of availability (currently there are only two options, available or not) and the availability level will be updated.
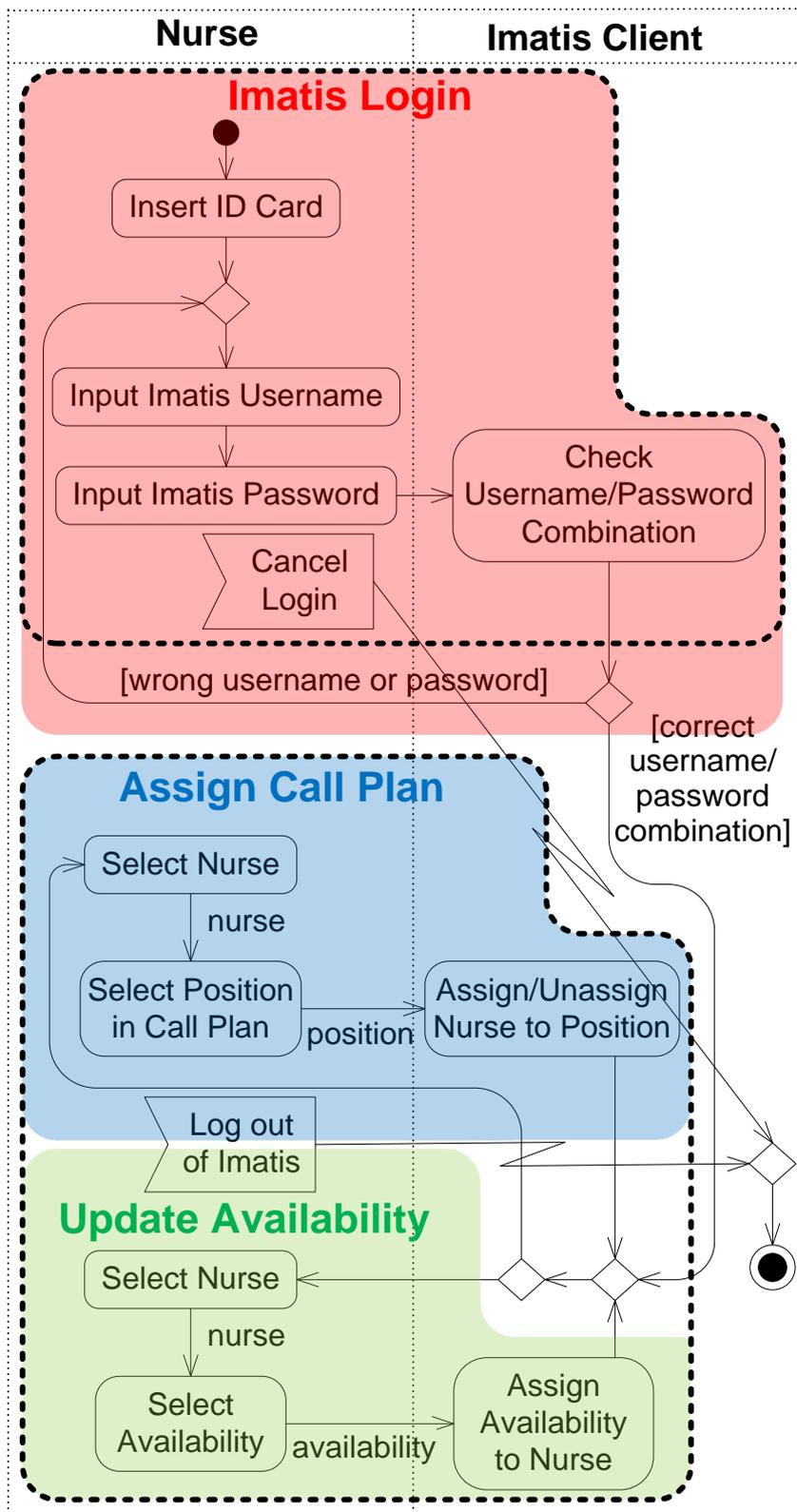
Figure 6.5: Upgraded call plan manager activity diagram.

The call plan hasn't been changed in any way, so that after having selected a nurse, selecting an availability level or a position in the call plan determines whether the call plan is updated or a nurse's availability is changed. Just as before the *lunch break* was implemented the call plan/update availability activity is never "done," so once a nurse has been selected and "handled" the system will wait for another nurse to be selected until the nurse logs out of the Imatis client; once the nurse has logged out time the activity will conclude.

6.3   Request nurse call
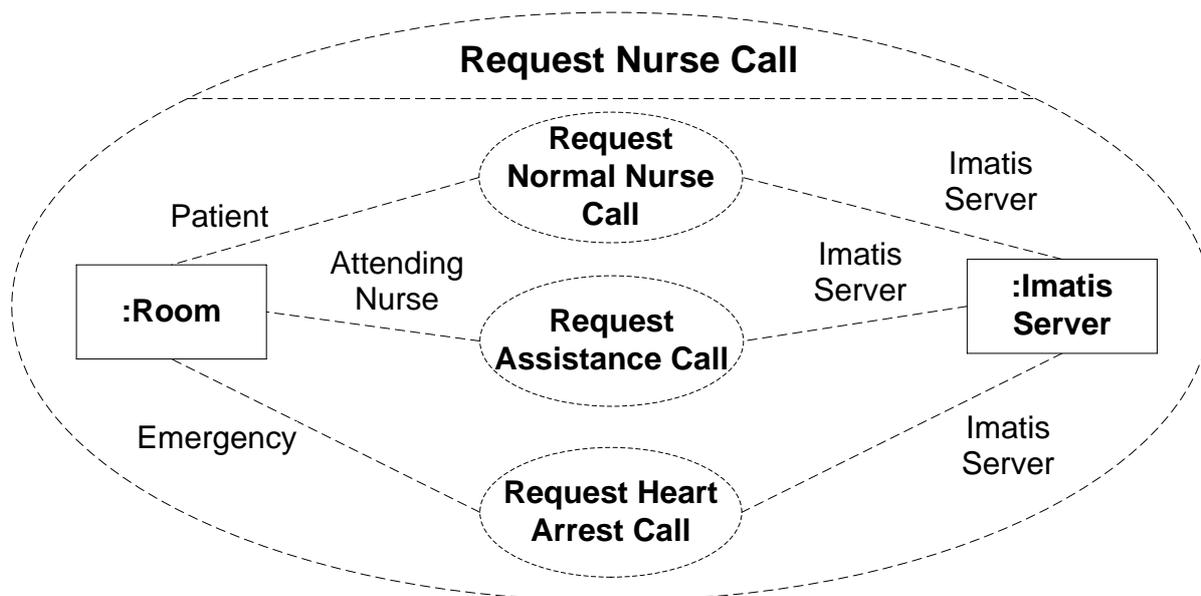
Figure 6.6: Request nurse call collaboration diagram.

The *request nurse call* sub-collaboration modeled on **Figure 6.6** is similar to the one from **Figure 5.7** with the addition of the *request assistance call* elementary collaboration, and a change of sub-role in the *request normal nurse call* elementary collaboration.

This addition represents the first part of the new assistance call feature, as mentioned before an assistance call supposed to be requested by a nurse; attending nurse is used as its sub-role to reflect that the nurse that has requested the assistance call has evaluated the situation and deemed that she needed help with the patient.

The change on sub-role in the *request normal nurse call* elementary collaboration is due to the fact that normal nurse calls are from now on assumed to be requested by patients.

As mentioned in this chapter's introduction the behaviour of heart arrest calls has not been modified in any way by the introduction of the two new features.

6.4   Deliver nurse call
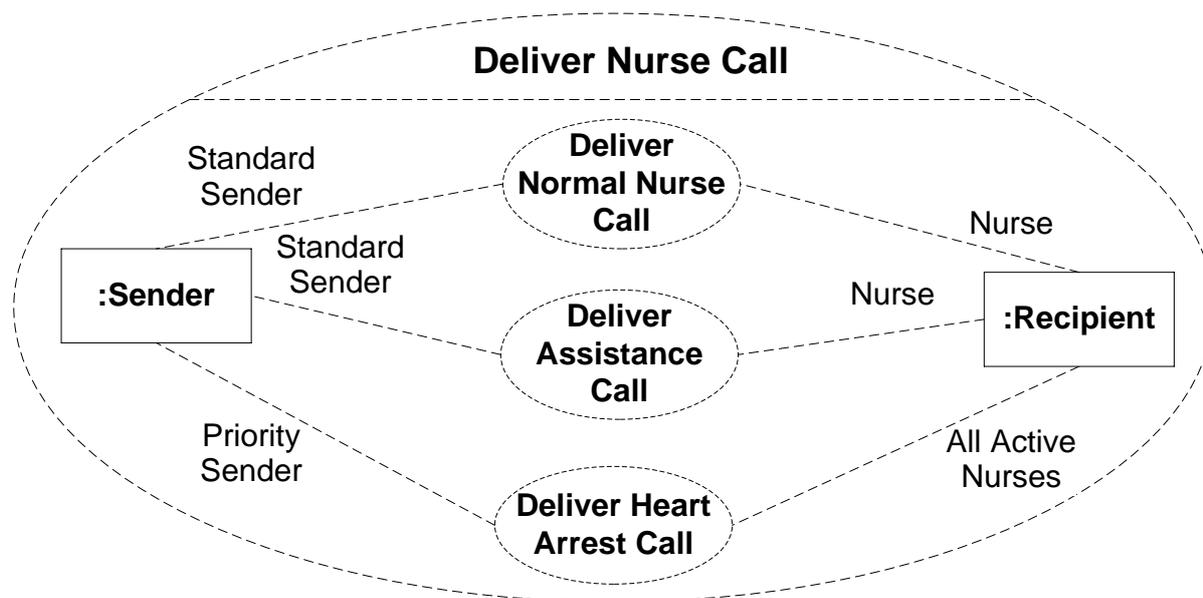
Figure 6.7: Deliver nurse call collaboration diagram.

The *deliver nurse call* sub-collaboration modeled on **Figure 6.7** is similar to the one from **Figure 5.8** with the addition of the *deliver assistance call* elementary collaboration.

This addition represents the second part of the new assistance call feature; assistance calls are treated without priority, (if it was an emergency a nurse would have requested a heart arrest call instead of requesting an assistance call) and delivered to nurses one at a time.

6.5   Respond nurse call
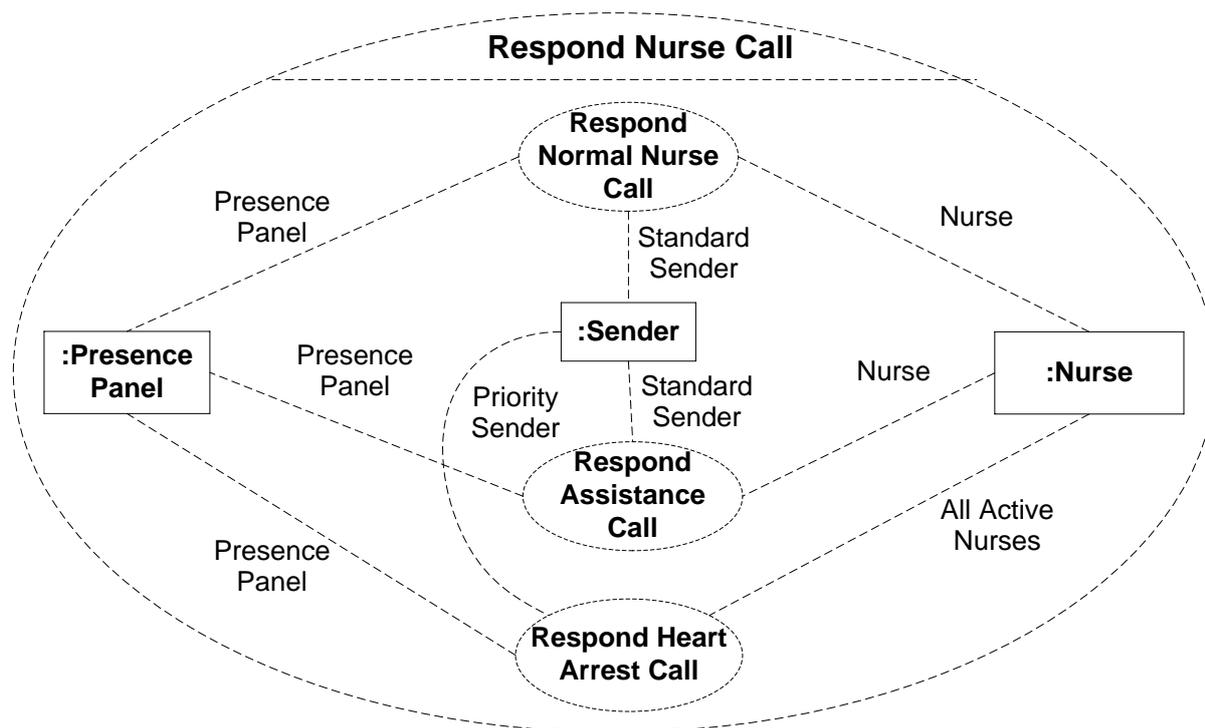
Figure 6.8: Respond nurse call collaboration diagram

Despite appearances the *respond nurse call* sub-collaboration modeled on **Figure 6.8** is very similar to the one from **Figure 5.9** with the only change being the addition of the *respond assistance call* elementary collaboration.

This addition represents the third part of the new assistance call feature; since assistance calls are treated without priority they will continue to be treated without it within the *respond nurse call* part of the system.

6.6   Behaviour of normal nurse calls

The behaviour of normal nurse calls modeled on **Figure 6.9** is very similar from the one from **Figure 5.10**; the only two changes are the fact that normal nurse calls are now considered to be requested by a patient, and *select active nurse* activity replacing *select nurse* activity (*select active nurse* is explained in further detail in **section 6.6.1**). For all other intends and purposes its behaviour is identical as it was before the new features were added.
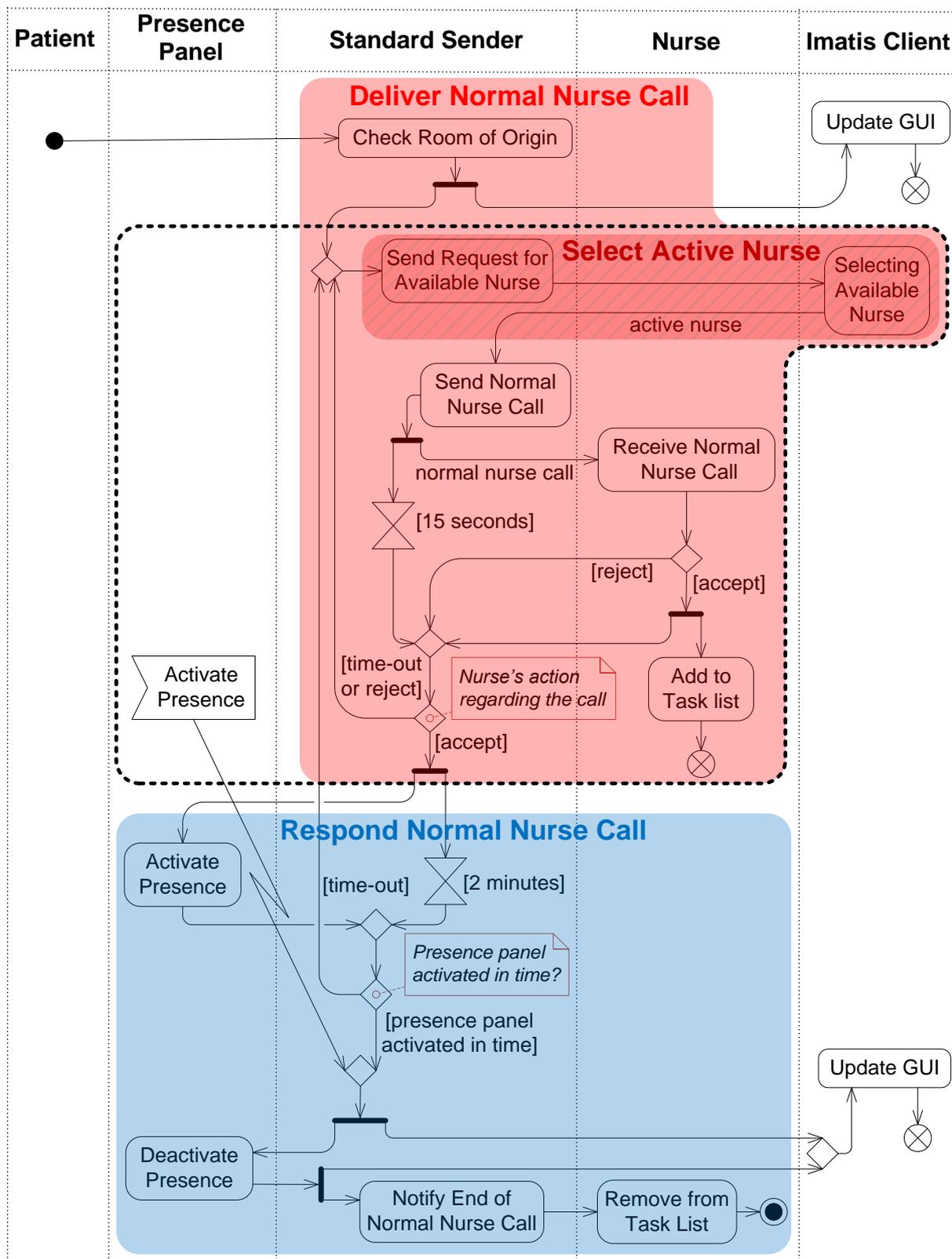
Figure 6.9: Normal nurse call activity diagram.

6.6.1 Select active nurse

The *select active nurse* activity modeled on **Figure 6.10** is quite similar to the one from **Figure 5.11**; the difference lies in that it won't select a nurse unless her status is listed as
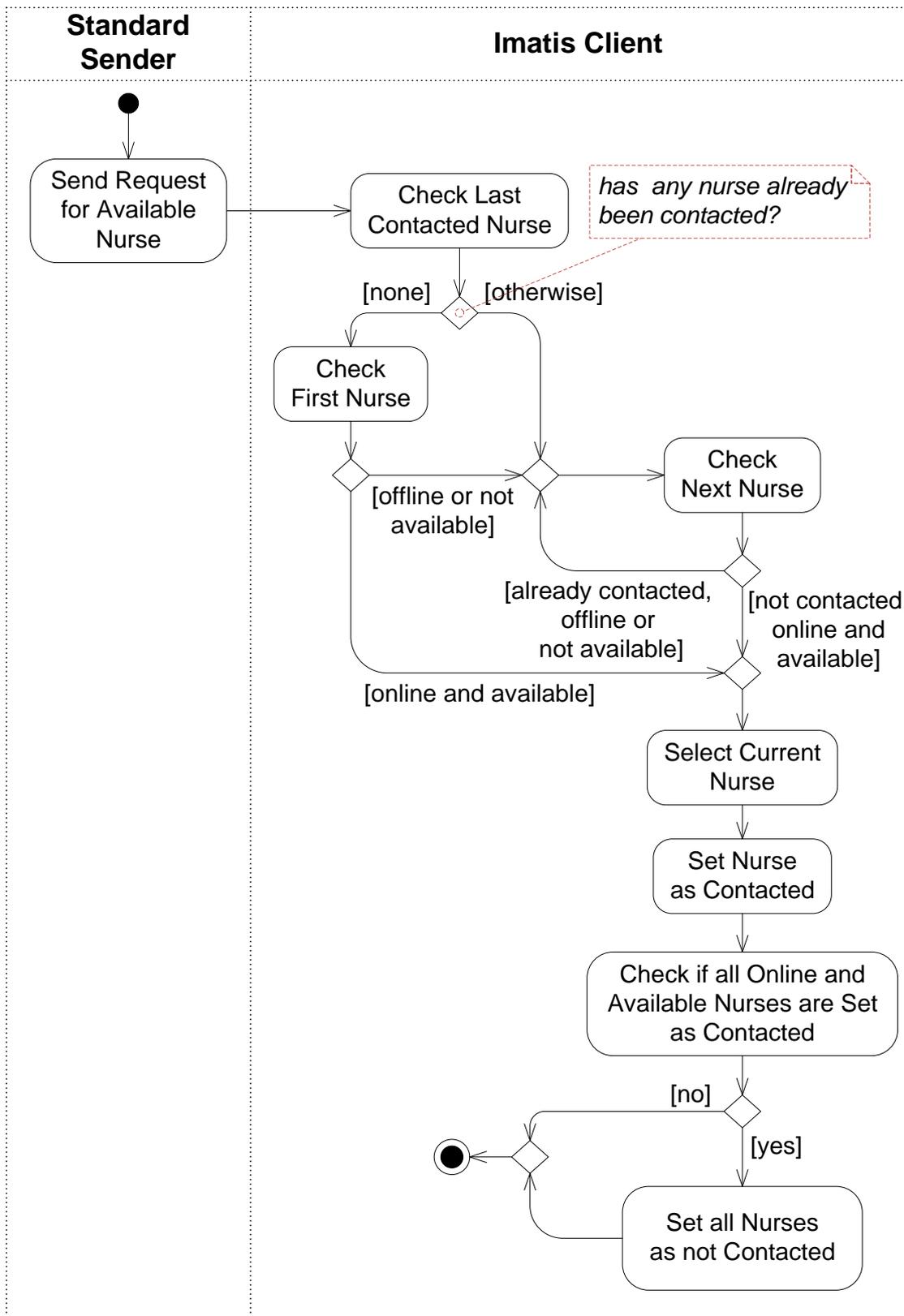
Figure 6.10: Select active nurse activity diagram.

$cxckrcdrg$0So whenever *select nurse* checked for an online nurse *select active nurse* will kpuygcf "ej gem for a nurse that is both online and available.

6.7   Behaviour of assistance calls

The behaviour of assistance calls modeled on **Figure 6.11** follows the same call path as normal nurse calls from **Figure 6.9**; nurses have the same options with them as they have
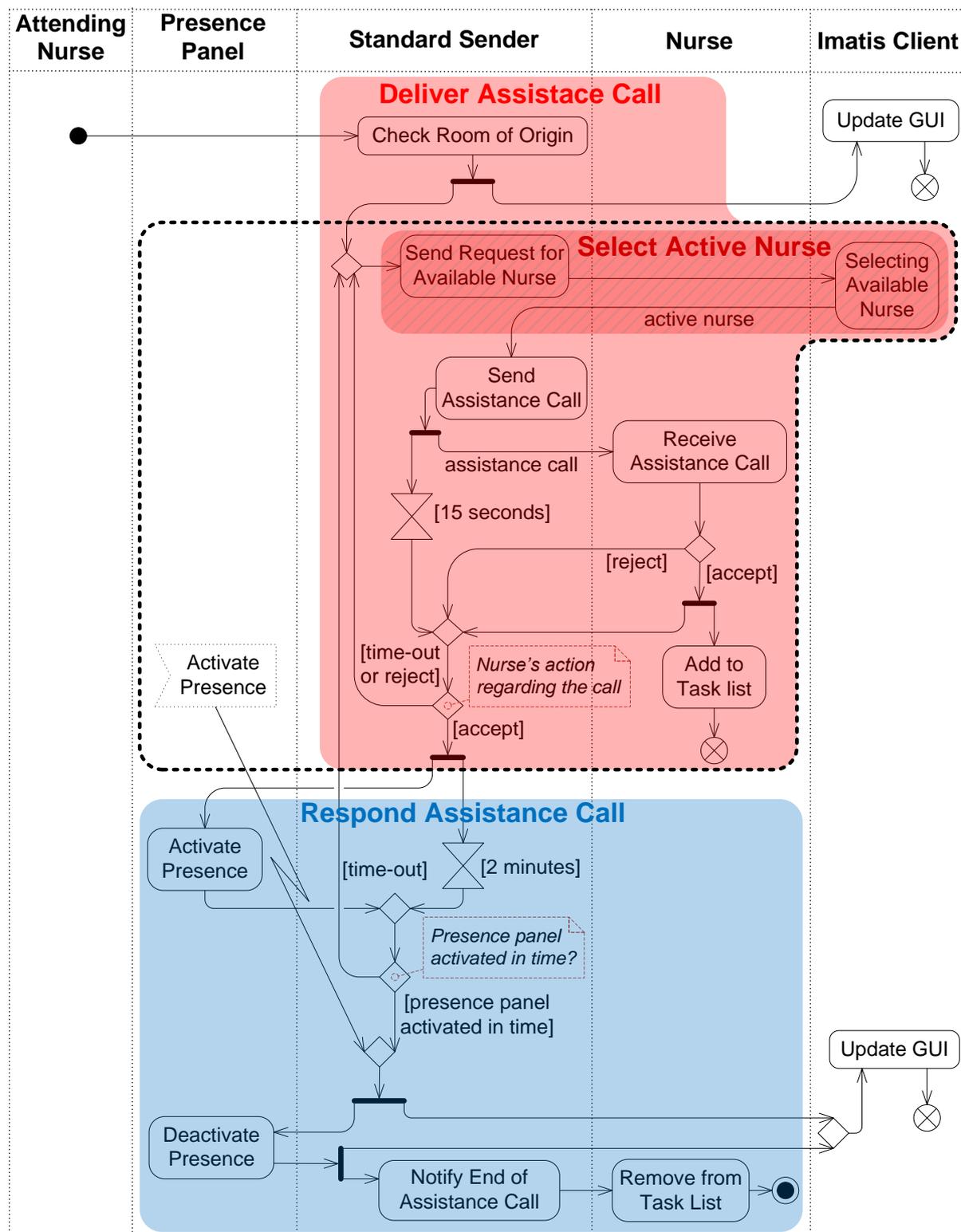
Figure 6.11: Assistance call activity diagram.

with normal nurse calls, they have the same time-constraints and have to be responded to in a similar manner: the nurse that requests assistance doesn't activate the presence panel but instead waits for the responding nurse to arrive and activate it.

The differences between the behaviour of normal nurse calls and assistance calls are listed below:

- Assistance calls are assumed to be requested by a nurse instead of a patient.
- Assistance calls are delivered to the nurses IP phones with a different message (e.g.: assistance needed in room #204).
- The Imatis client displays yet to be responded to assistance calls with a "blue A" icon.

The system doesn't know which nurse has requested an assistance call, and trying to infer such information from the last nurse that accepted a nurse call from that room won't work, mainly because there is no guarantee that the nurse that accepted the call was the one that visited a patient as part of her routine work and needed help with him.

7   Discussion of the Results

7.1   Discussion regarding the new features

Chapter 2 and Chapter 3 have helped cement the initial ideas behind the two new features implemented. Several studies have demonstrated that providing additional information with no apparent cost to the other party is almost always beneficial since it doesn't require additional effort for the initiating party but gives extra context to the situation (Grudin 1994).

The lunch break function provides a benefit to any nurse that updates her status: not being interrupted while on lunch break or being able to receive calls if she used to disconnect or leave her phone during lunch break and thus might warrant the effort of doing it (Grudin 1994). But if further impediments were placed, like forcing a nurse to log in the Imatis client with her own username in order to chance her availability, then nurses might choose to keep using the same work-around as they were before (leaving the phone on the work station on silent mode), and resign themselves to the fact that they might miss an important call during their lunch break that might have otherwise saved them a lot of time in the long run.

When a nurse receives an assistance call she might go to the room where the call was requested straight away even if she is not the primary nurse for that room; she might do that because she'll *know* that another nurse is asking for help whereas on the current system the same nurse might not go to the room until she gets the same nurse call twice or thrice. This is because continuity of care is important and since she has no information that can help her determine whether the primary nurse is busy elsewhere or not she has simply no way of knowing that the primary nurse is already in the room and needs help.

7.2   Discussion about wireless systems and their limitations

Trusting a wireless system too much can be just a minor inconvenience sometimes, but at other times, and more so in a setting as sensitive as healthcare it can be very serious. Since nurse calls are shown on the fixed nurse call system, nurses should keep an eye on it, in order to be able to use it as a redundancy; because if they do not do so what is going to happen when the wireless system fails?

The example below taken from an interview at a hospital should help illustrate the point of what may happen: *"We have wireless IP-phones, but suddenly the IP network fails. And we call ICT-support and tell them that we now have 3 patients without proper contact with the*

nurse call system, and that they must put priority on getting the IP-network up and running. ICT-support argues that the fixed nurse call system should work fine as a backup and that there is no urgent need for wireless nurse calls. We argue in several minutes before they realize that a change request in the fixed nurse call system is not carried out and that a small bed court area (mini-sengetun) is organised so that it is relying on wireless nurse calls and hence on IP for the whole weekend" (Kristiansen 2010c).

There are currently two issues concerning wireless nurse calls and their performance, the first is reliability which has been more or less addressed by most of the technologies presented in this thesis (MOSSA has not managed to address this one though), and the second one is the delays inferred on the wireless nurse calls, the smallest of which has been of 20 seconds (on the conventional paging systems of **section 2.4.1**); St. Olav's wireless system has shown the second smallest delay with a 32 seconds delay between the time a nurse call is requested and the time it is delivered to the first nurse. Such a delay renders the system unsuitable for heart arrest calls and other emergency situations, although a compromise might be reached where the wireless nurse call system is used along the fixed system so that heart arrest calls can be responded to in time, but in order to accomplish this nurses have to learn not to rely solely on the wireless part of the system.

Another issue related to wireless nurse calls are the increased availability offered by the devices that enable them, and the effects they have on the interruptibility of its users; but since the system implemented in this thesis deals with nurse calls only this hasn't been a real issue during the last two chapters, although it is something that could be further dwelt on in the future.

8   Lessons Learned, Conclusions and Further Work

8.1   Lessons Learned

After having been somewhat familiarized with nurse's work practice I realize that my intents when I tried to avoid losing any wireless nurse calls (**section 5.7.1**) due to no nurses being online in the call plan might have been contra productive, and may make nurses too dependable on the wireless system. Losing a few nurse calls in the wireless part of the system on the other hand may actually be alright, as it might help illustrate to nurses that the fixed system is an important part of the nurse call system (Kristiansen 2010a).

Although from an objective point of view trying to reengineer the whole system using Arctis remains as the best possible choice available at the time (January 2011), it might not have been the best one for me, since I did not have any previous experience in UML or the Arctis tool. Proof of that is that even though both the current system and the improved one with the new features have been fully modeled and characterized using UML 2.3 collaborations and activities, the Arctis version of them hasn't been completed.

The Arctis tool might also seem to be very intuitive but its interface is still lacking: sometimes creating something that should have been quite simple takes a lot of effort and time, also the lack of an undo button considerably lengthens the time it takes to create anything with it, as well as increasing the users frustrations every time he makes a mistake and presses "CTLR"+"z" in vain (it did increase mine at least).

Although there are a lot of open source alternatives available that allow the creation of UML diagrams, the painful truth that I've encountered after trying several of them is that what takes an hour to create using Microsoft Visio 2007 takes at least thrice as long and a lot of added frustration with the interface to create using any of them, and to top it off the diagrams created look much more visually appealing with Visio. I also want to add that despite the numerous warnings I received against using Microsoft Word to write my thesis I went ahead and used the 2010 version to write it; I must say that this has proven to be a smart choice for me, since I have found the process (once a few small details were solved) to be quite smooth and I have managed to keep the work-arounds used to a bare minimum (only to number the appendix figures the way I liked); in addition to that creating a PDF from the word version of the document while maintaining all the hyperlinks in place has proven to be far easier than expected.

8.2   Conclusions

Despite having failed to find a wireless system with a suitable level of delay for emergencies, it has been demonstrated that a combined fixed and wireless system like the one currently installed at St. Olav's Hospital, besides allowing for the speedy delivery of heart arrest calls can also provide a great combination of redundancy, context and mobility to its users. Thus it can be concluded that until wireless communication systems reach a maturity level that allows for the same level of reliability and speed than fixed systems, they won't be able to be used on their own for emergency purposes in healthcare; and even when that level of maturity is reached the context offered by a fixed system is hard to replicate using a mobile one, so even though cables might disappear from the fixed part of the system, there may still be used alongside mobile devices in order to provide context. The underlying fact is that users act in unpredictable ways, they can move a "mobile" system that wasn't supposed to be moved, but they can't move a sensor that is built into a wall, so "immobility" may sometimes be preferred on certain parts of a nurse call system.

The reengineered version of the existing system has been fully modeled and characterized using UML 2.3 activities and collaborations; also the new features that have been implemented into the reengineered version of the system should solve some of the issues nurses complained about and will hopefully increase their satisfaction once they have been implemented in the existing system at St. Olav's Hospital.

Increasing availability has also been proven to increase the level of susceptibility to interruptions which have been demonstrated to be a source of errors, regrettably a perfect balance between increased availability and excess interruptibility that minimizes these errors has yet to be found.

Since the different user groups in healthcare are so different satisfying, satisfying the wants and needs of all of them at the same time is all but impossible, and so a compromise that allows for a suitable level of satisfaction to be had by each of those groups has to be reached. The key is to figure what exactly constitutes a suitable level of satisfaction, and given the hierarchical nature of hospitals and the different value of time of each user group (Bardram 2000), this suitable level of satisfaction might not be the same for all them.

8.3   Further Work

Using the UML collaborations and activities developed in this thesis as a starting point the reengineered version of the system could be implemented using Arctis; the system could then work on Android based phones. Once the new features had been implemented a prototype system could be deployed at St. Olav's Hospital and integrated into the fixed system. On this deployment a phone with similar or better capabilities than the Ascom 9d24 MkII DECT phone (Ascom 2007) should be used in order to guarantee a good level of usability.

The lunch break feature could also be expanded to include other options that could help provide would be callers with further context that could reduce the level of interruptions. It is possible that if such context was made available to callers in a way that didn't require any effort from their part that they would use it in order to help them decide whether or not they should interrupt the other party.

In the following example the patient wanted some bread and called a nurse, but for some reason the nurse thought the call was an emergency and thus left what she had been doing; had she known that the call was a very minor issue she might not have left what she was doing and might have waited until she had finished in order to respond to the patient's call *"And there is no bread with the soup, and the patient is complaining that she has no bread, you know, and she [called] the nurse. The nurse is in the isolation room giving medications, and she thinks it is an emergency so she leaves the isolation room. [...]".* (McGillis Hall, Pedersen et al. 2010).

If the patient had known that the nurse was in an isolation room she might have decided to wait, so a presence system could be used to at least help alleviate the aforementioned issue so that a suitable level of satisfaction in this aspect might be reached by all the user groups.

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Appendices

A   Operating details of St. Olav's nurse call system

On September the 9th 2010 some tests were conducted on an empty bed court of the geriatrics department with the objective of finding out the exact behaviour of the installed system. The study was filmed and multiple chronometers were used to calculate the delays.

There were 3 terminals available for the test, as well as three usernames: Vikar 2, Vikar 3 and Vikar 4 (Vikar refers to a temporary employee).

A.1 General information necessary for the understanding of the study

The equipment displayed on **Figure A.1** and on **Figure A.2** is located in each patient room.

Figure A.1: Heart arrest button and signal cord (Sletten 2009).

Figure A.2: Presence panel on the door frame (Kristiansen 2010a).

The equipment displayed on **Figure A.3** is located at each work station in the new wards.

Figure A.3: Wall mounted display panel and the Imatis client (Sletten 2009).

In addition to this equipment each work station has a computer running the Imatis client which any nurse can to use to update the call plan and where the status of any nurse calls will

be displayed, **Figure A.4** offers a sample screenshot of how this program displays the status of any current nurse calls. As it can be seen nurse calls are letter and colour coded:

- Red "S": a nurse call has originated from that location.
- Red "H": a heart arrest call has been originated from that location.
- Green "T": a nurse has pressed the presence panel in that room.
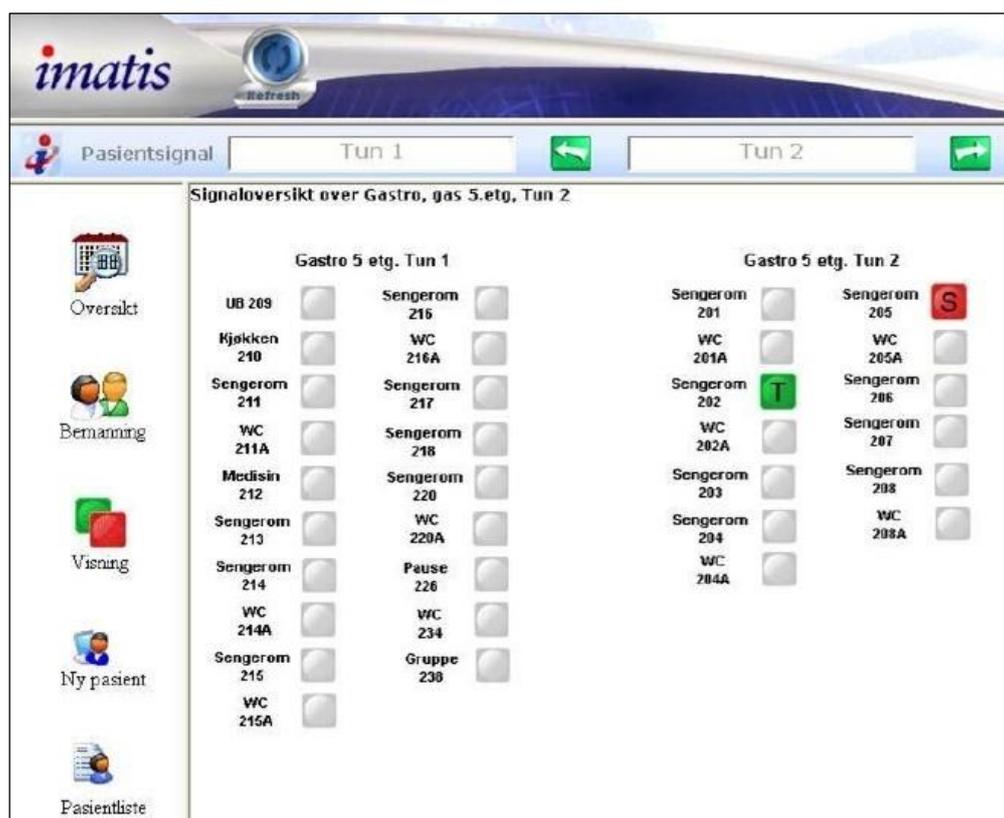
Figure A.4: Status of any active nurse calls (slightly modified from Sletten 2009).

Upon receiving a nurse call, the nurse may:

- Accept the call by pressing the accept button; doing this declares intent from the nurse to deal with the call within a given timeframe, which might vary from one department to another.
- Reject the call by pressing the reject button; doing this redirects the call to the following nurse, which will be the secondary nurse assigned to the room or the next nurse in the round robin.
- Do nothing; if a nurse has her hands busy or is otherwise unable to reach her phone, she can ignore the call, once this has gone on for a certain amount of time (by default 15 seconds) the call will be redirected to the next nurse as if it had been rejected.

A.2 Regarding the choice of test cases

The cases are *not* intended to be ordinary use cases illustrating nurse's behaviour. The cases shown in this appendix were tailored to check some technical details in the system, like what happens in unexpected situations such as: no nurse assigned to a room (**test case 2**), no nurse is accepting the call for a long period of time (several test cases), a nurse turning on the phone in the middle of a round robin (**test case 7** and **test case 8**)….

Issues raised by timing issues and "race conditions" such as when a nurse is about to accept the call when another nurse is entering the patient room…

A.3 Test case 1: First test of the round robin system using the cord

A call plan was manually set up in order to test the system as shown on **Table A.1**, and a nurse call was generated in room #44, this test case also simulated when nurses where busy and their phones were left to ring until the call was automatically redirected to another nurse by the system.

Table A.1: Cal plan used on test cases 1 and 2.

	Surname	Name	Nr	Online
Disp 1	Geriatri 4	Vikar 2	35141	Yes
Disp 2				
Disp 3				
Sengerom 41				
Sengerom 41_Disp				
Sengerom 43				
Sengerom 43_Disp				
Sengerom 44	Geriatri 4	Vikar 3	35132	Yes
Sengerom 44_Disp				
Sengerom 45				
Sengerom 45_Disp				
Sengerom 46	Geriatri 4	Vikar 3	35132	Yes
Sengerom 46_Disp				
Sengerom 50	Geriatri 4	Vikar 4	35133	Yes
Sengerom 50_Disp				
Sengerom 56				
Sengerom 56_Disp				

Results:

From the moment the nurse call was generated in room #44 by pulling the signal cord:

3 Seconds The wall mounted display on the work station displayed "044 SENG."

30 Seconds The Imatis client updated room's #44 status, with a red "S" on it.

31 Seconds Vikar 3 received the nurse call and ignored it.

46 Seconds Vikar 4 received the nurse call and ignored it.

61 Seconds Vikar 2 received the nurse call and ignored it.

76 Seconds Vikar 2 received the nurse call and ignored it.

91 Seconds Vikar 3 received the nurse call and ignored it.

106 Seconds Vikar 4 received the nurse call and ignored it.

121 Seconds Vikar 2 received the nurse call and ignored it.

125 Seconds Nurse call accepted by Vikar 2.

245 Seconds The system resumed the round robin where it had been left because 2 minutes passed since Vikar 2 had accepted the nurse call and the Imatis server hadn't registered the activation of the presence panel in the room.

245 Seconds Vikar 3 received the nurse call and ignored it.

250 Seconds Presence panel activated in room #44.

260 Seconds Vikar 4 received the nurse call and ignored it.

275 Seconds Vikar 2 received the nurse call and ignored it.

275 Seconds The Imatis client updated room's #44 status, with a red "S" on it.

280 Seconds The Imatis client updated room's #44 status, with a green "T" on it.

280 Seconds Vikar 2 stopped ringing mid call as soon as the Imatis server registered the activation of the presence panel in room #44.

Conclusions:

It took 3 seconds for the wall mounted display to register the nurse call, while the Imatis client took 30 seconds to update its status, which caused the information displayed on it to be inaccurate for a few seconds. Afterwards the Imatis server only took 2 seconds to initiate the round robin and deliver the nurse call to the first nurse, from then on the remaining nurses

received the calls almost immediately after the previous nurse had "done nothing" for 15 seconds or had rejected the call.

Since no secondary nurses had been assigned after the primary nurse had been contacted the round robin started by contacting the nurse situated directly "below" her in the call plan, afterwards the system contacted the nurse situated directly "below" the second nurse and so on, with the exception that no nurse would be contacted again until all other available nurses had been contacted. In this case Vikar 4 was contacted first, then Vikar 3, and then Vikar 4. After the first round since all available nurses had been contacted the round robin started again and contacted Vikar 2, then Vikar 3, then Vikar 4, and so on.

When the nurse call was accepted but the presence panel wasn't activated within 2 minutes the system resumed the round robin from where it had left it without restarting. And thus it contacted Vikar 3 instead of Vikar 2.

Although the system claims to support *"focused delivery of nurse calls,"* once the round robin restarted it didn't remind the nurse who had accepted the call or contact the primary nurse first, both of which would been more in line with that claim.

A.4 Test case 2: Second test of the round robin system using the cord

Using the same call plan as in **test case 1** and with the presence panel activated in room #44 a nurse call was generated in room #45 by pulling the signal cord.

Results:

From the moment the nurse call was generated in room #45 by pulling the signal cord:

3 Seconds The wall mounted display on the work station displayed "045 SENG."

3 Seconds The presence panel in room #44 displayed "045 SENG."

30 Seconds The Imatis client updated room's #45 status, with a red "S" on it.

32 Seconds Vikar 3 received the nurse call from room #45 and rejected it.

33 Seconds Vikar 4 received the nurse call from room #45 and rejected it.

34 Seconds Vikar 2 received the nurse call from room #45 and ignored it for a few seconds.

40 Seconds Nurse call from room #45 accepted by Vikar 2.

150 Seconds Presence panel activated in room #45.

160 Seconds The system resumed the round robin where it had been left because 2 minutes passed since Vikar 2 had accepted the nurse call and the Imatis server hadn't registered the activation of the presence panel in the room.

160 Seconds Vikar 3 received the nurse call and ignored it.

175 Seconds Vikar 4 received the nurse call and ignored it.

180 Seconds The Imatis client updated room's #45 status, with a green "T" on it.

180 Seconds Vikar 2 stopped ringing mid call as soon as the Imatis server registered the activation of the presence panel in room #44.

280 Seconds Presence panel deactivated in room #44.

310 Seconds The Imatis client updated room's #44 status by clearing it of any icons.

Conclusions:

It took 3 seconds for the fixed system to register the nurse call (both the wall mounted display and the presence panel), while the Imatis client took 30 seconds to update its status independently of whatever had changed. This delay was also present in the Imatis server and caused a nurse call to be delivered despite the fact that a nurse had already activated the presence panel in that room.

Since the room where the nurse call was initiated had no primary nurse assigned to it the round robin contacted first the nurse situated below that room in the call plan and then moved "down" along the call plan to contact other nurses as long as no nurse accepted the call.

A.5 Test case 3: First test of the round robin system using the red presence button

Using the call plan on **Table A.2** and with the presence panel activated in room #45 a nurse call was generated in room #46 by pushing the red button on the presence panel.

Note: "SENG" means bed and "SENGROM" bedroom.

Table A.2: Call plan used on test cases 3, 4, and 5.

	Surname	Name	Nr	Online
Disp 1	Geriatri 4	Vikar 2	35141	Yes
Disp 2				
Disp 3				
Sengerom 41				
Sengerom 41_Disp				
Sengerom 43				
Sengerom 43_Disp				
Sengerom 44	Geriatri 4	Vikar 3	35132	Yes
Sengerom 44_Disp				
Sengerom 45	Geriatri 4	Vikar 4	35133	Yes
Sengerom 45_Disp				
Sengerom 46				
Sengerom 46_Disp				
Sengerom 50				
Sengerom 50_Disp				
Sengerom 56				
Sengerom 56_Disp				

Results:

From the moment the nurse call was generated in room #46:

3 Seconds The wall mounted display on the work station displays "046 SENGROM."

3 Seconds The presence panel in room #45 displays "046 SENGROM."

30 Seconds The Imatis client updated the room status, with a red "S" on room #46.

32 Seconds Vikar 2 received the nurse call and rejected it.

33 Seconds Vikar 3 received the nurse call and ignored it for a few seconds.

40 Seconds Nurse call accepted by Vikar 2.

100 Seconds Presence panel activated in room #46.

130 Seconds The Imatis client updated the room status, with a green "T" on room #46.

Conclusions:

The fixed system differentiated between a nurse call generated by pulling the signal cord "SENG" and one generated by pressing the red button on the presence panel "SENGROM."

And since the Imatis system is connected to the BEST server (the fixed system), then the Imatis server could be modified in order to treat them in different ways as well.

The aforementioned feature exists because the system is prepared to handle hospitals with multiple beds per room. But given the fact that in certain isolation rooms there is a 3 button system identical to the one shown on **Figure A.5**, with the left button representing a normal nurse call, the middle button representing an assistance call (the nurse needs help with a patient), and the right button representing a heart arrest call.

Figure A.5: Three button panel used in some isolation rooms (Kristiansen 2010b).

The aforementioned feature could be redesigned to serve as an assistance call so that the nurse would get a different message on her phone and would thus know that there was a nurse present in the room who needed non-urgent help with a patient.

A.6 Test case 4: First test of multiple nurse calls

Using the same call plan as in **test case 3** and with the presence panel activated in room #46 two nurse calls were generated: the first one by pulling the signal cord in room #44 and the second one by pressing the red button on the presence panel in room #45.

Results:

From the moment the nurse call was generated in room #44:

3 Seconds The wall mounted display on the work station displayed "044 SENG."

3 Seconds The presence panel in room #46 displayed "044 SENGROM."

30 Seconds The Imatis client updated room's #44 status, with a red "S" on it.

32 Seconds Vikar 3 the nurse call from room #44 and rejected it.

33 Seconds Vikar 4 received the nurse call from room #44 and ignored it.

40 Seconds Red presence button pressed in room #45.

43 Seconds The wall mounted display on the work station displayed "045 SENGROM."

43 Seconds The presence panel in room #46 displayed "045 SENGROM."

From this moment the presence panel in room #46 started to alternate between displaying "044 SENG" and "045 SENGROM," while the wall mounted display panel on the work station displayed both calls.

48 Seconds Vikar 2 received the nurse call from room #44 and rejects it.

49 Seconds Vikar 3 received the nurse call from room #44 and ignored it.

64 Seconds Vikar 4 received the nurse call from room #44 and rejected it.

65 Seconds Vikar 2 received the nurse call from room #44 and ignored it.

70 Seconds The Imatis client updated room's #45 room status, with a red "S" on it.

70 Seconds Vikar 4 received the nurse call from room #45 and rejected it.

80 Seconds Vikar 2 received the nurse call from room #45 and ignored it for a few seconds.

80 Seconds Vikar 3 received the nurse call from room #44 and ignored it for a few seconds.

85 Seconds Vikar 2 rejected the nurse call from room #45.

89 Seconds Vikar 3 rejected the nurse call from room #44.

90 Seconds Vikar 3 received the nurse call from room #45.

90 Seconds Vikar 4 received the nurse call from room #44 and accepted it.

Conclusions:

When a phone was busy with a nurse call the system waited to send it to another one until the previous one had ended (by being ignored for 15 seconds, being rejected or being accepted).

In the event of multiple nurse calls both the active presence panels and the wall mounted displays alternated between them.

A.7 Test case 5: First test on nurse calls and heart arrest calls combined

Using the same call plan as in **test case 3** and with the presence panel activated in room #46 two calls were generated, first a normal nurse call by pulling the signal cord in room #44 and then a heart arrest call by pressing the red signal button in room #45.

Results:

From the moment the nurse call was generated in room #44:

3 Seconds The wall mounted display on the work station displayed "044 SENG."

3 Seconds The presence panel in room #46 displayed "044 SENGROM."

30 Seconds The Imatis client updated room's #44 status, with a red "S" on it.

32 Seconds Vikar 3 received the nurse call from room #44 and rejected it.

33 Seconds Vikar 4 received the nurse call from room #44 and ignored it.

40 Seconds Red signal button pressed on room #45.

43 Seconds The wall mounted display on the work station displayed "045 SENGROM."

3 Seconds The presence panel in room #46 displayed "045 SENGROM."

From this moment the presence panel in room #46 started to alternate between displaying "044 SENG" and "045 SENGROM," while the wall mounted display panel on the work station displayed both calls.

48 Seconds Vikar 2 received the nurse call from room #44 and ignored it.

63 Seconds Vikar 3 received the nurse call from room #44 and ignored it.

70 Seconds The Imatis client updates the room status, with a red "H" on room #45.

70 Seconds All nurses received the heart arrest call from room #45.

71 Seconds Presence panel activated in room #45.

101 Seconds The Imatis client updates room's #45 status, with a green "T" on it.

101 Seconds All terminals stopped ringing.

101 Seconds Vikar 2 received the nurse call from room #44 and accepted it.

Conclusions:

The heart arrest call had priority over normal nurse calls and the terminals didn't stop ringing until the Imatis served registered the presence panel as activated, after that normal nurse calls resumed the round robin as if the terminals had been ignoring the calls up to that point (that's why Vikar 2 received the nurse call from room #44 at T+101 seconds).

A.8 Test case 6: Logging out of the system

Vikar 3 logged out of the system and using the call plan on **Table A.3** a nurse call was generated in room #44 by pushing the red button on the presence panel

Table A.3: Call plan used on test case 6.

	Surname	Name	Nr	Online
Disp 1	Geriatri 4	Vikar 2	35141	Yes
Disp 2				
Disp 3				
Sengerom 41				
Sengerom 41_Disp				
Sengerom 43				
Sengerom 43_Disp				
Sengerom 44	Geriatri 4	Vikar 3	35132	-
Sengerom 44_Disp				
Sengerom 45	Geriatri 4	Vikar 4	35133	Yes
Sengerom 45_Disp				
Sengerom 46				
Sengerom 46_Disp				
Sengerom 50				
Sengerom 50_Disp				
Sengerom 56				
Sengerom 56_Disp				

Results:

The logging out procedure took approximately 50 seconds to complete.

From the moment the nurse call was generated in room #44:

3 Seconds The wall mounted display on the work station displayed "044 SENGROM."

30 Seconds The Imatis client updated room's #44 status, with a red "S" on it.

32 Seconds Vikar 4 received the nurse call and rejected it.

33 Seconds Vikar 2 received the nurse call and ignored it.

48 Seconds Vikar 4 received the nurse call and ignored it.

50 Seconds Vikar 3 started to log in.

… Vikar 2 & Vikar 4 alternated receiving the nurse call every 15 seconds

330 Seconds Vikar 3 finished logging in.

333 Seconds Vikar 2 received the nurse call and ignored it.

348 Seconds Vikar 3 received the nurse call and ignored it.

353 Seconds Vikar 4 received the nurse call and ignored it.

Conclusions:

Because Vikar 3 was logged out of the system, it was skipped from the round robin entirely, but in order to be included again in the round robin it was enough for her to log back in.

A.9 Test case 7: Turning off the phone

Vikar 3 turned off the phone and using the call plan on **Table A.4** a nurse call was generated in room #44 by pushing the red button on the presence panel.

Table A.4: Call plan used on test cases 7 and 8.

	Surname	Name	Nr	Online
Disp 1	Geriatri 4	Vikar 2	35141	Yes
Disp 2				
Disp 3				
Sengerom 41				
Sengerom 41_Disp				
Sengerom 43				
Sengerom 43_Disp				
Sengerom 44	Geriatri 4	Vikar 3	35132	Yes
Sengerom 44_Disp				
Sengerom 45	Geriatri 4	Vikar 4	35133	Yes
Sengerom 45_Disp				
Sengerom 46				
Sengerom 46_Disp				
Sengerom 50				
Sengerom 50_Disp				

Results:

From the moment the nurse call was generated in room #44:

3 Seconds The wall mounted display on the work station displayed "044 SENGROM."

30 Seconds The Imatis client updated room's #44 status, with a red "S" on it.

32 Seconds Vikar 3 received the nurse call and ignored it.

47 Seconds Vikar 4 received the nurse call and rejected it.

48 Seconds Vikar 2 received the nurse call and ignored it.

78 Seconds Vikar 4 received the nurse call and ignored it.

108 Seconds Vikar 2 received the nurse call and ignored it.

120 Seconds Vikar 3 started to turn on.

138 Seconds Vikar 4 received the nurse call and ignored it.

168 Seconds Vikar 2 received the nurse call and ignored it.

170 Seconds Vikar 3 finished turning on.

183 Seconds Vikar 3 received the nurse call and ignored it.

Conclusions:

Because Vikar 3 was logged in the system, it wasn't skipped from the round robin so it introduced a further 15 second delay. The system behaved as if the nurse was busy and waited until it hadn't received a response for 15 seconds to redirect the call to the next nurse. Once Vikar 3 was turned on again she was immediately reincorporated into the round robin as soon as her turn came around.

A.10 Test case 8: Taking out the phone battery

Vikar 3 took out the phone battery and using the same call plan as in **test case 7** a nurse call was generated in room #44 by pushing the red button on the presence panel

Results:

From the moment the nurse call was generated in room #44:

3 Seconds The wall mounted display on the work station displayed "044 SENGROM."

30 Seconds The Imatis client updated room's #44 status, with a red "S" on it.

32 Seconds Vikar 3 received the nurse call and ignored it.

47 Seconds Vikar 4 received the nurse call and rejected it.

48 Seconds Vikar 2 received the nurse call and ignored it.

60 Seconds Vikar 3 started to put the battery back into the phone.

78 Seconds Vikar 4 received the nurse call and ignored it.

108 Seconds Vikar 2 received the nurse call and ignored it.

120 Seconds Vikar 3 finished turning on.

123 Seconds Vikar 3 received the nurse call and ignored it.

Conclusions:

This presented the exact same behaviour as in **test case 7**, and thus from the system's viewpoint there was no difference between taking out the battery and turning off the phone.

A.11 Logging out versus turning off the phone versus taking out the battery

The only explanation as to why nurses take out the battery instead of turning off the phone is because it takes a little less time than to turning it off: removing the battery is instantaneous, and turning off the phone takes 3 seconds. It takes the same amount of time to get the phone on again, and you don't have to log in again once you turn the phone back on since both the Imatis system and the phone "remember you."

On the other hand it takes much longer to log in on the phone if you have logged out (depends on each user: size of the address book, stored messages…), while on the other hand turning off the phone or taking out the battery adds an extra 15 second delay to the round robin; all in all the disadvantages of logging out vastly outweigh its advantages which is probably why nurses only log out at the end of their shift.

A.12 Beep codes on the wall mounted display panel

The wall mounted display panel emitted different sounds depending on whether it was displaying a heart arrest call or a normal nurse call:

Heart arrest call: SHORT, SHORT, SHORT, SHORT, SHORT, SHORT, BREAK [repeat cycle] → (6 shorts + break).

Nurse call: LONG, BREAK [repeat cycle] → (1 long + break).

The beep codes in the documentation did not correspond with these and the nurses mentioned that they did not really understand them.

A.13 Red signal button

Some testing was done in the toilets, on which pressing the red signal button behaved identically as pulling the signal cord; both of them generated a normal nurse call, which was not according to the description in the training material.

In patient's rooms pressing the red signal button generated a heart arrest call, this change of behaviour coupled with the fact that the button is labelled "signal" might confuse some patients into thinking that it is a regular nurse call button instead of a heart arrest call one. Maybe renaming the button as alarm or something else, and making toilets behave as normal patient's rooms might help avoid confusions (no data was available as to how often a patient pressed the signal button by mistake).

A.14 User friendliness of Cisco Unified Wireless IP Phone 7921G

Both the heart arrest call and the regular nurse calls had different ringtones, on a personal opinion the heart arrest call seemed to have a greater sense of urgency and sounded more like an alarm would sound than the regular nurse call.

If a nurse received a nurse call while she was in the middle of a phone call the phone rang anyway, this was found to be very disturbing by most of the staff. The phone had a silent mode available, but when it was activated the phone vibrated for all types of calls not allowing a user to specify for which type of calls would use it (some nurses mentioned that they would like to be able to hear heart arrest calls while muting the others).

There wasn't a way to delete something written in a text message, the only way was to start over. Text messages couldn't be saved either and if a call was received while writing a message, the message was lost and had to be written again from scratch.

In addition to all that the phone was found to be quite bulky and heavy although it was quite sturdy and robust enough for hospital use.

Most of these issues could be solved by choosing a different phone; one that had been specially designed for certain environments (prisons, hospitals…) in mind such as the Ascom 9d24 MkII (Ascom 2007).

The aforementioned phone has 8 modes available for customization, allowing users to mute specific types of calls, configure when the vibrator will activate… thus enabling them to customize the phone in order not to be disturbed in certain situations, or unless a specific type of call was received. An overview of the different configuration possibilities is shown on **Figure A.6**, the alarm settings shown there are mainly used in prison environments so that the phone will activate an alarm in certain situations.
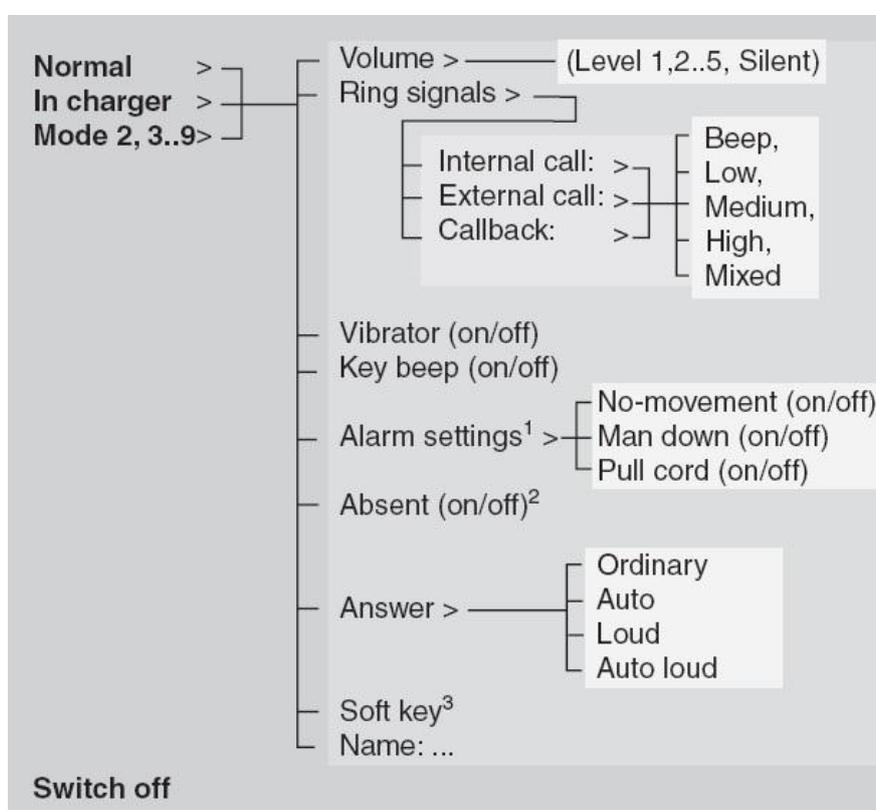

Figure A.6: Modes available to the Ascom 9d24 MkII DECT phone (Ascom 2007).

A.15 Conclusions

The fixed system has a 3 second delay in contrast with the 32 second delay of the Imatis system, on a personal note the aforementioned delay is tolerable most of the time with two notable exceptions: receiving a nurse call after the presence panel has been activated (a very undesirable interruption if the nurse that gets it is attending a patient), and emergencies (heart arrest calls) which are usually very time sensitive; for some case such as the acute caesarean section team the aforementioned delay is totally unacceptable.

The new wards at St. Olav's Hospital are very small and on the department where the tests were done conducted heart arrest calls were very infrequent and more often than not false alarms. This last issue is much more sensitive on night shifts (where less staff is available) and on other departments.

B   Tutorial on UML syntax and symbols[17]

B.1 UML activities

UML activities are well suited to indicate the behaviour of a system; the specific symbols used in the diagrams contained within this thesis are presented on **Figure B.1**.
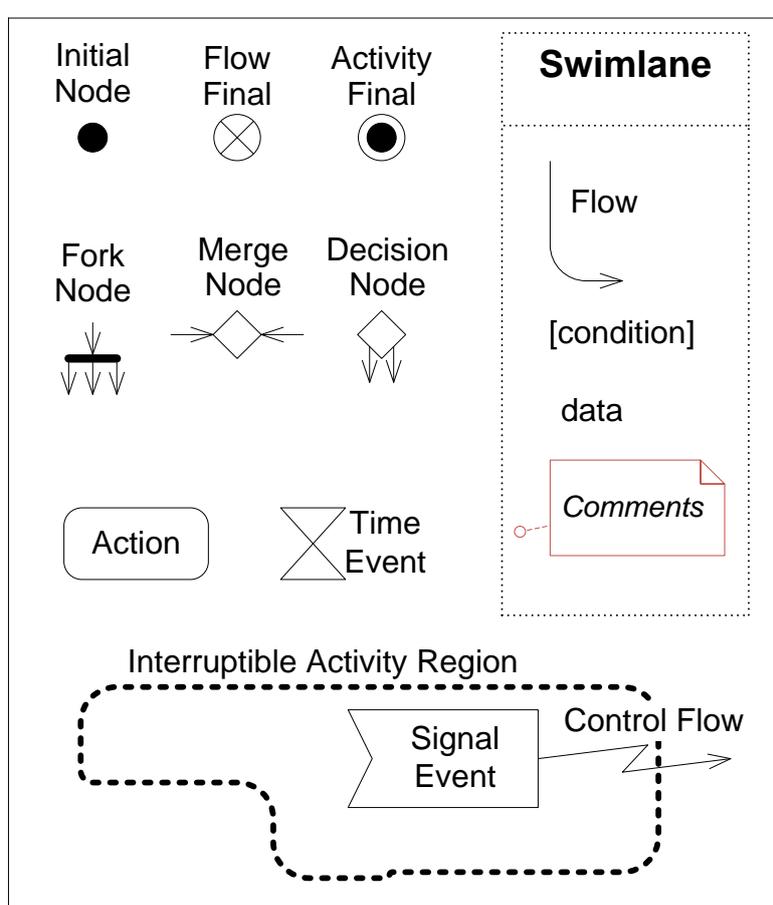

Figure B.1: Symbols used in UML activity diagrams

- A flow represents the "path" the activity takes.
- Conditions are written between [ ] and represent results from actions.
- Data is written without brackets and represents information send by an action.

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[17] This subchapter has been written using references from Kathayat, Le et al. (2010) and OMG (2010).

- Comments are meant to ease the understanding of some parts of the diagram.
- Initial Node depicts the beginning of the activity.
- Flow final depicts the ending of a particular flow but not of the activity since it might still be active in another flow.
- Activity final represents the conclusion of an activity.
- The fork node is used to split one flow into two or more concurrent flows.
- The merge node is used to combine two incoming flows into one outgoing flow, so that when either of the incoming flows enters the merge node the outgoing flow exits.
- The decision node is used to "guide" an incoming flow into one outgoing flow or another, depending on a decision taken beforehand.
- Time events are used to delay an incoming flow for a certain amount of time.
- Actions represent events that happen within the activity.
- An interruptible activity region is an area that can be interrupted at any time by a signal event, once that event happens all active flows within the interruptible region will be redirected to the control flow.
- Swimlanes are used to separate the activity diagrams in visual sections, each of them with its own swimlane which is labelled on top with the element responsible for the actions enclosed within.

Figure B.2 provides an example of an activity where a person asks someone else to go to the movies every day until the other person accepts or the cinema closes down.
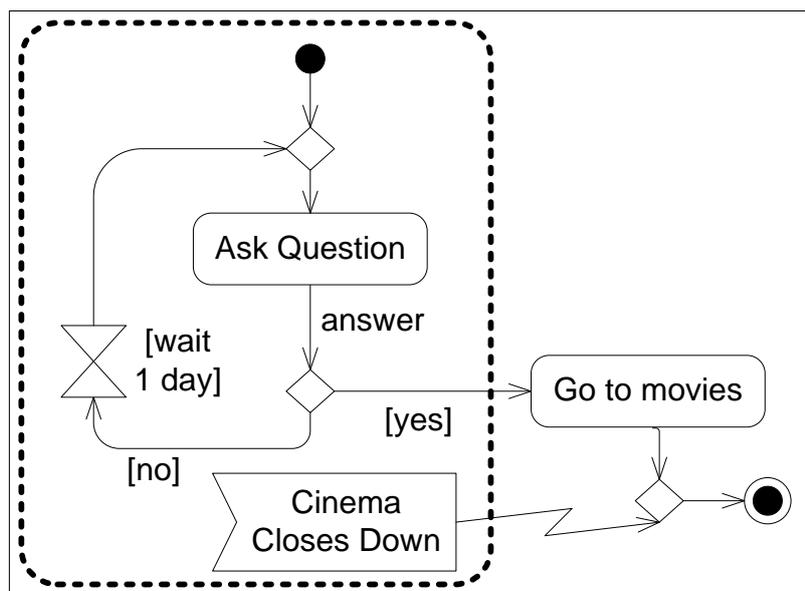

Figure B.2: Example activity diagram

B.2 UML collaborations

UML collaborations are well suited to model role structures and identify collaborations among those roles; **Figure B.3** represents an example of a collaboration diagram, where a doctor and a nurse represent the two main roles; but when those two roles handle assignments or complains the roles involved can be further refined in sub-roles, namely the head nurse and the department head (a sub-role can have the same name as the role refined by it).
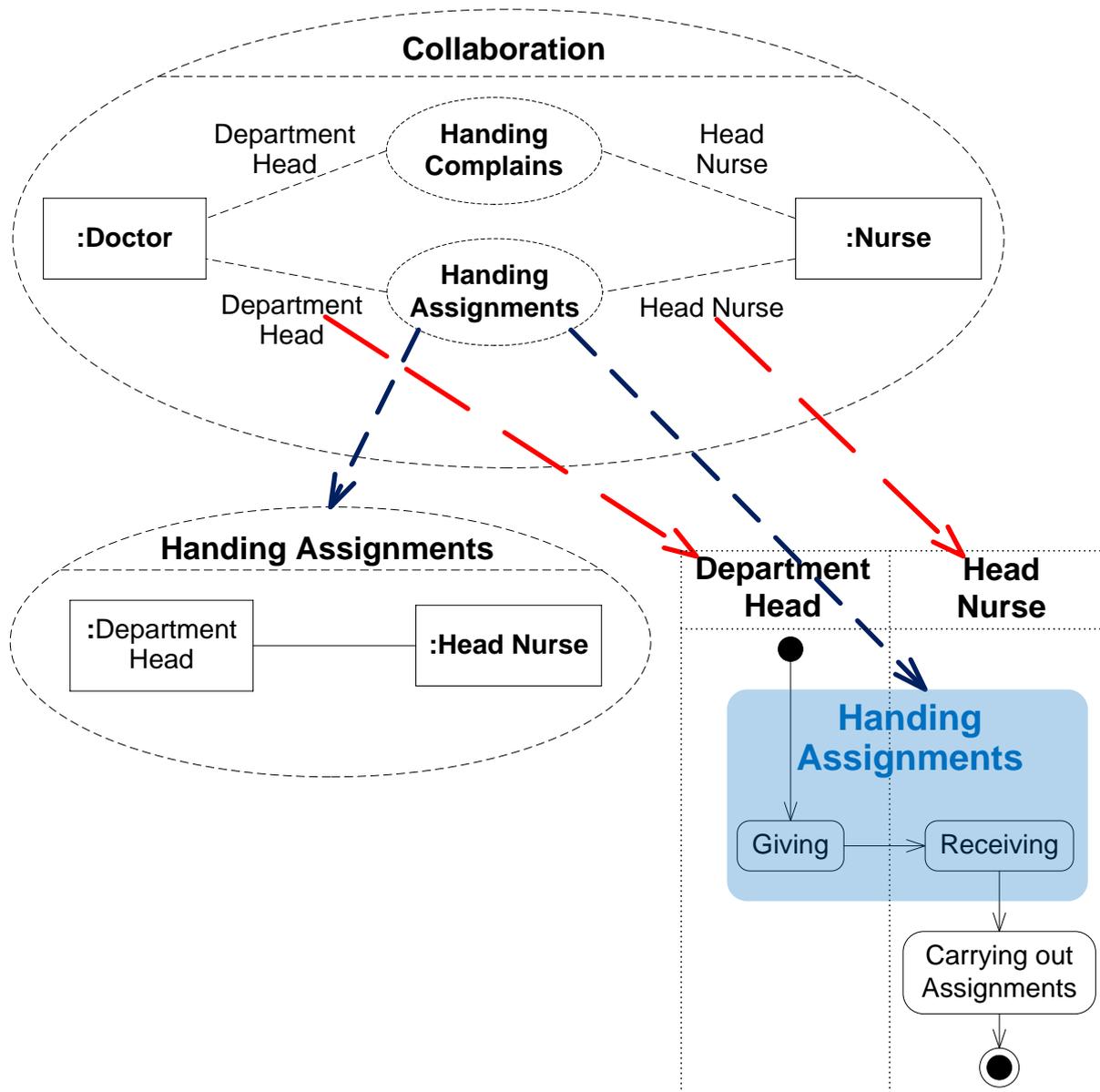

Figure B.3: Example of a combined activity and collaboration diagram.

On **Figure B.3** the *Handing Assignments* sub-collaboration is expanded below so that two roles that compose it can be seen more clearly; in this case both roles are joined by a continuous line which means that the elementary level of collaborations has been reached (e.g.: the innermost doll of a nesting doll), such collaborations are known as elementary collaborations.

B.3 Combining UML activities and collaborations

Two red arrows can be seen going from the sub-roles in the collaboration diagram to the swimlanes in the activity diagram of **Figure B.3**, so that each of the sub-roles has a corresponding swimlane. The activity diagram is thus divided into swimlanes to help differentiate the actions the department head is responsible for, from the ones the head nurse is responsible for.

Lastly the light blue rectangle means that what's on it forms the *handing assignments* activity; this last bit of syntax despite not being part of the UML standard makes diagrams much more approachable, especially in the case of highly technical diagrams where an extra set of lines doesn't help make them any clearer.