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Context-Aware System to Support Interruptions in Clinical Environments: Design and Evaluation Through a User-Centered Approach

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Problem Statement

Nurses do mobile work in a complex and hectic environment with many challenges. One specific challenge is related to interruptions. The nurses may be interrupted by a patient issuing a nurse call, disrupting nurses' thought processes and focus towards the current task. A *nurse call* is a signal carrying the patient room number from where the nurse call was issued [1]. Previous studies [1, 2, 3, 4] have indicated that nurses may decide to ignore or respond to calls depending on the context of the situation. They may even avoid the calls by leaving the phone behind when they are unavailable. In other words, some interruptions are unwanted. However, in other contexts, interruptions can be of high value.

Related research has proposed different strategies to handling interruptions. An example is "Nomadic Radio" [5], which is the idea of a wearable, audio-enabled, computer that handles interruptions. It modifies how to notify the user based on real-time analysis of context. Note that this technology-centered solution is not widely adopted due to context-aware systems being difficult to design without correctly inferring the context in which we deploy the system. We as designers must realize that it is all too easy to trivialize context, and as a result, we will end up building inappropriate applications [6].

Adoption of context-aware services is lagging behind what could be expected [7] when it comes to current implementations of wireless nurse call systems. These solutions were mostly developed by using a technology-driven approach, which resulted in low user acceptance. Designing a system such that it will assist the nurses in their work, rather than adding more work is essential. This fact thus calls for utilizing a user-centered system design approach that closely involves the users through the whole process.

This project's research question is about how we can design a system such that it can support nurses in managing interruptions. This thesis focuses on the modification notification strategy that, in turn, focuses on the use of features to modify the way in which individuals are notified of an incoming communication request [8]. Central questions are:

- How can we design, develop and integrate an interruption management system into a nurse call system?
- How and in what situations can a system infer context automatically?

- What situations are problematic when it comes to inferring context correctly and how can a system handle eventual incorrect inferring?
- How should the system modify notification in different situations?

We will use an existing prototype of a context-sensitive nurse call system as a basis and develop it further in agreement with the research questions. It is an Android based system consisting of three user interfaces: Nurse Client, Wall Panel (alternative interface, for nurses, that is placed on the wall of the patient room), and Patient Client.

We will conduct an interview session and use the results as a basis for developing the next iteration of the system. Next, workshops (i.e. role-play and focus group interviews), involving experienced and student nurses, will then be conducted to involve the users in the design process and to evaluate the system. We recruit participants from a major Norwegian hospital, S.T. Olav's Hospital, where nurses regularly use a nurse call system.

Abstract

Nurses may experience interruptions as double-edged swords as interruptions are essential tools to maintain awareness at the bed area while at the same time being harmful, disrupting current tasks and challenging cognitive capacity. This thesis seeks to reduce the impact of harmful interruptions by modifying notification of nurse calls using technologies for supporting context-awareness.

We use a nurse call prototype, developed on the Android platform, to enable research on the topic. The system has support for sensing the location of nurses by using low energy Bluetooth technology and Raspberry Pis, equipped with Bluetooth and Wi-Fi dongles.

To create the best possible conditions for user acceptance, this study adopts a user-centered approach and is based on iterative involvement of users (nurses). We conduct an initial study, where six full-time nurses are interviewed to gain a better understanding of context and nurse practices. We use the results of this study to develop a new iteration of the nurse call system, which in turn are evaluated by performing four workshops with seven nurses. The methods of the workshops include role-playing, focus group interviews, and a combination of cognitive walkthrough and think-aloud.

Results include how to design, develop and integrate an interruption management system into a nurse call system. Gathering and handling sensor data using smart communication protocols is essential to ensure proper integration of the many system components. State Machines are excellent for ensuring correct and efficient handling of the many system states when modifying notification based on subtle changes in context.

Further results include situations where the system can infer context automatically, such as sterile procedures, night shifts, or leaving the department. A combination of location and time sensor data is enough for the system to infer context accurately in most situations. However, some scenarios are prone to incorrect context inferring like, for instance, difficult conversations, or in case of fatalities. We can handle incorrect inferring by providing easily accessible interfaces to enable manual updating of nurse availability statuses.

Sammendrag

Sykepleiere kan oppleve avbrudd som tveeggede sverd på grunn av at avbrudd brukes som et essensielt redskap for å opprettholde en oversikt over sengetunet, samtidig som de kan ha en negativ effekt som utfordrer kognitiv kapasitet. Denne avhandlingen forsøker å redusere påkjenningen av negative avbrudd ved å endre måten pasientalarmer presenteres på ved å utnytte kontekstbevisst teknologi.

Vi bruker en prototype av et pasientalarmsystem, utviklet på Android plattformen, for å muliggjøre forskning på temaet. Systemet har støtte for lokasjonsdetektering av sykepleiere ved å benytte lavenergi-Blåtann teknologi og et sett Raspberry Pi utstyrt med Blåtann og Wi-Fi brikker.

For å sikre gode muligheter for brukerakseptanse benytter vi en brukersentrert tilnærming som er basert på iterativ involvering av brukere (sykepleiere). Vi utfører en innledende studie, hvor seks fulltids sykepleiere blir intervjuet for å underbygge en bedre forståelse av kontekst og sykepleiepraksis. Vi benytter resultatene fra denne studien for å utvikle en ny iterasjon av pasientalarmsystemet, som i sin tur blir evaluert gjennom utførelsen av fire workshops med syv sykepleiere. Metodene som benyttes her inkluderer rollespill, fokusgruppeintervjuer og en kombinasjon av "kognitiv gjennomgang" og "tenke ut høyt."

Resultater inkluderer hvordan vi kan designe, utvikle og integrere et avbruddshåndteringssytem med et pasientalarmsystem. Innsamling og håndtering av sensor data, gjennom bruk av intelligente kommunikasjonsprotokoller, er essensielt for å sikre god integrasjon av alle systemets komponenter. Tilstandsmaskiner er utmerket for å sikre riktig og effektiv håndtering av alle systemtilstandene når man endrer presentering av pasientsignaler basert på subtile forandringer i kontekst.

Videre resultater inkluderer situasjoner hvor systemet kan automatisk antyde kontekst, som for eksempel sterile prosedyrer, nattskift eller det å forlate avdelingen. En kombinasjon av lokasjons- og tidssensordata er tilstrekkelig for å nøyaktig antyde kontekst i de fleste situasjoner. Derimot så finnes det noen scenarioer som er utsatt for feilaktig antydning av kontekst, som for eksempel vanskelige samtaler eller ved dødsfall. Vi kan håndtere disse feilaktige antydningene ved å tilby lett tilgjengelige grensesnitt for å muliggjøre manuelle oppdateringer av tilgjengelighetsstatuser.

Preface

This study is a master thesis as part of the study program Communication Networks and Networked Services in association with the Department of Telematics, NTNU. It was conducted during the spring of 2015 (January-June) and counted for 30 credit points.

Trondheim, 08.06.2015

Mats Jørgensen

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M.J.

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Chapter 1

Introduction

1.1 Interruptions in Clinical Environments

So why are interruptions a problem? What is unique about a hospital environment in this regard? By definition, an *interruption* is an externally generated, randomly occurring, discrete event that breaks the continuity of cognitive focus on a primary task [10]. From this definition, it is not difficult to understand that interruptions can have a significant influence on focus-intensive tasks.

Interruptions are shown to be one of the main reasons that medication errors occur [11, 12]. There is also evidence of morbidity and mortality being a result of clinical communication failures [13]. Further, it has been found that nurses struggle to handle interruptions caused by the wireless nurse call system [2].

Does this mean that interruptions are unwanted? No, an interruption can provide new information that is valuable to the one being interrupted [14]. This fact relates to a concept called *situation awareness* (SA). Endsley and Jones [15] define SA as: Being aware of what is happening around you and understanding what that information means to you now and in the future [15]. Therefore, interruptions can be an important tool nurses use to maintain awareness at the bed area.

So what causes nurses to feel *interrupted*? Klemets, Evjemo, and Kristiansen [4] found that in situations where nurses are considered unavailable, the system still delivers nurse calls without any consideration. Example cases are lunch, isolation rooms, and visiting a patient who

the nurse is reluctant to leave [4]. It has been shown that current communication practices in hospitals are ineffective and cause an interrupt driven environment [16, 17].

Klemets and Evjemo [2] found three different strategies nurses use to deal with interruptions:

- Nurses communicate planned tasks to each other's to inform of their current situation.
- They keep an overview of the present situation at the department so that they know when to respond to particular nurse calls.
- Nurses prioritize work depending on what the other nurses are doing.

The same study also found that nurses evaluate interruptions by criteria like patient relationship and condition. This information is given indirectly when the nurse notices the room from which a nurse call originates. Klemets and Kristiansen [1] also found that some nurses prevent interruptions by choosing not to carry their phone with them.

1.2 Cognitive Load

Keeping an overview of the current situation naturally requires a mental effort. Because of this fact, nurses may face problems regarding cognitive capacity when dealing with interruptions. According to Endsley and Debra [15], there is an important issue that limits situation awareness. The limitation lies in the abilities of individuals, to handle information from multiple sources through different senses simultaneously. The following paragraph states another limitation:

"The combination of processing information and deciding on future actions can tax working memory to a great extent. Working memory is very limited, and forms the second major bottleneck for situation awareness" [15].

"The term working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning" [18].

1.3 Interruption Management Strategies

Grandhi and Jones [8] discuss four different strategies used for handling interruptions from a more technical standpoint. These strategies are interruption dissuasion, -prevention, -preview, or notification modification.

The *Notification Modification* approach tries to reduce the impact of interruptions (Interruption impact reduction paradigm) by modifying the way of notification based on status (e.g. less intrusive or no sound). *Interruption Preview* works by displaying information about the interrupter and his/hers reason for interrupting, making it easier to act upon the interruption. *Interruption Prevention* is the principle of preventing interruptions from even being possible (e.g. turning off the cell phone). Finally, *Interruption Dissuasion* is about conveying status information about the interrupted to the interrupter such that he/she can determine whether to interrupt or not.

The current nurse call system already supports a variation of *Interruption preview* through conveying room number along with a nurse call. *Interruption prevention* is also apparent when nurses choose not to carry their phone with them.

1.3.1 Context-Awareness

There are examples of research regarding how *context-aware* applications can manage interruptions. Context can be defined as any information that can be used to characterize the situation of an entity [19]. Likewise, context-awareness can be defined as the use of context to provide task-relevant information, services, or both to a user [19]. The following two examples do so by utilizing the notification modification strategy.

There has been done research on the use of context-aware systems to support interruption management in other domains than the clinical domain. A particular example is the *Nomadic Radio* [5], which is a neck-wearable computer that can recognize auditory queues, voice, and has ambient awareness and synthetic speech. They try to determine the interruptibility of the user to provide a dynamic auditory scaling of messages. Note that the Nomadic Radio was *not* developed through a user-centered approach and thus lacked a proper evaluation study. This study is quite old (1999), and this type of technology is not widespread today. This fact could

indicate that, even though the idea is good, it is not always the case that the target user group will use the system.

Kern and Schiele [20] used a mathematical approach when defining the interruptibility of the user. They found that this property could be estimated using multiple sensors attached to the body of the user. To determine the activity level and the social situation of the user, they utilize audio and acceleration sensors. The study propose to use context acquired from multiple, body-worn sensors [20] when considering context to manage notifications.

These examples do not adopt a user-centered approach. Still they attempt to handle interruptions through context-aware technology. As we do not see these solutions today, this could indicate that end users do not always adopt technology-centered design solutions as intended, sometimes not even at all.

1.4 Inferring Context

Understanding context is vital if we are to build effective, ubiquitous computing systems [6]. Greenberg [6] concludes with three principles to follow when attempting to infer context:

1. Study the context thoroughly by, for example, performing ethnographic studies.
2. Users should be able to override the system in case the system fails to infer context correctly.
3. Focus on good interface design that makes contextual decisions transparent to the user.

Principle 2 and 3 are in line with Erickson [21]. They argue that good context-aware applications let humans do the analysis and interpretation of context, while computers do the detection, gathering, aggregation, and presentation of data [21].

1.5 Scope and Objectives

This project is limited to developing a new iteration of the Android Nurse Call System in such a way that assists the nurses in their work. We adopt a user-centered methodology utilizing

interviews to gain insight into, and verify, existing challenges. An evaluation of the new iteration will be performed by the use of role-play and focus group interviews, involving both experienced and student nurses. Listed below are the three objectives of this study, while Table 1.1 lists the milestones associated with these objectives with their expected time spans.

1. Perform a pre-study, in the form of a literature study and interviews with nurses. This study is to gain insight into nurses' line of work and the problems regarding the research questions (Section 1.6). The study will serve as a basis for a hypothesis for the next objective.

2. Develop a new iteration of the Android Nurse Call System based on the findings of the interviews.

3. Evaluate the next iteration by performing workshops with both student- and experienced nurses.

Week	Date	Milestone
3	**12. January**	**Project start**
3-7	-	Literature study
3-7	-	Writing project description
7	**12. February**	**Deadline delivery of project description**
8	-	Plan for initial interviews
9-10	-	Conduct initial interviews
10	-	Analysis of interview material
10-13	-	New iteration of the nurse call system
13-14	-	Plan for workshops
15-17	-	Workshops (student nurses in practice)
16-18	-	Analysis of workshop material
3-24	-	Report writing
24	**8. June**	**Final Deadline**

Table 1.1: Project Milestones

This thesis is a continuation of a pilot study [3], which took place during the fall semester in 2014. Figure 1.1 shows the relationship between each objective of this thesis and the pilot study. The figure also shows how both fit in with the cyclic user-centered design process.

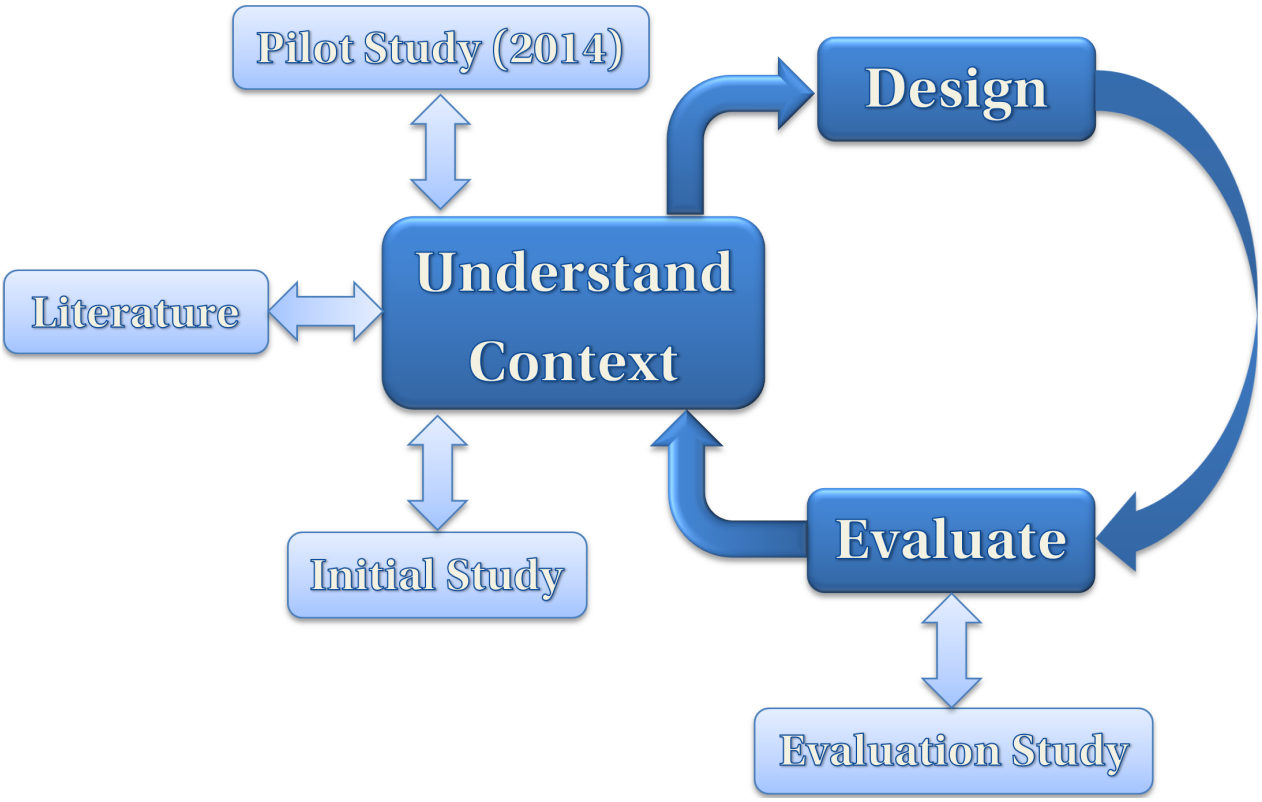


Figure 1.1: User-Centered Design Process

1.6 Research Questions

The central research question is how a system can be designed such that it can manage interruptions, generated by nurse calls, in the best way possible. This question is too broad to be answered accurately and need to be more focused.

The focus of this thesis is on the *notification modification* strategy, which Section 1.3 introduces. The reason for choosing such a focus is because this approach of interruption management enables control on how much demand the interruption requests place on user's attention [8]. Choosing this focus is rooted in the problem where humans cognitive load has limitations as explained in Section 1.2). The idea is to reduce the impact of interruptions to free nurses' cognitive load for other tasks.

Listed below are the research questions which this thesis attempts to address:

- How can we design, develop and integrate an interruption management system into a nurse call system?

- How and in what situations can a system infer context automatically?
- What situations are problematic when it comes to inferring context correctly and how can a system handle eventual incorrect inferring?
- How should the system modify notification in different situations?

1.7 Structure of the Report

This thesis is organized in a modified IMRaD format. Below is a list that states each chapter and briefly explains their purpose. References and appendices are attached to the end of the report. Note that Appendix A contains a complete list of all the acronyms used in this report.

- Introduction - Provides an introduction to the problem and its context.
- Background - Provides information on related work and research setting (i.e. system descriptions).
- Method - Lists the methods used to generate, analyze, and contemplate the data presented in Chapter 4 - Results.
- Results - Presents the data gathered from the interview- and workshop sessions.
- Discussion - Discusses the results and their implications and relationship to previous work.
- Conclusion - Answers the research questions and discusses future prospects.

Chapter 2

Background

2.1 Related Work

Related work includes many attempts to design and develop context-aware healthcare applications. The goal of this section is to review the state of the art to show that the work of this thesis is novel.

2.1.1 Context-Aware Communication System for Physicians

Botsis, Solvoll, Scholl, Hasvold, and Hartvigsen [22] designed and developed a context-aware health-care application to support physicians' mobile work through a user-centered approach. They conducted an initial study where they did both casual and structured interviews with different physicians to get a feel for user requirements. In the hospital environment, the success in system implementation is mainly dependent on users' acceptance [22]. In addition to the initial study, they used a wide range of different methodologies to determine user needs (e.g. workshops, observations, and brainstorming).

Their system integrated with the existing pager system and used location and physician availability as a basis for inferring context. They employed a module allowing the users to make simple rules regarding their availability (e.g. *"I am only available when I am in my office"* [22]). Note that they designed their system with *physicians* as their primary target user group. In addition, they do not attempt to modify notification through other means than re-routing contact

requests.

2.1.2 Ambient-Intelligent Nurse Call System

Ongenae, Duysburgh, Verstraete, Sulmon, Bleumers, Jacobs, et al. [7] also developed a context-aware application for nurse calls. They also determined user requirements by adopting a user-oriented approach where they started by interviewing and observing nurses while working. Further, they utilized workshops to evaluate concepts and have the users evaluate the system. Their system uses gathered context data to find the most appropriate caregivers to handle a call of a patient and generate new calls based on sensor data [7].

Their system specializes in routing nurse calls based on context cues such as a nurse's relationship with the patient, the closest (distance) nurse, and availability. If the system knows the reason for the nurse call, it can also consider expertise. The system can also modify notification based on the urgency of the call (regular nurse calls are muted and only vibrate while urgent calls ring instead of vibrating). Note that this system only modifies notification based on urgency, not raw context cues such as location.

2.1.3 "CallMeSmart"

Solvoll [23] developed a communication system, for handling interruptions in hospitals, called *CallMeSmart*. They used Computer Supported Cooperative Work (CSCW) and Human Computer Interaction (HCI) methods, such as field research, to determine user requirements. The resulting system attempts to reduce interruptions by using contextual information and improving awareness between users. It uses contextual information such as location, availability status, and personal commitments [23].

They found that by collecting context information about the user's situation, it is possible to decide on the availability of a user and, thereby, block or reroute calls directed to this person [23]. They also adjust the phone's behavior in relationship to the availability (*"available"* or *"busy"*) (notification modification). Even though the thesis considers nurses as users of CallMeSmart, the thesis mainly gathers data from physicians and surgeons.

2.1.4 Research on Interruptions in the Clinical Domain

Klemets, Evjemo, Kristiansen, and Toussaint [1, 2, 4, 24] have done extensive qualitative research to disclose why interruptions are causing problems in hospital environments and how they can be handled. Note that these papers were each written by a selective combination of these four researchers (refer to the reference list for details).

Methods include user-centered methods like fieldwork, workshops, interviews, and both paper- and real prototypes. Their findings relate to the following:

- How the impact of disruptive interruptions can be minimized [4].
- Whether all interruptions are unwanted [2].
- What contexts that may be troublesome for nurses if they are interrupted [1].
- Suggestions and improvements for future system design [1, 4, 24].

2.1.5 Nurse Call Prototype for Increased Awareness

Sund and Hafredal [9] researched awareness and interruptions related to the nurse call system at S.T. Olav's Hospital. They explored current work practices at this hospital and made a prototype of an improved nurse call system with availability statuses, similar to the Android Nurse Call System. Further, they used workshops to evaluate the assumptions they made when they created the prototype.

Their prototype considers the availability statuses *"available," "busy,"* and *"unavailable."* They discuss the possibility of modifying notifications and sounds along with status changes. They also experimented with the idea of automatic changing status to busy when entering a patient room and reverting to available when leaving. However, the technical solution of this function was outside the scope of their thesis.

2.2 Research Setting

This section covers system and technology descriptions relevant to the research setting. System descriptions include S.T. Olav's currently deployed nurse call system and the Android nurse call

prototype used in the pilot study [3]. Technology descriptions include a brief introduction to Reactive Blocks and SIP terminology.

2.2.1 S.T. Olav's Nurse Call System

This section provides an overview of the currently deployed nurse call system at S.T. Olav's, which is a major Norwegian university hospital located in Trondheim, Norway. Figure 2.1 shows the components and human-machine interfaces involved.

A patient draws a string to issue a *nurse call/patient signal*, which the *Fixed Server* first processes. This server forwards the call to all *active Room Panels* and the *Nurse Station Panel*.

Note that for a Room Panel to be active, a nurse has to click the green button to "mark presence". This act is also the criteria for terminating a nurse call if the signal originated in that room. Room Panels mainly hang on the wall of every patient room, but they can also be found at strategic places around the whole department. The Room Panels that are not in a patient room are usually always active so that all nurse calls are visible at all times from these panels. Note that a department is divided into multiple *bed areas*. Each bed area consists of seven to nine patient rooms [2], which hold one patient each.

The nurse call is also forwarded to the *Wireless Server*, which has a *call plan* that is configured, by the nurses, with a nurse-patient relationship. This relationship ensures prioritization of patients to specific nurses, which determine to which nurse to forward incoming nurse calls. Note that each nurse carries a work phone, here referenced to as "the phone", which can receive these nurse calls.

There is also a *patient signal application* that is available on a computer stationed at each bed area. It mainly provides five features [9]:

- overview,
- staff Management,
- overview of active Room Panels,
- registration of a new patient, and
- list of patients.

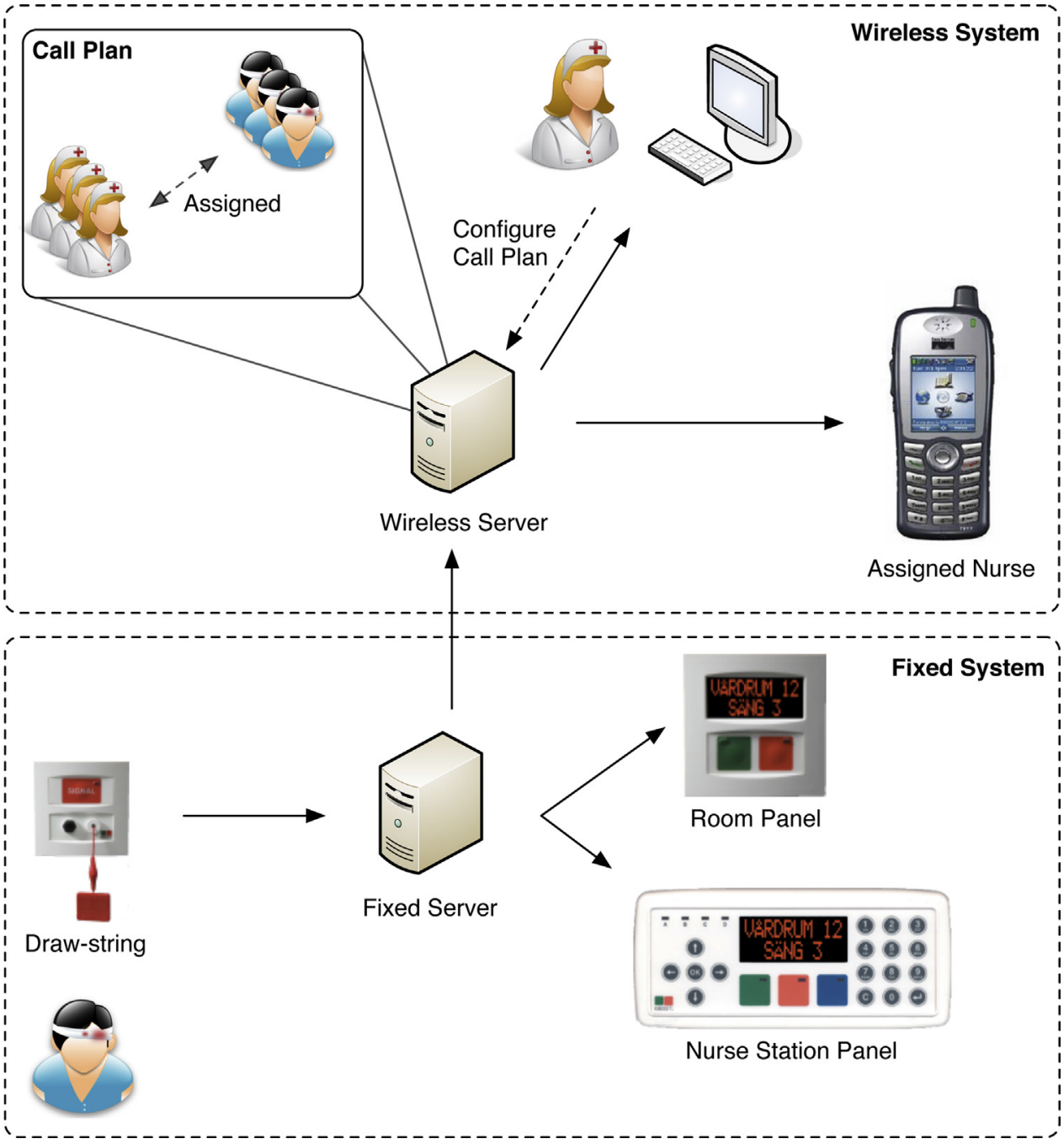


Figure 2.1: *An overview of the deployed nurse call system* [2]

Note that "Overview of active Room Panels" is the only feature relevant to this thesis. Figure 2.2 shows a listing of every Room Panel with various symbols. A green "T" denotes an activated Room Panel. *A red "S" means patient signal while a framed red "H" means an emergency nurse call. A red cross means error* [9].

Figure 2.2: *Overview of active Room Panels* [9]

2.2.2 Reactive Blocks

Reactive Blocks is a tool for model driven development using UML syntax. The tool is an Eclipse (see 3.5) plugin that uses UML 2.0 activities and state machines to generate runnable Java code. Every program starts with a *system block*. Figure 2.3 shows an example Reactive Blocks system block where the program starts at the *initial node* and enters the *"startMotor" pin*. If the motor failed to start, the program waits a while at the *timer*, before trying to start the motor once again via the *merge* node. If the motor succeeded to start, the program waits a while at another *timer*, before stopping the motor and terminating the program via the *final* node.

The Car block also has a *"drive pin"* (takes an integer indicating speed) and a *"break pin"* for breaking. Lastly, it has a *"turn pin"*, taking an object of type Direction as a parameter. This example illustrates how we can design a simple Reactive Blocks system. Table 2.1 shows the different nodes and their purposes.

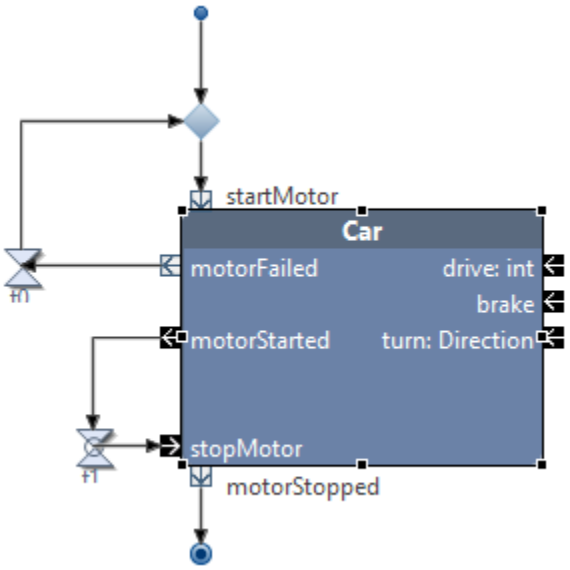


Figure 2.3: Reactive Blocks Example - Car

Icon	Name	Explanation
	Edge	Connects two nodes, can either be: • *Object flow* – Carries an object (thick line) • *Control flow* (thin line)
	Initial Node	Where the program starts • Can only exist in system block • Can be multiple initial nodes in one system block
	Fork	Splits an edge into two parallel edges
	Join	Joins two or more edges into one. This operation is blocking until every connected edge has joined.
	Decision	Signifies a decision (e.g. true/false)
	Merge	Merges two or more edges into one. This operation is non-blocking unlike join.
	Flow Final	Terminates a flow
	Activity Final	Where the program ends. Can only exist in system block.
	Timer	A timer that halts the flow until a given amount of time has passed.
	Variable	A variable. Can be any of the primitive Java types or any Java object.

Table 2.1: Reactive Blocks Nodes

2.2.3 Android Nurse Call System

The Android nurse call system is a prototype that was designed as a tool to enable user-centered studies of nurses and their relationship with S.T. Olav's Nurse Call System. Listed below are all system components that make up the system as a whole. Every component was built using the Reactive Blocks platform. Refer to Section 2.2.2 for more information on Reactive Blocks.

- Nurse Call Server,
- Nurse Client,
- Patient Client,
- Wall Panel, and
- Location Updating Software:
  - BLE Central,
  - BLE Server, and
  - Zone Scanner.

The system components communicate with each other by using the Session Initiation Protocol (SIP). This fact means that every message passes through an SIP proxy, which manages a relationship between IP-addresses and SIP URIs. An SIP URI can look like this: "sip:nurse1@example.no". This setup enables easy communication between different components, as long as it knows the SIP URI. RFC 3261 by Rosenberg, Schulzrinne, Camarillo, Johnston, Peterson, Sparks et al. [25] describes SIP and its details.

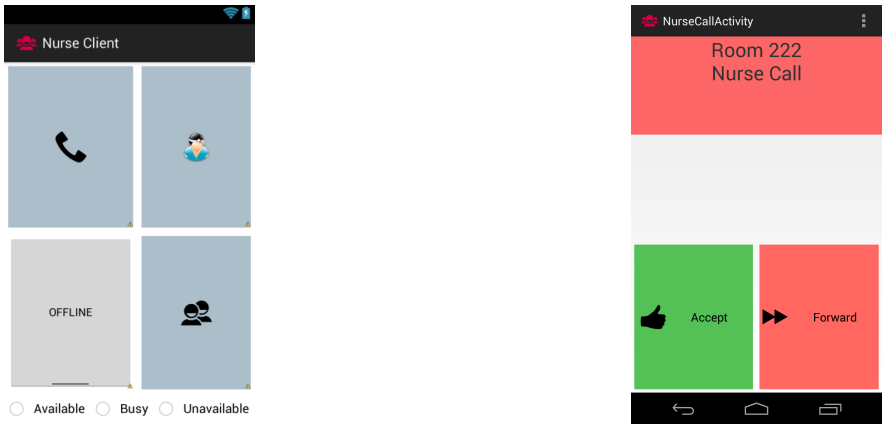
By using the *presence* functionality of the SIP server, the system can discern between three availability statuses that the nurses can use to change system behavior. Mainly it is the notification algorithm that is affected by these statuses, which are: *Available*, *Busy*, and *Unavailable*.

While *available*, the notification is unchanged (i.e. phone rings and vibrates while the Wall Panel rings). If *busy*, the Nurse Client goes into vibration-only while the Wall Panel only blinks (no sound). If unavailable, nurse calls are completely blocked. This fact holds true for both the

Nurse Client and potentially activated Wall Panels. Note that status-changes only affect a Wall Panel if a nurse is present in the patient room in which the Wall Panel is associated.

At the core of the system lies the Nurse Call Server. Its responsibility is to maintain the relationship between patients, rooms, and nurses. Initially, a configurable *call plan* gives this relationship, similar to the one in S.T. Olav's Nurse Call System. This relationship ensures the needed information to issue and manage nurse calls. Note that this component is a stand-alone Java application, not an Android application. See Appendix F for the system block (Reactive Blocks) of this component.

The Nurse Client represents an interface for nurses to interact with, in the form of an Android smartphone. Its purpose is to replace S.T. Olav's Nurse Call System's phone. Three of the functions of this component are relevant to this thesis: receiving nurse calls from patients, updating nurse status, and issuing phone calls between Nurse Clients. Figure 2.4a shows the graphical user interface of the main activity. When receiving a nurse call, the Nurse Client starts the nurse call activity and the notification thread for starting the ringtone and vibration. Figure 2.4b shows the nurse call activity's GUI. Appendix D shows the system block for the Nurse Client.



(a) *Nurse Client - Main Activity* [3] (b) Nurse Client - Nurse Call Activity

Figure 2.4: Nurse Client GUI

The Wall Panel mimics the *room panels* of the deployed nurse call system at the hospital (see Section 2.2.1). It has no function unless a nurse has marked her presence, in which case is will receive *all* nurse calls. It is also another interface for nurses to interact with the system. In the case where the system automatically registers a specific nurse as present in the room (explained later in this section), it is possible to update nurse status manually from the Wall Panel. Figure

2.5 shows the GUI of the Wall Panel. The upper left of the figure shows the GUI when there is no nurse present while the rest shows when there is a nurse present with each of the three availability statuses selected. See Appendix E for the system block of this component.

Note the difference of notation when referring to “room panel” or simply “panel’ which means the wall-attached panels from the fixed nurse call system. In contrast, we refer to the Android Wall Panel with capitalization.

Figure 2.5: *Wall Panel GUI* [3]

Similarly to the Nurse Client, the Wall Panel also starts a notification thread when receiving a nurse call. Vibration capabilities are not currently deployed, as wall-attached panels will not benefit from this feature. However, it has a function referred to as “blinking light” or “flash”, which makes a red box flash as seen in Figure 2.6.

The Patient Client is the patients interface to the system. It is a simple application with the sole purpose to initiate patient alarms, similar to the rope patients usually would pull. Figure 2.7 shows the GUI of this component.

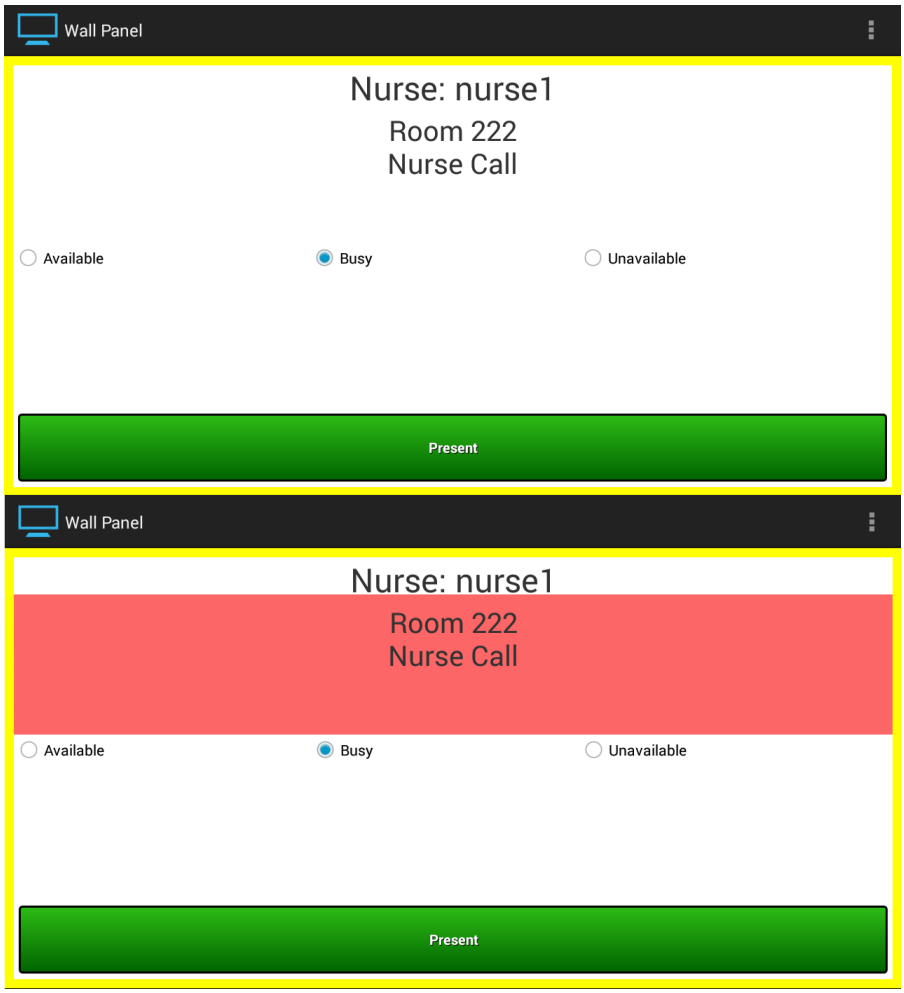


Figure 2.6: *Wall Panel Flashing* [3]

System Functions

A special feature of the Android Nurse Call System is that it can automatically detect a nurse that is entering a patient room by utilizing low energy Bluetooth. This feature frees nurses from having to mark their presence to activate the Wall Panel. Three components are handling this feature: BLE Central, BLE Server, and Zone Scanner. The Zone Scanner handles the setup and maintenance of a *zone*. A zone can be a room in the building or just a specific place in a big area [26]. Raspberry Pis, equipped with Wi-Fi and Bluetooth, represent a zone by running the Zone Scanner. A low energy Bluetooth beacon (fig 2.8) is used to measure the distance between the user and the center of each visible zone (i.e. the Raspberry Pis).

The BLE Central maintains an overview over every zone and detects transitions between

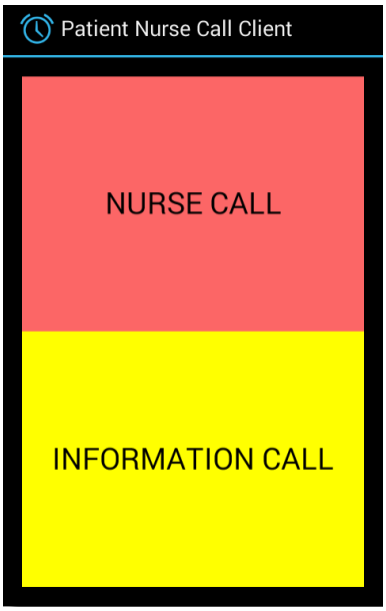


Figure 2.7: Patient Client GUI

zones. A transition is determined by comparing measured signal strength (RSSI) from each visible zone center. The node is assumed as present in the zone where the RSSI is strongest.

The BLE Server represents the bridge from the location updating software to the Android Nurse Call system. Its job is to inform Wall Panels about nurses who enter their vicinity. Further, it is the Wall Panels responsibility to initiate a subscription to the Nurse Client that entered the room. This feature enable users to perform manual status changes at any interface while shown

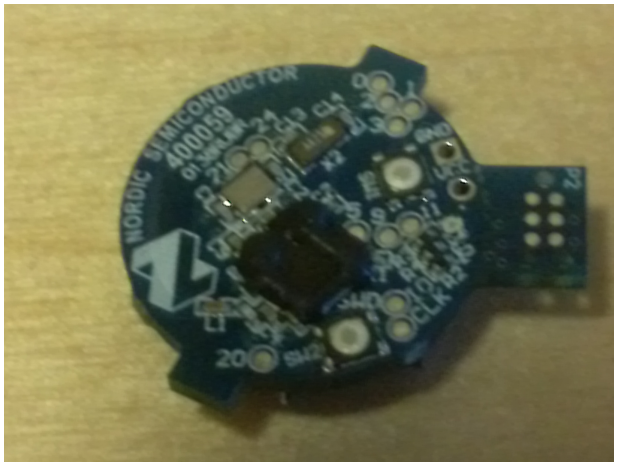


Figure 2.8: *Bluetooth Beacon* [3]

and updated simultaneously at all other interfaces.

Figure 2.9 shows all system components and the relationship between them. Note that the BLE Central and BLE Server are shown as one component in the figure for simplicity.

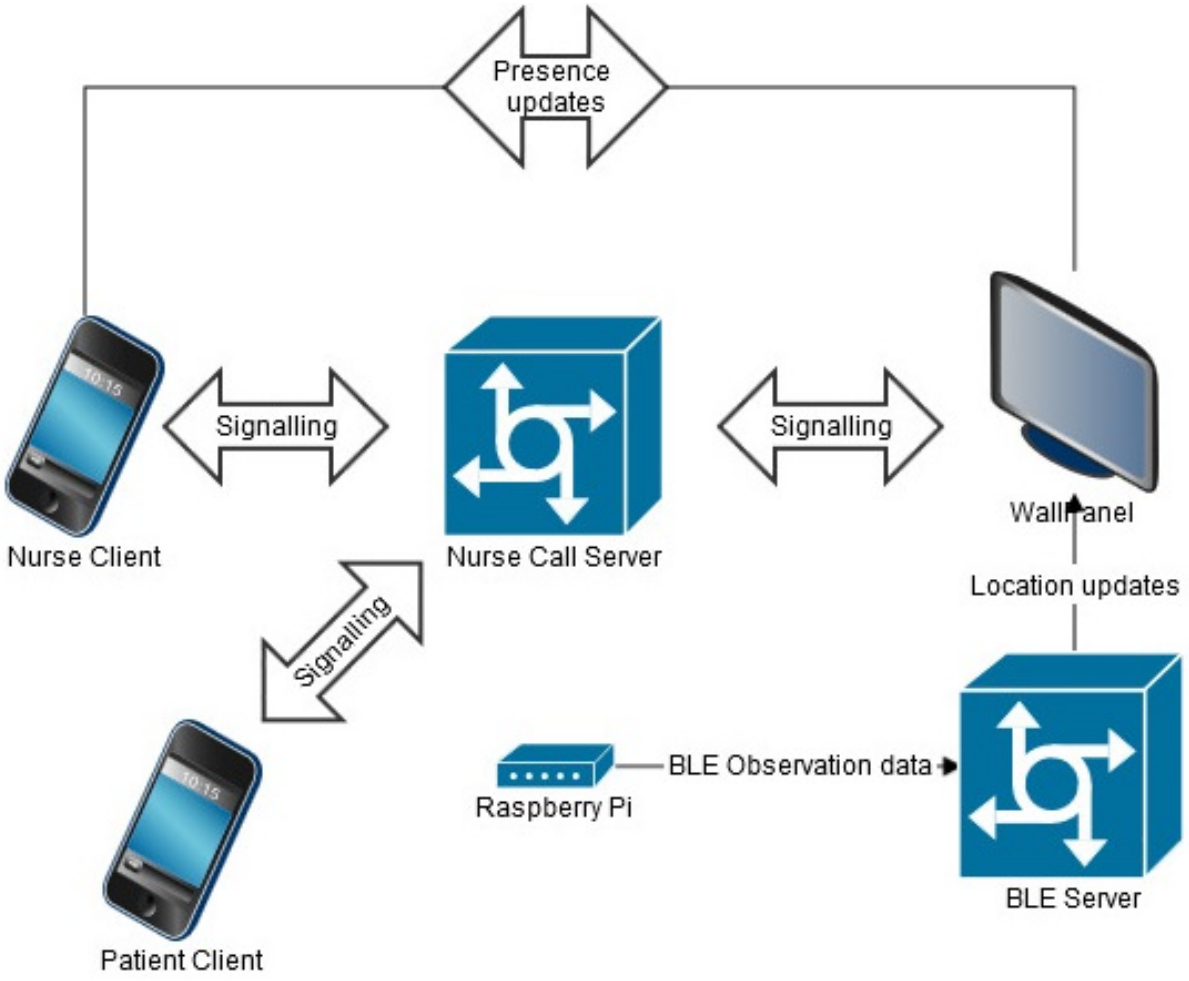


Figure 2.9: *Data Flow* [3]

A nurse call's lifespan starts at the Patient Client, where a patient clicks a button to initiate a call. This information is sent to the Nurse Call Server, which sends two messages, to inform of a nurse call, to the following components:

1. The Nurse Client of the primary nurse according to the call plan.

2. Each *activated* Wall Panel.

The primary nurse may decide to forward the call, in which case the server will issue a new

call to the next nurse, according to the call plan. The signal will be sent to the next nurse if a nurse call is left ringing for 15-20 seconds without responding, looping through every nurse in the call plan.

The system stops an active nurse call if any nurse marks as present in the room in which the call originated, identical to S.T. Olav's Nurse Call System. This fact means that a user can stop a nurse call by either pressing the presence button manually or using the automatic presence detection function of the BLE system. In other words, carrying the Bluetooth beacon into the room. Another feature is that the nurse status is automatically set to busy upon entering a patient room.

Chapter 3

Methodology

Traditionally, systems have been designed and developed from a technology-centered perspective [15]. This approach means that one designs software by focusing on satisfying every function in the system specification, without necessarily considering the actual users of the system. This view can especially be a problem when the customer is not the real end user of the system.

As previous research has shown (see Section 1.3.1), end users are not always adopting technology-centered as intended, sometimes not even used all. These facts support the decision for adopting user-centered design methodologies.

3.1 User-Centered Design

So what is user-centered design and what does it mean for this thesis? The user-centered design is a methodology used by developers and designers to ensure they are creating products that meet users' needs [27]. In practice, this means that the users are involved in the design process to ensure that the system operates *with* the users.

So what methods does user-centered design have to offer that we could use to generate empirical data? Table 3.1 lists the data generation methods used in each study along with general information. Note that all these methods yield qualitative data.

	Initial study	Evaluation Study
Goals	• Improve understanding of the problem and context	• Evaluate assumptions and findings of the initial study • Evaluate the new iteration
Methods	• Semi-Structured Interviews	• Role-Play • Focus Group Interviews • Cognitive Walkthrough/Think Aloud • Prototyping
Location	• Various meeting/conference rooms at S.T. Olav's	• W1-3: NSEP Usability Lab[1] • W4: NSEP Conference Room[2]
Participants	• Six full-time nurses	• Three full-time nurses • Four student nurses

Table 3.1: An Overview of Studies and Methods

Data generation methods produce empirical data, which we can categorize into two types, *Qualitative* and *Quantitative* data. Oates [28] define the two as follows:

"Quantitative data is numeric data, for example, the number of website hits, the number of employees, annual turnover, last year's profit. Qualitative data is all other types of data: words, images, sounds, and so on" [28]. What follows is a discussion about relevant quantitative methods and a discussion of their advantages and disadvantages.

3.1.1 Interviews

There are three types of interviews: structured, unstructured, and contextual. [27]. Structured interviews are planned in detail ahead of time and allow for little deviation from the interview manuscript. They are great for asking specific questions but have the disadvantage of not allowing subjects to come up with ideas on their own easily and freely.

Unstructured interviews are not as formal as structured ones. They are great for asking questions regarding concepts, rather than ones that are more specific. These questions typically allow for a free flowing conversation. By asking users about the problem space and letting them speak freely, you will be surprised by the insight you gain [27].

An interview does not have to be either structured or unstructured. It is also possible to have semi-structured interviews. For example by having a structured list of questions, taking

[1] See Section 3.3.3
[2] See Section 3.3.4

deviations into consideration, thus allowing users to bring their thoughts and ideas to the table.

Contextual interviews are of a somewhat different nature than the two other mentioned types. What is important about these interviews is that they are performed in the context where the subject is supposed to be using the application. These interviews help the interviewer thoroughly understand the context and eventual significant problems. However, they are not always feasible to perform easily (e.g. in a busy hospital environment).

3.1.2 Workshop as an Evaluation Method

Within user-centered design, several methods of evaluation exist. Jaspers [29] compares some of these methods that are especially suited for interactive health technologies: heuristic evaluation, cognitive walkthrough, and think-aloud. Other relevant methods include focus group interviews, role-play, and prototyping.

Focus Group Interview

Focus groups are a form of group interviews that capitalize on communication, between research participants, to generate data [30]. This fact means that, compared to a regular group interview, focus group interviews are designed to generate data from the *discussion* between participants. Focus groups should last between one to two hours and include between six to twelve participants [31].-

So why use a focus group interview? One advantage, as mentioned by Kitzinger [30], are that people who do not usually talk much get to contribute more easily as they can engage in the discussion initiated by the others.

Role-Play

Role-playing takes users and developers “out of the chair” and into the physical, social, and embodied reality of mobile computing [32]. Dramatized scenarios create a situated embodied context for the technology, which enhances the participants’ ability to envision needs and use of technology in specific situations [33].

Cognitive Walkthrough and Think-Aloud

Cognitive walkthrough is typically done by having experts simulate new users walking through the interface step-by-step, carrying out typical tasks [29]. Except that in this workshop, the facilitator of the workshop guided new users (i.e. nurses) through the tasks.

The think-aloud method is about instructing subjects to solve a problem while "thinking aloud"; that is, stating directly what they think [29]. According to Jaspers [29], the advantages of think-aloud is that it requires few participants while still providing a good amount of raw data. In addition, people can usually state their thoughts with ease in a particular, familiar situation. A drawback that Jaspers [29] mentioned is that the data may sometimes be a bit subjective and thus influenced by different personalities amongst the subjects.

Prototyping

The Android nurse call application can be considered a high-fidelity prototype of a real nurse call system. Prototyping is a powerful way to help your users visualize what you intend to deliver through your application [27]. That said, prototyping has some drawbacks as well. By habit, developers might focus too much on coding while there are other usability issues that need more attention. We solved this issue by allocating limited time to development, thus freeing more time to usability studies and research. Naturally, new additions and changes to the prototype were limited because of this choice.

3.2 Initial Study

We conducted an initial study in order gain a better understanding the problem and context. The study was done by having one-on-one interview sessions with experienced nurses. Table 3.2 shows an overview of the participants and their experience. Their departments were excluded due to confidentiality. We created an interview guide to document how the interview session was performed. It contains an introduction, objectives, and questions used in this study. Refer to Appendix B while reading this section.

A novice interviewer (i.e. the author of this thesis) conducted the interviews. They took place in various suitable conference/meeting rooms at different departments at S.T. Olav's University

Alias	Experience (years)
S1	15
S2	11
S3	4
S4	3
S5	10
S6	10

Table 3.2: Initial Study - Participants

Hospital. The reason for using different locations was that the subjects were not that flexible on time and location. They also usually were from various departments or bed areas. We gather data material by recording audio (see Section 3.5 for a complete list of hardware).

The interview session was semi-structured and divided into two parts. Part one used a regular interview strategy (i.e. questions and answers) to discuss problems regarding interruptions in general. More specifically, the questions were about nurses' experiences related to interruptions and about the managing of interruptions through the current nurse call system.

Part two was where the prototype was briefly introduced with key concepts and features explained orally. The questions of part two were more geared towards discussing the various functions of the prototype (e.g. automatic location detection and status updates, manual status updating, and notification modification).

As with semi-structured interviews, questions are prepared beforehand. We based these questions on previous literature and work, the pilot study, and different prototype functions. Also, note that the interviews were executed in the mother tongue of the participants (i.e. Norwegian).

3.3 Evaluation Study: Workshops

The objective of the second study was to evaluate the solution (4.2) that was built upon the assumptions and findings of the initial study (4.1). This evaluation was done by performing four workshops with both student and full-time nurses. Table 3.3 shows the participants, which workshop they attended and their experience. Because of confidentiality, which department the nurses were recruited was excluded. Also, note that three nurses attended both the initial study

and the evaluation study. These are: S1 = N5, S2 = N4, and S5 = N3.

Alias	Workshop	Experience
N1	1	Student Nurse
N2	1	Student Nurse
N3	2	Full-Time Nurse
N4	2	Full-Time Nurse
N5	3	Full-Time Nurse
N6	4	Student Nurse
N7	4	Student Nurse

Table 3.3: Evaluation Study - Participants

3.3.1 Planning and Execution

The workshop was divided into two main discussion sessions, split between four scenarios. That means that the two first scenarios were performed using *role-playing*, before having the first discussion. After finishing the last two scenarios by using cognitive walkthrough and think-aloud, the last discussion began. We performed the discussions by using *focus group interviews*. Note that the number of participants was lower than recommended (i.e. 6-12). This problem was a result of role-playing being difficult to organize with many participants and limited facilitator experience. Refer to Appendix C for a detailed overview of the scenarios and questions used in the interview while reading this section.

We used role-playing to form a basis for the discussion during the focus group interviews. For the latter two scenarios, a combination of cognitive walkthrough and think-aloud was used instead of role-playing. The reason for not using role-playing was that Scenario 3 and 4 did not cause an apparent change in the system that was directly visible to the users. For example, setting unavailable blocks all incoming nurse calls, which a difficult message to convey to the users in a role-play scenario. That is why the facilitator guided the users and explained the consequence of each action they performed.

As mentioned, four scenarios were prepared for this workshop. We designed these scenarios from the results of the initial study, which Section 5.1 discusses. Refer to Appendix C for a complete guide that explains each scenario in detail. Below is a list recapping the four scenarios:

1. Visiting an anxious patient while another patient issues a nurse call.

2. Checking in on a sleeping patient.

3. Unavailable during sterile procedure.

4. Nurse call during a phone call.

Svanæs and Seland [32] argue that the quality of scenarios can be assessed in the same way as other methods from social sciences: Through assessing *objectivity, reliability, validity, and transferability*. However, note that according to Steinke [34], this is just one of three positions to quality assessment in qualitative research. The two other positions argue against transferring quantitative methods to the qualitative field or against the possibility of formulating criteria for qualitative research [34].

Svanæs and Seland [32] define these evaluation criteria as following:

- Objectivity - Describes to what extent the scenarios and ideas originate from the users [32].
- Reliability - Describes how well the scenarios describe their corresponding situations.
- Validity - Describes how well the scenarios tie up towards the research questions.
- Transferability - Describes how well conclusions drawn from analyzing the scenarios can be generalized [32].

The scenarios have high *objectivity* because we designed with the situations the nurses mentioned, in the initial study, in mind. Also, the new iteration of the prototype was developed based on their ideas (see Section 4.1). We also regarded the reliability as high because the scenarios are divided into multiple smaller steps to describe their respective situations accurately. The scenarios have medium to high validity as they were designed to provide answers to the research questions. Transferability was regarded as strong medium as it is a bit unclear how common these scenarios are in the real situation. For example, how often does another patient issue an alarm at night, when a nurse is checking in on a sleeping patient?

Both the role-playing and focus group interviews were led by a novice usability practitioner (i.e. the author of this thesis), supported by two supervisors, both experienced in the field of

usability research. Also, note that the workshops were executed in the mother tongue of the participants (i.e. Norwegian).

We handed out action cards (also in Appendix C) to the participants to provide some context to the scenarios that are easy to read. This action was done to provide some structure, ensuring that everyone was on the same page. Also, for the nurses to get some tangible information about their patients may have increased the realism of the scenarios.

Audio and video from various angles were captured using an audio recorder the four on-site cameras. Refer to Section 3.3.3 and 3.3.4 for a detailed overview of the laboratory setup.

3.3.2 Hardware Setup

The SIP service ran from a server, at the Department of Telematics, using the domain name: "cococo.item.ntnu.no". Regarding the placement of the Raspberry Pis for the location updating system (2.2.3), refer to Section 3.3.3 and 3.3.4 as the positions varied with the two workshop scenes. The Nurse Station ran on the touch-TV and was placed at a central place in the bed area. A Toshiba laptop (specification in Section 3.5), which we placed on-site for easy access and debugging in case of eventual problems, ran the following server components:

- Nurse Call Server,
- BLE Central, and
- BLE Server.

3.3.3 NSEP Usability Lab

We conducted Workshop 1-3 in a laboratory specifically tailored for usability testing in health informatics, which is the NSEP Usability Lab. It has two patient rooms connected by a big room that would serve as a bed area in this workshop. Figure 3.1 shows a rough floor plan of the lab grounds. There are four cameras to record video and audio, angled in various directions. They can also be seen be seen in the figure.

Note that there are five circles of different colors in Figure 3.1. They signify the placement of relevant equipment, which is shown in the list below:

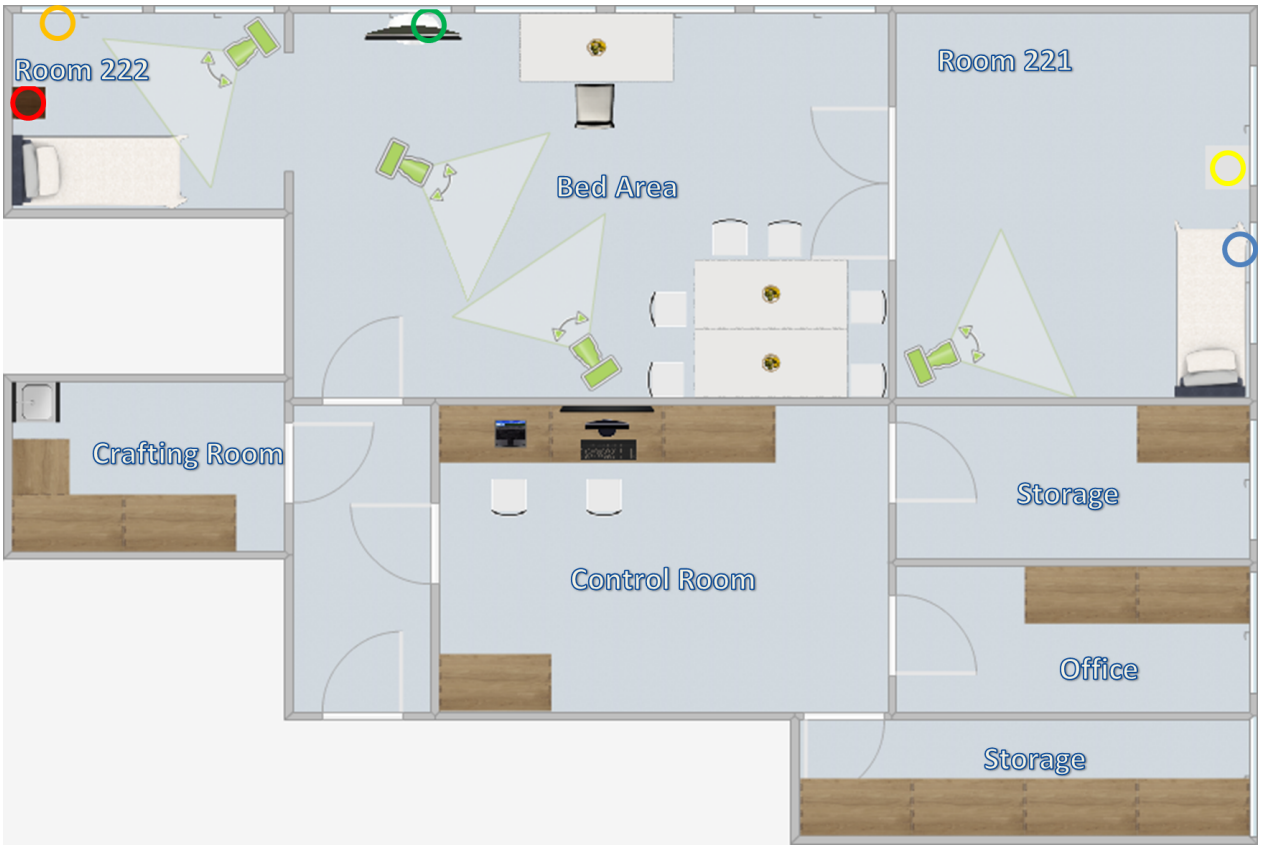


Figure 3.1: NSEP Usability Lab - Floor Plan

- **Blue** (window sill): Raspberry Pi configured to represent *Room 221*.
- **Green** (below the Nurse Station): Raspberry Pi configured to represent the *bed area*.
- **Orange** (window sill): Raspberry Pi configured to represent *Room 222*.
- **Yellow** (bedside table): Wall Panel configured to represent *Room 221*.
- **Red** (bedside table): Wall Panel configured to represent *Room 222*.

We found the ideal placement of the Raspberry Pis for optimal location event detection by trial and error. After some further testing, we decided to disable the Raspberry Pi in Room 222 (orange) because it had a tendency to cause faulty location updates. For example, the system would recognize a transition into Room 222 even if the beacon was placed on top of the Raspberry Pi in the bed area.

In Room 221, we put the Wall Panel on the bedside table so it would be easily visible and accessible. Its placement can be seen in both Figure 3.1 (yellow circle) and 3.2, which shows Room 221. Note that the placement of the Wall Panel in Room 222 (red ring) was irrelevant, as the participants did not directly interact with Room 222.

Figure 3.2: NSEP Usability Lab - Room 221

The Nurse Station was placed beside the wall in the middle of the bed area so that it would be easily visible while not standing in the way of anything. Its placement can be seen in both Figure 3.1 and 3.3.

Figure 3.3: NSEP Usability Lab - Placement of Nurse Station

3.3.4 NSEP Conference Room

We performed Workshop 4 in a conference room at NSEP, as the Usability Lab was unavailable at this time. The conference room was divided into two zones representing Room 221 and the bed area. Figure 3.4 shows a rough overview of the room. The split is a vertical line through the middle of the room with Room 221 on the left side and the bed area on the right. Room 222 was imagined to be the room through the door from the bed area.

Figure 3.4: NSEP Conference Room - Floor Plan

Note that there are four circles of different colors in Figure 3.4. The rings signify the placement of relevant equipment, which is shown in the list below:

- **Blue** (window sill): Raspberry Pi configured to represent *Room 221*.
- **Green** (bench): Raspberry Pi configured to represent the *bed area*.
- **Yellow** (chair): Wall Panel configured to represent *Room 221*.

- **Red** (outside the room): Wall Panel configured to represent *Room 222*.

We found the ideal placement of the Raspberry Pis for optimal location event detection by trial and error. Room 221's Wall Panel was placed in a chair to the left of the conference room. It was not possible to easily hang it on the wall or put it in a more visible place. Figure 3.5 shows Room 221's Wall Panel and Raspberry Pi.

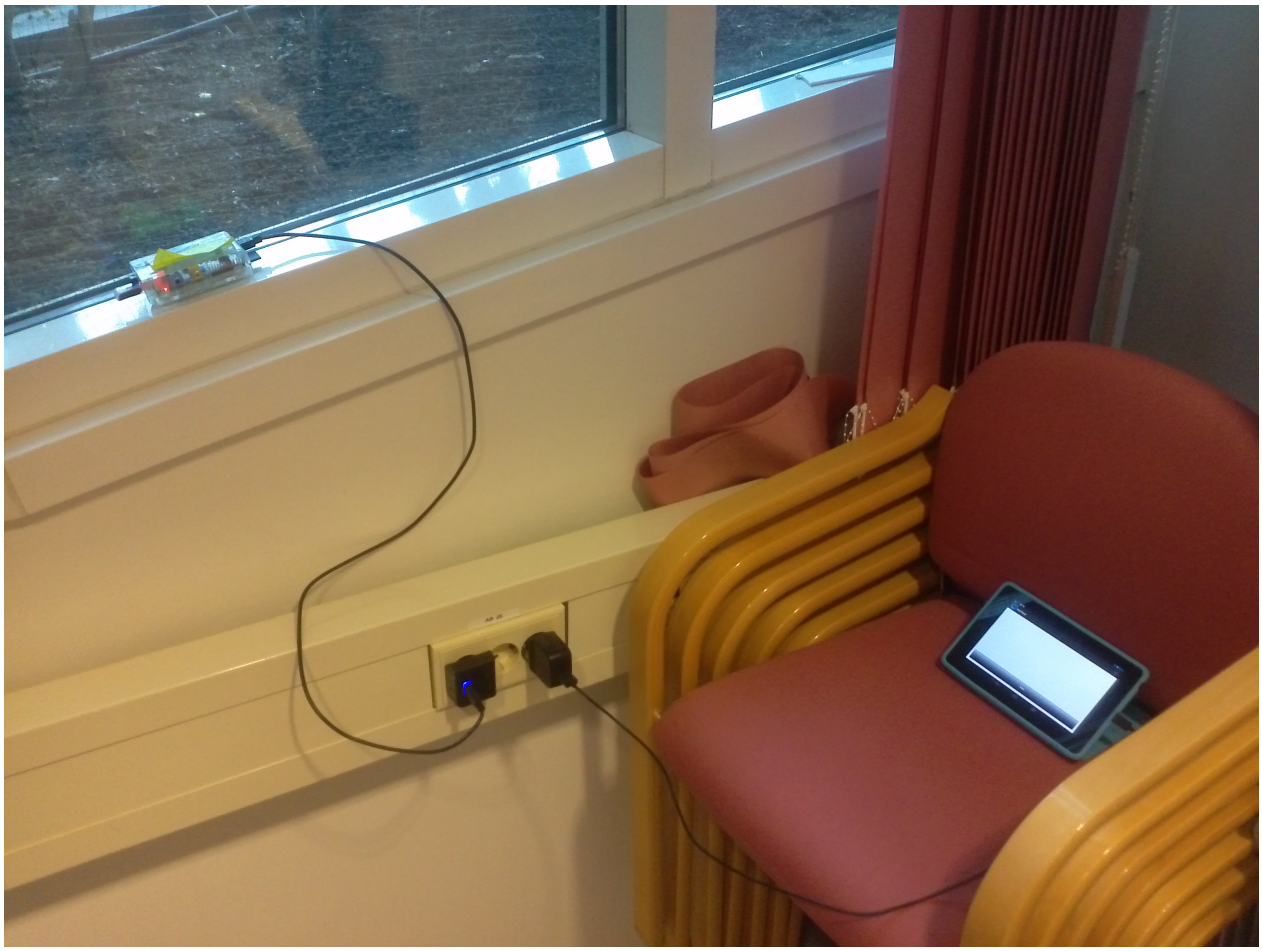


Figure 3.5: NSEP Conference Room - Room 221

We placed the Wall Panel for *Room 222* outside of the room so that the noise it made would not interfere with the participants' experience of the other Wall Panel and the Nurse Clients.

Regarding Nurse Station placement, it was placed against the east wall beside the bench with the Raspberry Pi. This placement can be seen in both Figure 3.4 and 3.6, which shows the bed area.

Figure 3.6: NSEP Conference Room - Bed Area

3.3.5 Fidelity Considerations

As the word implies, *fidelity* is a measure of how well a particular, simulated property resemble its real counterpart. In other words, how realistic were the workshops? Dahl, Alsos, and Svanæs [35] argue that to assess the usability of mobile ICT for complex use settings, such as hospitals, evaluators need to consider carefully the fidelity of the research setting vis-à-vis the actual performance context [35].

According to Dahl, Alsos, and Svanæs [35], there are two main types of fidelity: Physical- and Psychological Fidelity. Each of these two branches has two sub-types:

- Physical Fidelity (Engineering Fidelity), and
  - Environment Fidelity - Describes how well the simulated *environment* resembles the real environment.
  - Equipment Fidelity - Describes how well the simulated *equipment* resembles the real environment.
- Psychological Fidelity,
  - Task Fidelity - Describes how well the simulated *tasks* resemble real tasks.
  - Functional Fidelity - Describes how well the simulated *reactions* resemble the real reactions from a real system.

Table 3.4 shows an overview over how we estimated fidelity for the four workshops. Environment Fidelity was regarded as high because of the NSEP Usability Laboratory being designed to resemble the real hospital environment closely. We considered Workshop 4 to have low Environment Fidelity because it was performed in a regular conference room.

	Workshop 1	**Workshop 2**	**Workshop 3**	**Workshop 4**
Environment Fidelity	High	High	High	Low
Equipment Fidelity	Low	Medium-High	Medium-High	Medium-High
Task Fidelity	Low	Medium	Medium	Medium
Functional Fidelity	N/A	High	High	High

Table 3.4: Evaluation Study - Fidelity Considerations

The Equipment Fidelity was regarded as low in Workshop 1, where an issue with the SIP server prevented nurse calls from being initiated. This problem meant that the role-playing had to be canceled, thus resulting in low Task Fidelity as well.

For Workshop 2-4, we regarded the Equipment Fidelity as medium-high because of the prototype working properly, but there would still be some faulty location updates now and then. For example, the system would consider the user as being inside a patient room for a brief moment in time when, in reality, that was not the case at all.

The Task Fidelity for Workshop 2-4 was estimated to medium. Difficult conversations, sterile procedures, checking in on patients during night and phone calls are all highly plausible scenarios for a full-time nurse, which both the initial study and pilot study [3] confirms. However, role-playing will never compare to real world tasks. For Workshop 1, the Task Fidelity was considered low because the scenarios had to be explained orally instead of being acted out.

We regarded Functional Fidelity as high because the prototype provides realistic responses to the specified actions. For Workshop 1, Functional Fidelity was not applicable because the participants did not get to experience system responses to their actions.

3.4 Analysis of Data Material

We gathered a total of 463 minutes (close to 8 hours) of audio material, as of which 233 minutes were video, from the initial interviews and evaluation workshops. The raw data was processed by utilizing a method called *stepwise-deduction inductive* (SDI) which is explained by Tjora in [36]. First, we transcribed the raw data (i.e. speech to text process). Secondly, codes were generated from the raw data, which is the first step in the SDI process. Codes are simply short summaries (e.g. keywords or sentences) of relevant paragraphs from the raw material. The end-result of the *coding* was a list of codes that recapped the most important details.

There are different ways to transform raw data into codes. Tjora [36] mentions two methods: *"Sortable Coding"* and *"Coding Close to Text"*. The difference between the two is that sortable coding yields more generalized codes that do not say anything about details. *Coding Close to the Text* generates codes that are harder to sort, but are much more detailed. The latter method is the one preferred in the SDI approach (and used here) because of its ability to accurately

represent details. This ability makes it easier later in the process as one does not have to go back to the raw material to check details.

The last step in the SDI process is to *categorize* the codes and develop concepts. We grouped similar codes together under themes/categories that would be natural to use as headers in the Results chapter.

3.5 Hardware and Software

This section lists all hardware and software that we used in this project. Below is a list of all equipment and hardware.

- Samsung 400tsn-2 (Infra-Red Touch TV) - Used to run the Nurse Station software.
- 2x LG Nexus 7 Tablets (Figure 3.7a) - Used to run two Wall Panels.
- 4x LG Nexus 5 Smart Phones (Figure 3.7b) - Used to run two Nurse Clients and two Patient Clients.
- 3x Raspberry Pis with wireless and Bluetooth dongles (Figure 3.8) - Used as zone detectors for the location detection system.
- Olympus Digital Voice Recorder VN-713PC - For recording audio.
- Toshiba Satellite A500D-111 laptop (Specifications listed in Table 3.5) - Used to run all server software during the workshops.

Model	**Toshiba Satellite A500D-111**
Processor	AMD Turion II M500 / 2.2 GHz
Memory	2 x 2 GB
Graphics Adapter	ATI Mobility Radeon HD 4650 - 1 GB
Hard Drive	Intel X25-M SSD 80GB

Table 3.5: Toshiba Satellite A500D-111 Specifications

Listed below are software that we in this project. Development tools, servers, and model generation tools are included.

(a) *Nexus 7 Tablets* [3]

(b) Nexus 5 Phones prepared for Workshop 4

Figure 3.7: Tablets and Phones

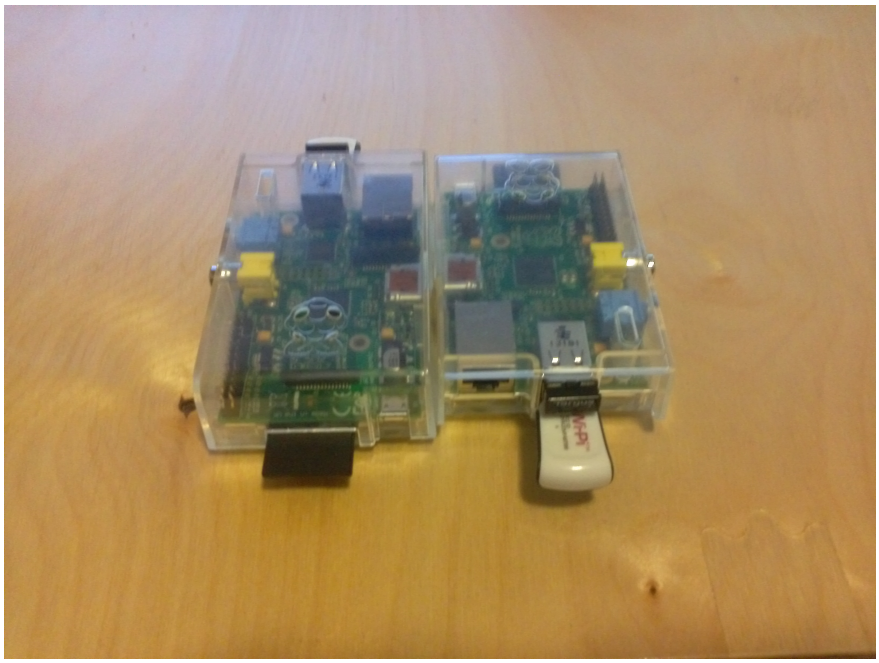


Figure 3.8: *Raspberry Pi* [3]

- Eclipse Luna with Reactive Blocks plugin and Git for version control.
- Opensips with presence module - Open source SIP service.
- PuTTY - SSH client for accessing Raspberry Pis.
- WinSCP - SFTP client for transferring files to Raspberry Pis.
- OpenGeode - Open source SDL modeling tool.

3.6 Development

Development was done by using Eclipse Luna with the Reactive Blocks plugin. Refer to Section 2.2.2 for an introduction to Reactive Blocks. The altered, already existing, components were originally developed using Reactive Blocks in the first place. Naturally, Reactive Blocks had to be used to develop these components further. Refer to Section 2.2.3 for a detailed overview of the system components.

We also used Reactive Blocks to develop the Nurse Station software (presented in Section 4.2.6). The reason for choosing Reactive Blocks, in this case, was because of its principle of reusable building blocks. For example, the SIP service (communication protocol) is represented by a building block in the other system components, so it was reused in the Nurse Station as well.

Creating software systems by connecting reusable building blocks seems to be an attractive development paradigm that can facilitate reuse and enable an incremental development style in which problems can be solved block-by-block [37].

Chapter 4

Results

This chapter presents the data, in analyzed form, generated from the interviews, and workshops. It also gives an overview of the changes done to the Android Nurse Call System, based on the requirements that resulted from the initial study. We generated data by using the methods explained in Chapter 3 - Methodology. Note that this chapter contains no discussion, own opinions, or thoughts, which Chapter 5 - Discussion presents. Remember that “panel/panels” is a reference to S.T. Olav’s nurse call system while “Wall Panel/Wall Panels” is a reference to the Android Nurse Call System.

4.1 Initial Study: Interviews

This section presents the results from the interview sessions of the initial study. See Section 3.2 for the methodological approach used to generate the data presented in this section.

4.1.1 Nurse Call System: Interaction and User-Friendliness

This section highlights some key elements to how nurses interact with the currently deployed nurse call system. it also presents some pros and cons.

Each department usually has a distinct culture on the way nurses interact with the nurse call system. However, one fact seemed to be valid regardless of the department, which is that nurses would usually carry their work phone with them unless they forgot to bring it. There are however exceptions to this fact, which are revealed later.

S6 stated: *"I might forget my phone, but it does not really matter because of the panels in the bed area."* As this statement suggested, nurses might not be dependent on the work phone. S1 further confirms this fact by the following comment by: *"The only good thing about the phone is for backup if you forget to mark your presence in a patient room."* S6 seemed to indicate that there was a difference in how much they relied on the phone, based on the time of day. The nurse stated: *"We would have made it through the day without the phone but during night one might be more dependent on the patient signals."*

One of the more experienced nurses (S1) questioned the need for the phone to present patient alarms at the phone at all. The nurse asked: *"Why is it good for me to know if a patient rings on the phone in addition to the panel?"* In essence, the nurse could not think of any advantage of having nurse calls arrive at the phone, as one would always get this information through the panels. The nurse added that some departments might like having prioritization of patients, but as you see who is calling on the panels, you would know to respond to your patients either way.

Several nurses mentioned that there used to be monitors attached to the roof, referred to as roof panels. The nurses indicated that they miss these roof panels and want more panels in general. A nurse stated: *"Almost worse now with phones instead of more panels and roof panels."*

One of the positive features of the phone is, as indicated in the previous paragraph, that the phone might serve as a backup solution if a nurse were to forget to mark presence in a patient room. S5 confirmed this fact by the following statement: *"If you do not mark presence in a room, you will not hear the alarms in the hallway, only from the phone."* The phone is good to have in similar situations, where there is no panel close by (e.g. WC). Other helpful features that the nurses mentioned include:

- Prioritization of patients based on a call plan.
- Fast and close-by presentation of emergency calls.
- Easily being able to reach colleagues by phone.
- Being able to reject or accept incoming nurse calls.

A negative attribute of the phone, which multiple nurses mentioned repeatedly, was that it is not very user-friendly. Nurses do not bother to learn all available functions. Especially nurses

of the older generations may not adapt to technology very easily. S5 commented: *"Phones are not easy to use, very unfriendly compared to a regular modern phone."*

Another negative feature that the nurses mentioned was hygiene issues as the phone is an infection carrier and that nurses are not good at accepting nurse calls by using the phone.

Regarding the intensity of interruptions, the nurses said that interruptions happen multiple times a day. S1 indicated that if they were to use the system as intended there could be about ten signals in 30 minutes. Another nurse, from another department, guessed at 4-5 times an hour. Because of the aforementioned negative attributes, some nurses avoid using the phone for its intended purposes. S2 said: *"The phone has no other function than making it easier for others to reach you."*

4.1.2 Interruptions and Tasks

Nurses may be interrupted while performing a variety of tasks. Multiple nurses said that they were tired of all the alarms and ringing phones. S6 stated that: *"People complain about the sharp alarm sounds from the phone,"* and mentioned the fact that sharp sounds might be to become aware of the patient signal. This section covers the tasks nurses usually perform when they feel interrupted.

A common situation where the nurses felt like patient alarms could interrupt was during important conversations. These conversations could for instance: involve patients, next of kin, or talking in general. In the case of talking with a patient, interruptions may also affect patients, as commented by S5: *"Patients often wonder about the sound and are affected."* One nurse indicated that one could leave the phone behind when having a sensitive conversation.

S3 thought that a conversation over the phone was no different from a regular conversation, worse even. S3 stated: *"Talking with a patient is fine, but an alarm during a phone call is worse,"* referring to interruptions from patient signals. The nurses gave the impression that they thought it was annoying that alarms might come during phone calls. Not only does the alarm abort everything you do on the phone (e.g. searching the contact list), its sound and vibration overpowers everything such that it is impossible to have a good conversation. S6 said that there exists a number combination to stop the alarm during a phone call, but it is too difficult to learn.

S4 seemed to indicate that feeling interrupted from patient signals when on the phone, is

not dependent of who is calling. The nurse also stated that: *"All phone calls that arrive at the work phone are work-related."*

The nurses mentioned sterile procedure as one of the difficult situations where interruptions are a problem. Mainly, the problem is that one can not stop the alarm by any means when sterile, as doing so would lead to contamination (e.g. touching phone or panel).

The case where a patient issues a nurse call during the night, while the attending nurse is checking in on a sleeping patient, is another problematic scenario. In this situation, the nurses indicated that they might avoid marking presence in the patient room, in addition to leaving the work phone behind. They do so to avoid having the panel or phone wake patients with nurse calls. S6 stated: *"Sharp sounds may wake patients at night and cause bad atmosphere."*

When automatic marking of presence was introduced, S5 mentioned: *"If you are in at night and automatically marked as present, the panel might wake the patient."* Note that "in" refers to as in a patient room. A solution was proposed where the problem could be solved by manually marking "not present" in a way.

Other situations, where the nurses felt interrupted, include performing a regular procedure (e.g. drawing blood), morning care, meetings/interviews, and doctor visitation.

4.1.3 Interruptions and Locations

This section covers the locations nurses usually find themselves at when they feel interrupted. Multiple nurses stated that the patient room is the most common place for interruptions to happen. This fact is true because nurses carry out most of their work either in the patient rooms or at the bed area. However, the feeling of being interrupted in a patient room might depend on the "mood" in there.

The decision on whether to leave a patient is an educated guess by the nurse. S6 stated: *"If I am inside a patient room, another nurse might take the alarm if it rings long enough."* The nurses indicated that the critical factors of this guess include:

- Who is issuing the nurse call (nurses know their patients well.)
- Duration of the nurse call (how long has it rung, without anyone responding?)
- What the current task is.

Another statement by S2 that builds up the facts presented above: *"If no one gets the clock for my patient – I might have to excuse myself if I am not doing something important."* Note that some nurses use the phrase "getting the clock" when they respond to a nurse call by entering the patient room and marking presence.

When leaving the department (e.g. lunch break or accompanying a patient to a physical) two possible interruptions may occur:

1. A nurse that brings the phone out of the department, allowing nurse calls to interrupt without being able to respond.

2. A nurse that turns off or leaves the phone when leaving the department, resulting in a lot more interruptions for those remaining. S4 stated the following when asked about this topic: *"A lot of sound for those left alone during lunch."*

Some nurses mentioned the workstation as a place where they might feel interrupted. However, S4 also indicated that one might want to be interrupted here: *"Easier to abort when sitting at the station, compared to working with the patient in the patient room."* Lastly, another problem location is in isolation rooms. Nurses typically leave their phones behind due to contamination issues, as they would not be able to touch the phone either way.

When we introduced automatic location updates upon entering/exiting a patient room, they all responded positively. For example, S5 said: *"Nice if you are automatically marked as present."* No one could think of any problems with this function. However, they mentioned three other rooms that possibly could have automatic status updates: Cafeteria, operations rooms, and labs. The impression was that not everyone would want to be unavailable during lunch, some might and some not.

4.1.4 Availability Status Discussion

When we introduced the possibility of having individual statuses, the nurses mostly responded with positive enthusiasm. One example by S1: *"I think it is very interesting with sound and choices, I have faith in it,"* referring to changeable availability statuses with different notifications. However, S1 pointed out some important facts like: *"People have to see the benefit of it all, so it has to be very simple."*

One thing that nearly all nurses pointed out was that availability status must not affect emergency signals, even when unavailable. They need to go through regardless of status.

When discussing the optimal number of statuses a common dilemma was the uncertainty between two or three. In other words: Is the unavailable status necessary? S1 questioned if it might be difficult to introduce new routines and wondered if three statuses might be too much: *"If everyone used them as intended three are fine... In practice, that may be too much... Might consider two,"* referring to the statuses. Most of the nurses agreed that keeping track of more than three statuses might be difficult. To quote S5: *"No more than three statuses. Otherwise it will be too much to deal with."*

The probability of forgetting to update the status manually is also high. There were also some nurses that pointed out the reluctance to update statuses manually. S6 said: *"Three is fine, but I will not edit them manually."* The same nurse mentioned: *"If I get a mission that takes 20 min, I will not set busy since it might come up something else to do that requires my attention."* One argument that came up was that users might consider having to click the phone to set the status as another interruption.

One concrete example of forgetting to update the status manually is that of remembering to go from unavailable to available. Especially if, to quote S1, that one may: *"Forget to update status when running around."* The nurses mentioned some possible solutions such as strict routines or having a timeout/remainder after a particular time-period. This function would be either to remind of the status being unavailable or to revert to another status automatically, upon timeout. S5 suggested this feature to be associated with the busy status, in addition to unavailable.

S5 mentioned a drawback with the timeout function mentioned earlier. This drawback revolves around having to update the status if a timeout came too soon. The nurse added, *"Yes, that would be another interruption again, but maybe less disturbing than it currently is."* Even though the nurses indicated a high reluctance to update statuses manually, they still wanted to have this opportunity.

Multiple nurses stressed the fact that it must be as simple as possible to perform status updates. To quote S6: *"I do not think people want to learn more than they have to so it has to be simple. There are some seniors working here that might not be that familiar,"* referring to famil-

iarity with modern technology.

According to S3, what makes status updating so difficult is that the task is just as important as location when it comes to determining status. S6 stated, *"One might be very busy, in locations where one would be, for example, available. It would not register that unless one could set unavailable manually, but might be too complex."* Here "it" refers to the automatic status updating of the system. On the other hand, S5 said: *"Task is most important, but most tasks are done in the patient room,"* referring to the importance of task and location when deciding status.

S5 noted that one should not be unavailable for too long, which could create many interruptions for those left available or busy. Also, everyone should not be able to set unavailable at the same time. As for how often the nurses thought they would be using the unavailable status, it would not be too frequently, especially compared to busy. S5 guessed: *"Unavailable once a week maybe,"* without giving an example situation.

A function that a couple of nurses briefly suggested was the possibility of displaying a log of unanswered nurse calls. Figure 4.1 shows a thought map indicating the different situations where the three statuses (i.e. Available, busy, and unavailable) would be used.

4.1.5 Optimal Notification

This section presents the results regarding how the nurses felt that the notification should be. There was a broad range of opinions on ways we could improve the notification. The nurses wanted to have *some* sound while in the patient room without it being too intense.

Now you supposedly have both phones and panels generating noise. S5 stated: *"It would be nice to avoid the interruption of both panel and phone ringing simultaneously."* The general notion was that the panels currently have discreet sound and does not need to change. However, some nurses thought it would be nice to be able to make the panel silent.

There was also some suggestions on how the notification should be with the different availability statuses. When "available," the alarm should present as usual and while "unavailable," the nurses indicated that both the panel and phone should not ring or vibrate at all. The notification while "busy', should be calmer (ringtone), maybe have volume escalate progressively, and vibrate. Some nurses complain about intense vibration being a bit distracting.

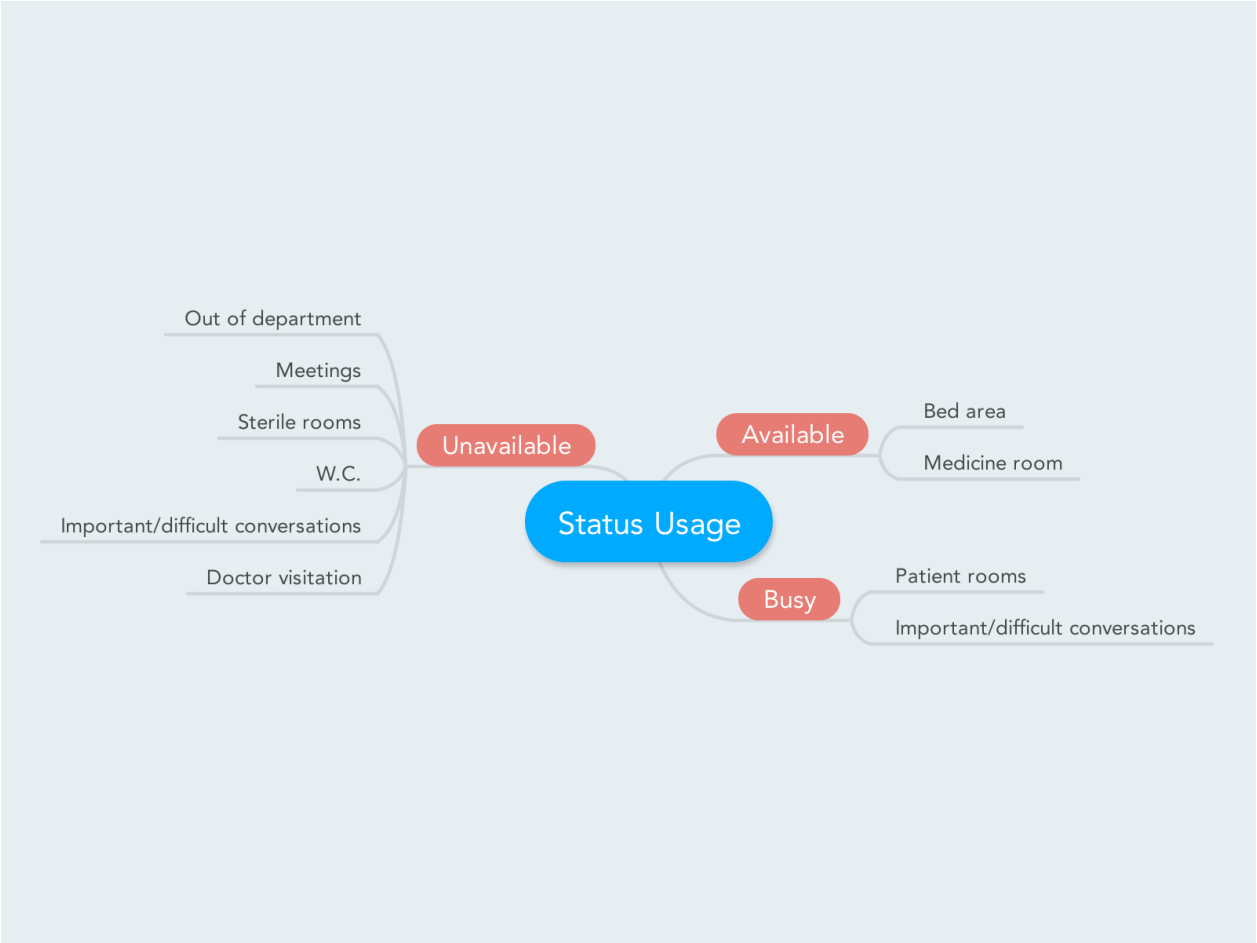


Figure 4.1: Status Usage

4.1.6 Requirement List

Below is a prioritized requirement list that was compiled based on the results presented in this chapter. Refer to Section 5.1 for the reasoning behind this list.

1. Add day and night capabilities as a secondary sensor input for better context-awareness.
2. Notification Modification: Modify notification to correspond to Table 4.1.
3. Timeout functionality for busy and unavailable.
4. Alarm during a phone call.
   (a) Status unavailable when receiving phone calls.

(b) Status available when a phone call has ended.

5. Develop a Nurse Station application that should:

   (a) Display the status of every nurse in a clear way.

   (b) Allow manual status updating.

   (c) Be tailored for a touch-enabled big screen/monitor.

6. Emergency alarm signals.

   (a) Implement basic functionality.

   (b) Should be presented at full strength, regardless of availability status.

7. Simplify user interface.

   (a) Improved representations of the availability status buttons.

	Phone			Wall-panel		
Patient room (Day)		**Available**	**Busy**		**Available**	**Busy**
	Vibration	Medium		**Vibration**	N/A	
	Sound	Off		**Sound**	Regular	Ring once[1]
	Volume	Mute		**Volume**	Medium	Low
	Flash	No		**Flash**	Blinking GUI[2]	
Patient room (Night)		**Available**	**Busy**		**Available**	**Busy**
	Vibration	Medium	High	**Vibration**	N/A	
	Sound	Off	Ring once[1]	**Sound**	Regular	Off
	Volume	Mute	Low	**Volume**	Medium	Mute
	Flash	No		**Flash**	Blinking GUI[2]	
Elsewhere		**Available**	**Busy**		**Available**	**Busy**
	Vibration	Medium		**Vibration**	N/A	
	Sound	Regular	Ring once[1]	**Sound**	Regular	
	Volume	Medium		**Volume**	Medium	
	Flash	No		**Flash**	Blinking GUI[2]	

Table 4.1: Notification Modification

[1] Ring Once: Ringtone is played only once at the beginning of the notification
[2] Blinking GUI: Flashing red box displayed in GUI

4.2 Development

This section describes the next iteration of the system we developed with the requirement list, presented in Section 4.1.6, as a basis.

4.2.1 Change Log

The following list summarizes both significant and minor changes done to the overall system during the development phase. It represents the next iteration of the prototype. Note that the changes are *not* sorted in any particular way.

- Optimized presence-relaying to include information about exit/enter events to enable different notifications when, for instance, available inside a patient room or busy in other places. See Section 4.2.3.
- Added day and night modes. See Section 4.2.4.
- Prepared the system to be able to edit the notification, based on context, more flexible. See Section 4.2.5 for details.
- Updated Nurse Client to be able to receive status relays from the Nurse Station.
- Added automatic status update associated with a phone call: Unavailable when initiating or accepting a call and available when terminating or hanging up.
- Created a new system component: the Nurse Station.
- Added support for changing of Nurse Call Server's SIP URI, using the GUI, at the Wall Panel.
- Fixed the loop bug that was discovered in the pilot study [3].
- Fixed the bug where the phone activity would linger on after a call.
- Blocking status updates caused by location updates while unavailable. This is so that timer-controlled unavailable is not reverted by regular location updates.

4.2.2 Unavailable: Timer Dialog

We created a Timer Dialog to pop up when clicking unavailable on either the Wall Panel or Nurse Client. The dialog displays a list of time suggestions as seen in Figure 4.2 (Nurse Client). Clicking any of these suggestions will set the status to unavailable and start a timer that will reset the status to the previous status upon timeout. We also modified the Nurse Client and Wall Panel to block status updates, caused by location updates while unavailable (see Section 5.3 for details).

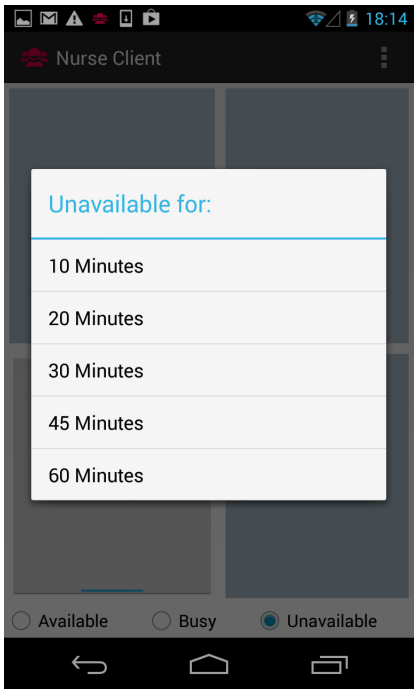


Figure 4.2: Timer Dialog

4.2.3 Location Updating

We slightly redesigned the location updating strategy for reasons discussed in Section 5.3. The changes are mainly tweaks to what information the components exchange. Upon a transition in or out of a patient room, the BLE Server will issue a message containing:

- A location update of type *ENTER* or *EXIT*.
- The SIP URI of the nurse associated with the beacon ID.

The Wall Panel stationed with the room in which the event originated is the receiver of this message. After the Wall Panel receiving this message, it will proceed by relaying the location update to the Nurse Client, using the attached SIP URI. Next, upon the Nurse Client receiving this relay message it will, in case of *ENTER*, subscribe or, in the event of *EXIT*, unsubscribe to/from the Wall Panel. While a Nurse Client is subscribed to a Wall Panel presence-relaying may take place, which means that updating the status manually by either using the Nurse Client or Wall Panel will cause the other one to update accordingly. In other words: The Wall Panel and Nurse Client will display the same status at all times. Figure 4.3 shows the subscription life cycle.

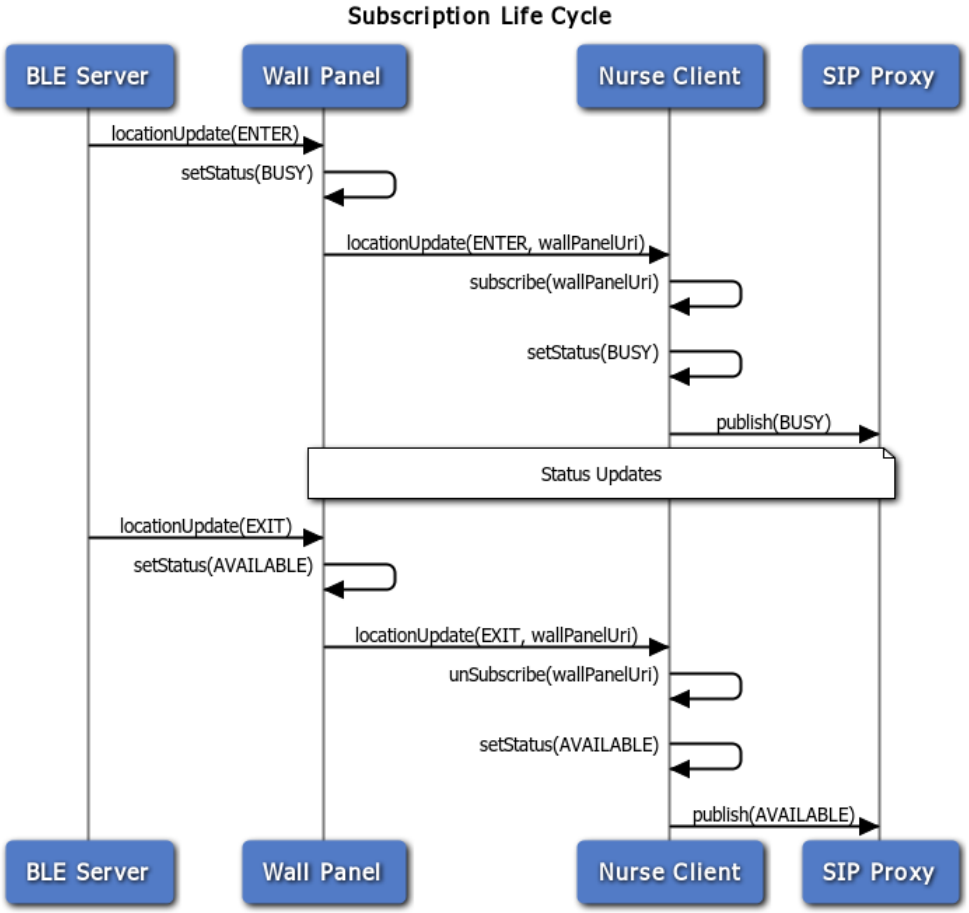


Figure 4.3: Subscription Life Cycle

4.2.4 Day and Night Context-Awareness

We added time as a context sensor to provide better context-awareness. The sensor was created by adding a toggle button to both the Wall Panel and the Nurse Client, which would control a Boolean flag (i.e. true/false). The system would use the flag when determining the proper notification when receiving an eventual nurse call. See Section 5.3 for the reasoning behind choosing this way to implement day/night context-awareness. Figure 4.4 shows the button at the Nurse Client (it is the same at the Wall Panel).

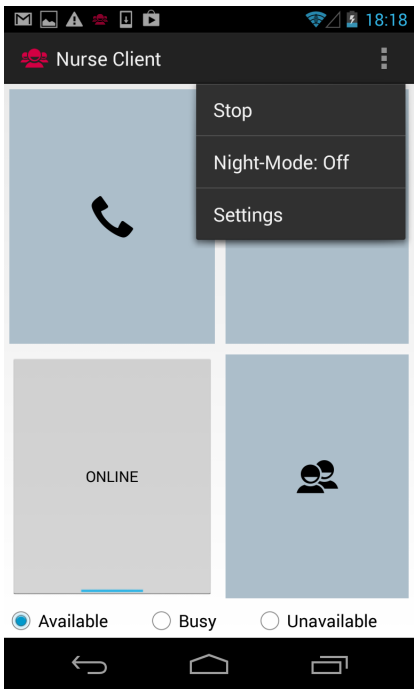


Figure 4.4: Setting Day/Night Mode

4.2.5 Notification Modification

Table 4.2 shows how the different levels (i.e. low, medium, and high) listed in the notification modification Table 4.1. The system calculates the volume by rounding the result of multiplying the maximum volume supported by the device by the float, associated with the respective levels, to the nearest integer. We determined vibration levels by “feel”.

We designed a state machine to take care of notification management. Each time a nurse call arrives at the Nurse Client, it activates this state machine. It has the following states: *IDLE*,

	Volume Level (integer)	Vibration (milliseconds)
Low	$[max \times 0.5]$	$Interval = 1000, duration = 100$
Medium	$[max \times 0.7]$	$Interval = 2000, duration = 200$
High	$[max \times 1]$	$Interval = 3000, duration = 300$

Table 4.2: Notification Levels

ACTIVE, *FLASH_OFF*, and *FLASH_ON*. Figure 4.5 shows the possible transitions between these states. The state machine switches between the *ACTIVE* and *FLASH_ON* state whenever it is time to either turn the "flash" on or off. This mechanism ensures that ringing is not be affected by flashes.

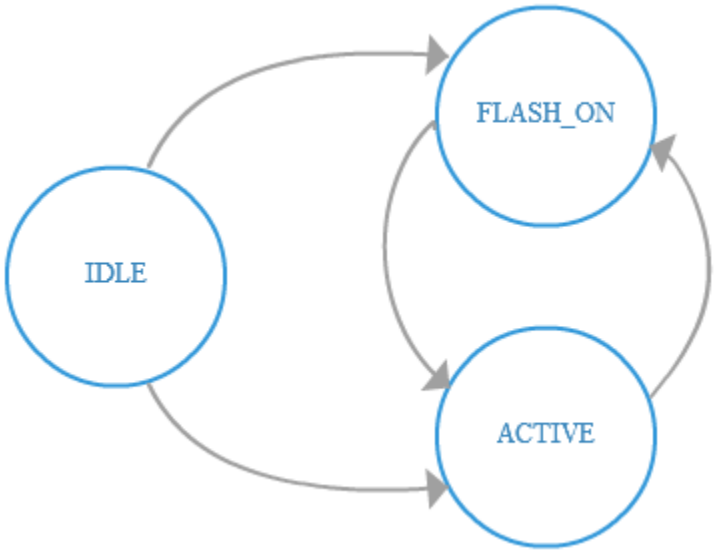


Figure 4.5: Notification SM - State Transitions

The state machine begins in state *IDLE* where it will act upon the events *START* or *STOP*. If the machine receives a *START* event, it proceeds by testing whether it should ring, vibrate, flash, or do any combination of the three. Finally, it moves on to either state *ACTIVE* or *FLASH_ON*. Figure 4.6 displays the SDL diagram for state *IDLE*.

State *ACTIVE* acts upon the events associated with the timers that eventually activated in the *IDLE* state. Figure 4.7 shows the SDL diagram for state *ACTIVE*. The *FLASH_ON* state is identical to the *ACTIVE* state except for the event associated with the *flashOffTimer*. Figure 4.8 shows the SDL diagram for state *FLASH_ON*.

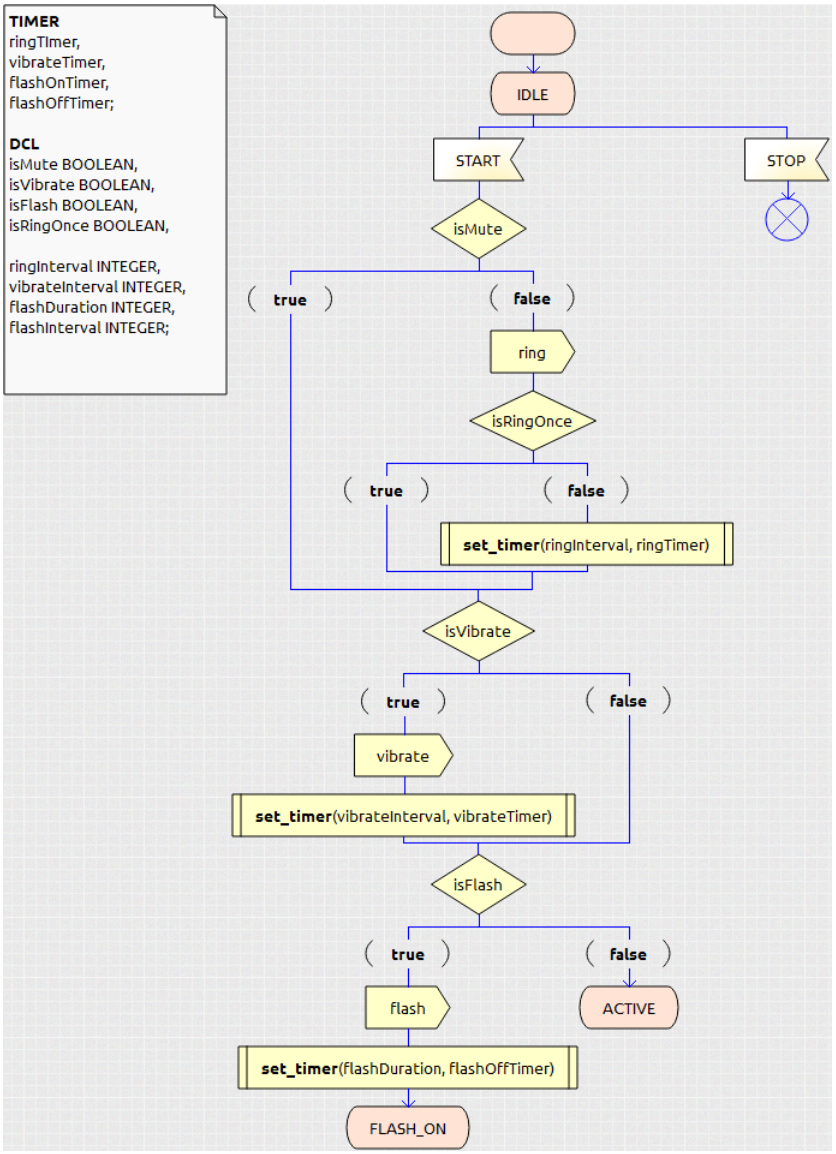


Figure 4.6: Notification SM - Idle state

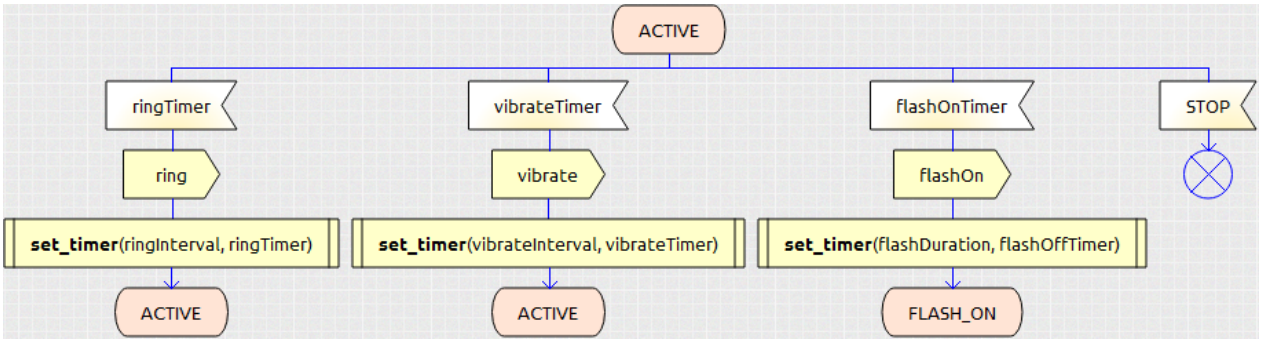


Figure 4.7: Notification SM - Active state

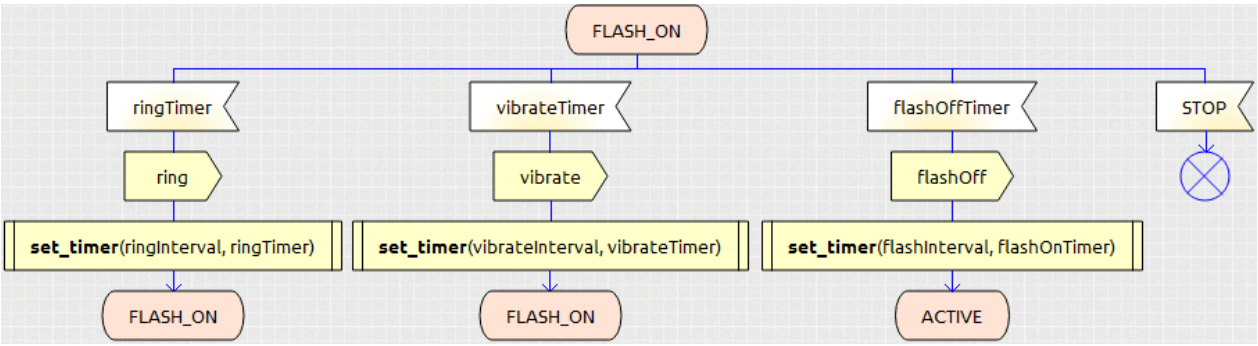


Figure 4.8: Notification SM - Flash_On state

4.2.6 Nurse Station Software

We developed a new system component: the *Nurse Station*. It was designed with a simple interface, which can be seen in Figure 4.9. The GUI displays the names (to the left) of three nurses considered *online* and their status showing to the right. A green *check* symbol represents available, busy is represented by a yellow circle, and unavailable is a red *no entry* symbol. Each of these availability icons acts as radio buttons, meaning that each nurse can update his/her status by using the Nurse Station software.

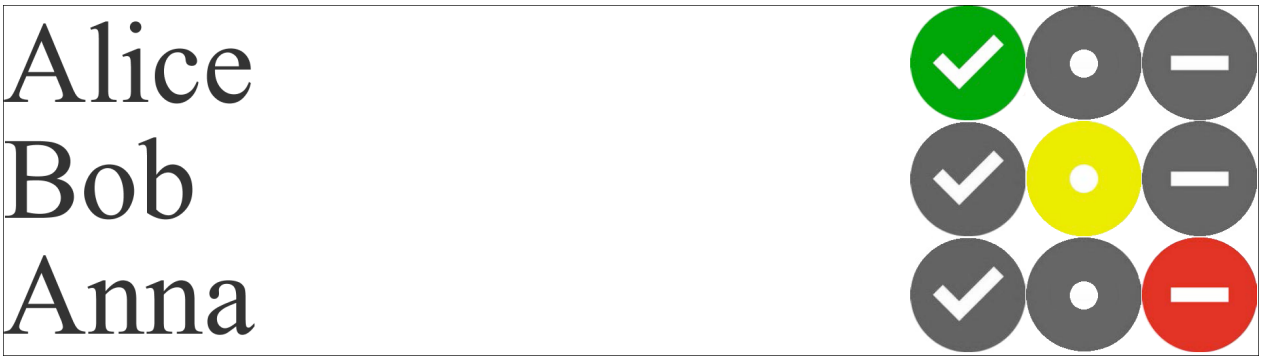


Figure 4.9: Nurse Station GUI

When clicking the unavailable button, the Nurse Station displays a list of time suggestions as seen in Figure 4.10. Clicking any of these suggestions will set the status to unavailable and start a timer that will reset the status to the previous status upon timeout. This feature is similar to the function explained in Section 4.2.2.

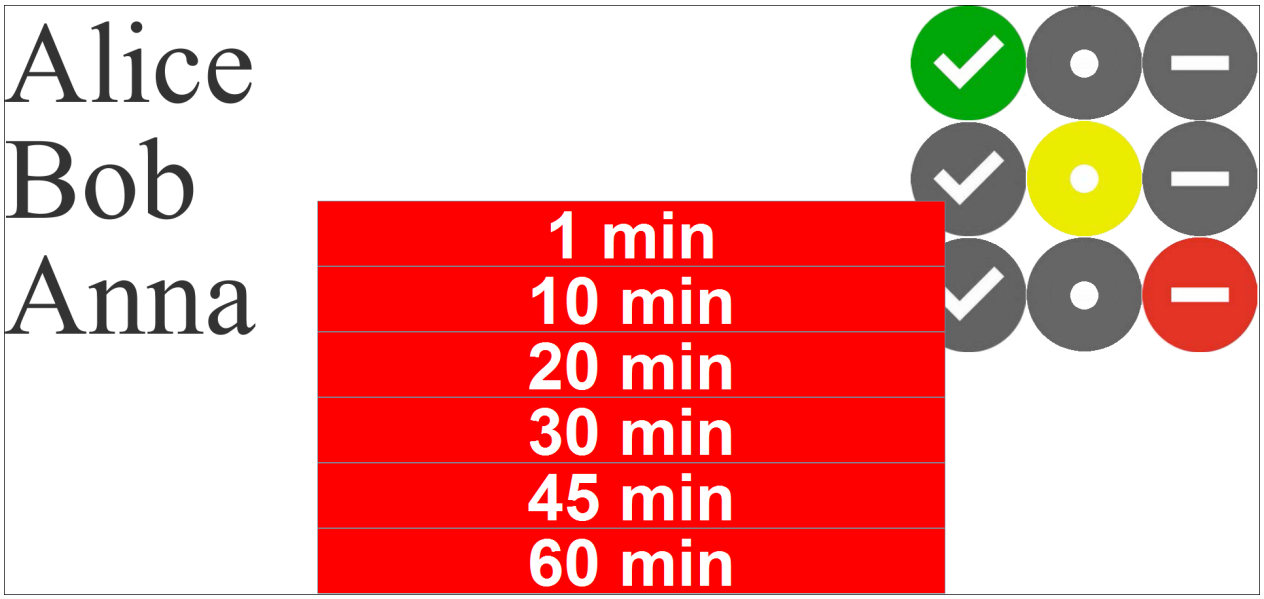


Figure 4.10: Nurse Station GUI - Unavailable Click

Figure 4.11 shows the Reactive Blocks System Block for the Nurse Station which consists of four blocks:

- SIP Client,
- Contact Presence Manager,
- Timer Manager, and
- GUI.

The SIP Client block provides an interface to an SIP service, enabling sending and receiving of SIP messages in addition to presence subscription and receiving of presence updates.

The GUI block builds the swing GUI upon initialization, taking an array of Contact objects, representing nurses, in this case, as the initialization parameter. The block also acts as an interface to/from the GUI components.

The Timer Manager block manages the timers generated, when clicking unavailable, by a given nurse. It will notify the GUI block upon a timer expiring such that the status can be automatically reverted to the previous status.

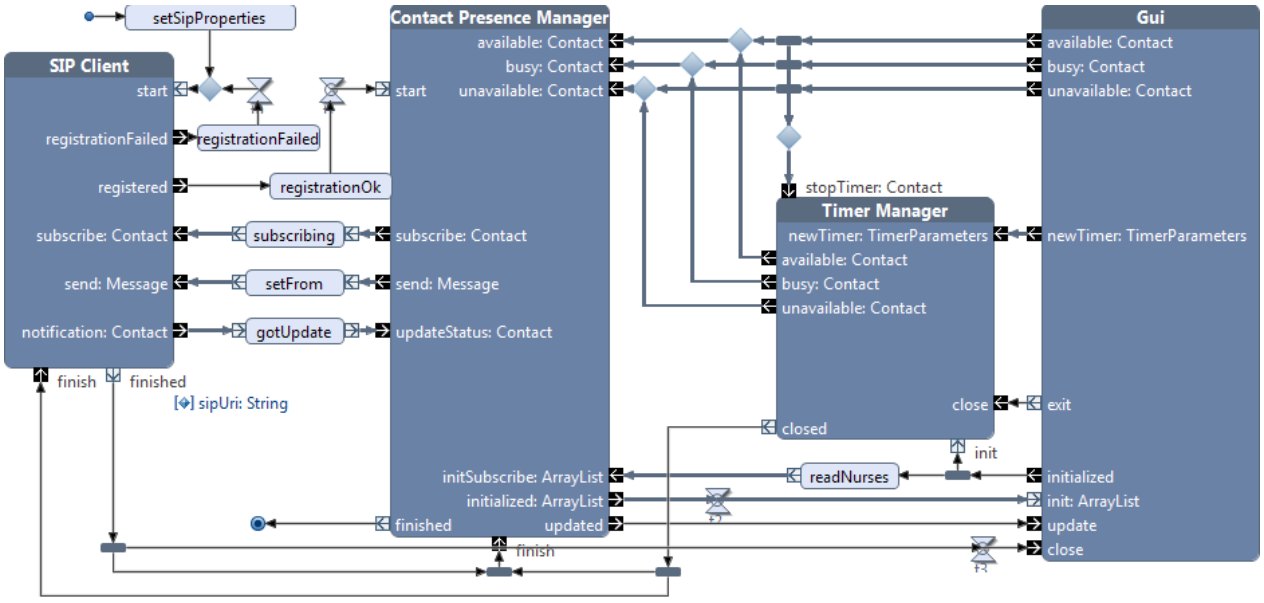


Figure 4.11: Nurse Station System Block

The Contact Presence Manager holds the array containing the nurses associated with this Nurse Station. It acts as a bridge between the GUI and SIP Client blocks and is the core block of the Nurse Station. Figure 4.12 shows the internal structure of the block.

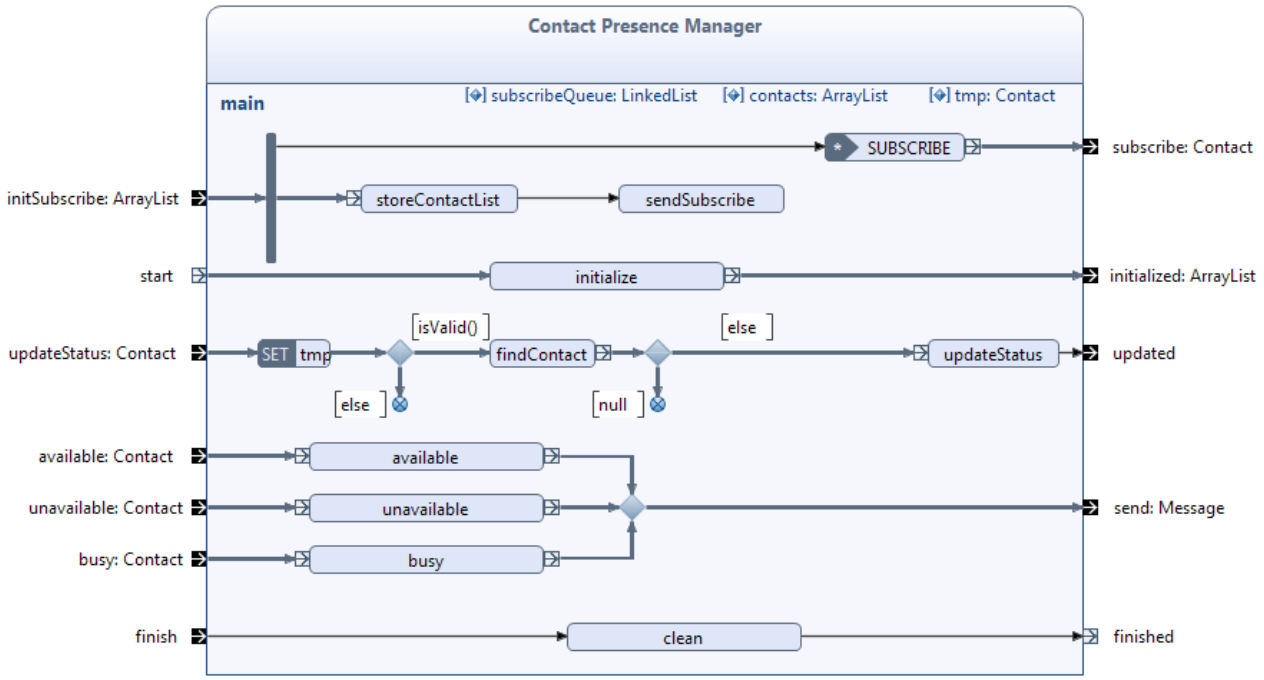


Figure 4.12: Nurse Station System Block

4.2.7 Other Minor Changes

This section lists minor changes, bug fixes and tweaks that have not been previously mentioned.

- The loop bug, which was discovered in the pilot study [3], was occurring if a Nurse Client received the same nurse call twice. This problem made it lose the reference to the original notification thread and create a new thread instead. The bug was two or more notification threads running simultaneously. We solved the problem by ensuring that no new thread can start if one is already running.
- The Wall Panel software was missing the possibility of editing the SIP URI for the Nurse Call Server without hard-coding. We added a new text field to the preferences activity to optimize this.
- The Nurse Client's phone activity (i.e. the activity responsible for calling another Nurse Client) would linger on after leaving the activity. We implemented a proper shutdown of this activity.

4.3 Evaluation Study: Workshops

This section states the results from the four workshops that make up the evaluation study. We use the abbreviations N1-N7 to refer to the participants as indicated in Table 3.3. Be aware of the fact that the nurses use the word "phone" interchangeably with the Nurse Client and the S.T. Olav's phone. Which one is the topic of the respective discussions should be clear from the context.

4.3.1 Issues

We encountered some issues during Workshop 1 and 4. This section presents these issues; refer to Section 5.4 for an in-depth discussion regarding these matters.

An issue with the SIP server made nurse calls temporary unavailable during Workshop 1 (N1 and N2). This fact made it impossible to conduct the planned scenarios. However, we explained the scenarios and their intentions to the participants as clearly and precise as possible, enabling

the discussion to take place regardless. As the participants did not get to experience the change in the notification, the discussion regarding this matter became rather artificial.

Neither of the participants of Workshop 4 (N6 and N7) had experienced many night shifts nor did they have much experience with carrying and using the phones. The nurses have not experienced the effect of a nurse call during a phone call. They did not know that this problem existed. Either way, they still had important opinions we must consider.

4.3.2 General Impressions

This section presents the results regarding general feedback towards the system. It includes positive and negative feedback and general impressions towards specific features. Figure 4.13 shows everyone gathered around the table during the focus group interview during Workshop 1.

The general impressions towards the system were overall positive, especially the fact that many functions operate automatically, without the need for direct user interaction. N2 said: *"I think it is very good that there is a method, making everything happen automatically,"* referring to this very fact. They also noted that the system seemed very user-friendly, orderly, and easy to use and learn.

N5 also liked the simple solutions where things happen automatically and that there are advantages of having automatic updates, beacon, and the monitor. N5 stated: *"I feel like there is a great need for that beacon, and to see who is in the patient rooms."* The nurses of Workshop 4 also had a positive reaction when presenting manual status updates. They also liked the function where you see that a nurse has marked presence in a room (i.e. the busy button becomes yellow at the Nurse Station).

N2 and N5 liked to use a smartphone as they thought it was more user-friendly than the current work phone. N2 said: *"I think it is very nice to use a smartphone."* The nurses of Workshop 4 praised the feature where the Nurse Client sends nurse calls to the next nurse automatically after a short time-interval.

N4 said that it seemed simple and that it was *"Nice to not having to mark presence and pick up the phone."* They also thought it was nice to be busy when you go into a patient room and said that automatic status updating is a good feature.

Figure 4.13: Workshop 1: Focus Group Interview

The nurses also mentioned some criticism. N2 indicated the importance of considering that nurses usually communicate a lot with each other and that technology should not take that away. N2 stated: *"I think that one may stop talking as much with each other."* More specifically, they do not want new system functions to replace human interaction. We discussed this issue in the context of whether getting to know the status of co-nurses is helpful through, for example, the Nurse Station.

N7 suggested that the availability buttons at the Nurse Client could have been a bit bigger. The same nurse also mentioned that the Wall Panel was not easy to see during Workshop 4 (see

Section 3.3.4). N7 also suggested that it might have been better if it had hung on the wall instead of lying in the chair.

When discussing whether the system would drastically change any work routines, N1 said, *"I do not think it would be very difficult to adapt, as automatic it is, in a way"*. In other words: It would not result in too much of a transition, to adapt to such a system. The nurses of Workshop 4 could not think of any situations where the system would possibly work against the standard routines of nurses.

N3 mentioned, *"I might have changed the fact that I would use the statuses better,"* referring to changes in work habits. All participant imagined using a system like this one in their working environment.

4.3.3 Current Work Practice

Nurses tend to find it easier to notice, and interact with the panel, compared to the phone. While in isolation rooms, this fact is especially true, due to hygiene issues. The nurses of Workshop 1 said that the panel is good to have in situations when you can not reach into the pocket, so that you can still see who is calling. Other example scenarios include sterile procedures or situations where it is simply unfeasible to use the phone. N5's statements support this view: *"I want to see the panel since I can not get my phone"* and *"Phones are an optional feature."*

4.3.4 Nurse Station

This section covers results related to the Nurse Station. According to the participants of Workshop 1, the system might organize the day a bit better by providing a better overview of busy nurses. N1 mentioned morning care as an example situation where nurses usually tend to do their routines at the same time. The same nurse thought that better overview could make a nurse choose to stay at the bed area if needed. N1 gave an example: *"Everyone scatters... Everyone being busy. Then there are four other patients that do not get any help."*

N4 imagined that the Nurse Station would be helpful to determine whether to respond to alarms: *"If you are at the bed area... You go and watch the screen. Ok, Alice is away eating. Then I will get that alarm."*

N5 seemed to like the Nurse Station, especially the availability statuses: *"I like those three circles, they seem very nice."* The advantage with the Nurse Station is, according to N5: *"The advantage of that screen is that it is pretty little information displayed."* N4 confirmed this and continued by mentioning an issue regarding sensitive information: *"It can not show too much. Confidential information can not be displayed in any case if it is supposed to be that big."*

When asked about the Nurse Station, N1, N2, N4, and N5 suggested that it could display room information along with nurse names. N1 argued: *"It will make it simpler to search for people, which is a regular problem."* This function would also provide better awareness at the bed area as indicated by the same nurse:

- *"It is nice to have a screen where one can see that others are doing something else... now I have to be available... that one got an overview over everyone."*
- *"I think it is an advantage if you can write up that I can not take alarms and such."*

N5 missed another thing from the Nurse Station, other than room number: The ability to see and respond to nurse calls. In other words, the Nurse Station should act as a Wall Panel that is permanently marked as present so that it receives every issued nurse call. Figure 4.14 shows N5 interacting with the Nurse Station during Scenario 3 (i.e. unavailable during a sterile procedure) of Workshop 3.

Similarly to room numbers, the nurses wanted the Nurse Station to show when a nurse is out of the department. N1 said that: *"I would imagine an automatic registration when leaving through the door that it would display 'out of department"'*

The nurses brought up a problem regarding surveillance and privacy concerns with the Nurse Station. N2 indicated that someone might feel like someone is watching. However, N2 also added that it should not be a problem if the data is not stored. N2 stated: *"If it gets deleted, in a way... That it just shows on the screen... In which case, I do not see any problems."*

A similar and just as important issue that we discussed during Workshop 4 is the social and ethical aspects associated with setting unavailable. Having the status of every nurse visible for everyone could affect the behavior of nurses when deciding to go unavailable. The essentials of the discussion were that the Nurse Station could provide a kind of "checks and balances" system where exploitation of the unavailable system could be enforced by co-workers. However, N6

Figure 4.14: N5 interacting with the Nurse Station

mentioned that such a system could create unpleasant situations and talking behind backs, e.g. *"Ah, how typical of that nurse to set unavailable."* However, N7 did not see it as too much of a problem: *"I think there are more advantages than disadvantages. One would be more attentive to what to click,"* referring to "clicking" statuses.

4.3.5 Location as Context Sensor

This section covers results regarding using location as a context sensor. N1 mentioned hygiene as an important advantage of automatic presence detection within a patient room: *"It is an advantage that one do not have to touch things."* N2 confirmed this benefit: *"I think it was very smart, especially the fact that one does not have to click."* N5 also said: *"It is a huge advantage to not having to press any buttons since I am wearing the equipment and can not enter the room with*

the phone." N5 was referring to Scenario 3: Sterile procedure where N5 assumed tuberculosis and decided not to bring the phone into the room. N5 said: *"It is a very common situation that I go into a room with infection guard equipment."*

The nurses of Workshop 1 also mentioned another advantage of being able to save some time in acute situations, by not having to mark presence manually. Further, no one could name any particular disadvantages with automatic presence detection.

Entering or Exiting Patient Rooms

N5 stressed the importance of safety concerning noticing patient signals. N5 thought that automatic presence detection would solve the problem of forgetting to mark presence in patient rooms, which is beneficial concerning safety. N5 also mentioned that it is possible to forget to turn off the panel when *leaving* the patient room. This problem may cause patient signals to disturb the patient, even with no nurse present in the room. Automatic presence detection will also solve this issue.

The nurses of Workshop 4 also thought it was a good thing that you are signed *out* of the room automatically. They mentioned a problem where the current system will issue a heart stop alarm if the patient pulls the rope while the panel is active. N6 gave an example: *"Disadvantage that many forget to turn off when leaving the room. When the patient calls and is thirsty... Wants a glass of water... Suddenly ten nurses arrive, wondering if everything is all right."*

The nurses brought up a problem regarding the reverting of the unavailable status after, for example, a sterile procedure. The nurses seemed in favor of doing this manually when done. Alternatively, one could set a shorter time than expected. We discussed a solution where one could automatically revert from unavailable when exiting a patient room. However, N3 argued that it might become annoying if you leave just to get something In which case one would have to repeat the sterile procedure. Still, N4 noted, *"I think it is rare that you have to leave. One must check that one brought everything needed."*

N5 also wanted unavailable to revert, when leaving the room, automatically: *"It could be a risk if I set an hour to be safe, maybe it only takes 15 minutes."* N5 also mentioned that the phone could play a notification upon unavailable timeout (kind of like a "new-mail" sound).

N4 indicated that there were situations where nurses do not mark their presence when en-

tering a patient room. N4 said: *"I do not mark presence in the room if I am just in there to get something or drop off something. Maybe not even when I am just cleaning a room."* However, they concluded that it would not matter if one would be marked as present automatically in those situations. In addition, nurses might not want to be detected automatically when there is no patient in the room. They mentioned some example tasks: making the bed, administering medicine, delivering dinner or water, idle chatting, or preparing a room. Figure 4.15 shows N4 talking to patient Bob while busy during Scenario 1, Workshop 2.

Figure 4.15: N4 busy while talking to Bob during Scenario 1

Entering or Exiting Departments

When discussing other possible *locations* where the system could perform automatic status changes, based on location, the nurses said that it would be nice to become automatically un-

available upon leaving the department. N4 specified, *"I do not think I will turn around to get the alarm if I left the department, except if it is acute."*

N3 argued it might be enough with busy when leaving the department. Also, that it might be better to set unavailable manually in this case: *"I would imagine that sometimes it might be good to know if it rings a lot, especially at night."* N4 commented: *"I thought it could be nice to have when in lunch, or if you are leaving the department. Whether it should be done automatically or manually could be debated."* However, N7 did not think it has to be done automatically: *"Might as well set it yourself."*

4.3.6 Time as Context Sensor

It was brought up that nurses check in with patients (some are asleep) during the night, especially if it is someone who is breathing poorly. N2 mentioned an important problem with phones, regarding this matter: *"I see many leaving their phones outside when they go to the patient so that they do not wake them up."* When discussing nighttime issues, the nurses of Workshop 3 also noted that it might be loud during the night, which is not good as it could wake an eventual sleeping patient. It is also important to notice that nurses might do sterile procedures during the night and that they always perform them in patient rooms.

According to the nurses, doctors may react if many alarms go during doctor visitations, which could indicate that this situation could be subject to automatic status changes.

4.3.7 Availability Status Discussion

When discussing the availability statuses, they once again brought up acute signals. These signals must come through regardless of status. The findings indicate that three statuses (i.e. Available, busy, and unavailable) would be optimal, though only if emergency signals (e.g. heart failure alarms) go through regardless of status.

What follows is a presentation of the discussion regarding busy and unavailable statuses. The results revealed advantages, disadvantages and situations regardless of location where the statuses could be used. Note that the discussion did not go in depth regarding the available status.

Busy

The nurses mentioned a situation where busy could be good to have. Sometimes nurses may experience difficult situations with patients or co-workers. N7 gave an example: *"Maybe one got scolded by a patient and wanted to have a conversation."* This situation is an example of when busy is good to have in locations other that the patient room. Another example of where busy can be used was mentioned. One might want to be busy in the common area, during for example walk training.

It was mentioned that busy might not be enough in all situations. N5 said: *"It would be in situations where I do not want the phone to ring, or the patient to hear the phone ringing,"* in addition to difficult conversations.

Unavailable

There were many mixed opinions regarding the unavailable status, and whether it is needed or not, which resulted in different and sometimes opposing statements from the same nurse.

N5 imagined that unavailable would be used whenever one would not want to be disturbed: *"The reason I bother to do it, is that I do not want to be disturbed. Those times I do not bother, well I am thinking I am available then."* N5 used doctor visitations as an example situation where N5 saw an advantage to using the phone to update availability status easily.

Another situation where unavailable could be used is during private, important or difficult conversations. N6 mentioned an example of such a conversation, which was when filling out an "ESAS" chart, which they use to describe level (1-10) of nausea, pain, depression, appetite and such. *"In such a conversation, it is really important that nurses have 100% focus towards the patient."*

N3 mentioned that it could be nice to be unavailable in the case of fatalities occurring inside a patient room. The situation is especially delicate if there are mourning family members and friends present.

N1 seemed to like the possibility of having an unavailable status: *"I think it is very nice to have unavailable as an option."* N5 thought that blocking unavailable is OK because of the safety provided by the Wall Panel. The nurse assumed that being unavailable would not affect the Wall

Panels. When it was explained that this was not the case as the prototype is now, N5 responded by stating that the Wall Panel can not be silent. N5 argued: *"No matter the importance of what we do, we have to see who is calling. It is a matter of life and death."* N5 imagined the unavailable status only to affect the phone: *"I can set unavailable to not get interrupted by the phone, but I have to have the Wall Panel enabled in case of emergencies."*

The nurses had a positive attitude towards the blocking unavailable status and automatic reverting from unavailable after X minutes. N6 said: *"You do not have to go back and turn it off yourself, as that might quickly be forgotten if it is a busy department."* N7 said: *"I think it would be nice to be able to set oneself as unavailable and tell colleagues that I am going to have that conversation and be unavailable."*

N3 mentioned that a good thing about the unavailable status was the quicker response times, concerning the patients. It is good that the signal goes directly to the next nurse, which results in both quicker response and fewer distractions for those that are unavailable. N3's statement: *"It is nice if you can avoid having the signals come by yourself as it delays the signals to the others as well."*

Regarding how often nurses would use an unavailable status, N3 thought it would not be too often: *"Not daily, no."* The nurses of Workshop 4 had similar opinions and said that it may depend on where you work. N7 stated: *"If it is a cancer department, then you probably have many important topics which the patient wants to talk about, so it might be nice to avoid alarms."*

According to N1, unavailable might not be necessary, as the busy status takes care of most of the problems associated with interruptions. N1 thought that a vibrating phone might not be that distracting: *"It might not be very disturbing if it vibrates in the pocket."*

The nurses mentioned one drawback with the unavailable status: It may be easy to exploit the unavailable status, for example by repeatedly re-apply the status after the timer has expired. The nurses thought it would be accepted socially, to be unavailable, as long as it no one exploited the status.

Regarding unavailable exploitation, we discussed whether there should be clear guidelines towards the usage, due to its controversy. N4 said: *"I was thinking, is a sterile procedure a completely unavailable state or is it just busy? It should be said something about that."* N4 also mentioned a problem with when a function, like unavailable, is easily accessible, it might not be

used in the situations for where it was intended. N4 said: *"I remember when it was another phone where it was possible to turn off the sound. We did that... I did that."*

Another situation where unavailable might be a problem is during the night. It this situation there are usually only two nurses are at work, which could create some problems if one or both nurses go unavailable, especially during emergencies. N2 said: *"I think the thought of not getting any signals is a bit scary."*

N6 brought up another problem that if someone would be much unavailable, there might be many nurses visiting the same patient. N6 stated: *"It is an advantage that the primary nurse gets the patient signal."*

There might be situations where regular nurse calls might be very urgent, for example in the case of patients marked with a danger of falling. We discussed that this might be a situation where regular nurse calls are important even while unavailable. A solution was suggested where one could set a system status on these patients that got screened with fall danger, as this information is usually given in a written report as of now.

N6 imagined an unanswered call list function that would display the nurses that took care of missed nurse calls while unavailable. However, the same nurse mentioned that the system should not try to replace human interactions. N6 said: *"If Per called, and I was slow into the room, then it is natural that Alice told me: Per called, but I took care of it."* Therefore, N6 decided that there would be no need for an indication that another nurse handled a nurse call while unavailable.

Phone Call

Most nurses thought it was annoying to get nurse calls during a phone call. Incoming patient signals supposedly abort everything you do on the phone (e.g. clicking, searching, or writing). N4 gave an example situation: *"Earlier today I was talking to the surgeons on the phone while it started ringing... Hurry and accept to get it away to continue talking... I did not even notice who issued the call."*

The nurses thought it sounded right to become automatically unavailable during a phone call. However, they once again brought up the problem regarding emergency alarms.

When asked if they thought it was important to become aware of nurse calls during a phone

call N1 responded: *"I would not say that. You are supposed to watch where you take phone calls with respect to confidentiality, which means you will usually be close to the designated cubicles reserved for such matters."* On the contrary, N5 stressed that it is just as important to become aware of nurse calls during a phone call. This issue would not be a problem as long as there would be panels available, roof panels even. N5 said that unavailable during a phone call is no safety concern as one get the information one need from the panels.

Supposedly, phone calls are usually short conversations, so the importance of nurse calls might not depend on who is calling according to N2. N2 further mentioned that patients usually call using the main phone of the bed area and that, leaders and head physicians might be the ones benefiting from becoming temporarily unavailable, as they call more often.

It was said during Workshop 4 that the disadvantage to blocking nurse calls while on the phone is that it might depend on the purpose of the call whether you want to notice nurse calls or not. N6 said that if you knew about the signal, you could start moving, while one the phone. The nurses also said that it might *not* be right to set unavailable for short conversations. In short, they disagree with becoming unavailable while on the phone.

Due to the above problems, N6 suggested that busy might be more appropriate during a phone call, or maybe just some (weak) vibration. The nurses also indicated that it should be easy to send the signal to the next nurse while on the phone.

N7 did not think it mattered if a small sound was played to notify of a new nurse call while on the phone, regardless of who has the primary responsibility for the patient: *"I do not think it matters if you get a notification while on the phone, even if it is someone else's patient."* The nurses of Workshop 3 supported this view. That said, when asked if vibration is a problem in this scenario, N4 responded: *"Yes, terrible!"*

N7 also mentioned that it could be helpful to have the possibility of discerning between phone calls and patient signals when selecting the appropriate status. N5 provided an example. N7 said: *"One is available for phone calls when one set unavailable for patient signals and that one set the phone to mute if you do not want to be disturbed."*

4.3.8 Optimal Notification

This section presents the nurses' opinions on *how* the notification should change in certain situations. When discussing the optimal method of notification, N2 stated: *"I feel like there is not much of a problem that the phone rings during daytime."* N1 said: *"I think that one ring, followed by constant vibration sounds nice."* They also mentioned the importance of choosing a good ringtone.

After Scenario 1, N3 also commented positively on the "ring-once" function (see Section 4.2.5): *"The first time only... That it rung as usual. I think that was very clever."* However, N3 also mentioned that the sound level was too low, as one might miss alarms: *"The first signal should have been even more powerful in that case."* N4 supported this view: *"If I put the phone in my pocket before I went in, I might not have noticed Ida calling, not with that tiny sound."* A nurse also mentioned that vibration, with the phone in pocket, might be difficult to detect. N7 said: *"If you do not notice vibration-only, it might be a bit stupid if you are not that busy."*

After Scenario 1, N5 also commented the sound level while "Busy": *"This sound, it might have had to be louder, but it is discreet."* The nurse thought it was smart that it did not ring all the time but rather ringing once and vibrating. However, it could ring occasionally with discreet sound. N5 also mentioned the importance of a discreet sound and noted that the sound (i.e. Android - Tejat) will be comfortable, even with more volume.

After Scenario 1, N6 explained how the situation was experienced: *"When he is anxious I want all my attention on Per, then the phone starts vibrating, sound, and blinking."* However, N6 lost focus because of the ringing and vibration, N7 noted that compared to a regular alarm it is better, especially since the phone stops ringing after 15-20 seconds. N7 added that if it is something important, you would have to get notified of alarms. N7 commented further on the notification: *"I think the sound was calm, it vibrated a bit, and you noticed the alarm. It was not overwhelming; I think the volume was fine."*

N5 thought that completely muting the sound would be troublesome: *"I think mute is difficult, we will not register that. It would have to be a very powerful vibration."* A nurse also mentioned that, during nighttime, the phone should vibrate a while, before ringing, so you can turn off the alarm before the ringing starts.

When discussing how the notification should change when entering a patient room, N5

thought that both the Wall Panel and the phone must ring at the same time. The nurse also said that the Wall Panel should be as it currently is at the hospital because: *"The panels are not experienced as stressful for the patients."*

Night

The nurses thought that both the Wall Panel and Nurse Client could ring during daytime. However, during night time both might be a bit too much. N3 suggested that the Wall Panel could make a sound. N3 also mentioned that one could manually override the status in the situation where the patient is sleeping. Otherwise, it could ring: *"If the patient is awake, it could ring."* N7 suggested a possible way the system could perform this status update automatically: If the lights are on, it could ring. N7 also commented on the notification during night: *"I think it seems like an advantage with lower sound, maybe not that much attention from the Wall Panel if it glows much, if it could wake the patient or be disturbing maybe."*

N2 commented on how nurses can perceive the notification in this during night: *"During night or a late evening shift one might notice a big difference if the phone rings loudly, compared to if it had a function that made it ring quietly."*

The nurses had some suggestions to how we can change the notification for the better at night. It could ring for a short time and then transition into vibration only. N1 added that humans notice high octaves easier than low ones while sleeping, which the system could take into consideration when selecting a less disturbing ringtone.

Another argument that came up was that patients might be used to a lot of sound, even during the night. The reason being that there could be loud monitor tools attached to the patient. N1 stated: *"Health is always the priority, not necessarily sleep and such."*

Chapter 5

Discussion

It is important to keep the research questions fresh in mind to start the discussion. The list below briefly restates the research questions presented in Section 1.6. Remember that "panel/panels" is a reference to S.T. Olav's nurse call system while "Wall Panel/Wall Panels" is a reference to the Android Nurse Call System.

- How can we design, develop and integrate an interruption management system into a nurse call system?
- How and in what situations can a system infer context automatically?
- What situations are problematic when it comes to inferring context correctly and how can a system handle eventual incorrect inferring?
- How should the system modify notification in different situations?

It is also crucial to have an overview of the most significant findings when attempting to discuss the results and their implications. As we discuss the various topics, we give a brief recap of the most valuable findings to initiate the discussion. Note that we discuss design choices regarding the results from the development process separately in Section 5.3

5.1 Discussing the Initial Study

This section restates and discusses the most significant findings from the initial study and explains how these forms the requirement list presented in Section 4.1.6.

5.1.1 Relationship to Previous Work

Due to the cultural differences between hospital departments, it is difficult to develop a system that satisfies everyone. Some departments use the phones actively while others only use the panels. As some nurses argue that they can not find any advantages to having nurse calls arriving at the phone, some like having prioritization of patients, to specific nurses, which is enabled by the phones. These facts mean that it is important to create a system that allows nurses to decide individually, how they want to use the system, without compromising critical values like patient safety, usability, and flexibility. By providing multiple interfaces where every necessary function is easily accessible, nurses can decide how they would like to work by themselves. This fact is in line with [3].

Currently, nurses experience the phone not to be very user-friendly. Even though the phone has many features, they consider it a bother to learn how to use them. Compared to today's smartphones, these Cisco phones can not compare when it comes to user-friendliness. This finding support the fact that users are not always adopting technology-centered solutions as intended (assumed in Section 1.3).

Interruptions in the hospital environment are indeed an important problem to address as also indicated by previous work. The results of the initial study indicate that nurses tend to work around the system in certain situations such as important conversations, (sterile) procedures, and during the night. They do this by, for example, leaving their phones behind. The reason they sometimes have to do so is because the system does not consider context and will present loud nurse calls whenever a patient issues an alarm. These findings support the need for utilizing a user-centered design approach as explained in Section 3.1 and are in line with [1, 2, 3, 4].

The intensity of interruptions (i.e. how often nurses feel interrupted) is difficult to estimate. The problem is that this number has a subjective nature because of how different nurses feel about interruptions. Also, the number of interruptions are highly dependent on how the nurse

call system is used, which means that it varies a lot between different departments. However, such numbers are probably better to determine through quantitative studies. The results, presented in this thesis, estimates that it is at least frequent enough to call it a problem.

We can map some of these situations to a certain location, as nurses perform some tasks in specific locations only. This fact means that a location sensor alone can detect many of these tasks and situations. Examples, taken from the results, where location detection could be helpful include isolation rooms, patient rooms, and while out of the department. These examples are in line with previous work [3].

5.1.2 Further Development and Evaluation

What follows is a discussion about different key problems discovered in the initial study. We also discuss how the discoveries laid the foundation for the development of the next iteration and the evaluation study. Note that the requirement list for the new iteration in Section 4.1.6 and the evaluation scenarios in Section C.4 (appendix) are both based on this discussion.

Night shifts are a problem because patients may be sleeping while nurses check in on them. The results indicate that nurses can solve this problem by manually removing presence from the room. However, we can also deal with this problem by adding another context sensor: time. By having the system modify notification considering the time of day it could take into consideration that patients may be sleeping if a nurse is present in a room during the night. This idea inspired the day/night context-awareness implementation and thus, the night shift is a suitable scenario to evaluate this function.

Determining the best method of notification is not easy as this is a whole research topic on its own. Quantitative studies might also be more suited to answering this kind of question as it is about finding the best commonly accepted method. However, the results indicate some key concepts that we should adjust:

- the interval between rings,
- volume, and
- vibration.

Adjusting these concepts to the different scenarios where nurses feel interrupted is essential towards finding the optimal notification method. By using the data presented in Section 4.1, we can form some assumptions, from which Table 4.1 is a direct result from:

- The panel and phone ringing simultaneously may be unnecessary in some situations.
    - Day: The phone can be muted when brought into the patient room since the panel is enough.
    - Night: The panel can be muted if the phone is brought into the patient room since the phone is closer to the nurse than the patient is to the panel.
- A “ring-once” function can reduce the impact of an important interruption by ringing once before transitioning into vibration only.

Difficult conversations and night shifts are good scenarios to evaluate the notification modification strategy. Both situations are scenarios where nurses feel that interruptions can be a problem.

An important issue to discuss is that nurses may forget to update their statuses from busy or unavailable if they were set automatically. A possible solution is to have the system notify to remind to update status at strategic intervals, which is in line with [24]. Another solution is to guess a time when setting unavailable in the first place. These facts inspired the timeout functionality for unavailable. As the results indicated sterile procedure as a situation where the status could be unavailable. Therefore, the situation is a suitable scenario for evaluating this functionality.

Many nurses complained about the alarms during phone calls. The assumption is that a possible solution could be to set the status to unavailable for the duration of a phone call automatically. Naturally, to evaluate this function, a phone call is the best option. Reasons for evaluating this function at all include unanswered questions like:

- Does it matter who the caller is?
- Is blocking unavailable the correct status while in a phone call?
- Is it important to become aware of nurse calls while on the phone?

As the results indicate, everything has to be very simple and easy to do. Otherwise, nurses will not bother to use the system as intended. This fact means that there has to be an easily accessible, functional, and simple interface in any given situation. As of now, the Nurse Client and Wall Panel are the only two existing interfaces. Another possible interface could be a big screen at the bed area that allows for a quick overview over all nurses and their statuses, as also suggested in [3]. It should also be possible to update the status manually at this interface. As related work has shown [2], nurses manage interruptions by keeping an overview of the current situation at the department. The assumption is that a central monitor will improve awareness and thus help handle interruptions. These facts gave birth to the Nurse Station Software.

Emergency signals should go through regardless of availability status. We should implement emergency signals to enable evaluation and have the notification modified accordingly. A possible scenario to evaluate this is an emergency like heart failure.

The four scenarios listed in the Evaluation Study: Workshop Guide are all based on the situations and solutions discussed in this section. We use the new iteration of the system to evaluate whether the assumptions presented in this section are valid in these four scenarios: difficult conversations, night shifts, sterile procedures, and phone calls.

5.1.3 Other Ideas for Further Exploration

Another possible interface is the Roof Panel. As indicated by the results, some nurses miss having roof panels that used to exist. One might argue what is more visible, a panel hanging from the ceiling or on the wall. However, one fact is clear: One cannot interact with a roof panel. Such a tool would only be for awareness purposes, which may be an advantage in situations where interactions are impossible.

5.2 Discussing the Evaluation Study

This section discusses the most important findings from the evaluation study and their implication in relationship with the initial study and previous work.

5.2.1 General Impressions

The results imply that the prototype is simple to both learn and use, especially with all the automatic functions operating properly. Not having to interact directly with anything, except under unusual circumstances, is a great advantage (e.g. hygiene). Using a smartphone makes the system more user-friendly automatically, as it is reasonably safe to assume that the general public already knows more or less how to operate them.

As the system currently is, it will not change the nurses' work routines in a bad way. Rather, it will improve on bad and inefficient routines like when nurses decide to leave their phones behind. It is not going to be a difficult transition for nurses to adapt to the system if a hospital were to deploy a similar solution. This fact is in line with the user-centered design methodology, presented in Section 3.1, which means that the system design is on the right track.

As revealed in the Results, the radio buttons (GUI) for availability at the Nurse Client and Wall Panel are a bit too small. Large, custom designed radio buttons may be a good solution. The GUI would have to be scaled and reordered a bit to make more room for the buttons.

5.2.2 Nurse Station

As the results imply, the Nurse Station should also display room numbers, thus making it easier to find colleagues, which can be a common problem at times. Also, in some situations, it could be helpful to know if a colleague is outside the department, which could also be displayed. However, it should not be too much information at the Nurse Station as confirmed by the results. Its purpose is to give a quick overview of the situation in the bed area and provide easy access for changing status. Also, no sensitive information should be displayed by the Nurse Station. Finally, it should also be possible to manage nurse calls from this interface.

The Nurse Station is a great addition to the nurse call prototype. Even so, there are some ethical aspects associated with the component. One may get the feeling of being watched all the time, which could alter nurses' behavior in some situations. Nurses might be affected by the fact that everyone can easily see their status and even location in some instances. However, it might be a good thing, as it enables collective enforcement towards exploitation of statuses.

The positive feedback towards the Nurse Station and the eager responses to improve it proves

that the original assumption to create it in the first place was a success. The key to making the Nurse Station a valuable component is to handle the ethical aspects and keep the information simplistic.

5.2.3 Context-Awareness

This section discusses situations where the system can infer context automatically and how we can do it from a technological viewpoint.

Location as Context Sensor

Using location as context sensor, the system can identify many contextual situations. The reason for this is that nurses perform most tasks inside patient rooms. The automatic detection and status change when entering and leaving patient rooms are indeed highly desired features. As mentioned earlier, hygiene is an important advantage of the automatic presence detection. Of course, it also solves the problem where nurses forget to update presence when entering or leaving the room.

We partially confirmed the assumption from the initial study where the system should block status updates, caused by location updates, while unavailable. This statement means that the assumption holds for "ENTER" events (i.e. when a nurse enters a patient room), not for "EXIT" events. In other words, the system should automatically revert from unavailable after leaving a patient room. This feature is to safeguard against forgetting to revert the status manually in case one finished before the expected time-frame. Whether this new assumption holds, require further research (see Section 6.1).

When leaving the department, should the system automatically set unavailable? The results indicate that nurses usually do not return to the department so that they can respond to a nurse call, however it is sometimes useful to know if one is needed back at the department due to, for example, high demand. This fact makes it difficult for the system to decide on an appropriate status automatically when out of the department. Alternatively, nurses could change the status manually while having the system flag nurses as "Out of Department" automatically, just to inform other nurses via the Nurse Station.

The positive feedback regarding these functions proves that nurses both want and need them. There are not many other locations, other than the ones already mentioned that could be associated with automatic status updates. At least not from the use of location context-awareness.

Time as Context Sensor

The evaluation study indeed confirms that this is an issue we need to address, as nurses tend to work around the system during the night. For example: leaving the phone behind and not marking present in the patient room to avoid disturbing a sleeping patient. Correctly inferring context in this situation is about making sure that the system knows that the patient is, in fact, asleep. Time might not always indicate a sleeping patient, which is why there might be a need for more context sensors. Some possibilities include: Check the state of the lights (as suggested by a nurse) and reading monitor data like heart rate and such. However, it may not be a problem if the system made a wrong assumption in this scenario, as the nurse should notice alarms either way.

Monitoring the Nurse Client as Context Sensor

Monitoring user activities performed on the Nurse Client/phone can also act as a context sensor in a way. Context clues such as active phone calls, message writing, and similar can be revealed by having the application monitor its usage.

Automatically becoming unavailable to block nurse calls during a phone call is a good way to solve the problem where nurse calls arrive in the middle of a phone call. As the results indicate, it is just as important to notice a nurse call in this situation, but one can do so by noticing the panels. That said, another solution where the phone changes its notification method could work just as well. For example, low beeps with a high interval between rings without any vibration.

5.2.4 Inferring Context and Problematic Situations

This section discusses specific situations where context is difficult to infer. Usually, there will be situations where the system can not do status updates automatically or when the system makes

a mistake in inferring context correctly.

The data from the evaluation study confirms the fact that important, difficult or delicate conversations are subject to interruptions. The problem with these situations is that they may occur in various locations independent of time, which makes it difficult or even impossible for the system to detect. Examples are conversations with patients, next of kin, friends or even colleagues. Similar situations include meetings and when performing walking training with patients. Any of these situations can, for example, occur in patient rooms, meeting rooms, bed areas, dedicated rooms and similar.

Another situation is prone to the same problem, namely when there has been a fatality in a patient room with mourning family and friends present. As the results indicated, loud nurse calls might be inappropriate in this particular situation.

We can handle these problematic situations by enabling manual updates of availability statuses through easily accessible interfaces. The Nurse Station is an attempt to increase the number of easily available interfaces to support this problem.

5.2.5 Availability Status Discussion

This section discusses availability statuses and some issues related to their usage. The results once again confirm that emergency signals must go through regardless of status. As the nurses brought up this fact at almost every workshop, this is an important feature we need to handle properly if a system with statuses is going to be deployed.

It is also important that a nurse call system does not attempt to replace human-human interactions, which are important in the nurses' line of work. The issue is that instead of a nurse asking a co-nurse for a substitution, he/she could set the availability to busy or unavailable. This argument is the major one speaking against improving awareness at the bed area through technological means. Remember that awareness is a property that nurses use to manage interruptions.

In contrast to the findings of Klemets and Toussaint in [24], both the initial and evaluation studies found that nurses seemed to like the idea of having a blocking unavailable status for special situations. These findings are in line with what the pilot study [3] found as well. As already indicated, there might be a need to reconsider blocking nurse signals if unavailable.

However, if patients could determine the degree of importance when issuing a regular nurse call, the system could have these go through while unavailable similar to as with emergency alarms. Also, note that the results indicated that some nurses might be happy with just having the busy status, which could indicate that the unavailable status is unnecessary. What further builds up under this statement is how often unavailable would be used, which is not even daily according to the results.

Night shifts might also pose a problem to blocking unavailable because there are usually few nurses at work. One might argue that someone might consider setting unavailable in such a situation as irresponsible. We can solve this problem by locking usage of the unavailable status during night time. Exploitation of the unavailable status is also another concern weighing in this particular direction.

An important discovery is that there is a situation where a regular nurse call means an emergency. The situation occurs when a patient has been marked with a danger of falling, issues an alarm. Since information regarding fall danger is written on the patient report, nurses know to be quick to respond to nurse calls from these patients. This is a situation where blocking unavailable is troublesome as this patient signal is a kind of emergency, but still a regular nurse call. We should reconsider the idea of blocking nurse calls when unavailable if there are other examples of these situations. Workshop 1 found that, because of possible situations like these, patients should be able to determine the degree of importance when issuing a nurse call.

Due to these problems, we should reconsider the unavailable status behavior. One in two possible solutions come to mind:

1. Continue to block nurse calls completely in contrast to Klemets and Toussaint [24].

2. Skip the primary nurse for n iterations of cycling through the call plan as suggested in [3].

5.2.6 Optimal Notification

The results indicate that the key concepts from the initial study, regarding notification modification, is correct. However, some assumptions were wrong concerning the optimal notification:

- The volume while busy was too low.

- Muting either phone or panel to prevent them from ringing at the same time.

During the daytime, both the Wall Panel and the Nurse Client should ring at the same time where both use increased ring intervals. Note that there was a lack of results regarding the available status. From this, one can only continue to assume that the system should not change behavior while available, regardless of time.

While busy, the system should modify notification according to the time of day. During the daytime, the ringtone should be short and only play with long intervals in between while vibration should be continuous. A key concept to take note of when deciding the notification method in this situation is that the system should allow nurses to terminate the call before it starts ringing. An example would be to let the phone vibrate for a given time before it starts ringing, giving the nurse a chance to pass it to the next nurse in time.

Deciding on the best notification during the night is difficult since the system must modify notification such that the nurse becomes aware while the patient does not wake up from the alarm. Another topic that would require some additional literature research is regarding what octaves that are more problematic while sleeping and avoid using such tunes.

5.3 Design Choices

This section discusses why we made the different design choices during the development process. Each of the following paragraphs contains the reasoning for each design choice.

The reason for re-designing the presence relay algorithm was that there was a flaw in the original design. This flaw was rooted in the fact that subscribing a Nurse Client to a Wall Panel, upon entering a patient room, was carried out by having the Wall Panel send a status relay (Busy) to the Nurse Client. This design does not consider the possibility of manually setting the status to busy using the Wall Panel. This flaw would make the Wall Panel issue another status relay (Busy), causing the Nurse Client to attempt subscribing even though it already had subscribed to a Wall Panel.

We adding the time context sensor by adding a button that would change between day and night mode at the Wall Panel and Nurse Client. A proper implementation would have the system monitor time automatically and switch between day and night based on a pre-determined time

(e.g. Night after 22:00). Note that it will be necessary to consider that local system time may differ between various components. Therefore, we should give the responsibility of accurately monitoring time to a central time monitoring system, which is distributing this information to the other components. The reason for not implementing a proper algorithm was that it would make it impossible to test this function during a workshop.

Designing a state machine to control notifications enabled multiple notification types (e.g. ringing, vibrating, or flashing) to be handled by one single thread. This feature is an advantage since it makes it easier to extend the state machine with future ways of notification without creating a many of new threads to manage them. Stopping an alarm also becomes as simple as stopping the state machine. Another reason for using a state machine is that its nature allows excellent management of changes to notification based on subtle changes in context.

The reason for blocking status updates caused by location updates, while unavailable, was because of an assumption that it would be bothersome if the system automatically changed the status afterward. Imagine a sterile procedure:

1. Set unavailable before entering the patient room using the Nurse Station.

2. Enter room (perform sterilization).

3. The system automatically sets busy, which would defeat the purpose of setting unavailable in the first place.

Due to the time constraints and the fact that it is obvious that emergency signals should go through regardless of status, this functionality was not developed. Also, we assumed that evaluating these facts would not yield any data we do not already know. This assumption further supports the fact of not developing and evaluating emergency signals. We prioritized improvements in GUI low compared to developing new functions and components due to limited time.

5.4 Limitations

This section lists possible limitations that could have influenced the data gathering or validity of the results.

As already mentioned in the fidelity considerations and the result section, Workshop 1 experienced some problems that made role-playing impossible. This problem may have influenced the validity of the results negatively. Even though we explained the scenarios and their intentions thoroughly to the participants, they did not get to experience the features of the prototype.

Due to a last minute cancellation, Workshop 3 only had one participant, which defeats the purpose of having focus group interviews. The facilitator took a more active part in the discussion to help make up for this problem while still attempting not to influence the participant by proposing ideas.

A possible limitation that might have affected the validity of the results from the evaluation study is that seven participants might be considered a bit low. The goal was to get at least 15, but this was not achieved due to starting the recruitment process too late. Also, as mentioned in Chapter 3, Workshop 4 was performed in a conference room instead of the usability lab. This fact influenced the fidelity of the workshop as explained in Section 3.3.5. Because of this location, we could not produce any video footage for this workshop. We created Workshop 4 due to some participants cancelling the last minute to make up for this at a time when the usability lab was unavailable.

A problem with the design of the interview guide for the initial study caused some participants to misinterpret a feature of the prototype. It might not have been clear to every interview candidate that the automatic update of presence *statuses* would remove the need for marking one's presence in the patient room manually.

Another limitation that could have influenced the data from the studies is that the facilitator is a novice when it comes to usability studies, performing interviews, and conducting workshops. Experience is limited to the pilot study [3]. That said, while the interviews were done without the presence of the supervisors, the outcome still turned quite well. Also, the workshops were all, except Workshop 3, performed with at least one attending supervisor.

Chapter 6

Conclusion

This section attempts to answer each research question that we introduced in Section 1.6. Finally, it also lists some topics that should be subject to further research as well as some other interesting research themes.

How and in what situations can a system infer context automatically?

It is possible to create a nurse call system that manages interruptions by having it attempt to infer context properly. This fact makes it crucial to understand the context around nurses, which should be done using user-centered design methods such as ethnographic studies.

Situations where context can be automatically inferred include updating presence in a patient room, sterile procedures, night shifts, phone calls, and when leaving the department. A combination of location and time sensors can effectively enable context-awareness in all these situations. This fact is true because:

1. Nurses perform many of their tasks inside the patient room.

2. Nurses may treat situations differently during night shifts compared to day shifts.

Monitoring user activities performed on the phone can also act as a context sensor. Context clues such as active phone calls, message writing, and similar can be revealed by having the application monitor its usage.

What situations are problematic when it comes to inferring context correctly and how can a system handle eventual incorrect inferring?

Situations that are prone to incorrect inferring of context are typically situations that fall outside the scope of the context sensors. Important, sensitive or difficult conversations are problematic situations because they are not always tied down at either a specific time or location. Other situations include walking training and in case of fatalities.

There will be situations where the system can not perform status updates automatically or when it makes a mistake in inferring correct context. A good solution is to allow for manual updating of status as long as nurses see the benefit of performing the update themselves. To ensure this, nurses' interfaces to the system should make interactions as easily as possible. Having enough easily accessible interfaces is an important point, as some nurses are reluctant to grab their phones from their pockets in certain situations. Also, it should be possible to perform all actions from any device so that it is up to the nurse to decide what the most practical choice is in any given situation.

How should the system modify notification in different situations?

We can assign different notification methods for nurse calls to specific contextual situations. The methods should consider time, location, and task when determining the proper way of notification. Important values to adjust are sound levels, notification intervals, vibration strength, and intensity. Ideally, three pre-determined statuses, along with time-context awareness, should be used to cover all situations: *available*, *busy*, and *unavailable*.

While *available*, the system should not change behavior. While *busy*, it should modify notification according to the time of day. During the daytime, the Nurse Client (and the Wall Panel if inside a patient room) should both be presenting nurse calls. The ringtone should be short and only play with long intervals in between while vibration should be continuous. The Nurse Client should also vibrate a while, before ringing, to enable nurses to turn off the alarm before ringing starts.

During the night, Wall Panel volume can be lowered, and the Nurse Client may be completely muted with stronger vibration. The same principle of ringing at specific intervals should also be

applied. The notification must allow nurses to pass the signal to the next nurse *before* ringing starts by using vibration. Unavailable should either:

1. Completely block nurse calls.

2. Skip the primary nurse for n iterations of cycling through the call plan.

How can we design, develop and integrate an interruption management system into a nurse call system?

We can gather location sensor data through the integration of a stand-alone indoor location application. Therefore, smart communication protocols are essential to ensure proper integration of the many system components. Time sensor data can be gathered by having a central application monitor time and distribute this information to the other components. State machines are excellent for handling sensor data and modifying notification. They ensure correct and efficient handling of the many system states when modifying notification based on subtle changes in context.

6.1 Future Prospects

Some questions are left unanswered after this study and require further research. Time and location are important context sensors for inferring context at the hospital. Further research should attempt to disclose whether there are other types of sensor data that could improve the accuracy of guessing the context.

As mentioned, the example where with patients with a risk of falling, disclosed that there are situations where regular nurse calls must go through even while unavailable. Future research should try to disclose other situations where this is the case, as this might be a big drawback with blocking nurse calls when unavailable.

Another topic that requires further research is regarding the assumption that nurses are finished with the task if they leave a patient room if they were unavailable during the task. Some results back up this assumption while other do not (e.g. a nurse might just leave the room to bring something).

Further research of the optimal notification is required in the form of a quantitative study. This research will ensure a wider range of opinions and thus provide a better overview of how nurses feel about this matter. Additionally, performing a more thorough literature study on the topic could also prove helpful. These rest of the unanswered questions are summarized in the list below:

- Should phone calls be affected by nurse status and if so, how?
- Should the Nurse Station display the remaining time left before reverting unavailable?
- Are there other situations where regular nurse calls must go through unavailable?

6.1.1 Other Ideas

This section contains ideas that are not directly related to the results of this thesis, but could be relevant in future research nonetheless. A possible problem with having a Nurse Station easily available could be that someone unauthorized may click on it, causing system changes that would affect nurses in their life or death critical work. This problem calls for proper authentication, which is outside the scope of this thesis. However, an idea would be to have a touch-TV with integrated fingerprint recognition. Solutions like this already exist for tablets and smartphones (e.g. Natural ID [38]).

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Appendix A

Acronyms

BLE Bluetooth Low Energy

CSCW Computer Supported Cooperative Work

ESAS Edmonton Symptom Assessment System

GUI Graphics User Interface

HCI Human Computer Interaction

ICT Information and Communication Technology

JDK Java Development Kit

MQTT Message Queue Telemetry Transport

NSEP Norwegian Centre for Electronic Patient Records

RFC Request for Comments

RSSI Received Signal Strength Indications

SA Situation Awareness

SDI Stepwise-Deduction Inductive

SDK Software Development Kit

SDL Specification and Description Language

SFTP SSH File Transfer Protocol

SIP Session Initiation Protocol

SSH Secure Shell

SM State Machine

URI Uniform Resource Identifier

Appendix B

Initial Study: Interview Guide

B.1 Introduction

Interruptions are inherently part of nurses' working environment. Whereas some interruptions happen purely orally (e.g., a colleague is asking something), others are communicated through some technological means (e.g. phone or panel).

This study specifically looks at interruptions that are communicated through the currently deployed nurse call system here at S.T. Olav's. More concretely, when we refer to an interruption in this interview, we mean that you receive a notification via the nurse call system. This notification could, for example, be an incoming nurse call that you should handle through the same system (e.g. accept it or pass it on to the next in the call plan).

The goal of this study is to gain a better understanding of these interruptions and to investigate whether it would be possible to design/optimize the nurse call system. This should be done in such a way that it can support nurses in managing interruptions better. Therefore, in the first part of the interview, I will first ask you some questions about your experiences related to such interruptions. I will also ask about the managing of interruptions through the current nurse call system. In the second part, I will ask you some more specific questions to gather some insights into how the current practice might be better supported by the system.

B.2 Objectives

The objective of the interview session is to verify some assumptions and provide new information to be used as a basis for the next iteration of a context-aware pervasive nurse call system.

B.3 Research Questions

- How can we design, develop and integrate an interruption management system into a nurse call system?
- How and in what situations can a system infer context automatically?
- What situations are problematic when it comes to inferring context correctly and how can a system handle eventual incorrect inferring?
- How should the system modify notification in different situations?

B.4 Interview Questions

B.4.1 Part 1

Part 1 contains questions about nurses experiences related to interruptions and about the managing of interruptions through the current nurse call system.

Initial

- For how long have you been working as a nurse?
- Can you remember how long you have been working with phones/the wireless nurse call system?
- Do you usually always carry the work phone with you?
    - If not, why is that?
    - Can you think of any examples?

- Briefly, did you find it intuitively/easy to learn how to use the system?

General: gaining insight in interruptions and the handling of interruptions

- To first of all gain a better insight into the interruptions as such:
    - Can you think of usual tasks you do when you get interrupted?
    - Where are you when this usually happens?
    - How often does this happen, e.g., during one shift?
- Are there better or worse times/situations to be interrupted?
    - Why?
    - Can you think of examples of good and bad times/situations to be interrupted?
- Can you briefly describe what you find positive about the current system to handle interruptions? In other words: what works well? What are advantages and why is that?
- Can you also think of potential aspects that are not that positive, that do not work well or that could be improved and why?

Notification modification and status

After having talked about the interruptions as such, let us now briefly talk about the ways in which you are notified.

- How are you currently notified of a patient calling?
- Does this way of notifying work well? Why/Why not?
- Do you think it would be helpful if you were notified in a different way?
    - When doing specific tasks? (Which ones?)
    - When at specific locations? (Which ones?)
    - How do you think the notification should change?
        - Examples?

B.4.2 Part 2

Introduce prototype here

- What do you think about if you had availability statuses (available, busy, and unavailable) with different ways of being notified of a patient call?
    - Can you think of positive aspects of such an approach?
    - Do you see any possible problems with such availability statuses? (Examples from practice in which this may be problematic?)
    - How about the number of possible statuses: is it too much with three statuses? If so, why?
    - Would you like more or fewer statuses? If so, why? Which ones?
    - How would you like the system to notify you when you are available/busy/unavailable?
- How could these different statuses be set and maintained? What would work in practice? Automatically? Or Manually?
- Would a location be sufficient to determine when to automatically modify notification/status?
    - What do you think about automatically setting busy when entering a patient room and available when leaving again?
        - Can you think of situations in which such an approach could work/be sufficient?
        - Can you think of any scenarios/situations where this would be a problem? (Examples?)
        - What could be a solution in such scenarios/situations?
    - Other “triggers” to changing notification than location?
        - Task at hand?
        - Setting status yourself?

Wrap up

- If you could change anything you want about today's system concerning interruptions, without having to think about whether it is realistic or possible, what would it be? Other than we already discussed of course.
- I am going to organize a workshop where I would like to test the prototype in action. You would not be interested in participating would you?

B.4.3 Time Allocation

Table B.1 shows the expected time to be used for each topic from Section B.4.

Topic	Time (min)
Introduction	3
Initial questions	2
General questions	8
Notification modification	12
Prototype introduction	2
Wrap up questions	3
Sum	**30 min**

Table B.1: Interview Guide: Time Allocation

Appendix C

Evaluation Study: Workshop Guide

C.1 Introduction

As you may already know, I am working on a master thesis where I use a user-centered approach to design a nurse call system. This means that I attempt to involve users in the design process to ensure that I make something that will be accepted by the people who will use the system. So what I have here is an early prototype of a nurse call system that I want you to help me evaluate. First things first, I will need you to sign this consent form so that I can record audio and video during the session.

The goal of this study is to evaluate the solution that was built upon the assumptions and findings of previous work. The workshop will be divided into two discussions where each discussion is based on role-playing two simple scenarios I have prepared. This means that there will be a total of four scenarios and two discussions. I will now give a short demo of the prototype to ensure that we are on the same page when it comes to explaining these scenarios.

C.2 Objectives

This section summarizes the objectives behind each scenario in relationship to the study.

Scenario 1: Notification modification during the day (Role-play)

1. Verify the assumptions made when designing the notification algorithm during the day.

2. Provoke discussion about notifications in and out of patient rooms during the day.

3. Provoke discussion about status maintenance and interaction.

Scenario 2 – Notification modification during the night (Role-play)

1. Verify the assumptions made when designing the notification algorithm during the night.

2. Provoke discussion about notifications in and out of patient rooms during the night.

3. Provoke discussion about status maintenance and interaction.

Scenario 3 – Manually modify status

1. Provoke discussion about status maintenance.

2. Provoke discussion about system interaction.

3. Provoke discussion about the unavailable status.

Scenario 4 – Phone call (Demonstration)

1. Provoke discussion about how notification should be handled during a phone call.

C.3 Research Questions

- How can we design, develop and integrate an interruption management system into a nurse call system?

- How and in what situations can a system infer context automatically?

- What situations are problematic when it comes to inferring context correctly and how can a system handle eventual incorrect inferring?

- How should the system modify notification in different situations?

C.4 Workshop Scenarios

This section lists the four scenarios to be used as foundation for the focus group interviews of this workshop. The scenarios are divided into two parts: Role-playing and Cognitive Walkthrough/Think-aloud.

C.5 Role-Play

The role-play part of this workshop consists of two scenarios. Scenario 1 tries to mimic the situation where an uneasy patient talks to a nurse while another patient issues a nurse call. The structure of the scenario can be seen in Table C.1. Scenario 2 is about checking in on a sleeping patient while another patient issues a nurse call. Table C.2 shows the structure of this scenario.

Scenario 1: Notification modification during the day

This scenario puts one nurse in the situation where he/she has to handle an uneasy patient (A), while another patient (B) issues an alarm. One nurse is required, while the second nurse's role is just to turn off the patient signal issued by patient B

Situation: Uneasy patient **Roles:** -Nurse A -Patient A -Patient B	#	**Action**	**Note**
	1	Nurse A is available at the department	
	2	Patient A at room 221 issues an alarm	
	3	Nurse A accepts the nurse call	
	4	Nurse A enters room 221	Status is automatically set to busy
	5	Patient A feels uneasy and wants to talk	Nurse should stay with the uneasy patient
	6	Patient B at room 222 issues an alarm	Nurse A knows patient B calls often and usually for minor reasons
	7	Nurse A becomes aware of the call	Vibrating phone + one initial beep at the wall panel
	8	Nurse A decides to ignore the call and continues to talk to the patient	
		Nurse A becomes aware of the call returning	Call returns to Nurse A after trying every other nurse.
	9	Nurse A eventually responds to Patient B	This is just to stop the alarm

No discussion yet

Table C.1: Workshop Guide: Scenario 1

Scenario 2: Notification modification during the night

This scenario puts one nurse in the situation where he/she has to handle a nurse call besides a sleeping patient. One nurse is required.

Situation: Checking in on sleeping patient **Roles:** -Nurse A -Patient A -Patient B	#	**Action**	**Note**
	1	Nurse A is available at the department during night	
	2	Nurse A decides to check in with patient A at room 221, to see if he is sleeping alright and if his/hers vitals are fine.	Status is automatically set to busy with night mode enabled.
	3	Patient B at room 222 issues an alarm	
	4	Nurse A becomes aware of the call	Silent wall panel. Phone: Vibration and one initial beep
	5	Nurse A accepts the call	
	6	Nurse A leaves room 221	Status becomes available
	7	Nurse A enters room 222	Status becomes busy and alarm stops

Discussion 1

Table C.2: Workshop Guide: Scenario 2

C.6 Cognitive Walkthrough/Think-aloud

The following two scenarios cause a change in the system that is not directly visible to the user. This fact means that regular role-playing may cause confusion to the intention of the scenario. The cognitive walkthrough will make the nurses interact with the system, but the interviewer will provide guidance and information about what happens behind the scenes. These scenarios will also save some execution time.

Scenario 3 is about a nurse planning to perform a sterile procedure, as described in Table C.3. Scenario 4 is about the case when a nurse talks on the phone when it is possible that a nurse call may be issued, as seen in Table C.4.

Scenario 3: Manually modify status

This scenario tries to put one nurse in a situation where he/she would set the status to unavailable. This is to provoke discussion about how the unavailable status should handle nurse-calls

Situation:	#	**Action**	**Note**
Sterile procedure **Roles:** -Nurse A -Patient A	1	Nurse A is available at the department	
	2	Nurse A notices that it is time to perform a sterile procedure on Patient A	
	3	Nurse A sets unavailable for 1 minute using the nurse station.	Nurse calls are blocked during the time-frame (1 minute to get to see the actual change)
	4	Nurse A decides undergo a sterile dressing in order to perform a sterile procedure on Patient A in room 221	
	5	Nurse A returns to the bed-area, finding the status automatically reverted to the previous status	Interviewer explains the effects of being unavailable to the nurse

No discussion yet

Table C.3: Workshop Guide: Scenario 3

Scenario 4: Phone call

This scenario puts one nurse in a situation where he/she receives an important phone call. During the call, the nurse receives a nurse call, however

Situation:	#	**Action**	**Note**
Nurse call during phone call **Roles:** -Head nurse -Nurse A -Nurse B -Patient A -Interviewer	1	Nurse is available at the department	
	2	The Nurse B calls Nurse A	
	3	Nurse A accepts the call	Status is automatically set to unavailable
	4	Interviewer explains the effects of being in a phone call	
	5	Patient A at room 221 calls during the phone call	Status is unavailable so call is routed to next nurse
	6	Phone call terminates	Status is automatically set to available
	7	Nurse A receives the nurse call	
	8	Nurse A enters room 221	Terminate the nurse call

Discussion 2

Table C.4: Workshop Guide: Scenario 4

C.7 Action Cards

This section contains the action cards that is to be handed out during the workshops. Note that this is the English translated version.

Role-play Scenario 1 - Nurse Bob

The participant plays Nurse Bob.

1. You are performing paperwork at the workstation.
2. Patient *Per* from room *221* issues an alarm that arrives at your phone.
3. You enter room *221* to talk to *Per* as he is usually anxious.
4. While you talk to *Per*, *Ida* from room *222* issues an alarm that arrives at your phone.
5. You continue to talk to *Per*, as *Ida* usually calls for minor reasons.

End Scenario 1

Role-play Scenario 1 - Patient Per

A facilitator plays Patient Per.

1. You are anxious and want to talk to a nurse (Start alarm from room *221*).
2. Nurse Bob enters the room and talks to you (Start alarm from room *222*).
3. Observe Bob when the alarm signal from room *222* arrives.

End Scenario 1

Role-play Scenario 2 - Nurse Bob

The participant plays Nurse Bob.

1. You are performing paperwork at the workstation during a night shift.
2. You see to patient *Per* in room *221* to verify that he is breathing properly.

3. While you check on *Per*, *Ida* calls from room *222*.

4. You walk over to room *222* to talk to *Ida*.

End Scenario 2

Role-play Scenario 2 - Patient Per

A facilitator plays Patient Per.

1. You are sleeping in room *221* (Start alarm from room *222*).

End Scenario 2

Execution Scenario 3 - Nurse Bob

The participant performs Bob's tasks.

1. You are planning a sterile procedure on *Per* in room *221*.

2. You set unavailable for 1 minute using the Nurse Station.

3. You enter room *221* and perform the procedure.

4. You return to the bed area and notice your status at the Nurse Station.

End Scenario 3

Execution Scenario 4 - Nurse Bob

The participant performs Bob's tasks.

1. You receive a phone call from Nurse *Alice*.

2. You hang up after the conversation is done.

3. You notice an alarm from room *221* after you hung up.

End Scenario 4

Execution Scenario 4 - Nurse Alice

A facilitator performs Alice's tasks.

1. You call *Bob* (Start alarm from room *221*).

End Scenario 4

C.8 Discussion 1

This section contains the questions to be asked during the *first* focus group interview.

Initial questioning

- What are your first impressions of the system?
    - Are there particular things you like/do not like about it?
- What do you think about your status being automatically updated when you move?
    - Can you think of advantages of such automatic system updates? Is it useful?
    - Do you see any possible negative aspects or potential problems related to it?
- What do you think about automatically being marked as present upon entering a patient room?
    - Can you think of advantages of such automatic system updates? Is it useful?
    - Do you see any possible negative aspects or potential problems related to it?

Interview Questions Scenario 1 – Notification modification during the day

- What do you think about how the notification changed when the status was set to busy?
    - Was the notification disturbing or stressful in any way?
    - How did you experience this compared to how the system works today?

- Should the notification be modified and if so, how?
    - What do you think about how the phone behaved?
        - Was it ok that it only vibrated?
        - Could it behave differently?
    - What do you think about how the Wall Panel behaved?
        - Was it too loud or too silent?
        - Could it behave differently?
- Can you think of any situations where you do not want to become busy when inside a patient room?
    - Would you manually edit the status in these situations?
        - What do you imagine would be the easiest way to update the status, eventually?
        - Can the status be updated automatically in some way?

Interview Questions Scenario 2 – Notification modification during the night

- What do you think about how the notification changed during the night?
    - Was the notification difficult to notice?
        - What could have been better?
    - How did you experience this compared to how the system works today?
- Should the notification be modified and if so, how?
    - What do you think about how the phone behaved?
        - What do you feel about the fact that:
            - It only rang once?
            - It vibrated intensely?
        - Could it behave differently?

    - What do you think about how the Wall Panel acted?
        - Was it ok that it was silent?
        - Could it behave differently?

- Do you think the Wall Panel, the phone, or maybe both should do the notification at night?
    - What do you think would be the best notification?
- Are there any situations where you do not want the notification to be quiet during the night?
    - Would you manually edit the status in these situations?
        - Can the status be updated automatically in some way?

C.9 Discussion 2

This section contains the questions to be asked during the *second* focus group interview.

Interview Questions Scenario 3 – Manually modify status

- What do you think about the big screen displaying statuses?
    - Are there any good things about it?
    - Bad things?
    - If you had to choose between using the phone or the Nurse Station for manually updating status, which one would it be?
        - Why is that?
- What do you think about manually editing the status in situations like these?
    - Are there any good or bad things about it?
    - Can it be done more efficiently?

- What do you think about the possibility of setting a time limit on the unavailable status?
    - When the timer expires, what do you think should happen?
    - When you are unavailable, what do you think should happen to the status when you enter or leave patient rooms as usual?
        - Can you think of any situations where you would want to be automatically removed from unavailable?
- Do you think unavailable was appropriate for this situation?
    - Why is that/Why not?
    - How did you expect the system to behave when selecting unavailable?
        - Would you like it to behave differently from what it did?
    - For what other situations could the unavailable status be suited?
        - What about different locations?
- What would be other situations where manually updating the status could be beneficial?
    - Are there differences between meetings, sterile procedures, doctor visitation, or lunch?
        - What status do you think would be appropriate in each of these situations?

Interview Questions Scenario 4 – Phone call

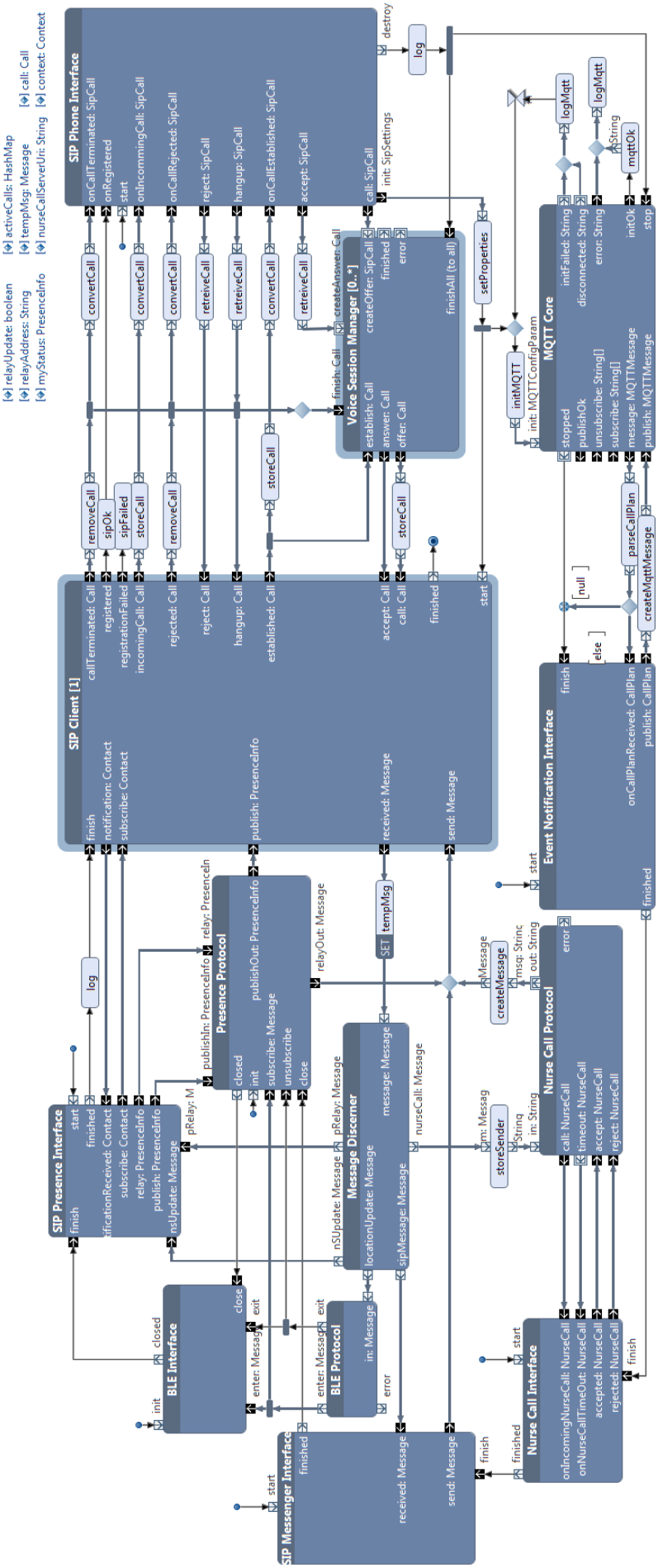
- Is it important that you become aware of the nurse call while on the phone?
- What do you think about being automatically set to unavailable during a phone call?
    - Is this a good way to solve the problem?
        - Would it be solved in a different way?
    - Can you see any problems with this approach?
        - If yes, can it be done in another way?
- Does it matter to whom you are talking?
- Are there other things that influence the importance of nurse calls when on the phone?

Wrap-up questions

- Can you think of other situations, than the ones you experienced here, where you could see the benefit of a change in notification or system behavior?
- Was the system easy to use?
- Do you imagine yourself using such a system?
- Do you think this would affect or influence your current work routines?
    - If so, how? In a positive or negative way?

Appendix D

Nurse Client System


SIP Phone Interface
SIP Client [1]
Voice Session Manager [0..*]
MQTT Core
Event Notification Interface
SIP Presence Interface
Presence Protocol
Message Discerner
BLE Interface
BLE Protocol
SIP Messenger Interface
Nurse Call Protocol
Nurse Call Interface
log
logMqtt
mqttOk
setProperties
initMQTT
parseCallPlan
createMqttMessage
createMessage
storeSender
tempMsg
storeCall
removeCall
retreiveCall
convertCall
sipOk
sipFailed
finishAll (to all)
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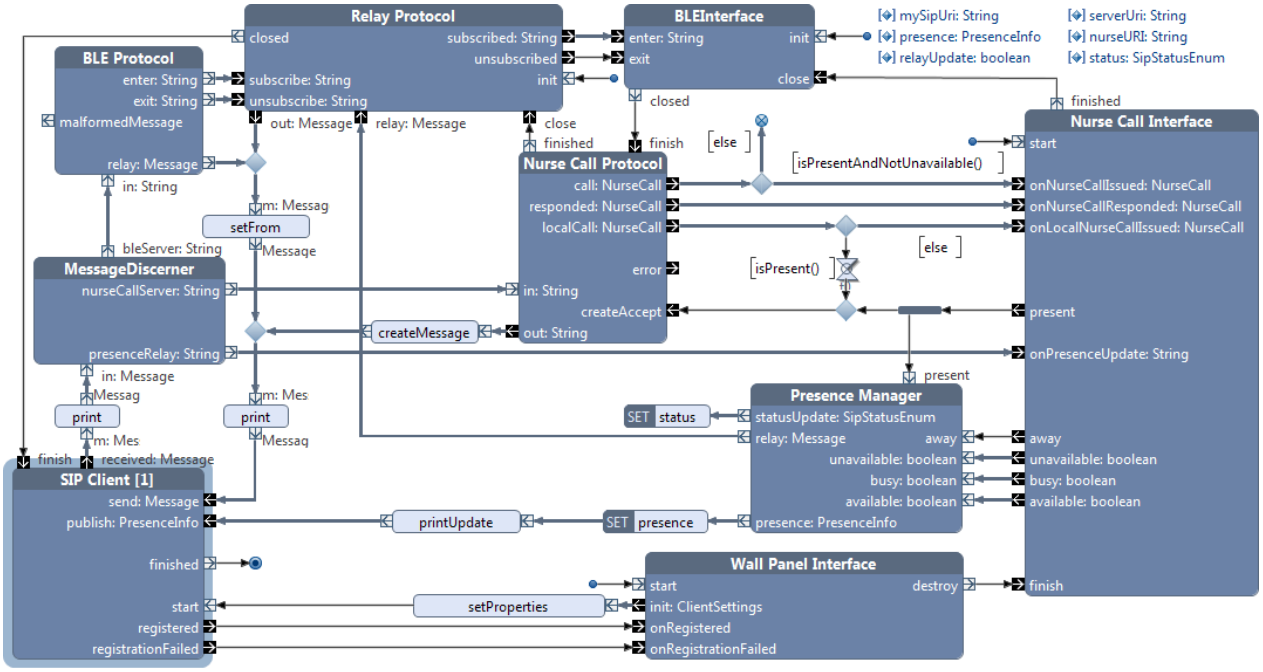
[else]

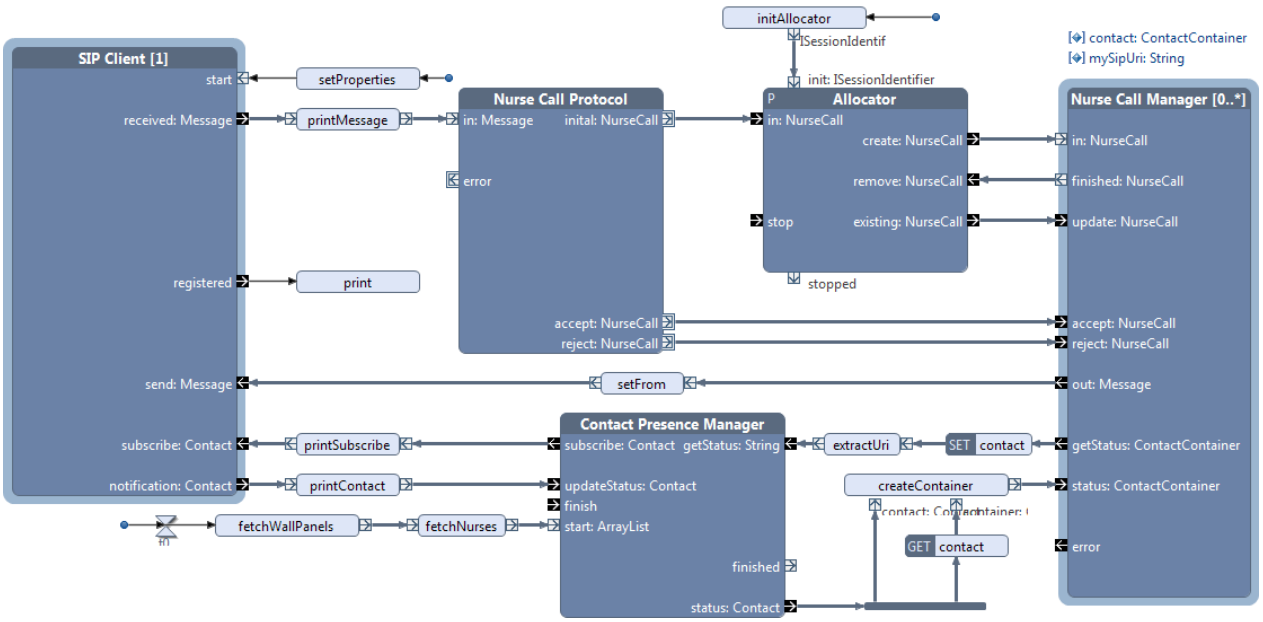
Appendix E

Wall Panel System



Appendix F

Nurse Call Server



Appendix G

Patient Client System