Context-aware systems for mobile communication in healthcare – A user oriented approach

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Abstract: A variety of communication problems is a common phenomenon in the current hospital setting. Physicians need a mobile context-aware communication system in their daily practice. Our approach, based on an initial study performed at the Oncology Department at the University Hospital of North Norway and an extensive collection of user needs according to CSCW and use case methodology, will develop a reliable communication system to help physicians accomplish their tasks.

Key-words: Mobile communication, Context-aware systems, Pagers, Wireless phones, CSCW

1 Introduction

Hospitals are an extremely dynamic and demanding working environment for health care professionals where critical information for patient care must be transmitted fast and accurately. Most of the time it is necessary for providers to coordinate their activities in a timeless and direct manner. However, a variety of communication problems is a common phenomenon in the current hospital setting. A significant number of medical errors have been attributed to failures in accurate communication [1]. Healthcare providers spend a great amount of their working time communicating to each other and any delay between the decision and the action taken or the information exchange can increase the risk of error. Hersh et al. study showed that it is the second cause of medical errors [2].

Among health care professionals, physicians are the group most in need of an adequate communication system in their daily practice. Their main working characteristic is mobility: often, a physician will not stay at a specific place for more than a few minutes, and will move frequently between wards, outpatient clinics, diagnostic departments, conference rooms and operating theatres and it is possible to be at a distant spot away from his department. As such, a mobile device could be useful for enabling him to communicate with colleagues any time and at any place. Apparently, mobile physicians change their context, notably their location, but in a hospital the context is far from location; the timing of exchange and the specific physician's role are equally important [3].

The target of our approach is to provide physicians with a reliable mobile context-aware communication system to use in their daily practice and accomplish their main tasks easier and successfully.

2 Background

The most common mobile communication device deployed in hospitals is pagers. Pagers offer a cheap and reliable way of contacting staff but they suffer from many limitations due to their simplicity. Digital Enhanced Cordless Telecommunications (DECT) phones are also used by some senior physicians who have a personal wireless phone that is kept in their office when they are not using it. The physician can provide the number to anyone inside and outside the hospital and request that the number be listed in the internal hospital directories, or limit interruptions by keeping the number 'unlisted' [4].

Moreover, mobile phones have been used extensively to fill the communication gap. Ammenwerth et al. studied the mobile communication tools at Heidelberg University Hospital at the first steps of mobile technology [5]. Additionally, some specific technologies that exploit the Global System for Mobile Communications (GSM) standard have been developed. Some service cellular providers offer a 'walkie-talkie' mode that allows one user to contact with a member of his group at the push of a button [1].

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Aziz et al. used Personal Digital Assistants (PDAs) with built-in mobile telephones and web-browsing facilities in order to facilitate communication between healthcare providers at a hospital setting [6]. The basic target of this study was the comparison of PDAs and the existing pager system as communication tools measuring mainly users' satisfaction; the results were encouraging for the wider application of such devices. PDAs have been also used for simple text or contextual message exchange [3, 7].

Bardram et al. developed a set of pervasive systems for clinicians' communication in a surgical ward that supported the context-sensitive communication [8]. The full system was comprised of three tightly integrated sub-systems: the location tracking, the AwareMedia and the AwarePhone systems. With these systems the clinicians were tracked in certain locations by tracing Bluetooth tags and devices (e.g. mobile phones) they wore. Their location information was displayed on AwareMedia touch screens along with some more data about their current schedule. Using the AwarePhone, an application running on mobiles devices, the clinicians could call or send a message to a person or an operating room; if the message was sent to a room it would be presented to all people in the room through the AwareMedia display.

The introduction of Wireless Ethernet (Wi-Fi) as a way to create a Local Area Network without wires has risen new potentials in data transmission. Voice can be digitized and transmitted across the network to any device with compatible software. This technology is called Voice over Internet Protocol (VoIP) and can be used to transfer calls through the LAN. Some companies have already developed systems using VoIP. Ascom Company (Goteborg, Sweden) offers the i75 VoWiFi handset as part of the VoWiFi System that supports wireless telephony, alarm and messaging in one unit.

Another system, Vocera (Vocera Communications Inc., Cupertino, California, USA), uses a small communication badge that is clipped to a pocket or worn around the neck, a voice recognition and call direction software and a dedicated server with optional telephony integration. This system works in a manner similar to a walkie-talkie and has significant advantages, e.g. it can handle multiple simultaneous calls and allows user to block calls.

Another manufacturer (Calypso Wireless, Miami, Florida) has developed the ASNAP™ technology that spans voice, video and data session transparency across Macro-Cellular networks and wireless local area networks. The wireless telephone that implements this technology works as a local extension and uses VoIP within the hospital. When the telephone leaves the building, it switches to a cellular telephone mode.

3 The context-aware project

The 'Context-aware systems for mobile communication in healthcare' project focuses on mobile communication services in hospitals. Facing the drawbacks of the current communication systems, this project aims to increase the ability to properly manage communication among the physicians. The goal is to design, develop and evaluate a mobile/multi-modal communication infrastructure that balances communication availability for physicians. This infrastructure will include middleware for multi-modal communication, an interruptions management system and devices with interaction forms for mobile text messaging and for switching roles.

3.1 The initial study

The initial study took place at the Oncology Department and was carried out in three stages. The first stage consisted of participatory observations including open interviews and informal discussions; the second stage included semi-structured interviews of a selected group of physicians at various levels of the hierarchy within the department and the third stage consisted of a second round of participatory observation sessions. Four observers signed confidentiality agreements and then participated in the actual work activities of certain physicians and nurses for four days and during the day-shift (from 08:00 to 15:30). In addition, a 30-minutes open interview was conducted with the head of the department in the first day and another 4 interviews with four other members (two residents and two attending physicians) of the department in the last day.

This study revealed a general concern among the physicians that wireless phones lead to more frequent and more severe interruptions than pagers. Whenever possible the physicians at the department adopted various strategies for obtaining benefits from wireless phones while avoiding interruptions. This included the use of wireless phones for outgoing calls; the number of these phones was not known to other staff members. Also, some physicians showed a general preference for pagers by avoiding carrying a wireless phone altogether.

In addition, the study revealed the use of role-based pagers that provide similar functionality to

role-based context-awareness, and the existence of a public charging rack that provides basic presence information about who is assigned to each role.

3.2 User Oriented Approach

In the hospital environment the success in system implementation is mainly depended on users' acceptance. Apart from the technical aspects of the system, there are many socio-organizational issues such as medical practice norms, organizational standards, and individual user preferences that play an important role in determining whether a system will fail or succeed [9]. According to Pratt et al. Computer-Supported Cooperative Work (CSCW) principles should be used for the development of a successful healthcare system [10]; these principles focus on three key areas:

- Development of incentive system and organizational structures to motivate users to properly use technology.
- Fit technology into the work process of its users.
- Figure out the appropriate techniques that will help users to be aware of and coordinate their work with the others using the system.

The communication system that will be developed in our study will affect the physicians' work and workflow, as well as the workflow of other people that communicate with them, such as nurses. So, we have to identify their needs following the aforementioned principles.

Various methodologies will be used for assessing user needs: questionnaires, interviews, participatory observations, requirements workshops, brainstorming sessions, and use cases. As mentioned above, interviews and participatory observations have already been conducted at the Oncology Unit of UNN.

During the main study period we will perform additional quantitative studies at another hospital department before developing the communication prototype. For this reason we have already contacted several surgical departments at UNN, as this is a demanding, high-traffic communication environment.

This study will be completed in three phases: the first phase will focus on participatory observations and use cases. Following this phase we will build the graphical model of our system as presented in Figure 1. In this figure the ellipses correspond to the different tasks that should be accomplished with the system and the arrows show each user's involvement (all users are physicians; the head nurse will be the only non-medical user of the system).

The needs collected at the first phase will help us develop a simple questionnaire based on Likert scale method. This questionnaire will be distributed to the physicians of the department in the second phase. The collected data of the first two phases will be analyzed and the analysis result will guide us in formulating specific scenarios that will be presented to the end users at a workshop. After the workshop a second questionnaire will be distributed to the physicians that will participate in the workshop; this will be done in the third phase of the study and a second quantitative analysis will be performed then. The results will establish the design specifications for the development of the communication prototype.

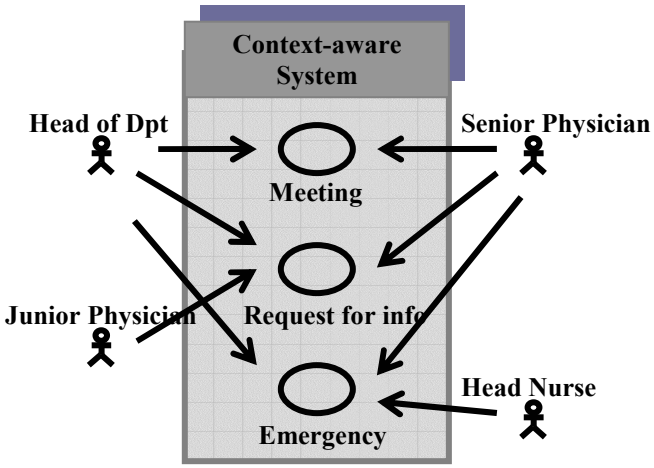

Fig. 1 A model of what the system is supposed to do (use cases), and the system's surroundings (users).

3.3 System architecture

The system architecture is presented in Figure 2. First of all, we intend to sniff the signals from the existing paging/phone system before they are sent out to the pagers/phones, leaving the existing system intact. Then these sniffed signals will be re-routed through our context aware mobile system.

When a call/page is routed to our server, it will check the number the call/page comes from and the number that is called. If the call is forwarded to a role-based device, the system will find the device that is assigned with this role and will route the call/page to this device. At this point we will use a role-based wireless tracking tag, to find out where to route the call. If the call is not role-based, there will be various options depending on the given context e.g. the physician's availability and location. For example, one option could be to provide a countdown from 5 in order to give the

person calling the opportunity to hang up if the call is not important; and they feel it would be acceptable to leave a voice message instead.

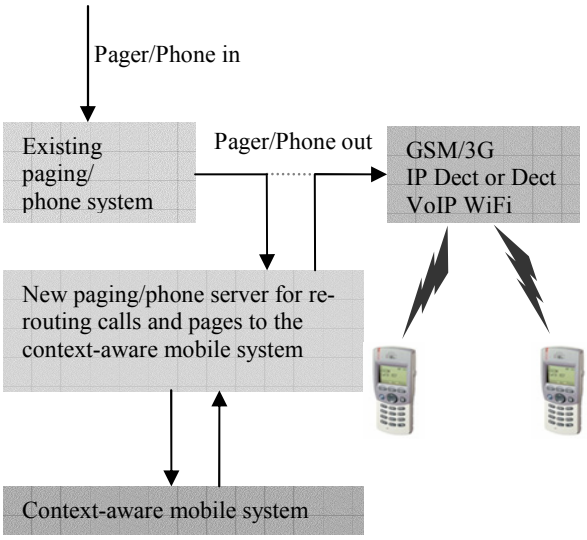

Fig.2 Proposed system architecture

The main idea is to equip physicians with only one device that will act both as a pager and a phone. This device will replace both the personal and the role-based pager and the DECT phone. The device will be a GSM/3G, a DECT or IP DECT, or a VoIP WiFi phone. A programmable device in Java Micro Edition (J2ME) is preferred since it can use ringer configuration software and it will be easier to develop a system where the physicians can make rules in a very simple way. These rules will be the type of "I am only available when I am in my office" or "I am always available, but not when I am in a patient room". We will probably have a software-based system for roles where the physician can sign in on a role and then update the server with the same information.

The device will be also equipped with a tracking tag that will alert the system about the device/physician location. So, the system can decide what to do with the placed call/page. Also, if we use wireless tracking tags for roles, we will be able to trace the role tag and the phone, and then route the call to that phone when a role based call/page is placed in the system.

4 Discussion

Mobile communication systems for hospitals are an important research area because hospitals are noted to suffer from poor communication practices with mobile communication technology being recommended as one potential remedy [11].

Most pagers permit only one-way transmission of a telephone number or short-text message. There is also no way to respond through a pager or even acknowledge receipt of an important message. Another obvious limitation is that they require staff to locate a telephone in order to respond to a page. Sometimes this takes a few minutes and in the meantime the person who made the call may have found an answer to the problem and left the phone from where the page was placed. When the page is returned there may be nobody at the other end who knows the reason for the initial page – possibly causing a page being placed to get hold of the initial page caller; wasting time and causing additional interruptions. If the telephone number is busy or an incorrect number was entered in the paging system it is possible to have further delays in communication. They also create a large amount of unnecessary interruptions and communication overhead [12, 13]. Due to all these, the public pager service in Japanese hospitals is planned to be stopped within 2007 and the installation of mobile voice communication is in progress [14].

Mobile phones provide two-way rapid communication and permit more information exchange compared to pagers. It should be mentioned though that many health care institutions in the United States and Europe have implemented policies that prohibit the use of wireless communication devices in patient care areas [15]. These policies came in response to early published studies in which mobile phones where suspected to cause malfunctioning in physiological monitors and life supporting devices [16]. However, recent studies tested cardiopulmonary monitors, ventilator models, pacemakers and implantable cardiac devices and all concluded that wireless networks do not interfere with medical devices [17, 18, 19]. For the same issue, IEEE published a Technical Information Statement that medical life-supporting equipment should be shielded to prevent the entry of stray signals [20]. Concluding the aforementioned remarks, there is no threat of electromagnetic interference (EMI) in a wireless network at hospital.

The VoIP solutions have already been studied in the hospital environment but it seems that there are some drawbacks in their use. For example, Jacques et al. studied the Vocera system implementation and they found problems targeted on (1) dropped calls due to 'dead spots' in the 802.11b network and (2) errors in speaker recognition [21].

It has been reported in many studies that all communication systems suffer from increased noise levels and various kinds of interruptions. This

is considered the case either for mobile phones if the public is allowed to access cellular networks in hospitals or for wireless phones because of conversations that would not occur otherwise [22, 23]. However, Spurck et al. reported fewer interruptions to patient care when providing a surgical nursing team with wireless phones [24]. The interviews and observations conducted at the Oncology Department at UNN revealed a general concern among the physicians about wireless phones leading to more frequent and more severe interruptions than pagers. For avoiding interruptions and coordinating communication we plan to augment the system with context-awareness.

On the other hand many studies do not consider the necessity for developing context-aware systems. However, each system should respect e.g. the different roles in a hospital setting. For example, it is obvious that there is a distinction among the tasks of the senior and junior physician. It is also clear that it is not possible to contact directly a clinician in all locations and at any time even if this is feasible, e.g. a surgeon should not be disturbed during an operation. In similar cases the system should follow alternative paths, such as redirect the call to a colleague in the previous example.

The target group of this study is mainly physicians. No other study has been reported so far focusing on examining physicians needs and developing a system for them. Though, if our study reveals that it is crucial involving some other key users (e.g. the head nurse of the department) then we will examine this possibility as well.

User participation is a crucial aspect not only for this study but also for a general better understanding of the mobile communication technologies for health. It is critical to identify their needs correctly in order to develop a successful product they can use in their daily practice; otherwise they will resist using it. In addition, we can foresee ways to improve mobile technology for hospitals and explore the possibility of new products. This is urged in the new era that a lot of discussion is done for m-health as an emerging area in telemedicine and telecare systems [25].

Another important issue is that we have to embed our system in the existing phone and paging system at the first place. This could limit our system due to a possible integration problem with the existing hospital infrastructure. However, the physicians should have the opportunity to choose an ordinary pager or DECT phone within the existing telephone or paging system, without any reconfiguration of our system.

The limited functionality of the existing systems, such the paging system, does suggest that the staff would benefit from increased use of messaging and phones. However, a single device integrating text, voice and paging services would be advantageous. Also, a critical component of such a system should be a set of mechanisms that allow users to manage their communication availability. Without such mechanisms, the device implementation will be resisted by many staff members, and it may have negative consequences on work practices.

Finally, specific ethical issues, privacy, data protection and security will be considered during the project. In addition, no users will take part in any field trials without their written consent. The research will conform to Helsinki Declaration by the World Medical Association.

5 Conclusion

Healthcare delivery is an important part of society and many systems have been developed to improve it. Regarding communication systems in hospitals, there are exciting challenges in dealing with new systems, where public infrastructures (such as GSM, WiFi) must co-exist with private ones (such as pagers). This approach focuses on context-aware interfaces, middleware and new interaction forms for mobile devices that support multi-modal communication in hospitals. The main aim is to improve the quality of care by making communication between physicians more efficient and effective. The successful implementation of this target is expected to have an enormous social impact.

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