Quality of Life through Quality of Information
J. Mantas et al. (Eds.)
IOS Press, 2012

doi:10.3233/978-1-61499-101-4-388

Proactive Authenticated Notifications for Health Practitioners: two way Human Computer Interaction Through Phone

Raphael W. MAJEED[a], Mark R. STÖHR[a] and Rainer RÖHRIG[a,1]
[a] *Section for Medical Informatics in Anaesthesiology, Justus-Liebig University Gießen, (Germany)*

Abstract. Notifications and alerts play an important role in clinical daily routine. Rising prevalence of clinical decision support systems and electronic health records also result in increasing demands on notification systems. Failure adequately to communicate a critical value is a potential cause of adverse events. Critical laboratory values and changing vital data depend on timely notifications of medical staff. Vital monitors and medical devices rely on acoustic signals for alerting which are prone to "alert fatigue" and require medical staff to be present within audible range. Personal computers are unsuitable to display time critical notification messages, since the targeted medical staff are not always operating or watching the computer. On the other hand, mobile phones and smart devices enjoy increasing popularity. Previous notification systems sending text messages to mobile phones depend on asynchronous confirmations. By utilizing an automated telephony server, we provide a method to deliver notifications quickly and independently of the recipients' whereabouts while allowing immediate feedback and confirmations. Evaluation results suggest the feasibility of the proposed notification system for real-time notifications.

Keywords. Clinical decision support systems, alert systems, reminder systems, human computer interaction, notifications

Introduction

Notifications and alerts play an important role in daily clinical routine. The rising prevalence of clinical decision support systems (CDSS) and electronic health records (EHR) also result in increasing demands on notification systems. Additionally, and similar to other industries, the health sector is challenged with delivering increased performance with decreased manpower. Failure adequately to communicate a critical value is a potential cause of adverse events.

Critical laboratory values are usually reported manually by laboratory staff or call centres [1]. Vital monitors and medical devices rely on acoustic signals for alerting which are prone to "alert fatigue" [2] and require medical staff to be present within audible range. Personal computers are unsuitable to display time critical notification messages, since the targeted medical staff are not always operating or watching the computer [3]. On the other hand, mobile phones and smart devices enjoy increasing popularity.

[1] Corresponding Author: rainer.roehrig@chiru.med.uni-giessen.de

By utilizing an automated telephony server, we propose a method to deliver notifications quickly and independent of the recipients' whereabouts while still following strict German privacy laws.

The work on this project was originally motivated by physicians asking for a timely notification if patients match certain eligibility criteria for inclusion in clinical trials. Specific research questions require blood samples to be taken early or allow only a short time frame to ask the patient for informed consent. Specifically patients suffering multiple trauma (often caused by severe road traffic accidents) undergo surgery immediately after arrival, thus requiring outright notification of appropriate medical staff to receive consent and take appropriate measures.

Similar difficulties are encountered for example during research on the systemic inflammatory response syndrome (SIRS, commonly known as sepsis): Analysing causal effects requires blood samples to be taken in early stages of SIRS which in turn is defined by conditions of temperature, heart rate, respiratory rate and white blood cell count. These parameters are usually measured by different machines and the clinic's laboratory at different times – a combination too complex for common alert systems. While the required aggregation of parameters from multiple sources and deductive reasoning can be done with clinical decision support systems (CDSS), such systems provide only basic notification capabilities. Additionally for SIRS, patient survival is directly dependent on the swiftness of the response [4], ideally requiring treatment within the first hour. Therefore, immediate notification of medical staff is crucial for clinical research as well as the patient's therapy.

Piva et al. developed and evaluated a computerized notification system using short message service (SMS) for cell phones [5]. In comparison to manual phone calls, they were able to reduce the average time for notification from 30 minutes for a telephone call to 11 minutes for text messages. More than 50% of the telephone call notifications were delivered later than 1 hour and 10.9% of text messages failed to receive confirmation by the recipient.

Gee and Moorman suggest that notification systems can reduce alarm fatigue and improve patient safety by sending messages directly to the responsible caregiver, possibly mobile devices, and by "providing closed-loop communications to ensure that alarms are received and acknowledged"[6]. In another study assessing the effectiveness of computerized test result notification system [7], designed to minimize breakdowns in critical communication between radiologists and clinicians, physicians failed to acknowledge electronically over one-third of alerts and were unaware of abnormal imaging results in 4% of cases 4 weeks after reporting.

Piva et al. provided patient information within the SMS sent to the physicians' cell phone [5]. German privacy laws do not allow transmission of patient data to a recipient without authentication. This limitation could be circumvented by sending not the original data but a unique ticket code. The recipient can then enter the code in the hospital information system to jump directly to the appropriate value while authentication is handled by the hospital information system. Yet, the problem of asynchronous communication and missing confirmations remains: A separate confirmation needs to be triggered by the recipient and the sender can only determine failures by waiting for the confirmation for a specified timeout period.

The aim of this project is the development of an automated real-time notification system, which allows immediate confirmations and feedback, while ensuring the correct recipient through authentication.

1. Methods

In the past two years, the university clinic in Gießen migrated all paging devices to mobile phones, thus providing a personal phone number to every physician and caregiver. The clinics telephone system provides ISDN interfaces to allow modems and external devices to communicate directly with both internal and external phones.

Low operational costs and high customisability favour the use of open source software. Therefore, the open source telephony server Asterisk[8] is used. The choice of Asterisk limits suitable operating systems to Linux. Through compatibility, any Linux distribution might be used for running Asterisk. Stability, long term support and existing local knowledge resulted in the choice of Debian Linux 6.0 as the operating system for the telephony server.

To connect a telephony server computer to the phone network, several technologies exist: Analogue modems can be used to connect the computer to simple phone lines. ISDN cards connect to most mid-sized to large digital telephone installations supporting multiple channels for two or more parallel calls. Voice over IP (VOIP) and the session initiation protocol (SIP) can be used to place calls through the network interface of the computer via modern digital telephone installations without limits on the number of parallel calls.

The telephony server should be able to read relevant information automatically to the called person, which requires integration of a text to speech (TTS) engine. Asterisk supports several TTS engines ranging from free open source implementations to expensive high end products (Festival, Flite, eSpeak, Swift/Cepstral, IVONA TTS). For the prototype architecture, the asterisk module cmd_swift[2] is used in conjunction with inexpensive Cepstral voices[3], which are easier to understand in comparison to free speech synthesis.

The suitability of the notification system for real-time alerts is to be evaluated by measuring the time from notification generation to ringing of the phone. By using artificially generated notifications and asking a test person to press a key once the telephone rings, the pure latency of the notification system is measured.

2. Results

For the implementation of the proposed real-time notification system, a virtual machine was used to install the Debian Linux operating system. Installation of the ISDN hardware required a kernel driver. VOIP and SIP connectivity is possible without additional software. The asterisk telephony server is available as a software package from the Debian Linux repository. Apart from configuration file editing, no programming skill is needed.

2.1. Operation of an automated call

To provide a notification, the notifying application places a text file ".call file" in a shared network folder. The telephony server Asterisk watches the folder (usually /var/spool/asterisk/outgoing) for changes and executes a call as soon as a new file

[2] http://www.voip-info.org/wiki/view/Asterisk+cmd+swift
[3] http://cepstral.com/cgi-bin/applications?page=telephony

appears. All call specific information, such as personal identification number (PIN), patient number and desired message is placed in the .call file. The precise course of action for a notification call is specified as a dial-plan in the Asterisk configuration. The computer calls the specified number and waits for an answer. If the call is not answered within the predefined time, the computer will call additionally assigned numbers before retrying the original number after a short delay. If no person can be reached after a predefined amount of time, the notification is considered failed. Once answered, a computer voice prompts for a four digit authentication PIN. The person answering the call can input his PIN using the keypad of the telephone. After authentication, the computer reads the notification message to the recipient using TTS technology. At the end of the notification, the recipient is able to give feedback using the phone's keypad or disable future notifications (e.g. 1 = helpful, 2 = irrelevant, 3 = switch off notifications). After hang-up or if no recipient could be reached, the original .call-File is annotated to indicate success or failure and placed in a second network share "done". Through file system notifications, the notifying information system is consequently notified by the completion of the call. Figure 2 illustrates the notification process.

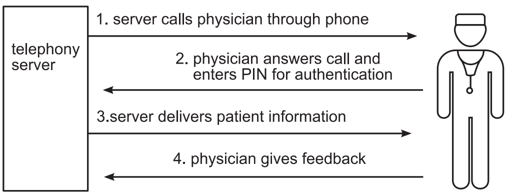

Figure 1. Authentication and interaction of telephony server with physician

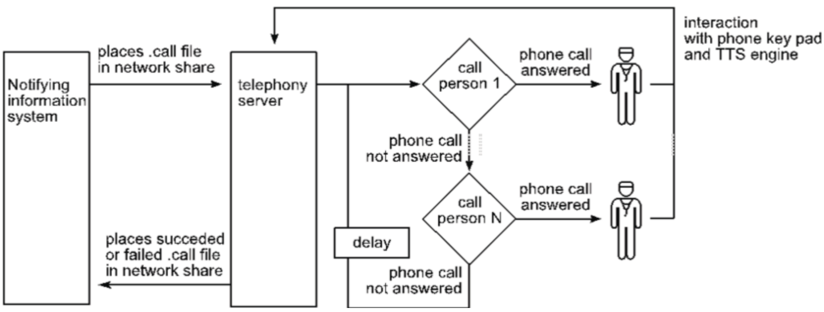

Figure 2. Flow chart showing the notification process. TTS: text to speech

2.2. Evaluation results

Real-time usability was evaluated by measuring the time from an artificial notification to the ringing of the called phone. Results are displayed in Table 1.

Table 1. Evaluation results measuring the time from generated notification to ringing phone.

Phone	n	min time	max time	avg time	std dev
Wireless DECT mobile phone	50	2.07 s	5.91 s	3.09 s	0.80
Standard wired phone	50	0.81 s	2.43 s	1.33 s	0.44

3. Discussion

For their short message service notifications, Piva et al. reported that 10.9% of their notifications were unsuccessful in terms of missing confirmations [5]. Singh reported no acknowledgments for one third of all notifications [7]. The described method of two way human computer interaction through phone calls should be able to reduce this number to zero. In this respect, further research is needed. The recipients' entering of a pin code implies delivering the message to correct person and the telephony server writes a log file entry whether the full message was heard.

Since automated phone calls might appear intrusive to some people, a computerized call system should be provided on an opt-in basis. While the system provides means for timely direct notifications, its primary benefit depends on the software used to produce these notifications. The authors' initial motivation originated from the need of real-time notifications for the inclusion of patients to clinical trials. According to the measured times in table 1, the presented solution is able to satisfy this need. It will be used in conjunction with complex rules to evaluate a real-time stream of HL7 messages for eligibility criteria of clinical trials [9].

During discussions with physicians and potential users of the system, additional use cases arose: Especially in small to midsized clinics, usually a single anaesthesiologist is responsible for several intensive care patients located in different wards or rooms. In many cases, there is no visual contact to all intensive care patients. A system monitoring certain critical combinations of parameters and notifying a mobile physician by phone would be of great use for such scenarios.

In summary, proactive authenticated real-time notifications are possible through automated individual phone calls. The choice of free or inexpensive components makes the system usable not only for small hospitals, but also for emerging markets and developing countries.

References

[1] Dighe AS, Jones JB, Parham S, Lewandrowski KB. Survey of critical value reporting and reduction of false-positive critical value results. Arch. Pathol. Lab. Med 2008; 132(10):1666–1671

[2] Riedmann D, Jung M, Hackl WO, Stühlinger W, van der Sijs H, Ammenwerth E. Development of a context model to prioritize drug safety alerts in CPOE systems. BMC Med Inf Decis Mak 2011; 11:35

[3] Röhrig R, Meister M, Michel-Backofen A, Sedlmayr M, Uphus D, Katzer C et al. Online guideline assist in intensive care medicine--is the login-authentication a sufficient trigger for reminders? Stud Health Technol Inform 2006; 124:561–568

[4] Sebat F, Musthafa AA, Johnson D, Kramer AA, Shoffner D, Eliason M et al. Effect of a rapid response system for patients in shock on time to treatment and mortality during 5 years. Crit. Care Med 2007; 35(11):2568–2575

[5] Piva E, Sciacovelli L, Zaninotto M, Laposata M, Plebani M. Evaluation of Effectiveness of a Computerized Notification System for Reporting Critical Values. Am J Clin Pathol 2009; 131(3):432–441

[6] Moorman BA, Gee T. Functional basics of third-party alarm notification systems. Biomed Instrum Technol 2011; Suppl:76–82

[7] Singh H, Arora HS, Vij MS, Rao R, Khan MM, Petersen LA. Communication Outcomes of Critical Imaging Results in a Computerized Notification System. JAMIA 2007; 14(4):459–466

[8] van Maggelen J, Madsen L, Smith J. Asterisk: The future of telephony. 2nd ed. Beijing: O'Reilly; op. 2007.

[9] Majeed RW, Röhrig R. Identifying patients for clinical trials using fuzzy ternary logic expressions on HL7 messages. Stud Health Technol Inform 2011; 169:170–174