

An Open Source Toolkit for Managing Patient Monitoring Device Alarms Based on the IHE Alarm Communication Management Profile

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Abstract

The “Integrating the Healthcare Enterprise” (IHE) initiative has defined an Alarm Communication Management (ACM) profile as part of the Patient Care Device (PCD) domain in order to communicate alarms from patient monitoring and therapeutic devices in a consistent way.

We developed and implemented an extensible, open source toolkit (C#) based on the ACM profile and interfaced our patient monitoring equipment and infusion pumps using several export interfaces available in the intensive care units of the Erasmus Medical Center.

The result was, an open source framework of the IHE PCD ACM profile which provides a starting point for a centralized, uniformed approach to device alarm management. In the future devices could use alarms generated by other devices to decrease the number of false alarms.

The toolkit is available at: <http://i-put.sourceforge.net>

1. Introduction

At an Intensive Care Unit (ICU) a patient is connected to multiple types of Patient Care Devices (PCD). Alarms generated by PCDs can both be of physiological and technical nature. Figure 1 provides an overview of the common PCDs associated with a patient. Parameters typically monitored on the ICU include: ECG, blood pressure (invasive and non invasive), O₂ saturation and temperature. Limit violations will trigger alarms, additionally advisory alarms are generated (for instance in the case of ECG lead disconnection). PCDs related to respiration, dialysis and other therapies may also be connected.

In the ICU, medications are frequently administered by infusion pumps, which generate alarms when the medication becomes depleted or in the case of obstruction.

The large number of monitored parameters and connected PCDs in an ICU can generate a high frequency of (false-positive) alarms [1].

In addition to PCD alarms, patients themselves are also able to generate an alarm by pressing a patient alert button.



Figure 1. Patient Care Devices at the point of care (ICU)

Although most PCDs generate very similar output for alarms, the devices are rarely integrated in a single system for alarm distribution.

Integrating the Healthcare Enterprise (IHE) [2] is an initiative started in 1997 by healthcare professionals and industry to improve the manner in which computer systems in healthcare share information.

In 2005 the IHE formed the IHE PCD domain to address the integration of medical devices with healthcare computer systems. The IHE PCD domain intends to improve flow of information between the point-of-care and the Electronic Healthcare Record. Work was started in 2008 on a profile for alarm management resulting in a draft for trial implementation: the Alarm Communication Management (ACM) profile [3]. The ACM profile strives to establish interoperability between systems of different manufacturers and may result in a communication standard for alarm messages.

Our aim is to provide better insight into the generated alarms and to enable techniques for combining alarms from different PCDs. To do this a centralized system needs to serve as a gateway for alarms from different PCDs.

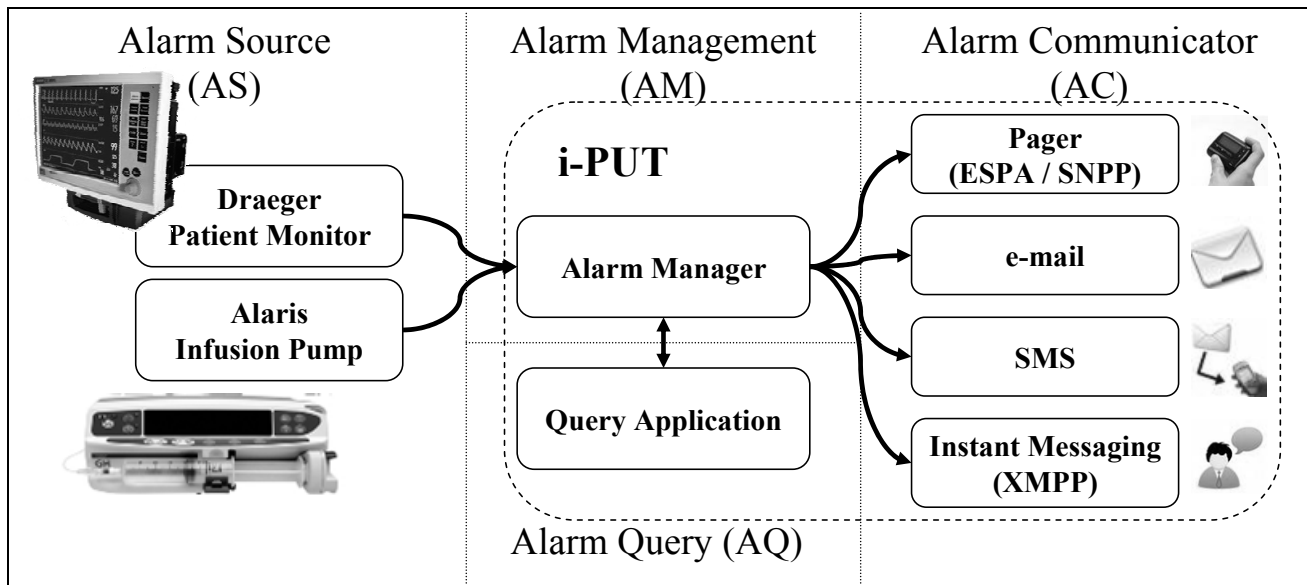


Figure 2. Overview of the intelligent Patient Universal Tele-alarm (i-PUT) toolkit and its integration at the Thoraxcenter.

2. Methods

The ACM profile (displayed in Figure 2) specifies four major elements: Alarm Source (AS), Alarm Manager (AM), Alarm Communicator (AC) and Alarm Query (AQ). The Alarm Manager is the central system that connects the three other elements.

After implementation of the central application (AM), as specified in the ACM profile, a suitable distribution mechanism for the now centrally received alarms needs to be chosen. The draft for trial implementation suggests a distribution mechanism (AM → AC) based on e-mail. However, more suitable distribution mechanisms are available for alarm distribution to the medical staff. The following alternative solutions were considered: pager, mobile phone, Personal Digital Assistant (PDA) and Smartphone. Some solutions are manufacturer specific, others will use open standards or are public domain.

Table 1 provides an overview of the provided solutions and their associated technologies (including paging, SMS, e-mail, RSS [4] and Instant Messaging). A key issue when comparing technologies is the ability to confirm delivery and acknowledgment of the alarm.

Pager, mobile phone and Smartphone can be used to deliver alarms to roaming clinical staff. When sending a SMS, a status report can be requested to provide information regarding the message delivery. However, implementing this solution would contribute significantly to the complexity of the system.

The use of a PDA is currently less desirable than a pager or mobile phone due to battery life limitations. Advantages of a PDA are that it can provide additional information for each alarm. This would enable the user to

review vital signs and ECG tracings that are related to the time of the alarm. A Smartphone combines the capabilities of PDAs and mobile phones. Development on this platform will most likely lead to a viable system for receiving alarms.

3. Results

We developed a toolkit to implement the ACM profile: the intelligent Patient Universal Tele-alarm [5] (i-PUT). I-PUT (C#, ASP.NET and SQL) consists of three applications. The main application is the alarm manager, which can receive and distribute the alarms to configured disseminators: paging (ESPA [6] and SNPP [7] protocols), e-mail (specified in the ACM profile), SMS (based on GSMComm [8]) and instant messaging (XMPP protocol [9]). Additionally, the alarms can be stored into a SQL database.

	Assured delivery	Confirmation	Pager	Mobile Phone	PDA	Smartphone	Personal computer
X: fully capable, P: partially capable							
Paging	X	X	X				
SMS	P			X		X	
e-mail	P			P	X	X	X
RSS				X	X	X	X
Instant Messaging		X			X	X	X

Table 1. Overview of systems and capabilities

The second application, AlarmQuery, enables a user to query for patient alarms. The third application, AlarmRSS, provides an RSS feed based on the database used by the alarm manager.

The alarm manager application can use multiple routes to distribute the received alarms. Additional distribution channels can easily be added using the plug-in architecture. The i-PUT toolkit is available to the public in accordance with the Apache License Version 2.0 [10].

An overview of i-PUT and its integration at our hospital is provided by Figure 2.

First, we implemented two alarm source (AS) applications. These AS applications are integrated with commercial systems. After implementation of the AS applications the alarms could be distributed.

To integrate the patient monitors we then intercepted the alarm pages that are generated by the Infinity Gateway Suite [11]. The Infinity Gateway provides an application to send patient monitor alarms to a pager using a serial connection (ESPA). These pages were transformed to HL7 messages as specified in the ACM profile.

Finally, the infusion pumps were integrated. We used the XML interface provided by the Asena Gateway Workstation to retrieve the alarms. The retrieved data was transformed to HL7 messages as specified in the ACM profile. The Asena XML interface provides a very useful solution to select a subset of the available information using eXtended Stylesheet Language Transformation (XSLT). Any changes in the selected data are then sent to the application over a TCP connection.

4. Discussion

The open source i-PUT toolkit, an implementation of the IHE PCD domain ACM profile, is a starting point for a centralized and uniform approach to alarm management.

PCDs on a single ICU are frequently from different manufacturers. The resulting differences for each type of device form an additional obstacle when integrating the alarms into a single system.

The i-PUT Toolkit needs testing with each manufacturer's implementation of the ACM profile. This process could be catalyzed by participation to an IHE Connectathon [2]. The ACM profile suggests support for both HL7 version 2 and 3. i-PUT does not yet support HL7 version 3, which limits the interoperability.

The integration of alarms generated by patient monitors can be further improved by using TapeRec [12], an application that can provide waveforms and trends associated with an alarm. These data could then be provided to the relevant care provider together with the alarm.

Finally, the integration of the alarms generated by

respiration and dialysis devices, and/or patient alarm buttons should be considered.

Patient monitoring and therapeutic devices at the bedside generate many audible and visual alarms, interrupting care by requiring a clinician to review each alarm. Few of the alarms actually represent life threatening events; most result from (slightly) abnormal values or artefacts. Alarms are often presented on different screens, use different sounds and visual effects. Also, to change specific alarm settings, each device needs to be configured separately. Finally, devices do not exchange alarm information with other devices of the same patient, so each device will generate its own stream of alarms. Thus, a single physiological event may trigger different alarms (time, message and/or level) for each attached device.

The application of the ACM profile can lead to systems which reduce the frequency and obtrusiveness, while improving the accuracy of these alarms. The i-PUT Toolkit forms a foundation for such new applications.

An additional advantage of integration of all alarms into a single central system is the ability to track and trace the generated alarms. This provides insight into the frequency and types of alarms. A first step was taken using the database to provide an overview of the alarms generated at the ICCU of the Thoraxcenter [13].

When implementing an ACM, especially when planning to distribute the alarms to clinical staff, one must consider the effect on patient care. Additional disturbance of the clinical staff by devices like a pager, phone and/or PDA need to be limited to instances when it is in the best interest of the patient. An increase of unnecessary alarms can lead to ignoring of alarms and potentially to a delay in patient assessment.

In addition to sending alarm data directly to the relevant care provider, other information, such as lab values and advice generated by clinical decision support systems could be considered as opportunities to improve efficiency and quality of care.

Acknowledgements

The authors thank S Mayr for his work on GSMComm software.

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