A Middleware Approach to Intelligent Emergency Health Care Messaging Using Wireless Networks

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Abstract

Use of emergency messaging system is a key to effective communication in healthcare applications by emergency responders during calamity. Evolving high speed wireless networks facilitate to connect emergency responders to an emergency electronic routing directory, data sharing systems, handling real time emergency information among multiple services. In this paper we analyze the performance of a middleware architecture that implements a prioritized context-centric loosely coupled messaging mechanism to support Emergency Medical Services (EMS). The context-centric messaging is an application layer messaging mechanism that provides reliable and secure messaging within the middleware architecture for distributed data sharing and location identification. Real-Time testing using CDMA 1XRTT network between a data capturing tool from an ambulance and a database server was performed to analyse the messaging mechanism efficiency. The test results based on round trip time and bandwidth are discussed in this paper.

Key Words: Middleware, Context-Centric Messaging, EMS, CDMA 1XRTT, Mobile Agents

1. Introduction

Intelligent information-assisted healthcare service is an evolving major research area in recent years. Healthcare industry focuses on equipping the next generation of healthcare providers, especially emergency service providers with intelligent information-assistance supported by contemporary communication technology. The evolution in mobile network technology such as CDMA, GSM/GPRS/HSDPA, WiMax, provides reliable high speed data transmission from anywhere and at any time. In North America, the role of the emergency services and related entities is expected to expand beyond traditional 911 services with higher levels of interaction, managed situational intelligence, enhanced capabilities, more comprehensive communication and coordinated response services. The privacy issues related to patient health information need to be strictly adopted by reliable and secure mechanisms. Implementing existing three decade old emergency service messaging interface with healthcare applications is radically constrained by a limited messaging capability and a lack of expandability to accommodate modern network facilities and services. In recent years various standards such as Health Level 7 (HL7), Digital Image Communication (DICOM), X12, CEN TC251, ISO TC215 and GEHR defines message format and sequence for healthcare data especially the clinical data [2]. Defining a new messaging standard for emergency services is a work-in-progress. We envision access to wireless network through mobile devices such as PDA, Tablet PCs, and Laptops with wireless network access cards provided to all emergency services. Hence, the challenges imposed by the wireless environment such as disconnection and mobility issues should be considered while designing emergency message standard [1]. A new intelligent approach is required to address an assortment of information request and response provided by the emergency service community.

The requirement is that clinical and emergency information based on needs of patients and healthcare providers should be anticipated and delivered in a timely and error-free manner. In this paper we have described a new Mobile Emergency Messaging Interface system that will be used to pass messages as quickly, concisely, and with as little redundancy as possible. To ensure efficient communications, an Agent-based Mobile Middleware Architecture (AMMA) has been designed to standardize and simplify the message handling process. AMMA was tested using a real-time data capturing tool for EMS, and the results are given in this paper.
This paper is organized as follows: Section 2 discusses about the related work. Section 3 describes the middleware architecture designed for implementation of messaging mechanism Section 4 describes the design of proposed emergency messaging mechanism and Section 5 discusses the test results and issues.

2. Related Work

Currently a great amount of research is being carried out globally to modernize the healthcare system using Electronic Health Record (EHR) system. Middleware and distributed system management architectures are designed for handling various issues related to EHR implementation. The EMS system involves both patient healthcare, operations/management of EHR for the patient and the emergency management.

The Automated Remote Triage and Emergency Management Information System (ARTEMIS) is an ongoing research effort that aims to provide real-time physiological information to first responders and command personnel in emergency/disaster situations. This middleware develop mechanisms to access EHR in a standard way and to develop Peer-to-Peer Networks of healthcare organizations interoperating through semantically enriched Web Services. The system employs wireless networking, portable computing devices, and reliable messaging technology as a framework for information analysis, information movement, and decision support capabilities [2]. The Wireless Internet Information System for Medical Response in Disasters (WIISARD) project is an integrated application that will bring cutting edge wireless Internet technologies from the hospital to the field treatment station [3]. This system implements web service based “Intelligent Tags” for tracking patients, service providers, devices and other participants. The electronic Point-Of-Care (e-POC) system is a PDA based mobile electronic Health Information System which manages client (patient) information, such as personal information, clinical information, electronic assessment and health care plans in an Ambulatory Care environment [4].

All the above projects proposed web-based solutions rather than network based solutions. The web-based solutions adopt Remote Procedure Call (RPC), a synchronous messaging mechanism that introduces notable delay due to reception of remote process completion confirmation message to proceed, which is non-acceptable in emergency care services. We propose a simple loosely coupled autonomous messaging system best suitable for both the mobile environment and the emergency services. Significant input regarding data semantics, context content and communication framework from the reference helped with the proposed messaging mechanism described in this paper.

3. Middleware Architecture

A light weight Agent-based Mobile Middleware Architecture (AMMA) in figure 1 was designed to provide reliable, secure and authenticated data transmission over the cellular network. AMMA adopts client/server architecture [5] [6] that implement a context-centric asynchronous messaging mechanism which enables quick and concise emergency message transmission using the available wireless network during phases of disconnectivity.

The architecture consists of: the user interface to collect the patient care data and it is posted on to the message board. The data is categorized and prioritized by the data segregator, the data store, and the data distributor components. Location information is added for intelligence, along with the power managing info and synchronised with the data. Context-centric messages are added to the header of these data segregated and sent to the transport protocol. The data flow sequence is explained below in detail.

![Figure 1 Middleware Architecture](image-url)
A. Message Flow Sequence

Data from the application is captured by the user interface, with a static agent and "POST" as a 'Message' with prefix: "OUT" and status "Incomplete" on the Message Board. Static agent components within the architecture check the message board at constant interval for messages. Data Segregator "POP" the message, performs message translation, assigns the priority label based on the messaging context and stores it into the Data Store. The Data Distributor "POP" the message from the Data Store to wrap/remove the message header to the message and "POST" the message back on the message board ready for transmission/display with prefix "IN" / "OUT" and set status to "Complete". Virtual Connector "PUSH" / "POP" the message with prefix "IN" / "OUT" from / into the transmission buffer of the appropriate socket for transmission. It assigns the sockets based on the message priority set and the available network bandwidth and speed. Power Manager keeps track of the availability of the battery power and triggers a message if the power available is insufficient for transmission. Geo Locator captures the location information and "POST" it into the message board. Data Synchronizer correlates the "IN" / "OUT" messages and removes the "OUT" messages when a corresponding "IN" message is posted.

B. Message Storage Framework

A unique categorized data approach best suitable for emergency message transmission is defined. A simple general structure of message storage framework is shown in Figure 2, for representation of the message categories.

```
<Category Name="<name>">
  <SeqID> = <sequence number>
</Category Name="<name>">
```

Figure 2 Message Storage Framework

Healthcare application is entitled to different categories of messages based on the emergency condition. Each element can be represented in any of the well established medical data messaging standard such as HL7, and DICOM. Message representation used is assigned in the message header for interpretation. A sequence number is assigned for each category which is used for message transmission as proposed by us and others in [7] [8] [9].

4. Proposed Messaging Interface

A unique loosely coupled messaging mechanism, Mobile Emergency Messaging Interface (MEMI), has been designed for data transmission using the wireless networks. Three main challenges of wireless networks – disconnection, security, reliability - are considered while designing this mechanism. The mechanism ensures that the data is transmitted without data loss and unnoticeable delay.

![Figure 3: Middleware Network Architecture](image)

AMMA works over wireless network architecture, as shown in Figure 3. In practice, each ambulance features two wireless network interfaces: short range (e.g., 802.11a/g/n) and cellular (e.g., CDMA/EVDO, GSM/GPRS). The general idea of this architecture is to use cellular communication to improve communication reliability. Cellular networks assure reliable data delivery with unpredictable delay.

A. Mobile Agents

Mobile agents are designed to suit the messaging mechanism. There exist two models of agent mobility: weak and strong. In weak migration model, the agent’s code and data is migrated to the new host and restarted from the beginning with its data. The agent must prepare for the transfer so that all the necessary information is in the data. The strong migration transfers agent’s state too and the agent restarts from the point where it stopped. A hybrid migration model is proposed for agent mobility within the middleware architecture to implement the loosely coupled...
messaging mechanism. In this model, agents communicate using sockets. Agent code and data is converted into byte array so that it is protocol independent. To perform this the agent invokes a public method on the local server after which it is serialized and prepared for transfer by passing it through multiple layers. When the agent is prepared, it can be transferred to the new location by using standard transport protocol (TCP/IP) [10].

B. Query / Response Model

A simple asynchronous Query / Response messaging model shown in Figure 4 was implemented. Messages are transmitted through mobile agents. Client agent generates a mobile agent with enclosed message. Mobile agents use the message board for picking up & posting messages. The agents move from the client to the communicator once the connection is established. Agents indicate its arrival at the communicator through a message to the communicator which then validates the agent through an ‘ECHO’ messaging with the client. Once the validation is successful the connection is released and the client is free to proceed further. Based on the context of the message, mobile agent generates a ‘QUERY’ message and sends it to the server to check its status. Server replies through a ‘RESPONSE’ message to indicate the availability status. If available, mobile agent moves to the server and delivers the message.

![Figure 4. Messaging Model](image)

Once the data is received properly, an ACK message is generated which is delivered to the client as a receipt. The ACK is stored in the communicator and delivered to the client by checking its availability. A “Message Board” communication model is adopted in the middleware where in all incoming and outgoing messages are pinned to message board with appropriate headers.

C. Emergency Message Transmission

Categorized message block transmission is adopted for the emergency messaging. A simple user interface was designed to select the category of transmission. Messages are transmitted based on these categories. Prioritization of the message to be transmitted is performed based on the category. For example, when there are sub categories, then each sub category is transmitted as a message block. A connection is established by exchanging the message framework syntax before the message blocks are transmitted. Message is forwarded for transmission as blocks according to the priority tag. Priority tag is set based on the condition of the patient. Each message block is encapsulated by the message header. Message header consists of priority tag, source, destination, location, category, subcategory, sequence id, following sequence id, timestamp, message format used, version, acknowledgement status, check sequence and block size. If the priority is ‘Normal’, then transmission is carried out based on the sequence in which each category appears in the framework. If a category is empty, it is eliminated from the sequence for the specific transmission. The following sequence id field in the header is set to the next non-empty category. If there exist a sub category, check sequence field represent the total number of subcategories present and the subcategory field represent which number it is out of the total number. This helps the receiver to collect the sequence correctly. Message is collected by the receiver and check for the sequence id. If the id is correct, then according to the sequence and fits it into the framework. An acknowledgement is send by the receiver for each message block transmitted. A consolidated acknowledgement is send if a sequence of subcategories transmitted.

5. Performance Evaluation

In this section, we present the evaluation of AMMA by conducting a real-time message transmission. We evaluate the performance of AMMA by traveling in an ambulance and capturing data for transmission from different geographical regions. We used an enhanced TCP/IP protocol for messaging and conducted testing by transmitting message at specified interval. Our goal is to show that the proposed solution provides better responsiveness and reliability.
A. Implementation

An electronic Patient Care Reporting (e-PCR) system has been developed for EMS, Saint John, NB, Canada. The e-PCR acts as the data capturing tool from the incident call site. A screen shot of the e-PCR system is shown in figure 5. AMMA was implemented as part of the system. The system was developed based on .NET framework using VB.NET and JAVA.

Two simple main methods: ‘QUERY’ and ‘RESPONSE’ are implemented in mobile agents. ‘QUERY’ method refers to the address of the servers and the data to be transferred. ‘RESPONSE’ method generates the ‘ACK’ message once the transaction is completed successfully. A Point-to-Point transfer was performed to ‘SEND’ the message to the communicator. The ‘QUERY’/‘RESPONSE’ messages was implemented based on ‘Publish/Subscribe’ model between the server and communicator as adopted in [11] [12].

B. Result

During testing, we observed that the cellular-only solution AMMA achieves 100% data lossless transmission with unpredictable transmission delay depending on the cellular coverage and environment. Since cellular communication incurs a cost and its bandwidth is limited, we tried to limit the number of packets transferred through the cellular network. Figure 6 plots the bandwidth available on this network as function of average speed. Analysis of this test result shows that network usage increases as the signal strength increases.

6. Conclusion

This paper has presented AMMA, mobile middleware architecture for emergency information transmission for EMS. This middleware works perfectly over cellular network architecture and other wireless networks. AMMA achieves over 99.7% timely delivery rate of messages. In addition, the transmission is quicker, reliable and avoids redundancy. The analysis also proves that mobile agents will be a better solution for mobile applications, especially emergency / disaster management applications.
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Reference