Ambulatory Data Aggregation and Reduction for Transmission Over Limited Bandwidth Network

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ABSTRACT

There is a growing interest in linking the ambulance to hospital emergency room for transferring patients’ vital signs’ data to the hospital while the patients are in transit. If the ambulance is linked to the emergency room, the physician can monitor patient’s vital signs and issue instructions to the paramedics for stabilizing the patient. When a disaster strikes, scores of people have to be transferred to the hospital in ambulances. During an emergency situation, the number of patients in critical condition is overwhelming. We propose a scheme to transmit vital signs’ data to the hospital in reduced and packed format via limited bandwidth wireless network. This scheme will help physicians in the hospital to monitor several patients who are in transit to the hospital. The effectiveness of data reduction techniques has been discussed for the purpose of transmission of data to the hospital on limited bandwidth wireless network.

KEYWORDS: CAN-UMTS, Data Reduction, EKG, Vital Signs, Ambulance

1. INTRODUCTION

Disasters can strike any time at any place. Earthquake, fire, building collapse, massive food poisoning and other such disasters need on-time medical response. First responders include ambulances besides fire brigades and elite emergency response teams. Disaster management relies greatly on effective emergency medical care arrangements. During an emergency, scores of people in critical condition are transported to the hospital where expert medical care is provided by the physicians. Sometimes several patients can be transported in large ambulances. Ambulance crew consists of paramedics and driver. Their job is to bring the patient to the hospital alive and stable so that the physician can attend to the patient. If patients’ vital signs (blood pressure, pulse, blood oxygenation and respiration) data and additional diagnostic medical data (e.g. EKG) is transmitted to the physician in real-time, then chances of saving patient’s life improve considerably. This is due to the fact that the first 60 minutes are the most critical for patients suffering from heart attack or other life threatening situations. If the ambulances are linked to the hospital via wireless network, vital signs and one dimensional (1-d) medical data can be transferred to the hospital in real time.

Many schemes have been proposed to transfer vital signs to the hospital using wireless networking. The wireless transmission of 12-lead EKG was demonstrated by Grim in 1987. Majority of work uses GSM/GPRS to transmit medical information while some used 3G systems [1, 2, 3, 4, 5, and 6]. The focus of most of the researchers has been on the transmission of the medical data of a single patient being transported to the hospital. We propose the design and development of a system that can deal with medical emergencies associated with disasters resulting in massive casualties.

In our proposed system, we assume that all the ambulances have cellular (3G UMTS) links. Due to the In-ambulance wireless linkage, it can use the cellular network for transmission of vital signs and additional data even if it is at a considerable distance from the hospital. The data can be aggregated to include vital signs of several patients being transferred to the same hospital. The maximum number of patients can be increased based on the demand of the situation.

In this paper, it is assumed that the ambulance will be equipped with set of medical instruments connected to a Medical Data Network (MDN). The medical instruments can collect patients’ vital signs such as EKG, heart rate, temperature and oxygenation etc. These instruments will inject digitized vital signs on MDN. The medical instruments will generate Controller Area Network (CAN) formatted data over medical Data Network [8, 9]. Controller Area Network Protocol is a serial
communications protocol originally designed for the automotive industry. However, due to its inherent robustness, CAN protocol has also been adapted for embedded control in medical environment. It is also assumed that the ambulance is equipped with a CAN-UMTS gateway that would convert the CAN messages to IP packet to be transmitted over the cellular network. Figure 1 illustrates the MDN, gateway and links for the ambulance to the hospital via cellular network.

![Figure 1: Medical Data Transmission from Ambulance via UMTS to Hospital](image1)

2. DATA AGGREGATION AND PACKET FORMATS

The aggregation of medical data for several patients is desired when an ambulance is carrying several patients. This aggregation is achieved by using special packet format that puts the data in order. We describe the packet header and payload formats in this section.

CAN header can be manipulated to aggregate medical data for patients. There are two versions of CAN protocols in use. They are called CAN 2.0A and 2.0B. Main difference between these versions is the length of message identifier. Version 2.0A and version 2.0B have 11 and 29 bits message identifier respectively as shown in Figure 2 [8]. We have selected CAN version 2.0A in our proposed system. CAN version 2.0A contains an 11 bit base identifier (BID) that determines the priority of the message.

![Figure 2: CAN Version 2.0A and 2.0B](image2)

<table>
<thead>
<tr>
<th>BID_0</th>
<th>BID_1</th>
<th>BID_2</th>
<th>Message definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Patient information</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Blood Pressure</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>EKG</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Pulse Rate</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Blood oxygenation</td>
</tr>
</tbody>
</table>

The 11-bits base identifier can be segmented in the following format: x1x2x3y1y2y3y4z1z2z3z4. First three bits x1x2x3 can represent CAN message type. CAN message types for medical data payload are shown in Table 1. Each patient will be assigned a 2 bits Patient Identification (PID) code and will be defined in BID’s bits BID6 and BID7. The patient’s name will be sent in 8 bytes in CAN’s message’s data field. If patient information type field is equal to 001 (Medical data) then patient’s medical data can be described in the format shown below, with 2 bytes for age, one byte for gender and 2 bytes for pre-existing condition, if available.

![Figure 2: CAN Version 2.0A and 2.0B](image2)

Table 1. Medical Data Payload Types For CAN Message

If first three bits of identification field are “000” then the message gives “patient information” as shown in the first row of Table 1. In this case, next three bits of BID (BID3 BID4 and BID5) will describe the patient information type as shown in Table 2 below. Patient name can be replaced by vital mote tag number if the name cannot be obtained due to emergency conditions existing at the disaster site.
Table 2. Additional Message Types

<table>
<thead>
<tr>
<th>BID3</th>
<th>BID4</th>
<th>BID5</th>
<th>Message definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Patient name</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Medical data</td>
</tr>
</tbody>
</table>

In our scheme, each CAN enabled medical equipment will send Patient’s digitized vital signs in 16 bits along with patient ID and vital sign code as shown in Figure 3.

![Figure 3: Vital Signs Data and Headers](image)

CAN-UMTS gateway gathers messages from CAN-enabled medical equipment from In-ambulance CAN network and keeps them in relevant buffers such as EKG buffer, BP buffer etc. The data field of a CAN message is up to 64 bits long, therefore, one CAN message can carry vital signs data of up to 4 patients. To distinguish the EKG data for different patients, it sets 2 bits patients’ ID in relevant field. For example, EKG data of four patients with ids 00, 01, 10 and 11 is shown in Figure 4.

![Figure 4: Packet Format for Aggregated Data](image)

CAN-UMT prepares packets of aggregated data and generates IP packets in which aggregated CAN message is treated as IP payload.

3. DATA REDUCTION ALGORITHM

There are strong chances that due to the mass emergency situation, the number of phone calls and the load over the network would leave very little bandwidth free. It is therefore required to compress the data so that the vital signs of large number of patients can be accommodated over a single UMTS connection. Furthermore, several patients’ vital signs data over MDN may lead to network saturation over in-ambulance medical data network. Accordingly, the number of waiting messages will increase austerely.

It has been suggested that patients’ medical information can be represented by CAN message’s payload. It is very likely that a considerable portion of message payload may remain constant depending upon the message type. For example, if a message represents patient’s body temperature information, then there are good chances that the temperature may remain constant for a considerable period of time. Therefore, the data bytes representing the temperature information will remain constant for that period. Based upon the “non-variability” feature of some of CAN messages, a Data Reduction (DR) algorithm for CAN network was developed in [7]. In the developed DR algorithm, it is assumed all CAN messages have fixed payload size of 64 bits. The transmitting and receiving CAN controller chip maintains a history of recently sent or received N CAN messages in buffers T_BUF and R_BUF respectively. Whenever the transmitting CAN chip schedules a previously sent message, its payload is compared with the payload of message saved in the T_BUF. If some data bytes in the newly generated message are found repeated, then the CAN controller prepares an 8 bit compression code (CC) to indicate this repetition. Eight bits of CC corresponds to 8 bytes of CAN’s payload size. If i-th data byte is repeated, the i-th bit in compression code is set to “1”. On the other hand, if i-th data byte is not repeated, the i-th bit in the compression code is set to “0”. Non repeated data bytes will follow the compression code. For example, if in a CAN message bytes 0, 1, 2 and 3 have been repeated and byte 4, 5, 6 and 7 are new then the compressed CAN message will be as shown in Figure 5. Figure 6 shows the complete MEDTOC (Medical Data Transmission Over Cellular Network) scheme as proposed.

![Figure 5: CAN message with compression code and non repeated data bytes](image)
We studied the data pattern in 12 channel EKG data and concluded that EKG digitized with 2 bytes is attributed with significant non-variability features. This observation encouraged us to apply the DR algorithm to ambulatory EKG data. All the medical equipment is CAN enabled. Therefore, DR algorithm can be applied by CAN-UMTS gateway to the aggregated CAN messages. Figure 7 indicates the resulting reduction ratio for the 12-channels EKG data.

Figure 7: Results for compression of 12-channel 2-byte EKG Data

For MIT heart rate series [9], the data for “hr7257.dat” was compressed to 85% of the original size and the data for “hr11389.dat” was compressed to 89% of the original size. The lower compression ratio for heart rate series is because of the fact that the heart rate value is rounded from floating point representation to one byte integer format and CAN protocol carries 8 readings per packet that differ in small amounts.

4. CONCLUSION

We have worked on developing a scheme for transmission of aggregated and reduced medical data generated with industry standard CAN network over 3G cellular networks. We have discussed the feasibility of applying CAN protocol based data reduction to the data representing vital signs of patients. It is demonstrated that the DR algorithm can effectively double the original capacity of the cellular network by reducing the data to less than 50% of its original size. Work is in progress to define aggregation and multiplexing standards in order to join the ambulance network to the hospital network in a transparent manner. This link is crucial in providing real-time guidance to the paramedic staff on board for stabilizing the patients in critical condition.

REFERENCES


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