Abnormal Human Being Vital Sign Detection Embedded on Smart Sensor with Collision Avoidance for Disaster Temporary Healthcare

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Abstract

In recent years, the production of mobile computing devices has motivated a revolutionary change in the computing world, which motivates the usage of a wireless ad-hoc and smart sensor network for monitoring the patient in disaster. Flow of signal from sensors to sink node may cause congestion in WSNs if a number of events sensing nodes attempt to send event information to the sink at the same time. Thus, this paper takes the advantages of smart sensors and proposes an energy-efficient and congestion avoidance vital signal detection framework to apply to the natural disaster results in a great number of injured people. The framework consists of several stages designed to improve the performance of wireless sensor networks. First, self-organized wireless ad-hoc and sensor network was simulated, in which all nodes try to organize themselves to organize a network. Nodes in the network reconfigure themselves repeatedly to respond to modifications in the number and location of nodes in order to prevent collisions in the receiver. In the second stage, we proposed a smart sensor processing system with the capability to extract the abnormal vital sign, to reduce the overhead in the aggregator and lower power consumption by sending only the abnormal vital sign. Furthermore, we propose to average polling rate to be suitable for both sender and receiver, in which the intermediate node can balance between the packet arrival rate and the packet service rate, thus avoiding congestion and enhancing the response time.

Keywords: Ad-hoc and Sensor Network; Disaster; Healthcare; Polling Rate

1 Introduction

In recent years, the production of mobile computing devices has motivated a revolutionary change in the computing world, which motivates the usage of a Wireless Ad-hoc and Sensor Network (WSAN) for monitoring the patient in disaster. An ad-hoc network is a group of wireless devices free from any infrastructure, where each of these devices offers a relay service to accept data from other nodes in order to forward it to another network device, which is out of radio reach.
of the original transmitter of this data. The main objective of this network is to permit a group of communication terminals to set up and keep up a network between themselves, without the support of infrastructure. Thus from the application viewpoint, wireless ad-hoc networks are useful for circumstances that need fast or infrastructure-less local network deployment, such as a disaster response. An essential sub-class of ad-hoc networks is Wireless Sensor Networks (WSNs). Sensor’s networks are currently being employed in a variety of applications, including environmental, medical, biological military, and industrial applications [1]-[3]. Wireless sensor devices that can be used to monitor human activities have gathered great research attention in recent years. Demand of wearable wireless devices has also been on the rise. The moveable and wearable devices can be used to monitor patients’ status while they are moving regardless of physical location. Bio-sensors can swap sensing medical information through these WSNs [4]-[5].

Flow of signal from sensors to sink node may cause congestion in WSNs if a number of events sensing nodes attempt to send event information to the sink at the same time. Authors in [6] have mentioned that in WSNs, network congestion can be improved during traffic control or by resource control. Thus, traffic control approaches avoid congestion by controlling the incoming traffic with consideration on the offered resource and achieve fairness among traffic flows. However, traffic control may violate the fidelity stage required by applications. The resource control approaches satisfy the requirements of each flow by increasing the resource of the node; therefore, it can support fidelity as well it can avoid congestion.

According to the abovementioned, this paper takes the advantages of smart sensors and proposes an energy-efficient and congestion avoidance vital signal detection framework to apply to the natural disaster result in a great number of injured people. Our research contributions are as follows:

- **Vital Sign Processing** Vital sign processing on smart sensor, to reduce the overhead in the aggregator (i.e., reduces the data communication in the main application processor), and thus lowers power consumption by sending only the abnormal sign.

- **Average Polling Data** We propose an average polling data rate that is suitable for both sender and receiver be balance between the packet arrival rate and the packet service rate, so that congestion can be avoided, and the response time can be enhanced.

2 Related Work

There is a lot of research in the area of emergency telemedicine, home monitoring, transmission of medical records, remote surgery and virtual hospitals [7]-[8]. Several variations have been developed including smart textile-based wearable biomedical systems (ST-WBSs) [9], optimal electrocardiographic lead systems: practical scenarios in smart clothing and wearable health systems [10], and guest editorial body sensor networks: from theory to emerging applications [11], and the triage system to meet the needs of the next generation of triage systems in [12]. Besides, a wireless body area sensor network for health monitoring integrated into multi-tier telemedicine systems in [13].
3 Abnormal Patient Vital Signal Framework

The main practical challenge is how to organize, administer the sensors, and manage the collected information to reduce the propagation delay, mitigate the congestion, and obtain a required fineness of monitoring. Thus, we propose an abnormal patient vital signal framework as shown in Fig. 1. The framework consists of several stages designed to improve the performance of wireless networks. At the start, all ad-hoc nodes try to organize themselves and shape a network by connecting each pair in transmission range, which corresponds to the range within which the frame can be effectively received and with no collisions in the receiver, as shown in Fig. 2. Node in the network reconfigures itself repeatedly to respond to modifications in the number and location of nodes. Nodes in our design are classified into patient source nodes, intermediate nodes, and temporary healthcare nodes (sink nodes). Whenever the node is ready to receive data, it polls its neighbors with Ready to Receive, a message (RTR), that indicates its readiness to receive data. Continuously, the patient nodes read the abnormality of human vital sign (for

![Diagram](Diagram.png)

Fig. 1: Abnormal patient vital signal detection framework
example, they check if the heart rate is abnormal or not), by using the proposed system shown in Fig. 3. If the polled patient node has data to send, it checks for RTR from the intermediate node, if it is available, it then chooses the shortest path and transmits the abnormal sign to any node not compulsory to the polling node. If RTR is not present, and by using Distributed Coordination Function (DCF), the patient node senses the medium, if the medium is idle for more than the Distributed Inter-frame Space (DIFS) period, then the abnormal vital sign frame can be transmitted. Otherwise, the transmission is deferred and the patient node uses Exponential Random Backoff (ERB) mechanism and chooses a backoff interval from zero to a contention window (0-CW).
3.1 Self-organized Ad-hoc Network

We design a self-organized ad-hoc network as shown in Fig. 2. It consists of 28 nodes, with each pair of nodes in communication range (100 m) organize themselves to form a wireless network. Nodes in this network reconfigure themselves frequently to respond to changes in the quantity and position of nodes to accommodate additions, modifications and deletions to the number of nodes within the network in addition to movable ad-hoc nodes all throughout the network.

3.2 On Smart Sensor Processing

A disaster can be defined as a serious disruption which may cause injury or death in human life. All the required steps for this special kind of accident should be prepared in advance for quick disaster rescue. Therefore, there is a need to improve measurements and models in such a situation. The disaster may lead to breakdown of communications infrastructure. In such a situation, the wireless ad-hoc network is the best solution. However, the huge amount of information congestion may cause a delay in response time and errors in crisis response [14]-[15]. The second stage within the framework is talking about how the patient nodes continuously read the abnormality of human vital sign. In this section, we propose a modified disaster wearable smart sensor as shown in Fig. 3. This system presents a wearable health-monitor that includes various types of small wearable sensors. These bio-sensors are able to measure important physiological parameters such as heart rate, blood pressure, body and skin temperature, oxygen saturation, respiration rate and electrocardiogram. Since sensing signals are very small in magnitude, the signal conditioning stage can improve the accuracy of data by amplifying/attenuating the signal to match the range of the analog-to-digital converter. As well, signal conditioning can include filters to reject unwanted noise within a certain frequency range. Instead of using an aggregator to process the data, we propose local computations in a smart sensor. These computations consist of automatically reading patients’ vital signs and comparing them with the range of normal ones. If this signal is above or below the normal range, then it extracts the abnormal vital sign, forwards it to an intermediate sensor node, and this is done at comparator stage.

3.3 Model the Human Heart Rate

To model the human heart rate during disaster, suppose \( x_1, x_2, \ldots, x_n \) are a sequence of independent heart rates, identically distributed random variable with parameter \( \mu \) mean and variance \( \sigma^2 \) so the distribution of

\[
\frac{x_1 + x_2 + \ldots + x_n - n\mu}{\sigma/\sqrt{n}}
\]

It tends to the normal standard as \( n \to \infty \), that is valid in [16], so:

\[
p \left| \frac{x_1 + x_2 + \ldots + x_n - n\mu}{\sigma/\sqrt{n}} \leq a \right|
\]

\[
\to \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{a} e^{-x^2/2} dx
\]

\( n \to \infty \). Therefore, the normal distribution which is also called (Gaussian distributed) has a
continuous probability density function that can be given by:

\[ f(x; \mu, \sigma^2) = \frac{1}{\sigma \sqrt{2\pi}} \exp \left\{ - \frac{(x - \mu)^2}{2\sigma^2} \right\} \]

where \(-\infty < x < \infty; -\infty < \mu < \infty; \sigma^2 < 0\). Thus, patient heart rate can be normal distributed, and completely determined by the parameters \((\mu & \sigma^2)\), which are also the expected value of regular and irregular with variance for a normal random variable. To determine the probability of a random variable patient heart rate, we assume the normal heart rate is between two limits where the patient heart rate is normally distributed with mean \(\mu\) and standard deviation \(\sigma\). We also plot the normal heart rate where the area between the lower_threshold and upper_threshold as shown in simulation result Fig. 4. Therefore, these steps help to minimize the congestion in the network and increase the response time. The abnormal sign, can be calculated by a simple program and by checking above or below the normal range of vital signs to give an alert for abnormality as shown in Table 1.

**Table 1: A simple program for abnormal heart rate**

<table>
<thead>
<tr>
<th>In</th>
<th>Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>(x = 0, 1, ..., n)</td>
<td>(Y)</td>
</tr>
<tr>
<td>Upper_threshold = (w)</td>
<td>Lower_threshold = (z)</td>
</tr>
</tbody>
</table>

If \((In < Lower\_threshold)\) OR \((In > Upper\_threshold)\) Then \((Out = \text{alert})\);

![Probability of normal & abnormal human heart rate](image-url)
4 Predicting the Polling Rate

Due to the fact that the polling node does not have information of a polled node packet queue, we proposed predicting the polling rate. Although we do not know the length of the next polled node packet rate, we can guess its value by expecting that the following node arrival rate will be the same in length to the earlier ones. Hence, by calculating an estimation of the length of the next node arrival rate, we can choose the process with the shortest predicted node packet rate.

The next node’s arrival rate is in general predicted as an exponential average of the measured lengths of the previous node arrival rate. If $t_n$ be the length at the nth node arrival rate and $\tau_{n+1}$ be our estimated value for the next node arrival rate, then for $\alpha$, $0 \leq \alpha \leq 1$, we can write:

$$\tau_{n+1} = \alpha t_n + (1 - \alpha) \tau_n.$$  

This equation explains the exponential average as in [17], the value of $t_n$ includes the most-recent information, and $\tau_n$ supplies the preceding history. The factor $\alpha$ controls the relative weight of the recent and past history in our prediction. If $\alpha = 0$, then $\tau_{n+1} = \tau_n$, and the recent history has no effect, if $\alpha = 1$ then $\tau_{n+1} = \alpha t_n$, and then only the most-recent node arrival rate matters, and therefore history is assumed to be old and unrelated. In general, $\alpha = 0.5$, so both the new history and past history are similarly weighted. The first $\tau_0$ can be defined as a constant or an overall system average. The intermediate node will set up an initial estimation node polling rate and it uses the actual nth node arrival rate to calculate the value of predicted next node arrival rate. After that it utilizes the predicted value, and the recent receive value to then calculate the second prediction value and so on as shown in Table 2.

<table>
<thead>
<tr>
<th>Actual nth node arrival rate($t_i$)</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>9</th>
<th>7</th>
<th>5</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted next node polling rate (Initial $\tau_i = 3$)</td>
<td>2</td>
<td>2.5</td>
<td>3.7</td>
<td>5.3</td>
<td>7.1</td>
<td>7.1</td>
<td>6.1</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Fig. 5: The simulation result of actual and estimated values
4.1 Simulation

The simulation result of both actual and estimated values of the node is shown in Fig. 5. It appears clearly that intermediate node increases or decreases its sending rate according to the recent receive rate. Therefore, the next node polling rate can be estimated, and by using this algorithm the middle node can be made to balance between the packet arrival rate and the packet service rate, thus avoiding congestion, and improving response time.

5 Conclusion

This paper proposes vital sign processing on smart sensor to reduce the sensor power consumption, besides, it proposes an average polling data rate to mitigate the congestion and enhance the response time during the natural disaster that results in a great number of injured people. The hypothesis is confirmed by analytical approach and simulation results.

References


