Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 154 (2019) 453–459

Procedia Computer Science

www.elsevier.com/locate/procedia

8th International Congress of Information and Communication Technology, ICICT 2019

An Intelligent Packet Drop Mechanism in Wireless Body Sensor Network for Multiple Class Services Based on Congestion Control

Qian Yu Xu[a], Suo Ping Li[a,b,]*[*], Hala Mansour[b]

[a]School of Electrical and Information Engineering, Lanzhou University of Technology, Lanzhou 730050, China
[b]School of Computer and Communication, Lanzhou University of Technology, Lanzhou 730050, China

Abstract

Considering the impact of congestion on wireless body sensor network (WBSN), an intelligent packet drop mechanism for multi-class traffic based on exponential random early detection is presented to mitigate the network congestion. A learning automaton is set in mote for "learning" intelligently from outside network environments. Obtained the learning result, an exponential random early detection algorithm is used in interactive node to control congestion by dropping packet. Meanwhile, based on the characteristics of WBSN, we also subdivide the packet dropping probability by the different priority traffic. Eventually, the packet dropping probability of traffic under different network environments, queue lengths and priorities is obtained. In consideration of a large amount of redundant data in WBSN, the proposed mechanism is able to actively dropping some low priority data, which can not only mitigate network congestion but also ensure the transmission of important vital signals.

Keywords: *Wireless body sensor network; Priority; Exponential random early detection; Packet dropping probability;*

1. Introduction

Fast development of both biosensors and wireless communication technology, new wearable fabrics integrated by wireless sensor network – "smart vest" – has been widely used in modern medical field to monitor the wearer's

[*]* Corresponding author: Suoping Li.+(15002510228)
E-mail address: lsuop@163.com

10.1016/j.procs.2019.06.064

health in real time. The WBSN is usually formed by biosensors implanted into the human body, which has different user groups from WSN. The biosensors are used to collect the physiological parameters of the wearer and transmit the data to a personal digital assistant (PDA), which is used to collect data and transmit it to the control center through interactive nodes. The health providers monitor the patient according to the received information and take actions for urgent patient in real time. Not only does WBSN provide a new solution for universal healthcare, disease monitoring and prevention, it is also an important perception and component of the Internet of things.

Congestion problem in wireless sensor network is unavoidable. In traditional WSN, random early detection (RED) proposed by Floyd et al. [1] is widely adopted as an active and effective algorithm for mitigating network congestion. Congestion is detected by implicitly monitoring the average queue length of buffer, which is able to notify the sender to adjust the rate in time before congestion occurs and drop a small number of packets in case of network congestion. RED algorithm can effectively avoid global synchronization and reduce packet loss rate, but there also exists the problem of fairness and parameter sensitivity.

Unlike WSN, WBSN works on living organisms, and the biosensors worn by the users are used to collect important physiological parameters of the body. Retransmission caused by congestion not only consumes energy but also affects the reliability of monitoring. Thus, network congestion occurring in WBSN is even more deadly and in some serious cases may endanger the patient's life. A congestion control method based on RED is presented [2], which can assign different priorities for vital signals to improve network quality of service (QoS). However, RED algorithm can only monitor congestion in buffer and does not consider the burst traffic of network. A network congestion solution in WBSN based on learning automata (LA) is proposed [3] by intelligently "learning" in the past. The main purpose of is to adapt processing rate of the node to its transmission rate. A LA-based congestion control and service priority protocol is put forward [4], which allocates network bandwidth by marking the congestion of the parent node and the priority of the child nodes. Furthermore, congestion inside the node is not considered.

Dropping part of redundant data can effectively mitigate congestion and improve QoS in WBSN. An intelligent packet dropping mechanism is proposed in this paper to control congestion. The rest of the paper is arranged as follows: section 2 gives a packet drop mechanism in WBSN. A priority classification method is depicted in section 2.1, in section 2.2, there is a learning automata at mote to "learning" from the network environment and in section 2.3, a packer drop mechanism is established based on ERED. In section 3, Packet dropping probability setting for different priority traffic is given to control congestion. The remaining of the content also include conclusion, acknowledgement and reference.

2. Packet drop mechanism in WBSN

The main reason for network congestion is that the available capacity of network cannot satisfy the number of packets send by users. Therefore, dropping some packets appropriately can help mitigate possible congestion. Especially in WBSN, there usually exists a lot of redundant data. Data services for patients with different health conditions have different priorities while priority differences also exist between life signals. For instance, intensive care patients tend to have higher priority. But for a patient with a history of hypertension, the priority of blood pressure monitoring should be higher than other signals such as body temperature.

Unlike the most single hop network established in WBSN, this paper focuses on a multi-hop network from the sink node to the control center. The overall model is presented in Fig. 1. In WBSN, a patient is equipped with i biosensors for monitoring vital signals (heart rate, blood pressure, blood glucose, temperature, etc.). Without loss of generality, we consider the priorities with class i are as follows: $class\,1 > class\,2 > \ldots > class\,i$ and allocate bandwidth with high throughput and low delay for high priority traffic.

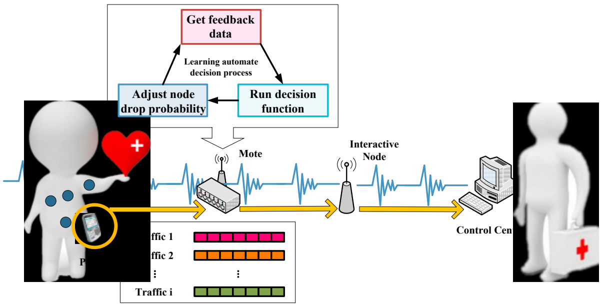

Fig. 1. System model.

The vital signals collected by biosensors are transmitted to a PDA that carried by patient. We regard the PDA as a traffic classifier and set up a differentiated queue for each type of traffic. The traffic with different priorities enter into the mote and a LA is set in mote to feedback the learning results of the network environments to interactive node. It should be noted that there is actually only one physical queue in interactive node. Then an ERED algorithm is used in interactive node. Such model in WBSN can monitor the congestion of the network environment through LA, which can feed the outside environments to interactive node and then drop a small number of packets actively by ERED to control congestion. In this paper, the drop ways of packers used to control network congestion in WBSN is also divided according to different priorities. Next we will describe the system model in parts.

2.1. Priority classification

PDA classifies the vital signals collected by biosensors according to different priorities. As shown in Fig. 2, vital signal with class i are queued based on priority.

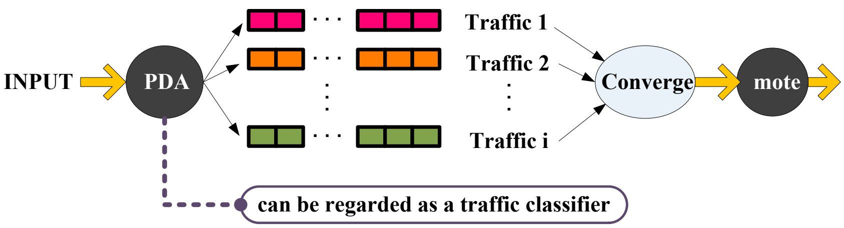

Fig. 2. Priority classification in PDA.

A weighted fair queue is used in PDA to ensure that high priority traffic can be transmitted to control center as soon as possible. We also allocate higher bandwidth to special patients according to some pre-hospital monitoring data, which is helpful for emergency rescue.

2.2. Intelligent "learning" from network environment

"Intelligence" is the main difference between WBSN and other WSNs. This network can either give higher priority to patients who are in need of emergency assistance or intelligently drop a part of routine data. The LA set in mote is also a way to express intelligence in WBSN. LA can "learn" from network environments and choose the best action and reward it with the greatest probability. By fully interbehavior, LA will ultimately choose the appropriate behavior to feedback to the environment. Fig. 3 shows the structure of the learning system based on LA.

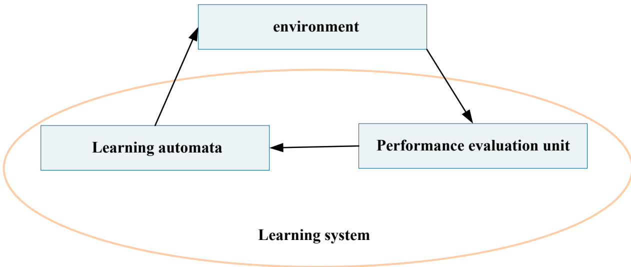

Fig. 3. Learning process at mote.

Against the characteristics of LA, this paper monitor the network environments outside the node by LA in order to compensate for the lag that feedback by the average queue length inside the interactive node. Refer to the learning result of LA at mote [3], the network environments will eventually return to one of the following actions: idle or stable, slightly congested and very congested. Corresponding the network environment with a set of actions E={E-Ⅰ, E-Ⅱ, E-Ⅲ}, then the result of the three actions can be defined as Table 1.

Table 1. Learning result at mote.

Action	Definition	Packet Dropping Probability
E-Ⅰ	There is no need to actively drop packets, keep the network maintain stable is OK.	0
E-Ⅱ	Dropping packets with a lower probability, prevent network congestion to ensure network QoS.	$\max_p/2$
E-Ⅲ	Dropping packets with a higher probability, avoid network lock-up and other problem caused by network congestion.	$\max_p$

Let us suppose the maximum packet dropping probability is $\max_p$, if the result of the return is E-Ⅰ (idle or stable), there will be no actively packet dropped and the packet dropping probability set to 0; if the result is E-Ⅱ (slightly congested), the packet dropping probability will be $\max_p/2$ to ensure network QoS; if the result is E-Ⅲ (very congested), packets will be dropped with $\max_p$ to mitigate congestion. Combine with Table.1, the packet dropping probability is denoted as $h \times \max_p$ (where $h = 0, 1/2, 1$). After that, current packet dropping probability is updated at interactive node based on an exponential packet drop mechanism.

2.3. Exponential packet drop mechanism

RED is one of the widely used congestion control methods, but it cannot monitor the congestion of outside network environment. In the case of increased traffic flows, the linear relationship between average queue length and dropping probability will deteriorate the performance. After "learning" by LA, the mote feedback the results (current external network conditions) to interactive node, we adopt a exponential nonlinear relationship between average queue length and dropping probability to set an ERED congestion control mechanism in interactive node. In this way, the feedback results of LA to the external network environments can be reflected in the packet dropping mechanism of ERED. Similarly, corresponding the average queue length ($AvgQ$) with an action set Q={Q- I, Q- II, Q- III}, Fig. 4 shows the relationship of packet dropping probability ($C(k)$) and $AvgQ$ with RED and ERED.

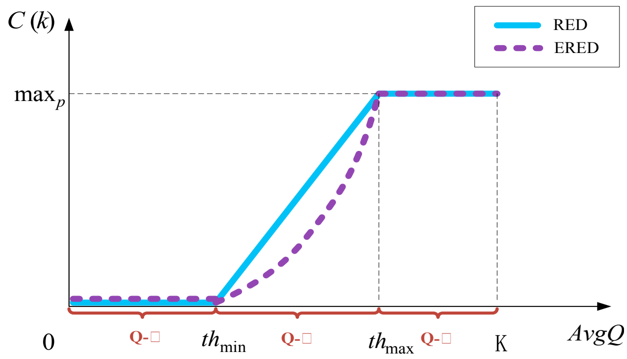

Fig. 4. Packet dropping analysis of ERED.

The packet dropping probability of ERED[5] is obtained:

$$C_{ERED}(k)=\begin{cases}0 & \text{Q-I}\\ \dfrac{1-2a^{(k-th_{\min})}+a^{2(k-th_{\min})}}{1-2a^{(th_{\max}-th_{\min})}+a^{2(th_{\max}-th_{\min})}}\times h\times \max_p, & \text{Q-II}\\ h\times \max_p & \text{Q-III}\end{cases}$$

where a is the bottom number of exponential function and $a>1$; k is the current queue length in buffer and K is the buffer capacity.

Based on the adjustment of the packet dropping probability by the exponential nonlinear method, combining with different network environment fed back in LA, the drop ways of the network can be reflected in Table 2.

Table 2. Packet drop under different network environments and average queue length.

$C_{ERED}(k)$	E- I	E- II	E-III
Q- I	0	0	0
Q- II	0	$\frac{1-2a^{(k-th_{\min})}+a^{2(k-th_{\min})}}{1-2a^{(th_{\max}-th_{\min})}+a^{2(th_{\max}-th_{\min})}}\times\frac{\max_p}{2}$	$\frac{1-2a^{(k-th_{\min})}+a^{2(k-th_{\min})}}{1-2a^{(th_{\max}-th_{\min})}+a^{2(th_{\max}-th_{\min})}}\times\max_p$
Q-III	0	$\max_p/2$	$\max_p$

According to the definition of packet dropping probability, we recommend an empirical value of 0.2. But such a division is not entirely in line with the actual network environments. For state (Q- I , E-III), although there is less data in the buffer, the external network environment has been very congested. It indicates that a large number of burst traffic coming outside the buffer, and it is unwise of no packet drop. Therefore, the packet drop results obtained in Table 2 based only on the queue of buffer and the external network environment are obviously not comprehensive. In next part, we subdivide the way of packet drop in Table 2 based on traffic priorities in WBSN.

3. Packet dropping probability setting for different priority traffic

The vital signals in WBSN often have different priorities according to the type of monitored patient. We classify the traffic with i priorities transmitted in the WBSN into high and low priority. For the traffic class n ($n\in[1,i]$ and $n\in Z$), if $n\in[1,\lfloor i/2\rfloor]$, then the traffic has high priority; if not, it has low priority, where

$\lfloor i/2 \rfloor = \max\{n \in Z | n \le i/2\}$. The corresponding packet dropping probability is denoted as $_{(Q-s,E-t)}C_{ERED}$, where $s,t=\{I,II,III\}$. We implement the following three adjustment methods for Table 2:

1) For states (Q-Ⅰ, E-Ⅰ) and (Q-Ⅱ, E-Ⅰ), there is no sign of congestion in the current external network, the packet dropping probability does not need to be adjusted.

2) For state (Q-Ⅰ, E-Ⅱ) and (Q-Ⅰ, E-Ⅲ), although there are few packets in the node, the external network has been congested, which indicates that burst traffic will enter into the node buffer soon. In order to provide greater network bandwidth for burst services, some of low priority packets should be dropped in advance. For state (Q-Ⅲ, E-Ⅰ), although there is no sign of congestion in the external network, the node's buffer is heavily congested. Some packets drop is necessary to improve network QoS and avoid the bandwidth shortage caused by burst traffic.

For the above three states, we use piecewise method to fine-tuning the corresponding packet dropping probability. Packet dropping probability of high priority vital signals is not changed in order to ensure the throughput. But for low priority traffic, we use the exponential nonlinear packet dropping probability in state (Q-Ⅱ, E-Ⅱ) to adjust the mentioned dropping probability to $_{(Q-II,E-II)}C_{ERED}$.

3) For state (Q-Ⅱ, E-Ⅱ) (Q-Ⅱ, E-Ⅲ) (Q-Ⅲ, E-Ⅱ) and (Q-Ⅲ, E-Ⅲ), both the buffer and the outside network have shown partly congestion. In order to control congestion and distinguish the different priority traffic in WBSN at the same time ensure the transmission of high priority traffic, we fine-tune the packet dropping probability in a non-linear way. Defined l as the index of congestion, let $l \in (0,1/i)$, the adjusted packet dropping probability is $_{(Q-s,E-t)}\widetilde{C}_{ERED} = {}_{(Q-s,E-t)}C_{ERED} + \lfloor i/2 \rfloor \times l, where\ s,t = II, III..$

According to the characteristics of different vital signals in WBSN, the packet dropping probability has been fine-tuned in Table 3 to control network congestion and guarantee the network QoS.

Table 3. Packet dropping probability of different priority traffic in WBSN.

Packet dropping probability	$n \in [1, \lfloor i/2 \rfloor]$ and $n \in Z$	$n \in [\lfloor i/2 \rfloor, i]$ and $n \in Z$
$_{(Q-I,E-I)}C_{ERED}$	0	0
$_{(Q-I,E-II)}C_{ERED}$	0	$\frac{1-2a^{(k-th_{\min})}+a^{2(k-th_{\min})}}{1-2a^{(th_{\max}-th_{\min})}+a^{2(th_{\max}-th_{\min})}} \times \frac{\max_p}{2}$
$_{(Q-I,E-III)}C_{ERED}$	0	$\frac{1-2a^{(k-th_{\min})}+a^{2(k-th_{\min})}}{1-2a^{(th_{\max}-th_{\min})}+a^{2(th_{\max}-th_{\min})}} \times \frac{\max_p}{2}$
$_{(Q-II,E-I)}C_{ERED}$	0	0
$_{(Q-II,E-II)}C_{ERED}$	$\frac{1-2a^{(k-th^i_{\min})}+a^{2(k-th^i_{\min})}}{1-2a^{(th^i_{\max}-th^i_{\min})}+a^{2(th^i_{\max}-th^i_{\min})}} \times \frac{\max_p}{2}$	$\frac{1-2a^{(k-th_{\min})}+a^{2(k-th_{\min})}}{1-2a^{(th_{\max}-th_{\min})}+a^{2(th_{\max}-th_{\min})}} \times \frac{\max_p}{2} + \lfloor 2/i \rfloor \times l$
$_{(Q-II,E-III)}C_{ERED}$	$\frac{1-2a^{(k-th^i_{\min})}+a^{2(k-th^i_{\min})}}{1-2a^{(th^i_{\max}-th^i_{\min})}+a^{2(th^i_{\max}-th^i_{\min})}} \times \max_p$	$\frac{1-2a^{(k-th_{\min})}+a^{2(k-th_{\min})}}{1-2a^{(th_{\max}-th_{\min})}+a^{2(th_{\max}-th_{\min})}} \times \max_p + \lfloor 2/i \rfloor \times l$
$_{(Q-III,E-I)}C_{ERED}$	0	$\frac{1-2a^{(k-th_{\min})}+a^{2(k-th_{\min})}}{1-2a^{(th_{\max}-th_{\min})}+a^{2(th_{\max}-th_{\min})}} \times \frac{\max_p}{2}$
$_{(Q-III,E-II)}C_{ERED}$	$\max_p/2$	$\max_p/2 + \lfloor 2/i \rfloor \times l$
$_{(Q-III,E-III)}C_{ERED}$	$\max_p$	$\max_p + \lfloor 2/i \rfloor \times l$

Obtained the results of Table 3, we can drop the packets in the buffer actively to mitigate network congestion according to the three indicators: external network environment, current average queue length at interactive node and traffic priority. At the same time, the proposed drop mechanism can also ensure the transmission of burst traffic and different priority services, which can provide better assistance for urgent patients in WBSN.

Conclusion

An intelligent packet drop mechanism based on different priority traffic is established to alleviate the congestion in WBSN. In this model, biosensors worn by patient are used to collect vital signals and a PDA carried by the patient can classify the collected data based on priority. In order to intelligent "learning" the network environment outside the node, a learning automata is used in mote. Meanwhile, the average queue length is monitored as an implicit congestion index and an ERED algorithm is used in interactive node to control congestion. In consideration of the characteristic of WBSN, we also drop packets based on the priority. In this way, the congestion in WBSN could be controlled by dropping packets based on different network environment, average queue length and priority. The proposed mechanism can not only control congestion in WBSN, but also provide a plan for disease surveillance and prevention.

Acknowledgement

This work is supported by the National Natural Science Foundation of China (Grant No. 61663024), the "Chunhui" Scientific Research Programme of Ministry of Education of China (Grant No. Z2016001), the Hongliu First Class Discipline Development Project of Lanzhou University of Technology, and the Erasmus+ Programme of European Commission (Grant No. 573879).

References

1. Floyd S, Jacobson V. Random early detection gateways for congestion avoidance. IEEE/ACM Transaction on Networking1993;1(4): 397-413.
2.Yaghmaee MH, Adjeroh D. A novel congestion control protocol for vital signs monitoring in wireless biomedical sensor network. Wireless Communications & Networking Conference 2010; 29 (16):1-6.
3.Misra S, Tiwari V, Obaidat MS. Lacas: learning automata-based congestion avoidance scheme for healthcare wireless sensor networks. IEEE Journal on Selected Areas in Communications 2009; 27 (4):466-479.
4.Yaghmaee MH, Bahalgardi NF, Adjeroh D. A prioritization based congestion control protocol for healthcare monitoring application in wireless sensor networks. Wireless Personal Communications 2013; 72(4):2605-2631.
5.Xuefen C, Yingying Z. Network analytical model of tandem queuing RED and ERED. Journal on Communications 2011; 32(9):174-181.