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A Traffic Redirection Based Congestion Control Scheme in Body Area Networks

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Abstract: Growing data traffic generated by several sources in a Body Area Network (BAN) leads to congestion. One of the major challenges in BANs is congestion alleviation. Congestion causes packet drops which leads to lower network performance and higher delay due to packet retransmission. In this study, a novel traffic redirection based congestion control scheme is proposed in BANs. In the proposed scheme, when a sensor node is congested, its neighboring nodes select new next hop node. New next hop node selection is based on the queue size and hop counts to the sink of the neighboring nodes. Simulation results show that our protocol provides significant improvement in packet delivery ratio and end-to-end delay compared with the existing protocol.

Keywords: BAN, congestion control, routing, traffic redirection

INTRODUCTION

Significant advances in sensor networks have provided many studies around the human body such as Body Area Network (BAN) or Body Sensor Network (BSN). A BAN enables physiological and vital sign monitoring of the patients whereby physicians can receive required healthcare information. Information from the patients is received by some sensors such as Electrocardiograms (ECGs), Electro-Encephalograms (EEGs), Electromyograms (EMGs) and body temperature and oxygen saturation (Fig. 1). Some sensors such as ECG (Baig *et al*., 2013) or EEG are used for real time monitoring. A BAN includes three tier: intra-BAN, inter-BAN and beyond-BAN (Chen *et al*., 2011). Intra-BAN communication handles sensors on or in the human body. In inter-BAN communication, gathered information is forwarded to the access points or the gateways. Communications between the gateway and the physicians are related to the beyond-BAN tier.

In applications such as cancer, remote surgery, emergency applications and fall detection which require vital sign information and remote monitoring, sending reliable information with low latency is an issue (Latré *et al*., 2011; Patel and Wang, 2010). In some applications, information must be sent to the physicians with low packet loss and low delay. Due to the large number of the packets in some sensors, congestion in BSNs is inevitable. When a sensor node is congested, packets are dropped because of the limited size of the buffer in the intermediate nodes. Packet drop causes retransmission which leads to the packet delay. Consider a disastrous situation or an emergency case in which the packets which are related to a dying patient are dropped because of congestion causing the death of the patient. Hence, congestion is one of the major challenges which need to be taken into account in BSNs (Darwish and Hassanien, 2011).

Congestion control protocols include three phases: congestion detection, congestion notification and congestion alleviation using rate adjustment (Dashkova and Gurtov, 2012; Pang *et al*., 2008; Rathod and Buddhadev, 2011). There are several researches on congestion control in WSNs, but they cannot be directly used in BSNs because of the body characteristics that mentioned before. Most of the congestion control mechanisms in BSNs have been employed for outdoor communications (Farzaneh and Yaghmaee, 2011; Rezaee *et al*., 2013; Yaghmaee *et al*., 2013).

In this study we propose a Traffic Redirection based Congestion Control scheme for intra-BAN networks (TRCC-BAN). The congestion detection mechanism of the scheme is based on queue size of the nodes and congestion notification is implicit. The proposed protocol mitigates congestion using traffic redirection mechanism based on the length of the queue and hop counts of the neighboring nodes. Each node monitors its queue. If the queue occupancy of next node is greater than a threshold, the next hop node to the sink is changed and new next hop node is selected. We evaluated our protocol in terms of packet delivery ratio and end-to-end delay and energy consumption for a variety of traffic sources.

LITERATURE REVIEW

Different congestion control protocols have been proposed for the sensor networks in the recent years. For example, CODA (Wan *et al*., 2003) (Congestion Detection and Avoidance), PCCP (Wang *et al*., 2006) (Priority based Congestion Control Protocol), RCRT

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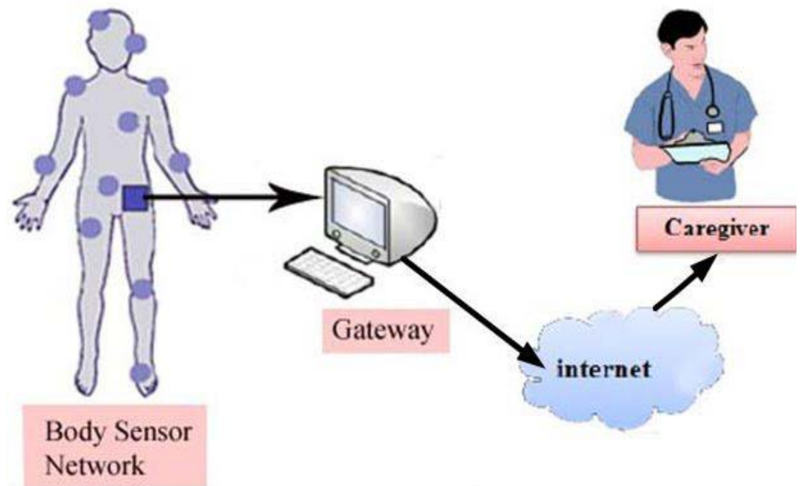

Fig. 1: An example of body area network

(Paek and Govindan, 2007) (Rate-Controlled Reliable Transport) and ECODA (Tao and Yu, 2010) (Enhanced Congestion Detection and Avoidance). CODA employs three mechanisms for alleviating congestion. It includes congestion detection, open-loop hop-by-hop backpressure and closed-loop multi-source regulation. Congestion is detected by queue occupancy of the intermediate nodes. PCCP uses a hop-by-hop priority-based rate adjustment mechanism to adjust the scheduling and the source rates of the nodes in WSN. RCRT is another protocol that was designed to control the traffic and rate in the sink node. The sink node handles congestion detection, rate adjustment and rate allocation. ECODA uses dual buffer thresholds and weighted buffer difference for detecting congestion.

In Monowar *et al*. (2008), an efficient multipath scheme for heterogeneous traffic in WSN was proposed. This scheme uses packet service ratio for detecting congestion. A multistage rate control mechanism in WSNs was proposed in Liang *et al*. (2012). The mechanism uses current queue length for congestion detection in each node and multi-stage rate adjustment for congestion control. In Lin *et al*. (2011), a queue management based mechanism for congestion avoidance based on IEEE 802.15.4 was proposed in WSN. HOCA (Rezaee *et al*., 2013) (Healthcare aware Optimized Congestion Avoidance), a data centric congestion management protocol, avoids congestion using queue management. HOCA has two phases. In the first phase, the demands of the sink are broadcasted and in the second phase, congestion is controlled. Baek *et al*. (2009) proposed an adaptive rate control for wireless body sensor networks. In this scheme, congestion is controlled by a prediction mechanism using a rate function. Yaghmaee *et al*. (2013) proposed a congestion control protocol for vital signs monitoring in biomedical sensor networks. The proposed protocol classifies different vital signals related to their priorities and provides better quality of service. LACAS (Misra *et al*., 2009), a learning automata-based congestion control scheme was proposed for healthcare wireless sensor network. LACAS controls congestion by the last information of congestion in each sensor. LACCP (Farzaneh and Yaghmaee, 2011) uses learning automata and adjusts arrival rate in the intermediate nodes. LACCP provides quality of service using weighted scheduling mechanism. Gunasundari *et al*. (2010), a congestion avoidance scheme was proposed for mobile healthcare. In this scheme, mobility of the nodes is considered by implementing LACAS in the nodes.

In Samiullah *et al*. (2012), the authors proposed a queue management based mechanism to control congestion in BSNs. The proposed energy efficient protocol provides reliability and reduces packet drops. The protocol includes congestion detection and congestion control mechanisms. In congestion detection mechanism, if queue occupancy in an intermediate node is more than a threshold, a Backpressure message (BP) is recursively passed toward the source node.

MATERIALS AND METHODS

In this section, we describe the network model and related algorithm. The proposed scheme has been designed for congestion control in intra-BAN communications.

A body sensor network based on multi-hop strategy is provided (Natarajan *et al*., 2009). Four types of nodes are used in intra-BAN communications: source node, intermediate node, source and intermediate node and sink node. Source nodes generate packets and send them through the network. Intermediate nodes acts as relay which buffer packets and forward them. In a source and intermediate node not only packets are generated but also packets which received from other nodes are relayed and forwarded to the next hop node.

Sink node is the destination node which gathers information from all sensor nodes and sends to the gateway.

This model detects congestion using current queue size. Queue size shows the level of congestion in each node. If queue occupancy of a node is greater than the threshold (α), congestion is detected. When congestion in a node is happened, a notification packet sends back to the predecessor nodes. This notification is a field in the control packet. An extra field called queue occupancy is piggybacked on the control packet header. The control packet is periodically sent to the neighbors. When a control packet is received in a node, the queue occupancy field is extracted and is saved into the neighbor's information. When a node receives the congestion message, it acts due to the queue size information. If queue size is greater than the threshold, the current node selects another next hop node with minimum queue size. If queue size of the neighbors is equal, next hop node is a node with minimum hop count to the sink node.

In the proposed model, at first, every node broadcasts a hello message to its neighbors. When all nodes receive their neighbors' information, each node chooses its next hop node based on the shortest hop algorithm. If next hop node of a node is congested, the predecessor node selects another next hop based on the queue size of its neighbors. A node with minimum queue size is selected as the next hop. In the case that the queue size of all neighbors is same, a node with the shortest hop to the sink is selected. This mechanism leads to congestion control and traffic balance throughout the network.

In our congestion detection and control algorithm (algorithm 1), three parts exist. In the first part, when a new packet is received in each node, the packet is pushed into the queue or its information is extracted related to the type of the packet. If the packet is a data packet, it is pushed into the queue. In the second part, in the predefined periods of time a control packet is generated. Some information of the node plus its queue size is put in the control packet and it is broadcasted to its neighbor. In the third part, queue size of the next hop is greater than the threshold (α), next hop selection algorithm is invoked and another node is selected as the next hop node. This algorithm is invoked from the nodes which their next hop node is node i.

Algorithm 1: Congestion detection and control algorithm

Input: Neighbor list of node I (N_i), packet (p), Queue Size of node i (QS_i), queue threshold (α)

1: On receiving a packet P from node j to node i:
2: if P is a data packet then
3: enqueue P
4: else if P is a control packet then
5: update information of neighbor j in N_i
6: end if
7: Sending control packet P from node i:
8: while (True) do
9: if (Time_period == now) then
10: generate new packet P
11: Put new information and current queue size of node i in P
12: Broadcast P to the nodes listed in N_i
13: end if
14: end while
15: Congestion control:
16: if ($QS_i \geq \alpha$) then
17: Call next hop selection algorithm for each node j that its next hop is node i

Algorithm 2 shows next hop selection mechanism that works as follows. The neighbor list of node i is sorted by ascending order of number of hop to the sink and ascending order of queue size. In the loop, queue size of neighbor nodes is checked. The node with minimum queue size is selected as the next hop node. This node also has shortest hop to the sink because the list N_i is sorted by ascending order of number of hop to the sink.

Algorithm 2: Next hop selection algorithm

Input: Neighbors list of node i (N_i), Queue Size of node j (QS_j), queue threshold (α)

Output: Next hop of node i ($NextHop_i$)

1: Sort N_i (Ascending order of num-hop-to-sink)
2: for those nodes which their num-hop-to-sink are equal do
3: Sort in ascending order of QS
4: m = first element of N_i
5: while (Not end of list N_i) do
6: if ($QS_m \geq \alpha$) then
7: m = next element of N_i
8: else
9: $NextHop_i$ = m
10: break
11: end if
12: end while

RESULTS AND DISCUSSION

The performance of the proposed TRCC-BAN scheme is evaluated and compared with the queue management based protocol (Samiullah *et al.*, 2012) using ns-2 simulator (Institute, 2003).

Setting and configuration: For simulation, 16 sensor nodes are deployed in 2×2 m^2 body area with the sink node on the waist of the patient as shown in Fig. 2. Network topology is mesh and hop by hop and routing protocol is the shortest hop to the sink node.

The simulation parameters are shown in Table 1. The maximum communication channel bit rate is 250

Table 1: Simulation parameters

Parameters	Value
Traffic type	CBR
Mobility	None
Queue length	150 packets
Initial node energy	2 joules
Packet size	60 bytes
Radio propagation model	Free space
MAC protocol	IEEE 802.15.4
Transmission range	70 cm
Queue threshold (α)	0.5
Simulation time	200 sec

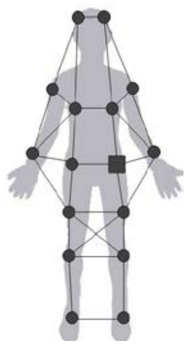

Fig. 2: Network model with 15 sensor nodes and one sink

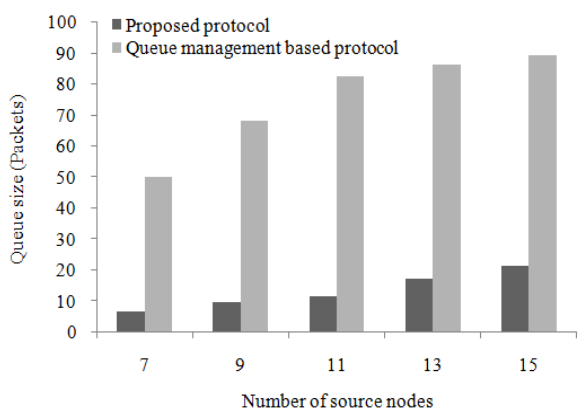

Fig. 3: Average queue size of the nodes

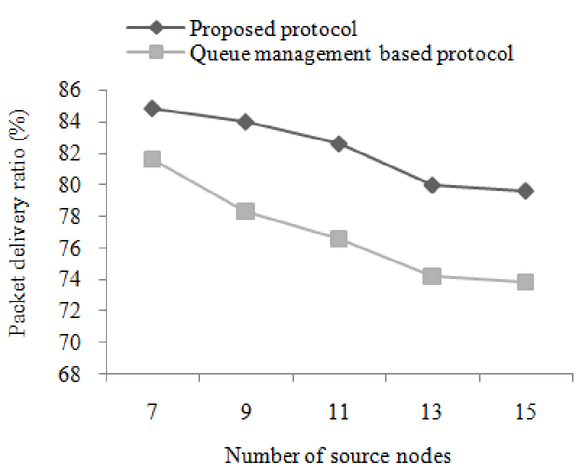

Fig. 4: Packet delivery ratio

kbps. Frequency band is 2.4 GHZ. For each plot, all results are averaged over 40 runs.

Performance metrics: In order to evaluate the performance of the proposed TRCC-BAN protocol, following factors were used in the simulation.

Packet delivery ratio: This metric is the ratio of the number of delivered data packets to the sink over the total number of data packets sent by all sources. We consider it in percentage. High percentage of the packet delivery ratio increases network reliability.

End-to-end delay: The total latency is experienced by a packet from the source node to the sink. Because some applications such as emergency applications, remote surgery and disaster applications are time-critical, delay is a parameter which is crucially important in BSNs. At the network model, the end-to-end delay is the sum of the queuing delay, the processing delay and the transmission delay and the propagation delay. The queuing delay has significant contribute on the delay.

Energy consumption: This metric is the average energy consumption of all nodes during the simulation, which is measured in Jules.

Simulation results: Average queue size of the nodes versus the number of source nodes is shown in Fig. 3. Queue size of the nodes shows the level of congestion. As can be seen in the graph, the proposed protocol has the lower average queue size compared to the queue management based protocol. In the proposed protocol when the queue size of a node becomes greater than the threshold, another path is selected for the predecessor nodes. The new next hop node likely has better condition than the congested node because the new next hop node is selected based on the queue size of the neighbors. Our protocol balances the traffic load on the network and leads to balanced queue size.

Figure 4 shows the packet delivery ratio due to the different number of source nodes. As can be seen from the graph, the proposed protocol is more successful in packet delivery compared to the queue management based protocol. This is because when congestion message is received in a node in the proposed protocol, the path to the sink node is changed. New path has better congestion situation than the old path because queue size of the new next hop node is minimum and packet drop is also lower. The lower the queue size, the lower the packet drops throughout the network. Lower packets drops lead to higher packet delivery ratio. In the queue management based protocol backpressure message is fed back to the predecessor nodes and their sending rates are adjusted.

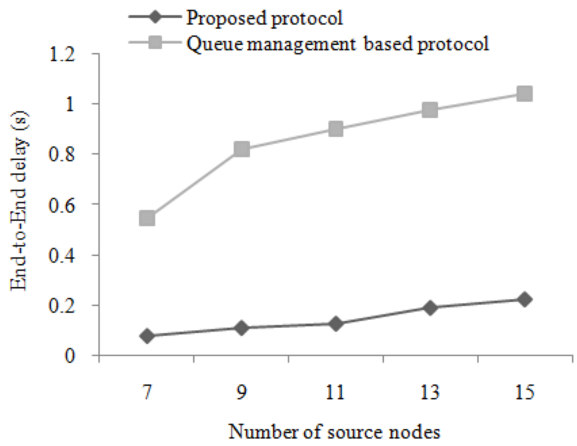

Fig. 5: Average end-to end delay

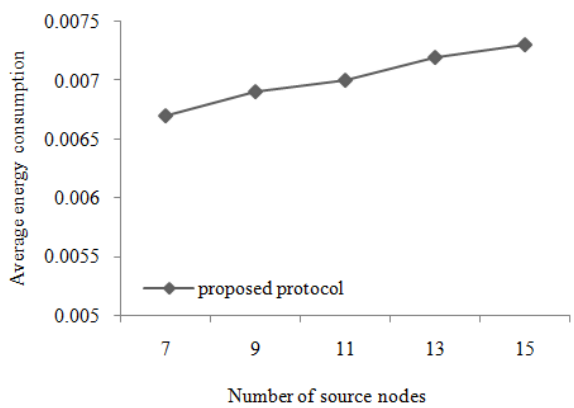

Fig. 6: Average energy consumption

Figure 5 shows the end-to-end delay versus the number of the source nodes. From the graph it is observed that the average end-to-end delay of the nodes in the proposed protocol is significantly lower compared to the queue management based protocol. In the proposed protocol number of packet retransmissions is lower than another one as mentioned before. Therefore, delay of the packets in the network is decreased. Also rerouting and changing the path causes the lower queue size. Hence, average packet queuing delay is decreased.

Figure 6 shows the average energy consumption of the nodes varying number of source nodes. With the increasing number of source nodes, energy consumption of the nodes also is increased. Average energy consumption in this simulation is about 0.007 J.

CONCLUSION

In this study, a traffic redirection congestion control protocol in intra-BAN communication has been presented. This protocol can be used in applications which need high delivery ratio and low delay such as medical emergencies, remote surgeries and medical disaster applications. The proposed mechanism can detect and control congestion in the sensors of the human body. The congestion is implicitly detected when the queue occupancy of the next hop node is greater than a threshold. The traffic path to the sink is changed when the next hop of a node is congested. New next hop node is selected based on the minimum queue size and hop counts of the neighboring nodes. We have evaluated the performance of TRCC-BAN scheme with different network scenarios using NS-2. The simulation results show that our mechanism can improve remarkably packet delivery ratio and end-to-end delay comparing with the existing mechanism.

In this research, we suppose that the network model is static and the sensors do not have any movement. For the future work, we decide to take into account movement of the human body and control congestion related to it. Moreover, the congestion control mechanism should provide QoS using packet prioritization.

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