International Journal of Integrated Engineering:
Special Issue 2018: Data Information Engineering, Vol. 10 No. 6 (2018) p. 59-65.
© Penerbit UTHM DOI: https://doi.org/10.30880/ijie.2018.10.06.008

CAMP: Congestion Avoidance and Mitigation Protocol for Wireless Body Area Networks

Muhammad Anwar[1*], Abdul Hanan Abdullah[1], Rd. Rohmat Saedudin[2], Farhan Masud[1,3], Fasee Ullah[4]

[1]School of Computing, Faculty of Engineering,
Universiti Teknologi Malaysia, Johor Bahru 81310, Malaysia.
[2]School of Industrial Engineering, Telkom University,
40257 Bandung, West Java, Indonesia.
[3]Faculty of Life Sciences Business Management,
University of Veterinary and Animal Sciences, Shaykh Abdul Qadir Jilani Road, Lahore, Pakistan.
[4]Department of Computer Science and Information Technology,
Sarhad University of Science and Information Technology, Peshawar, Pakistan.

Received 28 June 2018; accepted 5August 2018, available online 24 August 2018

Abstract: Advances in wireless communication technologies invented body sensor networks (BSNs) for health care systems. BSN monitors patients' health remotely and automatically. It is economical and helpful solution for both patients and healthcare providers. BSN is made up of small Bio-medical sensors (BMSs) and Body Coordinator (BC). BMSs sense and transmit data continuously. As BSN consist of many BMSs, the simultaneous data transmission results in congestion in the network. Congestion causes packet drops which attempt to be retransmitted again and again. Therefore, the BMSs drain their energy fast and consequently reduce the network lifetime. In this work, a congestion avoidance and mitigation protocol (CAMP) is proposed for BSNs. The experimental results shows that the proposed protocol carried out better results in terms of energy efficiency and network lifetime in BSNs.

1. Introduction

Word population of old age people is growing very fast. This is a leading threat to current health care systems which trends to lesser the health facilities in proportional to the population. As reported by US Bureau of Census, the number of aged population is expected to be twice in 2025 from 380 (in 1990) [1]. The aged people mostly fall to different chronic health issues which require steady healthcare. These people needs to stick with hospitals, if not, they may experience the life risk [2]. Researchers affirm that most diseases can be overcome if they could caught earlier [3]. So, there an intense requirement of an intelligent health system which serve the purpose of timely diagnosis of the diseases'.

To cope with these issues, scientists and technologists introduced Body Sensor Networks (BSNs) for health care systems [4]. BSN system can be deployed within a hospital or at the patient's home. These networks are made up of minimized bio-medical sensors (BMS) and capable of gathering information such as blood pressure, temperate, ECG from the human body and sending the information to the medical server[5]. Fig. 1 illustrate the types of BMS which can be used in BSN. Typically, medical server is placed at the healthcare facility which stores and analyze the information received form these BMS'. The server then generates alerts to the concerned health care experts and immediate caretakers if the found any abnormality. The system architecture of BSN is illustrated in Fig. 2. The BSN directly related to human body is known as intra-WBAN in which BMS are implanted under the human skin or wearable over the human skin or on clothes. These BMS' are controlled by Body Coordinator (BC) which collects and forward data to the outside BSN. BC has high computational, storage and power resources as compared to BMSs[6].

---

*Corresponding author: anwer.mirza@gmail.com

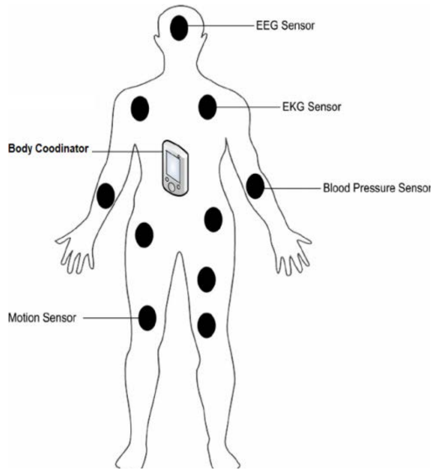

Fig. 1: Types of BMS' for BSN

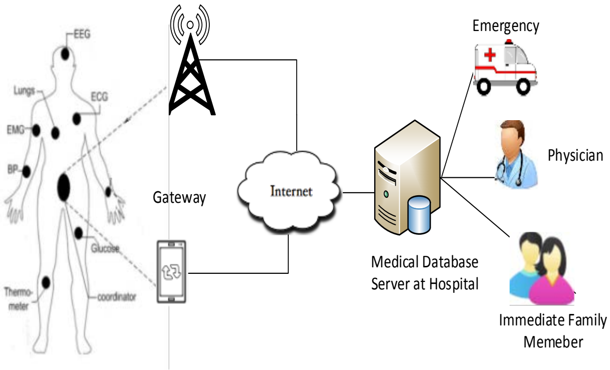

Fig. 2: System Architecture of BSN

The BMSs used in BSNs are small in size and having limited resources such as memory, computational power and battery capacity as compared to the traditional sensors[7].The replacement or recharging the battery is not suitable for BSN especially in case of implanted BMS'. Reliability is the main requirement in healthcare applications. To enhance the reliability and lifetime of BSN, we have to consider various QoS aspects. Mostly, battery power is consumed in network communications. The optimization of the communication processes can improve the overall network lifetime of BSN [8].

To achieve efficiency in BSN communication, there are many design challenges like congestion, coexistence, interoperability, coverage area, body temperature, mobility, scalability, and data security [9].The congestion is one of the most challenging issue in BSNs. Congestion occurs when too much data is trying to pass through a BMS or link [10]. Fig. 3 shows the traffic flow and probability of congestion in BSNs. The congested BMS consumes too much energy and reduce the network life time of BSN. Congestion over utilizes the network resources. It also causes high number of packet drops which attempt to be retransmitted [10]. Therefore, congestion is one of the major problem in BSNs which causes high impact on the network resources. The problem can be controlled either by enhancing the capacity of BMS' or adjusting the transmission rate.

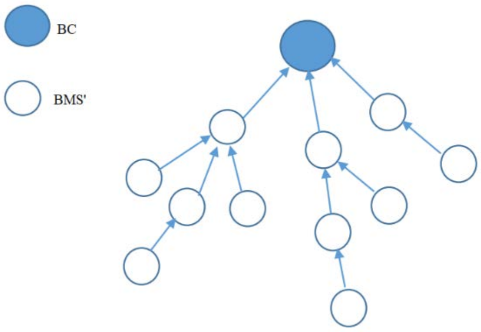

Fig. 3:Traffic flow and congestion probability

This work is primarily focused to avoid the congestion to occur. However, if occurs, it should be mitigated. Congestion avoidance algorithms comprise two mechanisms: congestion detection and congestion avoidance mechanisms. The congestion detection mechanism predicts and detects congestion in the network. The congestion avoidance mechanism avoids congestion using the preventive methods [11]. Congestion detection mechanisms can be based on channel load or buffer occupancy. Channel load of a node can be used to detect congestion in the MAC layer. Controlling the channel load tackles the packet collisions but cannot affect the buffer occupancy. The algorithms which use buffer occupancy for congestion detection consider the efficient MAC algorithms to avoid collisions. Buffer occupancy of a node can show the degree of congestion on that node. If queue occupancy of a node is higher than a threshold, a congestion avoidance algorithm should be run to prevent congestion.

The congestion control algorithms consist of three mechanisms: congestion detection, congestion notification, and congestion mitigation which are further described as follows: 1) Congestion is detected in BSNs using channel load, ratio between packet interval time and packet service time, and buffer occupancy. 2) After congestion occurs, a mechanism needs to notify other nodes about the congestion event. 3) Congestion control mechanism attempts to mitigate congestion in the network. Congestion can be mitigated by either traffic resource control or by traffic control approaches[12].

Many researchers proposed congestion control schemes in BSNs. They presented different criteria for congestion detection and mitigations. In this work, a congestion control routing protocol is proposed for congestion detection, avoidance and mitigation based on Traffic Redirection and Rate Control. The experimental results show that the proposed scheme carries out better results in terms of energy efficiency and network lifetime of BSNs.

The rest of the paper is structured as follows. Section-II review the existing related work. Section-III explain the proposed congestion control protocol for BSNs. Section-IV presents the results and comparison of proposed protocol with benchmark protocol and Section-V conclude the paper.

2. Related Work

Several congestion control algorithms have been applied to BANs. Baek et al. in [13] proposed an adaptive rate control scheme named ARCS for congestion avoidance in WBAN. In order to avoid congestion in the network. This scheme uses the functionalities of both routing and MAC. ARCS scheme dynamically adjust transmission rate of each node, based on a prediction mechanism. This rate function consists of a congestion risk degree. The scheme do not have any congestion detection and notification mechanisms, which leads to lower amount of power consumption. This scheme is designed to avoid congestion in the network. However, if congestion occurs, this scheme do not have mechanism to mitigate the congestion.

Moghaddam et al., in [14] designed a congestion control protocol named NCCP for vital signs monitoring in biomedical sensor networks. This protocol categorizes vital signs of the human body and assign them bandwidth according to their priorities, based on weighted scheduling mechanism. Higher bandwidth is assigned to the patients who have high priority physiological signals. This protocol used queue occupancy of the nodes to detect congestion in the network. If congestion occurred, it is implicitly notified. However, this algorithm does not consider queue occupancy of the next hop nodes which h results in buffer overflow and higher number of retransmitted packets.

A packet size optimization algorithm (PSOS) for congestion control in pervasive healthcare monitoring was proposed by Yaakob et al., in [15]. This algorithm chooses the ideal size for the packets in several error conditions to overcome congestion, caused to lower packet retransmission and overhead. However, this algorithm does not consider energy consumption of the nodes. Moreover, this algorithm only provides congestion mitigation mechanism and does not have mechanism for congestion avoidance. For this reason, this algorithm ignores the maintaining of queue occupancy level which results in buffer overflow.

Misra et al. in [16] proposed congestion avoidance scheme named LACAS for healthcare WSNs. LACAS is based on learning automata. Each intermediate node adjusts the incoming rate using a learning machine, which controls congestion locally in each node. For input of the learning machine, the number of packets drop are considered. Congestion detection in this algorithm is based on packet inter-arrival rate and packet service time. Later, Gunasundari et al. in [17] proposed an extended version of LACAS scheme named MLACAS. MLACAS is based on LACAS scheme with considering mobility of the nodes. Congestion is controlled in this scheme by the sending rate adjustment of the parent nodes. Congestion detection in this algorithm is based on packet inter-arrival rate and packet service time. Theseschemeshave high overhead due to the large number of control packets for learning machine. Moreover, these schemes only deals with congestion avoidance but there is no mechanism for congestion mitigation.

Bahalgardi at al in [18] proposed congestion alleviating protocol named Learning based Congestion Control Protocol (LCCP)for WBANs. This algorithm is based on learning automata approach, LCCP mitigates congestion using active queue management. According to data type, each packet is assigned priority i-e either high or low. Normal data packets are assigned low priority and critical data packets are assigned high priority, which have different queues in the nodes. Learning automata approach is used to adjust packet arrival rate in each node. Congestion detection in this protocol is based on the queue occupancy and packet loss rate. However, LCCP has high overhead due to the high number of control packets for learning automata.

Yaghmaee et al. in [19] introduced a Prioritization-based Congestion Mitigation Protocol (PCMP) for BSNs. This protocol categorized the patients' vital signs into two groups: critical and normal based on their priority. PCMP calculates the ratio of the packet arrival rate to the packet burst time, and the traffic priority, the congestion index of each node based on the queue occupancy. The transmission rate of each node is adjusted according to the calculated index. Congestion notification is implicitly sent to the parent nodes. This algorithm provides QoS requirements for each patient, using patient prioritization. However, it does not take into consideration the priority of the sensors on each patient's body.

Rezaee et al. [20]presented Healthcare Aware Optimized Congestion Avoidance and control algorithm (HOCA) in[20]. This algorithm works for both congestion avoidance and mitigation in BSNs. In the first step HOCA avoids congestion and if congestion still occurs, it is mitigated. In this algorithm congestion is avoided based on multipath routing. The traffic is categorized into sensitive traffic and non-sensitive traffic. Sensitive traffic is associated to the high priority data while non-sensitive traffic is associated to the normal data. In order to control the congestion in the network, this algorithm adjusts the packet sending rate of the nodes. In this algorithm congestion avoidance and mitigation is treated based on the data priority. However, this algorithm does not consider the priority of each sensor node located on the body for intra-BSN communications. Moreover, in this algorithm, exchange of the control packets the nodes rises the network overhead, which results in additional energy consumption.

The existing congestion control algorithms in BSNs do not have congestion avoidance and mitigation mechanisms along with routing decisions. Therefore our work is focused on congestion avoidance and mitigation. Our scheme make routing decisions based on congestion and number of hop counts to the BC. In this way, the BMS having congestion is not selected for next hop. This strategy helps to make the BSN more efficient in terms of network lifetime.

3. The Proposed CAMP Protocol

In medical applications which require vital signs and physiological signals monitoring, the sensor nodes need to transmit information simultaneously, which leads to high data traffic in the nodes. Growing data traffic in the nodes increases the likelihood of congestion in the BANs. Congestion postpones packets transmission, which leads to undesirable situations for the patients because delay-sensitive packets cannot be delivered to the sink node within a predefined delay deadline. Furthermore, congestion causes packet loss which increases energy consumption of the nodes due to the more packet retransmissions. In these applications, congestion needs to be avoided as much as possible. If congestion occurs, congestion should be mitigated. The proposed protocol is primarily designed to avoid the congestion to occur. However, if it happens to occur, it is mitigated. For this purpose protocol uses QOR and PSR which are described as below:

Queue Occupancy Rate (QOR)

The queue occupancy rate (QOR) of a node presents the fraction of the queue has been occupied in the node. This rate is used for congestion detection. The queue occupancy rate of node j (QOR_j) can be defined with the following equation:

$$QOR_j = \frac{QO_j}{QMax_j} \qquad (1)$$

Where QO_j is queue occupancy of node J and $QMax_j$ is the maximum queue size which is fixed for all nodes. The QOR_j is used for comparing with two thresholds which decides either to avoid or mitigate the congestion at a specific point in time.

Packet Sending Rate (PSR)

The packet sending rate (PSR) of each node is the rate at which node can send packets to the next hop. PSR of the node I can be defined as:

$$PSR_i = \left(1.0 - QOR_j\right) \times PSR(max)_j \qquad (2)$$

$$\forall\, j \in nexthopofnodei$$

Where QOR_j is the queue occupancy rate of node j, $PSR(max)_j$ is the maximum packet sending rate of node j. The equation (2) implies that the packets sending rate of a node is computed by the available free queue size of the next hop node in WBAN. If PSR of a node is adjusted higher than $PSR(max)$ of next node, the queue of next node will be overflowed and case the congestion to occur. Therefore, proper adjustment in PSR according to the QOR of next-hop will control the congestion in BSNs.

The proposed protocol identifies the congestion by using current queue occupancy of the BSN. The level of queue occupancy of each node indicates the level of congestion in that BSN. We defined two thresholds for detection of congestion level as first threshold α and second threshold β. If the QOR is between α and β then congestion should be avoided. However, if the QOR is greater than β, congestion must be mitigated. So if QO of the next hop is between α and β, the proposed scheme will redirect the traffic to another node to avoid congestion. Moreover, the scheme selects the next hop based on congestion on the BMS and number of hops to the BC. The node with low level of QO is selected as next hop. Selecting next hop having least QO will reduce the probability of congestion as well as the waiting time of the packets in the queue. If QO of next hop is greater than β, the node is considered as a congested one. The congestion in this node needs to be mitigated. So the packet sending rate control mechanism as stated in equation 2, will be activated to control the congestion. The flow chart of the proposed CAMP protocol is presented in Fig. 4. The flow chart shows the process and mechanisms for congestion detection, avoidance and mitigation at a glance.

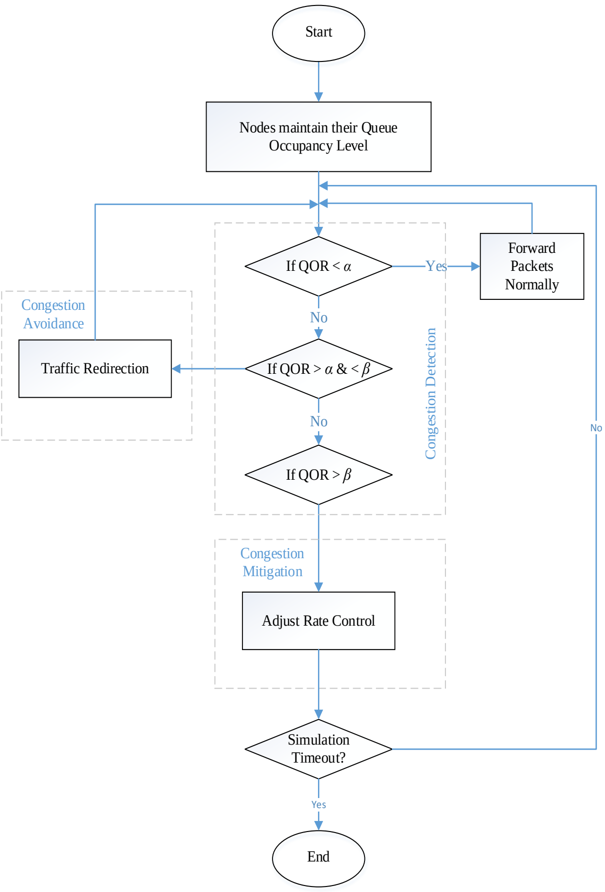

Fig. 4: Flow chart of proposed CAMP protocol

4. Results and Discussion

For assessment of the proposed work, series of experiments were carried out in NS2 simulator. The results are compared with HOCA protocol [20] in BSNs. For simulation setup, 10 number of BMS' and a BC are deployed on a single body. The simulation parameters are configured as stated in Table 1.

Table 1: Simulation Parameters

Parameter	**Value**
Initial Energy	1 Joule
Traffic	Constant Bit Rate (CBR)
Queue Length	100 Packets
Packet size	32 Bytes
Transmission Range	46cm
Transmission Power	0.3mW
MAC Protocol	IEEE 802.15.4
Network Interface	WirelessPhy
Simulation Time	120 seconds

The performance of the proposed protocol is evaluated in terms of throughput and network lifetime. The literature presents definition of network lifetime in two ways. It is a time period of network operations until the first node runs out of battery[21], [22]. Another definition describes network lifetime as the maximum duration of network operations till any of the nodes is active in the network and able to send data[23, 24]. This work uses the second definition to measure the maximum network lifespan of the proposed protocol.

Fig. 5 shows the analysis of network lifetime of the proposed protocol along with HOCA protocol. The proposed protocol performed well to avoid the congestion in the network. However, congestion is observed for a short period of time span. Subsequently, the proposed protocol prominently reduced the energy wastage of BMS' and increased the network lifetime of BSN. The Fig. 5 shows that the network operation time for proposed protocol is 10000 Centiseconds (CS) whereas for HOCA protocol is 7500 CS. Therefore, the proposed protocol shows 33% enhancement in network lifetime as compared to the HOCA protocol.

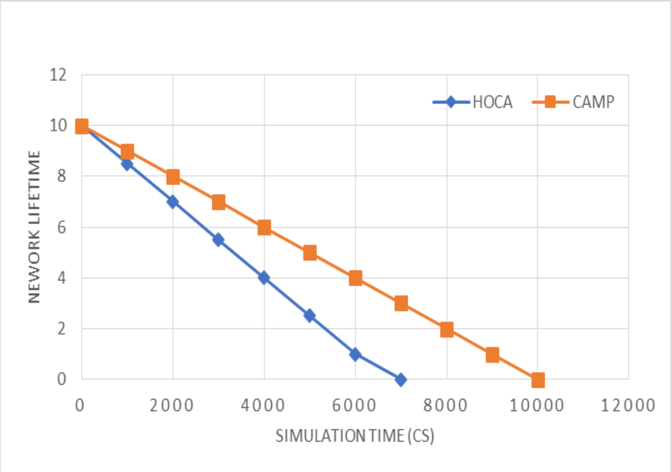

Fig. 5: Analysis of Network Lifetime

In BSNs the primary purpose of BMS' are to sense and transmit data to BNC. The successful data transmission in the networks is called network throughput [25]. Throughput is an important parameter to evaluate the network performance. Throughput should be improved to get the better network performance. Fig. 6 show that analysis of throughput in proposed and HOCA protocols. The proposed protocol performed well to control the congestion in the network which results in less number of packet drops. The Fig-6 shows the high number of successful packet delivery by the proposed protocol. The results show the proposed protocol performs better in achieving the throughput in the network as compared to HOCA protocol.

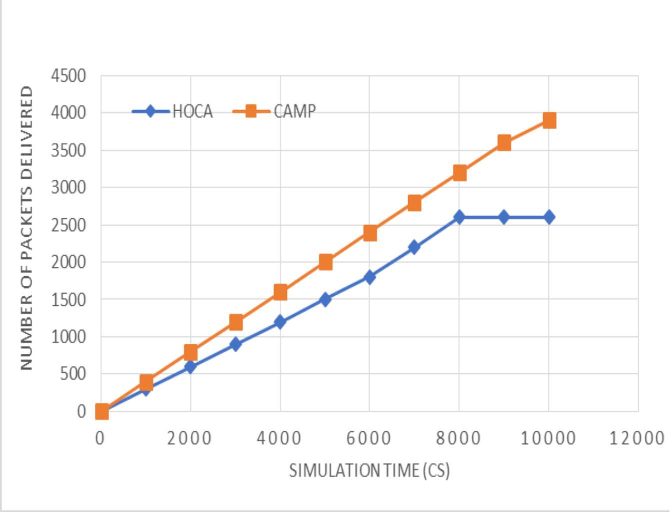

Fig. 6: Analysis of Network Throughput

Statistically, the proposed protocol successfully delivered 3900 packets while HOCA delivered 2600 packets. Therefore, the protocol achieved 49% better performance in terms of network throughput as compared to the HOCA protocol.

5. Conclusion

Body Sensor Networks (BSN) is convenient and economical solution for healthcare applications. This research highlights the issues related to congestion in BSNs. In this paper, a congestion avoidance and mitigation protocol (CAMP) is proposed for BSN. The primary focus of this protocol is to avoid congestion in the network. This is achieved by constant monitoring of queue level of the BMS'. The traffic is redirected if queue occupancy level is greater than first threshold α. However, if queue occupancy level is reached to second threshold $\beta$and congestion is occurred, the proposed CAMP protocol mitigated the congestion by adjusting the rate control. Moreover, routing decision are performed based on hop counts and congestion level on the BMS. The experimental results indicate the proposed protocol performed better in terms of network lifetime and throughput in BSNs.

Furthermore, this work can be extended towards differentiated routing based on multiple routing zones to further improve the energy efficiency in BSNs.

References

[1] S. P. Keehan *et al.*, "National Health Expenditure Projections, 2014–24: Spending Growth Faster Than Recent Trends," *Health Aff.*, vol. 34, no. 8, pp. 1407–1417, 2015.

[2] A. Nag, S. C. Mukhopadhyay, and J. Kosel, "Wearable Flexible Sensors: A Review," *IEEE Sens. J.*, vol. 17, no. 13, pp. 3949–3960, 2017.

[3] N. C. I. NCI, "Cancer Detection and Diagnostics Technologies for Global Health," pp. 1–188, 2011.

[4] B. Latré, B. Braem, I. Moerman, C. Blondia, and P. Demeester, "A survey on wireless body area networks," *Wirel. Networks*, vol. 17, no. 1, pp. 1–18, 2011.

[5] M. Chen, S. Gonzalez, A. Vasilakos, H. Cao, and V. C. M. Leung, "Body area networks: A survey," *Mob. Networks Appl.*, vol. 16, no. 2, pp. 171–193, 2011.

[6] M. Anwar, A. H. Abdullah, K. N. Qureshi, and A. H. Majid, "Wireless Body Area Networks for Healthcare Applications : An Overview," *TELKOMNIKA*, vol. 15, no. 3, pp. 1088–1095, 2017.

[7] G. K. Ragesh and K. Baskaran, "A survey on futuristic health care system: WBANs," *Procedia Eng.*, vol. 30, no. 2011, pp. 889–896, 2012.

[8] K. S. M. and A. J. Tanvir Ishtaique ul Huque, "Body Node Coordinator Placement Algorithms forWireless Body Area Networks," *IEEE INTERNET THINGS J.*, vol. 2, no. 11, pp. 94–102, 2015.

[9] D. M. Barakah and M. Ammad-uddin, "A Survey of Challenges and Applications of Wireless Body Area Network (WBAN) and Role of a Virtual Doctor Server in Existing Architecture," no. February 2012, 2016.

[10] A. Ghaffari, "Congestion control mechanisms in wireless sensor networks: A survey," *J. Netw. Comput. Appl.*, vol. 52, pp. 101–115, 2015.

[11] A. Ahmed, K. A. Bakar, M. I. Channa, K. Haseeb, and A. W. Khan, "TERP: A Trust and Energy Aware Routing Protocol for Wireless Sensor Network," *IEEE Sens. J.*, vol. 15, no. 12, pp. 6962–6972, 2015.

[12] C. Sergiou, P. Antoniou, and V. Vassiliou, "A Comprehensive Survey of Congestion Control Protocols in Wireless Sensor Networks," *IEEE Commun. Surv. Tutorials*, vol. 16, no. 4, pp. 1839–1859, 2014.

[13] Y. Baek, B. Lee, J. Li, Q. Shu, and C. Science, "An adptive rate control for congestion avaoidance in Wireless Body Area Networks," pp. 1–4, 2009.

[14] M. H. Yaghmaee Moghaddam and D. Adjeroh, "A novel congestion control protocol for vital signs monitoring in wireless biomedical sensor networks," *IEEE Wirel. Commun. Netw. Conf. WCNC*, no. February, 2010.

[15] N. Yaakob and I. Khalil, "Packet size optimization for congestion control in pervasive healthcare monitoring," *Proc. 10th IEEE Int. Conf. Inf. Technol. Appl. Biomed.*, pp. 1–4, 2010.

[16] V. Tiwari, S. Misra, and M. Obaidat, “Lacas: Learning automata-based congestion avoidance scheme for healthcare wireless sensor networks,” *IEEE J. Sel. Areas Commun.*, vol. 27, no. 4, pp. 466–479, 2009.

[17] R.Gunasundari, R.Arthi, and S.Priya, “An Efficient Congestion Avoidance Scheme For Mobile Healthcare Wireless Sensor Networks,” *Int. J. Adv. Netw. Appl.*, vol. 2, no. 3, pp. 693–698, 2010.

[18] N. F. Bahalgardi *et al.*, “An Adaptive Congestion Alleviating Protocol for Healthcare Applications in Wireless Body Sensor Networks : Learning Automata Approach,” vol. 26506, no. 1, 2012.

[19] M. H. Yaghmaee, N. F. Bahalgardi, and D. Adjeroh, “A prioritization based congestion control protocol for healthcare monitoring application in wireless sensor networks,” *Wirel. Pers. Commun.*, vol. 72, no. 4, pp. 2605–2631, 2013.

[20] A. A. Rezaee, M. H. Yaghmaee, A. M. Rahmani, and A. H. Mohajerzadeh, “HOCA: Healthcare aware optimized congestion avoidance and control protocol for wireless sensor networks,” *J. Netw. Comput. Appl.*, vol. 37, no. 1, pp. 216–228, 2014.

[21] M. Effatparvar, M. Dehghan, and A. M. Rahmani, “A comprehensive survey of energy-aware routing protocols in wireless body area sensor networks,” *J. Med. Syst.*, 2016.

[22] Q. Nadeem, “A New Energy Efficient Protocol for Wireless Body Area Networks,” 2013.

[23] M. M. et al. Sahndhu, “BEC : A Novel Routing Protocol for Balanced Energy Consumption in Wireless Body Area Networks,” pp. 653–658, 2015.

[24] WME W.M. Aiman, S.W.Ruslan, M.J.Che Soh, Design of Low Power CMOS Bioamplifier in 250 nm and 90 nm Technology Node. *International Journal of Integrated Engineering – Special Issue on ReSENT* 2017, Vol. 9 No. 4(2017) pp. 109-113..

[25] Q. Nadeem, N. Javaid, S. N. Mohammad, M. Y. Khan, S. Sarfraz, and M. Gull, “SIMPLE: Stable increased-throughput multi-hop protocol for link efficiency in Wireless Body Area Networks,” *Proc. - 2013 8th Int. Conf. Broadband, Wirel. Comput. Commun. Appl. BWCCA 2013*, pp. 221–226, 2013.