

A Study on Dynamic Connectivity Establishment and Cooperative Scheduling For QoS-Aware WBAN

M. Kundana Ravali¹, Dr M. Sampath Kumar²M.Tech Scholar, Department of Computer Science and System Engineering, Andhra University College of Engineering
(A), Visakhapatnam, AP, India¹,Professor, Department of Computer Science and System Engineering, Andhra University College of Engineering (A),
Visakhapatnam, AP, India²

ABSTRACT: Recently significant research works reported on communication standards of wireless body area networks (WBANs) due to emergence of WBAN in real time applications. There two primary challenges in opportunistic WBANs such as network management cost reduction and energy consumption reduction in order deliver the cost-effective and reliable services to critical patients in healthcare application. There are number solutions reported to address this challenges in recent past, however failed to cover all the aspects of WBANs communication. In this, project we propose novel opportunistic communication protocol for WBANs with aim to solve the research challenges not only the energy efficiency and network management cost reduction but also solves the problem non-reliable nodes data dissemination. Initially we proposed the novel energy-efficient and distributed network administration cost minimization system for dynamic availability and data dissemination in shrewd WBANs. At that point we proposed the estimating based approach for dependable hub data dissemination. This should be possible by notoriety based incentive strategies to rouse members to scatter dependable data in participatory sensing framework, while limiting incentive cost for keeping up adequate number of solid members. The reproduction comes about uncovers the adequacy of proposed technique. Wireless Body Area Networks (WBANs) deal with variety of healthcare services with diverse Quality of Service (QoS) requirements. However, QoS handling is a challenging problem in such networks. In general, QoS related problems can be addressed from different layers in the networking protocol suite. Design of an efficient QoS aware Medium Access Control (MAC) protocol can address this problem in MAC layer. This paper analyzes the QoS requirements of WBAN, identifies the requisites of QoS handling system, and outlines the trends that are being followed for its advancement with focus on QoS issues at MAC layer. We review some prior works, compare them, and analyze the current research concerned with problem of providing QoS in WBAN.

KEYWORDS: WBAN, QoS aware MAC, Wireless Body Area Network, Biomedical monitoring, Smart Health, Cooperative Packet Scheduling, Dynamic Connectivity Establishment, Coalition Game Theory, Performance Analysis.

I. INTRODUCTION

WBANs are useful for remote monitoring of physiological conditions of patients. In a typical WBAN architecture, several on-body sensors sense the physiological parameters of patients and transmit the sensed data to Local Processing Units (LPUs). Thereafter, LPUs send the aggregated data to the Access Points (APs) for further processing. In a hospital environment, several WBANs may coexist in the presence of multiple APs. Therefore, in such a scenario, multiple WBANs attempt to send their data to the APs. Further, as WBANs are inherently mobile in nature, a WBAN architecture inherits the traits of a group-based model in which each WBAN is composed of several heterogeneous body

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 8, August 2019

sensors.

Group-based mobility and changes in the body posture of WBANs have serious implications on the performance of WBAN communication, especially connectivity between a WBAN and AP. WBAN-based applications, the patient equipped with body sensor nodes moves from one location to another to fulfil their medical requirements. However, due to movement of WBANs, the connectivity among WBANs and LPUs gets affected, which inherently increases the service delay.

Additionally, in a particular location, there can exist multiple WBANs in order to get the adequate connectivity from an AP. All WBANs may not get the adequate connectivity with an AP. Thus, the QoS requirements of WBANs get affected, which necessitates a dynamic connectivity establishment algorithm for WBANs in order to minimize the service delay of the network and also to maximize the QoS requirements of WBANs.

Wireless Body Area Network (WBAN) is a key technological breakthrough in healthcare. WBAN consisting of autonomous portable sensor nodes with intercommunicating radio interface is meant to monitor the patient's physiological parameters such as Electrocardiography (ECG), blood pressure, blood glucose level, etc., and feedback the updates to the physician or the authorized agents like family members and care givers via the means of powerful external computing devices such as Personal Digital Assistant (PDA) or cell phones [1][2]. The external computing devices also serve as incharge of resource management.

WBAN offers two main advantages over conventional healthcare [3]. First, it is cable-less so that people are not confined in a small region any more. Second, multiple information can be collected autonomously by employing variety of sensor nodes without need of human intervention. Such new paradigm brings a number of unique advantages on healthcare [4][5]. For instance, it can play considerable role on Ubiquitous Healthcare (U-Health), i.e. on sensing and monitoring of the patient's health round the clock and automatically update the status to the physician or the authorized agents irrespective of the location. Apart from that, WBAN can also be used on interactive gaming, military services, and entertainment [6].

WBAN operates in close vicinity to, on, or inside a human body by employing various sensor nodes. As such, WBAN is also often referred to as a subset of Wireless Sensor Network (WSN). However, in spite of some common characteristics, there exist considerable differences between them. The main differences reside in the type and requirements of applications. In particular, energy efficiency and Quality of Service (QoS) requirements are much more important concerns in WBAN.

Sensor nodes used in implantable or wearable form in WBAN demand more energy efficient and miniaturized design in comparison to spatially scattered nodes in WSN. This requirement is stricter in case of in-body sensor nodes. As such nodes are used in implantable form, replacing the batteries, recharging them, or using higher weight batteries become inefficient approaches. In some cases, it may even require complex surgery.

WSN is generally used for event-based monitoring and deals with same type of traffic. Once any event happens, all the nodes in close proximity monitoring the environment sense that event and prompt for transmission. On the other hand, WBAN generally deals with heterogeneous traffic. Wide variations exist in the data generated by different healthcare applications. In essence, urgency, data transmission frequency, and delay-and-loss tolerances vary from application to application in WBAN. But, for right diagnosis and right prescription, medical personnel may need all the updates correctly and timely. A failure in timely delivery of the updates or a delivery with an error can impact severely and sometimes may even risk the patient's life. Therefore, prioritize data transmission with QoS guarantee is a primary requirement of WBAN.

Energy efficiency in WBAN is commonly practised by two different ways: efficient low power hardware design and efficient optimized network protocol design. Low power hardware design is a sensor design issue such as low-power

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 8, August 2019

sensor circuitry design, low-power transceiver design, signal processing, etc., [7]. Whereas, optimized network protocol design is an efficient communication protocol design issue such as efficient Medium Access Control (MAC) protocol design, efficient transport protocol design, and so on. More importantly, as coordinated and controlled channel access not only ensures reliability but also minimizes energy consumption, efficient QoS aware MAC protocol can address both the requirements of WBAN: energy and QoS. As such, recently, efficient QoS aware MAC protocol design is increasingly attracting the interest of researchers both from academia and industries [8-9].

QoS Demand in WBAN

To enable WBAN services to be as smooth as possible, a number of design considerations needs to be met. WBAN should be designed on a practical way so that it can fit into people's lives in an unobtrusive manner. Biocompatibility between the sensor nodes and human body also should be fully tested to ensure no adverse effects or reactions to occur. Moreover, great emphasis should be placed on the data availability and the QoS.

Despite significant technological advances in wireless technology, QoS handling in WBAN is still a challenging job. Throughput, delay, jitter, and loss/error rate are the main QoS parameters in traditional networks. While, data criticality comes as an additional parameter in WBAN. Loss, delay, or an error in life critical data can be highly problematic in WBAN. In addition, available energy level is another substantiating parameter. Aside from that, human body also presents various adverse fading effects to the WBAN channels. Channel characteristics can also vary with body size and posture [22]. At a same time, as WBAN employ low power sensor nodes with less computational capacity and buffer size, there exist risk of data drop and data error.

In traditional wireless networks, QoS is generally supported by prioritized QoS [27][28]. Prioritized QoS first categorizes the services into different Access Classes (ACs), like real time, non real time, best effort, etc., and then assigns different priority level to each of them such that channel access becomes the function of priority. Higher the priority is, higher will be the chance to access the channel and vice versa. However, once the priority is set, it remains unchanged on this approach. All the applications belonging to the specific AC always get the same access probability irrespective of any other constraints.

There is significant gap between traditional networks and WBAN. Since each of them deals with different applications, consumer electronics related applications and medical applications, respectively, great diversities in terms of traffic profile and QoS requirements exist there. QoS parameters, specially the level of criticality, vary from application to application in WBAN. Even a single application could have different QoS demand depending upon the patient's clinical condition. For example, ECG reading is often considered more important than body temperature reading in normal case and is assigned higher priority. However, during abnormal case when body temperature reaches very high, the priority is interchanged. Similarly, some of the applications are even correlated and attempt to send the updates simultaneously. For example, with the rise in body temperature, blood pressure and the heart beat rate also rise. However, if not managed properly during abnormal case when body temperature reaches extremely high, data redundancy and collision may occur. Similarly, even the real time traffic like multimedia traffic could be of different importance in WBAN. For example, multimedia traffic during surgery is highly important than the multimedia traffic during consulting and prescription. In addition, most of the non- real time traffic, like periodic blood glucose level update, do not have high delay constraint in normal situation. However, the delay constrain can be changed abruptly in abnormal situations.

Although WBAN also inherit almost all the QoS requirements of traditional networks, direct adoption of traditional QoS provisioning schemes do not fit well in WBAN. Data criticality and the condition dependent QoS requirements demand new QoS solution in WBAN. Most importantly, supporting critical data (emergency traffic) should always be considered as main issue in WBAN. Hence, as a whole, all these requirements and characteristics demand clear methodology and approach on design of an efficient QoS framework that can satisfy high degrees of data transmission

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 8, August 2019

reliability with specific latency requirements by assigning high priority to the critical data but without endangering the energy consumption and resource utilization in WBAN.

QoS Handling in WBAN from MAC Layer

In broad sense, QoS requirements for particular applications over Open System Interconnection (OSI) layered architecture network can be addressed from any of the layers of the networking protocol suite. For example, one of the important QoS issues like reliability can be addressed from three different layers: transport, MAC, and Physical (PHY). In transport, use of efficient congestion control mechanism could enhance the reliability. In MAC, using efficient error correction mechanism could enhance the reliability. Similarly, in PHY, using efficient modulation and coding technique could address the reliability. Similarly, another important QoS metric energy efficiency can also be addressed from multiple layers, for example network layer and MAC layer. In network layer, using efficient routing protocol and route discovery algorithm could save energy. Whereas, in MAC layer, collision resolution and duty cycle adjustment mechanisms could save energy. Apart from the single layer technique, QoS requirements can also be addressed from a cross layer technique as well. For example, the QoS requirements at the application layer can be informed to the MAC layer for efficient scheduling and the channel quality in PHY layer can be informed to the network layer for selecting a path with good channel state.

As common to all existing networking technologies, WBAN also follows the OSI layered architecture to maintain end-to-end connection between two entities in the network. Hence, QoS requirements of WBAN can also be addressed from various layers and cross layer techniques. For example, [29][30] have proposed QoS aware routing protocols for WBAN.

[29] has proposed a protocol called Data-Centric Multiobjective QoS Aware routing (DMQoS) to address delay, reliability, and energy requirements. DMQoS facilitates to achieve QoS for each traffic differentiated according to the generated data types. It exploits geographic locations and QoS performance of the neighbor nodes to implement localized hop-by-hop routing. [30] has proposed new QoS and geographical routing to address energy requirement. This protocol classifies the data traffic into several categories according to the required QoS metrics and then attempts to fulfill the required QoS in a power aware way, by selecting the best candidate for routing. Similarly, [31] has proposed the cross layer designed QoS-aware routing. In this protocol routes are determined by user specific QoS metrics, channel status, packet priority level, and sensor node's willingness to be a router. The layer design also facilitates routing service to send feedback on network conditions to the user application in order to adjust medical application service level.

MAC layer also plays vital role both on energy saving and QoS handling in WBAN and is becoming an important field of research. In what follows we describe the desirable properties of QoS handling system in MAC layer and review some prior works

II. RELATED WORK

In this section, we represent the review of research works on practical communication protocol and energy consumption techniques for WBANs.

Samanta et al. [8], [9] investigated that link-quality-aware resource allocation cum load balancing scheme for node in WBANs. In this technique, the researcher has utilized two sub problems- dynamic resource allocation and link-quality measurement in WBANs. These research works deal with the flexibility of WBANs they do not analyze the dynamics of network management cost in the existence of body/limb activity in WBANs, due to which the total amount of network cost raising and the QoS of WBANs raising.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 8, August 2019

Elias et al. [10] innovated that an energy-aware optimal design of energy effective and cost-effective WBANs. This technique investigated a cost-effective approach; the researcher does not analyze the impacts of dynamic connectivity and opportunistic data distribution in WBANs. This raising the delay and packet eliminated of the network.

Zhao et al. [11] investigated a network cost minimization scheme for data distribution in WSNs. First, this technique does not analyze the necessity index of WBANs in manner to quantify the medical situation of the WBAN-tools patients, which is one of the unique attributes of WBAN-based communications.

Energy-efficient and reliable communications are significant demands of WBANs; these are supplies sensitive medical information due to shadowing and fading consequences in the networks, the energy consumption rate of sensor nodes increases, and additionally the reliability in statistics transmission decreases, periodically. To boom the electricity performance and reliability in statistics transmission recently wide variety of strategies reported.

Yousaf et al. [12] investigated that, a new three-level cooperative relaying scheme for WBANs. As frame sensor nodes produce clinical statistics at a variable fee, their corresponding traffic pattern is uncertain in nature. Consequently, in the presence of negative hyperlink-satisfactory, the packets drop charge of the network and the power intake of body sensor node increase.

Andreagiovanni and Nardin [13] investigated that robust approach for joint optimization of energy accuracy and data rate in WBANs under traffic unreliability. In this innovation work, the packet transmission rate of body sensor nodes is consider to be homogenous in nature, but in condition of WBANs, the packet transmission rate of body sensor nodes is heterogeneous.

Huang and Cai [14] investigated proposed a concern-conscious scheduling scheme for used by a WBAN inside the presence of more than one coexisting WBANs. to maximize the community throughput of WBANs, a nonlinear optimization trouble is formulated, while considering the priorities amongst WBANs. This work is limited to handiest the concern conscious scheduling of WBANs inside the presence of interference amongst coexisting WBANs. but, they do no longer take into account the elevated network management value in the presence of interference Ibarra et al. [15] investigated a joint power and QoS control structure to supplies of energy and obtained the best possible QoS in WBANs. The base paper techniques are analysis the difficulty traffic ministry for the data transmission procedure. However, this technique is not used for all types of traffic management in the network.

Similarly, Seyedi et al. [16] evolved one-of-a-kind energy efficient data transmission scheme for WBANs. As a way to provide power-green statistics transmission, the tradeoffs between energy intake and packet errors possibility is embedded into the sensor nodes. This version fails to provide QoS to WBANs in the presence of community dynamics, because of mobility.

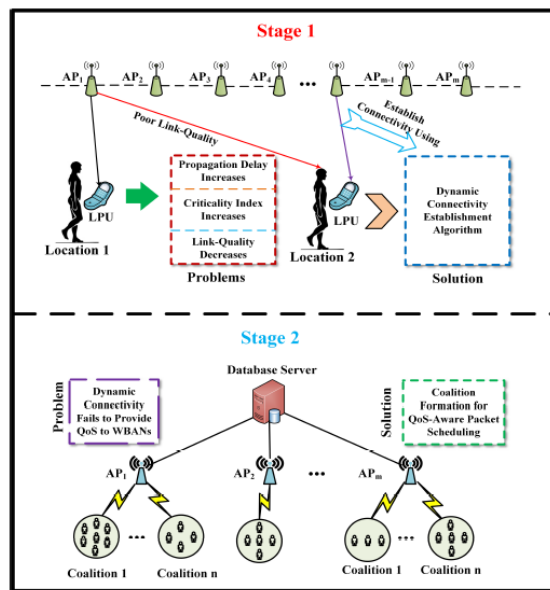
Also, Seyedi et al. [17] investigated that a Markov-chain based analytical approach for energy collective node in WBANs, in which the possibility of situation loss is analyzed to recognize the energy loss condition of body sensors node.

Ren et al. [18] investigated a approach which secure higher network throughput for synchronize WBANs. The base paper works does not fulfil to supplies robustness in the network management approach for WBANs.

M. A. Kafi et al. [10] The recent wireless sensor network applications are resource greedy in terms of throughput and network reliability. However, the wireless shared medium leads to links interferences in addition to wireless losses due to the harsh environment. The effect of these two points translates on differences in links bandwidth capacities, lack of reliability and throughput degradation. In this study, we tackle the problem of throughput maximization by proposing an efficient congestion control-based schedule algorithm, dubbed REFIACC (Reliable, Efficient, Fair and Interference-Aware Congestion Control) protocol. REFIACC prevents the interferences and ensures a high fairness of

bandwidth utilization among sensor nodes by scheduling the communications

III. ARCHITECTURE DIAGRAM



IV. METHODOLOGY

The modules involved in the project are as follows

- Node Formation.
- Create Connection Between WBAN and AP.
- Dynamic connectivity establishment algorithm.
- Quality Of Service.

A. Node formation Sensor nodes which are specially designed in such a typical way that they have a microcontroller which controls the monitoring, a radio transceiver for generating radio waves, different type of wireless communicating devices and also equipped with an energy source such as battery.

Create event scheduler:

```
set ns [new Simulator]
```

Schedule events:

```
$ns at <time> <event>
```

<event>: any legitimate ns/tcl commands

```
$ns at 5.0 —finishl
```

Start scheduler:

```
$ns run
```

B. Create connection between wban and ap.

Dynamic connectivity establishment for WBANs to manage transient connectivity between them and the APs, caused by factors such as body shadowing and mobility of WBANs. The proposed scheme opts for dynamic connectivity with an AP, in the presence of multiple WBANs in a critical emergency situation, in hospital environments. After addressing

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 8, August 2019

the dynamic connectivity problem, we propose to form coalition game to minimize the service delay and schedule the packets of different WBANs cooperatively. We prove the existence of Nash Equilibrium for the proposed coalition game to obtain a stable formation for the WBANs through cooperative packet scheduling. Further, a Markov model is used to analyze the stable coalition formation. We also propose a dynamic cooperative packet scheduling algorithm for use among WBANs, to minimize the service delay and increase the network throughput.

C. Dynamic connectivity establishment algorithm.

In medical emergency situations, to get connected to a dynamic AP with minimum delay, we propose an algorithm, that named Establishment of Dynamic Connectivity (EDC), increases the data packet delivery ratio among different WBANs in the communication range of a dynamic AP. Dynamically choosing connectivity is not sufficient to provide effective medical service to the critical WBANs, as realistically, in the proximity of a particular AP, several WBANs also attempt access at the same time. But due to channel and residual bandwidth constraints, it is not possible for an AP to secure solution all WBANs at a particular instant of time in a particular time-period.

D. Quality Of Service

The manage connectivity, we proposed the Dynamic Connectivity Establishment (DCE) algorithm, which is based on a price-based approach. Finally, critical WBANs in the proximity of an AP form coalitions to ensure QoS between them. In each coalition, the WBANs participate in cooperative packet scheduling to provide services to the critical WBANs. For handling cooperation between WBANs, we proposed another algorithm Optimal Cooperative Packet Scheduling.

- Dynamic connectivity establishment for WBANs to manage transient connectivity between them and the APs, caused by factors such as body shadowing and mobility of WBANs.
- The proposed scheme opts for dynamic connectivity with an AP, in the presence of multiple WBANs in a critical emergency situation, in hospital environments.

V. EXPERIMENTAL ANALYSIS AND RESULTS

The selection of an AP dynamically among multiple APs in a hospital environment in the presence of multiple WBANs. Also, we prove the requirement of dynamic selection of AP in medical emergency situations. A dynamic AP is chosen based upon different selection parameters — available bandwidth, received signal strength, residual energy, and criticality of the WBANs.

A. Introduction to ns-2 simulation

- Ns-2 implements a variety of network components and protocols.
- It is an open-source event-driven simulator designed specifically for research in computer communication networks.

1. Starting NS

NS starts with the command `ns` (assuming that we are in the directory with the `ns` executable, or that were path points to that directory), where is the name of a Tcl script file which defines the simulation scenario (i.e. the topology and the events). We could also just start `ns` without any arguments and enter the Tcl commands in the Tcl shell, but that is definitely less comfortable. Everything else depends on the Tcl script

2. Starting Nam

We can either start `nam` with the command `'nam<nam-file>'` where `'<nam-file>'` is the name of a `nam` trace file that was generated by `ns`, or we can execute it directly out of the Tcl simulation script for the simulation which we want to visualize. • `Nam` is a Tcl/Tk based animation tool that is used to visualize the `ns` simulations and real world packet trace data. • The first step to use `nam` is to produce a `nam` trace file. • The `nam` trace file should contain topology information like nodes, links, queues, node connectivity etc as well as packet trace information.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 8, August 2019

3. Characteristics Of NS2

- To evaluate that performance of existing network protocols
- To evaluate new network protocols before use
- To run large scale experiments not possible in real experiments
- To simulate a variety of ip networks.

A. Creating A Nodes

Network is initialized with the wireless node with their specified location. In this number of nodes created has been 48.

B. Sender, receiver and cluster head allocation

Initially packets select random nodes, after which Pheromone value will get updated by all the packets as it reaches the destination. After the particular process, all packets move in the resulted shortest path. Sender and receiver in which the data or packets can transmitted between the nodes

C. Data transmission between the nodes

In this data transmission has been occurred between the different types of sender and receiver. While sending the data occurrence of nodes may be happened.

D. Graph

In the graph green colour line indicates the existing method and red colour line indicates the proposed method.

E. Success rate

Network Lifetime shows that how much redundant data has been transmitted with failure

F. Throughput

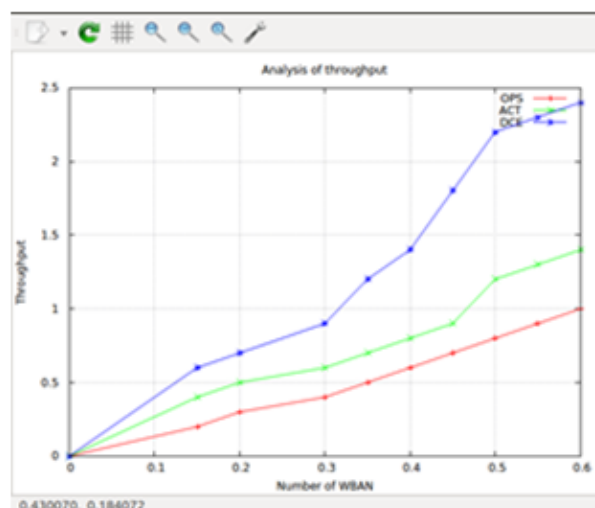
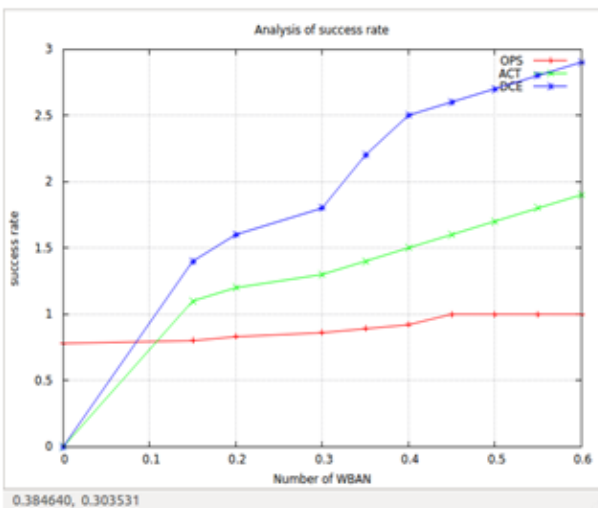
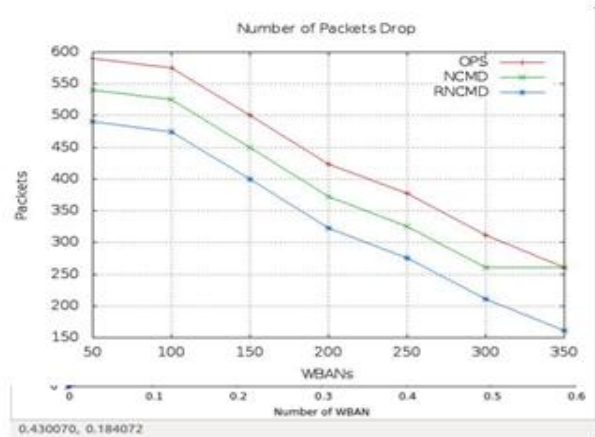
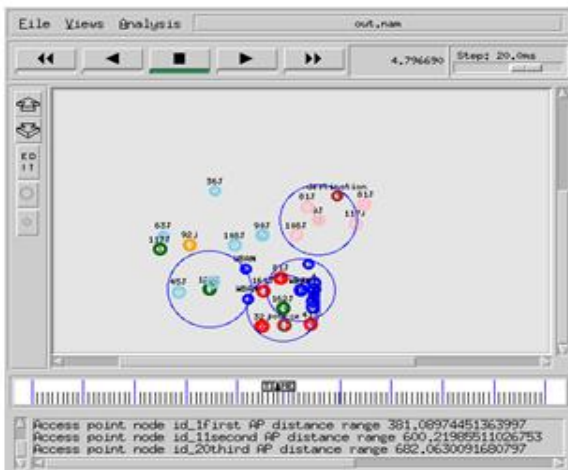
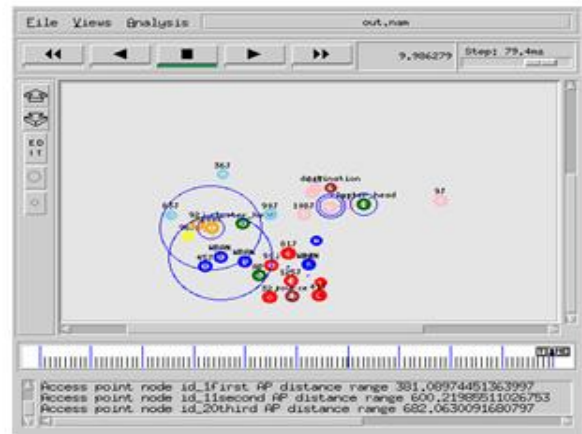
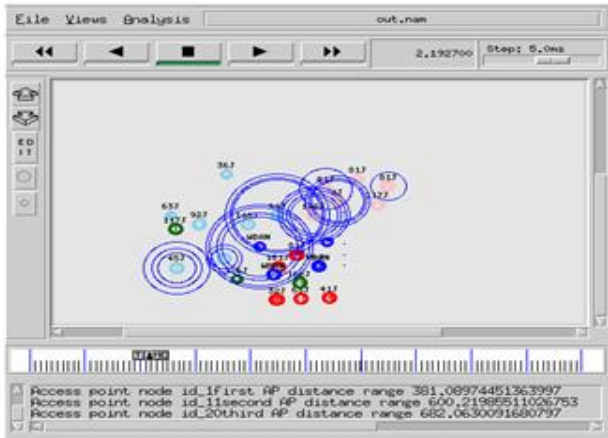
It is seen from our simulations that normal routing protocol outperforms in terms of throughput without being under the influence of worm whole attack. At varying speeds network when being under attack and also when prevented from attack by Intrusion detection, gives almost same throughput.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 8, August 2019



International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 8, August 2019

VI. CONCLUSION AND FUTURE WORKS

In this work, we presented a scheme for dynamic connectivity establishment and cooperative scheduling for QoS-aware WBANs. First, we dynamically choose a dynamic AP for the critical WBANs, so as to deal with the transient connectivity problem between WBANs and APs. To manage connectivity, we proposed the Dynamic Connectivity Establishment (DCE) algorithm, which is based on a price-based approach. Finally, critical WBANs in the proximity of an AP form coalitions to ensure QoS between them. In each coalition, the WBANs participate in cooperative packet scheduling to provide services to the critical WBANs. For handling cooperation between WBANs, we proposed another algorithm Optimal Cooperative Packet Scheduling. We compared our proposed schemes with the existing schemes, based on which we show that the former our approach outperform the later

FUTURE WORK

Future extension of this work includes studying and characterizing the dynamic behavior of link quality between WBANs and APs for the connectivity problem. Another extension of the work is to observe the performance of the proposed solutions in real-life setting for mobile edge computing applications. Consequently, in the presence of transient connectivity, the data rate adaption technique can be implemented to increase the overall performance of WBANs. On the other hand, we intend to address the security and privacy issues of cooperative packet scheduling among WBANs in critical emergency situations

REFERENCES

- [1] Yick, J., Mukherjee, B., & Ghosal, D. (2008). Wireless sensor network survey. *Computer networks*, 52(12), 2292-2330. [2] Borasia, S., & Raisinghani, V. (2011). A review of congestion control mechanisms for wireless sensor networks. In *Technology Systems and Management* (pp. 201-206). Springer, Berlin, Heidelberg
- [3] A.Rezaei and M.K. Rafsanjani, "Congestion control protocols in wireless sensor networks: A survey", *Journal of American Science*, Vol.8, No.12, pp.772-777, 2012.
- [4] C.Luo and W.X. Xie, "Fuzzy AQM for congestion avoidance and control in sensor networks", *Chinese Journal of Electronics*, Vol.42, No.4, pp.679-684, 2014.
- [5] G.Li, J. Li and B. Yu, "Lower bound of weighted fairness guaranteed congestion control protocol for WSNs", *Proceedings of IEEE INFOCOM*, pp.3046-3050, 2012.
- [6] D.J.Baker and J.Wieselthier, "A distributed algorithm for scheduling the activation of links in a self-organizing, mobile, radio network," in *Proc.ICC*, 2014, pp. 2F6.1_2F6.5.
- [7] J.Broch, D. A. Miltis, D. B. Johnson, Y.-C. Hu, and J. Jetcheva, "A performance comparison of multi-hop wireless ad hoc network routing protocols, 2018,".
- [8] T.Camp, J. Boleng, and V. Davies, "A survey of mobility models for ad hoc network research," *Wireless Commun. Mobile Computing.*, vol. 2, no. 5, pp. 483-502, 2014.
- [9] G.Chatzimilioudis, D. Zeinalipour-Yazti, W.-C. Lee, and M. D. Dikaiakos, "Continuous all k-nearest-neighbour querying in smartphone networks," in *Proc. IEEE MDM*, Jul. 2015, pp. 79-88.
- [10] T.-Y. Fu, W.-C. Peng, and W.-C. Lee, "Parallelizing itinerary-based KNN query processing in wireless sensor networks," *IEEE Trans. Knowl. Data Eng.*, vol. 22, no. 5, pp. 711-729, May 2010
- [11] M. Zhao, D. Gong, and Y. Yang, "Network Cost Minimization for Mobile Data Gathering in Wireless Sensor Networks," *IEEE Transactions on Communications*, vol. PP, no. 99, pp. 1-1, 2015.
- [12] S. Yousaf, N. Javaid, Z. A. Khan, U. Qasim, M. Imran, and M. Iftikhar, "Incremental Relay Based Cooperative Communication in Wireless Body Area Networks," *Procedia Computer Science*, vol. 52, pp. 552-559, 2015.
- [13] F. D. Andreagiovanni and A. Nardin, "Towards the Fast and Robust Optimal Design of Wireless Body Area Networks," *Applied Soft Computing*, vol. 37, pp. 971-982, 2015.
- [14] S. Huang and J. Cai, "Priority-Aware Scheduling for Coexisting Wireless Body Area Networks," in *Proceedings of International Conference on Wireless Communications Signal Processing*, 2015, pp. 1-5.
- [15] E. Ibarra, A. Antonopoulos, E. Kartsakli, J. Rodrigues, and C. Verikoukis, "QoS-Aware Energy Management in Body Sensor Nodes Powered by Human Energy Harvesting," *IEEE Sensors Journal*, vol. 16, no. 2, pp. 542-549, 2016.
- [16] A. Seyedi and B. Sikdar, "Energy Efficient Transmission Strategies for Body Sensor Networks with Energy Harvesting," *IEEE Transactions on Communications*, vol. 58, no. 7, pp. 2116-2126, 2010.
- [17] "Modeling and Analysis of Energy Harvesting Nodes in Body Sensor Networks," in *Proceedings of International Summer School and Symposium on Medical Devices and Biosensors*, 2008, pp. 175-178.
- [18] Z. Ren, X. Qi, G. Zhou, H. Wang, and D. Nguyen, "Throughput Assurance for Multiple Body Sensor Networks," *IEEE Transactions on Parallel and Distributed Systems*, vol. PP, no. 99, pp. 1-1, 2015
- [19] Amit Samanta, Student Member, IEEE, Sudip Misra, "Energy-Efficient and Distributed Network Management Cost Minimization in Opportunistic Wireless Body Area Networks", *IEEE Transactions on Mobile Computing*, 2017