Comparison of MANET Routing Protocols Used in Home Health-Monitoring System for Elderly Patients

Mohammad Hamoud[1], Rita Hassoun[2], Ahmad Mahmoud[3], Mothanna Alkubeily[4], Ahmad Sleiman Ahmad[5]

[1, 3, 5]Al-Andalus University, Department of Biomedical Engineering, Alkadmous - Tartous, Syria

[2,4] Tishreen University, Department of Mechanical and Electrical Engineering, Lattakia, Syria

Abstract: *Lately, many researchers have focused on implementing the Wireless Sensor Networks (WSNs) in medical applications. However, Wireless Body Area Networks (WBANs) promise to revolutionize health care in the near future. WBAN medical applications show great promise in improving the quality of life of people and satisfying many requirements of elderly people by enabling them to live safely, securely, healthily and independently. In this paper, we have simulated and analyzed well-known MANET routing protocols in WBAN of elderly long-term health monitoring system to determine which of them is much efficient to overcome MANET challenges in the medical applications. Various performance parameters used for comparison such as end-to-end delay, throughput, and packet loss ratio.*

Keywords: Ad Hoc Networks, MANET, WBAN, AODV, DSR, OLSR

1. Introduction

Wireless Sensor Networks (WSNs) are a technology consists of a large number of sensing nodes scattered in the environment that are low powered, efficient and small sized that sense, compute and connect with each other to send the sensed data to one or more collecting sink nodes using Internet, UMTS or other infrastructure networks. Therefore, an end user can use the received data for many applications like emergency medical situations, military conflicts or …etc [1]. WSN technology can be adapted for the design of practical health care systems that support the requirements of reliable communication, node mobility, multicast technology, energy efficiency, and the real-time delivery of data [2,3]. The application of WSNs in healthcare systems can be either monitoring of patients in hospitals or monitoring of elderly patients in home or others [4]. However, one of the main requirements of implementing the WSN in medical applications is the real-time reliable delivery of sensed data, which have to be focused on through the careful choosing of routing protocols.

Wireless Body Area Networks (WBANs) are systems of sensors that operate and attached close to the patients' body, monitoring their vital signs and provides feedback to the hospital to help maintain a health-related statue [5]. This study mainly focuses on the comparison between Ad hoc On-demand Distance Vector AODV, Optimized Link State Routing OLSR and Dynamic Source Routing DSR mobile ad hoc networks MANETs routing protocols in a scenario of monitoring vital signs for an elderly patient in WBAN home health monitoring system using OPNET modeler 14.5 as our simulator. The reminder of this paper is organized as follows: In section II, we talk about WSN in medical application of health care systems, the wireless body area networks WBANs. In section III, we reviews the MANET routing protocols, which are used in the simulation, and exhibits the

specific requirements for implementing WSN in medical applications. In section IV, we describes the system model and the studied performance parameters. Finally, conclusion and future work are presented in section V.

2. Related Works

2.1 Wireless Sensor Networks in Health Care System

There's a huge difference between HCWSNs and other WSN technology applications [1], many requirements that HCWSN should mainly support; it can be divided into 5 main categories: Reliable data transmission, Energy saving, Multicasting, Supporting of nodes' mobility and Real-time data delivery. Sensors are scattered in the environment and they're expected to perform without maintenance; collecting data also depends on the location. Therefore, many researchers have focused on the routing protocols in which can give the best performance with low costs and it is easy to implement in the health-care network system. Wireless technologies are being developed to give new interfaces to the large and expensive medical machines and make them interact with any new machines and procedures required in medical field [6], one of these technologies is Wireless Body Area Network WBAN.

A WBANs enable monitoring an individual's health continuously in free living conditions [7], and provides a continuous health monitoring of a patient without any constraint on his/her normal daily life activities. Many technologies have proved their efficiency in supporting WBANs applications, such as remote monitoring, biofeedback and assisted living by responding to their specific quality of service (QoS) requirements [8]. However, WBANs consist of many inexpensive, lightweight, and miniature sensors attached to the patients' body, allowing them to conduct their daily lives , sensing and collecting their

vital signs such as Electrocardiogram ECG, Blood pressure etc.

These devices communicate with a special coordinator node, which is generally less energy constrained and has more processing capacities. It is responsible for sending biological signals of the patient to the medical doctor in order to provide real time medical diagnostic and allow him to take the right decisions [8]. WBANs are suitable for medical applications specially the case of elderly people at home because it's flexible, low power and have real-time wireless transmission capability.

Moreover, WBANs consist of three main tires communication: Intra-BAN communications, Inter-BAN communications and beyond-BAN communications [8]. Intra-BAN communications are the communications between wireless sensors which allocate on the patient body and the master node of the WBAN. Inter-BAN communications contains communications among the master node and personal devices in the environment such as notebooks, mobile phones and so on. The beyond-BAN tier connects the personal device to the Internet.

2.2 Routing Protocols in MANETs

A Mobile Ad-hoc Network MANET can be defined as a decentralized, infrastructure-less network that uses multi-hop radio relaying and self-organizing [9]. It also has many challenges such as the nodes' mobility, power consumption, high bit error rate and the narrow bandwidth, which need to be overcome especially in medical applications. Nodes are mobile, so the topology can be very dynamic in many situations. Routing Protocols describe the way in which nodes communicate and share data in the network by choosing the best route or the top best routes by a specific algorithm selected due to the protocol, MANET routing protocols categorized into three main classes: Proactive, Reactive and Hybrid protocols[10]. Proactive Protocols are table driven, which means each node share it's routing table with the other nodes. Therefore, it provides the required routes immediately when needed, at the cost of bandwidth and the network load because the frequent updates of the topology; some examples of the proactive protocols are: Optimized Link State Routing Protocol OLSR, Destination Sequenced Distance Vector DSDV and others [11]. While, Reactive protocols are on-demand protocols, which attempts to discover routes by flooding it's query in the network. This type of protocols reduces control traffic overhead, at the cost of increased latency in finding the route to a destination [11], and it's divided into source routing and hop-by-hop routing protocols such as Ad-hoc On-demand Distance Vector Protocol AODV, Dynamic Source Routing Protocol DSR and others. On the other hand, Hybrid routing protocols combines both proactive and reactive routing protocols, they are mostly used for hierarchal routing. The limitation of these protocols is that the nodes consume more memory and power, as they have to maintain high-level topological information. One example of these protocols is Zone Routing Protocol (ZRP) [9].

Therefore, to implement a health care WBAN we have to take into account its most important requirements in order to choose the most efficient routing protocol.

2.2.1 Optimized Link State Routing Protocol (OLSR)
OLSR is a proactive routing protocol, it performs hop by hop routing, i.e. each node uses its most recent information to route a packet [11]. Due to its proactive nature, this protocol has the route immediately available when needed. It also has many advantages; it reduces the size of control packets: instead of all links, it declares only a subset of links with its neighbors who are its multipoint relay selectors, and it minimizes flooding of this control traffic by using only the selected nodes, called multipoint relays, to diffuse its message in the network [11]. So that, using MPR reduces the number of duplicate retransmissions while forwarding a broadcast packet.

This protocol is particularly suitable for large and dense networks as the technique of MPRs works well in this context.

2.2.2 Ad-hoc On-demand Distance Vector (AODV)
AODV is an example of reactive protocols [12,13], which is on-demand acquisition system as the paths are created when required. It can determine multiple routes to the destination from the source but it's implemented by using only the shortest active route; and keep up a traditional routing table, that is, single entry per destination. AODV algorithm enables dynamic, self-starting, multi-hop routing between participating mobile nodes wishing to establish and maintain an ad-hoc network. It is considered as a hop-by-hop routing protocol which makes it suitable for the dynamic, large networks and the real-time based applications - as in medical situations - due to the continuous updating of nodes' routing tables. However, it adds load to the network because of the Hello messages between nodes.

2.2.3 Dynamic Source Routing (DSR)
DSR| protocol is another example of reactive protocols, which is on demand routing protocols in ad-hoc networks [14], that means whenever a source node needs a route to send its data the protocol's mechanism creates route for it. It's considered a Source Routing protocol, each sent packet contains full address from source to destination nodes and the relay nodes route the packets depending on the header's information of those packets, the source node can keep many routes to the destination.

It uses only less bandwidth in networks where the mobility is low [15]. DSR protocol minimizes the network's overhead due to its source routing nature. However, its performance becomes low in the large networks because of the huge number of the relay nodes which results increasing of the packet's overhead and increasing of the probability for route's failure.

2.3 Home health-monitoring requirements

Long-term health-monitoring requires intensive and repetitive assessment that could last for months or even years to regain the lost functions, such as in the case of

rehabilitation and elderly people health-monitoring [8]. It is really important to be careful when it comes to choose the most efficient MANET routing protocols in medical applications, which are supposed to support the medical WBAN requirements especially when used in Home Health-Monitoring systems for elderly person.

Therefore, there's several requirements have to be considered and taken into account during the implementation of the network, first of all the sensors should be implemented under the patient's skin on different parts of the body or can be wearable to form a WBAN each of them has specific requirements and is used for different missions as explained before. However, the most important requirements of the network are:

1) Real-time data delivery: In medical applications, especially when monitoring a health status for an old man, timing is considered as a very important parameter in the system in order to quickly send an ambulance to help him when an urgent situation happens. Therefore, wireless network reveals the caregivers real-time access to accurate patient data, clinical histories, treatments, medications, tests, lab results, insurance information, … etc [6].

2) Energy Efficiency: Sensors' battery life should also be taken into account in WSN because they're hard to be replaced when scattered in the environment. However, battery replacement in WBAN is easy and so there is less focus on power consumption, for some scenarios [8].

3) *Reliable communication*: It means the ability to send and receive different types of data in WBANs with a very low bit error rate. This parameter is very important in home health-monitoring system especially in emergent situations, and the efficient routing affects the reliability that lead us to choose the routing protocols carefully.

4) Device mobility: Both patients and caregivers are mobile, requiring that the communication layer adapt rapidly to changes in link quality [16]. In order to keep the network efficiency the selected routing protocol should be able to find new routes immediately. For example, when the doctor, the patient or the relay nodes moves at any speed.

5) Security: Security and privacy of patient's sensitive sensed data should be taken into consideration. Aside from that, Recent work on private-key and public-key cryptography schemes for sensor networks [17, 18] is applicable here, but must be integrated into an appropriate authentication and authorization framework [16].

6) IEEE standard: Sensor nodes often make use of ISM band, they also make use of the UWB band and ZigBee as per the IEEE 802.15 standard. WSNs tend to use license-free communication frequencies: 173, 433, 868, 915 MHz and 2.4 GHz [9]. In our studied scenario, it's better to use the IEEE 802.15.4 standard at home while use IEEE 802.15.6 standard at hospitals, because some researchers have found that packet losses for radios following the IEEE 802.15.4 standard is

higher in hospitals than other indoor environments [16]. Moreover, the devices that are susceptible to interference from WiFi networks, Bluetooth devices, and cordless phones usually use 802.15.4 radios and all of those interference-causes are heavily used in many hospitals.

3. System Model

In our studied scenarios, we've assumed a home monitoring system to an old aging patient, who's suffering from several health disorders, so he/she needs continuous monitoring and frequent check-ups on his/her vital signs such as: Body temperature, blood stress, heart rates, blood oxygen percent and .. etc. Therefore, the performance of MANET routing protocols have to be suitable and efficient to the network.

To form wireless body area network that is similar to the reality. We've formed a network consists of two basic parts; the first part of the network follows the MANET model which contains the wireless vital sensors that allocate on the patient body. The master node of the WBAN and several wireless mobile nodes in the environment that mainly backup with creating and forming the routes to the destination node to inform them with the vital sings of the patient or any other urgent states. The destination node could be a hospital, a responsible doctor or some nurses using the internet for example. The other part is a small model of UMTS cellular network, which supports Internet access through either GPRS or 3G.

After implementing the network, we've compared the performance of AODV, DSR and OLSR MANET routing protocols through implementing three scenarios varies only with the routing protocol.

4. Results and Analysis

4.1 Performance Metrics

We will demonstrate the different metrics used in our study in order to compare between the MANET routing protocols.
1) **Wireless LAN Throughput***:* The amount of correctly received data packets at the target node in a given period. It is generally measured in bits per second. The goal is to increase this value.
2) **Wireless LAN Delay***:* It is the time needed by the data packet to reach the destination when it's transmitted across a network. The lower the better this metric.
3) **Wireless LAN Load***:* It is defined as the extra time that it takes to transmit the data on a switched network. Some routing algorithms requires adding extra formatting information to the sent packets, which decreases the overall transmission speed of the raw data. We tend to make this parameter as low as we can.
4) **Total Packet Dropped***:* It is the difference between the total number of packets sent by the source and the total number of packets received at the destination. We aim to decrease the packet loss.
5) **Route Discovery Time***:* It is the time needed by the routing protocol to create the perfect route.

4.2 Simulation Environment and Setup

We have used in our research the OPNET modeler 14.5 in order to modeling different types of networks. This modeler has many features and the most important one is the wide database that includes various kinds of networks. Starting with the simple protected LANs to the third generation's cellular networks such as UMTS networks, as well as, its flexibility and smoothness especially in the field of protocols which was the basic reason to choose it as modeler in our study. It also provides support to the students' researches.
We have used some OPNET modeler tools like the Profile Configuration node and the Application Definition node and …. We have also assumed that there are four basic sensors allocated on the old-aged patient, which are:

1) **Temperature Sensor:** Which has been represented by a wireless mobile node uses File Transfer application and sends data each 20 minutes.
2) **Blood Pressure Sensor:** It has been represented by a wireless mobile node uses Video Conferencing application, thus it sends data each 10 minutes.
3) **Oxygen's Percent in blood Sensor:** This sensor node also has been represented by a wireless mobile node which uses Email application and sends collected data each 15 minutes.
4) **Patient's Hands shaking Sensor:** It's also been represented by a wireless mobile node and it uses Voice Over IP application, thus it sends its collected data each 30 minutes.

4.3 Simulation Results

To evaluate the different MANET protocols, several extensive simulations were conducted. We got the following results for the considered performance evaluation metrics.

1) Delay: Figure.1 Shows the Delay of three studied protocols and the comparison of them implies that delay is outrageous in AODV followed by DSR and OLSR, which have the lowest and most stable Delay in mobility.
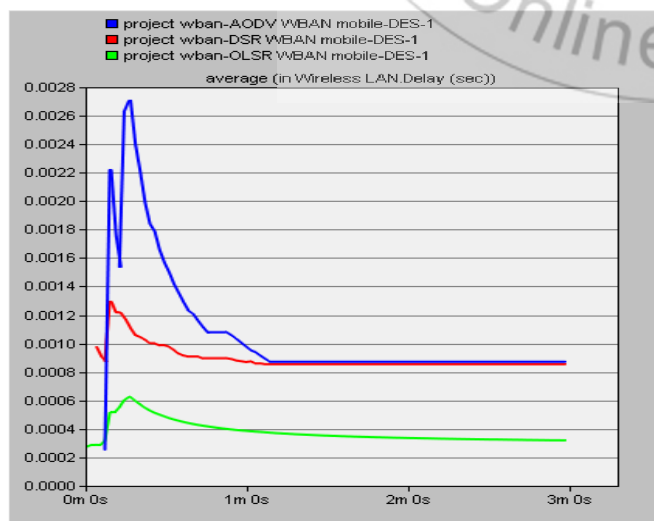

Figure 1: Delay of AODV, DSR and OLSR.

2) Load: Figure.2 exhibits the Load added to the network of implementing the three protocols, it's observed that OLSR has huge control load because of updating the routing table periodically so there's a lot of Hello messages to be sent among the different nodes in the network. Then AODV is slightly lower than DSR and OLSR because it has lower control overhead than the two other routing protocols, due to sending the Hello messages only when creating the routes.
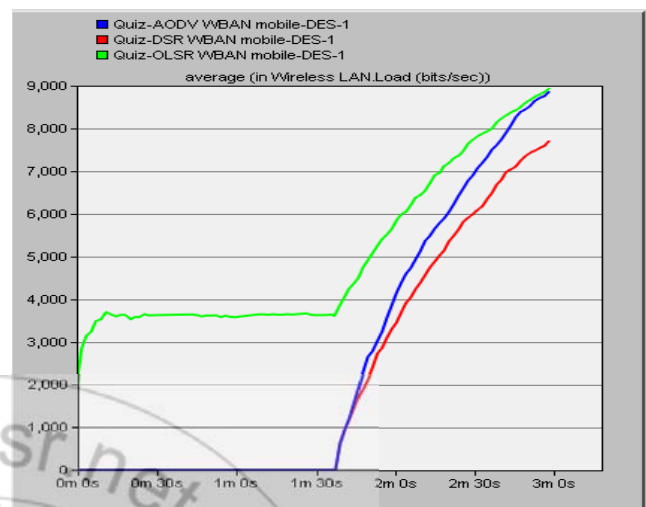

Figure 2: Load of AODV, DSR and OLSR.

3) Throughput: Figure.3 details the Throughput resulting from the three different protocols. We can notice that OLSR has the highest throughput comparing to AODV and DRR due to its proactive nature, while we see that DSR has the lowest throughput and that's because of its source-routing reactive nature which added an overhead to the sent packets and it's increasing with the number of nodes in the network.
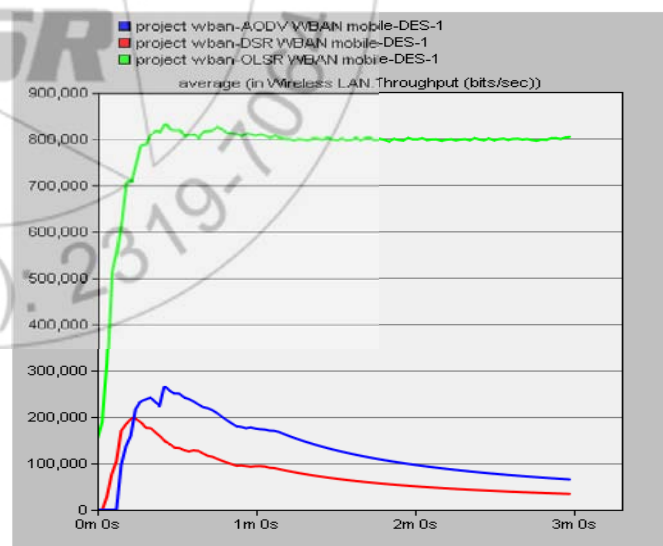

Figure 3: Throughput of AODV, DSR and OLSR.

4) Route Discovery Time: On the other hand, Figure.4 exhibits the Route Discovery Time of DSR and AODV, it's clearly observed that DSR needs more time than AODV to create the routes, it's because that AODV is hop-by-hop routing protocol and the nodes update its routing tables periodically.
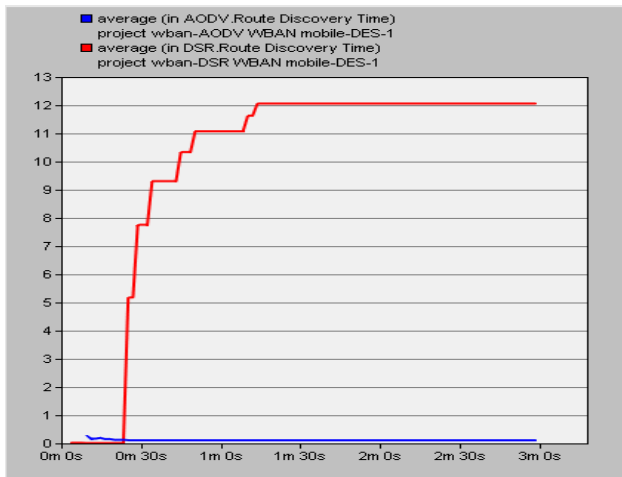
Figure 4: Route Discovery Time of AODV, DSR and OLSR.

5) Packet Dropped: Finally, Figure.5 Shows the Packet Dropped when the AODV and the DSR protocols are used, we can observe that theres many loss in packets in the case of using AODV protocol which is unacceptable in medical application.

5. Conclusion and Future Work

In this paper, we compare between different MANET routing protocols in medical WBAN applications for home monitoring system of elderly people, it's really important to receive the sensed data, by the responsible doctor or nurses, correctly and at real time especially when it comes to urgent and emergency situations. By studying the effects of implementing AODV, DSR and OLSR routing protocols in WBAN network, it is clear that AODV and DSR have less throughput and loads than OLSR, while OLSR adds a huge load to the network. On the other hand DSR has less packet dropped than AODV but it needs more time when discovering the routes. So that, when implementing such network it is better to use OLSR indoor because of its decreased delays due to its proactive nature, while using AODV outdoor when there's dynamic networks which have high nodes' mobility; or using DSR in the case of small networks which needs less packet losses.

As a future work, we plan to develop a hybrid protocol that give a best prrformance for real time home monitoring system of elderly people.
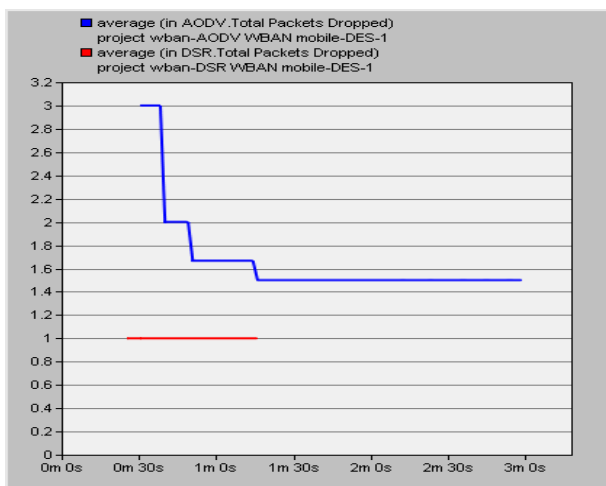

Figure 5: Packet Dropped of AODV, DSR and OLSR

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Author Profile

Mohammad Hamoud is currently a fourth-year student at the Biomedical Engineering Department at the Al-Andalus University- AlKadmous- Tatrtous, SYRIA.

Rita Hassoun is currently a fifth-year student at the Communication and Electronic section of Mechanical and Electrical Engineering Department, Tishreen University- Lattakia, SYRIA.

Ahmad Mahmoud is currently a fourth-year student at the Biomedical Engineering Department at the Al-Andalus University- AlKadmous- Tatrtous, SYRIA.

Mothanna Alkubeily is currently Assistant Professor in the Communication and Electronic section at Mechanical and Electrical Engineering Department, Tishreen University, Lattakia, SYRIA. He received the M.S. degree and PhD degree in Application-Level Multicast Protocols from the University of Technology of Compiegne (UTC, France) in 2006 and 2009 respectively. His research interest includes Wireless Sensor Networks, MANET, VANET and Application-Level Multicast.

Ahmad Sleiman Ahmad is currently Assistant Professor in the Biomedical Engineering Department at Al-Andalus University, Alkadmous, SYRIA.. He received the D.E.A. degree in Industrial Control System and Human from the Valenciennes University- France and the PhD degree in Electrical Engineering from Ecole Centrale de Lyon- France in 1992. His research interest includes Reliability, Modelling and Simulation in electrical engineering.