Pertanika J. Sci. & Technol. 26 (3): 1333 - 1354 (2018)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Protocols Performance Investigation using Ad Hoc WLAN for Healthcare Applications

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ABSTRACT

Medical emergencies are life-threatening situations which need immediate interventions. Response to such emergency situation will depend upon the resources available at that instant. A response time of any healthcare system will make a difference between life and death of a victim. In this work, the authors investigated the performance of various routing protocols for Ad Hoc network application in healthcare services for emergency situations where the data from the patients were collected via wearable devices. The comparison study is done to test the suitability of the Medium Access Control (MAC) protocols for such m-health applications established through an ad hoc network. The established network, however, diagnoses the patient's parameters on real-time basis and sends the data to the doctors and to a database within the hospital, which is constantly monitored, creating a virtual Intensive Care Unit (ICU) for a victim so as to address any abnormal behaviour during remote process. The proposed architecture was designed with the aim to manage emergency situations by reducing delays and increase the effectiveness of the patient monitoring mechanism in situations where the delay in providing medical aid to the patient maked a difference to his / her survival. To demonstrate the effectiveness of the study, an Electrocardiogram (ECG) pattern of a patient was monitored on real-time basis. A custom packet frame was designed for data transmission having a special field to store ECG data along with other general information as per the packet standards.

Keywords: Ad hoc network, ECG, healthcare system, MAC protocols, performance evaluation, telemedicine, WLAN

ARTICLE INFO

Article history:
Received: 29 December 2017
Accepted: 30 March 2018

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ISSN: 0128-7680

INTRODUCTION

In the past few decades the advancement in communication technology has helped health care professionals to adopt the technology available, making their routine job easier and safer. Although such technical advancements may be efficient, fast and easy to use, the reliability and fault-free services, along with adoption and getting used to such new technologies, especially for critical applications from a practitioner's point of view are some of the challenging issues. The impact of Internet growth in telemedicine advances is very significant. With networks having capabilities of packet switching, it's become possible for different types of data to be transmitted on a single transmission medium. While the US, European nations and other developed countries have such applications happening in actual practice, it still remains a mere concept for developing and underdeveloped nations. There are many reasons for this, such as financial support, lack of infrastructure and unavailability of technical resources, being some of them. In such limitations one can deploy or choose a network that is simpler and widely available in every part of one's country for one's healthcare applications. The capability of communication network can support healthcare applications in many areas, from information sharing to audio (tele-consultation), still images, video images database, vital signs (ECG: electrocardiogram, EEG: electroencephalogram) and reliability (Cicalo, Mazzotti, Moretti, Tralli, & Chiani, 2016). It is important to note that the reliability aspect of such critical applications is very important as it deal with the quality of service QoS assurance. Further, such work should demonstrate a quantitative reliability aspect and promise a better-quality assurance when supporting such lifesaving applications, as quality is perhaps the most important attribute in creating a trust of users for such healthcare services.

Taking into consideration the aspect of easy deployment and scalability in view of developing countries such as India, Wireless Local Network (WLAN) can be a better choice, which is based on IEEE 802.11 standard. WLAN provides mobility to its users within a few meters, which is suitable for scenarios where patient nodes are assumed to have mobility within the hospital premises (Batistatos, Tsoulos, & Athanasiadou, 2012; Koutsakis, 2017). For this application, the authors simulated WLAN Ad Hoc network where the patients served as the nodes of the network. Ad Hoc allows ease of data transfer by being an autonomous system, where every node is responsible for transmitting and receiving the desired data. Since we are considering a case of emergency where multiple new nodes need to be added to the network, Ad Hoc offers an advantage of quick adaptation to topology changes (Yadav, Agrawal, & Kashish, 2018). The authors used the structure of ECG packets to serve as the data packets in their simulated environment. As WLAN is chosen as the network in the paper, the authors aimed to analyse the performance of three routing protocols, Ad Hoc On-Demand Distance Vector (AODV), Destination-Sequenced Distance-Routing (DSDV) and Dynamic Source Routing (DSR) on different MAC protocols, IEEE 802.11-DCF (Distributed Coordination Function), Carrier Sense Multiple Access (CSMA), Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA) and their influence, application and suitability in remote healthcare services.

In this paper, first, general information about the wireless routing protocols, along with the various MAC protocols which are widely used has been introduced. This will give basic understanding to the reader to clearly know the performance of these protocols for the proposed application. The next section presents the proposed network architecture and its simulation framework. Further, the parameters on which the three protocols are evaluated are highlighted, followed by the simulation results and discussions. Finally, conclusions are drawn in the last section.

WIRELESS ROUTING PROTOCOLS IN AD HOC NETWORKS

The major categories of WLAN networks can be chalked up to two types - infrastructure-oriented and Ad Hoc Networks or infrastructure-less (Vetrivelan & Reddy, 2008). In infrastructure-oriented networks, nodes are always connected to an access point which acts as a central point. Meanwhile, in Ad Hoc networks, the mobile nodes create a decentralised network, without the need of a central node (Perkins & Watson, 1994). The pattern of the network changes with the change in routing table, which is done according to the requirement of the application.

Even though infrastructure-based networks outperform Ad Hoc network in efficiency, however, when additional nodes (or emergency case patients in the case of this study) are to be added immediately, infrastructure based network will fail to provide such support. Hence, in this paper, the authors decided to keep the focus on Ad Hoc networks for implementing the desired patient monitoring system. Routing protocols in Ad Hoc networks are further classified into three categories: Table Driven, On Demand and Hybrid (Subramanya, Shwetha, & Devaraju, 2012; Kim, Moon, Cho, 2009; Mbarushimana & Shahrabi, 2007; Toh, 2002; Corson & Macker, 1999).

Table-Driven routing protocols have the characteristic feature of the routing tables which are updated periodically on the information of the nodes within the network (Abolhasan, Wysocki, & Dutkiewicz, 2004). On-demand Routing Protocol decides the route on the basis of the demand response that it obtains after the entire network is flooded by Route Request Packets (RRPs). The combination of the best features of these two protocols, known as the hybrid protocol is presented in Mbarushimana and Shahrabi (2007) and Subramanya et al (2012). The routing protocols discussed in this paper are AODV, DSDV and DSR, while AODV and DSR are examples of On-Demand, and DSDV is an example of Table-Driven routing protocol (Royer & Toh, 1999).

Ad Hoc On-Demand Distance Vector

The primary feature of Ad-Hoc On-Demand Distance Vector (AODV) protocol is the routing tables, which give continuous updates to design the desired routes (Corson & Ephremides, 1995; Perkins & Watson, 1994). These tables have updated information about the active nodes in the network. This is done with the use of messages such as route request (RREQ), route reply (RREP) and route error (RRER) (Liu, Yang, & Wang, 2013). The changes in network configuration (topology) are periodically detected via the table and the route designing is done accordingly. In AODV, the route of packet (information) between two nodes is initiated only by exploring the best possible route, taking into consideration the information about other nodes from the table.

Destination-Sequenced Distance Vector

Destination-Sequenced Distance vector (DSDV), often defined as an advancement of the classical Bellman-Ford Routing Algorithm is a source-initiated protocol, that is, a route is designed after a source requests the path discovery to a fixed destination in the network (Ford

& Fulkerson, 1962). It is a hop to hop protocol (Perkins & Watson, 1994). Every individual node maintains a table continuously with information regarding the next hop and the number of hops to all its neighboring nodes and the nodes that it can access. DSDV solves the problem of routing algorithm problem in networks.

Dynamic Source Routing

Dynamic Source Routing is an "on-demand" routing protocol, that is, the path discovery is only done when a source responds to any of the RRPs that flood the network periodically with a request for path to any destination in the network. DSR is self-organised and self-configuring, since it eliminates the need for both infrastructure and monitoring (Johnson & Maltz, 1996). The senders under DSR protocols are aware of the entire hop-to-hop route to the destination (Basavaraju, Sarkar, & Puttamadappa, 2006).

MEDIUM ACCESS CONTROL PROTOCOLS METHODOLOGY OVERVIEW

IEEE 802.11-Distributed Coordination Function (DCF)

802.11 MAC is one of the distributed Wireless MAC protocols and specifies two modes: Distributed Coordination Function (DCF) and Point Coordination Function (PCF). DCF, used for ad-hoc purposes, is a distributed algorithm, where all the nodes run the algorithm individually, whereas PCF needs an infrastructure to operate as an access point runs the centralised algorithm (Youssef, Vasan, & Miller, 2002). The DCF mode of 802.11 is a Carrier Sense Multiple Access (CSMA) with Collision Avoidance type protocol and is often referred to as a combination of the CSMA and Multiple Access with Collision Avoidance (MACA) schemes (Basavaraju et al., 2006).

In DCF protocol, the sender node senses the medium to check if another node is transmitting currently. If the medium is found to be free, the node waits for varying DCF Interframe (DIFS) Space time slots. If the medium is available for the decided time slot, the node transmits the data; lest a back-off process is enabled where the node waits till the current transmission is complete.

Carrier Sense Multiple Access (CSMA)

CSMA is the simplest and earliest of the MAC protocols. Operating on CSMA, the sender node senses the medium to check if it is available. If it is not, it waits for a random time period and then attempts again. If the medium is free the transmission of data is performed by the sender node.

Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)

An enhanced version of CSMA, is CSMA Collision Avoidance (CSMA/CA), the node listens to the medium for a specified period of time and transmits the data packets only when the medium is checked to be idle. The receiver node is programmed to send an acknowledgement

'ACK' to the sender. If no such acknowledgment is received, the packet is assumed to be lost and another transmission takes place.

PROPOSED NETWORK ARCHITECTURE FOR HEALTHCARE MONITORING USING WLAN

Attributable to WLAN's limited range coverage and mobility, an indoor scenario of a hospital is assumed. As in Figure 1, each patient is provided a unique ID tag. This helps in maintaining and retrieving the patient's data efficiently. Various forms of patient data, such as ECG records, scanned images, and patient vitals (blood pressure, oxygen saturation level, heart rate) are stored into the database whenever required. This database ensures smooth contact between patients' data collection and providing this data to the nurse stations or to the doctor concerned at any moment in time. The transmission of data uses routing protocols depending on the requirements of the particular data type which will be discussed in this paper. In the implementation of the scenario, the authors assumed the patients as nodes in a network design, which transmit ted data to a central database which could be accessed by doctors as well as nurse stations for regular monitoring and emergency situations. For the purpose of simplicity, the authors took only one parameter, ECG of the patient that was supposed to be sampled and transmitted from the patient's device. For accurate data samples, actual ECG data samples available on online database were used.

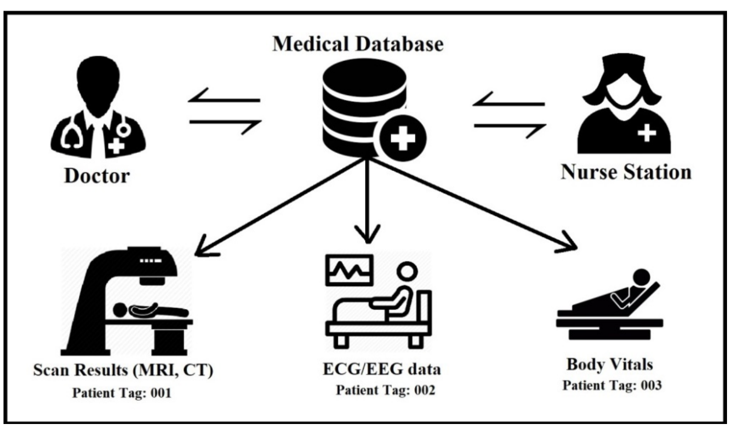

Figure 1. System architecture for proposed scenario

It is important for any support system to have the flexibility of scaling based on the need. The proposed system/framework can be scaled by adding additional nodes representing a situation where there is a large number of patients. Such situation can very well envisage in case of disaster management where the size of the network is not known. In such situation, the patients can be added to this Ad Hoc network and the vital parameters can be transferred to the main hospital or control stations for possible diagnosis of the disease and course of action. The suggested framework can be an effective solution in such cases where it is difficult to carry all the equipment or staff. A virtual ICU or hospital can be formed to provide medical help to critical patients and could save lives of many patients. Through this, one can also minimise the delays caused by taking up the vital parameters of the patients physically.

Table 1
WLAN Properties

Technology	Frequency	Range	Upstream	Downstream
OFDM/MIMO	5, 2.4 GHz	30m	54 Mbps	54 Mbps

Note: Adapted from Standards ISO/IEEE (2008)

PERFORMANCE METRICS OF ROUTING PROTOCOLS

The evaluation of the performance of the three routing protocols was done on the basis of the following parameters:

Packet Delivery Ratio

Packet Delivery Ratio (PDR) is the number of packets successfully received by the receiver (R_i) over a number of packets sent by the source node (S_i) (Tamilselvan & Sankaranarayanan, 2007). It measures the reliability of the routing protocols. The packet delivery ratio of channel is N and i represents sequence number.

$$\text{Packet delivery ratio} = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{R_i}{S_i}\right)$$

Throughput

Throughput means the total number of bits transferred (B_i) over the receiver in per unit time (T_i). The capacity of the channel depends upon the throughput. The throughput capacity of the channel is N and i represents sequence number.

$$\text{Throughput} = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{B_i}{T_i}\right)$$

Average End-to-End Delay

It defines the total delay (D_i) over number of packets received by a receiver (S_i). Average end-to-end delay defines the average time taken by the packets to reach the receiver. Average end-to-end delay includes time like transmission queuing, processing, propagation delay, the lesser the E2E delay, the better is the performance of routing protocol. The average end-to-end delay with channel capacity is N and i represents sequence number.

$$\text{Average End to End delay} = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{D_i}{S_i}\right)$$

SIMULATION ENVIRONMENT

Simulation Model

In order to conduct the Performance Comparison of AODV, DSDV and DSR for different MAC protocols, the authors used the open source Network Simulator (NS2) for the simulation purpose. NS2 is a discrete network simulator that simulates the behaviour of both types of routing protocols wired and wireless networks for both single hop and multi-hop (Kaur, Kaur, & Mahajan, 2017; Chen, Yang, & Huang, 2016; Breslau et al., 2000). In this work, simulations were done by two types:

Scenario 1: In the first scenario, the simulations are based on keeping the speed of the node constant and varying the number of nodes (network size), The network size is increased from 30 to 50 to study the scalability of the routing protocols. This will give a better insight into the conduct of routing protocols for large, medium and small networks. This represents the variation in the number of patients at a particular instant within the hospital being monitored.

Scenario 2: In the second case, the simulations are carried out by keeping the number of nodes constant and varying the speed of the nodes (varying traffic), that is, if the patient is moving. The speed of the nodes is varied with pause times of 5 ms, 10 ms and 20 ms. Mobility enables us to study how the protocol performs in dynamically evolving networks.

Figure 2(a). Network setup

Figure 2(b). Network simulation (Scenario-1)

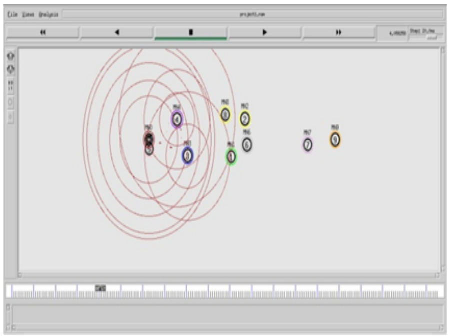

Figure 2(c). Network simulation (Scenario-2)

Figure 2(a), 2(b) and 2(c) show the setup and the simulation of the network in NS2. The figures also show the movement of nodes before and after simulation.

The Test scenarios of varying nodes and speed were applied to the three MAC protocols to evaluate their performance on varying network environment. In this work, the authors considered the simulation area 900 m x 900 m.

Simulation Parameters

For the simulation, the authors took the data to be ECG packets. An ECG packet, as shown in Figure 3, is made of the IP header (20 bytes), UDP header (12 bytes), RTP header (8 bytes) and the ECG data.

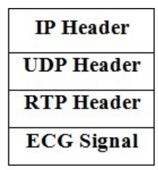

Figure 3. ECG Packet

National Institute of General Medical Sciences (NIGMS) and the National Institute of Biomedical Imaging and Bioengineering (NIBIB) have provided various ECG records ("Apnea-ECG Database", 2017); the authors considered record 'apnea ecg/a01' with some of the data values available in Table 2. The range of the ECG samples in this record varies from -0.885mV to 1.75mV. In this work, the data is taken as the ECG payload or symbols. To represent these values in a packet, a maximum of 12 bytes of data is enough.

Table 2
ECG data records

Time Elapsed (min)	ECG Values (mV)
0:00.000	-0.06
0:03.770	1.7
0:06.540	0.35
0:13.930	-0.035
0:18.990	0.045
0:26.090	-0.885
0:26.870	1.75
0:29.740	-0.025
0:35.700	-0.075
0:49.100	-0.02
0:52.960	-0.005
0:57.180	-0.135
0:59.750	-0.235
0:59.780	1.18
0:59.990	0.09

Hence, for the simulation scenario, packet size as 52 bytes was selected, its headers occupying 40 bytes and 12 bytes of ECG message. In the simulation, the authors streamed ECG signals (10,000 per node) for over an hour. The total ECG packets varied with the number of nodes active in the scenario.

Table 3
Simulation parameters

Parameter Name	Propagation	Simulator and Version	Packet Size	Antenna	Link Layer	Routing Protocols	Performance Parameters
Parameter Value	Two Ray Ground	NS2 (NS-allinone-2.35)	52 bytes (40 bytes headers; 12 bytes ECG symbol)	Omni Antenna	LL	AODV, DSDV, DSR	Packet Delivery Ratio, Throughput, End-to-End Delay

SIMULATION RESULTS AND DISCUSSION

The value of simulated parameters was obtained for two cases – for varying nodes and speed. The simulated results show that the performance of the three protocols varies with respect to changes in the number of nodes or speed of the nodes for the different MAC protocols.

This variation in nodes and speed reflects are associated with the variation in the number of patients connected and the mobility of the users in the network. These two variations mimic the real scenario in terms of usage where the patient/practitioner/staff is added or taken off from the network or they are on move. The objective is to simulate the study on these practical aspects of the usage so as to suggest a routing protocol which is best suited to transmit the data for such applications. Addressing these two issues in the system leads to saving of time in pre-operative and vital sign collection, which is the necessary and basic step for extending any medical aid to the patient.

The performance parameters for AODV, DSDV and DSR protocols with different MAC protocols are presented in the following sub-sections.

Packet Delivery Ratio

Figure 4(a) shows the Packet delivery ratio of AODV, DSDV and DSR for MAC 802.11-DCF when number of nodes are varied.

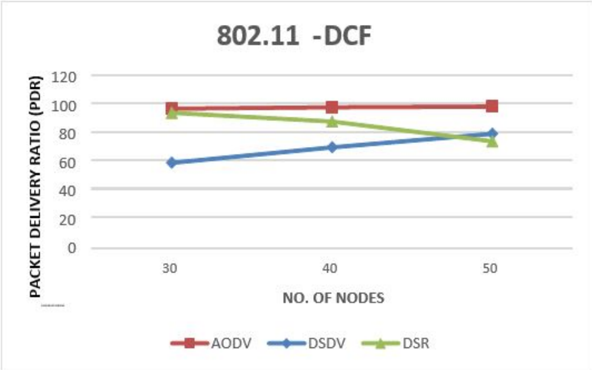

Figure 4(a). Packet delivery ratio over MAC 802.11-DCF with varying number of nodes

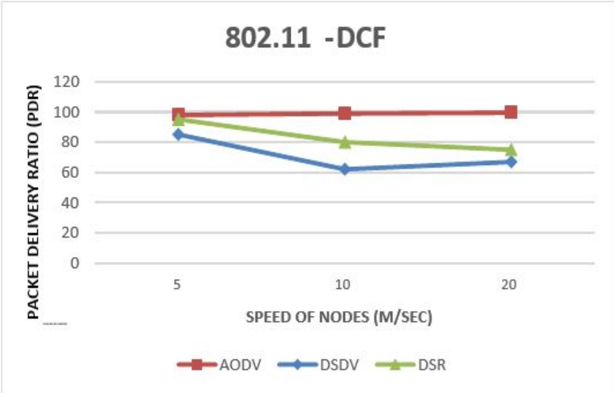

Figure 4(b). Packet delivery ratio over MAC 802.11-DCF with varying speed of nodes

Figure 4(b) shows the PDR, when the speed of the nodes is varied. AODV performs uniformly across both, increasing the speed and number of nodes and outperforms over other two protocols while DSR shows a better performance than DSDV. However, it shows a non-uniform behaviour with variations of speed and number of present nodes.

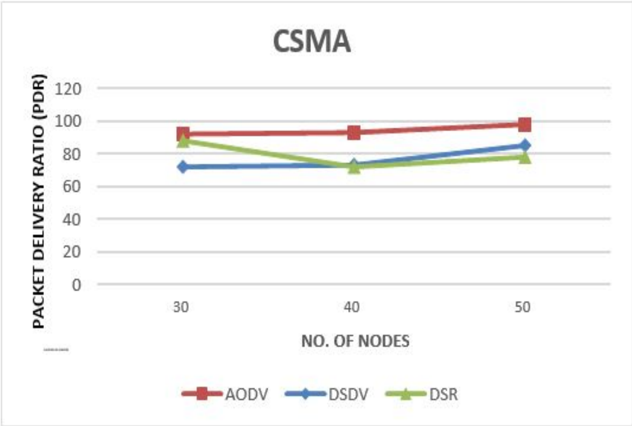

Figure 5(a). Packet delivery ratio over MAC CSMA with varying number of nodes

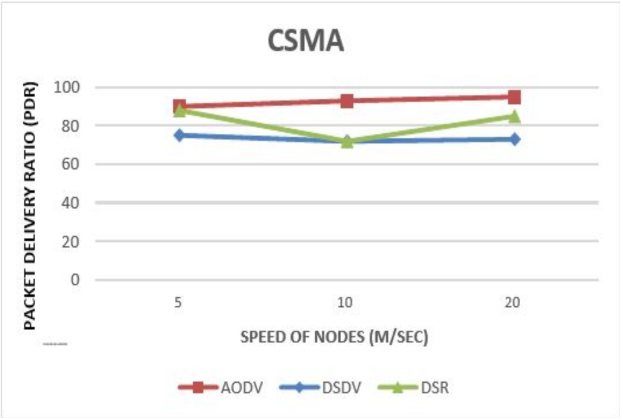

Figure 5(b). Packet delivery ratio over MAC CSMA with varying speed of nodes

Figure 5(a) shows the packet delivery ratio of DSR, AODV and DSDV for MAC CSMA when the numbers of nodes are varied and Figure 5(b) shows the same, when the speed of the nodes is varied. Similar to the case of 802.11-DCF, when run over CSMA, AODV shows a higher value of Packet Delivery Ratio (PDR) constantly than DSDV and DSR.

Figure 6(a) shows the result of PDR of DSR, AODV and DSDV when ran over MAC CSMA-CA when the number of nodes are varied and Figure 6(b) is the PDR performance of the routing protocols when the speed of the nodes is varied. AODV, similar to the other two MAC shows a uniformly good performance on CSMA/CA as well for varying nodes and speed. However, here DSR also shows a much better performance than other MAC protocols and clearly outperforms DSDV and even AODV for certain scenarios.

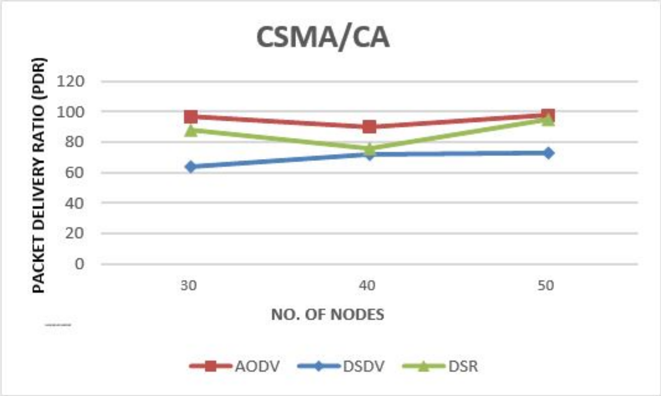

Figure 6(a). Packet delivery ratio over MAC CSMA/CA with varying number of nodes

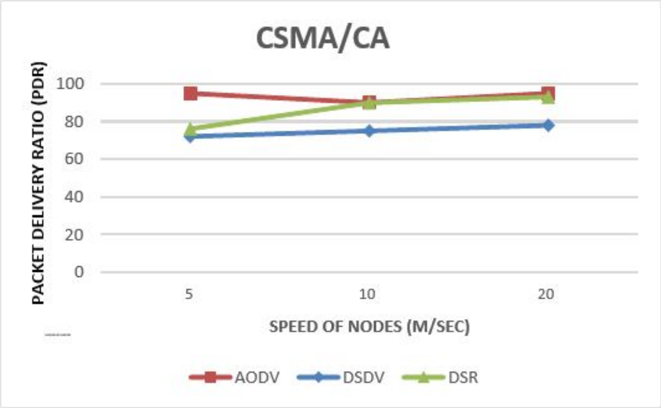

Figure 6(b). Packet delivery ratio over MAC CSMA/CA with varying speed of nodes

Throughput

From Figure 7(a) and 7(b), it is noticed that the throughput of AODV is significantly higher and reliable compared to DSR and DSDV. However, throughput of AODV almost remains constant except that it is decreased, when either the number of nodes or speed of nodes is increased to high values.

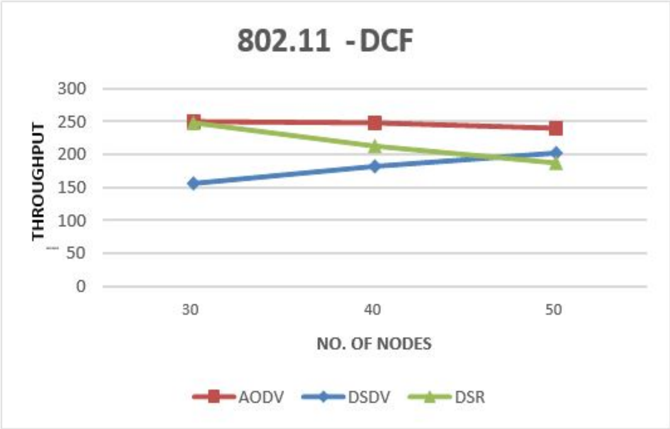

Figure 7(a). Throughput over MAC 802.11-DCF with varying number of nodes

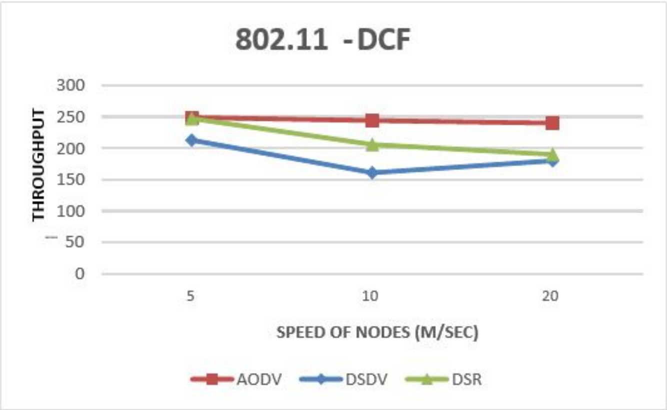

Figure 7(b). Throughput over MAC 802.11-DCF with varying speed of nodes

The throughput of DSR demonstrates a performance, although not as good as AODV but better than DSDV over 802.11-DCF. The throughput of DSDV increases with increase in the number of nodes. Further, it lowers with increase in the speed of nodes. It is observed that AODV has better throughput performance up to even 77.09% than DSDV in the case of varying network size.

In case of CSMA as observed from Figure 8(a) and Figure 8(b) and CSMA/CA as seen in Figure 9(a) and Figure 9(b), the performance of the protocols somewhat remains the same as the PDR performance with AODV outperforming others and with DSR performing better than DSDV.

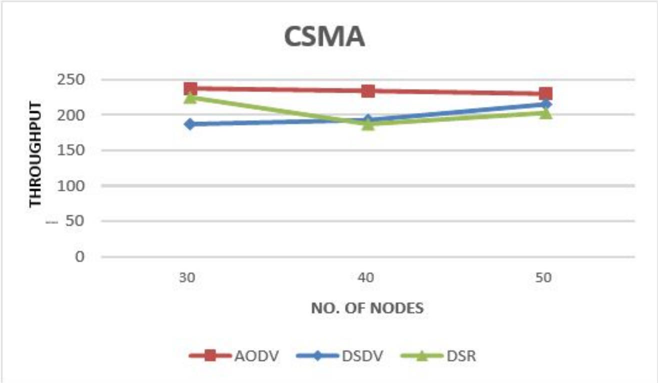

Figure 8(a). Throughput over MAC CSMA with varying number of nodes

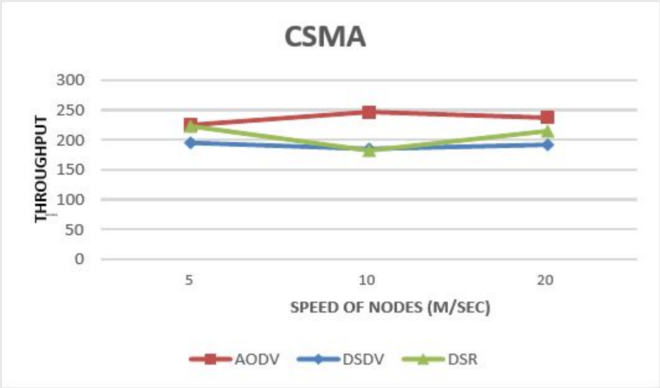

Figure 8(b). Throughput over MAC CSMA with varying speed of nodes

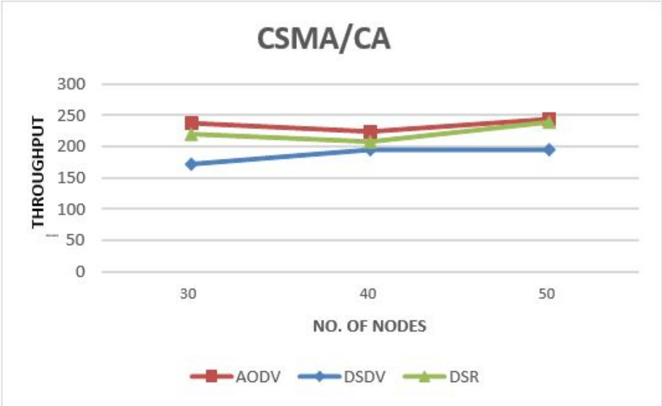

Figure 9(a). Throughput over MAC CSMA/CA with varying number of nodes

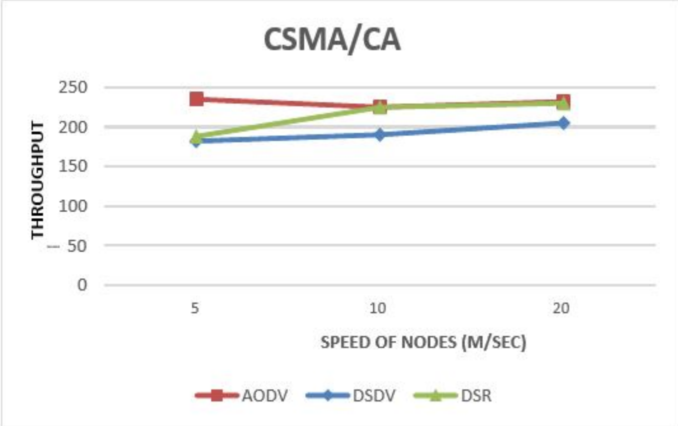

Figure 9(b). Throughput over MAC CSMA/CA with varying speed of nodes

Based on the above, it reflects that AODV is suitable in emergency cases, showing better throughput performance than DSR and DSDV.

End-to-End Delay

End-to-End delay of AODV and DSDV is calculated as shown in Figure 10(a), when the number of nodes is varied. Figure 10(b) represents the calculation of end-to-end delay of AODV and DSDV, when the speed of the nodes is varied over MAC 802.11-DCF. Due to the provision of maintaining a route only when its activity level is high, AODV suffers from the least end-to-end delay than DSR and DSDV. In case of MAC 802.11-DCF, DSR performs much better than DSDV by establishing the source-destination route much more efficiently.

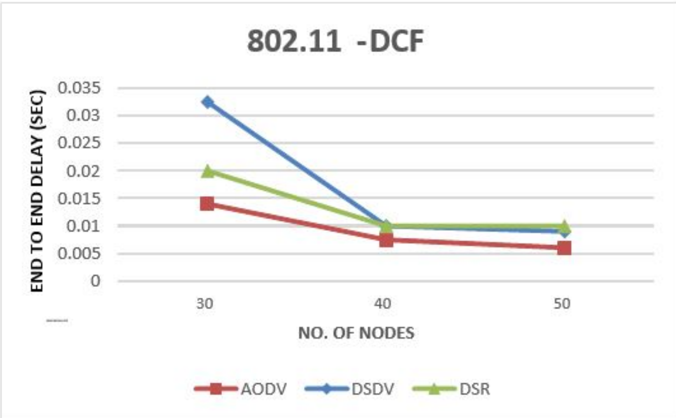

Figure 10(a). End-to-End Delay over MAC 802.11-DCF with varying number of nodes

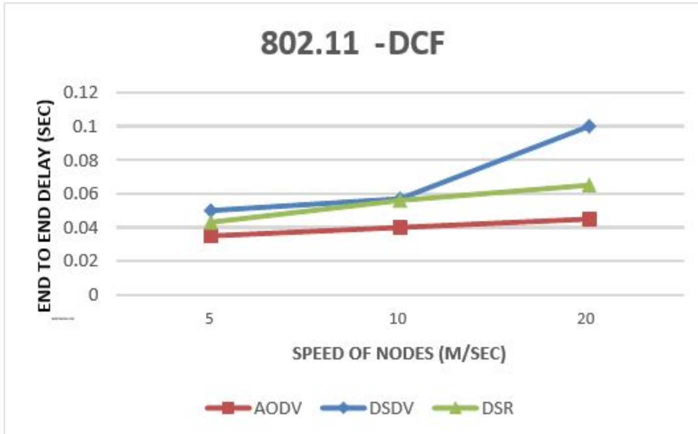

Figure 10(b). End-to-End Delay over MAC 802.11-DCF with varying speed of nodes

Figure 11(a) and 11(b) are the End-to-End Delay performance of the routing protocols over MAC CSMA with varying number of nodes and speed of nodes respectively. In both the cases, the performance of AODV is recorded as much better than DSDV and DSR with DSR depicting an inconsistent behaviour with changing cases.

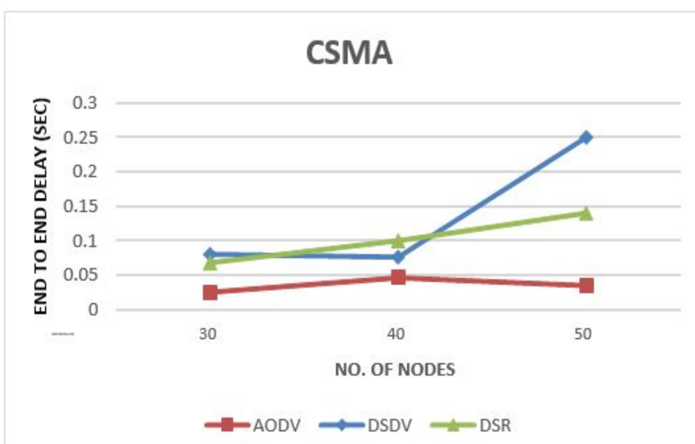

Figure 11(a). End-to-End Delay over MAC CSMA with varying number of nodes

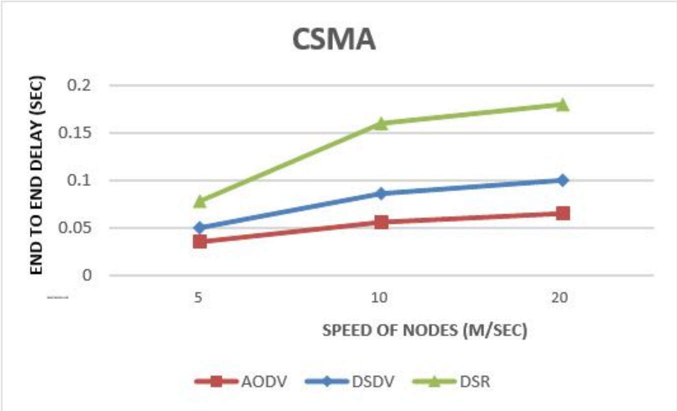

Figure 11(b). End-to-End Delay over MAC CSMA with varying speed of nodes

Meanwhile, when ran over MAC CSMA/CA as in Figure 12(a) and Figure 12(b), DSR outperforms the other two protocols with AODV as the second-best choice.

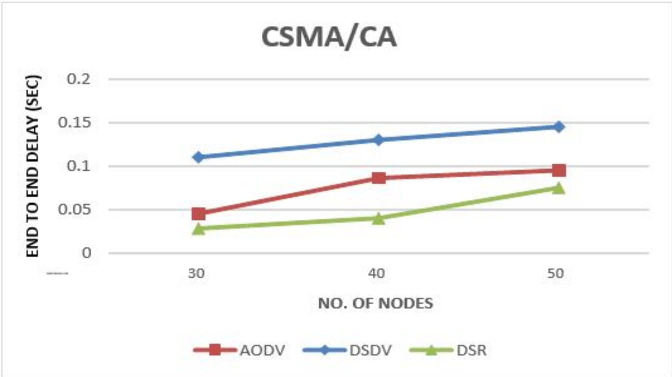

Figure 12(a). End-to-End Delay over MAC CSMA/CA with varying number of nodes

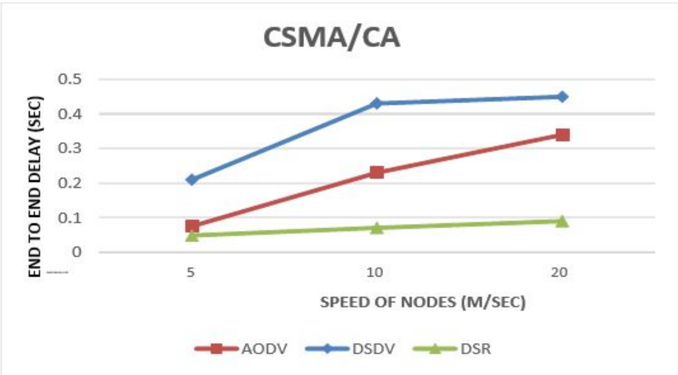

Figure 12(b). End-to-End Delay over MAC CSMA/CA with varying speed of nodes

Table 4
Parameter values using 802.11 DCF

Parameter Values by Varying Number of Nodes				Parameter Values by Varying Speed of Nodes			
Parameter Measured	Packet Delivery Ratio	Throughput	End-to-End Delay (sec)	Parameter Measured	Packet Delivery Ratio	Throughput	End-to-End Delay (sec)
AODV				AODV			
30 Nodes	100	250	0.014	5mps	99	250	0.035
40 Nodes	102	250	0.0075	10mps	101	246	0.04
50 Nodes	100	242	0.006	20mps	100	242	0.0425
DSDV				DSDV			
30 Nodes	60	155	0.0325	5mps	82	214	0.05
40 Nodes	72	181	0.01	10mps	60	157	0.06
50 Nodes	80	203	0.008	20mps	67	180	0.1
DSR				DSR			
30 Nodes	97	250	0.02	5mps	96	247	0.0435
40 Nodes	91	211	0.01	10mps	80	208	0.06
50 Nodes	77	182	0.009	20mps	76	192	0.062

Table 5
Parameter values using CSMA

Parameter Values by Varying Number of Nodes				Parameter Values by Varying Speed of Nodes			
Parameter Measured	Packet Delivery Ratio	Throughput	End-to-End Delay (sec)	Parameter Measured	Packet Delivery Ratio	Throughput	End-to-End Delay (sec)
AODV				AODV			
30 Nodes	94	234	0.03	5mps	90	225	0.04
40 Nodes	95	234	0.05	10mps	92	251	0.05
50 Nodes	99	227	0.042	20mps	97	242	0.063
DSDV				DSDV			
30 Nodes	70	181	0.084	5mps	78	248	0.05
40 Nodes	72	193	0.075	10mps	76	239	0.08
50 Nodes	85	214	0.25	20mps	77	248	0.1
DSR				DSR			
30 Nodes	85	223	0.064	5mps	88	224	0.075
40 Nodes	72	188	0.1	10mps	72	237	0.17
50 Nodes	79	200	0.14	20mps	83	216	0.18

Table 6
Parameter values using CSMA/CA

Parameter Values by Varying Number of Nodes				Parameter Values by Varying Speed of Nodes			
Parameter Measured	Packet Delivery Ratio	Throughput	End-to-End Delay (sec)	Parameter Measured	Packet Delivery Ratio	Throughput	End-to-End Delay (sec)
		AODV				AODV	
30 Nodes	98	242	0.048	5mps	97	241	0.08
40 Nodes	92	224	0.08	10mps	90	225	0.22
50 Nodes	101	247	0.094	20mps	93	228	0.32
		DSDV				DSDV	
30 Nodes	64	172	0.116	5mps	73	181	0.205
40 Nodes	76	192	0.182	10mps	75	189	0.424
50 Nodes	76	196	0.148	20mps	79	206	0.45
		DSR				DSR	
30 Nodes	86	223	0.03	5mps	76	183	0.052
40 Nodes	78	202	0.038	10mps	90	225	0.08
50 Nodes	99	243	0.077	20mps	93	227	0.097

Table 4, 5, and 6 sum up the parameter values obtained in the previous section using 802.11-DCF, CSMA and CSMA/CA.

Thus, AODV and DSR are two best choices when End-to-End performances of the routing protocols are considered over three different MAC protocols with DSR giving an exceptional behaviour on CSMA/CA and AODV when ran on 802.11-DCF and CSMA.

CONCLUSION

The performance investigation study of three routing protocols, AODV, DSDV and DSR, over the various types of MAC protocols, namely 802.11-DCF, CSMA and CSMA/CA was carried out. The potential of Wireless Local Area Network in telemedicine applications was discussed based on QoS parameters of the three Ad Hoc WLAN protocols on the basis of their end to end delay, throughput and packet delivery ratio behaviour. To demonstrate the efficacy of these protocols, an ECG data packet is taken as the sample data to be transferred. The performance evaluation of AODV, DSDV and DSR was carried out by varying the network size along with mobility of user (node) to mimic an actual hospital scenario, where the practitioners and patients are supposed to be mobile and their numbers are variable. The results show that over IEEE 802.11- DCF and MAC CSMA, AODV exhibit almost constant behaviour and a better performance than the other two protocols in terms of throughput when the number of nodes and mobility rates are varied. However, DSR shows better performance in End-to-End delay and packet delivery ratio. It is important to note that in telemedicine application minimisation of patient delay and packet loss is an important aspect for effective and successful transmission of medical data.

Hence, it can be concluded and suggested that AODV and DSR should be the preferred protocols as they show better performances than DSDV routing protocol for the proposed applications. However, further studies with large number QoS parameters and high level of scalability ratio will be useful with other MAC protocols.

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