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Quality of Service Analysis in Wireless Sensor Networks for Peer to Peer Topology

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Abstract

IEEE 802.15.4 is the emerging next generation standard designed for low-rate wireless personal area networks (LR-WPAN). The popularity of Wireless Sensor Networks (WSN) have increased tremendously in recent time due to growth in Micro-Electro-Mechanical Systems (MEMS) technology. WSN has the potentiality to connect the physical world with the virtual world by forming a network of sensor nodes. The work reported in this paper provides performance evaluation of quality of service parameters for WSN based on IEEE 802.15.4 peer to peer topology. The performance studies have been evaluated for varying traffic loads using MANET routing protocol in QualNet . The data packet delivery ratio, average end-to-end delay, total energy consumption, network lifetime and percentage of time in sleep mode have been used as performance metrics. Simulation results show that DSR (Dynamic Source Routing) performs better than DYMO (Dynamic MANET On-demand) and AODV (Ad–hoc On demand Distance Vector) routing protocol for varying traffic loads rates.

Keywords: Wireless Sensor Networks (WSN), Ad-hoc On Demand Distant Vector (AODV), Dynamic Source Routing (DSR), Dynamic MANET on demand (DYMO), Quality of Service (QoS).

Introduction

The term ―QoS is used in different meanings, ranging from the user‘s perception of the service to a set of connection parameters necessary to achieve particular service quality. ITU-T (Recommendation E.800 [ITU-TE.800]) and ETSI [ETSI-ETR003] basically defines Quality of Service (QoS) [14] as ―the collective effect of service performance which determines the degree of satisfaction of a user of the servic. The goal of QoS provisioning is to achieve a more deterministic network behaviour so that information carried by the network can be better delivered and network resources can be better utilized. Moreover, certain service properties such as the delay, reliability, network lifetime, and quality of data may conflict by nature. For example, multi-path routing can improve the reliability. However, it can increase the energy consumption and delay due to duplicate transmissions. The high resolution sensor readings may also incur more energy consumptions and delays. Modeling such relationships, measuring the provided quality and providing means to control the balance is essential for QoS support in WSN [15].

The rest of the paper is organized as follows. In Section II, we present the Challenges for QoS Support in WSNs and Parameters Defining WSN QoS. Section III presents a survey on various MANET reactive routing protocols. Section IV presents the related work. We present simulation setup and performance metrics in section V. In section VI we present simulation result using Qualnet network simulator. Finally section VII concludes the paper.

Challenges for QoS Support in WSNs and Parameters Defining WSN QoS

WSNs inherit most of the QoS challenges from general wireless networks, their particular characteristics pose unique challenges as follows [**16**].

Severe resource constraints*:* The constraints on resources involve energy, bandwidth, memory, buffer size, processing capability, and limited transmission power.

Data redundancy*:* WSNs are characterized by high redundancy in the sensor data.

Scalability*:* A wireless sensor network usually consisting of hundreds or thousands of sensor nodes densely distributed in phenomena

Network dynamics*:* Network dynamics may arise from node failures, wireless link failures, node mobility, and node state transitions due to the use of power

Packet criticality: The content of data or high-level description reflects the criticality of the real physical phenomena with respect to the quality of the applications.

The QoS service parameters used in traditional wired networks are throughput, reliability, delay and jitter. Security and mobility are essential in any wireless network, while data accuracy is especially relevant to the WSNs. The Network lifetime is usually shortened by decreasing latency or increasing any of the other parameters which affects energy consumption of WSN nodes in terms of processing, transmission and reception of data packets. The QoS parameters for WSN as given in [**4**] are Data accuracy, Energy usage, Reliability Latency, Security, Mobility, Throughput ect.

MANET Reactive Routing Protocols

Ad-hoc On-demand Distance Vector Routing (AODV)

Ad–hoc on demand distance vector routing (AODV) is a stateless on-demand routing protocol [**17**]. It establishes routes on as desired by a source node, using route request (RREQ) and route reply (RREP) messages. When the source node needs a route to another node, it broadcasts a RREQ message with a unique RREQ identification number. The message will reach the neighbouring nodes, which will update the sequence number for this source node. At same time, each neighbour node can also set up a reverse route to the source node in the routing table. Under the following two conditions, the neighbour node that receives a RREQ will send back a RREP to the requesting source node: (1) The neighbour node is the destination node. (2) The node has a route to the destination node that meets the freshness requirement specified in the RREQ message.
Figure 1 shows the process of signals with AODV from node 1 to node 8.

Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) [**19**] is an on demand reactive routing protocol based on the concept of source routing . That is, the sender knows the complete hop-by-hop route to the destination for data packets to be transverse in the whole network. These routes are stored in a route cache. The data packets carry the source route in the packet header. The nodes can dynamically discover a source route across multiple network hops to any destination in the network. This makes the network completely self-organizing and self-configuring without the need for a network infrastructure or administration. DSR protocol is composed of two mechanisms: route discovery and route maintenance.

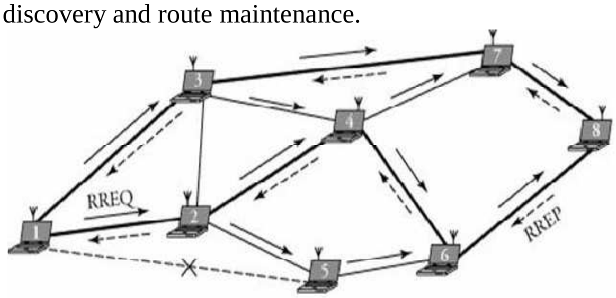

Figure 1: AODV Communication signaling from node 1 to node 8 [18]

Figure 2 shows an ad-hoc wireless network with eight nodes and a broken link (3-7). Node 1 wants to send a message to the destination, node 8 using DSR routing protocol.

The Dynamic MANET On-demand (DYMO) routing protocol

The Dynamic MANET On-demand (DYMO) routing protocol [**90**] is a unicast reactive routing protocol which is intended for used by mobile nodes in wireless multi-hop networks. DYMO is a reactive routing protocol. In this routing message (control packet) is generated only when the node receives a data packet and it does not have any routing information. The basic operation of DYMO protocol is route discovery and route management.

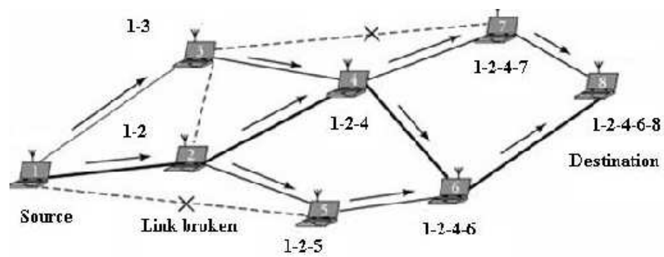

Figure 2: DSR Communication signaling from node 1 to node 8 [18]

Related Work

J. Zheng and M.J. Lee [**2**] implemented the IEEE 802.15.4 standard on NS2 simulator and subsequently produced the comprehensive performance evaluation on 802.15.4. Similarly in [**91**], the authors provided performance evaluations of IEEE 802.15.4 MAC in beacon-enabled mode for a star topology. J.S.Lee [**22**] attempted to make a preliminary performance study via several sets of practical experiments. T.H.Woon and T.C. Wan [**23**] extended existing efforts but focuses on evaluating the performance of peer-to-peer networks on a small scale basis using NS2 simulator. A Mathematical Model for performance analysis of IEEE 802.15. 4 non-beacon enabled mode has been presented in [**24**]. In [**25**], the authors presented a novel mechanism intended to provide Quality of Service (QoS) for IEEE 802.15.4 based Wireless Body Sensor Networks (WBSN) used for pervasive healthcare applications.

Simulations set up and Performance Metrics for Peer to Peer Topology

In this section, performance evaluation of different popular reactive wireless mobile ad hoc routing protocols like AODV, DSR and DYMO on static IEEE 802.15.4 mesh topology has been done for varying traffic loads. The simulations have been performed using QualNet version 4.5, a scalable wireless networks simulator. In the mesh topology simulation model, 200 FFD devices are uniformly deployed in an area of

1000x100m2. One of them is a PAN, static mains powered device placed at the centre of the simulation area. The simulation parameters are listed in Table 2. In our simulation model, function for acknowledging the receipt of packets is disabled. It is due to the fact that RTS/CTS overhead mechanism is too expensive for low data a rate WSN application for which 802.15.4 is designed. The CBR traffic with the following average packet rates: 0.1 packet per second (pps), 0.2 pps, 1 pps, 5 pps and 10 pps are used. There are 20 CBR applications between FFD nodes which are separated by an average of 8 hops away from each other to establish peer to peer communication as shown in Figure3.

Packet delivery ratio (PDR): It is the ratio of number of data packets successfully received by the PAN Coordinator to the total number of data packets sent by RFD.

Average End-to-End delay: It indicates the time taken for a packet to travel from the CBR source to the destination.

Throughput: It is the number of bits passed through a network in one second. It is the measurement of how fast data can pass through an entity (such as a point or a network).

Energy Consumption: This is amount of energy consumed by MICAZ Mote devices during the periods of transmitting, receiving, idle and sleep. The unit of energy consumption used in the simulations is mJoule.

Energy per goodput bit: It is the ratio of total energy consumed to total bits received.

Network Lifetime: This is defined as the minimum time at which maximum numbers of sensor nodes are dead or shut down during a long run of simulations

TABLE 1: IEEE 802.15.4 Mesh topology simulation parameters

Parameter	**Value**
Area	100m *00m
Transmission range	10meter
Simulation Time	170M,85M,18M,5Mand 3M
Channel Frequency	2.4GHz
Data rate	250Kbps
TX-Power	0dBm
Path Loss Model	Two Ray Model
Phyand MAC Model	IEEE 802.15.4
Energy Model	MICAZ Mote
Battery Model	Simple Linear,1200mAhr
Payload Size	1000 and 50 bytes
BO and SO	15

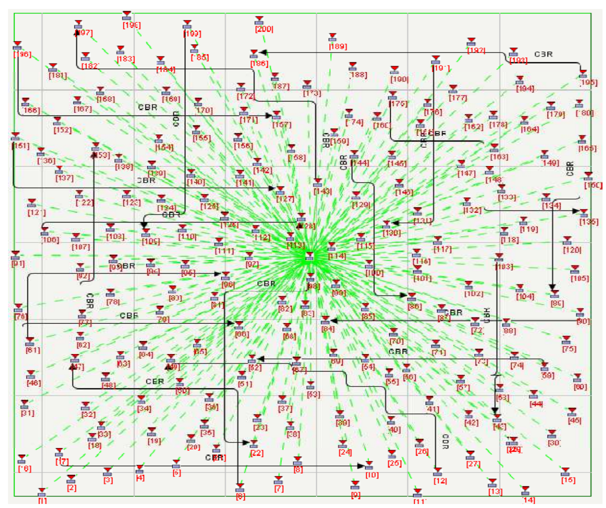

Figure 3: Simulation set up for peer to peer Topology

Simulation Results Discussion for Peer to Peer Topology

In this section, the simulation results of various performance metrics for on demand routing protocols like ADOV, DSR and DYMO routing protocols on IEEE 802.15.4 mesh topology using varying traffic load is presented.

Packet delivery ratio (PDR): Figure 5 shows performance of the packet delivery ratio vs. loads for different types of applications. For all types of traffic load, DSR performs better than AODV and DYMO. DSR attained a PDR of 99.5 % at low traffic load of 0.2

i.e. when the inter arrival of packet is 5 seconds. Then it decreases to 56% at a higher traffic load of 10 packets per second. The packet delivery ratio drops at high traffic due to well-known hidden terminal problem in multihop environments. DSR also performs well due to its beaconless mechanism. It does not require transmission of hello packets to neighbour nodes as in AODV protocol. DSR source routing based on aggressive caching approach is also effective in better performance of PDR; but when it encounters a large number hops for data delivery between source and destination, PDR performance degrades severely. This is because when the payloads size goes beyond standard IEEE 802.15.4 *MaxMACFrameSize* which is equal to 102 bytes, then it simply drops the packet.

Average end to end delay: Figure 6 shows performance of the average end-to- end delay vs. varying traffic loads. The average end- to- end delay of a packet depends on route discovery latency, besides delays at each hop (comprising of queuing, channel access and transmission delays), and the number of hops. At low loads, queuing and channel access delays does not contribute much to the overall delay. The overall average end-to-end delay performance of the DSR is lower than DYMO and AODV. The average end to end delay is lower at traffic of 1 packet per second for all three routing protocols considered. DSR has a significantly low delay due to its source routing, which helps to know the complete path to the destination node for data transferring rather than AODV approach.

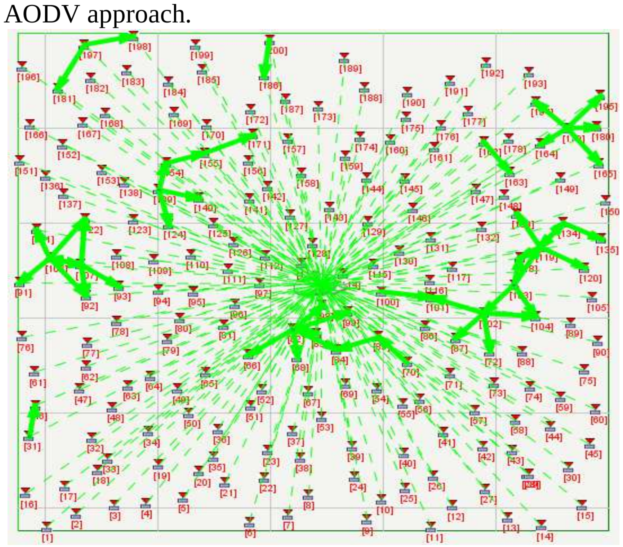

Figure 4: QualNet animator during simulation execution for mesh

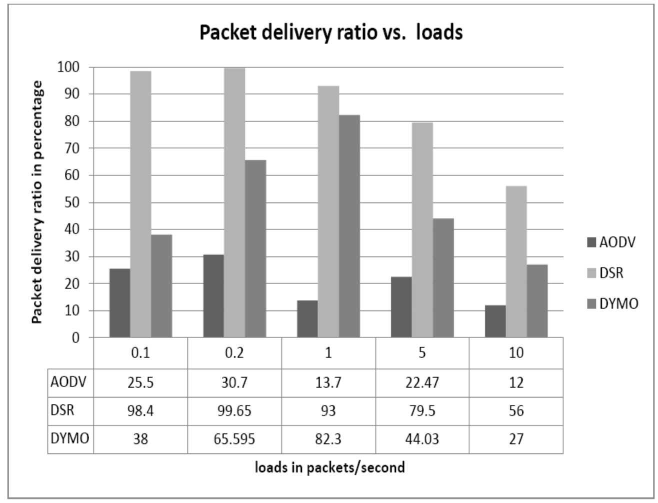

Figure 5: Packet delivery ratio vs. loads (packets/second

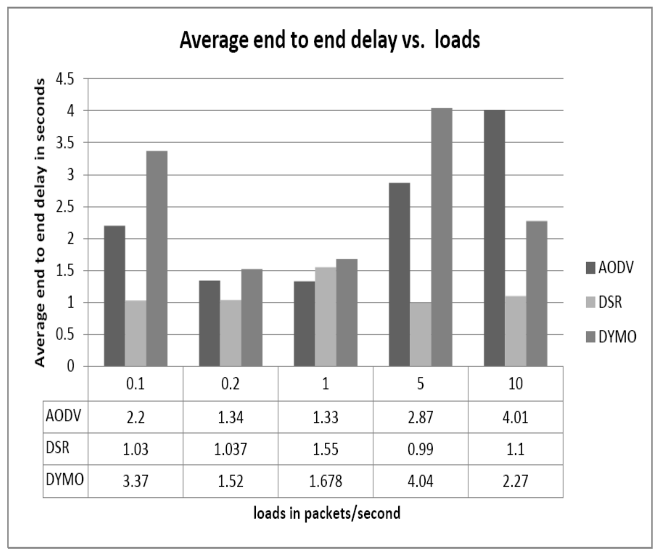

Figure 6: Average delay vs. loads (pkts/sec)

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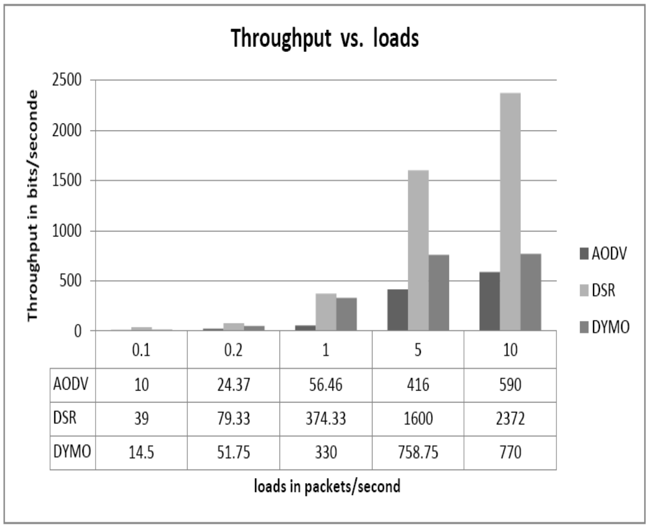
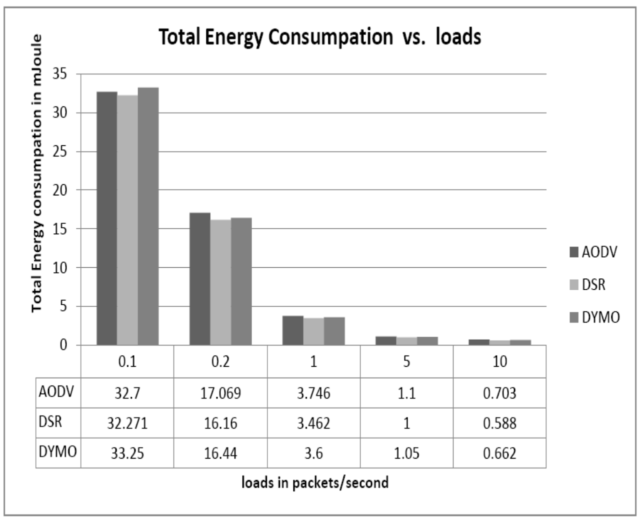


	0.1	0.2	1	5	10
AODV	10	24.37	56.46	416	590
DSR	39	79.33	374.33	1600	2372
DYMO	14.5	51.75	330	758.75	770

Figure 7: Throughput vs. loads (packets/second)



	0.1	0.2	1	5	10
AODV	32.7	17.069	3.746	1.1	0.703
DSR	32.271	16.16	3.462	1	0.588
DYMO	33.25	16.44	3.6	1.05	0.662

Figure 8: Total energy consumption vs. loads (pkts/sec)

Throughput: Figure 7 shows performance of the throughput in kbps vs. traffic loads in packets per second. From the graph, it is observed that maximum throughput of 2.3kbps is achieved at a rate of 10 packets per second. DSR shows higher throughput in comparison to AODV and DYMO.

Total energy consumption: The total energy consumption vs. load for three routing is shown in Figure 8. The total energy consumption is the energy consumption in transmission, reception, idle and sleep. The total energy consumption of three routing protocols decreases gradually from lower traffic loads to higher traffic loads.

Energy per goodput bit: Figure 9 shows performance of energy per goodput bit vs. traffic loads. The energy per goodput bit is the metric to measure the amount of energy consumed per one bit of payload data. The result has been obtained by the taking the ratio of total energy consumed in transmission of data to the total bits delivered to the receiver. DSR routing protocol shows least energy per goodput bit in comparison to AODV and DYMO routing protocol. It is due to the protocol low energy consumptions and high number of packets received at the destination in DSR. The energy per goodput bit value decreases when traffic loads is low to high .The best value of energy per goodput bit is obtained when the load is 5 packets per second for all the three routing protocols.

Network Lifetime: The Figure 10 shows performance of network lifetime vs. traffic loads. Network lifetime calculation in our simulation based on residual battery capacity as shown in Figure 11 after running it full battery capacity 1200mAHr to the respective simulation time for varying traffic loads. For the mesh topology considered, all nodes are FFD so as to relay data to the nearest radio range devices. They are always on active router device and never goes to sleep mode. Therefore, the network lifetime is lesser in comparison to RFD in star topology. The network lifetime can be increased if end users are assigned as RFD. The DSR routing protocol has maximum lifetime in comparison to ADOV and DYMO. This is due to fact of lower control overhead of DSR. DSR does not use periodic routing messages and conserve the battery power by not sending or receiving any advertisement

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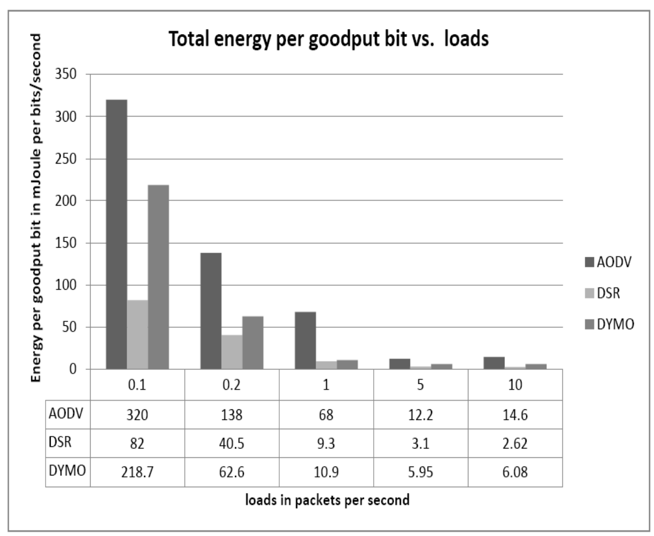

	0.1	0.2	1	5	10
AODV	320	138	68	12.2	14.6
DSR	82	40.5	9.3	3.1	2.62
DYMO	218.7	62.6	10.9	5.95	6.08

Figure 9: Energy per goodput bit vs. loads (packets/second)

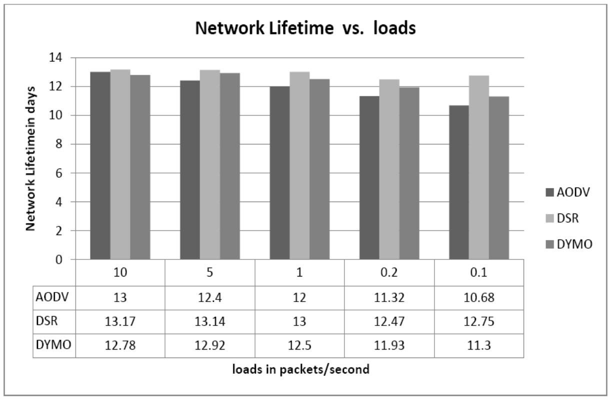

Figure 10: Network lifetime vs. loads (pkts/second)

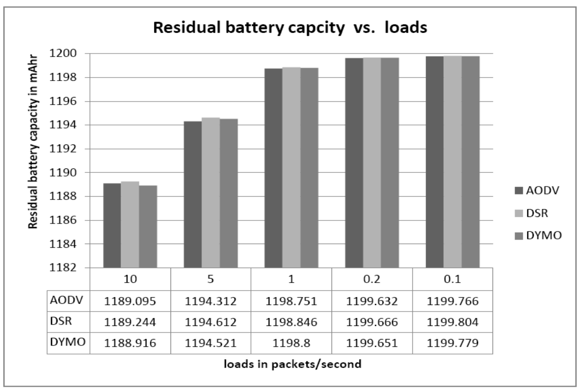

Figure 14: Residual battery capacity vs. loads (pkt/sec)

Conclusion

The Wireless Sensor Networks Quality of service is significantly different from traditional wired and wireless networks. This chapter discussed the challenges for quality of service support and parameters for defining QoS in WSNs. It also discussed support and design choices of different layers like application layer, network layer, transport layer, data link layer and physical layer. To support QoS, cooperation between layers is essential. Otherwise, each layer may try to maximize different QoS metrics, which will have unpredictable and possibly undesirable results. The QoS is more challenging in heterogeneous wireless sensors networks where a diverse mixture of sensors for monitoring temperature, pressure, and humidity are deployed to monitor the phenomena, thereby introducing different reading rates at these sensors.

This section evaluated the performance analysis of Quality of Service parameters of WSN based on IEEE 802.15.4 peer to peer mesh topology. Simulations have been performed using reactive MANET routing like AODV, DSR and DYMO in QualNet for varying loads**.** From the simulation results, it can be concluded that on an average DSR performs better than DYMO and AODV for different rates of traffic loads. The simulations are performed for 200 nodes and 20 application per sessions. If the payload size goes beyond standard IEEE 802.15.4 *MaxMACFrameSize* which is equal to 102 bytes, then it simply drop the packet. So, the overall performance of the three protocols on IEEE 802.15.4 for standardizing for WSNs is not promising. The major reason behind the performance degradation is all these protocols are designed mainly for mobile ad-hoc network where topology changes frequently. To meet these challenges of performance degradations, new routing protocols should be designed for IEEE 802.15.4 networks keeping in view of above routing protocols key features.

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