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Wireless Sensor Networks: A Performance Study of IEEE 802.15.4 Standard

M. Subramanya Bhat*
Research Scholar, Department of Electronic Science
Bangalore University, Bangalore, India
subramanyabhat@bub.ernet.in

J.T. Devaraju
Associate Professor, Department of Electronic Science
Bangalore University, Bangalore, India
devarajujt@bub.ernet.in

D. Shwetha
Research Scholar, Department of Electronic Science
Bangalore University, Bangalore, India
shwethad@bub.ernet.in

*Abstract***:** Wireless Sensor Networks (WSN) play a key role in sensing, computing and communicating the information in most of the fields bringing substantial improvements in a broad spectrum of modern technologies. Data to be routed from source to destination is very difficult in WSN due to the mobility of the network elements and lack of central administration. In this paper an attempt has been made to evaluate the performance of routing protocol Ad-hoc On-demand Distance Vector routing (AODV) for the wireless sensor nodes(IEEE 802.15.4 standard). The performance of routing protocol is analysed using various metrics like total packets received, throughput, average end-to-end delay, total bytes received and average jitter using Qualnet 5.0.2 simulator.

Keywords**:** WSN, AODV, Simulator, Jitter, Delay, Throughput, PDR.

I. INTRODUCTION

Wireless sensor and actuator networks (WSANs) constitute an important and exciting new technology with great potential for improving many current applications as well as creating new revolutionary systems in areas such as Wireless sensor networks (WSN). This will potentially affect all aspects of our lives, bringing about substantial improvements in a broad spectrum of modern technologies ranging from battlefield surveillance, environmental monitoring, biological detection, smart spaces, disaster search and rescue, industrial diagnostics, sensing a building integrity or structural vibrations during an earthquake, the stress of an airplane's wings, are some of the applications where WSN promise to change how researchers gather their data.

Recent advances in micro-electro-mechanical systems, digital electronics, and wireless communications have led to the emergence of inexpensive wireless communication, computation, and sensing. This has created a new generation of smart devices. Using tens to thousands of these devices in self-organizing networks has created a new technology referred to as wireless sensor networks (WSNs). Typically, WSANs are composed of large numbers of minimal capacity sensing, computing, and communicating devices and various types of actuators. These devices operate in complex and noisy real world, real-time environments. Current and past research[1] have produced many excellent low level mechanisms and protocols to collect, transport, and perform sensor fusion of this raw data and react with control actions. However, many challenges remain.

Today, many sensors exist around the world collecting environmental data. In most cases, the WSAN systems focus on single problem, such as the effect of tides on island. Most of these systems measure a limited number of parameters at a large granularity. WSANs have the potential of dense and flexible coverage and most importantly enabling correlation across many WSANs. Such capabilities will result in new understanding of environmental conditions. Dense coverage might include sensors placed within centimeters or meters of each other, enabling a precise understanding of certain phenomena.

A single sensor node may only be equipped with limited computation and communication capabilities. However, nodes in a WSN, when properly programmed and networked, can collaboratively perform signal processing tasks to obtain information of a remote and probably dangerous area in an untended and robust way [1, 2].

Routing protocols are divided into two categories: Proactive and Reactive. Proactive routing protocols are table-driven protocols that always maintain current up-to-date routing information by sending control messages periodically between the hosts which update their routing tables. The proactive routing protocols use link-state routing algorithms which frequently flood the link information about its neighbours [1]. Reactive or on-demand routing protocols create routes when it is demanded by the host. Such protocols use distance-vector routing algorithms [2].

II. ROUTING PROTOCOLS

A. Proactive (Table-Driven) Routing Protocols:

In proactive routing, each node has one or more tables that contain the latest information of the routes to any other node in the network. Various table-driven protocols differ in the way how the information propagates through all nodes in the network when topology changes. The proactive routing protocols are not suitable for larger networks as they need to maintain each and every node entries in the routing table. This causes more overhead in the routing table leading to consumption of more bandwidth. Examples of such schemes are the conventional routing schemes: Destination Sequenced Distance Vector (DSDV), Optimized Link State Protocol (OLSR) etc.

B. Reactive Protocols (On-Demand):

Reactive routing is also known as on-demand routing protocol since they do not maintain routing information or routing activity at the network nodes if there is no communication. If a node wants to send a packet to another node then this protocol searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet. The route discovery usually occurs by flooding the route request packets throughout the network. Examples of reactive routing protocols are the Dynamic Source Routing (DSR), Adhoc On-demand Distance Vector routing (AODV).

a. Ad-hoc On-demand Distance Vector routing protocol:

This protocol performs route discovery using control messages route request (RREQ) and route reply (RREP) whenever a node wishes to send packets to destination. The forward path sets up an intermediate node in its route table with a lifetime association RREP. When source node receives the route error (RERR) message, it can reinitiate route if it is still needed. Neighbourhood information is obtained from broadcast Hello packet [3].

AODV is a flat routing protocol which does not need any central administrative system to handle the routing process. AODV tends to reduce the control traffic messages overhead at the cost of increased latency in finding new routes. AODV has great advantage in having less overhead over simple protocols. The RREQ and RREP messages which are responsible for the route discovery do not increase significantly the overhead from these control messages. AODV reacts relatively quickly to the topological changes in the network. It updates the hosts that may be affected by the change, using RRER message. The Hello messages are responsible for the route maintenance and are limited so that they do not create unnecessary overhead in the network. The AODV protocol is a loop free and uses sequence numbers to avoid the infinity counting problem which are typical to the classical distance vector routing protocols [3].

III. RELATED WORK

In the paper [4] four routing protocols AODV, TORA, DSDV and DSR are compared using ns-2. It is shown through simulation results that DSR generates less routing load than AODV. AODV suffers from end to end delay while TORA has very high routing overhead.

Performance comparison of AODV and DSR routing protocols in a constrained situation is done using GolMoSim by R. Misra et.al.[5]. The authors claim that the AODV outperforms DSR in normal situation but in the constrained situation DSR outperforms AODV, where the degradation is as severe as 30% in AODV whereas DSR degrades marginally as 10%.

A comparison of Link State, AODV and DSR protocols for two different traffic classes, in a selected environment is done in [6]. It is claimed that AODV and DSR perform well when the network load is moderate and if the traffic load is heavy then simple Link State outperforms the reactive protocols.

The performance comparison of two on demand routing protocols DSR and AODV is studied using ns-2 in [7]. Though both use on demand route discovery, they have different routing mechanics. The authors observe that for application oriented metrics such as delay, throughput DSR outperforms AODV when the numbers of nodes are smaller. AODV outperforms DSR when the number of nodes is very large. The authors do show that DSR consistently generate less routing load than AODV.

In the paper [8] authors compared three routing protocols AODV, DSR and ZRP using Qualnet 4.5 simulator. In the paper they demonstrated ZRP delivers really low packet ratio when compared to DSR and AODV. AODV performed well in most of the network sizes (better than ZRP). However they could not able to compare OLSR (proactive routing protocol) in their scenario. In this paper performance evaluation of on-demand reactive protocol AODV is studied for wireless sensor network standard IEEE 802.15.4. The performance evaluation study is done by using Qualnet network simulator 5.0.2 for WSNs with various node density scenarios.

IV. SIMULATION PARAMETERS

In this paper QualNet 5.0.2 simulator with wireless sensor network module is used for simulation. This provides mobility for wireless sensor nodes and support more accurate wireless models for propagation, path loss, multipath fading and reception on wireless sensor networks. The simulations are carried out for network sizes of 5, 10, 15, 25, 50 and 100 nodes respectively. The area considered for the above network sizes are 100m X 100m (for network sizes of 5, 10, 15 and 25 nodes) and 300m X 300m (for network sizes of 50 and 100 nodes). For all the above specified network sizes the node placement strategy used is uniform node placement method. Figure 1 shows the snap shot of Qualnet network simulator [9] for 50 node scenario.

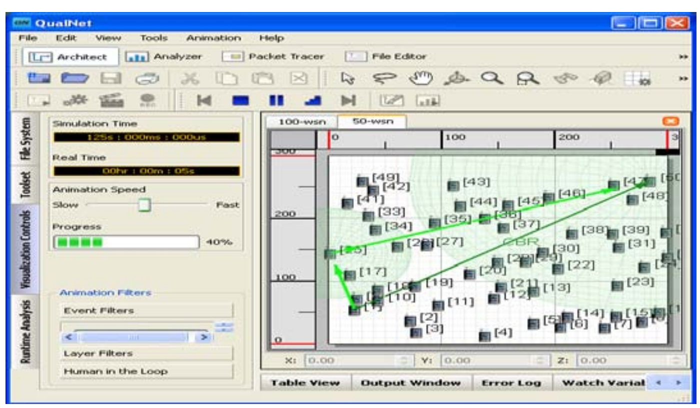

Figure 1. Snap shot of Qualnet simulator for 50 node scenario

The simulation parameters configured for the performance evaluation are shown in the table.1.

Table.1. Simulation parameters

Radio type	IEEE 802.15.4
Transmission power	3.0 dBm
Routing Protocol	AODV
Channel frequency	2.4 GHz
Shadowing Model	Constant
Path loss Model	Two ray
Energy Model	Mica-Motes
Battery Model	Simple Linear
Simulation Time	300 Second
Modulation scheme	O-QPSK
Packets sent	400
Packet size	64 bytes

The following metrics are used in studying the performance of AODV routing protocol.

- ***a. Packet Delivery Ratio (PDR):*** It's the ratio between the number of packets received at the application layer of the destination node to the number of packets sent from the application layer on the destination node.
- ***b. Throughput:*** It is the average number of messages successfully delivered per unit time i.e. average number of bits delivered per second.
- ***c. End to End delay:*** It is the time taken for a packet to be transmitted from the source node to the destination node which includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times.
- ***d. Jitter:*** The term jitter is often used as a measure of the variability over time of the packet latency across a network. A network with constant latency has no variation (or jitter). Packet jitter is expressed as an average of the deviation from the network mean latency [10].

V. RESULTS AND DISCUSSIONS

Effects of different parameter on performance of AODV protocol are discussed below.

a. Total bytes received: Total bytes received for AODV protocol under various node density scenarios are shown in figure.2. Due to enhance mechanism of route table and better signal strength, AODV performs well in the low density scenario (up to 25 nodes). The decrease in received bytes for the protocol with increase in node density is observed, due to increase in number of hops which in turn increases the routing over head for route discovery and latency[9]. This ultimately results in dropping of the pay load packets.

Nodes	5	10	15	25	50	100
Bytes	18432			17792	18176	14436

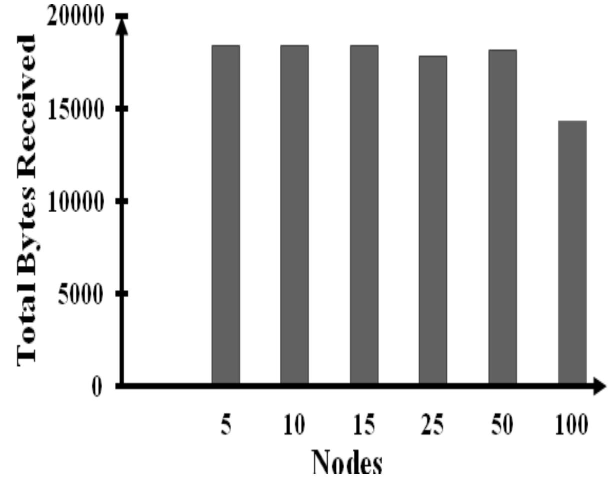

Figure 2 : Plot of total bytes received at the destination node for AODV under various node density scenarios.

b. Throughput: The variation of throughput (bps) with node density is shown in Figure.3. It is observed that the throughput for all the node density is same.

Nodes	5	10	15	25	50	100
bps	512				504	512

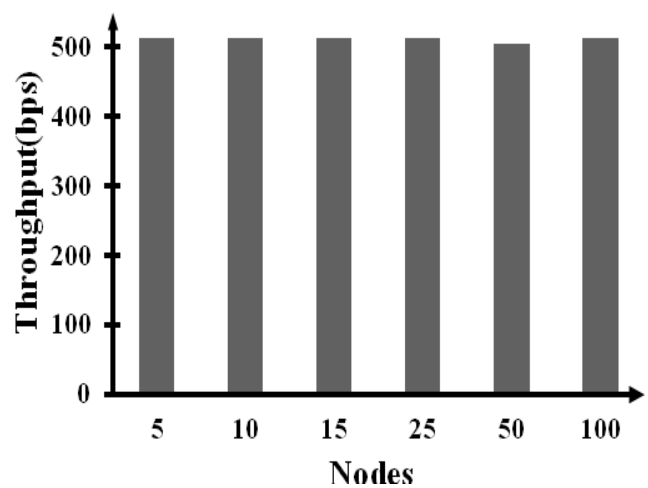

Figure 3: Plot of Throughput for AODV protocol under various node density scenarios.

c. Average end-to-end delay: The variation of average end-to-end delay at the receiver node with increase in node density is shown in Figure.4. From figure.4. it is evident that the variation in average jitter for AODV protocol is minimal, the end-to-end delay for the AODV varies when the node density is increasing. This is due to the increased route maintenance flooding messages in the protocol.

Nodes	5	10	15	25	50	100
Delay	81.066	81.042	80.436	81.042	83.913	81.048

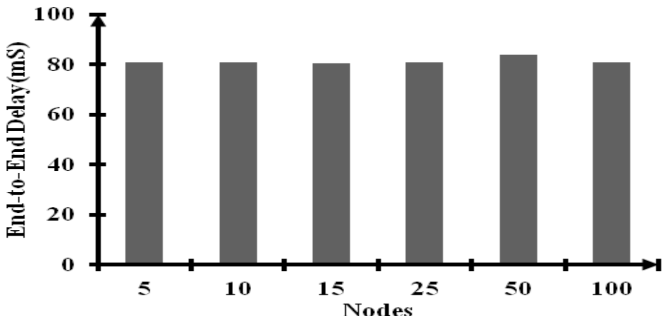

Figure.4: Plot of End-to-End Delay for AODV protocol under various node density scenarios.

d. Total Packets Received: The variation of total packets received for the protocol AODV in different node density scenarios is shown in figure 5. It is clear from the performance that as node density increases the number of packets received decreases due to network congestion.

Nodes	5	10	15	25	50	100
Packets	288	288	288	278	284	224

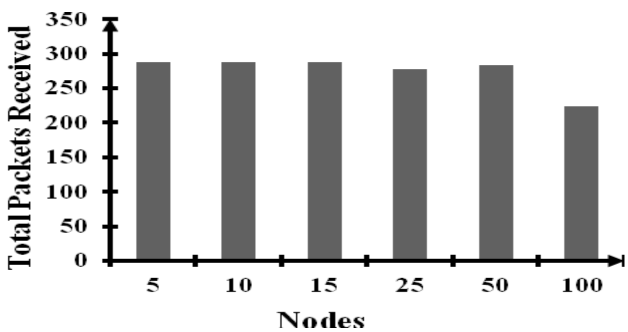

Figure 5: Plot of total packets received for AODV protocol under various node density scenarios.

e. Average Jitter: The variation of average jitter for AODV protocol in different node density scenario is shown in Figure 6. As the node density increases the value of jitter also varies, which is due to the increase in the load.

Nodes	5	10	15	25	50	100
Jitter (mS)	27.618	27.843	27.873	27.492	32.974	27.135

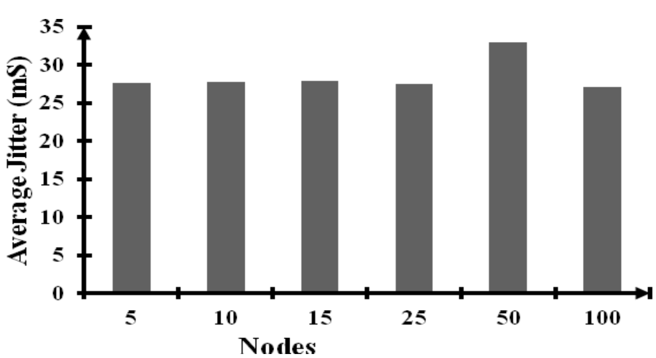

Figure 6: Plot of Average jitter(s) for AODV protocol under various node density scenarios.

VI. CONCLUSION

In this paper an attempt is made to study the performance of one of the reactive routing protocols AODV for wireless sensor network module IEEE 802.15.4 using Qualnet network simulator 5.0.2. In the scenarios selected for the study node density is varied and the metrics like average jitter, total bytes received, total packets delivered, throughput, end-to-end delay are studied.

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