Performance Study of Ad Hoc Routing Protocols in IEEE 802.15.4

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Abstract— In present industrial automation scenario, the technologies for wireless communication, sensing, and computation is progressing at faster rates, bringing considerable improvements in a wide spectrum of modern technologies. A new standard IEEE 802.15.4 has been uniquely designed to suit personal area wireless networks requirement consuming low power, provides low data rate and low cost. In this paper, the performance of the Ad Hoc routing protocols AODV, LAR and ZRP are compared and studied using Qualnet 5.0.2.Network Simulator under various CBR connections with various metrics like throughput, total number of bytes received, average jitter, end-to-end delay, and packet delivery ratio successfully routed to their destination.

Keywords— Proactive, Reactive, Hybrid, AODV, LAR, ZRP, Qualnet, Routing.

1 INTRODUCTION

Wireless sensor networks (WSN) are complex disseminated systems having nodes with sensing, data processing, storage capability, wireless-communication interfaces and limited power. With the advent of communication technology, wireless devices have become more compact, less expensive and more powerful. Such rapid technology advance has provoked great growth in mobile devices connected to the Internet. Hence, various wireless network technologies such as 3G, 4G of cellular network, Ad-Hoc, IEEE 802.11 based Wireless Local Area Network (WLAN) and Bluetooth [1] are presently in use. IEEE 802.15.4 is a very important technology of ubiquitous Wireless sensor network used for low-data-rate wireless personal area networks. The IEEE 802.15.4 defines medium access control (MAC) layer and physical layer (PHY) whereas ZigBee defines higher layers (namely, network and application) [2]. ZigBee finds applications for home, building and industrial control. ZigBee/IEEE 802.15.4 is slower compared to Wi-Fi and Bluetooth with a maximum speed of 250 Kbps at 2.4GHz, but is designed for low power so that batteries can last for long time [3].

IEEE 802.15.4 supports two different device types that can communicate in low range-WPAN network: a full-function device (FFD) and a reduced-function device (RFD). The FFD can operate in three modes to serve as a PAN coordinator, a coordinator, or a device. An FFD can communicate to RFDs or other FFDs, while an RFD can communicate only to an FFD. RFD does not have the capability to relay data messages to other end devices. It is mainly used for applications that are extremely low resource in capability like a light switch or a passive infrared sensor. They would only be associated with a single FFD at a time to transfer data. Depending on the application requirements, an IEEE 802.15.4 may operate in either of two topologies: the star topology or the peer-to-peer topology. In star topology, devices are interconnected in form of a star in which there is a central node as PAN coordinator and all the network nodes (FFDs and RFDs) can exchange their data packets only through PAN. The PAN coordinator is the primary controller of the network. All devices operating on a network have unique 64-bit addresses. The PAN coordinator might be mains powered, while the other devices will be battery powered. Applications of a star topology include industry automation, home automation, toys, personal health care systems, games, etc. [4].

In this work an attempt is made to study the performance evaluation of the routing protocols: Ad-hoc On-demand Distance Vector routing (AODV), Location Aided Routing (LAR) and Zone Routing Protocol (ZRP) using Qualnet 5.0.2. Network simulator. The study includes various metrics namely, throughput, average jitter, end-to-end delay, data delivery ratio and number of packets successfully routed to the destination.

The rest of the paper is organized with a brief discussion of routing protocols followed by related work, Simulation parameters models and attributes, results and discussion and conclusion.

2 ROUTING PROTOCOLS

Routing is a method of sending the information from source to sink by selecting an optimal path in the network. Routing in WSN depends on various factors such as topology, selection of routers and location of request initiator that serve as an aid in finding the path quickly and efficiently. One of the major requirements in designing a routing protocol is that a node should have the information of its neighbors to reach the destination. An interesting problem open for research is to consider physical layer based routing and broadcasting where nodes may adjust their transmission radii. The different types of routing protocols are discussed in detail below.

2.1 Proactive Routing Protocols:

Proactive algorithm employs classical routing strategies such as distance-vector or link-state routing and any changes in the link connections are updated periodically throughout the network. It maintains latest routing information among all the nodes of the network and hence is called table-driven routing protocol. 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. In addition, the quality of channels may change with time due to the shadowing and fast fading and may not be suitable to use even if there is no mobility [5]. Examples of such schemes are the conventional routing schemes: Destination Sequenced Distance Vector (DSDV), Optimized Link State Protocol (OLSR) etc.

2.2 Reactive (On-Demand) Routing Protocols:

Reactive routing is also known as on-demand routing protocol since the nodes discover routes to destinations on-demand. Reactive routing protocols often consume lesser bandwidth, but the delay in determining a route can be substantially large. The route discovery usually occurs by flooding the route request packets throughout the network. Some of reactive routing protocols are the Dynamic Source Routing (DSR), Adhoc On-demand Distance Vector routing (AODV) and Location Aided Routing (LAR).

1) Ad-hoc On demand Distance Vector routing (AODV):Ad hoc On Demand Distance Vector (AODV) protocol is suitable for "Unicast" and "Multicast" routing. It is a reactive routing protocol [6] and basically a combination of DSDV and DSR. It incorporates the basic on-demand mechanism of route discovery and route maintenance from DSR and, the use of hop-by-hop routing, sequence numbers and periodic beacons from DSDV. 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. Neighborhood information is obtained from broadcast Hello packet. AODV is a flat routing protocol which does not need any central administrative system to handle the routing process. AODV tends to reduce the traffic control messages overhead at the cost of increased latency in finding new routes. The RREQ and RREP messages which are responsible for the route discovery do not significantly increase 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 RERR 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.

2) Location Aided Routing (LAR):The Location-Aided Routing protocol is an on-demand scheme [7]. It utilizes location information to limit the route query flooding area. The prerequisite is that every host knows its own location and the global time, which can be provided by a Global Positioning System (GPS). LAR defines the concepts of "expected zone" and "request zone". For instance, when node S wants to send messages to node D, it will broadcast a route query message, which is forwarded only by the nodes in the "request zone". When a node forwards the route query, it appends its node ID to the head of the packet. After node D finally receives the route query, it sends a route reply back to the source node S using the reverse path which is recorded in the head of the route query packet. The route from S to D is established when the source node S receives the route reply packet. LAR can efficiently reduce the RREQ flooding cost. The main problem with this method is that obtaining accurate location information may be difficult in some environments (for example, GPS does not work well indoors, and proximity does not guarantee connectivity).

2.3 Hybrid Routing Protocols:

Hybrid protocols combine local proactive and global reactive routing in order to achieve higher level of efficiency and scalability.

Zone Routing Protocol (ZRP):ZRP [8] limits the scope of the proactive procedures only to the node's local neighborhood, while the search being global throughout the network can be performed efficiently by querying selected nodes in the network, as opposed to querying all the network nodes. Hence, ZRP is said to be a neighbor selection based protocol. A node employing ZRP proactively maintains routes to destinations within a local neighborhood, referred to as a routing zone. Routing zone is defined as a collection of nodes whose minimum distance in hops from the node in question is no greater than a parameter referred to as zone radius. Each node maintains its zone radius and there is an overlap between neighboring zones. A node learns its zone through a proactive scheme Intra zone Routing Protocol (IARP). For nodes outside the routing zone, Inter-zone Routing Protocol (IERP) is responsible for reactively discovering routes to destinations located beyond a node's routing zone. The IERP is renowned form of standard flooding-based response protocols by exploiting the constitution of the routing zone. The routing zones increase the probability that a node can respond positively to a route query. This is beneficial for traffic that is intended for geographically close nodes.

The performance of the routing protocols AODV, LAR and ZRP are compared using Qualnet 5.0.2. network simulator with the metrics like total packets received, throughput, average end-to-end delay, total bytes received and average jitter.

3 Related Work

A comparison of Link State, AODV and DSR protocols with two different traffic classes in a selected environment has been carried out in [9]. Authors claims 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.

In the paper [10] authors proposed a comparative study of routing protocols AODV, DSR and ZRP using Qualnet 4.5 simulator. In the paper they established that ZRP delivers really low packet ratio when compared to DSR and AODV. AODV performed well in most of the network sizes. However they could not compare OLSR (proactive routing protocol) in their scenario.

In the paper [11] authors implemented the IEEE 802.15.4 standard on NS2 simulator and provided the comprehensive performance evaluation on 802.15.4. The literature comprehensively defines the 802.15.4 protocol as well as simulations on various aspects of the standard. It mainly confined to performance of IEEE 802.15.4 MAC.

In the paper [12], authors presented a comparative study of routing protocols for Mobile Ad-Hoc Networks (MANET's). A variety of routing protocols with varying network conditions are analyzed to find an optimized route from source to destination. The Authors presented performance comparison of four routing protocols i.e. Landmark Ad-hoc Routing Protocol (LANMAR), Location Aided Routing scheme 1 (LAR1), Dynamic MANET On-Demand (DYMO) and Zone Routing Protocol (ZRP) in variable pause time. Network simulator QualNet 5.0 is used to evaluate the performance of these protocols. The performance analysis is done based on different network metrics such as average jitter, packet delivery ratio, average end-to-end delay and throughput.

In the work [13], four ad-hoc routing protocols are evaluated using nS-2 for 50-node network models. Besides comparison of ad-hoc networks several other papers have dealt with ZRP and worked on the perfect zone radius value. In [14] DSR and AODV is evaluated using NS-2 network simulator for 50 and 100 nodes in a rectangular space. Various routing protocols are been analyzed in [14] including AODV and DSR.

In this paper performance evaluation of AODV is compared with LAR and ZRP protocols. The performance evaluation is done using network simulator Qualnet version 5.0.2 [16]. The packet size of 512 bytes are used which makes the comparison fair between LAR, ZRP and AODV with appropriate modification for fair performance evaluation and implementations of routing protocols.

4 Simulation Parameters Models and Attributes

The simulation process with Qualnet 5.0.2 simulator has been carried out to estimate the performance of routing protocols considering IEEE 802.15.4 standard. The simulations are carried out for network size of 20 stationary nodes placed randomly in the simulation area of (300m x 300m) and simulation period of 300 second. In the scenarios considered, the number of destination nodes used is one and the number of CBR sources to transmit the data packet is varied from 2 to 7. The simulation parameters configured for the performance evaluation are shown in the Table1. The performance of the routing protocols AODV, LAR and ZRP are compared and analyzed with various metrics like throughput, total number of bytes received, average jitter, end-to-end delay, and packet delivery ratio with respect to the increase in number of CBR sources.

TABLE 1. Simulation parameters

Radio type	802.15.4
Routing Protocols	AODV, LAR & ZRP
No. of Channels	One
Channel frequency	2.4 GHz
Path loss model	Two Ray
Energy model	Mica Motes
Shadowing model	Constant
Simulation time	300 second
Battery model	Linear model
Number of nodes	20
Traffic types	2,3,4,5,6 and 7 CBR sources
Mobility of nodes	None
Node Placement	Random
Packet size	50 bytes

For studying the performance of routing protocols, the following metrics are chosen.

Throughput: It is the average rate of successful message delivery over a communication channel. High throughput is always desirable in a communication system.

End to End delay: It refers to the time taken for a packet to be transmitted across a network from source to destination. This includes all possible delay caused by buffering during route discovery latency, queuing at the interface queue, retransmission delay at the MAC, propagation and transfer time.

Packet delivery ratio: It is the ratio of data packets delivered at the application layer of the destination node to those generated at the application layer of the source node.

Jitter: It is 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.

5 Results and Discussion

Throughput: The variation of throughput (bps) with the variation of CBRs for AODV, LAR and ZRP is shown in the fig. 1. The recorded values of throughput are shown in Table 2. From the values, it is clear that ZRP show better throughput compared to AODV and LAR, since the ZRP utilizes the properties of both reactive and proactive routing protocols [8]. AODV shows low throughput compared to LAR or ZRP.

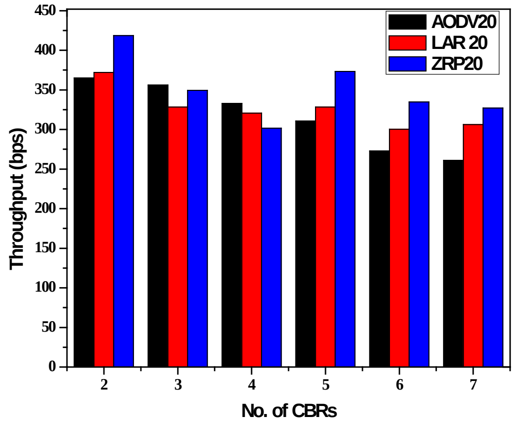

Fig.1 Throughput for AODV, LAR and ZRP protocols

TABLE 2: THROUGHPUT WITH CHANGE IN CBR

CBRs	Protocols		
	AODV	LAR1	ZRP
2	365	372	418.5
3	356	328.3333	349.3333
4	333	320.5	301.5
5	310.6	328.4	373.4
6	272.6667	300.1667	334.8333
7	260.8571	306.1429	327

Total bytes received: Total bytes received for AODV, LAR and ZRP protocols respectively under various CBR connections are shown in fig. 2.

The recorded values of total bytes received at the destination node are shown in Table 3. It is observed from the values that the number of bytes received is almost same for AODV and LAR, since they are reactive and on-demand routing protocols [6]. The number of bytes received for ZRP is less compared to AODV and LAR.

TABLE 3: TOTAL BYTES RECEIVED WITH CHANGE IN CBR

CBRs	Protocols		
	AODV	LAR1	ZRP
2	13150	13550	12350
3	12833.33	11983.33	10766.67
4	11987.5	11550	10087.5
5	11160	11910	10110
6	9783.333	10916.67	9825
7	9342.857	11128.57	9414.286

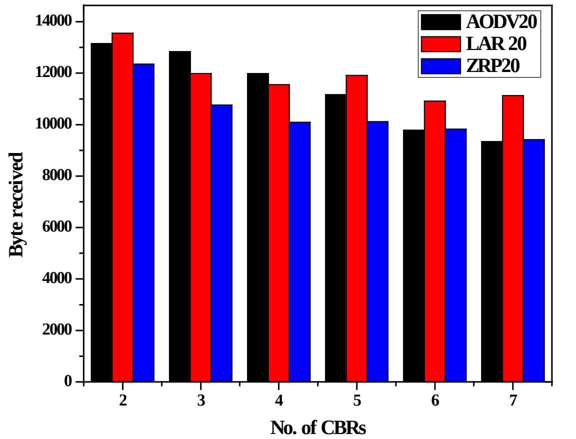

Fig.2 Number of bytes received for AODV, LAR and ZRP protocols

Average end to end delay: The variation of average end-to-end delay at the receiver node under various CBR connections are shown in fig. 3.The recorded values of End to End delay are shown in Table 4. It is clear from the values that the End to End delay is very less for AODV compared to LAR and ZRP. The delay for ZRP is more compared to AODV and LAR since; it is partially proactive in nature [8].

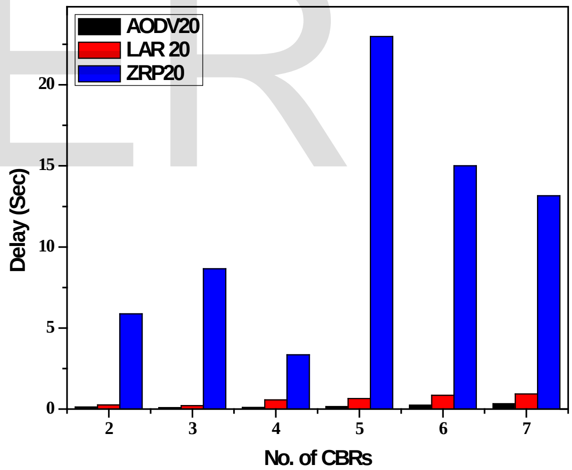

Fig.3 End to End delay for AODV, LAR and ZRP protocols

TABLE 4: END TO END DELAY WITH CHANGE IN CBR

CBRs	Protocols		
	AODV	LAR1	ZRP
2	0.130082	0.252054	5.866485
3	0.089637	0.208599	8.65316
4	0.100853	0.570577	3.339933
5	0.149516	0.65462	22.97925

6	0.234555	0.840261	15.00216
7	0.318747	0.93562	13.16035

Total packets received: Total packets received for AODV, LAR and ZRP protocols under various CBR connections are shown in fig. 4. The recorded values for total packets received are shown in Table 5. It is observed from the graph that the response for total packets received is similar to that of bytes received.

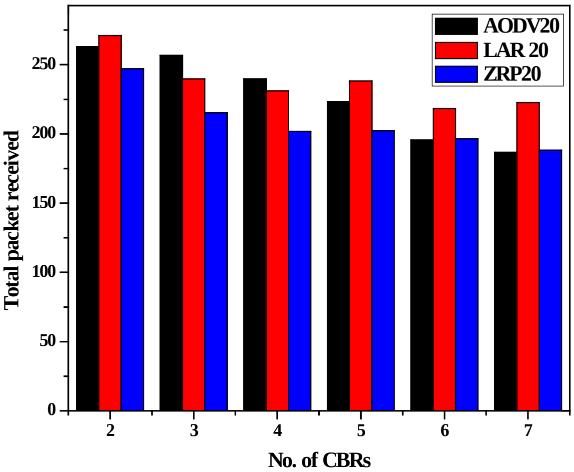

Fig.4 Total packets received for AODV, LAR and ZRP protocols

TABLE 5: TOTAL PACKETS RECEIVED WITH CHANGE IN CBR

CBRs	Protocols		
	AODV	LAR1	ZRP
2	263	271	247
3	256.6667	239.6667	215.3333
4	239.75	231	201.75
5	223.2	238.2	202.2
6	195.6667	218.3333	196.5
7	186.8571	222.5714	188.2857

Average Jitter: The variation of average jitter for AODV, LAR and ZRP protocols respectively under various node connections are shown in fig. 5.The recorded values for average jitter are shown in Table 6. It is evident from fig.5. and Table 6, the average delay is very less for AODV compared to LAR and ZRP [6]. The delay for ZRP is more compared to AODV and LAR [8].

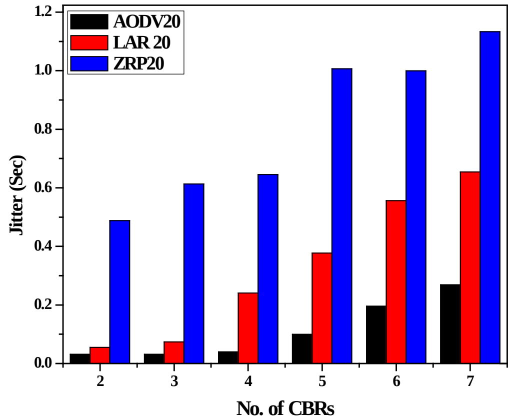

Fig. 5: Average jitter for AODV, LAR and ZRP protocols

TABLE 6: AVERAGE JITTER WITH CHANGE IN CBR

CBRs	protocols		
	AODV	LAR1	ZRP
2	0.031468	0.054705	0.487853
3	0.031293	0.074084	0.613149
4	0.039936	0.240596	0.645241
5	0.099727	0.377322	1.006446
6	0.19573	0.556391	0.999589
7	0.268828	0.653991	1.132953

6. Conclusion

In this paper, three protocols i.e., AODV, LAR and ZRP have been studied and evaluated using Qualnet 5.0.2 simulator with various CBR connections. The result obtained from the evaluation scenarios makes it clear that ZRP suits applications where End-to-End delays are very critical like video streaming. AODV and LAR are selected for the traffic which is highly dominated with packet delivery and given minimal importance to end-to-end delay scenarios.

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