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End to End Delay based Comparison of Routing Protocols in Wireless Networks

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Abstract— **Wireless Sensor Networks (WSNs) consist of tiny nodes with sensing, computation, and wireless communications capabilities. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy and delay is an essential design issue. The focus is on the routing protocols which might differ depending on the application and network architecture. The routing protocol has to be able to cope with the new challenges that a wireless sensor network that creates such as nodes mobility, security maintenance, and quality of service, limited bandwidth and limited power supply. Overall, the routing techniques are classified into three categories based on the underlying network structure: flat, hierarchical, and location-based routing. Furthermore, these protocols can be classified into multipath-based, query-based, negotiation-based, QoS-based, and coherent-based depending on the protocol operation. . In this paper, we present performance based comparisons between different routing protocols like as RIP, OLSR, ZRP and LAR. The main objective of this paper is to compare the performance analysis which is based on average end to end delay present in transmission of packet. This system is developed for IEEE 802.11 based Wireless network and simulated through QualNet 5.0. Packet size and No. of nodes are the two parameters in this paper which helps to find out the suitable type of traffic that can be use in a WSN.**

Index Terms—**Wireless Sensor Network, OLSR, RIP, LAR, QualNet 5.0, ZRP**

I. Introduction

Wireless sensor network (WSN) is a wireless network consisting of small nodes with sensing, computation, and wireless communications capabilities. The sensors measure ambient conditions in the environment surrounding and then transfer measurements into signals that can be processed to reveal some characteristics about phenomena located in the area around sensors [1] [6].

However, sensor nodes are constrained in energy supply and bandwidth. Such constraints, combined with a typical deployment of large number of sensor nodes, have posed many challenges to the design and management of sensor networks [2]. Distinguished from traditional wireless communication networks, for example, cellular systems and Mobile Ad Hoc Networks (MANETs), WSNs have unique characteristics, for example, denser level of node deployment, higher unreliability of sensor nodes, and severe energy, computation, and storage constraints [3], which present many new challenges in the development and application of WSNs.

Recently, wireless sensor network (WSN) is being rapidly utilized for interconnectivity of smart meters. WSN is a class of ad hoc network which organizes the smart meters in an infrastructure less distributed reconfigurable topology. Smart meters with their wireless capability transmit their own and relay other meter readings to the power grid control centre. Many WSN ad hoc routing protocols have been proposed which consider the limited battery life and computational capability of sensor nodes. Data centric protocols reduce redundancy in data transmissions for prolonging nodes lifetime [1]. They utilize Query method which is not suitable for time driven monitoring applications. Hierarchical routing protocols improve energy consumption by locally grouping the nodes into clusters. However, they require frequent exchange of control messages for cluster formation. Location aided protocols, although energy efficient, require the use of expensive localization hardware for their working. Most of the WSN routing protocols work on flooding mechanism for event reporting to the sink. However, smart metering infrastructure represents a specific kind of network deployment due to large number of static metering nodes communicating in outdoor environment in time driven periodic fashion. Most of the time smart meter reading collection exhibits a many-to-one scenario with all metering nodes communicating with the sink and overloading the nodes close to it. Furthermore, smart meters running on power lines use rechargeable batteries for wireless communication module and back up requirements in case of power failure scenarios so energy consumption of protocols should also be considered [2] [4] [6] [13].

Wireless Sensor Network communication is particularly useful in relaying information (status, situation awareness, etc.) via data, video, and/or voice from one rescue team member to another over a small handheld or wearable wireless device. Current challenges for ad hoc wireless networks include [9]:

- Multicast
- Location-aided routing
- Power-aware routing
- QoS support

As mentioned above, multicast is desirable to support multiparty wireless communications. Since the multicast tree is no longer static (i.e., its topology is subject to change over time), the multicast routing protocol must be able to cope with mobility, including multicast membership dynamics

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(e.g., leave and join). In terms of QoS, it is inadequate to consider QoS merely at the network level without considering the underlying media access control layer. Another important factor is the limited power supply in handheld devices, which can seriously prohibit packet forwarding in an ad hoc mobile environment [4]. Hence, routing traffic based on nodes' power metrics is one way to distinguish routes that are more long lived than others. Finally, instead of using beaconing or broadcast search, location- aided routing uses positioning information to define associated regions so that the routing is spatially oriented and limited [6]. Wireless networks are used in emergency operations, meetings or conventions to share information and data acquisition operations in hospitable terrain, disaster recovery and automated battlefields as wireless networks don't need central administration or infrastructure. Wireless networks are characterized by the following issues [1] [3]:

- No centralized controller and infrastructure
- Loop free Routing and minimum control overhead
- Frequent routing updates
- Short time contact between nodes
- Higher number of nodes and large network
- High error rate
- Low radio bandwidth
- Limited bandwidth
- Battery lifetime
- Nodes can perform the roles of both hosts and routers

The rest of the paper is organized as follows: Section II includes the optimization objective to related works. The infrastuctureless and autonomous of WSNs III. Classification of routing protocols for WSN is described in Section IV. Description of protocols is presented in section V. Simulation environment are presented in section in VI. Simulation results and description is presented in section VII. The paper is concluded in section VIII

II. Optimization Objective

A routing metric is essentially a value assigned to each route or path, and used by the routing algorithm to select one, or more, out of a subset of routes discovered by the routing protocol. These values generally reflect the cost of using a particular route with respect to some optimization objective, and could take into account both application and network performance indicators. More specifically, the objective of the routing algorithm and thus the routing metric may be to:

A. *Average End to End Delay:*

The packet End-to-End delay is the average time that a packet takes to traverse the network. This is the time from the generation of the packet in the sender up to its reception at the destination's application layer and it is measured in seconds. It therefore includes all the delays in the network such as buffer queues, transmission time and delays induced by routing activities and MAC control exchanges [7]. Delay sensitive applications such as voice require a low average delay in the network whereas other applications such as FTP may be tolerant to delays up to a certain level. Wireless sensor network are characterized by node mobility, packet retransmissions due to weak signal strengths between nodes, and connection tearing and making. These cause the delay in the network to increase. The End-to-End delay is therefore a measure of how well a routing protocol adapts to the various constraints in the network and represents the reliability of the routing protocol [5].

Average End-to-End Delay: measures the average time it takes to route a data packet from the source node to the destination. It is expressed as:

(Σ Individual data packet latency)/ (Σ Total number of data packets delivered) [5] [13].

B. *Minimize delay:*

This is often the canonical objective of the routing function. The network path over which the data can be delivered with minimum delay is selected. If queuing delays, link capacity, and interference are not taken into account, then delay minimization often ends up being equivalent to hop-count minimization.

C. *Maximize probability of data delivery:*

For non real-time applications, the main requirement is to achieve a low data loss rate along the network route, even at the expense of increased delay. This is equivalent to minimizing the probability of data loss between network end-points.

D. *Maximize path throughput:*

Here, the aim is the selection of an end-to-end path that consists of links with high capacity.

E. *Maximize network throughput:*

Contrary to the first three objectives, which are user application-oriented, network throughput is a system objective. The objective may be formulated as the maximization of data flow in the whole network or, implicitly, through the minimization of interference or retransmissions.

F. *Minimize energy consumption:*

Energy consumption is rarely an issue in wired networks. However, it becomes a major concern in sensor networks and mobile ad hoc networks, where the battery lifetime constrains the autonomy of net-work nodes.

G. *Equally distribute traffic load:*

By minimizing the difference between the maximum and minimum traffic load over the network links. Load balancing may have an indirect effect on other objectives such as battery lifetime, per node throughput, etc. It is worthwhile to note here that the first three objectives in the above list are concerned with individual application performance, that is, to optimize the performance for a given end-to-end path, while the last three are "system-oriented" objectives that focus on the performance of the network as a whole.

III. Infrastructureless and Autonomous Properties of WSNs

Wireless sensor network does not depend on any established infrastructure or centralized administration. Each node operates in distributed peer-to peer mode, acts as an independent router and generates independent data [7] [13].

1) *Multi-hop routing:*

No default router available, every node acts as a router and forwards each other's packets to enable information sharing between mobile hosts.

2) Dynamically changing network topologies:

In mobile ad-hoc networks, because nodes can move arbitrarily, the network topology which is multi hop can change frequently and unpredictably resulting in route changes, frequent network partitions and possibly packet losses [7].

3) Variation in link and node capabilities:

Each node is equipped with one or more radio interfaces that has varying transmission or receiving capabilities and operate across different frequency bands. This heterogeneity in node radio capabilities can result in possibly asymmetric links. Each node has a different software or hardware configuration resulting in variability in processing capabilities [7].

4) Energy constrained operation:

Because batteries carried by each mobile node have limited power supply so the processing power is limited, which in turn limits the services and application that can be supported by each node. This becomes a bigger issue in wireless because each node acts as both an end system and a router at the same time; additional energy is required to forward packets from other nodes [7] [11].

5) Network scalability:

Many wireless applications involve large networks with tens of thousands of mobile nodes as found for example in sensor and tactical networks. Scalability is critical to the successful deployment of these networks [8].

B. Properties of wireless routing protocols:

In the conventional routing protocols do not meet our demands, so we need a new routing protocol. Here we discuss some of the important properties are discussed as follows.

1) Distributed Operation:

The protocol should of course be distributed. It should not be dependent on a centralized controlling node. This is the case even for stationary networks. The difference is that nodes in a wireless network can enter or leave the network very easily and because of mobility the network can be partitioned [8].

2) Loop free:

To improve the overall performance, we want the routing protocol to guarantee that the routes supplied are loop free. This avoids any waste of bandwidth or CPU consumption.

3) Demand based Operation:

To minimize the control overhead in the network and thus not wasting network resources more than necessary, the protocol should be reactive. This means that the protocol should only react when needed and that the protocol should not periodically broadcast control information [8] [11].

4) Unidirectional Link Support:

The radio environment can cause the formation of unidirectional links. Utilization of these links and not only bi-directional links improves the routing protocol performance [7] [14].

5) Security:

The radio environment is especially vulnerable to impersonation attacks, so to ensure the wanted behavior from the routing protocol, we need some sort of preventive security measures. Authentication and encryption is probably the way to go and the problem here lies within distributing keys among the nodes in the ad-hoc network. This can be uses tunneling to transport all packets.

6) Power Conservation:

The nodes in wireless network can be laptops and then clients, such as PDAs that are very limited in battery power and therefore uses some sort of stand-by mode to save power. It is therefore important that the routing protocol has support for those sleep modes [8].

7) Multiple Routes:

To reduce the number of reactions to topological changes and congestion multiple routes could be used .if one route has became invalid, it is possible that another stored route could still be valid and thus saving the routing protocol from insulating another route discovery procedure [8].

8) Quality of Service Support:

Some sort of quality of service support is probably necessary to incorporate into the routing protocol. This has a lot to do with what these networks will be used for. It could for instance be real- time traffic support [8].

IV. Classification of Routing Protocol for Wireless Sensor Networks

WSN Routing Protocols may be classified in four ways, according to the way of routing paths are established, according to the network structure, according to the protocol operation and according to the initiator of communications. Fig.1 shows the classification of WSN routing protocols [7].

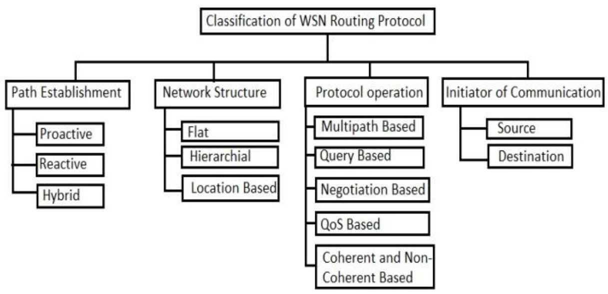

Fig1 Classification of Routing Protocols in Wireless Sensor Network.

A. Reactive Routing Protocols:

These are also called as on demand routing protocols. These are fully opposite to the table driven routing protocols. In this all the up to date routing information is not maintained at all node, instead the routes are created when required. When the source want to communicate with the destination then it starts route discovery process to find the path to the destination [3] [7]. The route remains valid till the destination is reachable or until the route is no longer needed. Unlike the proactive, the reactive or on demand routing protocols do not maintain an update table. i.e. DSR, AODV, etc.

B. Proactive Routing Protocols:

These are also called as table driven routing protocols. In proactive routing protocols, each node maintains one or more tables containing routing information to every other node in the network. All the nodes update these tables so that an up to date network is maintained [3] [8]. When the topology changes, the nodes sends update messages to the entire network. The main disadvantage of the proactive routing protocols is that all the nodes in the network should always maintain an updated table. i.e. DSDV, OLSR, etc.

C. Hybrid Routing Protocols:

The Ad Hoc network can use the hybrid routing protocols that have the advantage of both proactive and reactive routing protocols to balance the delay and control overhead (in terms of control packages) [3] [13].These are the mixture of both table driven and on demand routing protocols. i.e. TORA, ZRP, etc.

V. Description of Protocols

A. OLSR:

The Optimized Link State Routing Protocol (OLSR) is an IP routing protocol optimized for wireless networks, which can also be used on other wireless ad-hoc networks. OLSR is a proactive link-state routing protocol, which uses hello and topology control (TC) messages to discover and then disseminate link state information throughout the wireless network. Individual nodes use this topology information to compute next hop destinations for all nodes in the network using shortest hop forwarding paths [9] [12].

B. RIP:

Routing Information Protocol (RIP) is an Interior Gateway Protocol used to replace routing information within a sphere or autonomous system. RIP lets routers exchange information on the destinations for the purpose of computing routes throughout the network. Destinations may be individual hosts, networks, or special destinations used to convey a default route. RIP is based on the Bellman- Ford or the distance-vector algorithm. This means RIP makes routing decisions based on the hop count between a router and a destination. RIP does not alter IP packets; it routes them based on destination address only [10].

C. LAR:

LAR is based on flooding algorithms (such as DSR). However, LAR attempts to reduce the routing overheads present in the traditional flooding algorithm by using location information. This protocol assumes that each node knows its location through a GPS [10]. Two different LAR scheme were proposed in, the first scheme calculates a request zone which defines a boundary where the route request packets can travel to reach the required destination. The second method stores the coordinates of the destination in the route request packets. These packets can only travel in the direction was the relative distance to the destination becomes smaller as they travel from one hop to another. Both methods limit the control over-head transmitted through the network and hence conserve bandwidth [10] [14].

D. ZRP:

Zone Routing Protocol or ZRP was the first hybrid routing protocol with both a proactive and a reactive routing component. ZRP was proposed to reduce the control overhead of proactive routing protocols and decrease the latency caused by route discovery in reactive routing protocols. ZRP defines a zone around each node consisting of the node's neighborhood. A proactive routing protocol, Intra-zone Routing Protocol (IARP), is used inside routing zones, and a reactive routing protocol, Inter-zone Routing Protocol (IERP), is used between routing zones [11] [12].

VI. Simulation Environment

This work is done by simulating the designed scenario with the help of simulation tool QualNet [15]. QualNet uses simulation and emulation to predict the behavior and performance of networks to improve their design, operation and management. QualNet enables users to optimize new and existing models, also design and develop new protocol models. QualNet work on design large wired and wireless networks using pre-configured or user- designed models, analyze and investigations on the performance of networks and perform to optimize them. QualNet is the commercial preferable simulator for network operation and solution [13].

QualNet is a commercial simulator that grew out of GloMoSim, which was developed at the University of California, Los Angeles, UCLA, and is distributed by Scalable Network Technologies. The QualNet simulator is C++ based. All protocols are implemented in a series of C++ files and are called by the simulation kernel. QualNet comes with a java based graphical user interface (GUI).It must be noted that QualNet is a discrete event simulator which provides a good balance between ease of use and extensibility and power in terms of what scenarios can be simulated. Table 2 shows the parameters and values which we are taking for our designed scenario [15].

TABLE: 2 PARAMETERS USED FOR DESIGNING A SCENARIO OF POWER ANALYSIS AND MANAGEMENT OF HYBRID (ZRP) PROTOCOL

Parameters	Value
Protocols	
Channel Type	channel/wireless channel
Type of Traffic flow	CBR
MAC type	IEEE 802.11
Starting time	10 sec
End time	300 sec
Antenna Type	Omni-directional Antenna
Network Layer	PHY wireless
Network interface type	Physical/ Wireless Phy
Varying No of Nodes	60
Radio-propagation model	Two Ray Ground
Topological area	1500 x 1500 sq. m
Energy Model	MICA-MOTES
Packet Reception Model	PHY 802.11b Reception Model
Data Rate	10 Mbps
Mobility Model	Random Way Point
Battery Model	Linear Model
Physical layer protocol	PHY802.11b
Queuing policy at router	First-in-First-out (FIFO)
Duration of Experiment	300 sec

The overall goal of this simulation study is to evaluate and analyze the performance of four existing routing protocols; they are: OLSR, RIP, LAR1 and ZRP over wireless sensor networks (WSNs) environment. The simulations have been performed using QualNet version 5.0, software that provides scalable simulations of Wireless Networks. The simulation model over different networks in which network varies from 60 nodes (server) to (clients) over a terrain of 1500m x 1500m area. Transmission of data packets is done by user defined by node nos. 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 54, and 60. We used high mobility models for all the cases. There are four simulation models used to perform this task:

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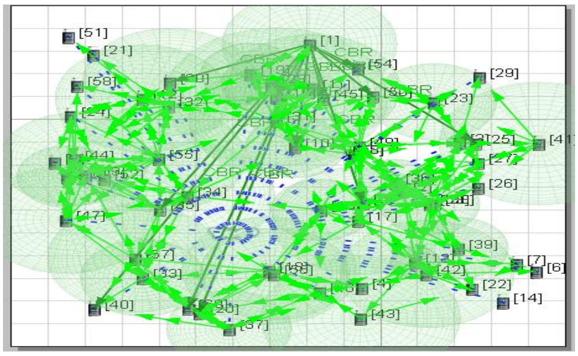

Fig. 2. Outcome designed simulation scenario for average end to end delay of 60 nodes for OLSR, RIP, LAR and ZRP routing protocol.

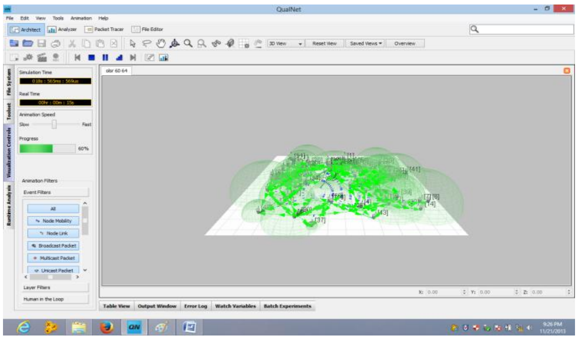

Fig. 3. X-Y Outcome of designed simulation scenario for average end to end delay of 60 nodes for OLSR, RIP, LAR and ZRP routing protocol.

Model 1: In this model, the network used is very small of size 60 nodes.

Model 2: This packet size has been increased from 32, 64,128,256,512 and 1024.

Model 3: The no. of users, in this network is increased to 65 users and now there is an increase in congestion.

Model 4: Now, the network is of 60 nodes, such that the users got closed and network becomes more compact and crowded. The senders and receivers are different length destination in each model among network are placed at same place initially but as the simulation starts, the nodes starts moving and the location of source to destination node changes and also other nodes which are in the network. The packet size without header is changing from 32, 64, 128, 256, 512 and 1024.

VII. Simulation Result and Discussion

In this section simulation results for the selected protocols in term of average end-to-end delay are elaborated.

Delay vs. packet size:

We vary the simulation time and calculate end to end delay. We run these simulations for OLSR, RIP, LAR and ZRP individually, incrementing the number of nodes from 1 to 60. The simulation time is 30 seconds. In addition to simulation parameters given in Table 2, Table 2 shows scenario parameters applicable to this simulation.

A. Simulation Result for Average End to End Delay of OLSR, RIP, LAR and ZRP routing protocol

The average end-to-end delay is less for the OLSR approach than for the RIP, ZRP than LAR approach. The reason is that the periodic gateway information sent by the gateways allows the nodes to update their route entries for the gateways more often, resulting in fresher and shorter routes. With the OLSR's node continues to use a route to a gateway until it is broken. In some cases this route can be pretty long (in number of hops) and even if the node is much closer to another gateway it does not use this gateway, but continues to send the data packets along the long route to the gateway further away until the route is broken. Therefore, the end-to-end delay increases for these data packets, resulting in increased average end to end delay for all data packets. The average end to end delay is decreased slightly for short pause time intervals when the advertisement interval is increased. At the first thought this might seem unexpected.

However, (Fig. 4 to10) it can be explained by the fact that very short advertisement intervals result in a lot of control traffic which lead to higher processing times for data packets at each node as shown in graphical representation of 5, 10, 20, 30, 40, 50 and 60 nodes.

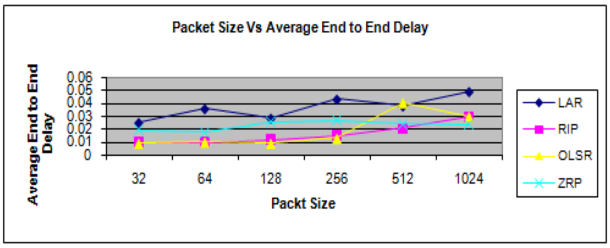

Fig. 4. Average End to End Delay of 5 nodes in Physical Layer for different Routing Protocols

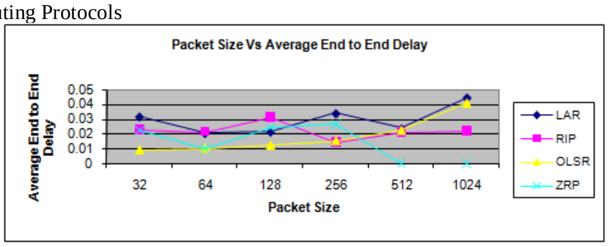

Fig. 5. Average End to End Delay analysis of 10 nodes in Physical Layer for different Routing Protocols

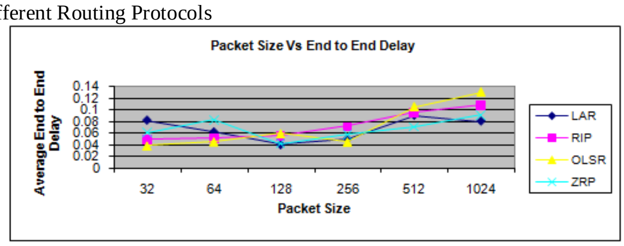

Fig. 6. Average End to End Delay analysis of 20 nodes in Physical Layer for different Routing Protocols

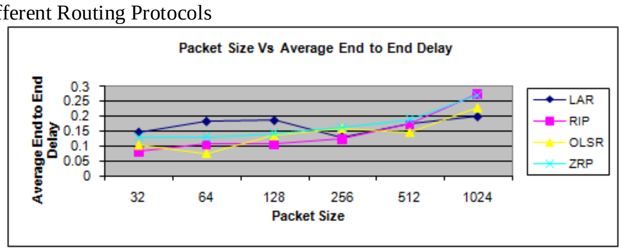

Fig. 7. Average End to End Delay analysis of 30 nodes in Physical Layer for different Routing Protocols

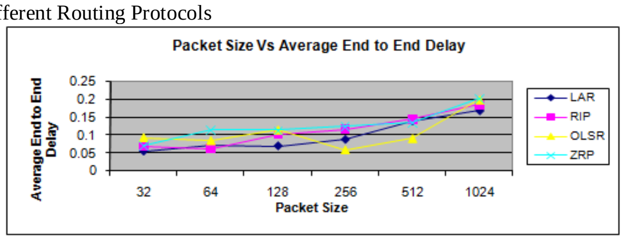

Fig. 8. Average End to End Delay analysis of 40 nodes in Physical Layer for different Routing Protocols

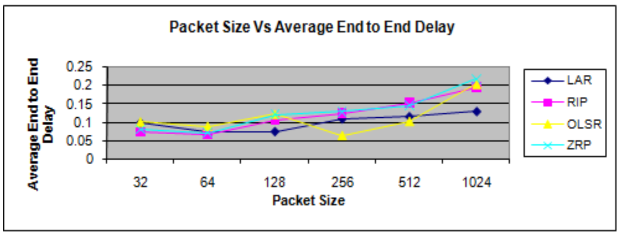

Fig. 9. Average End to End Delay analysis of 50 nodes in Physical Layer for different Routing Protocols

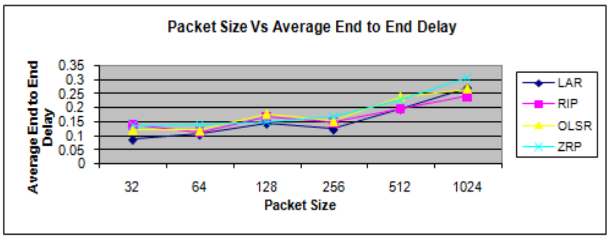

Fig. 10. Average End to End Delay analysis of 60 nodes in Physical Layer for different Routing Protocols

This is the time when a sender generates the packet and it is received by the application layer of destination, it is represented in seconds. It is also called Data Latency. This is the whole time that includes all possible delays caused by buffering of data packets during route discovery, queuing at the interface queue, retransmission delays at the MAC and propagation and transmission times. As observed in fig, 7, (no of nodes is 30 and 256kb of packet size) the average end to end delay is almost equal and the hybrid protocol ZRP is having medium end to end delay. Hence it is obvious that the time at which the first packet received will be smaller for OLSR and RIP as compared to ZRP and LAR.

VIII. Conclusion

In this paper, we propose on average End to End delay of multipath source routing (DMSR) protocol to provide end-to-end delay requirement in wireless ad hoc networks. We analysis the component parts of the end-to-end delay and introduce a packet size, QoS metric, node delay, which is used to evaluate the state of the nodes and analysis and investigations are carried protocols, OLSR, RIP, LAR and ZRP. OLSR has the poorest performance amongst the four protocols examined. ZRP which is a hybrid protocol has moderate performance but as the number of nodes increase to 50 its performance deteriorates considerably, so ZRP can be used for small networks. So it is concluded that OLSR (On-Demand Routing Protocol) shows the comparatively high performance than all other type of protocols. So when aim is to minimize the end to end delay, On Demand Routing protocols can be used. This work can be further extended to improve this system by implementing another parameters like average jitter, packet delivery ratio, security issues etc. such that the overhead of selecting routing protocol can be minimized.

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