ISSN 2047-3338

Comparison of AODV, DSR and TCRP Protocols for Routing Algorithms in WSNs for IEEE 802.15.4 Standard Based Devices

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***Abstract*– IEEE 802.15.4 is the prevailing standard for low-data-rate wireless personal area networks. The IEEE 802.15.4 protocol has recently been adopted as a communication standard for low data rate, low power consumption and low cost Wireless Sensor Networks (WSNs). This protocol is quite flexible for a wide range of applications by adequately tuning its parameters. This feature is quite attractive for time-sensitive WSN applications. The IEEE 802.15.4 standard specifies the physical layer and MAC sub-layer for Low-Rate Wireless Personal Area Networks (LR-WPANs). The ZigBee standard is closely associated with the IEEE 802.15.4 protocol and specifies the network (including security services) and application (including objects and profiles) layers. In IEEE 802.15.4 standard, Packet monitoring statistics along with optimal route selection between nodes is the research topic of major concern from the very first day of its implementation. In this paper, we first try to analyze the existing reactive (on-demand) routing protocols for mesh networking based on random waypoint mobility model and then try to propose new approach for this model.**

***Index Terms*– IEEE 802.15.4 Standard, ZigBee, Wireless Sensor Networks, Packet Loss and Routing Algorithms**

I. INTRODUCTION

IEEE 802.15.4 is the standard used for low-data-rate wireless personal area networks. While IEEE 802.15.4 defines medium access control (MAC) [2] layer and physical layer (PHY), ZigBee takes care of higher layers (network and application). ZigBee is used for home, building and industrial control. It conforms to the IEEE 802.15.4 wireless standard for low data rate networks. With a maximum speed of 250 Kbps at 2.4GHz, ZigBee/IEEE 802.15.4 is slower than Wi-Fi and Bluetooth, but is designed for low power so that batteries can last for months and years. The fast development of wireless communication and electronic device technology has urged the development and the application of low power loss, the low price and the multi-purpose miniature sensor.

In general, along with signal distance enlargement, the cost of system complexity, the power loss as well as the system is increasing. Compared with the existing kinds of wireless communication technologies, ZigBee/IEEE 802.15.4 technology will be the technology of the lowest power loss and cost. Meanwhile, because of the ZigBee/IEEE 802.15.4 technology's low data rate and small communication range, it has made this technology to be used in the small load data current capacity business.

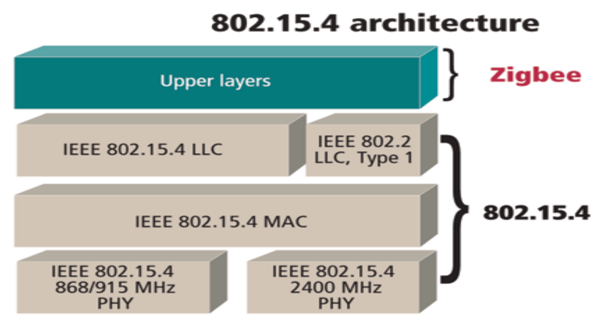


Fig. 1: How IEEE 802.15.4 standard and ZigBee are related?

The new standard targets home and building control, automation, security, consumer electronics, PC peripherals, medical monitoring, and toys. These applications require a technology that offers long battery life, reliability, automatic or semiautomatic installation, the ability to easily add or remove network nodes, signals that can pass through walls and ceilings, and low system cost.

The IEEE 802 wireless space can be categorized into different wireless technologies based upon the data rate which they operate on. These wireless technologies are provided with particular IEEE standards. Our area of interest is IEEE 802.15.4 standard/ZigBee which operates in the 0.01 to 0.1 Mbps data range which is the lowest data range of all existing wireless technologies.

IEEE 802.15.4 standard/ZigBee transmits data at a relatively slow 250 Kbits per second at 2.4 GHz, 40 Kbps at 915 MHz, and 20 Kbps at 868 MHz, which works well for simple sensor systems that transmit only small amounts of data occasionally.

II. ZIGBEE/IEEE 802.15.4 STANDARD ARCHITECTURE

The ZigBee/IEEE 802.15.4 network node is designed for, battery powered or high energy savings, searches for available networks, transfers data from its application as necessary, determines whether data is pending, requests data from the network coordinator, can sleep for extended periods.

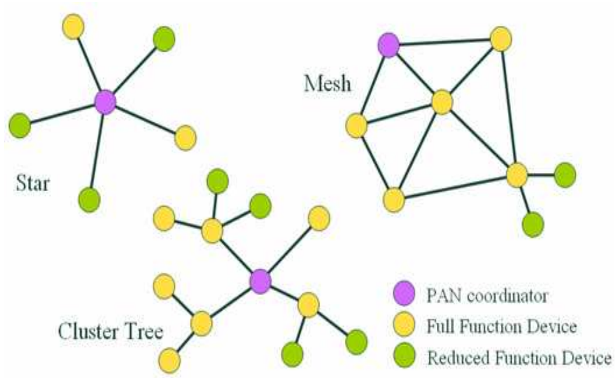


Fig. 2: Different topologies that exists in IEEE 802.15.4/ZigBee Networks

There are two physical device types for the lowest system cost defined by the IEEE. Full function device (FFD) [6] can function in any topology, is capable of being the network coordinator and can talk to any other device. Reduced function device (RFD) is limited to star topology, cannot become a network coordinator, talks only to a network coordinator has very simple implementation.

An IEEE 802.15.4/ZigBee network requires at least one full function device as a network coordinator, but endpoint devices may be reduced functionality devices to reduce system cost. The FFD can operate in three modes serving as a personal area network (PAN) coordinator, a coordinator, or a device. An RFD is intended for applications that are extremely simple, such as a light switch or a passive infrared sensor; they do not have the need to send large amounts of data and may only associate with a single FFD at a time. Consequently, the RFD can be implemented using minimal resources and memory capacity.

In peer-to-peer topology, there is also one PAN coordinator. In contrast to star topology, any device can communicate with any other device as long as they are in range of one another. A peer-to-peer network can be ad hoc, self-organizing and self-healing. Applications such as industrial control and monitoring, wireless sensor networks, asset and inventory tracking would benefit from such a topology.

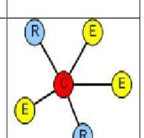
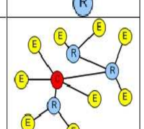
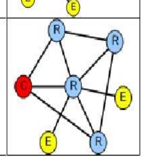
Topology Type	Addressing	Parent/Child	
Star	Distributed (structured)	Only one parent, all other devices are child devices	
Tree	Distributed (structured)	Multiple parents and child devices	
Mesh	Stochastic (random)	Multiple parents and child devices	

Fig. 3: Comparison of topologies in IEEE 802.15.4/ZigBee Networks

III. ROUTING PROTOCOLS IN IEEE 802.15.4/ZIGBEE STANDARD

There are several kinds of routing protocols for wireless sensor networks. These routing protocols are categorized as reactive or proactive routing protocols [8]. WSN routing protocols which have both proactive and reactive merits, is called hybrid routing protocols. The first kind of protocol is called reactive or on-demand routing protocol. The second kind of protocol is proactive or table driven routing protocol.

Here, as we are dealing with WSN based on IEEE 802.15.4/ZigBee standard using mesh topology, we only talk about on-demand routing protocols.

A. Source-Initiated On-Demand Routing

This type of routing creates routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery process within the network. This process is completed once a route is found or all possible route permutations have been examined. Once a route has been established, it is maintained by a route maintenance procedure until either the destination becomes in accessible along every path from the source or until the route is no longer desired.

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

AODV [10] is an on-demand protocol, which initiate route request only when needed. When a source node needs a route to certain destination, it broadcasts a route request packet (RREQ) to its neighbours. Each receiving neighbour checks its routing table to see if it has a route to the destination. If it doesn't have a route to this destination, it will re-broadcast the RREQ packet and let it propagate to other neighbours. If the receiving node is the destination or has the route to the destination, a route reply (RREP) packet will be sent back to the source node. Routing entries for the destination node are created in each intermediate node on the way RREP packet propagates back.

C. Dynamic Source Routing (DSR)

Dynamic Source Routing protocol [11] is a reactive protocol i.e. it determines the proper route only when a packet needs to be forwarded. The node floods the network with a route-request and builds the required route from the responses it receives. DSR allows the network to be completely self-configuring without the need for any existing network infrastructure or administration. Route discovery is performed when a source has a packet to send, but does not know a route to its destination. The source broadcasts a query called a Route Request (RREQ) to each of its immediate neighbor, which on receiving, checks whether it is the destination, or has a route to the destination. If so, the node uncast a response called a Route Reply (RREP) back to the source, informing it of the route to the destination.

D. Threshold Constrained Routing Protocol (TCRP)

The threshold constrained routing protocol is an on-demand routing protocol, also called reactive protocol designed mainly for the wireless sensor networks (WSNs). As the already discussed routing protocols are designed mainly for the Mobile Ad-hoc networks (MANETs), this protocol is designed keeping in mind the requirements of the WSNs. This protocol depends upon the constrained threshold routing in which route discovery method is different from the above discussed routing algorithms. In this, each sensor that has some data packet to send will only send data if the other sensor or node is within the transmission range of that sensor. Further, transmission of data packet also depends upon the constrained threshold radius of the sensor. Only if the two conditions are met, the transfer of data packets will take place. Thus, this routing protocol is somewhat more effective than the two protocols discussed above. Comparison of these protocols based upon performance metrics i.e. packet monitoring statistics is done.

IV. MOBILITY MODEL

A. Random Waypoint Mobility Model

To evaluate the performance of a protocol for a wireless sensor network, it is necessary to test the protocol under realistic conditions, especially including the movement of the mobile nodes. Since not many WSNs have been deployed, most of this research is simulation based. These simulations have several parameters including the mobility models and the communicating traffic pattern. Routing protocol performance may vary drastically across different mobility models. In the literature, there are a lot of models used, mostly in simulations. Among the common one is the Random Waypoint Model, which is a simple model that may be applicable to some scenarios.

A node begins the simulation by waiting a specified pause time. After this time it selects a random destination in the area and a random speed distributed uniformly between 0 m/s and Vmax. After reaching its destination point, the node waits again pause time seconds before choosing a new way point and so on. The nodes are initially distributed over the simulation area. This distribution is not representative to the final distribution caused by node movements.

The Random Waypoint Mobility Model [12] is very widely used in simulation studies of WSNs. As described in the performance measures in wireless sensor networks are affected by the mobility model used.

V. RESEARCH METHODOLOGY

In this research work, first step is to figure out or identify our requirement of WPAN sizing or dimensioning. i.e. how much area we want to cover under WPAN using IEEE 802.15.4/ZigBee standard devices. Then, our next step would be to deploy the network in that particular area. This deployment would only be possible if we establish the network by selecting appropriate physical as well as simulation parameters. Then, we'll the apply several algorithms by creating a mathematical model for this. Already existing algorithms include AODV and DSR in this scenario. But, our aim is to identify/develop new algorithm so that our packet monitoring statistics will be optimized.

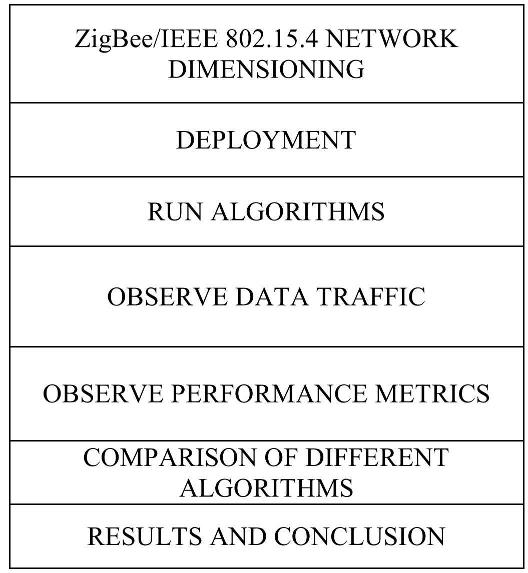


Fig. 4: Steps to be followed in research methodology

Till now, we have compared the AODV and DSR algorithms in the given simulation domain. Data traffics would be observed and we'll look for the performance metrics optimization which will be followed by Results/conclusion at the end.

VI. MATHEMATICAL MODEL

We will formulate the mathematical model for studying ZigBee sensor behavior while communication is running throughout the network.

1. Let there be ZN number of sensors = { N1 N2 . . . . . . Nn }.
2. Define personal area network definition.
3. Deploy no. of sensors in domain area/PAN e.g. (100 * 100).
4. Identify coordinates of stationary and mobile nodes.
   4.1 Let SM be stationary matrix = { SM1 , SM2 , SM3 . . . . . SMn }
   where SM1 = (x,y)
   4.2 Let MM be mobile matrix = { MM1 , MM2 , MM3 . . . MMn }
   where MM1 = (x,y)
5. Let SR be the sensor radius.
   5.1 we define sensor radius of all nodes to be constant and its value is assumed using IEEE 802.15.4 standard.
6. Let transmission radius of sink be equal to as specified in IEEE ZigBee specification.
7. Let GB be assumed as gateway having coordinates (x,y).
8. Let TOP be an enumerator used to define topology of zigbee network.
   8.1 We will take MESH topology as one of the enumeration.
   TOP = { TREE = 0 , MESH = 1 , STAR = 0 }.
9. Let TOD be used as an enumerator to study different types of data traffic .

TOD = { INTERMITTANT =1|0 , PERIODIC = 0|1, REPETITIVE = 0|1 }

10. Let PS be = data packet size of TOD.
    PS = TOD.SIZE { value chosen by default as mentioned in IEEE specification}.
11. Iterate the simulation having data running in the network.

VII. EXPERIMENTAL SETUP

To build, construct and develop analytical study of various aspects of IEEE 802.15.4 standard. The experimental setup was done using Matlab R2010b.

A. Performance Metrics

Following important metrics are evaluated:

Packet Delivery ratio (PDR): Packet delivery ratio is calculated by dividing the number of packets received by the destination through the number of packets originated by the CBR source. The number of packets dropped does not take into account retransmissions. This would effectively make the number of transmitted packets equal to the sum of the number of received packets and number of dropped packets.

Delivery_Ratio =

*(Number_of_Received_Packets/Number_of_Transmitted_Packets) *100*

Loss Packet Ratio (LPR): Loss Packet Ratio is calculated by dividing the number of packets that never reached the destination through the number of packets originated by the CBR source. In this metric, the packets received are not taken into account as long as the packet is dropped. In other words, there is no difference between transmissions and retransmissions, and this metric is not an exact reflection of the successful delivery of the upper layer payload. The packet drop ratio can be used for the indication of congestion in the network.

Loss_Ratio =

*(Number_of_Packets_not_recieved/Number_of_Transmitted_Packets) *100*

Routing Overhead: Routing overhead, which measures the ratio of total routing packets sent and the total number of packets sent. Routing overhead can be used for the indication of how many total routing packets sent in order to sent some data packets.

Routing_Overhead=

*(Number_of_total_routing_packets_sent/Total_Number_of_packets_sent) *100*

VIII. SIMULATION PARAMETERS

Simulation is a flexible means for assessment of the performance offered by a telecommunication system. However, identifying the correct simulation parameters is a key for a successful and nearly realistic analysis of any study. The following list focuses on the task of identifying the correct parameters to generate a realistic network scenario. Simulation parameters used in our study are given in Table I.

Table I: IEEE 802.15.4 Mesh topology simulation parameters

SIMULATION PARAMETER	VALUE
Topology Used	Mesh
Domain	100m*100m*100m
Type of traffic	CBR
Burst Time	200 msec.
Packet Size	127 bytes
Data rate	100k
Random Noise	0
Mobility Strategy	Random way point
Operating Frequency	2.4 GHz(worldwide band
No. of nodes	100,110,120,130,140,150
Transmission Radius of each node	20m

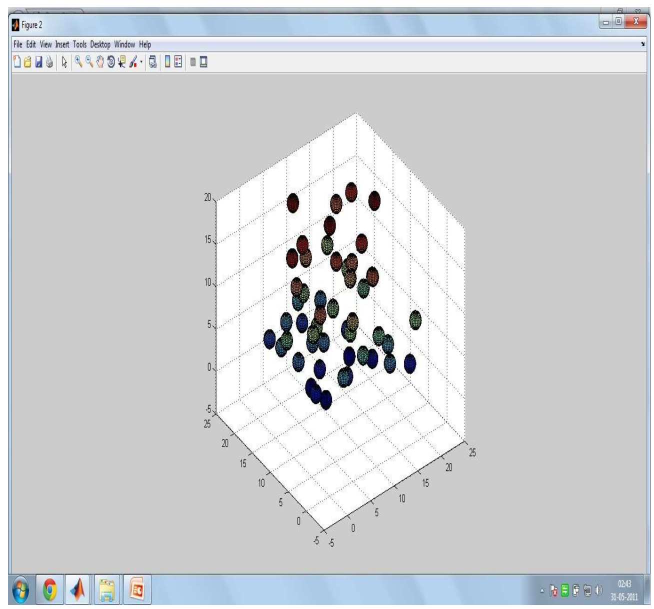


Fig. 5: Position of sensors in 3D domain i.e. any particular area, deployed in Matlab

Now, the basic simulation setup is complete. Then, for the sensors deployed in the domain, different routing algorithms were run and a Log table and a trace file is generated for each routing algorithm. The network statistics are then monitored for each routing algorithm. The number of data packets send, packets received, and packets dropped etc. are stored in the respective log tables of each routing protocol. From these values, comparison based upon the PDR, LPR & routing overhead is done. A snapshot showing the data entries is also shown in Fig. 5.

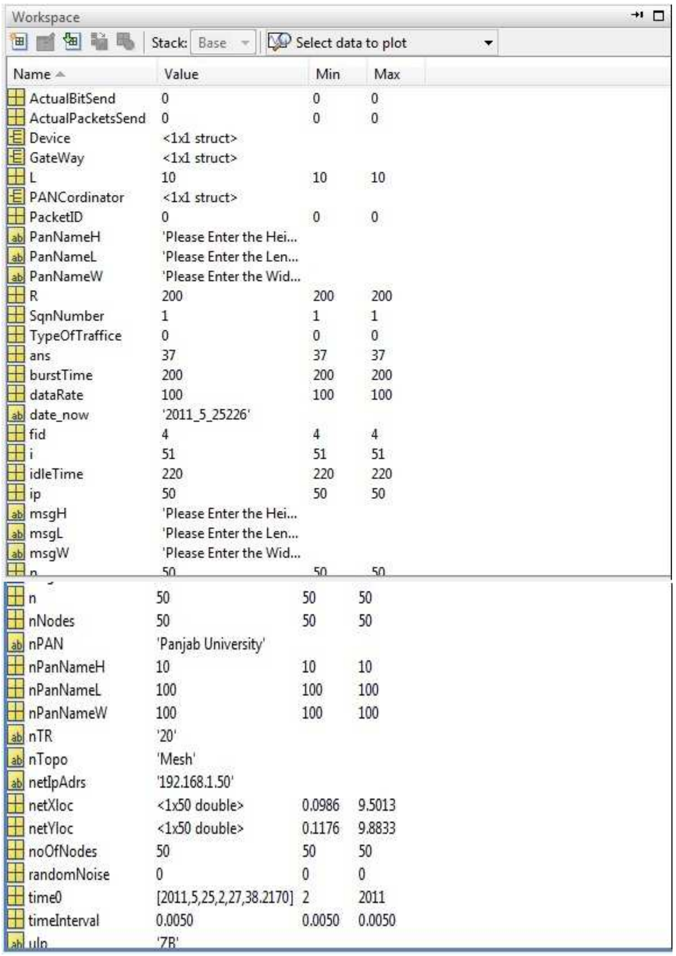


Fig. 6: Snapshot showing LOG Table being generated in MATLAB

IX. PERFORMANCE EVALUATION

Throughout the simulation performance of AODV is consistent and is always on the way of improvement, even though it is not as good as compared to the performance of DSR. It can be observed in figure, that Packet delivery ratio performance of ADOV improves gradually as the number of nodes increases. Although PDR of both AODV and DSR is dropped drastically at the same point when number of nodes are between 110 to120.

Improvement in DSR is observed when number of nodes exceeds 120, while improvement in AODV is observed as the number of nodes reached 130.

AODV starts to perform much better than DSR when the number of nodes exceeds 135 nodes, while DSR shows a big drop in the PDR. It can be observed in figure, that Loss Packet Ratio in AODV is always greater as compared to DSR, even though it can be observed that performance of AODV is drastically improved as the number of nodes exceeds 140, while DSR starts to perform poorly at the same point.

After observing in figure, AODV and DSR are performing equally in terms of Routing Overhead factor. Even though DSR performs much better as compared to AODV, until a point where number of nodes exceeds 140. Around 115 nodes value, performance of both AODV and DSR starts to improve.

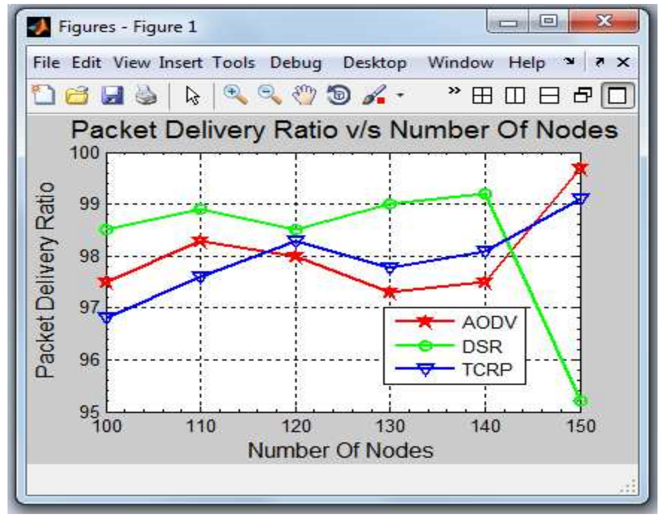


Fig. 7: Number of Nodes Vs Packet Delivery Ratio

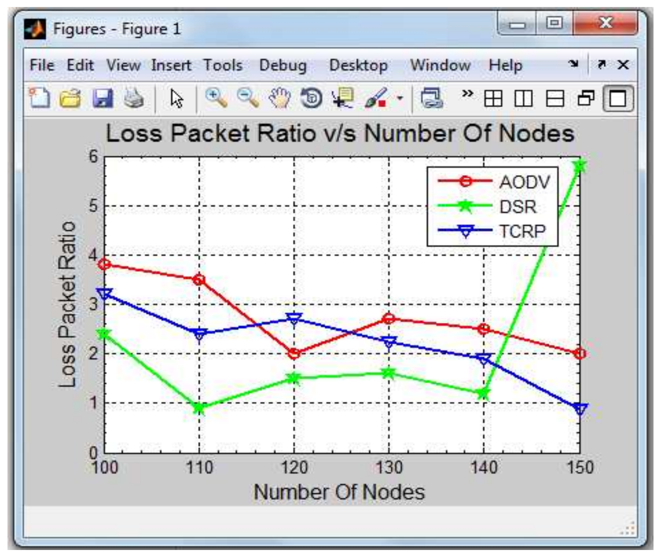


Fig. 8: Number of Nodes Vs Loss Packet Ratio

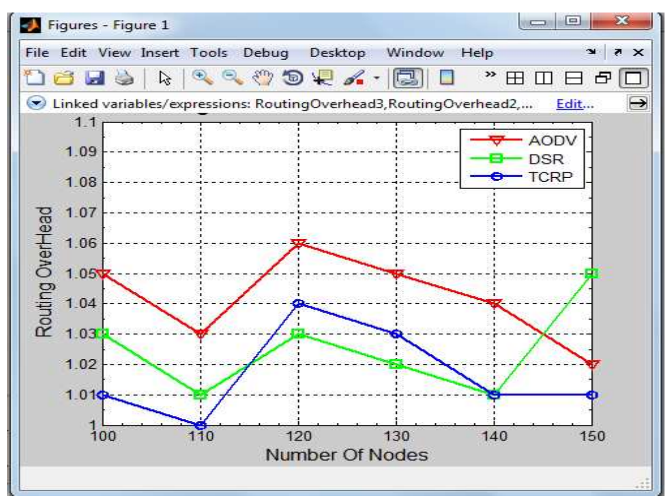


Fig. 9: Number of Nodes Vs Routing Overhead

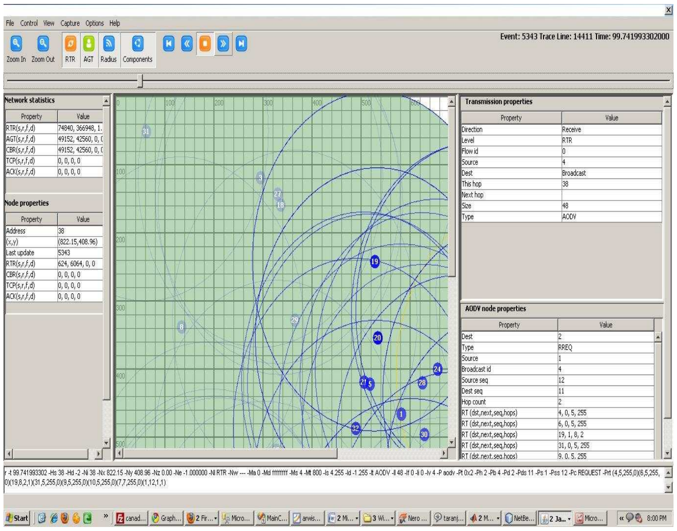


Fig. 10: Packets being transmitted b/w nodes

AODV continues to improve while DSR shows more routing overhead. Although, all the implementation is done in MATLAB R2010b, but as we know that Matlab is not a pictorial tool. MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. i.e., it doesn't work like other open source network simulators available now-a-days. So, to represent the work done in pictorial way, I have used another open source network simulator called NetBeans. All the algorithms were simulated in this network simulator just to show the pictorial representation. Some Snapshots of the network simulator are also shown in Fig. 7 to Fig. 11.

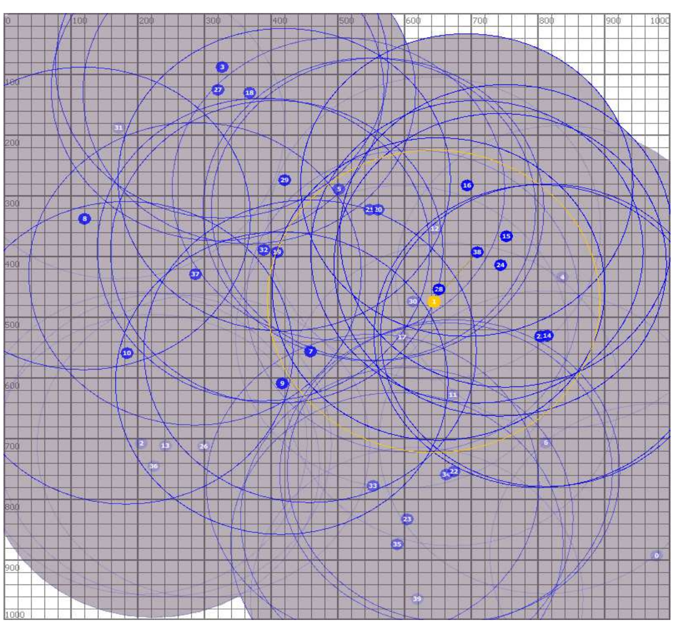


Fig. 11: Snapshot showing packets being transmitted from one node to another considering the transmission radius

X. PROPOSED RESEARCH WORK AND CONCLUSIONS

In this paper, two on-demand (reactive) routing algorithms AODV and DSR has been compared with the new routing protocol TCRP based on several packet monitoring statistics e.g. packet delivery ratio, packet loss ratio an d routing overhead. To conclude the research paper, the following are some suggestions for the future work which can be done. The future work suggested is the development of modified version of the selected routing protocols which should consider different aspects of routing protocols such as rate of higher route establishment with lesser route breakage and the weakness of the protocols mentioned should be improvised.

Secondly, security as a QoS parameter has not been evaluated in this thesis. So, new security based routing protocols for IEEE 802.1 5.4 networks and its validation can be a field of study.

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