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Enhancing Ad Hoc network performance using different propagation models in cluster based routing protocols

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Abstract: A mobile ad-hoc network (MANET) consists of a number of mobile nodes that are connected dynamically without any infrastructure. In this network type, the use of the clustering technique significantly reduces the routing traffic that occurs during the routing process. Clustering is used to divide an ad-hoc network into small sets of nodes, where each cluster consist of a cluster head, ordinary nodes and gateway nodes. It can be used for the effective utilization of resources for large ad-hoc networks. In most of the previous studies, the performance of ad-hoc routing protocol has been measured using Two-ray ground propagation model, which cannot measure the realistic network topology, since it represents the optimal environment and does not take into account the effect of different obstacles which appeared during the signal transferring. Hence, the most realistic propagation model is the shadowing model which considered all of these obstacles into calculations. This paper measures the impact of using different propagation models, i.e. Two Ray Ground and shadowing, on the Cluster Based Routing Protocol (CBRP) which is considered the most important routing protocol of the cluster. The effect on performance of MANET, using various performance parameters like throughput, packet delivery ratio (PDR), end-to-end delay and number of dropped packets have been calculated. The results have showed the importance of propagation on MANET performance.

Key words: Adhoc networks; Clustering; CBRP; Propagation models

1. Introduction

Many studies had proposed an idea of dividing the entire system into a number of groups which is called cluster. This idea was produced and changed over the time into a distributed method which kept the structures of the network in case of mobility, congestion and nodes failure. This method was more suitable in the Battlefield Information Distributed (BID) framework, High Frequency Intra Task Force (HFITF) correspondence system, Packet Radio Network (PRNET) and Advanced Mobile Phone Service (AMPS). The HFITF system is adaptable and helpful system that gives nearly (50-1000km) distinguishable line of sight for oceanic group units. By using an HF method (2-30MHz) call radio waves, the nodes will be connecting but the nodes connectivity will be varied according to the network topology changes, link failures, nodes failures, entrance of new nodes, etc. From this point, the real need for an adaptable network without need for the central administration has emerged, and the need for a new wireless channel with less congestion was increased. Thus, many writers proposed an alternate structural system which is called linked cluster design, where the network is divided into a number of groups i.e. clusters and all nodes must attach to one group. Cluster head for each cluster should be directly connected to all its member nodes; in order to solve the all the members' problems using the existing busy tone multiple access (BTMA) method (Tobagi and klinrock, 1975).

However, clustering is considered one of the most popular techniques which are used to reduce traffic in routes and minimize energy consumption in large wireless networks by collecting the nodes into groups called clusters. The collecting of the nodes is constructed according to the distance; it means each node is connected with its nearest nodes. Any node is considered neighbor to other node, if each one is located in the transmission range of each other, and there is a direct links between them. Clusters in MANET are mainly classified into overlapping cluster and disjoint cluster, as shown in Fig.1. Each big circle represents a cluster and the small nodes within the cluster stand for the wireless nodes within the network. The lines which connecting the wireless nodes represented the connection among them.

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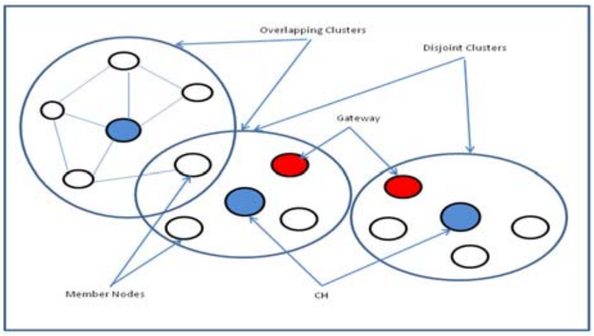

Fig. 1: Overlapping and non-overlapping clusters

2. Advantages of clusters

Using clustering in MANET resulted in many advantages in comparison with other types of networks. Some of these advantages are:

1- It can be used to enhance the routing process in the network layer by minimizing the routing table size.
2- It can reduce the transmission traffic overhead by making the update operations for all the routing tables after network topology has been changed (Roberto et al., 2007).
3- It improves the performance of the routing protocol in the Medium Access Control (MAC) layer by enhancing the throughput and power consumption for the network.
4- It reduces the network bandwidth and the energy consuming for MANET.
5- It is considered the practical representation for the aggregation technology, since each node contains a small piece of entire routing information and this node is small when it compared with the network nodes (Naveen et al., 2011).

3. Stages of clustering stages of clustering

The clustering process is divided into three main stages which are: clustering formation stage, clustering maintenance stage and clustering routing stage.

3.1. First stage

The clustering formation stage: The wireless nodes are divided into numbers of small sets and elected one of these nodes to be the cluster head of the set. The selection of the cluster head for the group in MANET is considered a difficult issue because of the dynamically topology changes, and the cluster head is considered the controller of the cluster since it is responsible for the packets routing and the administration operations of all the nodes in its cluster (Gary and Johnson, 1975). Hence, many suggested algorithms had been presented for cluster head selection depending on the power consuming, node ID, weights of each node, etc. (Basagni, 2006).

3.2. Second stage

Clustering maintenance stage: The main aim of this stage is to keep the topology of the cluster as much as possible. In one node clusters, each node is communicated directly with a cluster head, so that if one of them moves out of the transmission range of the other node, the failure of the link will occur and the member nodes must select another cluster to join. This process is called a re-election process and this operation resulted in consuming more calculated costs and the packets complication, so that it needs for developed algorithms to reduce this challenges.

3.2. Third stage

Clustering routing stage: This stage also consists of two main phases, the first phase is called Route Discovery and the second one is Route Maintenance. The Route Discovery is used when the source node need to send packets to destination node and need to find the suitable route in order to reach the destination. However, the Route Maintenance is done only when the source node have a suitable route to the destination node, but it cannot reach because of the frequently topology changes, so the old route to the destination is no longer available (David, 2004).

4. Clustering algorithms for MANET

There are a great number of different clustering algorithms which have been suggested, but from the structural point of view, clustering algorithms can be classified into cluster Head based, and non-cluster Head based algorithms (Marco, 2008). Cluster Head based algorithms is depended on selection one of the cluster nodes to be the cluster head node (CH, i.e. the group leader), which is responsible for all the internal and external management and routing operations for the other nodes. On the other hand, in the non-cluster head based algorithm, each node can decide, which sets have to be joined and what group they have to leave without need for any participation from the other nodes (NS-2 Manual, 2010). Some studies proved that cluster head based algorithm may result in high number of packet loss because it is based on only one node to find, maintain and calculate the suitable route for all the other nodes (Ismail, 2011). In addition, Cluster head may become suffer from bottleneck problem when the network traffic load has increased (Ashish and Sourabh, 2011).

5. Routing in Ad Hoc network

Routing is the mechanism which is used to direct the information from a sender node to the receiver node. It is considered one of the most significant aspects in MANET because of its structure which is distinguished by lot of modification. In MANET, each node can be used to send, receive, and forward the data, so that the routing must select the most suitable routes for the nodes, and forward the data to the specific destination node.

6. Routing strategies

The way of selection the most suitable route and forwarding the data is based on the routing strategy. The most important routing strategies are as follows:

6.1 First Routing Strategy: Flooding

Flooding is important strategy which is used in MANET routing protocols. It depends on sending control data to all nodes which are virtually available in network. The procedure of this strategy is as the following: the source node transfers the data to all its neighbor nodes and the last will transfer this data to all other neighbor until this data has delivered to all nodes in the network. The main disadvantage of this way is the minimum bandwidth overload (Charles et al., 2003

6.2. Second routing strategy: distance vector

In this strategy, each node in the network calculates the distances to all other nodes in the network, and keeps this information in a specific table and periodically broadcast this information to all other node in the network. Destination Sequenced Distance Vector (DSDV) is one example of this strategy (Azzedine, 2009). Distance vector operation is shown in Fig. 2.

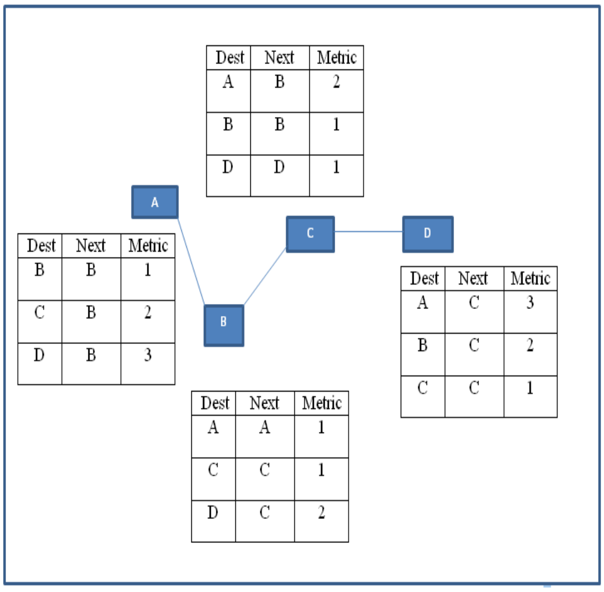

Fig. 2: Distance vector routing

6.3. Second routing strategy: link state

In link state routing, each node keeps a complete table of the network structure and the weight of each route. Each node periodically broadcasts the route weight to all other nodes in order to update their routing information and select the most suitable route. Optimized Link Status Routing (OLSR) is an example of this strategy (Panagiotis and Zygmunt, 2003).

6.4. Fourth routing strategy: source routing

Each packet must contain complete information about the route; so that the routing selection is made at the source node. Dynamic Source Routing (DSR) is an example of this strategy (Tony and Nicklas, 1998).

7. Ad-Hoc routing protocols classifications

Routing protocols between any nodes in Ad-hoc network must be included into one of the following three classifications (Tobagi and klinrock, 1975), as shown in Fig. 3.

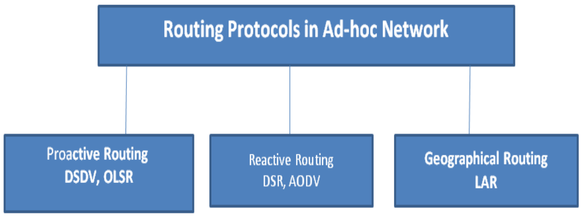

Fig. 3: Reactive protocols classification

7.1. Reactive routing protocols

In this type of routing, the route is established according to a specific request, it means that route is constructed for the mobile nodes which need to send packets to a specific node. There is no need for updating the routing information table periodically. It uses the available connection foundation process for making communication between nodes. Route establishment is usually executed by sending a route request to all the available nodes in a network. When this request is delivered to a node with a specific route, this node will send a route replay to the sender node. Reactive protocols can be categorized into two types: Source routing protocols and Point-to-point routing protocols. In Source routing protocols (Johnson et al., 2004) (Toh, 1996), each packet must contain the full address for the sender and the receiver, and intermediate nodes in its header. All intermediate nodes will follow this address to forward the data to a specific destination, without the need to update their routing table for every active route. In this type of routing, the node does not check the connectivity with the other nodes by using periodic messages. The main disadvantage of the source routing protocols is the disability of using this method in a network with a large number of nodes, and the main reasons of this drawback is that when the size of the network increases, the number of intermediate nodes will also increase and the probability of congestion and link failures will also grow. It is not suitable for a large scale network due to its disability to update its information according to the network changes, especially when it deals with Ad-hoc network which is distinguished by its dynamic topology.

In point-to-point routing protocol, each packet contain only the destination address and the address of the next hop. So, the intermediate nodes will forward the packets according to its routing table. The major advantage of using this method is its simple construction, minimum delay and less network overload, because control routing information will not send periodically to all available nodes. Its main disadvantage is that all the intermediate nodes should store complete routing information for all the active routes. Ad-hoc On-demand Distance Vector Routing (AODV) and Dynamic Source Routing (DSR) are examples of Proactive Routing Protocol (Atekeh et al., 2011).

7.2. Proactive routing protocols

This type the routing protocol is pre-established even if there is no virtual routing request available, and the routing information is sent periodically to all other nodes in the network. Each node must contain the routing information for all the other nodes which are available in the network. This routing information must be updated according to the network structure changes. The information that must be updated in the routing table is the number of nodes which are needed in order to reach to a specific destination and the sequence number for each node (Mingliang et al., 2009). The main advantage of this routing protocol is its ability to modify the routes according to the network topology changes, which gives the minimum end to end delays (Basu et al., 2012). However, the main drawbacks is the great network overload and high consumption of the bandwidth in routing table which resulted from sending the routing information to all nodes in the network. Destination Sequenced Distance Vector (DSDV) and Optimized Link State Routing Protocol (OLSR) are examples of Proactive Routing Protocol and Optimized Link State Routing (OLSR) (Patil, 2012).

7.3. Geographical routing protocol

Geographic routing has become one of the most important routing methods in MANET, because of its accuracy. This routing protocol is based on the geographical notifications for routing data. This geographical information is given in a form of coordinates for the actual position. The information is taken from the static coordinates systems or from the Global Positioning System (GPS). This type of routing protocols is considered more suitable for ad-hoc networks because it does not need to know the network topology changes and update routing information or the location information. The importance of the routers in this routing protocol is reduced because the forwarding process is based on the location information only.

In Geographical routing protocol, the routing information will not be kept, only the status of the closes (neighbor) nodes will be constructed. This situation will result in reducing the network (Raja, 2007). The main advantages of this type are minimum end-to-end delay, less network overload, less number of dropped packets and minimum routing information. It can determine the accurate destination with less search process. Location Aided Routing (LAR) is an example of the Geographical Routing Protocol (Thomas et al., 2008).

8. Cluster-based routing protocol (CBRP)

The cluster-based routing protocol (CBRP) was first presented in 1999 by Jiang. In this type of routing protocol, wireless network nodes are divided into a number of disjoint and overlapping clusters. Each cluster selects one of its nodes to be a cluster head. This type of node is responsible for the routing process. The cluster heads are capable of communicating with one another using gateway nodes. Another type of cluster node is a gateway, which is defined as a node with two or more cluster heads as its neighbors. The clustered technique leads to little traffic because any route request is passed between cluster heads only and passing through the entire network is not necessary (Jiang and Tay, 1999).

9. Propagation model types

9.1. Free space model

It is one type of propagation models that are used for short distance. Free space model can only be influenced by noise of the source only. The free space propagation model assumes the ideal propagation condition that there is only one clear line-of-sight path between the transmitter and receiver. The free space model basically represents the communication range as a circle around the transmitter. If a receiver is within the circle, it receives all packets. Otherwise, it loses all packets.

The following equation is used to calculate the received signal power in free space at distance d from the transmitter:

$$P_{r(d)} = P_t\ G_t\ G_r\ \lambda / (4\Pi)^2 (d)^2\ L \qquad (1)$$

Where:

$P_{r(d)}$ is the received signal power in free space at distance d.

P_t is the transmitted signal power.

G_t and G_r are the antenna gains of the transmitter and the receiver.

λ is the wavelength. It is common to select.

d is the distance.

L (L≥1) is the system loss.

9.2. Two-ray ground model

It is another type of propagation that is used with long distance because it is accurate in prediction and giving excellent results. Two-Ray Ground can be influenced by the noise from the source and noise of the earth (Ground). Two-Ray ground is evaluated by:

$P_{r(d)} = P_t\ G_t\ G_r\ (h_t)^2(h_r)^2/d^{4\ L}$ (2)

Where:

$P_{r\,(d)}$ is the received power at distance (d)

G_r and G_t are the antenna gains of the transmitter and the receiver.

h_t and h_r are the heights of the transmit and receive antennas respectively.

d is the distance.

L (L ≥ 1) is the system loss (Johann et al, 2004).

9.3. Shadowing model

Shadowing model is more realistic model because shadowing models are influenced by noise from of source, destination, obstacles and air. The shadowing model is represented by the following function (Yahia and Biro, 2006):

$(P_{r(d)} / P_{r(d0)}) = -10ß \log(d/d_0) + X$ (3)

Where:

$P_{r(d)}$ is the received power at distance (d) in db.

$P_{r(d0)}$ is the received power at close-in distance (d_0).

ß is a Gaussian random variable with zero mean in db

X is called the path loss exponent.

10. Network simulation

The benefit of utilization propagation model on clusters can be proved by analyzing performance of Ad-hoc network using CBRP. The performance comparison between parameters is achieved between shadowing and two ray ground models based on QoS parameters such as throughput, PDR, average end-to-end delay and number of dropped packets. The simulations are modeled using the network simulator NS2. The source and destination nodes are transferred in random way over the Ad-hoc network. The mobility model uses a square area of 1000 m × 1000 m with 30, 60, 100 and 150 nodes. The simulation time is 150 seconds. The parameters of the model are shown in Table 1.

Table 1: Simulation parameters

Simulation Parameters	Value
Cluster Routing Protocol Type	CBRP
Simulation Time (sec)	150
Number of Nodes	30,60, 100,150
Speeds (m/sec)	2,5,8,10
Simulation Area (m)	1000 × 1000
Simulation Model	Two Ray Ground, Shadowing Model
Packet Size (bytes)	512
Mac Type	802.11
Simulator	NS2

11. Performance parameters

11.1. Throughput

Throughput is defined as the ratio of correctly received data to simulation time, the units of this parameter are data packets/second data packets or /time slot.

11.2. PDR

Packet delivery ratio is defined as the ratio between the total number of data packets delivered and the number of data packets sent.

11.3. End to end delay

This metric is defined as the time taken by the data packets to reach the destination nodes. Such time can be calculated by dividing the sum of all time differences between the sending and receiving of packets. A low end-to-end delay average is a good performance indicator of the routing protocol (Akshai Aggarwal et al., 2011).

11.4. Number of dropped packets

When a packet reaches a network layer, it is sent to the destination node if a correct route is identified. Otherwise, the packet is buffered until the appropriate route by which to reach the destination node is discovered. If the buffer is full, then the packet is dropped (Nor et al., 2009).

12. Simulation results and discussion

The performance of two propagation types on CBRP is measured based on two different scenarios. The first scenario is to study effect of two ray ground and shadowing on the cluster using different node density and the second scenario is to study the effect of two ray ground and shadowing on cluster using different mobility speeds.

12.1. First scenario

Study the performance parameters in both two models with respect to node density i.e. number of nodes. The obtained results are as the following:

12.1.1. Throughput

In both Two Ray Ground model and shadowing model, the throughput of CBRP is decrease as the number of the nodes increase, as shown in Table 2 and Fig. 4. However, the Shadowing model shows higher throughput than Two Ray Ground model with the improvements in throughput around (50 to 130) Kbps.

Table 2: Throughput for the two ray ground model and shadowing

No. of Nodes	Two Ray Ground	Shadowing
30	540.21	675.24
60	510.23	610.25
100	496.58	536.21
150	465.11	510.32

This ratio is affected very clearly in the protocol performance, so that the performance of the CBRP using shadowing model is greater than that in Two Ray Ground model in terms of throughput.

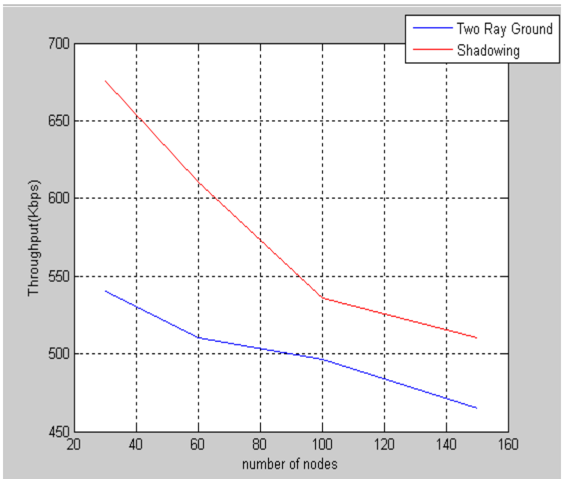

Fig. 4: Throughput for the two ray ground model and shadowing

12.1.2. Packet delivery ratio

The general observations is that the PDR of CBRP in Shadowing model is the higher than that in Two Ray Ground model, as shown in Table 3 and Fig. 5. As the number of the nodes is increase, this ratio is increase in a shadowing model but it is decrease in a Two Ray Ground model. Thus, the shadowing model performance is greater than that in Two Ray Ground model in terms of packet delivery ratio even when the node density is high.

Table 3: PDR for the two ray ground model and shadowing

No. of Nodes	Two Ray Ground	Shadowing
30	**92.23**	94.25
60	90.52	95.26
100	88.56	95.97
150	87.25	97.65

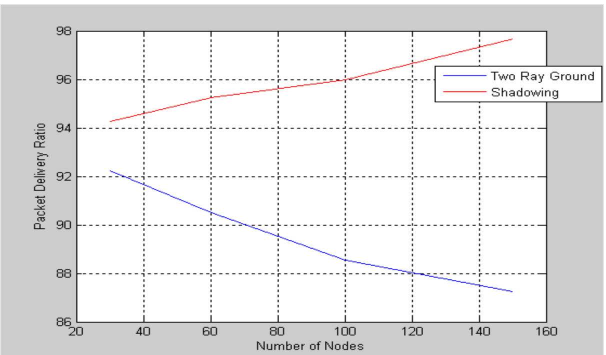

Fig. 5: PDR for the two ray ground model and shadowing

12.1.3. End to End delay

In both Two Ray Ground and shadowing model, the End to End Delay is increase as the number of nodes decrease, the End to End Delay in shadowing model is slightly changed when the number of nodes increased, and the minimum end to end delay value can be observed in shadowing model, as shown in Table 4 and Fig. 6. However, the difference between two models is very small.

Table 4: End-to-end delay for two ray ground model and shadowing

No. of Nodes	Two Ray Ground	Shadowing
30	250.25	241.21
60	254.21	243.25
100	256.02	246.32
150	258.98	249.77

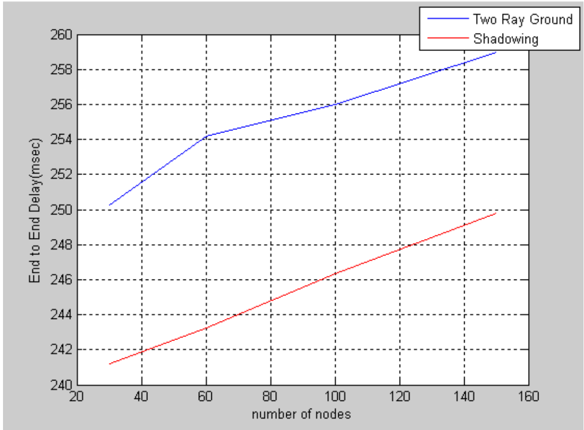

Fig. 6: End to end delay for two ray ground model and shadowing

12.1.4. Number of dropped packets

In both Two Ray Ground and shadowing model, the number of dropped packets increased when the node density increase, and vice versa, as shown in Table 5 and Fig. 7. However, the less number of dropped packets can be observed in a shadowing model and this value is increase when the number of the nodes is increased. The difference between two model is around (7 to 28 packets), which is considered a very high amount and clearly appeared on the performance of the protocol.

Table 5: Number of dropped packets for Two Ray Ground model and Shadowing

No. of Nodes	Two Ray Ground	Shadowing
30	18	11
60	27	14
100	36	17
150	47	19

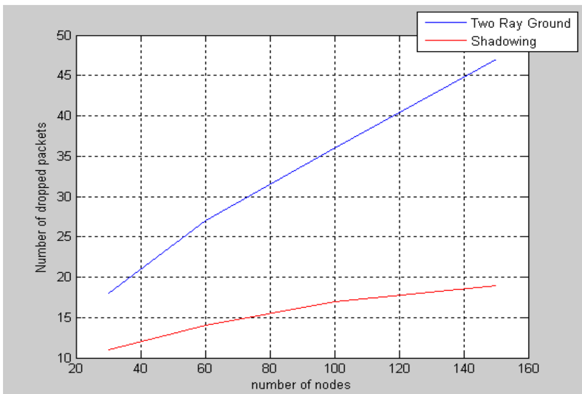

Fig. 7: Numbers of dropped packets for two ray ground model and shadowing

12.2. Second scenario

Study the performance parameters in both two models with respect to mobility speeds of nodes. The obtained results are as the following:

12.2.1. Throughput

The throughputs for both Two Ray Ground and shadowing models decrease as the speed of the node increases, as shown in Table 6 and Fig. 8. The main reason for this decrement is that the increment in speed increases the distance between the nodes. Thus, the number of the packets received in the destination node is minimized. But the Shadowing model is registered higher throughput value than Two Ray Ground which means that it can increase the number of successful delivered packets in a specific time, that reflect positively in CBRP protocol performance.

Table 6: Throughputs for the two ray ground model and shadowing

Speeds(m/sec)	Two Ray Ground	Shadowing
2	547.25	590.21
5	511.23	540.21
8	428.01	501.23
10	411.20	472.33

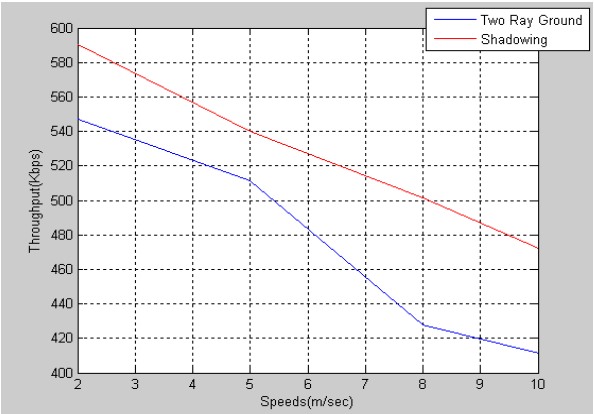

Fig. 8: Throughputs for two ray ground model and shadowing

12.2.2. Packet delivery ratio

For both Two Ray Ground and Shadowing models, the packet delivery ratio enhances as the speed of the node decreased, as shown in Table 7 and Fig. 9. However the packet delivery ratio of shadowing is greater than that of Two Ray Ground, which means that the Shadowing can minimize the number of damaged data packets, which reflect in enhanced the protocol performance.

Table 7: PDR for the two ray ground model and shadowing

Speeds(m/sec)	Two Ray Ground	Shadowing
2	90.24	93.21
5	89.52	91.25
8	87.21	90.21
10	86.32	89.65

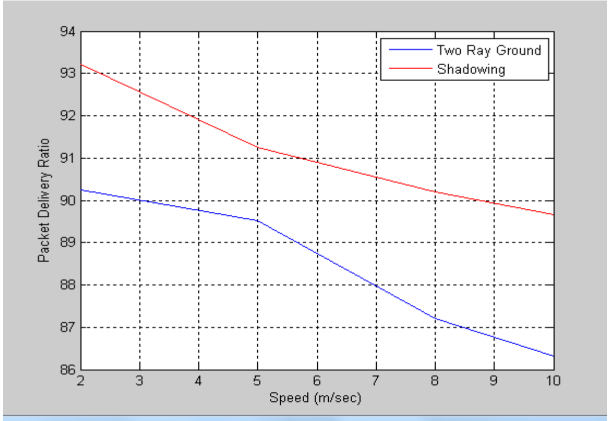

Fig. 9: PDR for the two ray ground model and shadowing

12.2.3. End to end delay

In both Two Ray Ground and shadowing model, the end-to-end delay is increase as the speed of the nodes increase, as shown in Table 8 and Fig. 10. However, the end-to-end delay in shadowing model is minimum than that in Two ray ground model, which means that the shadowing model can reduce the time required to deliver the data to the destination node, which result in improved cluster routing protocols performance.

Table 8: End to end delay for two ray ground model and shadowing

Speeds(m/sec)	Two Ray Ground	Shadowing
2	220.25	167.21
5	248.24	185.46
8	282.23	193.23
10	289.28	210.02

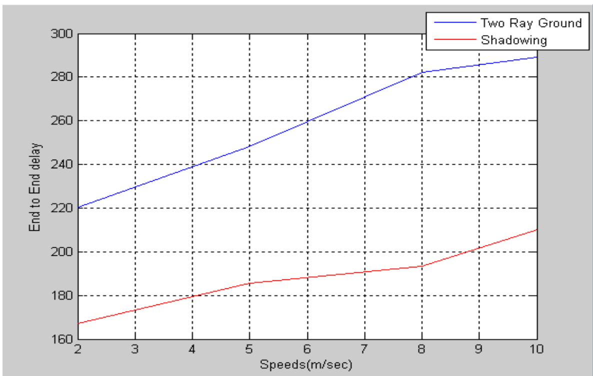

Fig. 10: End to end delay for two ray ground model and shadowing

12.2.4. Number of dropped packets

In both the Two Ray Ground and Shadowing models, the number of dropped packets increased when the speed of node is increased and vice versa, as shown in Table 9 and Fig. 11. However, the number of dropped packets in shadowing is less than that in Two Ray Ground, which means that this model has accurate route selection method than that in Two Ray Ground.

Table 9: Number of dropped packets for two ray ground model and shadowing

Speeds(m/sec)	Two Ray Ground	Shadowing
2	18	14
5	24	17
8	25	19
10	28	20

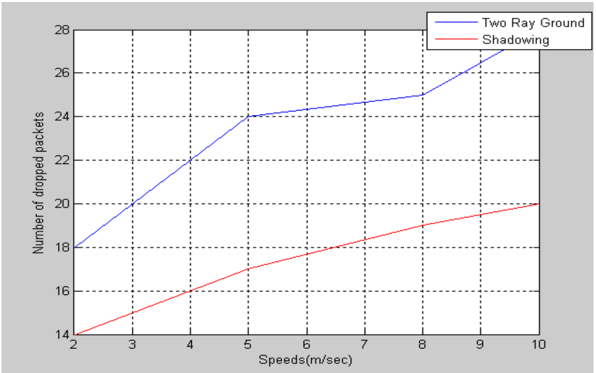

Fig. 11: Number of dropped packets for two ray ground model and shadowing

13. Conclusion

Two propagation models that are two ray ground and shadowing are analyzed and their effects on cluster routing protocol are compared. The simulation results have showed the importance of propagation on MANET performance. The previous works did not measured the effect of propagation on cluster, the results have shown that the shadowing model can enhance the performance of MANET by significantly increasing the throughput and number of packets delivery ratio, and decreasing the end-to-end delay and number of dropped packets. When all these considerations are taken into account, it can be concluded that shadowing model can be used for improving the performance of ad-hoc networks, and it can be used as the main propagation type for the future work.

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