Improving Ad Hoc Network Performance by using an Efficient Cluster Based Routing Algorithm

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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 consists of a cluster head, ordinary nodes and gateway nodes. Clustering can be used for the effective utilization of resources for large ad-hoc networks. This paper measures the impact of using clustering strategy in MANET and how this strategy can enhance the performance of this network, and resulted in increasing the calculated quality parameters, like throughput, packet delivery ratio, end-to-end delay and normalized control overhead. This study produced a simulation for Low-Energy Adaptive Clustering Hierarchy (LEACH) which is considered one of the clustering based routing protocols. A comparison is done between LEACH with the other types of routing protocols such as AODV, DSDV and OLSR which are considered non-clustering routing protocol. Conclusion and discussion of the simulation results have demonstrated the importance and effect of using clustering in MANETs.

Keywords: Ad-hoc Networks, Ad-hoc Routing Protocols, Clustering, LEACH

1. Introduction

Clustering is considered one of the most popular techniques used to reduce traffic in routes and minimize energy consumption in large wireless networks by collecting the nodes into groups called clusters¹. 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 is mainly classified into overlapping cluster and disjoint cluster, as shown in Figure 1, each big circle represent a cluster and the small nodes within the cluster stand for the wireless nodes within the network. The lines which are connecting the wireless nodes represented the connection among them.

2. Advantages of Cluster

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 changed².

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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 the 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.

3. Stages of Cluster

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

3.1 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. So that many suggested algorithms had been presented for cluster head selection depending on the power consuming, node ID, weights of each node, etc.

3.2 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 be occurred 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.

3.3 Clustering Routing Stage

This stage also consists of two main phases, the first phase is called Route Discovery and the second one is the Distance vector routing.
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 to the destination, but 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.

4. Clustering Structure

The wireless nodes in the Ad-hoc network can be sorted in two types of structures: The flat structure and hierarchical structure. The flat structure is as shown in Figure 2. Each node must forward the data to all other nodes in the same cluster. It works as a router, so that a huge number of flooded data are transferred and it needs a great control mechanism which operation reflected negatively on the network bandwidth. However, in the hierarchical structure, all the available nodes are specified to do a various operations. The same node can be acted as a cluster head, gateway and ordinary nodes, so it can send, receives, forward data, control communication and connect with another cluster, as shown in Figure 3.

Based on the size of the clusters, there exist two types of cluster structures management. The first one is called one-hop cluster and the other is a multi-hop cluster. In the first type, each node in the cluster must be only one node distanced from the cluster head of the cluster, so that all the available nodes are distanced from each other in a maximum two nodes. In the second type of cluster, there are limitations for formation the cluster, so each node must be distanced away from the other node in a specific distance (d) in order to construct the cluster.

5. Clustering Algorithm 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. 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. Some studies proved that cluster head based algorithm may be resulted 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. In addition, Cluster head may become suffer from bottleneck problem when the network traffic load has increased.

6. Routing In MANET

Routing is the mechanism which is used to direct the information from a sender node to the receiver node. Routing is considered one of the most significant aspect 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 be select the of most suitable routes for the nodes, and forward the data to the specific destination node.

7. 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:

7.1 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 transfer the data to all its neighbor nodes and the last will be transferred 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\(^1\).

7.2 Distance Vector Routing

In this strategy, each node in the network have calculated the distances to all other nodes in the network, and kept this information in a specific table and periodically broadcasted this information to all other node in the network. Destination Sequenced Distance Vector (DSDV) is one example of this strategy\(^12\). Distance vector operation is shown in Figure 4.

7.3 Link State Routing

In link state routing, each node keep 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\(^13\).

7.4 Source Routing

Each packet must contain the 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\(^14\).

8. MANET Routing Protocols Classification

must be included into one of the following three classifications\(^1\), as shown in Figure 5.

8.1 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 used 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 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\(^15,16\), each packet must contain the full address for the sender and the receiver and intermediate nodes in its header, so that all intermediate nodes will follow this address to forward the data to a specific destination, without need to update their routing table for every active routes. 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 increased, the number of intermediate nodes will also increase and the probability of congestion and link failures will also grow. It is not suitable for using in 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\(^17\).

8.2 Proactive Routing Protocols

This type the routing protocol is pre-established even if there is no virtual routing request available, and the rout-
ing 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\(^1\). 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\(^1\). However, the main drawbacks is the great network overload and high consumption of the bandwidth in 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)\(^2\).

### 8.3 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 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 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\(^2\).

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\(^2\).

### 9. Network Simulation

The benefit of utilization the clustering can be proved by analysing the performance of Ad-hoc network using Cluster Based Routing protocols. The performance comparison between the parameters is achieved between cluster routing protocol LEACH and three other routing protocols namely, AODV, DSDV and OLSR, based on QoS parameters such as throughput, Packet Delivery Ratio (PDR), average end-to-end delay and Normalized Control Overhead. The simulations are achieved 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 10, 20 and 50 nodes. The simulation time is 150 seconds. The parameters of the model are shown in Table 1.

### 10. Simulation Parameters

#### 10.1 Throughput

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

#### 10.2 Packet Delivery Ratio

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

#### 10.3 End to End Delay

This metric is defined as the time taken by the data packets to reach the destination nodes. 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 in a network is a good performance indicator of the routing protocol\(^2\).

#### 10.4 Normalized Control Overhead

It is calculated by dividing the total number of packets transmitted under protocol control by the total number of delivered data packets\(^2\).
11. Analysis and Results

11.1 Throughput

The improvements in throughput are obtained when LEACH routing protocol is used, as shown in Table 2 and Figure 6.

The throughput differs according to the number of nodes. There are (68 to 160 Kbps) improvements in throughput due to the use LEACH, between LEACH and the other routing protocols. When the number of nodes is small (10 nodes), the difference between LEACH (routing protocol with clustering) and the other routing protocols (without clustering) is small value but when the number of nodes increased to (20 and 50 nodes), the differences between them is increased. The throughput of LEACH is the highest and this value is increased as the number of nodes decreases, followed by DSDV and OLSR, and the lowest throughput is obtained in AODV.

11.2 Packet Delivery Ratio (PDR)

LEACH shows the highest packet delivery ratio compared with the other routing protocols, as shown in Table 3 and Figure 7, followed by AODV, DSDV and OLSR respectively. When the number of nodes is increased, the packet delivery ratio in LEACH also increases. Therefore, LEACH has the best performance in terms of packet delivery ratio. The main reason behind this improvement is that the cluster based routing protocol can increase the stabilization of Ad-hoc network by making groups of nodes. So that all of the nodes remain in a stable state as long as possible. This reflected in increasing the number of the corrected received packets.

11.3 End-to-End Delay

End-to-end delay is obtained at the minimum value when LEACH Routing Protocol is utilized, as shown in Table 4 and Figure 8, whereas the maximum end-to-end delay in AODV. This value changed according to the number of nodes. In LEACH, when the number of nodes decreases, the end-to-end delay increases, and vice versa. The main reason behind this result is that the clustering algorithm will depend on an accurate strategy in selecting the correct routes with high stability, less congestion, and minimum traffic load, so that the time delay is reduced as a result of this strategy.

11.4 Normalized Control Overhead

LEACH routing protocol shows a small NCO, as shown in Table 5 and Figure 9, followed by DSDV, OLSR and AODV. This result is based on the fact that all of the
other protocols send many control packets and controlling information in the construction stage only; but the LEACH routing protocol send these information in distributing form during all the stages of clustering.

12. Conclusions

This paper aim to prove the importance of clustering algorithm which is used to minimise the routing traffic load by grouping the network into a number of clusters. The simulation results of this study have shown that LEACH is considered one of the cluster based routing protocols which has the highest throughput and packet delivery ratio, compared with the other three routing protocols that are: AODV, DSDV and OLSR, which are considered non clustering routing protocol, even when the network size is increased in size. LEACH routing protocol has also shown the minimum end-to-end delay and normalized control overhead compared to the other three routing protocols. When all these consideration take into account, it can be concluded that the clustering
algorithm can be used for improving the performance of ad hoc networks.

13. References

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