PERFORMANCE ANALYSIS OF BROADCASTING IN MOBILE AD HOC NETWORKS USING CLUSTER APPROACH

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ABSTRACT

Broadcasting is a fundamental service in Mobile Ad hoc Networks (MANETs). Cluster based approach are proposed in literature to reduce the network collision, to reduce delay of packet transmission, to reduce the energy consumption and improves the throughput. In this paper, a cluster- based infrastructure is proposed for broadcasting in MANETs. The backbone of the network takes advantage of the cluster structure and only requires cluster- heads and some selected gateways to forward the broadcast packet. Each cluster head selects some gateways to forward the packet when it sends the packet to all the cluster heads in its coverage set. Cluster structures have been simulated using mobile simulator Glomosim 2.03, which gives better performance to reduce the network collision, to reduce delay of packet transmission, to reduce the energy consumption and improves the throughput.

KEYWORDS

MANET, Connected Dominating Set, Cluster, Ad Hoc Network

1. INTRODUCTION

A mobile ad hoc network (MANET) is a special type of wireless mobile network which forms a temporary network without the aid of an established infrastructure or a centralised administration. Each node in MANET is a router. If a source node is unable to send a message directly to its destination node due to limited transmission range, the source node uses intermediate nodes to forward the message towards the destination node. Broadcasting is the process in which a source node sends a message to all other nodes in MANET[3]. Broadcasting is important in MANET for routing information discovery,[1] for instance, protocols such as dynamic source routing (DSR) , ad hoc on demand distance vector (AODV)[2][9] , and location aided routing use broadcasting to establish routes. Broadcasting MANET poses more challenges than in wired networks due to node mobility and scarce system resources. Because of the mobility there is no single optimal scheme for all scenarios. Mobile ad hoc networks (MANETs) are collections of autonomous mobile hosts without the help of centre base stations. Applying such networks into practice brings many challenges to the protocol design, such as routing in highly dynamic networks [10], allocating shared wireless channels and saving limited bandwidth. Trade offs are needed in the protocol design to achieve these conflicting goals. The broadcast nature of wireless transmissions, that all the neighbours of a host will receive the packet when the host transmits a packet. Extremely limits the scalability of the network. When the size of the network increases and the network becomes dense, even a simple broadcast operation may trigger a huge

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transmission collision and contention that may lead to the collapse of the whole network [16]. This is referred to as the broadcast storm problem [4]. Therefore, building some type of backbone infrastructure for a network can enhance the performance of the whole network when the network becomes dense. Basically, the backbone of a network converts a dense network to a sparse one to relieve the communication overhead of the whole network. The cluster structure is a simple backbone infrastructure which has only two levels of hierarchical structure. The network is partitioned into a group of clusters. Each cluster has one cluster head that dominates all other members in the cluster. Two cluster heads cannot be neighbours. Gateways are those non-cluster head nodes that have at least one neighbour that belongs to other clusters. It is easy to see that cluster heads and gateways form a backbone of the original network. Theoretically, we can describe a MANET as a unit disk graph G=(V, E), where the node set V represents a set of wireless mobile hosts and the edge set E represents a set of bi-directional links between the neighbouring hosts, assuming all hosts have the same transmission range r. Two hosts are considered neighbours if and only if their geographic distance is less than r. We use $N^k(v)$ to represent v's h-hop neighbour set, including v itself. Generally, a backbone infrastructure of a network can he considered as a connected dominating set (CDS) [7] of a given graph. A dominating set (DS) is a subset of nodes such that every node in the graph is either in the set or has an edge linked to a node in the set. If the sub graph induced from a DS of the graph is connected, the DS is a CDS. Another concept, an independent set (IS) is defined as a set of nodes of the network; in which each pair of nodes are not neighbours. In a cluster network, the set of cluster heads is an IS and the set of the cluster heads and gateways is a CDS [15].

2. RELATED WORK

Flooding is one of the earliest protocols for multicasting and broadcasting in ad hoc networks [2], [3]. In flooding, every node in the network transmits the message to its neighbours after receiving it. Flooding can lead to severe contention ,collision and redundant transmissions: a situation referred to as broadcast storm [1].In a series of papers [4], [5], [6], it was proposed that a connected dominating set (CDS)[7] can be used as a virtual backbone for routing in ad hoc networks. Williams and Camp [3] have classified the broadcast protocols into flooding, probability-based, counter based, distance-based, location-based and neighbour knowledge schemes. Similarly, neighbour knowledge schemes can be divided into selecting forwarding neighbours and clustering-based. In counter-based scheme inhibits the rebroadcast if the packet has already been received for more than a given number of times. In the probabilistic scheme when receiving a broadcast packet for the first time, a node rebroadcasts the packet with a probability *p*; when *p*=1, this scheme reduces to blind flooding. In the distance-based scheme a node rebroadcasts the packet only if the distance between the sender and the receiver is larger than a given threshold. In the location-based scheme, a node rebroadcasts a packet only when the additional coverage due to the new emission is larger than a certain bound. In the selecting forwarding neighbours a broadcasting node selects some of its1-hop neighbours as rebroadcast nodes. Finally, the cluster structure is a simple backbone infrastructure whereby the network is partitioned into a group of clusters. Each cluster has one cluster head that dominates all other members in the cluster. A node is called a gateway if it lies within the transmission range of two or more cluster heads. Gateway nodes are generally used for routing between clusters. The rebroadcast is performed by cluster heads and gateways.

In this paper, we report results from Glomosim. 2.03 as the simulation platform. Glomosim 2.03 is a popular network simulator which has originally been designed for wireless networks and has been support simulations in MANET settings in order to characterise neighbourhood's information, such as the average number of neighbours of a given node by means of 'Hello' packet exchanges. We proposed cluster structure for broadcasting in MANETs for analysing the performance of network collision, delay for packet transmission, energy consumption and the throughput.

3. PRELIMINARIES

3.1. Ad Hoc Broadcasting Approach

In this approach, only nodes selected as gateway nodes and a broadcast message header are allowed to rebroadcast the message. The approach is described as follow

1. Locate all two hop neighbours that can only be reached by a one hop neighbour. Select these one hop neighbours as gateways.
2. Calculate the cover set that will receive the message from the current gateway set.
3. For the neighbours not yet in the gateway set, find the one that would cover the most two hop neighbours not in the cover set. Set this one hop neighbour as a gateway.
4. Repeat process 2 and 3 until all two hop neighbours are covered.
5. When a node receives a message and is a gateway, this node determines which of its Neighbours already received the message in the same transmission. These neighbours are considered already covered and are dropped from the neighbour used to select the next hop gateways.

In Figure 1. node 2 has 1, 5 and 6 nodes as one hop neighbours, 3 and 4 nodes has two hop neighbours. Node 3 can be reached through node 1 as a one hop neighbour of node 2. Node 4 can be reached through node 1 or node 5 as one hop neighbours of node 2. Node 3 selects node 1 as a gateway to rebroadcast the message to nodes 3 and 4. Upon receiving the message node 5 will not rebroadcast the message as it is not a gateway.

The Limitations are deduced from a detailed comparative study in [12].

1. All methods apart from neighbour based methods require more rebroadcasts, with respect to the number of retransmitting nodes [15].
2. Because it does not use local information to decide whether to rebroadcast or not, the Ad hoc broadcasting approaches have difficulties in a very high mobile MANET.

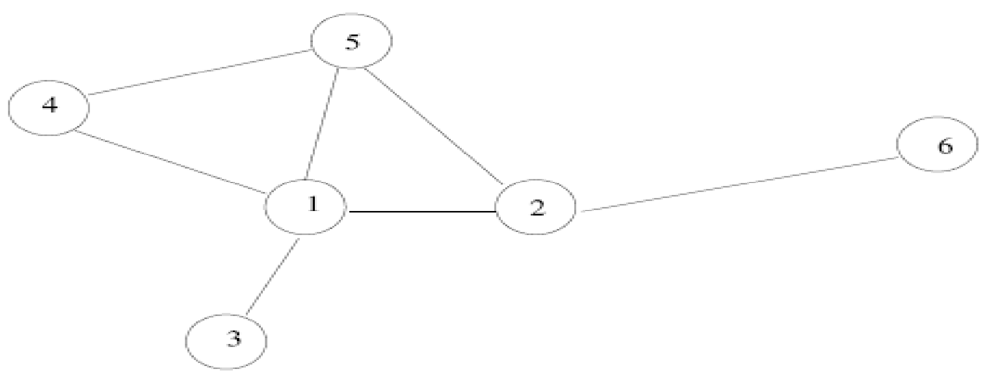

Figure 1. Ad Hoc Broadcasting Approach

3.2. Cluster Network

The clustering problem can now be defined formally. We are given an undirected graph G = (V, E) representing a communication network where the vertices are the nodes in the network and the edges are the communication links. The clustering process first divides V into a collection of (not necessarily disjoint) subsets $\{V_1, V_2, \ldots, V_k\}$, such that each subset V_i induces a connected sub graph of G. Note that these induced sub graphs can overlap. Each such vertex subset is a cluster [11] [12] [13]. Ideally, the size of the clusters falls in a desired range and the induced sub graphs have small diameters. Note that the clustering approach has been used to address traffic coordination schemes, routing problems and fault tolerance issues. Note that cluster approach proposed in [15] was adopted in order to reduce the complexity of the storm broadcasting problem . Each node in a MANET periodically sends "Hello" messages to advertise its presence. Each node has a unique ID. A cluster is a set of nodes formed as follows. A node with a local minimal ID will elect itself as a cluster head. All surrounding nodes of a head are members of the cluster identified by the heads ID. Within a cluster, a member that can communicate with a node in another cluster is a gateway. To take mobility into account, when two heads meet, the one with a larger ID gives up its head role. This cluster formation is depicted in Figure 2.

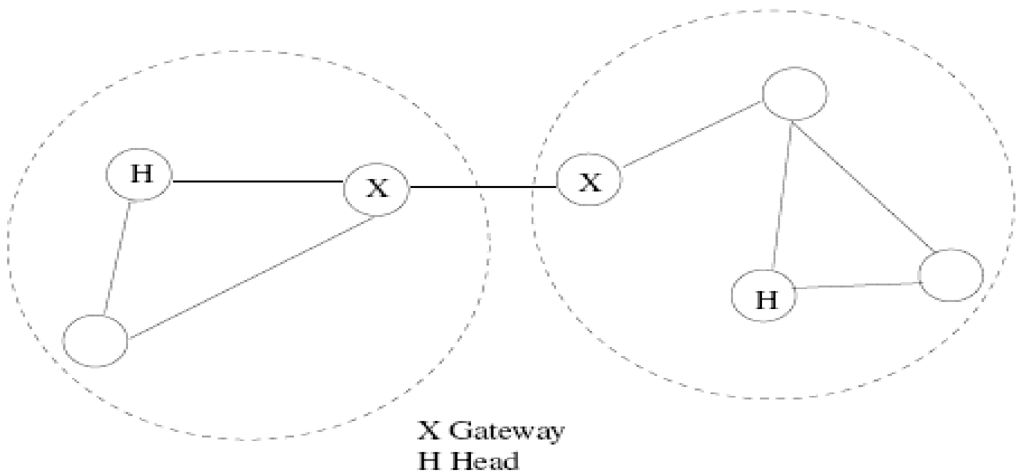

Figure 2.Clustered MANET

In a cluster, the heads rebroadcast can cover all other nodes in its cluster. To rebroadcast message to nodes in other clusters, gateway nodes are used, hence there is no need for a non-gateway nodes to rebroadcast the message [17].

3.3. Graph Dominating Set

A dominating set of a graph $G = (V, E)$ is a subset $S \subseteq V$, such that every vertex $v \in V$ is either in S or adjacent to a vertex of S [5]. The solid black vertices in Figure 3. form a dominating set of the graph. A vertex of S is said to dominate it self and all adjacent vertices. We say that an edge is dominated if either of its endpoints is in S and refer to other edges as free. In general, a vertex subset S is called a distance-k dominating set if every vertex v is within the closed distance-k neighbourhood of some vertex of S. The solid black vertices in Figure 3. Form a dominating set of the graph. A vertex of S is said to dominate itself and all adjacent vertices. We say that an edge is dominated if either of its endpoints is in S and refer to other edges as free. In general, a vertex subset S is called a distance-k dominating set if every vertex v is within the closed distance-k neighbourhood of some vertex of S. A dominating set is an independent dominating set if no two vertices in the dominating set are adjacent. An example is shown in Figure 4. Another important variant is the connected dominating set.

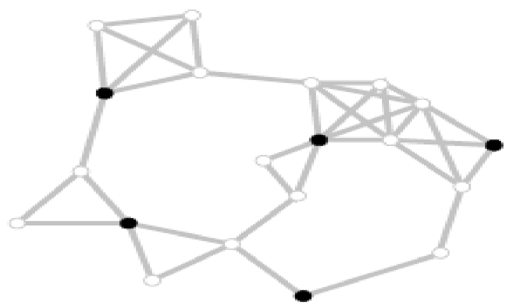

Figure 3. Dominating Set

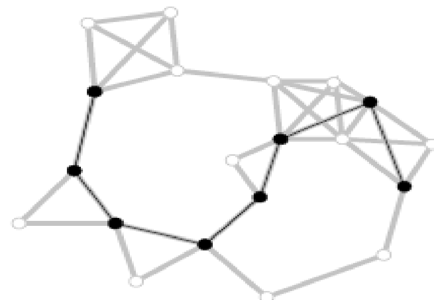

Figure 4. Connected Dominating Set

4. Broadcasting in Cluster Manet

4.1. The Cluster Broadcasting

Considering the case that the backbone of the network consists of the fixed cluster heads and dynamically selected gateways that depend on the source of a broadcast; that is, the gateways are selected at the time when a cluster head needs to relay the packet. Since this backbone is constructed step by step as the broadcast traverses the network, some pruning techniques can be used to reduce the. Broadcast redundancy. Generally, pruning techniques can eliminate some redundant broadcasting operations between two downstream neighbours of a sender if these two neighbours know that they have received a broadcast packet from the same upstream sender. For a simple network with 3 nodes in Fig 5. Suppose node u broadcasts a packet, both nodes v and w receive the packet, and then they rebroadcast the packet to each other. Apparently, the last two transmissions are redundant. There is many ways to reduce this kind of transmission redundancy. When a node receives a broadcast packet, if it can back-off a short period of time before it relays the packet, it may receive more copies of the same packet from its other neighbours. If all of its neighbours can be covered by these already received broadcast copies, it can resign its role of re-broadcast operation. For the network in Fig 5, when both v and w receive the packet from u, if both v and w have a random delay before they relay the packet, and w receives the duplicated packet from v before its delay times out, w realizes that all its neighbours (u and v) have already received the packet. Therefore, it does not relay the packet. In this case, one redundant transmission is saved. Another way to reduce transmission redundancy is to piggyback the covered nodes with the broadcast packet when the sender broadcasts a packet. From the information of the piggybacked packet, each receiver can compute which subset of its neighbour set has already received the packet.

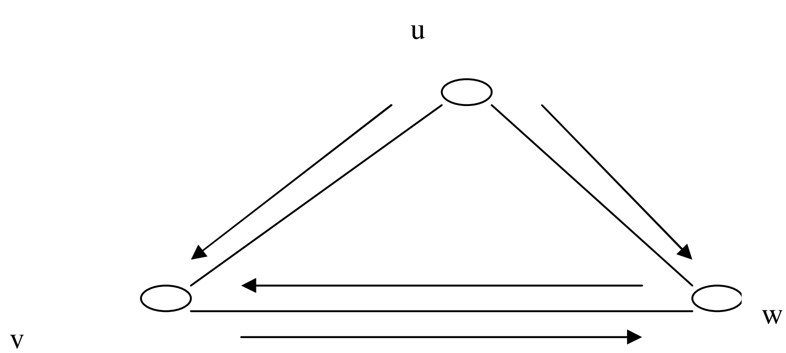

Figure 5. An illustration of the transmission redundancy in a network with three nodes

For example, in Figure 5. u broadcasts a packet that piggybacks v and w because they have received the packet when u broadcasts the packet. At the time that v and w receive the packet, they know that all of their neighbours (for v they are w and u; for w they are u and v) have received the broadcast, therefore, none of them will relay the packet again. In this case, two redundant transmissions are saved. Of course, these methods will introduce some extra cost, for example, the first one will lead to more delay time and the second one will increase the message length. By using the pruning technique of attaching the sender's coverage set and selected gateways will broadcast the packet.

4.2. Working Principle of the Cluster

1. If the source is not a cluster head, it just sends the broadcast packet to its cluster head.
2. When a cluster head receives the broadcast packet from its upstream cluster head sender for the first time, it executes the selection process: It chooses some gateways, called forward nodes, to forward the packet to all the cluster heads in its coverage set. Its overage set is updated by excluding the cluster head sender and those cluster heads in the sender's coverage set that are piggybacked with the broadcast packet. The coverage set of this cluster head, together with its selected forward nodes, are piggybacked with the broadcast packet for the forwarding purpose. A Cluster head will do nothing if it receives a duplicated packet.
3. When a non-cluster head node receive the broadcast packet for the first time and if it is a forward node, it relays the packet; otherwise, it does nothing.

5. SIMULATION RESULT

The simulation was carried out using Glomosim. 2.03. The parameters used in the following simulation experiments are listed in Table 1. The MAC layer scheme follows the IEEE 802.11 MAC specification. We have used the broadcast mode with RTS/CTS/ACK mechanisms for all packet transmissions. The following graph shows the simulation output for ad-hoc networks with IEEE 802.11 MAC protocol. Figure 6. Shows the reduction of the collision rate. Figure 7. Shows the reduction of energy consumption. Figure 8.Shows the reduction of delay of transmission of packets between the clusters heads. Figure 9.Shows throughput for cluster structure MANET.

Table 1. The parameters used in the simulation

Parameter	**Value**
Simulator	Glomosim. 2.03
Network Area	900 x 900 m^2
Transmission Range	100~300 meter
MAC Layer	IEEE 802.11
Bandwidth	2 M b /s
Data Packet Size	512 bytes
Number of Nodes	20~100
Routing-Protocol	AODV
Simulation Time	100 s
Number of Trials	10

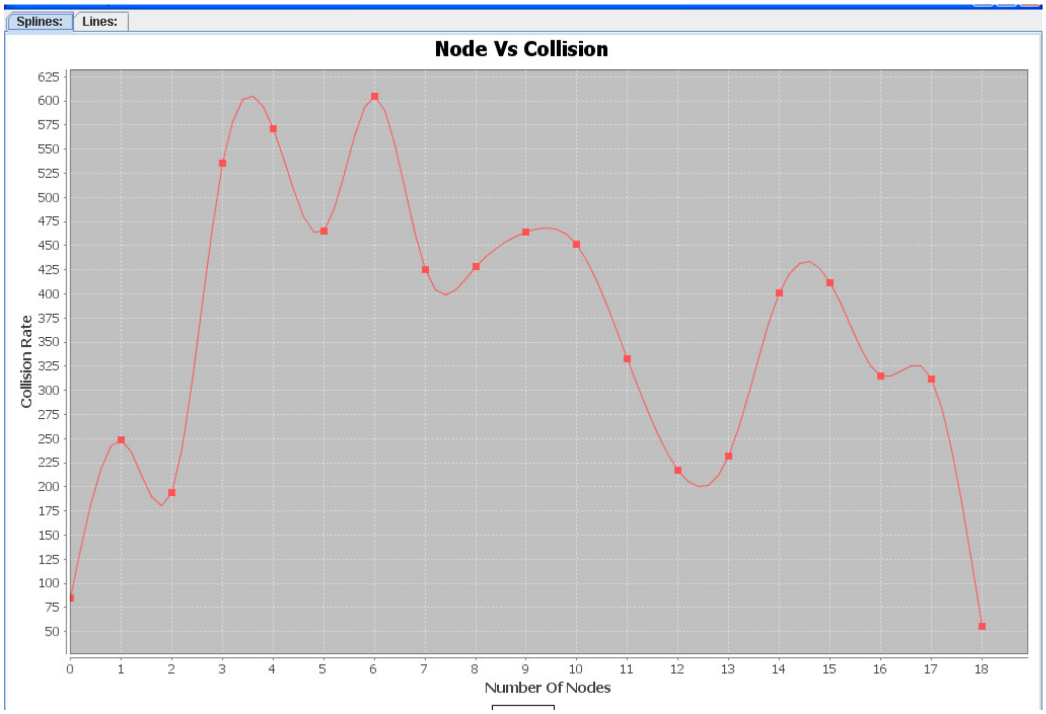

Figure 6. Number of Nodes Vs Collision Rate

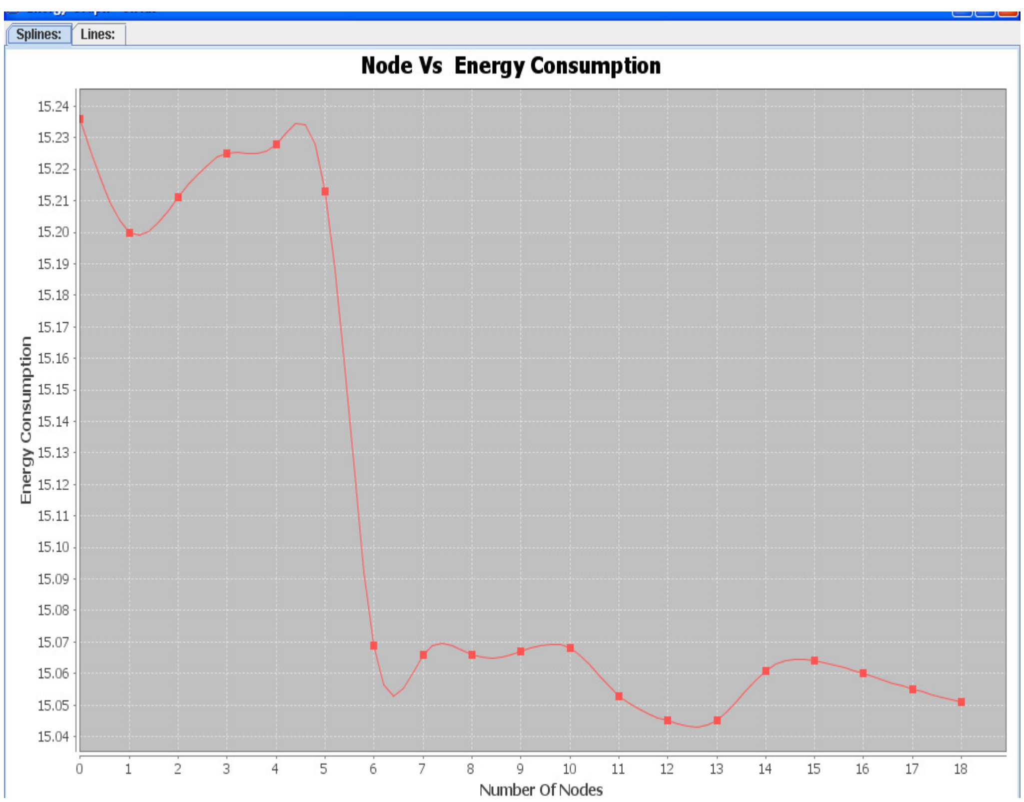

Figure 7. Number Nodes Vs Energy Consumption.

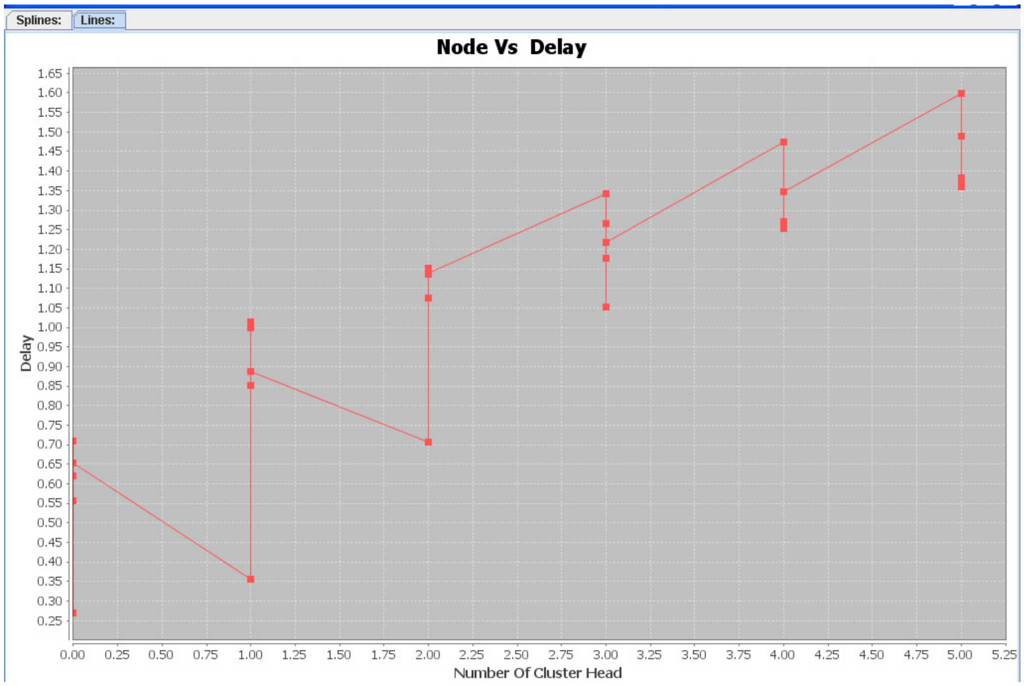

Figure 8. Nodes Vs Delay

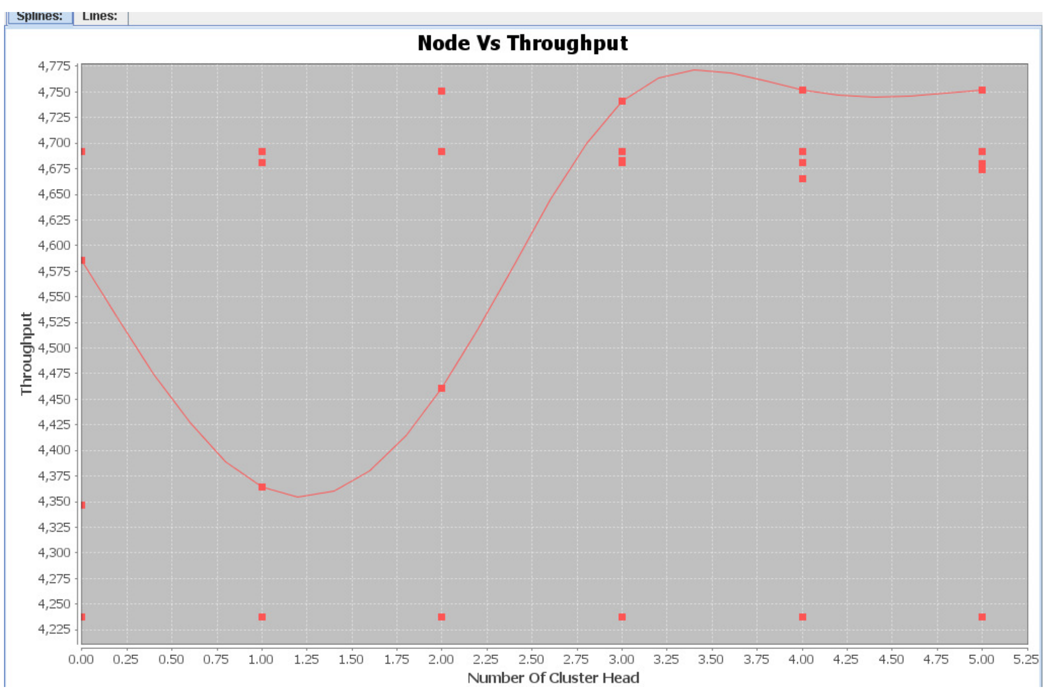

Figure 9.Nodes Vs Throughput

6. CONCLUSIONS

The broadcast nature of wireless transmissions, that all the neighbours of a host will receive the packet when the host transmits a packet. Extremely limits the scalability of the network. When the size of the network increases and the network becomes dense, even a simple broadcast operation may trigger a huge transmission collision and contention that may lead to the collapse of the whole network [16]. This is referred to as the broadcast storm problem. To reduce this problem, we proposed cluster structure for broadcasting in MANETs. We describe the construction of the cluster-based networks. It point out that maintaining a network without collision at all times for broadcasting is costly and unnecessary rebroadcast will occur. Therefore, building a Cluster Networks is better choice for collision free transmission in MANET. Based on our simulation results, we conclude that cluster structure is best to reduce the network collision, to reduce delay of packet transmission, to reduce the energy consumption and improves the throughput.

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