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Influence of periodic control messages on the Performance of Mobile Ad Hoc NETworks (MANET)

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ABSTRACT

Clustering is an important research area for mobile ad hoc networks (MANETs) as it increases the capacity of network, reduces the routing overhead and makes the network more scalable in the presence of both high mobility and a large number of mobile nodes. In cluster or hierarchical structure local connectivity knowledge of mobile nodes is necessary for the formation and maintenance of cluster. For determining and maintaining local connectivity information, MANET utilizes periodic control messages commonly known as hello messages. A reception of hello message indicates the presence of a neighbor. This results in at least one hello message broadcast during every time period. Frequent exchange of hello messages cause considerable overhead, which consume considerable bandwidth and drain mobile nodes energy quickly, likely cause congestion, collision and data delay in larger networks. Overhead due to periodic hello messages is a function of two variables, namely, number of nodes in networks and hello interval which is the maximum time interval between the transmissions of control messages. Changing the variables affect the number of hello messages transmitted and hence the overhead. This paper uses an implementation of Cluster Based Routing Protocol (CBRP) to examine the influence of periodic hello messages on the performance of mobile ad hoc networks by keeping the number of nodes constant and varying the hello interval. Packet delivery fraction, average end to end delay, normalized routing load, channel utilization and control overhead are evaluated by varying mobility and hello interval to show the effect of control messages.

Categories and Subject Descriptors

C.2 **[Computer Systems Organization]**: COMPUTER-COMMUNICATION NETWORKS; C.2.1 [COMPUTER-COMMUNICATION NETWORKS]: Network Architecture and Design-*Wireless communication*

General Terms

Algorithms, Performance

Keywords

Mobile Ad hoc networks, Clustering, hello messages, Simulation, Performance evaluation.

1 INTRODUCTION

Ad hoc wireless networks (formerly known as packet radio networks) are defined as mobile distributed multi hop wireless networks that are formed by autonomous system of mobile nodes, in which communication is directly between nodes or through intermediate nodes acting as routers that utilize multi-hop radio relaying and connected by wireless links without any preexisting communication infrastructure or centralized administration. This requires each mobile host to be more intelligent to perform both the transmission and receiption of data as a host and to forward packets to other node as a router. Such a network system provides rapid deployment, robustness, flexibility and inherent support for mobility. Due to their quick and economically less demanding deployment, they find applications in military operations, collaborative and distributed computing, emergency operations, wireless mesh networks, wireless sensor networks and hybrid networks.

Routing protocols for Mobile ad hoc networks can be classified into two main categories: Proactive or table driven routing protocols and Reactive or on-demand routing protocols [1]. A flat architecture exclusively based on table-driven or on-demand routing approaches cannot perform well in a large MANET [2–4]. This is because a flat architecture or topology encounters scalability problems with increased network size, particularly with node mobility at the same time. The reason for this is their built-in characteristics. Proactive routing is table –driven based and requires control overhead for building and updating those tables, containing information about the state of the network. The control overhead for proactive routing protocols is O (n^2), where n is the total number of nodes in a network [5]. Since in reactive routing protocols routes are found on – demand; incur significant route setup delay which becomes intolerable in the presence of both a large number of nodes and mobility. Therefore, both proactive and reactive routing schemes are not scalable.

Clustering is a known technique in the area of distributed network computing in which the local properties of a network are used to speed up a computation by sharing information, preferably inside of a local group or cluster. And the overall load on the network is decreased by performing as much computation as possible locally and sending out data that in some sense represents all nodes in a cluster. As the load depends generally on the number of nodes in a group, clustering is needed to make a protocol scalable.

Clustering partitions the network into groups called clusters. A clusterhead is selected in each group. Different Clusterheads are interconnected by gateways (nodes which forms part of more than one cluster) to carry out the routing process to establish a route or path between intended source (having packets to transmit) to the desired destination. Within a cluster, the nodes have complete topology information about its cluster and use proactive routing.

However, constructing and maintaining a cluster structure usually requires local connectivity knowledge of mobile nodes. For determining and maintaining local connectivity information, MANET utilizes periodic control messages commonly known as hello messages. A reception of hello message indicates the presence of a neighbor. This results in at least one hello message broadcast during every time period. Frequent exchange of hello messages cause considerable overhead, which consume considerable bandwidth and drain mobile nodes energy quickly, likely cause congestion, collision and data delay in larger networks. This additional control overhead involved in clustering is a key issue to validate the effectiveness and scalability enhancement of a cluster structure.

The rest of the paper is organized as follows: Section 2 provides an overview of the routing protocol used in the study. The simulation environment and performance metrics are described in Section 3 and then the results are presented in Section 4. Finally Section 5 concludes the paper.

2 OVERVIEW OF CBRP

In CBRP [6] the nodes of a wireless network are divided into clusters. The diameter of a cluster is only two hops and clusters can be disjoint or overlapping. Each cluster elects one node as the clusterhead, responsible for the routing process. The head of a cluster knows the addresses of its members. Clusterheads communicate with each other through gateway nodes. A gateway is a node that has two or more clusterheads as its neighbors when the clusters are overlapping or at least one clusterhead and another gateway node when the clusters are disjoint.

The routing process works in two steps. First, it discovers a route from a source node to a destination node, afterwards it routes the packets. When a source has to send data to destination, it floods route request packets (but only to the neighboring cluster-heads). On receiving the request a clusterhead checks to see if the destination is in its cluster. If yes, then it sends the request directly to the destination else it sends it to all its adjacent clusterheads. The cluster-heads address is recorded in the packet so a cluster-head discards a request packet that it has already seen. When the destination receives the request packet, it replies back with the route that had been recorded in the request packet. If the source does not receive a reply within a time period, it backs off exponentially before trying to send route request again. It also uses route shortening that is on receiving a source route packet, the node tries to find the farthest node in the route that is its neighbor and sends the packet to that node thus reducing the route. While forwarding the packet if a node detects a broken link it sends back an error message to the source and uses local repair mechanism.

3 SIMULATION AND PERFORMANCE METRICS

3.1 Simulation Model

Network Simulator2 (NS-2)[7] a object-oriented, discrete event driven network simulator developed at UC Berkely written in C++ and OTcl, particularly popular in the ad hoc networking research community is use for the simulations. The traffic sources are CBR (continuous bit – rate). The source-destination pairs are spread randomly over the network. The node movement generator of ns-2 is used to generate node movement scenarios. The movement generator takes the number of nodes, pause time, maximum speed, field configuration and simulation time as input parameters. The parameter, which is of primary importance, is pause time. Pause time basically determines the mobility rate of the model, as pause time increases the mobility rate decreases. At the start of the simulations nodes are assigned some random position within the specified field configuration, for pause time seconds nodes stay at that position and after that they make a random movement to some other position. The propagation model is the two ray ground model [8]. Each simulation scenario is run for enough time to reach and collect the desired data at steady state. Several runs of each simulation scenario are conducted to obtain statistically confident averages. Simulation parameters are listed in table 1.

Table 2. Simulation Parameters

Parameter	Value
Simulator	ns-2
Studied protocols	CBRP
Simulation time	300 seconds
Simulation area	2000 m x 500 m
Transmission range	250 m
Node movement model	Random waypoint
Speed	10 m/s
Traffic type	CBR (UDP)
Data payload	512 bytes/packet
Packet rate	4 packets/sec
Node pause time	0, 60, 120, 180, 240 and 300s
Bandwidth	2 Mb/s

3.2 Performance Metrics

In order to compare the performance of cluster architecture based, CBRP and flat architecture based, DSR this paper focus on the following performance metrics for evaluation:

Packet Delivery Fraction (PDF): The ratio of the data packets delivered to the destinations to those generated by the sources.

Average end-to-end delay: This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times.

Normalized routing load: The number of routing packets "transmitted" per data packet "delivered" at the destination.

Channel utilization capacity: This metric gives the fraction of channel capacity used for data transmitted by the network and is computed as

$$CU\left(\%\right) = \frac{PR * SZ}{SET * BW}$$

where PR is the number of data packets received by the destination nodes, SZ is the size of the data packets, SET is simulation end time and BW is the nominal channel bandwidth.

Control Overhead: The total number of non data packets transmitted by the protocol. The control overhead is the sum of clustering overhead (COH) and routing overhead. Clustering overhead is the number of clustering messages sent by each node in cluster formation and cluster maintenance operation. It is an important measure for the scalability of a protocol. If a protocol requires sending many control packets, it will most likely cause congestion, collision and data delay in larger networks.

4 SIMULATION RESULTS

Simulation results of the effect of varying hello interval on packet delivery fraction, average end-to-end delay, normalized routing load, channel utilization and control overhead (in terms of packets and bytes both) as function of pause time are discussed in this section.

4.1 Packet Delivery Fraction

The simulation result in Fig.1 shows the effect of varying mobility under different hello intervals on the packet delivery fraction. The result show that in high to moderate mobility scenario the PDF increases with hello intervals. As the network tends to static the effect of hello interval is negligible. In dynamic situation increasing hello interval decreases the control overhead which improves the throughput performance.

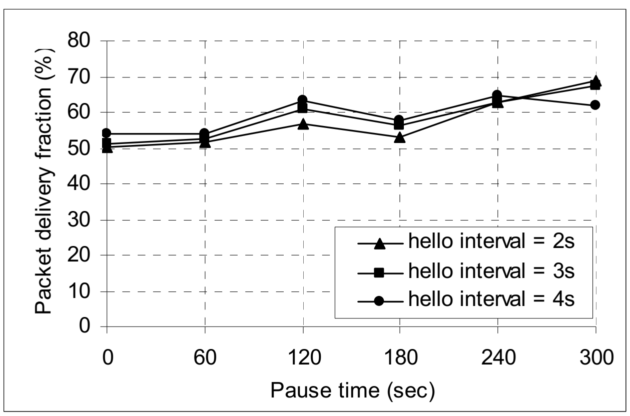

Figure 1. Packet delivery fraction vs pause time (sec) for different hello intervals.

4.2 Average End to End Delay

The effect of varying mobility under different hello intervals on average end-to-end delay is shown in Fig.2 which indicates that average end-to-end delay increases with hello interval.

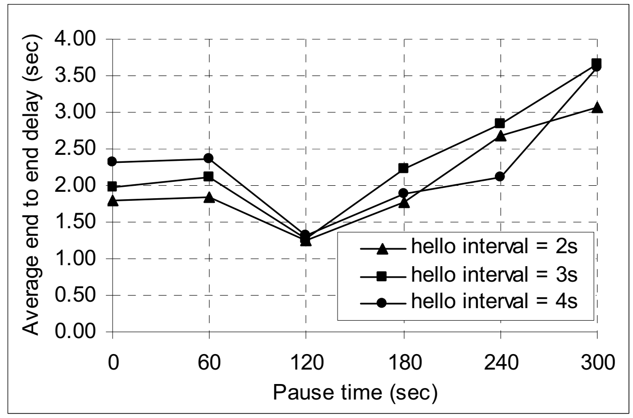

Figure 2. Average end to end delay vs pause time (sec) for different hello intervals.

4.3 Normalized Routing Load

The normalized routing overhead as a function of pause time with different hello intervals is plotted in Fig.3. With increasing mobility (decreasing pause time) with increase in the hello interval normalized routing overhead decreases. This is due to increase in PDF causing decrease in average per data packet routing overhead.

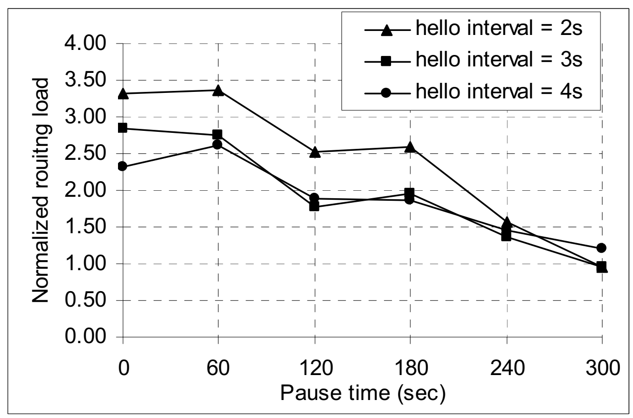

Figure 3. Normalized routing load vs pause time (sec) for different hello intervals.

4.4 Channel Utilization

The simulation result in Fig.4 shows the effect of varying mobility under different hello intervals on channel utilization. The result shows that in high to moderate mobility scenario the channel utilization increases with hello interval.

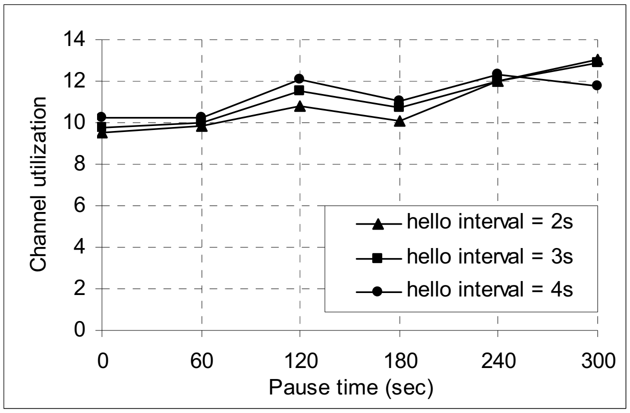

Figure 4. Channel utilization vs pause time (sec) for different hello intervals.

4.5 Control Overhead

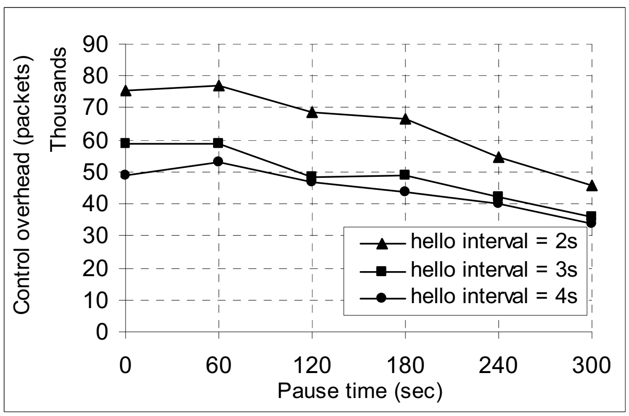

Figure 5. Control overhead (in packets) vs pause time (sec) for different hello intervals.

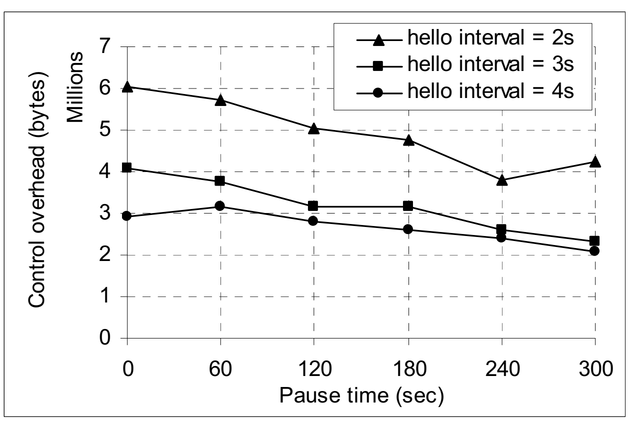

Figure 6. Control overhead (in bytes) vs pause time (sec) for different hello intervals.

Fig. 5 and Fig. 6 show the effect of varying hello interval on control overhead in packets and in bytes respectively with respect to pause time. As hello interval increases control overhead decreases in terms of packets and bytes both.

5 CONCLUSION

The effect of hello interval on different performance metrics is discussed in this paper. The packet delivery fraction, average end to end delay, normalized routing load, channel utilization capacity and control overhead are examined by varying mobility and hello interval to show the influence of control messages on the performance of mobile ad hoc networks. It is clear from the results that the PDF, channel utilization capacity, the normalized routing load and control overhead (in packets and in bytes) improves with the increase in hello interval whereas the average end-to-end delay degrades. This clearly shows that control overhead play a significant role in performance of routing protocols based on clustering for mobile ad hoc networks.

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