Impact of MAC Protocol on the Performance of Routing in MANETs

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Abstract— Mobile Ad hoc Network is an autonomous system of mobile nodes that utilize multi-hop radio relaying and are capable of operating with any support from fixed centralized infrastructure. Since nodes in such networks can leave or enter any time development of a routing protocol that can respond quickly to underlying dynamic topology and utilizing the available bandwidth efficiently is a research challenge. There have been many research works comparing the performance of routing protocols under varying conditions and constraints. The majority of the research is focused towards coping up with the node mobility, network density, energy reduction, routing and control overhead minimization and increasing the throughput. Most of them are unaware of MAC Protocols, which affect the relative performance of routing protocols considered in different network scenarios. As routing and MAC protocol runs in coordination, the choice of MAC is an important criterion. This paper investigates effect of MAC protocols on the relative performance of AdHoc routing under various scenarios. Two routing protocols are simulated in NS2 with two different MAC protocol and the results show that the performance of routing protocols of ad hoc networks will suffer when run over different MAC Layer protocols.

Index Terms— MANET, Routing, MAC, DSR, AODV, Overheads, Performance

I. INTRODUCTION

Mobile Ad-Hoc network (MANET) is a collection of nodes, which are capable of communicating with each other utilizing multihop relaying without any centralized infrastructure by forming an arbitrary and dynamic wireless network. The dynamic topology of MANET makes it necessary to route the traffic through multihop paths to make communication possible between two nodes. So the routing protocol must have the capability to respond in a whiz to the changes in underlying topology. Available bandwidth is also an important constraint that should be dealt optimistically by incorporating the methodologies to minimize the routing and control overheads.

Several routing protocols exist, addressing the problems of routing in mobile ad-hoc networks. Depending on the route acquisition time the protocol may be Proactive or Reactive. Reactive protocols are characterized by nodes acquiring and maintaining routes on-demand. In general, when a node has some data to send to some unknown destination a query is flooded onto the network and replies, containing possible routes to the destination, are returned. There are various reactive routing protocols among which Ad Hoc On Demand Distance Vector Routing Protocol (AODV) and Dynamic Source Routing (DSR) have caught a great attention. The routing protocol runs over a MAC layer protocol so the selection of MAC protocol plays a vital role in the efficiency of a routing protocol. The nodes in MANETs share a common broadcast radio channel. Due to limited available radio spectrum there are limitations on the bandwidth for communication. Access to this shared medium should be controlled by the underlying protocol in such a way that at the same time it should maintain the fairness of share of the available bandwidth towards the nodes and utilize it efficiently. The basic aim of any communication system shall be to transport the data, from source to destination successfully, in a reliable way and in minimum time. If a good routing protocol is selected to run on an inferior performance MAC frequent link breaks will result in increased end to end delay and choice of robust MAC for a substandard routing mechanism may result in increased routing overheads and packet drops thereby increasing the end to end delay resulting in bandwidth consumption. Although substantial attention have been devoted towards the design and development of routing protocols there is relatively less understanding of interaction of routing protocol with other network layers and effect of other layers on routing and that of routing on other layers. There exist many MAC protocols for MANETs which can be broadly categorized as contention based, contention based with reservation mechanism and contention based with scheduling mechanisms. In this paper the effect of two different MAC protocols on two popular routing protocols is presented to demonstrate the effects of MAC on the performance of routing.

Rest of the paper is organized as follows. Section 2 discusses the related work. Routing and Media access control protocols considered in this study are explained in brief in Section 3. Simulation environment is explained and the results with the performance metric are presented in Section 4. Last section concludes the paper with discussion on results and future scope.
II. RELATED WORK

In this section the previous studies concerning routing performance in AdHoc network and effect of MAC on routing are summarized. Most of the previous studies compare the different routing on the basis of various performance metrics which take into account the factors involved in routing activity only. Previously very less work has been carried out to investigate the effect of MAC on the performance of routing. MAC and routing both are very crucial functions in any type of communication. In [1] author compare four routing protocols based on node pause time. AODV, DSR and STAR protocols are compared for their routing performance [2]. There are few studies investigating the choice of MAC-Routing combination suitability. Authors in [7,8] used statistical ANOVA method to analyze the interaction but they used only two connections and compared the performance of AODV, DSR and LAR1 with IEE802.11DCF, CSMA and MACA with latency, total number of packets received and long term fairness of the protocols as the performance measures. In [9] four routing protocols DSR, AODV, DSDV and WRP are investigated with IEE802.11DCF, CSMA and E-TDMA with 25 nodes over a large area of size 1000m X 600m and considered average end to end delay as the major performance metric which includes queuing delays and retransmission delays along with Packet delivery ratio and control overhead as other metrics. But it is not clarified how end to end delay take into account the MAC behavior as it is the average time taken by a data packet to reach from source to destination.

This paper includes number of MAC packets transmitted as an additional performance metric to understand the relative behavior of underlying MAC protocol and 50 nodes are simulated over a relatively small area of size 500m X 500m to increase the node density.

III. OVERVIEW OF PROTOCOLS

This section gives brief introduction of the protocols used in this study. DSR and AODV are two popular demand driven routing protocols. Performance of these routing protocols is studied with IEE802.11DCF and TDMA media access control protocols in this paper.

A. Dynamic Source Routing (DSR)

DSR [4] is a beaconless demand driven routing protocol designed for controlling the bandwidth consumed by control packets in infrastructureless multihop wireless networks with elimination of the periodic table update messages required in table driven approaches. In this protocol when a mobile (source) node has a packet to send to some destination, it first checks its route cache to see if there exists already a route to the destination. If there exist an unexpired route to the destination or an intermediate node in the upstream of the path to the destination, the node (with a fresh enough path to the destination) sends a reply to route request till the intermediate node is checked by comparing the sequence numbers to identify the most recent path. When a source node has a packet to send to some destination it initiates a path discovery process by broadcasting a route request packet to all the neighboring nodes in its range which then forward the request to their neighbors. This process is repeated by all the intermediate nodes receiving the route request till the intermediate node is either a destination or has a fresh enough path to the destination. The freshness of the path available at the intermediate node is checked by comparing the sequence number in the request packet to the number available at the node. While forwarding the route request the intermediate nodes, discarding the duplicate copies, record the address of the neighboring node from which it has received the first copy of the route request along with its broadcast identity. Upon receipt of route request the destination or an intermediate node sends a route reply along the reverse path. A route discovery process is reinitiated by the source if it receives a link failure error message propagated by the node in the upstream of the path break.

B. Ad Hoc On-demand Distance Vector (AODV)

AODV [5] is also a demand driven routing protocol similar to DSDV [6] algorithm which employs destination sequence numbers to identify the most recent path. When a source node has a packet to send to some destination it initiates a path discovery process by broadcasting a route request packet to all the neighboring nodes in its range which then forward the request to their neighbors. This process is repeated by all the intermediate nodes receiving the route request till the intermediate node is either a destination or has a fresh enough path to the destination. The freshness of the path available at the intermediate node is checked by comparing the sequence number in the request packet to the number available at the node. While forwarding the route request the intermediate nodes, discarding the duplicate copies, record the address of the neighboring node from which it has received the first copy of the route request along with its broadcast identity. Upon receipt of route request the destination or an intermediate node sends a route reply along the reverse path. A route discovery process is reinitiated by the source if it receives a link failure error message propagated by the node in the upstream of the path break.

C. IEEE 802.11 DCF

The IEEE 802.11 specifies two modes of MAC protocol: Distributed Coordination Function (DCF) mode (for ad hoc networks) and Point Coordination Function (PCF) mode (for centrally coordinated infrastructure-based networks). The DCF in IEEE 802.11 is based on CSMA with Collision Avoidance (CSMA/CA), which can be seen as a combination of the CSMA and MACA schemes. The protocol uses the RTS–CTS–DATA–ACK sequence for data transmission. Time slots are divided into multiple frames and there are several types of inter frame spacing (IFS) slots. The node waits for the medium to be free for a combination of these different times before it actually transmits. Different types of packets can require the medium to be free for a different number or type of IFS. For instance, in ad hoc mode, if the medium is free after a node has waited for DIFS, it can transmit a queued packet. Otherwise, if the medium is still busy, a backoff timer is initiated. The initial backoff value of the timer is chosen randomly from between 0 and CW-1 where CW is the width of the contention window, in terms of time-slots. After an unsuccessful transmission attempt, another backoff is performed with a doubled size of CW as decided by Binary Exponential Backoff (BEB) algorithm. Each time the medium is idle after DIFS, the timer is decremented. When the timer expires, the packet is
transmitted. After each successful transmission, another random backoff (known as post-backoff) is performed by the transmission completing node. A control packet such as RTS, CTS or ACK is transmitted after the medium has been free for SIFS.

D. TDMA
Unlike contention based IEEE802.11MAC protocol a TDMA MAC protocol allocates different time slots for nodes to send and receive packets. The superset of these time slots is called a TDMA frame which contains preamble besides the data transmission slots. Within the preamble, every node has a dedicated subslot and uses it to broadcast the destination node identity of outgoing packet. Other nodes listen in the preamble and record the time slots to receive packets. Each node turns its radio on and off explicitly to avoid unnecessary power consumption. The radio only needs to be on when it is in the preamble phase and there is a packet to send and receive.

IV. SIMULATION AND RESULTS
A. Simulation model
Network Simulator2 [10] is used for the simulations. The traffic sources are CBR. 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 propagation model is the two ray ground model. The simulation parameters used are shown in table 1. Several runs of each scenario are simulated for enough time to reach and collect the desired data at steady state to obtain statistically confident averages.

| Table 1. Simulation parameters |
| Simulation Parameters       |
| Network size                | 50 nodes                          |
| Area                        | 500m x 500m                       |
| Traffic model               | CBR                               |
| Traffic sources             | 30%                               |
| Packet size                 | 512 bytes                         |
| Packet rate                 | 4 packets/s                       |
| Max. speed                  | 20m/s                             |
| Transmission range          | 250m                              |
| Bandwidth                   | 2 Mb/s                            |
| Node movement model         | Random way point                  |
| Simulation Time             | 100 s                             |
| Pause time                  | 0, 20, 40, 60, 80, 100 sec.       |

B. Performance Metric
Following performance metrics are considered for studying the effect of MAC on routing.
Packet delivery fraction (PDF): The Packet delivery is defined as the ratio of number of data packets successfully received to number of total data packets transmitted.

Average end to end delay: It is the ratio of total delay to number of packets received successfully.
Normalized routing overhead: Ratio of number of routing packets transmitted to number of data packets successfully received.
MAC overhead: Number of MAC packets transmitted.

C. Results
Following figure shows the effect of MAC on the performance of routing protocols. Fig.1 shows the number of MAC packets transmitted over the simulation time of 500 seconds.

![Fig.1 - Number of MAC packets transmitted](image)

It can be observed that number of MAC packets transmitted is far less for DSR as compared to AODV with both TDMA and IEEE802.11DCF. It is also clear for both the routing protocols TDMA requires less number of MAC packets as compared to IEEE802.11DCF.
The normalized routing overload is shown in Fig.2. The normalized routing overhead is more for AODV as compared to DSR with both IEEE802.11DCF and TDMA. TDMA MAC has slightly lower normalized routing overhead.

![Fig.2 Normalized routing overhead](image)

Fig.3 (a) and Fig.3 (b) show that the average end to end delay with TDMA is very large as compared with IEEE802.11DCF but still AODV performs better to DSR. It is obvious because DSR packet carries the entire route it has to go through where as AODV packet carries the information of only next hop in the route.
Fig.3 (a) Average end to end delay (IEEE802.11DCF)

Fig.3 (b) Average end to end delay (TDMA)

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IV. CONCLUSION AND FUTURE SCOPE

The routing and MAC both are very crucial in wireless communication and the choice of MAC affects the performance of routing. In this paper two routing protocols are investigated to observe the effect of MAC with only two MAC protocols and it is shown that the routing performance is MAC dependent. So it is necessary to understand the performance of MAC and routing together instead of analyzing the routing performance in isolation. The detailed investigation of interaction of MAC and routing protocols needs to be carried out to understand the behavior of the system when it is scaled up in terms of node density and traffic both.

REFERENCES

