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An efficient passive approach for quality of service routing in MANETs

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***Abstract*— The application of Mobile Ad hoc Networks (MANETs) has been increasing everyday. Attractive features of MANETs are absence of infrastructure and decentralized nature. Routing protocols for mobile ad hoc networks have been explored extensively in recent years. Much of the work is aimed at finding a feasible route from a source to a destination without considering current network traffic and application requirements. This may lead to the network become overloaded due to heavy traffic and the application has no way to improve its performance under a given network traffic condition. Many applications that use MANETs include multimedia data that require Quality of Service (QoS) support for effective communication. We approach the problem of providing Quality of Service in mobile ad hoc networks by the technique of bandwidth based path finding. This paper proposes a contention aware routing algorithm that incorporates an admission control scheme which is suitable for the mobile ad hoc networks. The Ad hoc On demand Distance Vector (AODV) routing protocol provides efficient route establishment between nodes with minimal control overhead and minimal route acquisition latency. In our work the modified AODV(M_AODV) establishes a path between the source and the destination meeting the application stipulated throughput requirement. Contention which is the inherent problem in MANET is considered effectively in this approach. M_AODV is implemented so that additional overhead requirement will be very less. In this paper, we present a scalable and efficient contention aware routing to support QoS in ad hoc networks. Simulation results show significant performance advantages of our approach when compared with existing approaches.**

***Keywords*— Mobile Ad hoc Networks (MANETs), Quality of Service, bandwidth estimation, contention, admission control.**

I. INTRODUCTION

Ad hoc wireless network is made up of a group of mobile nodes and all communication is carried out through wireless medium in a distributed fashion without central controller. Nodes in MANETs are small radio devices with limited computational capacity and memory. MANETs (Mobile Ad hoc Networks) inherently possess many challenges [1][2] for its deployment. Nodes are normally battery powered, and battery life is often a limiting factor. The radio transmission channel is limited in bandwidth. Channel bandwidth is shared among nodes. In MANETs nodes mobility makes determining and maintaining the network topology the most challenging issue. Discovering and maintaining the routes in ad hoc networks require more control traffic. This makes the task of performing ad hoc network routing more complex and less efficient. A lot of work has been made on routing in ad hoc networks: the destination - sequenced distance vector (DSDV) protocol [3], the wireless routing protocol [4], the temporally-ordered routing algorithms [5], the dynamic source routing protocols [6], the associativity based routing protocol [7], and the zone routing protocol (ZRP) [8], etc. All these solutions only deal with the best-effort data traffic. In order to support vast range of services best-effort routing solutions are not sufficient. Normally multimedia applications often have stringent bandwidth and delay requirements. Any networks supporting multimedia applications must cater above requirements. Hence focus has been shifted from best-effort services to the provision of better defined QoS in ad hoc networks.

II. RELATED WORKS

QoS provisioning is becoming a critical issue in designing mobile ad hoc networks. In this section we present an overview of the existing solutions. Chen and Nahrstedt [9] proposed a ticket based QoS routing algorithm for ad hoc networks. This ticket based probing scheme achieves a balance between the single-path routing algorithms and the flooding algorithms. It does multi path routing without flooding. The required QoS is ensured during the time when an established path remains unbroken. The QoS support however is disrupted during the rerouting time. Lin and Liu [10] proposed a new bandwidth routing scheme which contains bandwidth calculation and reservation for mobile ad hoc networks. They suggested a TDMA-based approach. This approach requires effective synchronization between all nodes in the networks. Applying highly synchronized solutions in ad hoc networks becomes expensive and synchronization may fail when the nodes are mobile. Sarr et al. [11] presented a non-intrusive technique called Available Bandwidth Estimation (ABE) to estimate the remaining bandwidth between two neighbour nodes on a per node basis. Bandwidth estimation is based on watching the medium to get its total idle time duration within the stipulated observation period.

Medium idle time includes periods during which no frame is ready to transmit as well as periods of backoff time and inter frame spacing. Idle times shorter than DIFS are not considered in this approach to improve estimation accuracy. Solution to deal with bandwidth utilization in MANET by the node’s contention neighbors is not suggested in this work. Hanzo et al. [12] proposed Quality of Service routing in ad hoc networks. They suggested throughput constrained Quality of Service routing utilising the Dynamic Source Routing (DSR) protocol. DSR is based on source routing which requires more overhead compared to AODV.

In order to support quality of service, path finding approaches need to be combined with suitable admission control strategy. At the time of making admission control decisions, a node considers its local resources simultaneously it must account the resource of its contention neighbors because nodes flow may consume their resources through contention. This paper fulfils this objective by modifying AODV to perform admission control logic at every node and also to consider both node's local resources and resources available at its contention-neighbors. We only consider bandwidth as the admission criteria. This is because bandwidth guarantee is one of the most critical requirements for real time applications. The performance of M_AODV is compared with the approach ABE suggested in [11] using NS-2 simulator.

The rest of the paper is organized as follows. Next section explains the complete functioning of quality of service support AODV. Section IV describes route discovery process of M_AODV. The protocol simulation and results are discussed in section V.

III. FUNCTIONING OF MODIFIED AODV

Basic AODV [13] is based on flooding the network with Route Request (RREQ) messages. Each RREQ is uniquely identified through a sequence number. When a node receives the RREQ it records the address of the node that sent the message. When the first RREQ reaches the desired destination, a route reply (RREP) message is generated and sent back to the source node through the recorded reverse path, ensuring a path from the source to the destination. Modified AODV differs from AODV in the way the route discovery process is enhanced to provide quality of service support by performing bandwidth constrained admission control at each node in the network.

The main problem of the MANET comes from the shared nature of the wireless medium in single-channel networks. Essentially nodes that cannot communicate with each other directly may still contend directly with each other for the same resources. This extended contention area, known as ‘neighborhood contention’ affects resource allocation at individual nodes in two-ways. First allocation decisions at an individual node require bandwidth information of nodes outside of its communication range and along the entire route. Second, contention for resource may involve multiple nodes along a route. Modified AODV performs admission control based on the knowledge of these characteristics of MANET. We focus on ad hoc networks based on single-channel MAC layers like IEEE 802.11. The physical characteristics of wireless channel introduce the following two challenges. First challenge is available bandwidth estimation at a node; second challenge is estimation of flow bandwidth requirement in a shared medium.

A. *Node’s Available Bandwidth*

In shared wireless medium, when a node starts to transmit a flow, it consumes bandwidth from its contention neighbors. Because each node has a different view of the network, the node cannot decide on its own whether its contention neighbors have sufficient unused bandwidth for the new flow. Also, obtaining contention neighbor information is not easy since a node may consume the bandwidth of contention neighbor but not able to directly communicate with those neighbours.

B. *Flow Bandwidth Consumption*

Multiple nodes belong to a route may contend for bandwidth at a single location and not know about each other. A node on the route of flow cannot tell how much bandwidth the flow will consume at its contention neighbors.

C. *Admission Control*

The objective of admission control is to determine whether the available resources can meet the requirements of a new flow while maintaining bandwidth levels for existing flows. Each node views a different channel state, hence the available bandwidth in the network is not a local concept [14]. To tackle this condition, two terms are introduced: local bandwidth available (BW_{local}), contention-neighborhood bandwidth available ($BW_{c\text{-}neigh}$). Local bandwidth available is the amount of unconsumed bandwidth as observed by a given node. Contention neighborhood available bandwidth is the maximum amount of bandwidth that a flow can avail for transmission without affecting the reserved bandwidth of any existing flows in its carrier-sensing range.

1) *Calculation of Local Bandwidth Available (BW_{local}):* It is the unconsumed bandwidth at a given node. Each node in the MANET can determine its BW_{local} by passively listening network activities. In our approach, we use the fraction of channel idle time based on the past history as an indication of local available bandwidth at a node. A node can perceive the channel as either idle or busy. The channel is idle if the node is not in any of the following three states. First, the node is transmitting or receiving a packet. Second, the node receives a RTS or CTS message from another node, which reserves channel for a period of time specified in the message. Third, the node senses a busy carrier with signal strength larger than a certain threshold, called the carrier-sensing threshold, but the node cannot interpret the contents of the message. Idle time calculation requires estimation of node busy time (T_{busy}) for the period of time T_p. Normally the medium is busy with the routing messages like RTS, CTS, ACK and the

transmission, reception and detection of data frames. Hence the amount of time required for single data packet transmission [15] is computed as in

$$T = T_{r\_msg} + T_{mac} + T_{frame} \qquad (1)$$

Where T_{r_msg} - time consumed by the RTS, CTS, ACK routing messages overhead.
T_{mac} - time consumed by DIFS, SIFS, Backoff intervals i.e. MAC overhead.
T_{frame} - time needed for single data frame transmission

Backoff time is the product of a time slot and a random number from 0 to 31. The data frame preamble (192 bits) is also taken into consideration. Preamble bits are transmitted at the basic rate of 1 Mbps. Data frame includes the payload and the IP and MAC headers. The accuracy of the estimation depends on the interval T_p, between successive measurements. Larger the value of Tp, the estimate is more accurate. Smaller the value of T_p, the estimate is transparent to the channel dynamics. Hence choosing the value of it is a tradeoff between accuracy and transparency. The formula to estimate the channel busy time while 'L' number of packets are transmitted, received or detected for the duration of 'T_p' is given as in

$$T_{busy} = T_{r\_msg} + L * (T_{mac} + T_{frame}) \qquad (2)$$

Related to the backoff time estimation, during contention the nodes involved in it will decrease their backoff simultaneously. When the node hears a next transmission, it pauses its backoff counter and restarts it when the medium remains idle again for DIFS duration. Also backoff time value is very small when compared with T_{frame}. So it can be neglected from the calculation of packet transmission time. Channel idle time T_{idle} within the period T_p is deduced as follows:

$$T_{idle} = T_p - T_{busy} \qquad (3)$$

By monitoring the amount of channel idle time T_{idle}, during every period of time T_p, the local bandwidth available BW_{local} of a node can be computed using a weighted average [16] as follows:

$$BW_{local} = \omega\, BW_{local} + (1-\omega)(T_{idle} / T_p)\, BW_{channel} \qquad (4)$$

Where $BW_{channel}$ is the capacity of the channel and weight $\omega \varepsilon [0,1]$.

2) *Calculation of Contention Neighborhood Bandwidth Available ($BW_{c\text{-}neigh}$):* Each node perceives the network in a different state. Hence a node's local bandwidth available cannot provide information about its contention neighbours, since it does not know the amount of BW_{local} available at other nodes. In our approach, during the normal medium access using IEEE 802.11, node listens to the medium using a threshold value known as contention carrier sensing threshold. In Fig.1 the inner circle shows the transmission range of node A. Outer circles indicate the carrier sensing range of nodes B, A and C respectively.

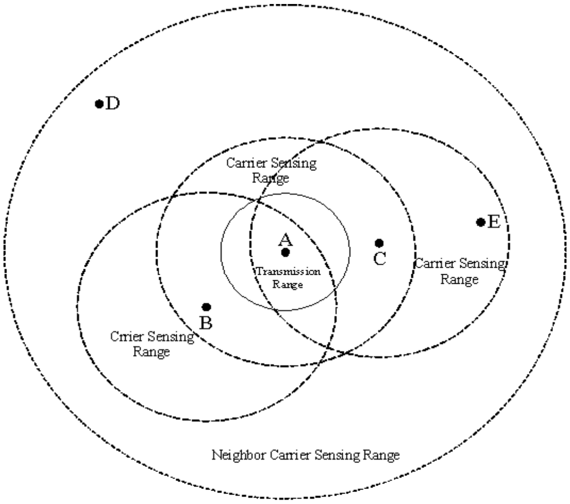

Fig. 1 Different sensing ranges of a mobile node

Normally carrier sensing range is twice the transmission range of a node. Contention carrier sensing threshold refers the range that covers the carrier sensing ranges of all of the sensing node's contention neighbours. Hence it is set to a value much lower than the carrier sensing threshold. When the signal strength of the carrier sensed by a node is smaller than the contention carrier sensing threshold there is no communication in its contention neighborhood and contention neighbors of the node experience idle channels. The amount of time that the channel is in this idle state, denoted as $T_{idle}^{contention}$, for every period of time T_p, contention neighborhood available bandwidth(BW_{c_neigh}) is calculated using the following formula:

$$BW_{c\text{-}neigh} = \omega\, BW_{c\text{-}neigh} + (1-\omega)(T_{idle}^{contention}/T_p) BW_{channel} \qquad (5)$$

3) *Calculation of Application's Flow Bandwidth Consumption (BW_{flow}):* M_AODV needs to quantify the bandwidth that a new flow requires so that it can be decided whether the bandwidth available will satisfy the requirements of the flow. Foremost, the application's data rate has to be converted into the corresponding channel bandwidth requirement. This conversion includes the protocol overhead incurred in the MAC layer and the network layer. Hence each data packet's transmission time is calculated as follows:

$$T_{data} = T_{rts}+T_{cts} +T_{ack}+T_{difs}+3T_{sifs}+(P+Q)/BW_{channel} \qquad (6)$$

Where T_{data} - transmission time of each data packet
T_{rts} - time for transmitting RTS
T_{cts} - time for transmitting CTS
T_{ack} - time for transmitting ACK
T_{difs} - DCF inter frame space defined in the IEEE 802.11 protocol standard

T_{sifs} - short inter frame space defined in the IEEE 802.11 protocol standard
P - size of the data packet
Q - IP and MAC packet header length
$BW_{channel}$ - Channel capacity

If at every second, the application generates ‘R’ packets with average packet size 'P', the corresponding channel bandwidth requirement is computed as follows:

$$BW_{flow} = R \times T_{data} \times BW_{channel} \qquad (7)$$

IV. MODIFIED AODV ROUTE DISCOVERY PROCESS

Like AODV [2], modified AODV is a reactive unicast routing protocol for mobile ad hoc networks. During the route discovery process, the source broadcasts route request (RREQ) packets. Each RREQ packet contains the addresses of the source and the destination, the broadcast ID, the last seen sequence number of the destination as well as the source node's sequence number. Application's channel bandwidth requirement (BW_{flow}) is computed by the source as per (7) and included in the RREQ packet. In modified AODV, each node computes BW_{local} and $BW_{c\text{-}neigh}$ as per (4) and (5) respectively. Every intermediate node receiving RREQ performs admission control as given in Fig.2. If the bandwidth requirement of the flow BW_{flow} is lower than node's local available bandwidth BW_{local} and contention neighborhood available bandwidth $BW_{c\text{-}neigh}$, admission control succeeds, otherwise it fails. In case of failure, the RREQ is discarded. On success of the admission control process the node sets up a reverse route entry in its routing table, adds its identifier in the RREQ packet and rebroadcasts the route request. Recording the sequence of hops in RREQ packet enables to determine the lower bound of the contention count of the complete route and also it can be used to eliminate circular routes.

When the intended destination receives a route request, it receives the full route and sends a route reply (RREP) back to the source along the same route. On success of admission control, a soft reservation of bandwidth is made in the routing table and RREP is forwarded to its immediate predecessor. On failure, admission failure message is sent to the destination via the same reverse route. It enables cancellation of bandwidth reservation by the successor nodes. On successfully receiving RREP, a source has enough end-to-end bandwidth reserved route and the transmission can start. The bandwidth reservation at the node automatically expires, if no data packet arrives due to link breakages.

V. SIMULATION AND RESULTS

The proposed modified AODV routing protocol is implemented using the NS-2 network simulator [17]. AODV protocol already exists in the network layer. In M_AODV the packet structure of RREQ is changed to carry additional information. The routing table structure is also changed to hold the extra details. Simulations are run for different scenarios. Different scenarios are created using 10, 20, 30, 40 and 50 nodes. Protocol evaluations are based on the simulation of wireless nodes forming an ad hoc network,

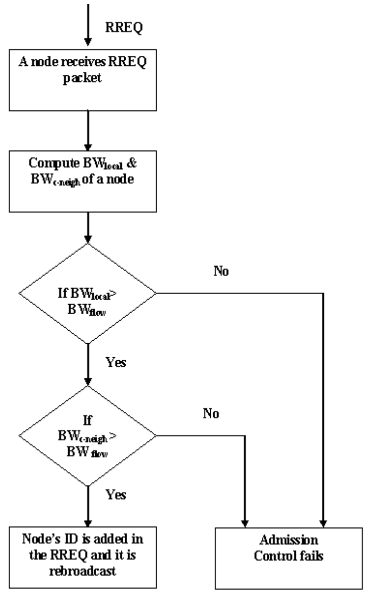

Fig. 2. Admission Control Process

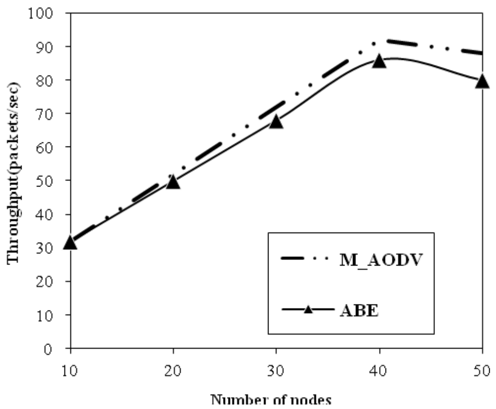

Fig. 3 Throughput of Modified AODV

moving about over a rectangle. Rectangle size is 1000m x 1000m, simulation time is 200seconds. For medium access control the 802.11 protocol is used. Radio transmission range of a node is set to 250m and the carrier sensing range is set 550m. Node movement is set as per “random way point” model. Each flow generated 10 packets per second. Each packet size is 512 bytes. Speed of nodes is 5m/s and the bandwidth of the channel is 2 Mbps. Scenarios are run for different node pause time values. The performance of the modified AODV is compared with ABE approach [11] in terms of throughput, overhead requirement, packet dropped ratio, end to end packet delay and QoS effectiveness.

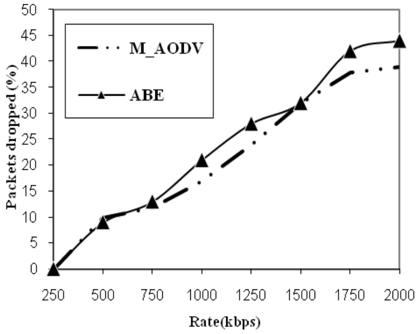

Fig. 4 Packets dropped for different transfer rates

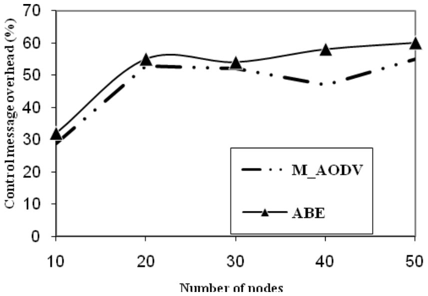

Fig. 5 Control message overhead for pause time = 10sec

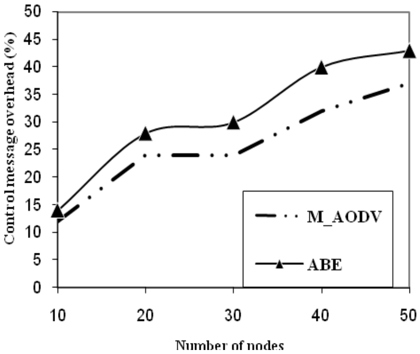

Fig. 6 Control message overhead for pause time = 20sec

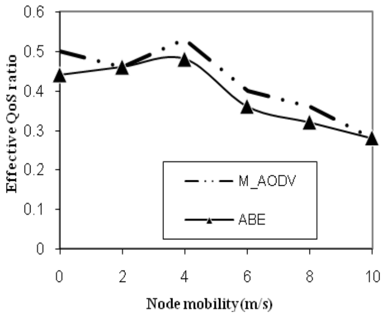

Fig. 7 QoS effectiveness of M_AODV

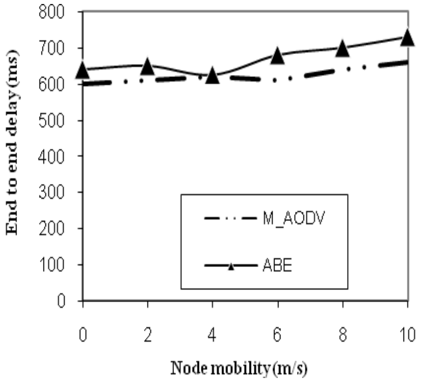

Fig. 8. Average end to end packet delay of data packets

Throughput of modified AODV gets increased significantly as shown in Fig.3. Fig.4 presents the number of packets dropped in both cases for various transfer rates. When compared with ABE, packets dropped percentage in M_AODV for higher rates of data transmission is reduced by 10% to 19%. From Fig. 5 and Fig. 6, it is inferred that control message overhead of M_AODV execution is comparatively lower than ABE execution. Also as the nodes' pause time value increases, control message overhead decreases drastically. Fig. 7 depicts the QoS effectiveness achieved in both approaches. When compared with ABE the QoS effectiveness in the proposed approach is increased by 11%. Average end to end packet delay achieved for various rates of node movements is shown in Fig. 8. Both the approaches show higher delays for increased node mobility. Considerable reduction in end to end packet delay is achieved in the proposed approach. Overall performance of the M_AODV is improved because it accounts contenting neighbours available bandwidth also at the time of admission control thereby avoiding overestimation of available bandwidth in the shared medium.

VI. CONCLUSIONS

In this paper, we proposed a QoS enhanced AODV routing algorithm for ad hoc networks. The existing AODV performs routing with low control overhead and effective packet transmission. But it does not have QoS support. The M_AODV is designed to perform path finding that meets the application stipulated bandwidth requirement. Our path finding approach is modified in such a way that it deals with common medium sharing problem of the ad hoc networks effectively. The modified AODV performs path finding with less overhead by adopting passive approach of listening to the medium. Simulation results show that it performs better than existing ABE in terms of throughput and control message overhead. In the proposed approach number of packets dropped due to heavy load condition and the average end to end packet delay are considerably reduced than in ABE. It improves packet delivery ratio greatly without affecting the overall end-to-end throughput of existing flows.

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