A Novel Delay Oriented Reactive Routing Protocol for QoS Provisioning in MANETs

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***Abstract*— Due to the recent developments in the hand-held devices and communication enhancements in wireless networks like mobile ad-hoc network (MANETs), these networks are targeted for providing real time services like video streaming, video conferencing, VOIP etc. Although, the basic design of MANETs is not fully capable to provide multimedia services, therefore some sort of quality-of-service is required in these networks. In this thesis, we have proposed a delay-aware routing protocol that discovers routes for a source-destination pair with the application provided delay constraints. The methodology is focused on using a reactive routing approach, AODV, to discover the delay-aware routes during its route discovery phase; hence, our proposed protocol is called as DS-AODV (Delay Sensitive AODV). In this way, we are able to provide the QoS to the requesting application in terms of delay metric. The delay constraint provided by the application that wishes to transmit its traffic is used to find suitable routes that can send the application traffic from source to destination node within the specified delay bound. Simulation results are developed using the trial version *of" Exata Cyber"* network simulator and analyzed to show the effectiveness and correctness of the proposed method.**

***Keywords*— Mobile Adhoc Networks, real time services, Quality of Service, delay aware routing, reactive routing, AODV.**

I. Introduction

Mobile Ad-hoc Networks, popularly called as MANETs, are infrastructure-less, multihop networks without any physical connections. MANETs consists of a number of mobile hosts that are connected by means of wireless links. These MANET nodes acts as routers and are themselves responsible for forwarding packets within a MANET without the need of a centralized authority. The key feature of Mobile Ad-hoc Networks is its easiness of deployment. So it makes it suitable for battlefield, search and rescue and disaster management. In MANETs, nodes rely on multihop communication (nodes within each other's transmission range can directly communicate through wireless channels whereas, those outside the range have to communicate indirectly through intermediate nodes) to exchange data between source and destination nodes. MANET nodes can move freely in the network. When the nodes move, the network topology will be changed frequently, i.e., the more the node mobility, the higher is the frequency of topology change.

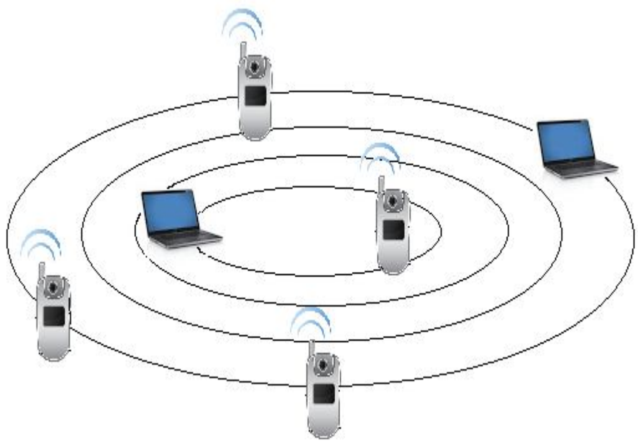

Fig. 1 A typical MANET System

MANETs are highly spontaneous [1]; self organized, self-maintained and decentralized in nature. Hence, in Mobile Ad-hoc Networks, there is no fixed topology due to node mobility, interference, multipath propagation and path loss. Also, each mobile node has limited resources such as battery, memory and processing power [2][3]. As a result, establishing a correct and efficient routing protocol for MANETs is quite a challenging task to accomplish since traditional routing protocols may not be suitable for MANETs. Routing protocol design for MANETs is therefore, an active field of research.

II. QoS in MANETs

In MANETs, one of the important issues is routing, that is, finding a suitable path from a source to a destination. Because of the rapid growth in the use of applications, such as online gaming, audio/video streaming and other multimedia applications in MANETs, it is now a mandatory requirement to provide the required level of QoS for reliable data delivery. Providing the required QoS guarantees in wireless multihop networks is much more challenging than in wireline networks mainly because of its dynamic topology, distributed nature, interference, multihop mode of communication, and contention for channel access. Particularly for routing protocols, it is important to provide QoS guarantees in terms of performance metrics, such as achievable throughput, delay, packet loss ratio, and jitter [4].

Despite the large number of routing solutions available in MANETs, their practical implementation and use in the real world is still limited. Multimedia and other delay or error-sensitive applications that attract a mass number of users toward the use of MANETs have led to the realization that best-effort routing protocols are not adequate for them. Because of the dynamic topology and physical characteristics of MANETs, providing guaranteed QoS in terms of achievable throughput, delay, jitter, and packet loss ratio is not practical. So QoS adaptation and soft QoS have been proposed instead [5]. Soft QoS means failure to meet QoS is allowed for certain cases, such as when a route breaks or the network becomes partitioned [5]. If node mobility is too high and topology changes very frequently, providing even soft QoS guarantees is not possible.

QOS Metrics

QoS in MANETs is defined as a set of service requirements that should be satisfied by the network when a stream of packets is routed from a source to a destination [6]. A data session can be characterized by a set of measurable requirements, such as maximum delay, minimum bandwidth, minimum packet delivery ratio, and maximum jitter. All the QoS metrics are checked at the time of connection establishment, and once a connection is accepted, the network has to ensure that the QoS requirements of the data session are met throughout the connection duration [7].

QOS guarantees the network to provide a set of definite service and performance features with respect to jitter, bandwidth, end to end delay and packet loss probability.

Several enhancements to existing routing protocols for MANETs have been proposed aiming on choosing routes based on the above QOS metrics, delay being one of them [8]. Delay aware protocols reckon delay as the chief QOS metric for discovering routes for a source-destination pair, i.e., the paths are selected based on delay constraints provided by the application. Delay can be in the form of routing delay, end to end delay, propagation delay, delay jitter etc. [8]. A major issue with the routing strategies in current scenario is that they are not designed to support QOS metrics, hence delay aware protocols comes into picture to deal with this problem.

III. AODV ROUTING PROTOCOL

A The Ad-hoc On-demand Distance Vector protocol is an ad-hoc network routing protocol that is purely reactive in nature because no routing tables are needed by the nodes to maintain any routing information. AODV is based upon DSDV and DSR routing protocols [2]. Being an on-demand protocol, AODV maintains information only "active" routes.

In AODV, a node can either be a source or a destination or an intermediate node. If a source node has some data to send to a destination, it checks its routing table to decide whether it has an already available "working" route [3]. In case no such route exists, it performs a route discovery operation to find the needed path. The route discovery process is dynamic and is accomplished in MANETs through various control messages.

Route Discovery

AODV uses a combination of two messages for accomplishing route discovery in Mobile Ad-hoc Networks:

a) Route Request (RREQ)
b) Route Reply (RREP)

When a source node wants to establish a connection with a destination for data transmission, it sends the RREQ message to all its immediate neighbors. RREQ contains the IP address of the source and the destination, a pair of fields related to sequence numbers and a hop count field initialized to zero. Each RREQ message is uniquely identified by a RREQ ID which goes on increasing with each newly generated RREQ in the network [3]. If a node receives an already processed RREQ via some other neighbor node, it is discarded. The source broadcasts this RREQ to its immediate neighbors. The neighbor nodes on receiving the RREQ, generates a backward route to the initiating source. Also, the hop count (distance from source node) in RREQ message format is increased by one.

The node receiving the RREQ checks its route table for the availability of fresh route(s) to the required destination. If it does not have any such route, it simply rebroadcast the RREQ further to its immediate neighbors with the previous hop count value being incremented. Hence, to search a valid route to a destination, RREQ packet is flooded in the network.

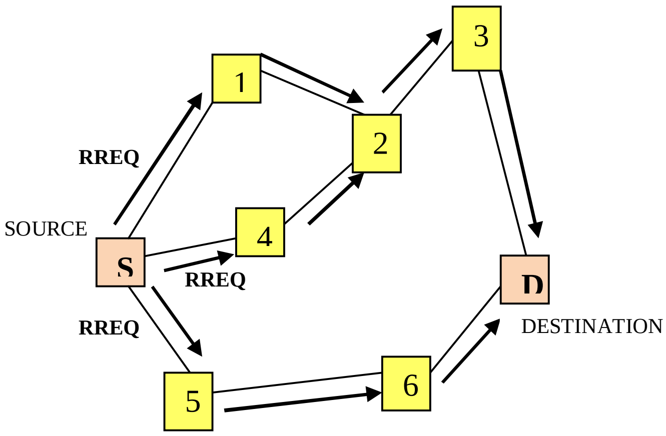

Figure 2 Flooding of Route Request (RREQ) packets

On the other hand, if the node receiving the RREQ is itself the destination or it does have an unexpired route to the required destination with the sequence number of the path to that destination (indicated in node's routing table) greater than or equal to the sequence number mentioned in the RREQ message, the node creates a *Route Reply* (RREP) message and transmit that on the backward route it created towards the node that sent RREQ. Hence, the backward node that was created during RREQ broadcast from source is now utilized for sending RREP back to the source node.

RREP packet contains the source and destination IP addresses, the sequence number of the path to the destination as indicated in the node's route table and the hop count field set equal to the distance between the node and the destination. The hop count is zero if the destination is creating and sending the RREP itself.

IV. PROPOSED PROTOCOL: DS-AODV

Our proposed routing protocol DS-AODV (Delay Sensitive AODV) is based on AODV routing protocol. DS-AODV search delay aware path during the route discovery stage. With this approach, we are able to provide some degree of QOS, in terms of end to end delay, to the application by searching suitable routes on which traffic can be transmitted from source to destination within bounded delay. If such a route is not available in the network, our proposed solution will reject the source's request for the session admission in the network, thus avoiding the overloading of network. In this way, DS-AODV ensures that the flow transmissions are not degraded due to incorrect admission of new sessions in the network.

For selecting the base routing protocol for our research, the motivation for choosing AODV mainly comes from its popularity and widespread use in adhoc networks. Apart from that, distance vector routing, being simpler, doesn't need much computations and memory.

The DS-AODV protocol searches all available routes between a source and destination that lies within the specified delay constraints. The applications running at source and destination specifies their maximum allowable delay thresholds in the RREQ and RREP messages respectively during the route discovery operation. This is specified in the extra added field "max_delay" in both these message formats.

We have shown in figure 3 the process of initiating a route discovery operation in DS-AODV.

Before searching any route towards the destination, the source node has to specify its maximum allowable delay bound in the RREQ message before sending it. The field offset_time is initialized to zero. Also, the session admission control process assigns a timer to the source application so that when it expires, route discovery can be attempted again.

In DS-AODV, the routing table contains an additional field route_delay. Each intermediate node will update this entry on receiving the RREQ message.

After initializing all the required fields, the RREQ message is created and broadcasted by the source node to its immediate neighbors. When a RREQ arrives at its destination, the destination creates a RREP packet by initializing all the fields including max_delay and offset_time and unicast it back towards the source S that originated the RREQ message.

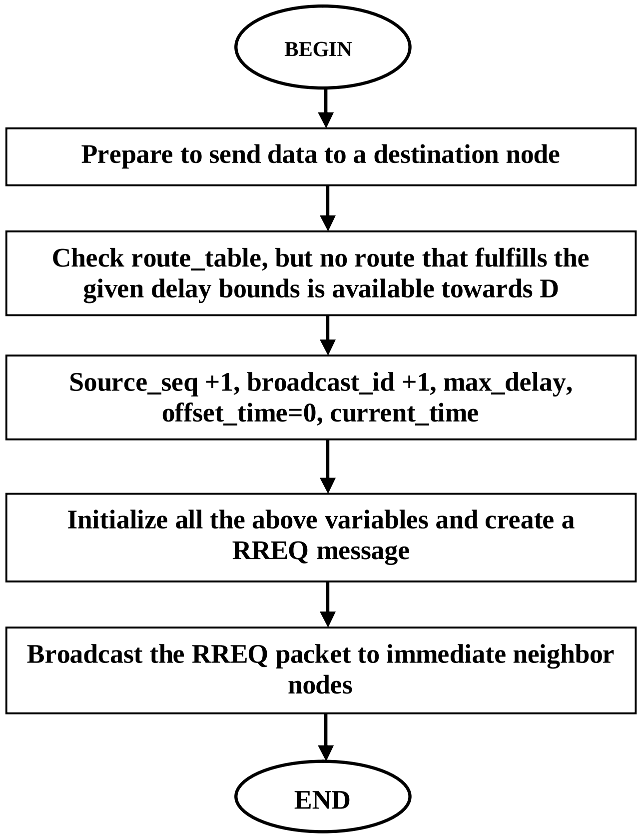

Fig. 3: flowchart for the initiation of Route Discovery process in DS-AODV

Algorithm 1 shows the detailed proposed protocol DS-AODV and how RREQ and RREP messages are handled at each node in the network.

Algorithm 1

DS AODV ALGORITHM

Variables used in the Algorithm:

S is the source node;

D is the destination node;

l_delay is the link delay;

q_delay is queuing delay;

t_delay is transmission delay;

Max_delay carry the maximum delay specified by the requesting application;

Offset_time specifies the time that is spent by the RREQ (RouteREQuest packet) till the current node;

R_count is the average number of retransmissions over a fraction of time;

Difs, sifs, p_len, c_bwd are predefined MAC values;

Algorithm:

// Set the fraction of time to t seconds over which a node monitors the loss probability (Pl) by using the number of HELLO messages it receives

// The Pl is used to calculate the link loss probability using the equation:

Link_Pl = 1 – Pl

// Based on the retransmission policy of 802.11 MAC, the approx. retransmission count can be calculated using the following equation:

R_count = 1/(1-Link_Pl)

Back_off_time= ((2 pow (5 + r_count) – 1)/2) * slot_time

//Back_off_time is set to initial contention window size specified in MAC 802.11 specification. Back_off_time increases with increase in number of retransmission of a data packet

//Each node N calculates following values at network startup

t_delay= (difs + (p_len/c_bwd) + sifs + back_off_time) * (r_count + 1)

l_delay= p_delay + q_delay + t_delay

//offset_time is initialized with zero

For (each node N in route discovery phase)

If (l_delay is less than max_delay)

Offset_time$_N$ = l_delay$_N$ + offset_time$_{N-1}$

Then RREQ message is forwarded

Else

Re-broadcast towards the destination

//D receives RREQ

//D unicast RREP message that contain l_delay (link delay) in one direction

S receives RREP message

S calculates link delay (l_delay$_S$)

If (l_delay$_S$ is less than max_delay)

Session is admitted by source S

Else

Source S rejects the session request

END ALGORITHM

V. SIMULATION RESULTS

In our analytical part, we have used trial version of Exata Cyber Developer Version 2.0 [9] to design MANET scenarios as well as for generating simulation results to check the effectiveness of our proposed protocol DS-AODV.

In table 1, we have mentioned various parameters for designing a typical MANET scenario that we have considered to carry out our simulation study.

TABLE I
SIMULATION PARAMETERS

Simulation Tool	Trial version of Exata Cyber Developer Version 2.0
Topology area	1000x1000m
Simulation Time	500 sec
Application Traffic type	CBR (Constant Bit Rate)
Number of nodes	60
Node Placement model	Uniform
Routing protocols under study	DS-AODV, AODV
MAC Layer protocol	IEEE 802.11
Physical Layer protocol	802.11b
Data Rate	11 mbps
Node Mobility model	Random Waypoint model
Packet size	512
Flow specification	50 packets/second
Node pause time	20 m/s (for constant network load)

We have evaluated the performance of our proposed routing protocol, DS-AODV, by comparing it with the traditional reactive routing protocol AODV over the two performance metrics average end to end delay and packet delivery ratio in terms of varying scenario parameters like number of data sessions and mobility of nodes.

A) Average End to End Delay [10]

The comparison of average end to end delay of DS-AODV and AODV is shown in figure 4. It is quite evident that end to end delay of DS-AODV is quite lower than that of AODV and varies as a function of number of sources under all values of number of CBR data sessions. This is due to the fact that DS-AODV is specifically meant for delay aware transmission of application data and due to additional delay oriented fields in request and reply messages, the discovered routes is bounded by a specific required delay. Hence the end to end delay of DS-AODV is drastically lower than that of AODV.

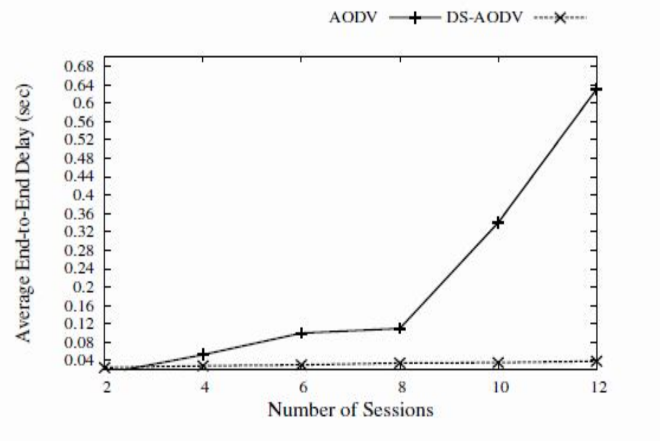

Figure 4 Effect of increased number of data sessions on delay

Figure 5 shows the variation of end to end delay with respect to change in node mobility. It can be clearly observed that average end to end delay is quite lower in DS-AODV, as compared to AODV. This is due to the fact that DS-AODV discovers routes within the delay requirements of the source application, hence, end to end delay cannot exceed beyond an acceptable limit, else the session would not have been admitted.

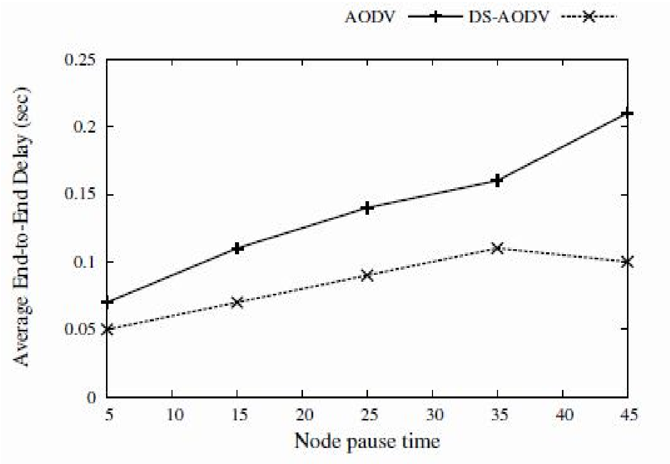

Figure 5 Effect of increased network mobility on delay

B) Packet Delivery Ratio (PDR) [10]

Figure 6 shows the effect of varying number of sources on packet delivery ratio in DS-AODV protocol compared to AODV. The figure shows clearly that the on packet delivery ratio for AODV is quite lower than DS-AODV, with increasing network load. The AODV protocol drops a larger amount of packets with increase in number of sources. The on packet delivery ratio of DS-AODV decreases faster with larger number of sources but is found to be greater than almost 70% always. The reason behind this tradeoff is that a larger number of sources in the network increase the probability of congestion leading to packets being dropped.

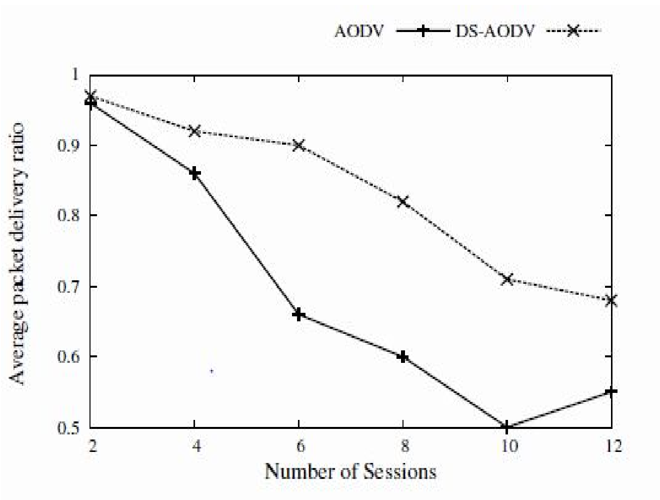

Figure 6 Effect of increased number of data sessions on PDR

The packet delivery ratio of the two protocols is depicted in figure 7 showing the variation of packet delivery ratio with the changing node mobility values. The increase in nodes' movement results in high probability of route breakages causing an increase in number of packets being dropped. DS-AODV has a better packet delivery ratio than AODV for all values of node pause time. The simulation study shows that more than 80% data packets are delivered by DS-AODV to the specified destination for all node mobility values. Hence, DS-AODV is found to be more robust than AODV.

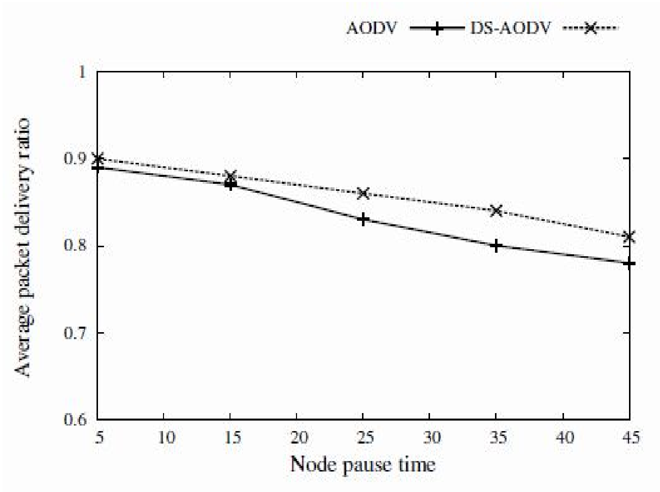

Figure 7 Effect of increased network mobility on PDR

VI. CONCLUSION AND FUTURE SCOPE

In this paper, we have proposed a novel delay aware routing protocol DS-AODV and analyzed its performance based on various performance metrics. This reactive routing protocol has been specifically designed for mobile adhoc networks and is based on the traditional protocol Ad hoc On-demand Distance Vector. The simulation study performed demonstrates that DS-AODV is able to perform fairly well over a range of node mobility and network load values. The simulations have been performed on Trial version of Exata Cyber simulator. The results have been used for comparing the performance of DS-AODV with AODV over various performance metrics.

Looking at the future extensions in this research, we can try to implement this with node mobility models other than the random waypoint mobility model that we have followed here. Also, in DS-AODV, route_delay values stored in routing tables of nodes may not always be up-to-date due to dynamic nature of mobile adhoc networks. A common synchronized update mechanism can be implemented to solve this problem.

Also, the robustness of DS-AODV can be verified in case of congestion of network. Lastly, we recommend a performance comparison of DS-AODV, based on various parameters, with other QOS aware protocols that have been proposed in recent past to verify its performance further in terms of various parameters, other than delay.

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