International Journal of Engineering Technology and Management Sciences[IJETMS]

Website:ijetms.in Issue:2, Volume No.2, July-2018

Simulation and Performance Evaluation of On Demand Multicast Routing Protocol (ODMRP) on ns-2

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Abstract:

An ad hoc network is a collection of wireless mobile nodes dynamically forming a tempory network with out the presence of a wired support infrastructure. In this environment, routing/multicasting protocols are faced with the challenge of producing multi-hop routes under host mobility and bandwidth constraints. In recent years, a number of new multicast protocols of different styles have been proposed for ad hoc networks. ODMRP (On Demand multicast routing protocol) is a mesh based, rather than a conventional tree based , multicast scheme it well suited for adhoc wireless networks. ODMRP has been simulated on PARSEC and its performance evaluated wehave implemented ODMRPon ns-2 and have done a simulation based performance analysis. Based onour experience during implementation, we have also suggested some enhancements to the protocol which we believe improve its performance.

1. Introduction:

An adhoc network is a dynamically reconfigurable wireless network with no fixed infrastructure or central administration. In a typicalad hoc environment network hosts work in groupsto carry out a given task .Hence multicast plays akey role in ad hoc networks . protocols used instaticnetwork: MOSPF[M94], PIM[DE96], DBMRP[DC90], CBT[BFC93]), However , do not perform well in a dynamically adhoc network environment. Multicast tree structure orfragile and must be readjusted continuously has connectivity changes. Furthermore, typical multicast trees usually require global routing sub structure such has linkstate or distant vector. The frequent exchange of routing vectors or linked state tables, triggered by continuous topology changes, yields excessive channel and processing overhead. A mobile adhocnetworking (MANET) working group has been formed within the Internet Engineering TaskForce (IETF) to develop a routing frame work for IP based protocols in adhoc networks.

On demand Multicast RoutingProtocol (ODMRP) is amesh based multicast routing protocol for ad hoc networks. It has been implemented and its performance has ben analyzedon PARSEC[BM98]. Areal system implementation of ODMRP has also been doneon the Linux Kernel version 2.0.36 [LSG99]. Ourgoal was to implement ODMRP on the network simulatorns-2[FV97], carry out a performance study and compare the results with those obtained on PARSEC. This also enabledus togain an understanding of the issues involved inimplementing and simulating a wireless protocolon ns. We intend to integrate our implementation with the standard ns distribution there by making it available to the research community. ODMR Pwassimulated in diverse network scenarios .We studied the impact of mobility on performance by varying the speed of network hosts. Different multicast group sizes were simulated to investigate the impact on performance. We apply metrics that shows the "efficiency" in addition to the "effectiveness" for the protocol.2. Background:

In this section, we first give taxonomy of multicast adhoc routing protocols. Then we briefly describe the working of ODMRP. Finally, we give a brief introductiontons-2.

2.1 A Taxonomy of Multitude Ad-hocProtocols :

There exists a multitude of multicast protocols (AMRoute[BLAT98], AMRIS[WTT98], CAMP[GM99], MAODV[RP99], ODMRP[LSG99]) for ad hoc networks (hence forth referred to as multicast protocols). Based upon their routing techniques and forwarding methods multicast protocols can be categorized in following ways:

®Routingtechniques

1. On demand routing: The routes are discovered and updated as and when needed .In other words, whenever a sourcehas some data to send and does not already route to the destination, it initiates a route discovery. There are nolonglived routing tables to make instantaneous routing decisions.

2. Not on demand Routing: This type ofrouting is very similar to static routing in wirednetworks where routing tables are periodicallyupdated.

® Forwardingtechnique:

1. Tree based multicast: members of a multicast group are organized in a tree like structure. Information from the source node flows to its parent and towards the root, each node in turn disseminates multicast message to its other children.

2. Mesh-based multicast: Members of a multicast group form a mesh like structure with redundant links between apair of hosts. Amesh supports shortest paths between any member pair. The mesh provides a richer connectivity among multicast members compared to tree.

The key motivation behind the design of ondemand protocols is the reduction of therouting load.High routing load usually has asignificant performance impact in lowbandwidth wireless links.Hence on demandroutingisa highlydesirable feature ofany outing protocol for adhoc networks. In a mobile scenario, mesh based protocols have been claimed to out perform tree based protocols [LSHGB00]. Among them ,the on demand mesh based multicast routing protocol, ODMRP [LGC99,LSG99] has been claimed to be highly effective and efficient in all adhoc network scenarios.

ODMR Pcreatesamesh of nodes (the forwarding group) which forward multicast packets via flooding (within the mesh), thus providing path redundancy. ODMRP is on –demand protocol, thus it does not maintain route information permanently . Ituses a soft state approach in group maintenance. Member nodes are refreshed as needed and do not send explicitleavemessages.

In ODMRP group membership and multicast routes are established and updated by the source on demand. Figure1depicts this process .Similar to on demand unicast routingprotocols, a request phase and a reply phase comprise the protocol. When multicast sources have data to send, but do not having routing or membership information, they flood a JOIN QUERYpacket. When a node receives a nonduplicate JOINQUERY it stores the upstream node ID and rebroadcasts the packet. Whena JOINQUERY packets reaches a multicast receiver, the receiver creates a JOINREPLY and broadcasts to the neighbours. When anodereceive JOINREPLY it checks if then extnode ID of on eoftheentries matches its own ID.If itdoes, the node realizes that it is on the path tothe source and thus is part of the forwarding group. It then broadcasts its own JOINREPLY builtup on match edentries.

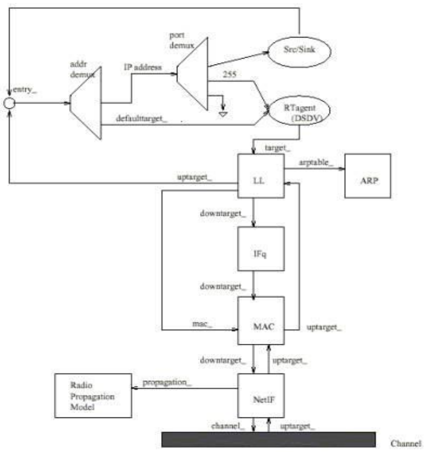

Figure 2: Model of an basic wireless mobile node.

The JOIN REPLY is thus propagated by each forwarding group member until it reaches the multicast source via the shortest path. This processconstructstheroutesfromsourcestoreceiversand buildsameshofnodes,theforwardinggroup.Multicastre nders refresh the membership information and update the routes by sending JOINQUERY periodically

We use the ns network simulator [FV97] to do our simulation of ODMRP. ns is a discrete event simulator developed by the university of California at Berkeley and the VINT project.It is target edat networking research. It is an object simulator, written in c++, with an OTcl interpreteras the front end. The back end is used for varying parameters or configurations during the simulations of the protocols. The OTcl front endis used for varying parameters or configurations during the simulation. The Monarch project at CMU extended ns [BMJHJ98] to allow simulation of pure wireless LANs ormulti-hop adhoc networks. The extensions include:

®Nodemobility.

®Area listic physical layer including a radios propagation model supporting propagation delay, capture effects, and carriersense[R95].

®Radio networking interfaces with propertiessuch as transmission power, antennagain, and receiver sensitivity.

®TheIEEE802.11MediumAccessControl(MAC)

3. Design:

In this section we first describe the basic wirelessmodelin ns.We thendescribe our modification to the basic model for implementing ODMRP.

Figure2 shows the model of a basic wireless mobile node in ns. Each mobile node makes useof a routing agent for the purpose of calculatingroutes to other nodes in the hoc network.Packetsare sent from the application and are received by the routing agent. This decides a path that the packet must travel to reach its destination.It thensends the packet down to the link layer.The linklayer uses an address Resolution Protocol(ARP)to decide the hardware address of neighboring nodes and mapIP addresses to the ircorrect interfaces.

When this information is know,the packet is sentdown to the interface queue and awaits a signal from the MAClayer. When the MAC layer decides it

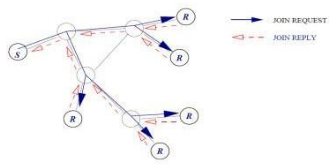

Figure 1: On-Demand Procedure for Membership Setup and Maintenance.

is ok to send it onto the channel, it fetches the packet from the queue and hands itoverthe network interface which in turn sendsthe packet onto the radio channel. This packet iscopiedand is delivered to all network interfacesat the time atwhichthe firstbitof the packetwith the receiving interfaces properties and theinvokes the propagation model.The propagation modeluses the transmit and receive stamps todetermine the power with which the interface willreceive the packet. The receiving interface thenuses the packetsproperties to determine if it successfully received the packet, and sends it tothe MAC layer if appropriate. If the MAC layerreceives the packeterror-free and collision-free, it passes the packet to the mobile node's entry point. From there it reaches a de multiplexer, that decides if the packet should be forwarded again ,or if it has reached its destination node. If the destination node is reached ,the packet is sent to aport demutiplexer which decides the application to which the packet should be delivered. If the packet should beforwarded again,the routing agent will be called and the procedure will be repeated.

We make the ODMRP agent the entry point ofthe node. This enables the agent to overhear allthe packets on the channel by tapping into the MAClayer. This is needed to support the passive acknowledgement feature of ODMRP which enables there liable delivery of JOINREPLAY messages.

4 Implementation Details:

We have implemented ODMRP according to theIETF draft specification [LSG99]. The following points are worth nothing.

® We have not assumed GPS capability for mobilenodes.

® The timers used for all ODMRP simulations aregivenabove.

® Join Replay Propagation:The specificationallows for any method of reliable delivery of JOINREPLAY(e.g., explicit acknowledgments, passive acknowledgments, unicast). We chose to unicast theJOIN REPLAY messages because we can takeadvantage of the IEEE 802.11 MAC reliable transfer mechanism.

®We have also implemented the unicast version of ODMRP.

In order to verify that our implementation meets those specifications of the protocol, we developed validation suite.The validation suite was written in OTcl and covered most of the scenarios tha tarise. In addition to this, the source code of the implementation was independently validated by two of the authors.

5. Protocol Enhancements:

In this section we describe some of our enhancements to the protocol as specified in the IETE draft.While implementing ODMRP, we faced some implementation issues. These issues arise because the specification of the protocol isnotclear on certainaspects.The enhancements discussed in this section resulted from our solutions to these issues. We believe that these enhancements improve the performance of theprotocol.

5.1 JOINT QUERYjitter:

An ODMRP agent on receivinga JOINTQUERY broadcasts it., Node Abroad casta JOINT QUERY and notes B and C receive it at the same time. Now, Band C rebroadcast the JOINQUERY in overlapping times which results in a collision. Thus node D , which canonly get a JOINT QUERY from B or C, does not receive the JOINT QUERY and any node that depends on D to forward packets is effectively cutoff from the multicast group.

To solve this problem we introduced a small random jitter during the broadcast of a JOIN QUERY. This greatly improved the effectiveness of theprotocol.

5.2 JOINREPLYImplosion:

According to the specification of ODMRP, when a node in the forwarding group receives a JOINREPLY message, i tshould forward it towards the source. So, when there are many nodes. In the multicast group, this will lead to what we call the "JOINREPLY Implosion" problem, similar to the ACK/NACK Implosion problem in multicast protocol [FJLMZ97]. To solve this problem, each node maintains an extra flag and a corresponding time rinits forwarding groupcache. Whenever a node sends a JOIN REPLY towards the source it sets this flag and the timer and nomore JOINREPLY messages are sent if the flag is set. Theflag is reset when the timer expires. The valueof this timer is set to be less than the JOINREFRESHINTERVAL.

6. Simulationmodelandmethodology:

Our simulation modeled a network of 50 mobilehosts placed randomly within a 1000 m*1000 m area. Radio propagation range for each node was 250 meters and channel capacity was 2Mbits/sec. The multicast groups varied in size with eachgroup having one source sending at a rate of 20 packets/sec.Each simulation executed from 300 seconds of simulation time .Multiple runs withdifferentseednumberswereconductedforeachscenario and collected data was averaged overthoseruns.

6.1 MediumAccessControl Protocol:

The IEEE 802.11 MAC with Distributed Coordination Function (DCF)[IEEE97] was used as the MAC protocol.DCF is themode which allows mobiles to share the wireless channel in an hoc configuration.The Specific access schemeis Carrier Sense Medium Access/CollisionAvoidance (CSMA/CA) with acknowledgements. Optically,the nodes can make use of request To send/clearTo send (RTS/CTS) channel reservationcontrolframes for "unicast" ,and virtual carrier sense. By setting timers basedupon the reservations in RTS/CTS packets, the virtual carrier sense augments the physical carrier sense in determining when mobile nodes perceive that the medium isbusy. According to the specification, JOINREPLY messages must be reliably transmitted. We employ RTS/CTS exclusively to reliably unicast JOINREPLY messages directly to specific neighbours. All other transmissions useCSMA\CA.

6.2 ChannelandRatioModel

The radio model uses characteristics similar to a commercial radio interface, Lucentswave LAN[ES96],[T93]. WaveLAN is a shared media radio with a nominal bit-rate of 2 Mb/sec and a nominal radio range of 250 meters. A detailed description of simulation environment and the models is available in[BMJHJ98],[FV97].

6.3 Trafficpattern:

We use constant bit rate (CBR) sources.The sizeof the datapayloadwas 512bytes.The senderwas chosen randomly among multicast members who inturn were choosen with uniformprobability among 50 network hosts. The member nodes join the multicast session at the beginning of the simulation and remains as a members throughout the simulation.

6.4 Mobilitymodel:

The mobility model uses a random waypointmodel [BMJHJ98] in a rectangular field of 1000mX 1000m with 50 nodes.Here each node starts itsjourney from a random location to a randomdestination with a randomly chosen speed. Notethat this is a fairly high speed for ad hocnetworks,comparerable to a traffic speeds inside acity .Once the destination is reached, anotherrandom destination is targeted after a pause.pass time,which affectsthe relative speedsof themobiles ischosenrandomlybetween0-10sec.When the node reaches the simulation terrain boundary, it bounces back and continues to move.

6.5 Performancemetrices

We have used the following metrices to evaluate the performance of ODMRP.. These metrics were suggested by the IETF MANET workinggroup for routing /multicasting protocolevaluation[CM99].

®PacketDeliveryratio:

The ratio of the number of the data packets actually deliver to the destinations versus the number of data packets supposed to be received. Packet delivery ratio is important as it describes the loss rate that will be seen by the transport protocol, which in turn affects the maximum throughput that the application perceives.

®DataTransmitRatio:

The ratio of the number of data packets transmitted per datapacket actually delivered. Datapackets transmitted is the count of every individual transmission of data by each node over the entire network. This coun tincludes transmission of packets that are eventually dropped and re transmitted by intermediate nodes. Note that unicast protocol this measure is alwaysequal to or greater than one. Inmulticast, inceasing letransmission can deliver data to multiple destinations, the measure can be less than one.

®Control Overhead:The ratio of the number of control by testransmitted per data byte delivered. Instead of usin game asure of the pure control over head, we chose touse the ratio of control by testransmitted to databytes delivered to investigate how efficiently control packets are utilized in delivering data. Note that not only bytes of control packets but also bytes of data packets of headers are included in the number of control by testransmitted .Accordingly , only the data payload bytes contribute to the data bytes delivered.

The first metric above characterizes the 'Effectiveness' of the routing protocol while these condand third metrics characterize the 'Efficiency' of the protocol.

Node mobility	Random waypoint model, bounce back into the field if a boundary is encountered.
Speed	A random value between 0 and a predefined maximum, where the maximum varies in the range [0,20] m/s
Traffic type	Constant bit rate
Data packet payload	512 bytes
Data packet header	28 byte (IP header : 20 ,sequence number : 4,identification number :
Join Query size	40 bytes(IP header : 20,routing information : 20)+Data payload
Join reply size	40 bytes (IP header : 20, join table : 20)

Parameter	Value
Number of nodes	50
Field area	1000m X 1000m
Field area	1000m X 1000m
Simulation duration	300 secs
Transmitter range	250m
Channel Bandwidth	2 Mbits/s

SimulationResults:

7.1 Packet delivery ratio: The size of the multicast group is varied to examine the scalability of the protocol. The result indicates that ODMRP delivers a high portion of data packets in most of our scenarios .In highly mobile situations, the performance is least effective in two membercase.Having only two multi cast members corresponding to a unicast situation. When ODMRP functions as a uncastprotocol, a mesh is not formed and there is no redundancy in packet for warding. Since there are no multiple routes, the probability of packet drop increases with mobility speed. As the number of members increases, the forwarding mesh group creates a richer connectivity among members. We can see from the result that ODMRP delivers over 87% of multicast packets in the face of high mobility.

7.2 Control Overload:
We can see that ODMRP efficiently utilizes control packets in delivering data. As expected, the efficiency improves as the number of multi cast members grows larger.

7.3 Transmission Overhead:
The average number of total packets transmitted per data byte delivered, the number remainsr elatively constant with varying speed and protocol Becomes more efficient when more multicastmembers exist. The result shows the channel efficiency of ODMRP.The performance we obtained has similar shapes to those obtained on PARSEC[LGC99], although the values are slightly less in magnitude.This might be because of the followin greasons:
® The simulators used in the studies aredifferent,sothepeculiaritiesoftherespectivesimulatorsmighthaveinfluencedtheresults.
® The scenarios might be different since we usedifferenttoolstogeneratethescenarios

®Theimplementationoftheprotocolmightbediffer. Thedifferencesmightoccur primarily in the interpretation of thefeaturesnotpreciselyspecifiedinthespecification.

®Theremightalsobedifferencesinthecomputationoftheperformancemetrics.

8 Relatedwork:

Protocol designers of core assisted mesh protocol(CAMP)[GM99]andODMRPhaveperformed simulationstudiesoftheirprotocols.Simulationstudies in [GM99],[MG99a]and [MG99b] use asimplifiedsimulators.Aperfectchannelwasassumedandradiopropagationwasnotconsidered

.FAMA[FG97] wasused as the medium accessprotocol,whichisdifferentfromIEEE802.11[IEEE97] , the standard MAC protocol forwirelessLAN,thatweuseinoursimulation.Onlyasmallportionofnetworkhostshadmobility intheirstudy where as inourcases,allthenodesaremobile,Thecriticalnodesfor CAMPperformance,however,remainedstationary. All the nodes in [GM99],[MG99a] and[MG99b] were multicast session members ,whichisnotrealisticintypicalmulticastapplications.Thenetworktrafficloadwasextremelylight.Informationon datasize,radiopropagationrange,orsimulationterrainrangewerenotgiven.Thustheresultsin[GM99],[MG99a] and [MG99b]are somewhatlimited .In [LSHGB00] a more realistic channelwasmodeledand802.11wasusedasMACprotocol . The simulation studies were carried outonPARSEC[BM98].
Fouradhocwirelessmulticastprotocolswereevaluated and it was concluded that mesh basedprotocolsoutperformtreebasedprotocolsingeneralandODMRPoutperformedall.In[LSHGB00],allnodes movedatapredefinedspeed without any pause.Our scenario is differentin that each node, after arriving at a destinationpausesforarandomtimebeforestartingtowardsa new destination. In [BLG00] the unicast performanceofODMRPhasbeenevaluatedonatestbedoflaptops.

9 Conclusion:
Overhead.WefoundthatODMRPperformswell in most of our scenarios. The performancecurve we obtained have similar shapes to thoseobtained on PARSEC [LGC99] , although ourvalues areslightlylessinmagnitude.

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