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Multicast Routing in Scalable Networks using MAODV

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Abstract

Wireless mesh network (WMN) is used to develop techniques for guaranteeing end-to-end delay performance over multihop wireless communication networks. The aim of WMN is to provide seamless communication in large heterogeneous networks and between heterogeneous devices. According to the architecture of WMN, mesh cloud will allow scaling the network easily. Hence we are addressing WMNs as scalable networks. Routing protocols play an important role in increasing the performance of WMN as the size of network is scaled. Routing process is also affected by the type of communication, like unicast and multicast. Multicasting is eminent type of communiqué nowadays, due to its applications like Distance Learning, Access to Distributed Data Base and Teleconferencing etc. This paper proposes the multicast routing protocol for WMN. Multicast Ad hoc on demand Distance Vector (MAODV) is modified to support scalable WMN. MAODV creates bi-directional shared multicast trees for connecting multicast sources and receivers. In this research work authors briefly narrate the MAODV protocol and it is compared with unicast AODV. Using NS2 a simulation based performance evaluation is done by considering performance metrics, such as Packet Delivery Ratio (PDR), end-to-end delay, throughput, overhead and dropped packets. Results show that MAODV routing protocol throughput is 43% and PDR is 31% more than AODV. Bandwidth utilization is measured in terms of overhead; the MAODV is having 50% less overhead than AODV.

Keywords

Wireless mesh network, Multicast routing, Unicast routing and TCP/IP protocol stack.

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1. Introduction

Now a day's WMNs have been deployed and grown in popularity in many metropolitan areas. The deployment of such networks has allowed joining more and more clients and also letting them to gain access to publicly available broadband networks. The implementation of WMN includes back-haul services and it is maintained via wireless mesh points. A WMN contains mesh clients, mesh routers and gateways, which are organized in hierarchical structure [1]. The mesh clients are often laptops, cell phones and other wireless devices, while the mesh routers forward traffic to and from the gateways. The mesh cloud is formed by making use of routers and gateways which helps to access internet by different client networks.

Since the WMN is having mesh topology, it will provide reliability, scalability and redundancy for better performance. It can be implemented with various wireless MAC standards like 802.11, 802.16 and cellular technologies or combinations of more than one type. WMNs use multi-hop communications to access the services of internet and these are different from flat ad hoc networks. Mesh routers have minimal mobility and form the mesh backbone for mesh clients with access points and mesh clients always form an ad hoc networking [1]. The scalability of WMN can be measured in terms of number of mesh routers or nodes, the volume of data, the users and applications etc. Unicast routing protocols like AODV performs node to node communication and not capable to support scalability in WMN [2]. Therefore multicast routing protocol is preferable to transmit huge volume of data to many users in WMN.

WMNs can provide an excellent means for targeting a large group of end users to relay the data, due to their mesh structure. This may be achieved by means of broadcasting or more specifically multicasting. Multicast is another fundamental routing service in multi-hop mesh networks. It provides an efficient means of supporting collaborative applications such as online games, distance learning among a group of users, distribution of financial data, billing records, audio/video conferencing and distributed interactive games. Even though multicast is in high demand in communication, research on multicasting in WMN is still in initial stage. The reason for this is complex environment of WMN.

In multicast, communication may be within the group or non group member may communicate with the group. Figure 1 depicts the multicast group in hybrid two tiers WMN. The lower tier consists of mesh clients in ad hoc components and upper tier is having mesh routers forming the mesh cloud [1]. In the mesh cloud dotted circle represents multicast group. The mesh router G is the group leader and G1, G2 are group members. Group leader G will become the root of the tree. Router M1 is the tree member and helps to provide the communication between G2 and other members of the group.

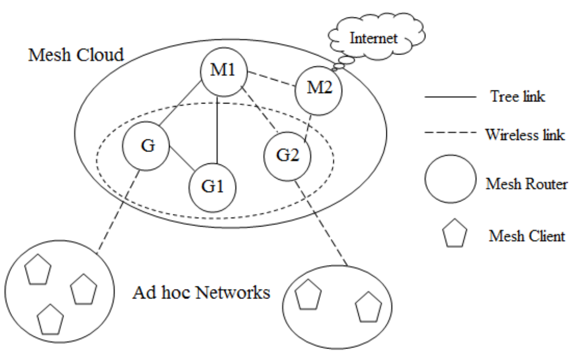

Figure 1: Multicast scenario in WMN

This paper addresses usage of multicast in WMNs by modifying MAODV routing protocol and evaluating its performance against multiple unicast communication. It uses Group-shared tree approach and sparse multicast environment. The parameters used for comparison are like throughput, PDR and end-to-end delay etc.

The rest of this paper is organized as follows: section 2 discusses existing related work. Section 3 presents architecture of MAODV. Section 4 deals with result analysis and finally conclusion and future work is given in section 5.

2. Related Work

In internet the wired networks uses IP multicast protocols like Protocol Independent Multicast-Sparse Mode (PIM-SM) and are not suitable for WMNs, because these are not able to take advantage of the wireless environment. In WMN wireless channels or links are more affected by errors than wired links [3]. Hence special routing mechanisms are designed to achieve efficient multicasting support in WMN. The common routing protocol AODV for wireless networks is modified for multicast operation [4] and it constructs multipath tree as need in WMN. The survey of multicast routing is provided in the following discussion.

There are two fundamental multicast routing approaches: Shortest Path Trees (SPTs) and Minimum Cost Trees (MCTs). The SPTs algorithms construct a Minimum Spanning Tree (MST), by considering sender as the root of the MST. In MST the distance (or cost) between the sender and each receiver along the tree is minimum. Thus the SPT algorithms minimize the end-to-end delay in the network. On the other hand MCT algorithms aim to minimize the overall cost of the multicast tree. Since internet or WMN are large in size, it is more difficult get the overall cast of the network. Thus most of the multicast networks are using SPTs algorithms. Jin Xu and Uyen Trang Nguyen [5] compare the SPTs and MCTs algorithm using different performance metrics like end-to-end dealy. In muticast communication the tree can be constructed using minimum number of transmissions (MNT). Uyen Trang Nguyen [6] has done the comparison of SPTs, MSTs and MNT trees in WMNs using different performance metrics like throughput and end-to-end delay etc. SPTs performance is better than MCTs, but SPTs are not performing well when the group size is large and multicast rate is high. With some considerations author recommends SPTs for WMN.

Construction of multicast tree with minimum bandwidth is an issue in WMN. This issue is also known as Steiner tree problem. Pedro M. Ruiz and Antonio F. Gomez-Skarmeta [7] has redefined Steiner tree problem in terms of minimum number of transmissions. The authors also propose heuristic method to construct bandwidth optimal trees. The results show that heuristic method generates more optimal tree than the Steiner tree.

Iqbal M. and Wang, X. and Wertheim D. [8] propose Uni-Directional Link-aware MAODV (UDL-MAODV) for Linux operating system to transmit multicast video in WMN. The MAODV route discovery process is modified for reliable multicast video transmission. Swan Mesh WMN test bed is used for the experiment and the results show that UDL-MAODV is more reliable and resourceful.

Since WMN is supporting heterogeneous environment, it is more complex for finding out reliable and efficient path between a pair of source and destinations. The routing metrics will play an important role in the construction of efficient path to destinations. Farhat Anwar and Aisha Hassan Abdalla et al. [9] describe the technique of integrating multiple routing metrics to improve the performance of a routing protocol. They have tested this technique on MAODV and their results show the major improvement in the performance of MAODV. In WMN immobile or relatively mobile mesh routers force to redesign the routing protocols, which find the high throughput path between source and destination along with maintaining the connectivity between them. Sabyasachi Roy and Dimitrios Koutsonikolas et al. [10] survey the link quality routing metrics for high throughput multicast in WMN. They have also proposed adaptation of unicast link-quality metrics for multicast. Authors conduct the experiments by using On Demand Multicast Routing protocol (ODMRP) with link quality metrics on mesh network test bed. ODMRP with link quality metrics performs better than regular ODMRP.

WMN faces many challenges, while doing the multicast communication between mesh routers. Liang Zhao and Ahmed Al-Dubai et al. [11] discuss the issues and challenges in multicast communication for WMN. They also present the Gateway Associated Multicast Protocol (GAMP) load balancing algorithm for WMN. GAMP improves the performance of multicast communication.

Md. Saiful Azad, Farhat Anwar and et al. [12] analyze the performance of proactive and reactive multicast protocols. ODMRP and MAODV are reactive protocols, where as Multicast Open Shortest Path First (MOSPF) is proactive protocol. The simulation results show that proactive multicast routing protocol like MOSPF are introducing lot of overhead in the routing process. So these are not suitable for WMN. On the other side reactive protocol ODMRP performance better than MAODV.

The hybrid WMN uses 802.11s MAC standard. The routing protocol used by this standard is Hybrid Mesh Network Protocol (HWMP). Mustapha GUEZOURI and Ali KADDOURI [13] modified HWMP to support multicast routing in WMN. The modified HWMP performs better even in large WMN, but overhead is still more in the network.

3. Architecture of MAODV in WMN

MAODV is network layer protocol in TCP/IP network model. Hence it provides the services to above layers to run the applications like video conferencing and playing interactive games etc. Figure 2 shows the position of MAODV in TCP/IP protocol stack for multicast communication. As in internet, WMN also uses UDP transport layer protocol to support multicast applications. If the multicast application wants the reliable communication, then application layer is responsible for this type of transfer over UDP. Since WMN is heterogeneous in nature, network access layer will support both wireless and wired media.

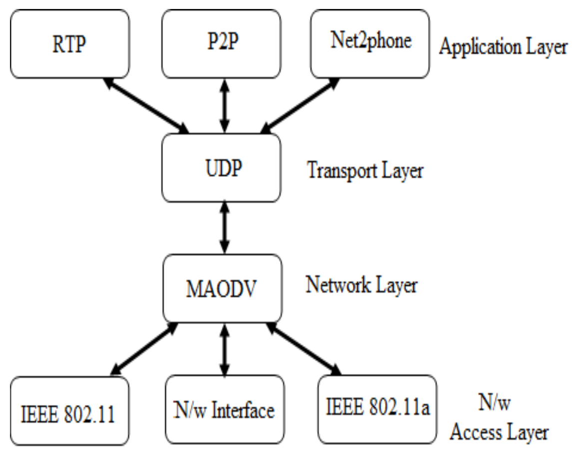

Figure 2: Multicast TCP/IP protocol stack

The main goal of this article is to provide an extensive and though concise study of MAODV. Since MAODV is multicast routing protocol, it follows rules of multicast like, source address is unicast address and destination address is group address. MAODV maintains one-to-many relationship within the WMN and it constructs group shared tree for routing the data. The mesh routers perform mainly three operations when using the MAODV protocol, which are join the group, communication and leave the group. MAODV classifies the mesh routers as group member, group leader and tree member. Group leader controls the communication within the group, where as group member can receive the multicast data. Tree member is not the part of the group, but helps to provide the link between the members. Mesh routers are also maintaining unicast route, multicst route and group leader tables to store next hop address, type of member and multicast address respectively [14]. MAODV mainly uses three types of message in routing process, which are Route Request (RREQ), Route replay (RREP) and Group hello (GRPH) messages. RREQ and RREP are used to construct tree, on the other hand GRPH is used keep the group active.

The further subsections confer MAODV routing process and implementation of this in Network Simulator NS2 architecture.

3.1 Routing in MAODV

Initially first node in the group will become the leader. Other mesh routers, who wants to join the group, will send joining request message RREQ-J to the leader. Leader will send the reply message RREP-J to the requested routers. Before sending the RREQ-J message, routers will enter their information in the multicast route table [14]. The any new router wants to join the group; it makes the entry in multicast route table and gives the RREQ-J message to the nearest group member. The member, who receives the joining message, will forward it towards the group leader. After receiving the joining message, group leader sends the RREP-J and this reply message traverses on the reverse path to reach the sender. For the router, the next hop router is towards the leader, the next hop router will become the upstream router and otherwise the next hop router will be downstream router. Whenever the mesh router wants to leave the group, it will intimate to upstream router and it leaves the group by cancelling the entry in the multicast routable.

The group members receive RREQ, RREP and GRPH control messages at time of communication. The actions taken by the member after receiving the messages is represented by the dataflow diagram in the Figure 3. The group member receives RREQ message and if it is the destination, then it will send the RREP with fresh route information. The RREP is received by the member, who is sender and then it just forwards the message in the tree. If the received GPRH message is not duplicate one then the group member broadcast the message in the group.

Any group member wants to send the multicast data in the group; it sends the unicast data packet to the group leader. The group leader unwrap the unicast data packet to get the multicast data and flood it in the group. Similarly suppose the non group member wants to do the communication with the multicast group, it sends the unicast data packet to the nearest group member. The member connected to the outsider, receives the unicast packet and forwards towards the leader. After receiving packet group leader repeats the same procedure as explained above. Once again the replay from the group traverses in the reverse path and reaches the sender back.

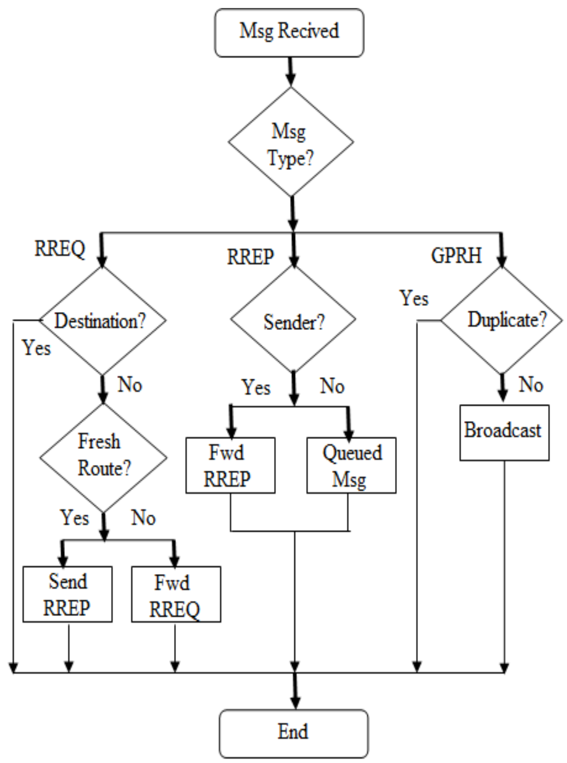

Figure 3: Communication by group member

3.2 Implementation Design of MAODV

To test the performance of MAODV in WMN, the authors have implemented the MAODV protocol using simulation tool NS2 as specified in [14]. The implementation design architecture is shown in Figure 4. NS2 uses object oriented Tcl (OTcl) as the front end and C++ as the backend tools. In the design single group is consider for multicast communication. The simulation scenario is written using OTcl and it mainly considers routing protocol and traffic pattern as input. As illustrated in Figure 4 authors use MAODV, AODV routing protocols and traffic pattern Constant Bit Rate (CBR) at application layer as input to the scenario file. This simulation scenario file generates trace file as output. The AWK scripts are used to extract the required values from trace file to calculate the desired parameters like throughput, PDR and overhead etc.

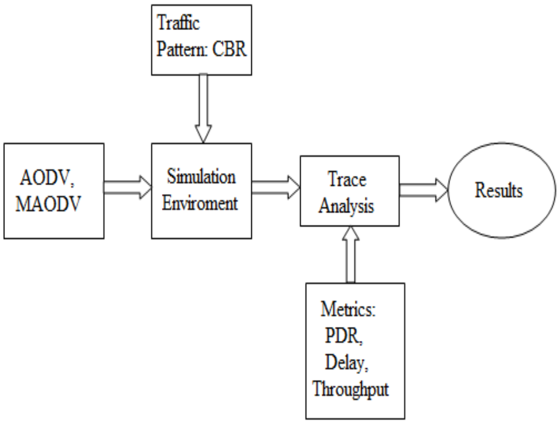

Figure 4: Design Architecture of MAODV

4. Result Analysis

The MAODV protocol is plugged in NS2 as described in [14] and few modifications are done to MAODV to support WMN environment. To compare AODV and MAODV, the authors set up multiple unicast network for AODV. The experiments consider only one multicast group with maximum 4 senders and 24 receivers. The size used for communication is 512 bytes and maximum 10000 packets are flooded in the network. The description about simulation environment is given in Table 1**.**

To measure the performance of MAODV the performance metrics used are throughput, overhead, PDR, end-to-end delay and drop of packets.

Throughput in network is the total data packets received by the receivers at a particular unit of time and Figure 5 shows the comparison of throughput. At the beginning MAODV shows zero throughput, because it is involved in setting up the group. After 15 seconds throughput of MAODV is better than AODV. In Between 50 and 70 secs all CBR traffics have started sending data; therefore throughput is high in this region. The MAODV illustrates 43% more throughput than AODV.

The metric end-to-end delay considers all possible delays occurred during data transmission. The delays included are queuing delay, retransmission delays at the MAC, propagation delay and transfer times. Figure 6 shows comparison of end-to-end delay. The graph depicts that, all the time data received in MAODV is much better than AODV.

Table 1: Simulation environment of WMN

Simulation Area	1000 m X 1000 m
Simulation Time	100 secs
Propagation Model	Two Ray ground Propagation Model
MAC protocol	IEEE 802.11
Interval Time	0.025 secs
Address Type	Hierarchical
No. of Nodes	6
Routing Protocol	MAODV and AODV
Transport layer protocol	UDP
Senders	1-4 nodes
Receivers	5-24 nodes

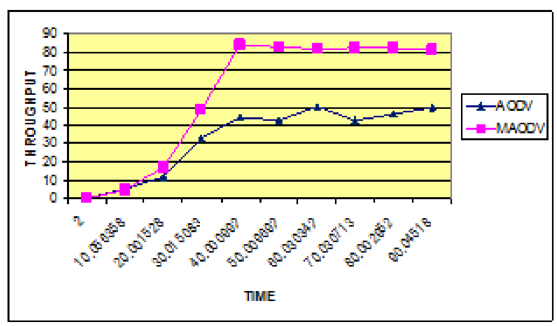

Figure 5: Comparison of Throughput

Overhead is the summation of the size of all controls packets and header part of the all data packets transmitted. The overhead comparison of MAODV and AODV is depicted in Figure 7. The overhead of MAODV is more at the beginning due to group setting process. After 10 seconds overhead of MAODV is less than AODV. Normalized routing overhead is The number of routing packets transmitted per data packet delivered at the destinations. The study shows that MAODV is having 50% less normalized routing overhead compared to AODV.

The ratio of successfully delivered data packets to sent packets is termed as PDR. Figure 8 demonstrates the comparison of PDR. The PDR of MAODV is zero at the beginning due to route discovery and as simulation proceeds the PDR of MAODV is 31% more than that of AODV.

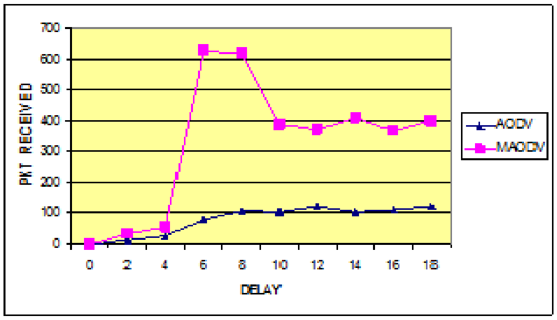

Figure 6: End-to-end delay V/s Packet Received

The number of packets dropped due to no route found at the MAC layer, which is given by DROP_RTR_MAC_CALLBACK flag in NS2 trace file. As shown in Figure 9, up to 5.5E-1 bps error rate drop of packets occur in MAODV is almost nil. But MAODV suffers from few drop of packets for higher than this rate. On the other hand AODV is having higher rate of drop of packets after 2.5E-1 bps error rate only.

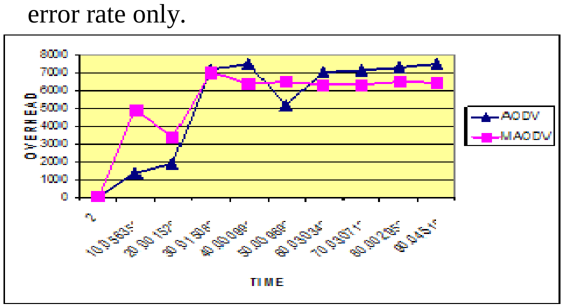

Figure 7: Comparison of overhead

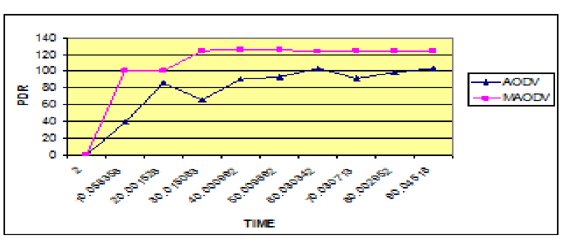

Figure 8: Comparison of PDR

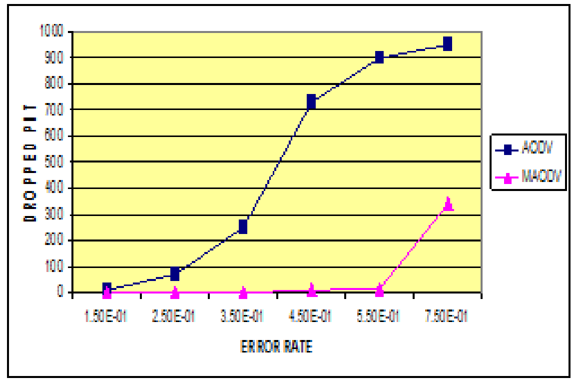

Figure 9: Comparison of Drop of Packets V/s Error Rate

5. Conclusion

In this internet era, most of the social service networks like Face book are prefer the multicast communication. The multicast applications have surely reduced the size of globe. The author's investigation and study about MAODV will lead to the fruitful results for scalable networks like WMN. Since the overhead of MAODV is less, it utilizes the bandwidth better than unicast AODV. The PDR and throughput of MAODV is better, because of less number of drops of packets. In MAODV all group members are responsible for delivery of data; due this end-to-end delay is less in MAODV.

MAODV limits its communication only for one group in the WMN. In future authors have planned to enhance the MAODV for multiple groups in WMN and compare this designed protocol with other multicast protocols.

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