I. J. Computer Network and Information Security, **2022, 3, 47-62**
Published Online June 2022 in MECS (http://www.mecs-press.org/)
DOI: 10.5815/ijcnis.2022.03.04

Multimedia Traffic Transmission using MAODV and M-MAODV Routing Protocols over Mobile Ad-hoc Networks

Lavanya. Poluboyina
Department of ECE, Sreenidhi Institute of Science and Technology, Hyderabad-501301, Telangana, India
E-mail: lavanyamam@yahoo.com

Mallikarjuna Prasad. A, Sivakumar Reddy. V and S V Maruthi Rao
Department of ECE, JNTUK, Kakinada-533003, Andhra Pradesh, India; Department of ECE, MRCET, Hyderabad-500100, Telangana, India and Department of ECE, SIET, Hyderabad-500068, Telangana, India
E-mail: a_malli65@yahoo.com, vskreddy2003@gmail.com and maruthichinnam@gmail.com

Received: 25 September 2021; Revised: 02 November 2021; Accepted: 06 December 2021; Published: 08 June 2022

Abstract: Many applications of mobile ad-hoc networks like conferencing, handling emergency situations, military operations require the multicast routing. Moreover, in such applications there is a demand for multimedia traffic such as audio/video calls or audio/video conferencing. For mobile ad-hoc environments, it is accepted that the on-demand reactive routing protocol AODV has become default. Moreover, to get the benefits of using a single protocol for both unicast and multicast routing, in this work, the multicast routing protocol MAODV (multicast extension of AODV) has been considered and its performance is observed for CBR, VoIP and video data traffics. Since to accommodate multimedia traffic, a routing protocol demands for stringent QoS requirements in terms of delay, jitter and packet losses; the performance of the protocol is measured in terms of QoS performance metrics such as average delay, average jitter and packet delivery ratio. Further, a modified version of MAODV (called M-MAODV) is taken and its performance is also evaluated for multimedia traffic. A fair comparison of MAODV and M-MAODV protocols is achieved through the use of same network conditions for the evaluation. From the results, the improved values of delay, jitter and packet delivery ratio have been observed for M-MAODV irrespective of node speeds and for all data traffic types.

Index Terms: MANET, MAODV, Mobile ad-hoc network, Multimedia traffic, Network simulation.

1. Introduction

A mobile ad-hoc network (MANET) [1] is one kind of wireless ad-hoc networks and is the one where a group of mobile nodes that are furnished with necessary wireless communication technologies as well as routing capabilities are connected together instantly to serve a purpose on temporary basis. Clearly, in these networks, the communication is possible anytime and anywhere between/among the nodes without the aid of any centralized administration and/or networking infrastructure.

The motivating applications of MANETs [2] are an autonomous network formed in a conference/meeting or; providing communication in emergency situations where the calamities (earthquake, tsunami, accidents etc.) have partially or fully destroyed the existing infrastructure or; a temporary network formed in battlefields. Moreover, in these application fields, group communication has become equally important which requires multicast routing. Further, there is a demand for multimedia support in these application domains. In consequence, the quality of service (QoS) support for multicasting in MANETs is required to accommodate multimedia applications.

Multimedia applications require high values of throughput as well as low values of delay, jitter and packet loss. Specifically, the real-time multimedia applications such as audio/video calls, audio/video conferencing generate the data traffic which usually demands low delay and jitter values that greatly differs from the requirements of traffic generated by data applications.

In the literature, various multicast routing protocols have been proposed for MANETs. However, to allow optimal communication to happen in a MANET, the routing protocol must be able to offer both unicast and multicast transmissions [3]. There are various benefits of combining both unicast and multicast communication abilities into a single protocol. In such protocols, the routing information acquired when looking for a multicast route will also increase the knowledge about unicast routes, and vice versa. In constrained resources environments like MANETs, any reduction in routing overhead is a notable benefit. Moreover, coding of such protocols can be done in an efficient and simple way.

Finally, any improvements that have been done to the basic algorithm can be advantageous for data transmissions of both multicast and unicast. Hence, the chosen multicast routing protocol for this research work, MAODV (Multicast Ad-hoc On-Demand Distance Vector) is the multicast extension of unicast routing protocol, AODV (Ad-hoc On-Demand Distance Vector). AODV is a widely accepted reactive routing protocol for MANETs, and recently it is drawing attention from other networks too [4].

In this work, first, the MAODV's behaviour is examined for various data traffics such as constant bit rate (CBR), Voice over Internet Protocol (VoIP) and video, in order to check the suitability of the protocol for supporting multimedia applications in dynamic environments like MANETs. For this, the QoS evaluation metrics considered are packet delivery ratio (PDR), average delay (AD) and average jitter (AJ). Thereafter, the behaviour of a modified version of MAODV, namely M-MAODV, is also evaluated. However, the evaluation has been done for the same data traffic types under the same network conditions to achieve fair comparison between MAODV and M-MAODV protocols.

1.1. MAODV

The MAODV [5] is a distributed on-demand shared-tree-based multicast routing protocol. Once nodes join the multicast group (MCG), a multicast tree (MCT) consisting of members and the forwarding nodes that connect group members is formed. The first member of the MCG becomes that group's leader. The MCG leader initializes the sequence number and increments it periodically to ensure the latest routes available. The formats for route request (RReq) and route reply (RRep) messages are same as in AODV [6] with some extension fields. Similar to AODV operation, *hello* messages are used for maintaining local connectivity. Each node maintains three tables: routing table (RT), multicast routing table (MCRT), request table (ReqT). The RT is similar to the one discussed in AODV, containing same information fields. The entries in MCRT are only for the MCGs for which the node acts as the forwarding node, i.e., a member of the MCT. The ReqT is basically a small table maintained by each node that supports multicast routing. The MCG leader broadcasts a group hello (GH) message periodically.

2. Literature Survey

In this section, initially, the works that have concentrated on multimedia transmission using MAODV in MANET environments are focused. Following, the contributions that had concentrated on modifying the existing MAODV protocol in order to improve its QoS performance have been discussed.

However, while considering the works only those works in which the routing protocols evaluation was done for atleast one of the QoS parameters such as PDR, AD and AJ have been taken. Moreover, the research works that had furnished the simulation details either fully or atleast the details such as node speed have been only taken for consideration. This is required to make sure that the network considered for protocols evaluation was absolutely a MANET.

In Table 1, the research works that had been conducted on multimedia transmission using MAODV employing the network simulation tool, NS-2 for simulation are tabulated. While the works that had concentrated on modifying the existing MAODV protocol for achieving better QoS performance are presented in Table 2. Here, the constraint of considering the works only using NS-2 has been relaxed. However, the works where each sample point of result graphs was the average of the simulation results taken atleast for three network topology-scenarios, are only accommodated in the tables.

Table 1. Works on multimedia transmission using MAODV

Author(s)	Traffic type & Results Consistency	Network Parameters*	Varying Parameters	Performance Metrics**
Dharmendra Sutariya [7]	CBR & Multimedia (a combination of CBR data and a video file); average of 10 simulations.	1000mx1000m; 800s; IEEE 802.11; omni-directional antenna; two-ray ground; 250m; random waypoint model; 20m/s; 5s; 4 packets/s; 256bytes; one MCG.	1. Number of nodes (50,100,150,200) 2. Number of senders(10,20,30,40) 3. Number of receivers(20,40,60,80) 4. Node mobility (5,10,15,20,25,30m/s)	PDR, AEED, RO, TP

*Simulation area; simulation time; number of nodes; transport layer protocol; MAC layer; physical layer; propagation model; channel bandwidth; node transmission range; mobility model; node speed; pause time; number of connections; packet rate; packet size.
**AEED-Average End-to-End Delay; PDR-Packet Delivery Ratio; RO-Routing Overhead; TP-ThroughPut.

The author in Ref. [7] had worked on two well known multicast routing protocols, MAODV and ODMRP using *NS-2.34*. From the author's summary, it is inferred that under both CBR and multimedia traffics, the MAODV protocol is working and scaling well compared to ODMRP and thereby showing its suitability for multimedia applications in MANET.

The authors in Ref. [8] had proposed an improved MAODV protocol, namely Mobility Prediction and Self pruning flooding (MMPS). The developed protocol uses self-pruning flooding mechanism to reduce the routing overhead and the mobility prediction mechanism to establish a new route before a link breaks. The mobility prediction mechanism had been implemented by deriving a link prediction formula on the basis of two-way ground reflection model. When a node receives a multicast data packet, it records the power and received times in addition to other information. Then the node, after receiving two multicast data packets, calculates the time when the link fails through the formula. The formats of RReq and GH messages have been extended to accomplish self-pruning flooding.

Table 2. Works done on modifications of MAODV

Author(s)	Protocols used	Simulator/ Simulation Tool	Traffic type & Results Consistency	Network Parameters*	Varying Parameters	Performance Metrics**	Conclusions
Xiaohua Chen, Qiu Zhong and Danpu Liu [8]	MAODV, MAODV-MMPS	NS	CBR; average of 7 simulations.	1500mx300m; 910s; 50; 250m; pause time: 0s; 5m/s; 2 packets/s; 256bytes; 1 MCG of size 30 with 5 source nodes.	1. MCG receivers (10,20,30,40,50) 2. Mobility (1,5,10,15,20m/s)	PDR, average route overhead	Simulation results have proved that MMPS has reduced overhead & increased PDR.

*Simulation area; simulation time; number of nodes; transport layer protocol; MAC layer; physical layer; propagation model; channel bandwidth; node transmission range; mobility model; node speed; pause time; number of connections; packet rate; packet size.
**PDR-Packet Delivery Ratio.

In Ref. [9], an algorithm named as QoS-MAODV that improves the route discovery process in MAODV for providing QoS support multicast routes is proposed. It reserves the bandwidth on per flow chosen. By extending the methods used for estimation of consumed bandwidth in unicast routing approach, the authors had achieved the resource reservation in MCTs. A network was created and simulated using *Qualnet* for the following parameters: 1000x1000m^2, 300s; 50 nodes, IEEE 802.11 DCF, 250m, 2MBPS, random waypoint mobility model and 1024bytes. The protocols were evaluated under two sets: in one set by varying node speed from 0 to 150KMPH with pause time: 3s and in another set by varying group size from 3 to 30 with a step of 3; for PDR and end-to-end delay. For evaluating the effect of node speed, 3 MCGs of size 5 nodes were formed with one source node generating data at any one of the rates {128, 256, 512} in KBPS, per each group. The effect of group size was evaluated setting node speeds to zero and in sender in each group as mentioned above. The sessions were set after 5s from the beginning of simulation and remained till the end of the interval. Through the simulations results, it is shown that the QoS-MAODV protocol produces higher TP and lower end-to-end delay compared to MAODV protocol.

A multicast routing protocol, named MAODV-LFP (MAODV with link failure prediction) based on MAODV is proposed in Ref. [10]. The algorithm was on the basis of a link failure prediction technique which is logically same as prescribed in Ref. [8]. The protocol was implemented and simulated using the tool, *NS-2* for the network parameters: 1500m×300m, 900s, 250m, 2MBPS, 4 packets/s, 256bytes and single group of size 20 with 5 sources. The performance was evaluated in terms of PDR and end-to-end delay for changing speed mobility (5, 10, 15, 20m/s) and the number of senders (1, 5, 10, 15, 20). The authors had concluded that the proposed MAODV-LFP has increased the PDR and decreased the end-to-end delay.

Reference [11] had presented a protocol, namely MP-MAODV that distributes traffic through two node-disjoint routes. Basically, it is a MAODV-based multipath routing algorithm to improve efficiency of the network and balance the network loads. Accordingly, each source node maintains two paths and hence it initiates the route discovery process only when both the links fail. Thereby, it decreases the number of route requests and hence reduces the routing control overhead in the network. To achieve this, authors had added two control messages: MACT-S and RRep-S, and one RT called MP-MAODV. They had also provided the mathematical modeling analysis of the presented protocol. The proposed model was implemented and simulated using *NS-2* with: 50 nodes in 1500×300m^2, 900s, IEEE 802.11 DCF, 250m, 1 m/s, 256bytes and one MCG of size 10 with single source. Both the protocols were evaluated for packet delivery rate, average delivery delay, TP and control packet overhead by varying the network traffic from 10 to 50 packets/s with a step of 10. The simulation results had shown that the MP-MAODV is robust and ensures the performance for increasing traffic loads. In Ref. [12], the same work had been presented without mathematical modelling analysis and also the evaluation for the same parameters excluding TP.

The authors in Ref. [13] proposed and implemented an improved MAODV protocol, namely GTR-MAODV for group team communication using *NS-2*. The algorithm was developed considering that some nodes in the network exist with additional features like high processing speed, adequate power, high-speed transceiver. Authors had first proposed GT-MAODV to determine the optimal repair node for performing link repair when a link failure happens in such network. Later, a link repair mechanism, GTR-MAODV that ensures optimal paths from all the nodes to the group leader was proposed based on GT-MAODV. It improves the successful repair rate effectively through differentiating different MCT branches. An additional flag (Branch_No flag) is added to the messages RReq, RRep, MACT and GH for selecting and setting up different MCT branches. The Branch_No flag is also added to MCRT to identify different branches in the GTR-MAODV. Moreover, the mathematical analysis of GTR-MAODV was also discussed. The proposed protocols were compared with the MAODV by varying network size (500*500m^2, 800*800m^2) and speed of the nodes (1, 5, 10, 15, 20m/s) for PDR and AEED. The other network parameters were as following: 20 nodes, 910s, IEEE 802.11, 250m, 2MBPS, and number of receivers is 6. The results indicated that GT-MAODV provides better PDRs as well as AEEDs than MAODV while GTR-MAODV provides better performance than GT-MAODV.

An optimized protocol, MAODV-BB (MAODV with Backup Branches) that combines tree and mesh structures is proposed in Ref. [14]. It constructs MCTs with backup branches in addition to updating shorter tree branches. Shorter tree branches reduce resources engaged while the maintenance of backup branches avoids frequent tree reconstructions and thereby enhance the robustness of the protocol. To achieve this, authors had added an additional field to the GH message that carries the information regarding number of active downstream branches in the tree. Apart from this, a backup RT was added to each on-tree node to save this backup tree branches information. Authors had also provided the mathematical proof and derivation for the proposed protocol. *NS-2* was the simulation tool used for evaluating the proposed protocol for PDR, AEED and CO by varying packet rate (5, 10, 15, 20 packets/s) and node speed (1, 5, 10m/s). The considered network parameters were: 500mx500m, 910s, 20nodes, IEEE 802.11 MAC, two-ray ground propagation model, 250m, 2MBPS, pause times: 0-10s, 5 packets/s, 512bytes and a group of 6 nodes. Simulation results had demonstrated that MAODV-BB has improved the network performance over MAODV under heavy loads.

The authors in Ref. [8,9,10,11,12,13,14] had developed various versions of MAODV by concentrating on specific limitations of it. However, in all works except in Ref. [8] the numbers of simulations conducted were only one. In Ref. [8,9,10], the authors had evaluated their proposed protocols by changing a multicast routing parameter and a MANET environment parameter while in Ref. [11,12,13,14] only the MANET parameters had been changed.

From the literature survey, it is observed that a limited research progress is seen in the area of multimedia transmission over MANETs exploiting a multicast routing approach that supports unicast routing also. Moreover, all the works from Ref. [8,9,10,11,12,13,14] had considered the CBR data traffic only. Nevertheless, the focus on the transmission of multimedia traffic over mobile ad-hoc environments is to be increased as the exchange of multimedia files playing an important role in serving a wide range of MANET applications. Further, the authors of Ref. [8] had evaluated the proposed protocol only for its PDR values while the authors in [9,10,11,12,13,14] had done the experimentation on their proposed protocols only to assess the performance of the protocols in terms of PDR and end-to-end delay. However, the performance of any routing protocol for multimedia applications could be evaluated greatly if delay, jitter and packet losses are measured. Hence, there is a need for evaluating the multicast routing protocol for multimedia traffic considering the QoS measuring metrics such as PDR, AD and AJ atleast. Moreover, due to random nature of MANET environments, it is always preferable to run multiple simulations taking different topology-scenarios for every change in any of the network parameters in order to achieve consistent results. Since the objective of this work is mainly on QoS support of the MAODV for multimedia applications, the work proposed in Ref. [9] has been retaken and is evaluated for various data traffic types such as CBR, VoIP and video. In addition, the performance is measured in terms of evaluation metrics: PDR, AD, AJ and normalized routing load (NRL). Further, to achieve consistency of results, 10 different topology-scenarios are created and the final results are the average of the obtained individual topology results.

3. M-MAODV

The modified version of MAODV, called M-MAODV establishes the multicast routes by reserving the minimum required bandwidth along the path from a source node to a destination node. Clearly, in a MCT, both the group members and the forwarding nodes must reserve the bandwidth for a data transmission to takes place. It is achieved through the implementation of admission control and resource reservation mechanisms at all nodes of the network. The flow chart of the M-MAODV protocol is depicted in the Fig. 1.

Similar to MAODV protocol, it uses five types of messages such as RReq, RRep, multicast activation (MACT), GH and *hello* in addition to an added message called RB-lost (Reserved Bandwidth-lost). The format of all the messages remains as specified in MAODV [5] except some flags and extensions are added to provide QoS. However, after the modifications, the messages RReq and RRep have been named as M-RReq and M-RRep respectively. The periodic local *hello* and GH messages are extended to incorporate the reserved bandwidth and the state of bandwidth reservation. The nodes that have not received these messages at specified intervals (indicating a link/node breakage) release the reserved bandwidth or change the state of bandwidth reservation. The added RB-lost message informs the other nodes about the lost reserved bandwidth.

Each node maintains three additional tables: bandwidth reservation table (BWRT), neighbours table (NT) and multicast consumed bandwidth table (MCCBWT). BWRT is used to maintain the bandwidth reservation information of different MCGs. An entry in this table includes: MCG address, amount of reserved bandwidth, state of the reservation, hop-count from the source node, source node's IP address and time stamp. MCCBWT keeps the information required for calculating consumed bandwidth at each node and an entry in this table contains the information of reserved bandwidth for uplink and downlink nodes in MCT, and information about state of reservation. NT holds the information about neighbours such as neighbour address, amount of reserved bandwidth in neighbour node, state of the reservation, amount of consumed bandwidth in neighbor, state of neighbour (sender, receiver or forwarding node) and time stamp. Upon receiving a GH, a node updates its BWRT, NT and MCCBWT tables. The NT table is updated every time a node receives a *hello* message.

When a member of the MCG wishes to initiate a data transmission, it broadcasts an M-RReq packet with the bandwidth field set to required bandwidth, depicted in the figure. On receiving an M-RReq packet, a member of corresponding MCT can respond with an M-RRep message only when it has a valid route to the destination with required amount of bandwidth available. An intermediate node has to rebroadcast this request only if it is able to meet the requirements. Otherwise, it simply rejects it. However, the nodes that have reserved (at this stage, temporarily) the bandwidth on accepting the request, update their tables by recording the sequence numbers and next-hop address towards the multicast source. Keeping this information is required to send M-RRep back to the source node.

As shown in the figure, when the multicast source receives multiple M-RRep messages, it computes the end-to-end delay for each of the received path and selects the path with a minimum hop-count to the MCG leader. In addition, it sends the path activation message (MACT) to change the state of bandwidth to reserve, along the chosen path. The intermediate nodes that have not received any MACT message in specified interval; they simply free the temporarily reserved bandwidth. If the multicast source has not received any M-RRep message within prescribed time interval of time, it then rebroadcasts the M-RReq message and there is a limit on the number of retries.

Along the established path, if any node detects that the requested bandwidth can no longer be allocated, then the node sends RB-lost message back to the node which had requested for the reservation. When a node receives RB-lost message, it updates its BWRT.

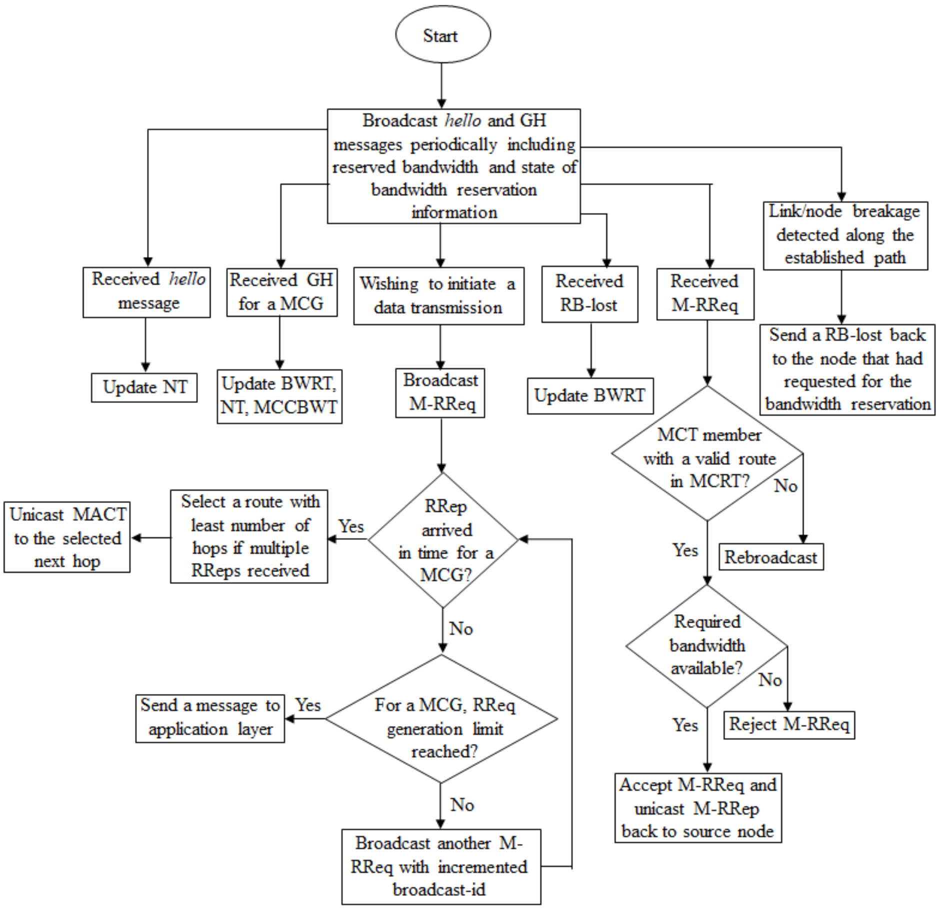

Fig.1. Flowchart of M-MAODV Protocol

A node in a MCT can have multiple downstream (DS) nodes though having single upstream (US) node. Moreover, the DS nodes further can have their DS nodes. However, to estimate the consumed bandwidth of the channel accurately, the methods proposed for unicast routing [9] have been extended to multicast routing. If $B_{self}(I)$ can be defined by the total reserved bandwidth of all existing flows at node I for all nodes J in the neighbourhood of node I. Available bandwidth at node I can be given by:

$$B_{self}(I) = \sum_{k} B_I(k) \tag{1}$$

$$B_{available}(I) = B - \sum_{J \in N(I)} B_{self}(J) \tag{2}$$

where B - raw data rate of the node I
$B_{self}(j)$ - total traffic between node j and its neighbours.

Clearly, the $B_{self}(j)$ is the bandwidth consumed by the traffic transmitted or received by node *j*. Given the requested bandwidth B_{min}, the bandwidth to be reserved for the flow *j* at node *I* is:

$$B_I(j) = \begin{cases} B_{\min} \ if \ \ source\ or\ destination \\ 2B_{\min} \qquad\qquad\qquad else \end{cases} \tag{3}$$

Since the intermediate nodes need to receive and forward flow *j*.

As illustrated in [9], the consumed bandwidth for flow *j* on node *I*'s channel can be given by:

$$B_{consumed}(I, j) = B_{uplink(I)}(j) + B_{downlink(I)}(j) \tag{4}$$

where $B_{uplink(I)}(j)$ is the reserved bandwidth for flow *j* on the US neighbour of node *I*, and $B_{downlink(I)}(j)$ is the bandwidth that the DS neighbour of node *I* reserved for flow *j.* Note that $B_{uplink(I)}(j)$ and $B_{downlink(I)}(j)$ can be either equal to B_{min} or $2B_{min}$ as shown in “(3)” for unicast flows. In unicast routing protocols each node only has one US and one DS node, therefore “equation (4)” can be used for estimating the consumed bandwidth. However, with multicast routing protocols, it is not the case. Let say, d_r be the number of receiver downlink nodes and d_f be the number of forwarding downlink nodes. In MCTs, d_r and d_f can be 0 or >1. To calculate the bandwidth that the DS neighbours of node *I* reserved for flow *j* by:

$$B_{down}(I, j) = \begin{cases} \left\lceil \dfrac{d_r}{d_r + 1} \right\rceil * B_{\min} & d_r \geq 0, d_f = 0 \\ (1 + d_f) * B_{\min} & d_r \geq 0, d_f > 0 \end{cases} \tag{5}$$

By comparing the values of $B_{available}(I)$ and $B_{consumed}(I,j)$, each node can now decide whether to accept the flow or not.

4. Methodology

An open-source simulation tool, NS-2 [15] has been selected for this work because of its popularity and, availability of proper documentation and user support. Specifically, the version NS-2.34 is used. However, the multicast routing protocol MAODV is not available with basic version of NS-2.34. Hence, the protocols MAODV and M-MAODV are brought into the NS-2.34’s environment through the guidelines provided in [16]. Moreover, the support for VoIP data traffic, and video data traffic (utilizing EvalVid tool) has been incorporated in the simulation tool [17,18].

The parameters used for the network set up are presented in Table 3. A pause time of 0s assures the uninterrupted motion of the nodes in the network, denoted by No-Pause (NP), resulting in a highly dynamic network. The performance evaluation of MAODV and M-MAODV has been carried out by generating three communication patterns: 1x1x10, 2x1x10 and 3x1x10 for the three data traffic types (CBR, VoIP and video). For representing a communication pattern, ***G***x***S***x***R*** is the notation used where ***G*** denotes the number of MCGs in a network scenario, ***S*** is the number of senders in a MCG, and ***R*** is the number of receivers in a MCG. Clearly, the number of MCGs has been changed as 1, 2 and 3; each of size 10 nodes with single sender. Moreover, two node mobility patterns: Low-Speed No-Pause (LSNP) and Medium-Speed No-Pause (MSNP) have been created in order to evaluate the performance of the protocols under MANET environments, described in the table.

The ITU-T codec G.711 that generates 50 VoIP packets of size 160bytes (each packet) per second has been selected for voice traffic. A video trace file generated for the video file foreman.yuv [19] with a size of 352×288 (CIF) and a frame rate of 30 frames/s, has been used for the simulation. The video file has been encoded using the MPEG-4 standard, resulted in 400 frames, including 80 I-frames, 80 P-frames and 240 B-frames, with the GOP pattern IBBPBBPBBI.

However, to achieve consistency of results in mobile ad-hoc environments, 10 different topology-scenarios are created and the final results are the average of the obtained individual topology results. To achieve this, a total of 20 topology files for the specified two node mobility patterns are generated. Hence, on the whole, 180 different simulations i.e., 60 runs for each data traffic (20 for each communication pattern) have been performed for the evaluation work.

In 1-MCG scenario, the data connection starts at 60.0s and stops at one minute before the simulation time. In 2-MCG scenario, the data connection in first MCG originates at 60.0s while in the second at 300.0s. Each connection stays active for 240s. Finally, in 3-MCG: the senders in first, second and third MCGs initiate the data connection at 30.0s, 210.0s and 390.0s respectively. The data transfer continues for 180s. The members of MCGs are joining the group just 30s before the beginning of each data connection.

Table 3. Network Setup

Network Parameter	Value
Simulation area	1000mx1000m
Number of nodes	50 (randomly placed)
Simulation duration	600s
Application data traffic:	
CBR	4 packets/s, 64 byte packet (i.e. a data rate of 2KBPS)
VoIP	Codec ITU-T G.711 (64KBPS - 50packets/s, 160bytes)
Video	foreman_cif.yuv (400 frames, 512bytes of packet)
Transport layer protocol	UDP
Network layer protocol	MAODV, M-MAODV
MAC protocol	IEEE 802.11
Radio propagation model	Two-ray ground
Wireless network channel interface queue type and length	DropTail/PriQueue and 50
Wireless channel bandwidth	2MBPS
Node transmission range	250m
Mobility model [20]	Random waypoint
Pause time	0 seconds (NP)
Pause type	1 (constant pause time)
Speed of the node	Low-Speed(LS): 1-5m/s and Medium-Speed (MS): 5-10m/s
Speed type	1 (uniform speed)

The performance of the protocols is evaluated in terms of AD in ms, AJ in ms, PDR in % and NRL in %. To differentiate the unicast QoS metrics from multicast, a letter ‘M’ (stands for *multicast)* has been used as prefix. *M-AD* provides the average time taken by a data packet to reach the destination node from the source node. *M-AJ* is defined as the average of variations in data packets arriving at the destination nodes of all the data connections of the MANET. *M-PDR* is computed as the ratio of total number of unique data packets received to the total number of data packets transmitted by all source’s times the number of receivers. *M-NRL* is defined as the number of routing/control (RReq, RRep etc.) packets transmitted per data packet delivered at the destination.

5. Results

The outcomes of simulation works are presented in the form of graphs shown in Figs. 2 to 31. Graphs show QoS metrics of the MAODV and M-MAODV protocols on the basis of network parameters: *node speeds* and *number of MCGs*. This is required for creating an environment where the multicast routing protocol’s behaviour can be explored clearly in dynamic environments of MANETs.

The knowledge of QoS requirements for various data traffic types is needed to properly evaluate the routing protocol’s behaviour for the given application area [21,22,23]. The M-AD in VoIP applications should be less than 100ms, otherwise the VoIP stream quality degrades. The M-AJ for VoIP traffic should not exceed 400ms. Though the VoIP applications can tolerate packet loss up to 10%, a packet loss of 1% is acceptable to maintain the quality of the VoIP. For video transmission also, a maximum M-AD of less than 100ms, M-AJ of less than 400ms and a packet loss of less than 1% are recommendable. For CBR data traffic, though there are no strict requirements on time related parameters, a packet loss rate of less than 0.01% is recommended. However, since the attractive application of MANETs is to handle emergency situations, it is always preferred to have low M-AD, M-AJ and packet loss values.

5.1. MAODV-Discussion

The sets of Figs. {2-5}, {6-9} and {10-13} represent 1-MCG, 2-MCG and 3-MCG scenarios respectively for MAODV protocol. From all the plots, it is observed that the performance of the protocol is degrading at MSNP for all QoS evaluation metrics in case of CBR traffic. For VoIP and video traffics, the increase in node mobility has resulted in improved values of M-AD and M-AJ randomly. However, these improvements are not even at satisfactory levels. The obtained M-AD values are ranging between 379-628ms while the M-AJ values are from 193-335ms for VoIP traffic. Whereas for video traffic, the M-AD values have the range of 1178-1642ms while the M-AJ values 446-776ms. Hence, it is concluded that the protocol’s performance is lagging at MSNP for all traffic types in terms of all QoS metrics.

In fact, the increased node mobility has resulted in frequent link breaks in the network which has triggered frequent route repairs to take place, either to reconnect or to reconstruct the tree for maintaining up-to-date routing information. This in turn has increased the routing overhead (since a large number of RReq, RRep and MACT messages are generated) as well as the M-AJ and M-AD values of the received data packets. In addition, till a new route is established, the data packets have to wait at the buffers during route repair time. However, if a new route is not found, all the packets will be dropped - the main reason for low M-PDRs.

For increasing MCG numbers, the M-PDR values of MAODV (in Figs. 2, 6 and 10) for CBR traffic is relatively good, i.e., 90-81% at LSNP. However, for VoIP and video traffics, the protocol's performance is even worse since it has produced M-PDR values of a maximum of 59% for VoIP and 29% for video. This is due to the higher data rates of VoIP and video traffics which has caused the network getting congested that has led to the considerable amounts of data packets dropped at interface queues and due to number of increased packet collisions.

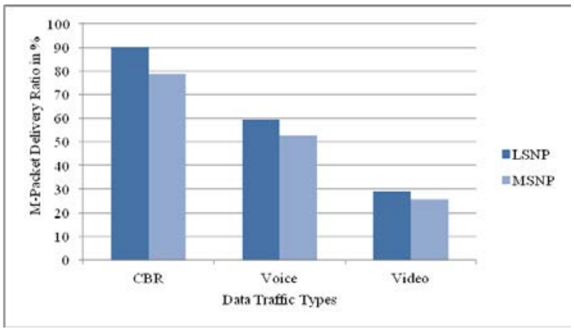

Fig.2. M-PDR in % vs Data traffic types for 1x1x10 (MAODV)

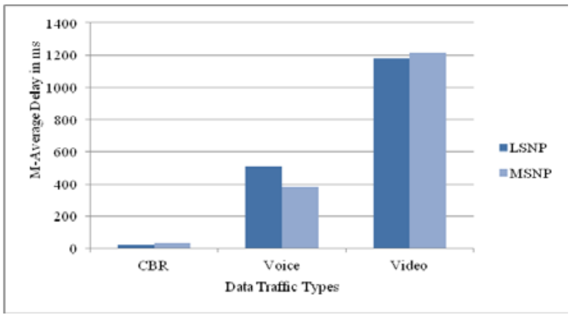

Fig.3. M-AD in ms vs Data traffic types for 1x1x10 (MAODV)

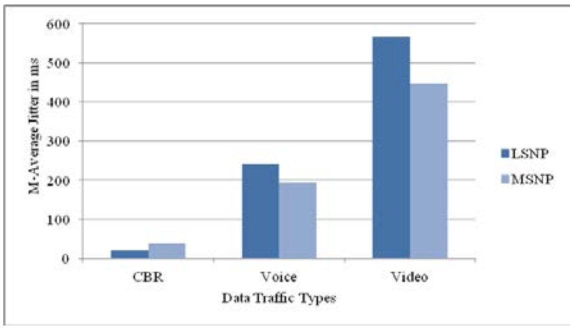

Fig.4. M-AJ in ms vs Data traffic types for 1x1x10 (MAODV)

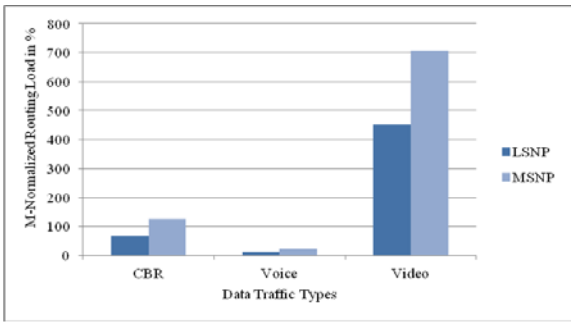

Fig.5. M-NRL in % vs Data traffic types for 1x1x10 (MAODV)

In MAODV, each MCG is maintained by one dedicated MCT. The maintenance of increased number of trees is handled by generating huge numbers of RReq, RRep and MACT messages in the network. Hence, with increasing MCGs, the probability of these messages getting interfered with each other increases which results in packet loss. This is the reason for getting decreased values of M-PDR for increasing MCGs for all the three data traffic types. Moreover, huge amounts of overhead in the network increases the waiting periods of the data packets at the interface queues that have caused an increase in M-AD (in Figs. 3, 7 and 11) and M-AJ (in Figs. 4, 8 and 12) values for increase in number of MCGs. The other side, though the amount of routing overhead increases in the network for maintaining the increased number of trees, the improved values of M-NRL have been observed. This is due to the fact that increasing the number of MCGs has increased the overall number of receivers in the network thereby increasing the number of data packets delivered to the receivers, and hence resulted in reduced values of M-NRL as shown in Figs. 5, 9 and 13.

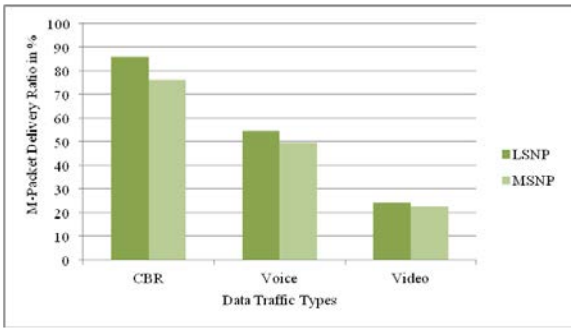

Fig.6. M-PDR in % vs Data traffic types for 2x1x10 (MAODV)

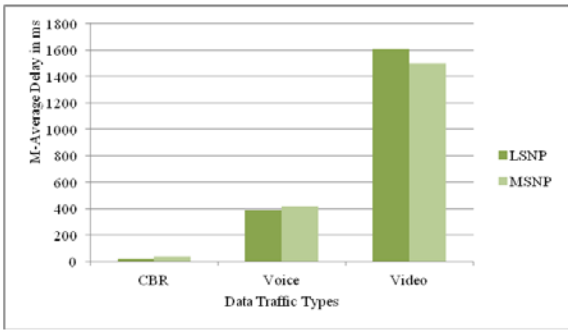

Fig.7. M-AD in ms vs Data traffic types for 2x1x10 (MAODV)

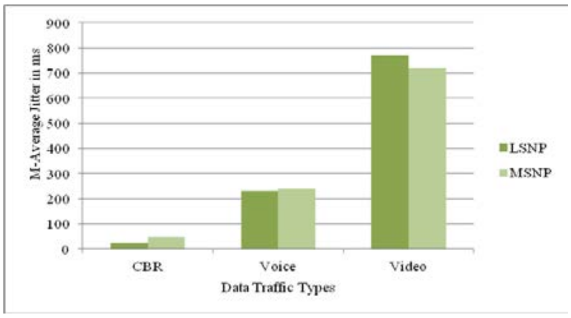

Fig.8. M-AJ in ms vs Data traffic types for 2x1x10 (MAODV)

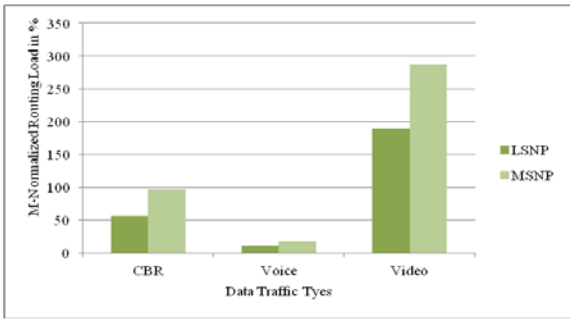

Fig.9. M-NRL in % vs Data traffic types for 2x1x10 (MAODV)

Another reason for getting very low M-PDR values for VoIP and video traffics is due to the nature of MAODV. In this, a node initiates a route repair process with an assumption that the links are broken though the packets have been lost due to network congestion, if it has not received any packet at the specified intervals. This characteristic of MAODV has increased the number of RReq, RRep and MACT packets which has increased the network congestion further. However, the random nature of MANET has kept its mark on the performance of routing protocol, especially with high data rates.

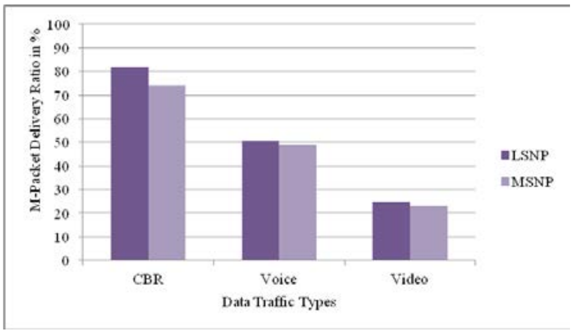

Fig.10. M-PDR in % vs Data traffic types for 3x1x10 (MAODV)

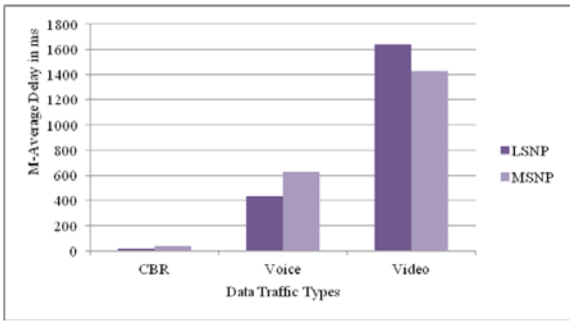

Fig.11. M-AD in ms vs Data traffic types for 3x1x10 (MAODV)

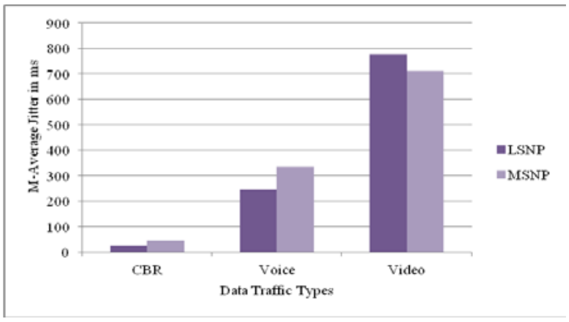

Fig.12. M-AJ in ms vs Data traffic types for 3x1x10 (MAODV)

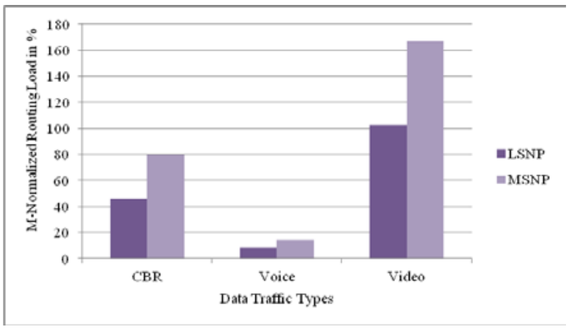

Fig.13. M-NRL in % vs Data traffic types for 3x1x10 (MAODV)

From the set of Figs. {3, 7, 11}, the M-AD values of less than 41ms while from the set of Figs. {4, 8, 12}, the M-AJ values lying in 20-26ms have been observed in the case of MAODV. Moreover, for VoIP traffic, the M-AD and M-AJ values are less than 508ms and 246ms respectively at LSNP. Further, for the same case, the M-AD and M-AJ values for video traffic are lying between 1178-1642ms and 565-776ms respectively. These observations clearly shown the non-suitability of MAODV for supporting multimedia traffic under dynamic environments presented by MANETs.

5.2. M-MAODV-Discussion

Though the data connections have been properly designed to avoid the congestion in the network, from the section

5.1, it has been observed that the existing MAODV protocol is not suitable for multimedia applications because of its not acceptable M-AD and M-AJ metrics. Now, in this part of simulation works, the M-MAODV protocol is evaluated and to have a fair comparison between the MAODV and M-MAODV protocols, the same simulation setup that has been defined earlier under section 4 is only considered again. The graphs from Figs. 14 to 25 depict the QoS metrics of the M-MAODV protocol. The sets of Figs. {14-17}, {18-21} and {22-25} represent 1-MCG, 2-MCG and 3-MCG scenarios respectively. From the overall plots, the significant improvements in all QoS metrics irrespective of node speeds as well as increasing number of MCGs have been observed in M-MAODV compared to MAODV for all three data traffic types.

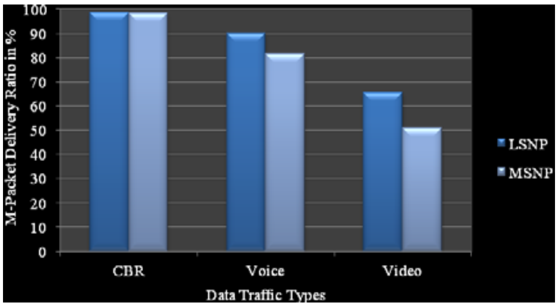

Fig.14. M-PDR in % vs Data traffic types for 1x1x10 (M-MAODV)

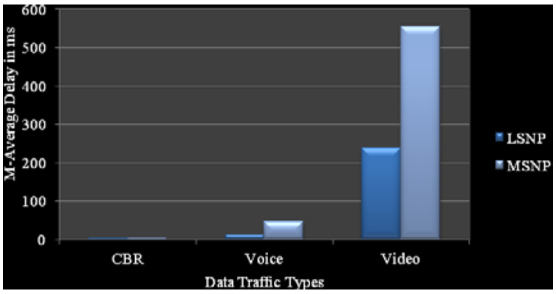

Fig.15. M-AD in ms vs Data traffic types for 1x1x10 (M-MAODV)

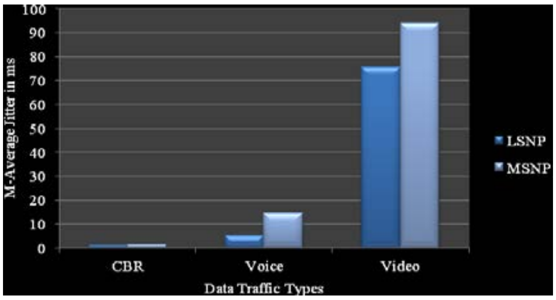

Fig.16. M-AJ in ms vs Data traffic types for 1x1x10 (M-MAODV)

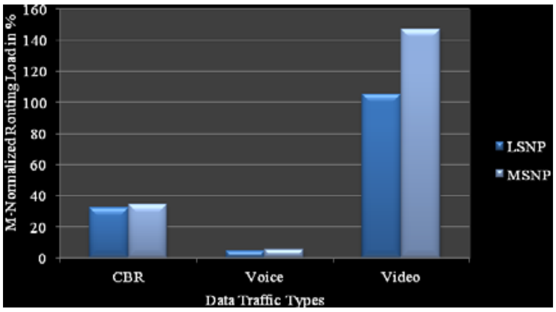

Fig.17. M-NRL in % vs Data traffic types for 1x1x10 (M-MAODV)

For CBR traffic, the performance of the protocol has remained almost constant for all QoS metrics both at LSNP and MSNP. While in VoIP traffic, at MSNP, decreased values of QoS metrics have been observed, however only with narrow gaps. The increased node mobility in video traffic has increased the M-AD and M-AJ considerably and has produced the degraded values of M-NRL.

For increasing MCGs, the decreased values of M-PDR i.e., from 98% to 94% have been recorded with the CBR traffic, shown in Figs. 14, 18 and 22. The M-AD (in Figs. 15, 19 and 23) and M-AJ (in Figs. 16, 20 and 24) values have been remained constant regardless of the number of MCGs. For VoIP traffic, a decrease in M-PDR values and an increase in the M-AD and M-AJ values are noticed. For video traffic, it is observed that a decrease in M-PDR values and an increase in M-AD and M-AJ values (except at 2-MCG scenario). However, an improvement in the values of M-NRL has been observed for all data traffic types. Since the M-MAODV establishes a route only when the path from a source to a destination can afford the required bandwidth of the flow, the degraded performance of the protocol for VoIP and video traffics is marked.

When the set of Figs. {5, 9, 13} are compared with the set of Figs. {17, 21, 25}, the improved values of M-NRL in the case of M-MAODV have been clearly observed. This is due to the increased values of M-PDRs. Moreover, it is realized that the modified version of MAODV has not affected the routing overhead considerably.

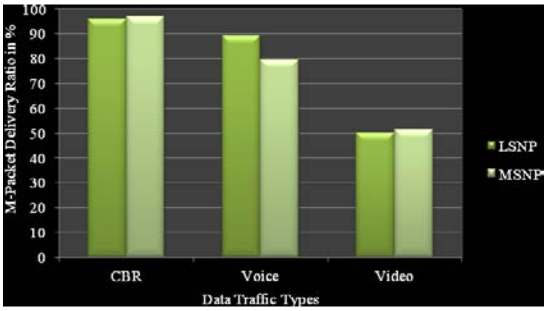

Fig.18. M-PDR in % vs Data traffic types for 2x1x10 (M-MAODV)

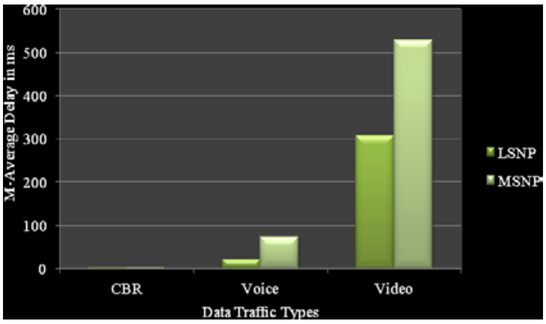

Fig.19. M-AD in ms vs Data traffic types for 2x1x10 (M-MAODV)

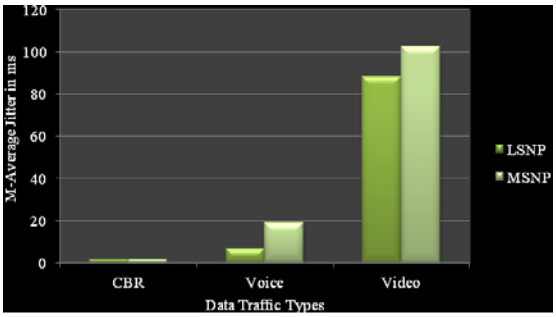

Fig.20. M-AJ in ms vs Data traffic types for 2x1x10 (M-MAODV)

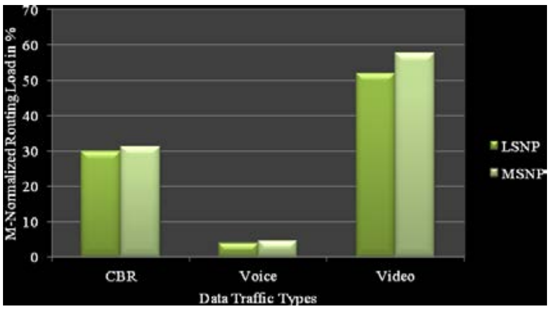

Fig.21. M-NRL in % vs Data traffic types for 2x1x10 (M-MAODV)

Comparing the sets of Fig.s {2, 6, 10} and {14, 18, 22}, a raise in M-PDR values, ranging between 96-98% has been observed clearly in M-MAODV for CBR traffic. At LSNP, for VoIP and video traffics, the MAODV's performance is poor and has M-PDR values of a maximum of 29% for video and 59% for VoIP. However, in M-MAODV, the M-PDRs resulted with video traffics are a maximum of 65% and for VoIP traffic occupying the values between 83-89%. Though improved, the M-PDR values for VoIP and video data traffics are not satisfactory even with the M-MAODV protocol. The reason for getting low values of M-PDR for VoIP and video traffics is due to the QoS path reconstructions and their high data rates.

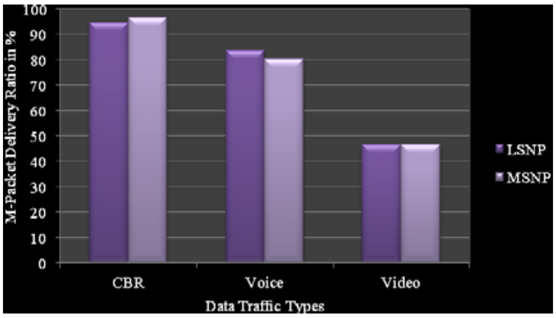

Fig.22. M-PDR in % vs Data traffic types for 3x1x10 (M-MAODV)

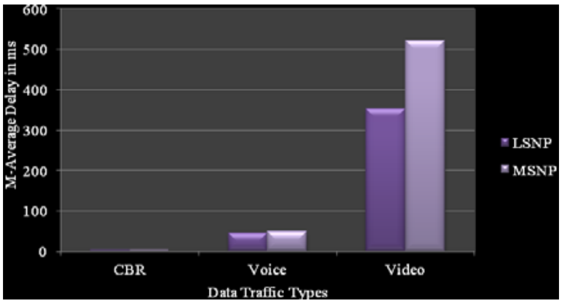

Fig.23. M-AD in ms vs Data traffic types for 3x1x10 (M-MAODV)

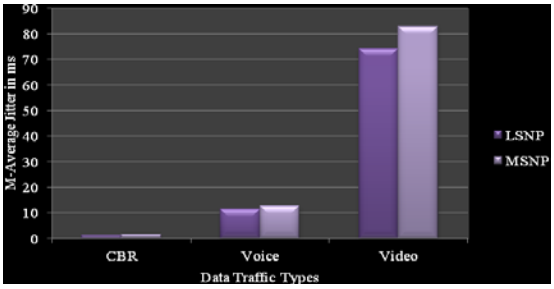

Fig.24. M-AJ in ms vs Data traffic types for 3x1x10 (M-MAODV)

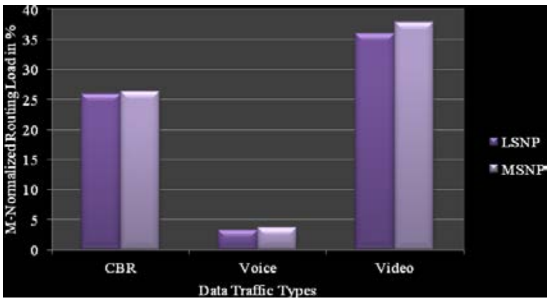

Fig.25. M-NRL in % vs Data traffic types for 3x1x10 (M-MAODV)

As depicted in set of Figs. {15, 19, 23}, the M-AD values of less than 3ms have been noted regardless of the number of MCGs for CBR traffic. For the same traffic, the values of M-AJ are less than 1.5ms, shown in set of Figs. {16, 20, 24}. Due to large packets and high frame rates, the overall performance of the M-MAODV is poor for the video traffic. The large sized packets need more time to travel along the path, hence increase the associate packet delays steadily in the congested network, which is due to high data rates. Hence, the generated values of M-AD and M-AJ for video traffic is lying between 238-553ms and 74-102ms respectively. However, the great improvements in the results have been observed with the VoIP traffic. The obtained values of M-AD and M-AJ are lying in 11-45ms and 6-19ms respectively and hence showing the QoS support of the protocol for CBR and VoIP traffic clearly.

6. Conclusion

The work has focused on the support of multimedia traffic in mobile ad-hoc networks utilizing multicast routing for group communications to handle emergency situations. To allow optimal communication to happen in a MANET, a unicast routing protocol that supports multicast transmissions is the preferred choice. Since the AODV is a widely accepted reactive routing protocol for MANETs, its multicast extension i.e., MAODV has been opted for the work. In the literature, there has been various works proposed, designed and discussed on the multicast operation of the AODV for CBR traffic under MANETs. However, in this work, the performance of the MAODV protocol for various data traffics such as CBR, VoIP and video has been evaluated in terms of QoS performance metrics such as average delay, average jitter and packet loss rate by varying node mobility patterns and number of MCGs.

Though the data connections have been properly designed to avoid the congestion in the network, however, from the results, it has been observed that the existing MAODV is not suitable for supporting multimedia applications under dynamic environments presented by MANETs because of its not acceptable M-AD and M-AJ metrics. Hence, some modifications have been done to the MAODV protocol to achieve improved QoS performance of the protocol for multimedia traffic.

The modified MAODV, namely M-MAODV works on the network layer utilizing the admission control and resource reservation mechanisms. The performance of M-MAODV for multimedia traffic is evaluated in the same simulation setup which has been used for the evaluation of MAODV, to achieve a fair comparison. From the plots, the great improvements in terms of all QoS metrics have been noted in M-MAODV for the three data traffics. For CBR and VoIP traffics, the obtained values of M-AD and M-AJ have shown the protocol's suitability for providing QoS in MANETs clearly. However, from the overall results, it is observed that the network bandwidth, congestion and video rate significantly affect the video traffic transmission. Hence, there is a need to further enhance the MAODV protocol to accommodate multimedia traffic greatly.

References

[1] J. Hoebeke, I. Moerman, B. Dhoedt, and P. Demeester, "An overview of mobile ad hoc networks: applications and challenges," *Journal of the Communications Network*, vol. 3, no. 3, pp. 60-66, July 2004.

[2] M. Conti, and S. Giordano, "Mobile ad hoc networking: milestones, challenges, and new research directions," in *IEEE Communications Magazine*, vol. 52, no. 1 pp. 85-96, January 2014.

[3] E. M. Royer, and C. E. Perkins, "Multicast operation of the ad-hoc on-demand distance vector routing protocol," in proceedings of the *5th ACM/IEEE international conference on Mobile computing and networking*, Washington, USA, pp. 207-218, August 1999.

[4] Shruti Singh Roy and P. L. Zade, "Performance optimization of ad hoc on demand vector routing protocol in cognitive radio network," *International Journal of Wireless and Microwave Technologies*, vol. 8, no.3, pp. 23-32, 2018.

[5] M. Elizabeth-Royer, "Multicast ad hoc on demand distance vector (MAODV) routing," *IETF Internet Draft*, University of California, Santa Barbara, July 2000.

[6] C. E. Perkins, and E. M. Royer, "Ad-hoc on-demand distance vector routing," *Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications*, New Orleans, LA, pp. 90-100, February 1999.

[7] Dharmendra Sutariya, "Performance evaluation of multicast routing protocols in mobile ad hoc networks," *proceedings of International Journal of Computer Networking, Wireless and Mobile Communications* (IJCNWMC 2016), vol. 6, no. 2, pp. 45-54, April 2016

[8] X. Chen, Q. Zhong, and D. Liu, "An improved MAODV protocol based on mobility prediction and self-pruning flooding," *2009 WRI International Conference on Communications and Mobile Computing*, vol. 2, pp. 127-131, January 2009.

[9] B. O. Vida Lashkari, and M. DeAhghan, "QoS-aware Multicast Ad Hoc On-Demand Distance Vector Routing," *Proceedings of the World Congress on Engineering*, WCE 2007, London, UK, pp. 1506-1511. July 2007.

[10] H. Tang, F. Xue, and P. Huang, "MP-MAODV: A MAODV-based multipath routing algorithm," *2008 IFIP International Conference on Network and Parallel Computing*, pp. 296-301, 2008.

[11] Y. Jia, and Y. Hu, "Improvement of Wireless Multicast Routing with Link State Based on MAODV," *2008 4th International Conference on Wireless Communications, Networking and Mobile Computing*, pp. 1-5, 2008.

[12] Weiliang Li, and Jianjun Hao, "Research on the improvement of multicast Ad Hoc On-demand Distance Vector in MANETS," *2010 The 2nd International Conference on Computer and Automation Engineering* (ICCAE), vol. 1, pp. 702-705, 2010.

[13] X. Li, N. Gaowa, and M. Yang, "Improved MAODV link repair technique for group team communication in MANET," *2013 9th International Wireless Communications and Mobile Computing Conference* (IWCMC), pp. 1023-1028, 2013.

[14] X. Li, T. Liu, Y. Liu, and Y. Tang, "Optimized multicast routing algorithm based on tree structure in MANETs," in *China Communications*, vol. 11, no. 2, pp. 90-99, February 2014.

[15] Network Simulator 2, http://www.isi.edu/nsnam/ns/

[16] Y. Zhu, and T. Kunz, "MAODV Implementation for NS-2.26," Systems and Computer Engineering, Carleton University,

Ottawa, Canada, Tech. Rep. SCE-04-01, 2004.

[17] A. Bacioccola, C. Cicconetti, and G. Stea, “User-level Performance Evaluation of VoIP using NS-2,” *Proceedings of the 2nd International Conference on Performance evaluation methodologies and Tools*, Institute for Computer Sciences, Social Informatics and Telecommunication Engineering, no. 20, pp. 1-10, October 2007.

[18] Vijay S Ukani, and J. Bhatia, "Testing Video Transmission in NS-2 Using The Evalvid Framework." *Research Gate*, 2015.

[19] YUV Video Sequences. [Online]. Available: http://trace.eas.asu.edu/yuv/

[20] Anuj K. Gupta, Harsh Sadawarti, Anil K. Verma,"Performance Analysis of MANET Routing Protocols in Different Mobility Models", International Journal of Information Technology and Computer Science, vol.5, no.6, pp.73-82, 2013.

[21] Y. Chen, T. Farley, and N. Ye, "QoS requirements of network applications on the Internet," *Information Knowledge Systems Management*, vol. 4, no. 1, pp. 55-76, January 2004.

[22] P. B. Velloso, M. G. Rubinstein, and O. C. M. B. Duarte, "Evaluating voice traffic requirements on IEEE 802.11 ad hoc networks," *annals of telecommunications - annals des telecommunications*, vol. 63, no. 5, pp. 321-329, 2008.

[23] Brett Berliner, Brian Clark, and Albert Hartono, "QoS requirements of multimedia applications." https://cse.osu.edu/, Accessed 26, no. 04 (2011): 2017.

Authors' Profiles

Lavanya. Poluboyina completed B.Tech. in Electronics and Communication Engineering from Vignan’s Engineering College, Jawaharlal Nehru Technological University, Hyderabad, Andhra Pradesh in 2004 and done M.Tech. in Digital Systems and Computer Engineering from University College of Engineering, JNTUH, Hyderabad, Telangana in the year of 2009.

She has teaching experience of more than 17 years and presently working as Assistant Professor in the department of Electronics and Communication Engineering, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana. Her areas of interest are Advanced Data Communications, Wireless Communications and Networks, Routing in Wireless Networks, Wireless Ad-hoc Networks, and Mobile Ad-hoc Networks. She published more than 10 research papers in the International Journals and Conferences. She is a Senior Member of IEEE and, is a member of IEEE Communications Society.

Mallikarjuna Prasad. A received Ph.D. in Electronics and Communication Engineering from University College of Engineering, JNTUH, Hyderabad, Telangana in the year 2009. Completed M.E. from Andhra University, Andhra Pradesh in 1992 and in 1988 done B.Tech. from Acharya Nagarjuna University, Andhra Pradesh.

He has teaching and industry experience of more than 31 years together and presently working as Professor in the department of Electronics and Communications Engineering, JNTUK, Kakinada, Andhra Pradesh, India. He is having more than 50 research publications in the National and International Conferences and Journals. His research interests include Bio Medical Signal/Image Processing, Wireless Communications, Antennas, VLSI, and Electronic Instrumentation.

Sivakumar Reddy. V, Alumni of IIT Kharagpur, obtained Ph.D. in the area of Multi-media Signal Processing and Communication Protocols in the year 2008. Received M.Tech. degree in Digital Systems from JNTU College of Engineering, Hyderabad, Telangana and B.Tech. from NBKRIST, Nellore, Sri Venkateswara University, Andhra Pradesh.

He has an experience of more than 19 years in teaching and industry put together and currently working as Principal, Malla Reddy College of Engineering & Technology, Hyderabad, Telangana. He published more than 45 research papers in the National and International Conferences and Journals. His areas of interest include Architecture for Signal Processing and Image/Video Coding and Video Communications, Computer Networks, TCP/IP Networks and Protocols, and Multimedia System Design.

Dr Reddy is a fellow of IETE, Life Member of ISTE, and Member of IEEE. Awarded as “Best Teacher” in three consecutive Academic years with citation and cash award. Recipient of “India Jewel Award” for outstanding contribution in the research in the field of Engineering and Technology.

S V Maruthi Rao Chinnam completed his M.S. in Embedded Systems and Robotics from University of Essex, U.K. in the year 2004. He did his B.Tech. in Electronics and Communication Engineering from NCET, Vijayawada in the year 2001. He is currently pursuing part-time Ph.D. in KL University, Vaddeswaram, Vijayawada.

He is currently working as an Associate professor in the Department of Electronics and Communication Engineering at Sreyas Institute of Engineering and Technology. He has 14 years of teaching experience and his research interests include Digital Systems, Embedded systems, Internet of Things and Wireless Ad-hoc Networks. He published more than 10 research papers in the National and International Conferences and Journals. He is a member of IEEE and is a part of Robotics and Automation society.

How to cite this paper: Lavanya. Poluboyina, Mallikarjuna Prasad. A, Sivakumar Reddy. V, S V Maruthi Rao, "Multimedia Traffic Transmission using MAODV and M-MAODV Routing Protocols over Mobile Ad-hoc Networks", International Journal of Computer Network and Information Security(IJCNIS), Vol.14, No.3, pp.47-62, 2022. DOI: 10.5815/ijcnis.2022.03.04