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QoS Constrained H.264/SVC video streaming over Multicast Ad Hoc Networks

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ABSTRACT

Support for QoS enabled multimedia transmission over multicast ad hoc network is necessary these days. Researchers have developed various encoding/decoding schemes which can efficiently deliver the multimedia contents over wireless networks. In case of ad hoc networks, performance of routing protocol depends upon different factors i.e. traffic type being used for wireless transmission, dynamic network behavior, bandwidth and computational power of nodes etc. It is essential to investigate the performance of multicast routing protocol using various data types because they may consume huge network resources thus results in degradation of transmission quality. In case of multicast group communication, Audio/Video data stream can cause extra overhead on network performance and it is quite difficult to maintain Quality of Services for such type of data. H.264 offers a rich codec library for Scalable Video Coding, to transfer SVC video traffic efficiently over wireless networks. In this paper, we will analyze the performance of MAODV and PUMA routing protocols using H.264/SVC video streaming traffic under the various QoS constraints such as Throughput, PDR, Delay, Routing Load and Jitter etc.

Keywords- Ad Hoc, Multicast, QoS, MAODV, PUMA, H.264/SVC

I. INTRODUCTION

Real time data streaming over Multicast ad hoc networks is essential but it may suffer due to unpredictable behavior of network and the performance of Multicast routing protocol. It is very challenging to provide the QoS support for real time communication because it consists of audio/video streams. Any sort of delay in packet transmission/forwarding may result in extra control overhead and traffic load, delay etc. To enhance the network efficiency for multicast group communication, better Quality of Experience and Quality of Services for end users, there is need to analyze the behavior of Multicast routing protocol using audio/video streaming. H.264/SVC (Scalable video coding) standard library is often used to maintain the quality of video compression [18][19]. H.264 library offers single layer non scalable (H.264/AVC) video coding and layer scalable (H.264/SVC) video coding which is the extension of H.264/AVC that supports scalability in terms of Temporal/ Spatial/Quality and maximum 128 layers are supported. Temporal Scalability is achieved using frame frequency of hierarchical B frame structure. Spatial Scalability is achieved by introducing spatial frame with different resolutions. Quality Scalability is achieved by introducing eight quality layers those can increase the signal to noise ratio related to each frame and it can be further enhanced using quantization methods [19].

Group of Picture (GoP)

In case of multimedia file, data is arranged into number of frames as following:[21]

a. Intra Coded Picture (I-Frame): Independent coding of a picture can be done

b. Predictive coded picture (P-Frame): It contains prediction information and individual frame can be used to refer a single picture only.

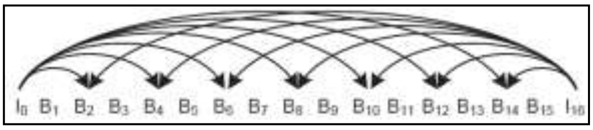
c. Bipredictive coded picture (B-Frame): It can refer more than one I/P picture only at a time.

DC direct coded picture (D-Frame): These are used for frequent access and can be used only in MPEG-1 standard [19].

Bi-directional Prediction (B frame) for H.264/SVC

H.264/SVC uses B frames which can be used to refer another frame. Figure:1 shows the classical B-frame that is used by MPEG and figure:2 shows hierarchical B frame that is used in H.264/SVC [19].

Figure:1 Classical B frame prediction [19]



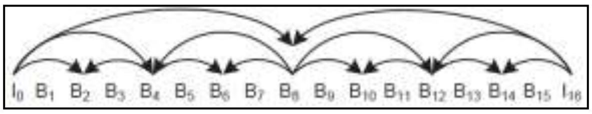


Figure:2 Hierarchical B frame prediction [19]

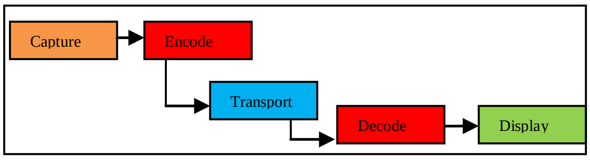


Figure:3 H.264/SVC Packetization Process[19]

Figure:3 above shows the Packetization process followed by H.264/SVC. It uses network abstraction layer units (NALU) and encapsulates the encoded video in to NALU header and transmits data over network and at receiver side video is displayed after decoding process.

YUV Sequences

It is used to define a RGB color space and can be denoted as YCbCr/YUV where Y used to represent luminance, b and r are used for color information coded in signals [22].

Common Intermediate Format (CIF)

It is used to define constraints for resolution (352 × 288) of the pixel data of YUV sequences. Following Table: shows the various resolution standards defined by CIF:[23]

Table:1 CIF standards [23]

Format	**Video Resolution**
SQCIF	**128 × 96**
QCIF	**176 × 144**
SCIF	**256 x 192**
SIF(525)	**352 x 240**
CIF/SIF	**352 × 288**
4SIF	**704 x 480**
4CIF/4SIF	**704 × 576**
16CIF	**1408 × 1152**
DCIF	**528 × 384**

This paper is organized in to different sections (I-VI). Section-I contains introduction to the research area. Section-II is related to the research work proposed by other authors in the relevant field. Section-III contains the basic configuration used for simulation purpose. Section-IV contains the results and discussion, Conclusion is discussed in Section-V.

II. LITERATURE SURVEY

Researchers have explored the various solutions for H.264/SVC video streaming over wireless networks but there is need to revise it further for multicast mobile ad hoc networks. Now we will discuss the efforts made by them. Jun-Li Kuo et al. [1] presented a cross-layer design for P2P live streaming over mobile ad hoc networks to improve the performance of video streaming service. It integrates the routing protocol with P2P protocol for adapting real-time service to the dynamic network. Results show that it effectively improves the playback continuity under the impact of scalability, mobility, churn with the reasonable overhead. Sha Hua et al. [2] presented a scalable video broadcast/multicast solution ((SVBCMCS)) that can be used to integrate scalable video coding, 3G broadcast and ad hoc forwarding etc. They studied the optimal resource allocation problem in SVBCMCS and developed practical helper discovery and relay routing algorithms. Results show that SV-BCMCS can improve the system-wide video quality but it degrades the quality of few viewers that are close to the boundary. Zhanwei Chen et al. [3] proposed a reliable video multicast scheme for wireless networks. In the method, the network layer adopts the on-demand multicast routing protocol and the application layer combines the Forward Error Correction with Automatic Repeat Request to effectively control errors, so it can provide the reliable data transmission of the wireless video multicast with almost no affecting the system performance. Results show the effectiveness of the method. Shujuan Wang et al. [4] presented a retransmission method that can handle the clients' requests at the cost of minimum retransmission attempts. It uses a soft video reconstruction scheme to improve the quality of reconstructed video and finally clients receive more packets. Ruixiao Yao [5] et al. proposed a priority-validity delivery scheme for reliable SVC video streaming for wireless networks. It can utilize the transmission history stored on server side for transmission purpose over multiple channels. It can arrange the data as per priority into to umber of frames, called group of picture (GOP) and can prepare a transmission schedule for queue buffer and on the expiry of transmission schedule, further transmission is not possible for that particular GOP. They used various sequences such as foreman, container, crew, tempete, mobile, soccer, waterfall and football. They used JSVM 9.19.7 with a GOP size of 16 for 2273 frames and did simulation using NS-2. Simulation results show that proposed scheme can maintain the quality of received video. Shenglan Huang [6] et al. proposed a method which can combine the SVC streamlining with P2P transmission. It uses a allocation method which can predict the various parameters such as traffic load and link quality between sender and receiver. They used Paris sequence encoded with H.264/SVC using Medium Grain Scalability (MGS) at CIF (Common Intermediate Format) resolution at bit rates streams of 42, 80, 116 KB per second with GOP size of 8 frames, for simulation and simulation results show that resource estimation can manage the networks resources sufficiently and can deliver video with quality. Mohammud Z [7] et al. proposed extension of the H.264/AVC standard and developed a rate-optimization method to deliver scalable video sequences over wireless channels. This method can calculate the optimal selection rate of video layers in order to increase transmit rate. Simulation results show that it is necessary to find out the optimal rate for quality of transmission which suffers from channel conditions, number of video layers, granularity loss and encoding scheme etc. Dong Zhang [8] et al. proposed a framework for SVC bit stream transmission by combining both error resilient (ER) coding and error concealment (EC). They developed a ER coding scheme which can produced redundant picture information (RPI) under rate-distortion criteria and transmitted to media gateway along with the SVC bit stream. ERS can be achieved at the media gateway by introducing coded pictures of various video coding layers as per RPI and network link conditions. For decoding, they used Wiener filtering method to recover missing enhancement layer pictures. The proposed scheme does not degrade coding efficiency because it transmits RPIs only and it is able maintains coding process, error resiliency, and operation complexity etc. Simulation results show that the proposed scheme performed well as compared to other ER transmission methods. Hao Cui [9] et al. presented a method to resolve temporal and spatial redundancy in uncoded video signals and results show that quality of video transmission can be achieved using receiver side denoising. They also introduced a resource allocation scheme using on variable-size L-shaped chunk division, to optimize energy consumption. Proposed work can be extended to support multicast session in which receiver can customize the video resolution as per the display configuration of mobile devices. P.Kalaiselvi et al. [10] explored the resource allocation and scheduling issues related to scalable video multicast over wireless mesh cell. They defined the maximization of video quality with minimization of energy consumption under the constraints of medium access. Each node share the data using a centralized server and broadcast it at regular intervals in order to reduce the access time, energy consumption and complexity. C. P. Lau et al. [11] cross-layer superposition coded multicast (SCM) for scalable video transmission using superposition coded (SPC) modulation method with IEEE 802.16e. They used emulator for experiments and results show that proposed scheme performs well under QoS constraints. Sheng-Chieh Wang et al. [12] presented cooperative multicast methods, OppCM and CodedCM for SVC transmission. OppCM uses opportunistic listening and conditional demodulating and CodedCM delivers layer-encoded video with multi-resolution modulation using cooperative multicasting. Simulation results show that the proposed methods performed well for SVC frame transmission and it can be extended to adopt higher layer video streams with various bit ratios. Jun Liu et al. [13] proposed a low-complexity method for SVC transmission, called Energy Opportunistic Scheduling (EMOS) which can perform well under the constraints of limited resources i.e. energy, bandwidth and Qos etc. For experiments, they used homogeneous and heterogeneous networks and different scheduling methods such as MUSR, TMS and MAX and compared the EMOS performance and simulation results show that it can preserve energy and can maintain QoS constraints and suitable for homogeneous multicast operations. Olfa Ben Rhaiem et al. [14] evaluated the performance of various ad hoc routing protocols using H.264/SVC codec. They considered different performance parameters such as PSNR, delay, packet loss ratio, decoded image rate etc. Simulation results show that node density affects the performance of routing protocols. DSDV and AOMDV performed well as compared to AODV/DSR in terms of decoded image rate and delay etc. Qing Xu et al. [15] proposed a flexible allocation scheme for multimedia multicast operations over mobile networks called F2R2M to optimize resource allocation. They developed a analytical cost function for resource estimation which can fulfill the QoS constraints, energy consumption and perform well using limited resources. Proposed method uses different Model phases: (a) Parameter Collect Phase is used to collect user information, (b) Estimation Phase is used to optimize resources and (c) Resource Allocation Phase is used allocate the channel for selected users. Simulation results show its performance in terms of QoS, fair channel allocation and energy optimization etc. Basem Almadani et al. [16] proposed a method based on Data Distribution Service in order to enhance the video transmission over wireless network. This method can manage the upper and lower layers streams for error free video transmission. Due to packet drop at upper layers, lower layers can be protected and quality of transmission can be stabilized. Results show its performance in terms of error free transmission, receive Video quality, Throughput etc. Pengrui Duan et al. [17] developed a algorithm to manage the length of payload by exploring the impact of payload length over the network performance considering various parameters i.e. Bit error rate, frame reconstruction, code duplicity and efficiency etc. To control the bit error rate, they optimized the payload length to reduce the BER. In case of packet loss and retransmission, they used FEC coding method to regulate the frame reconstruction rate. Simulation results show that all these parameters are affected by adopted payload length so this should selected as per the available resources to keep the quality of video at acceptance level. Fraser Cadger [18] developed a Geographic Predictive Routing (GPR) based Neural Networks which can adopt the dynamic behavior of the ad hoc network and can perform under high mobile environment. It uses prediction to estimate the current location of the nodes and to build the routes as per the mobility patterns. They performed the analysis by varying node density and protocols with multimedia traffic. They used a training method for learning process and location services to collect the real time positions. Training program adopts the updates as per directed by location services. Simulation results show its performance in terms of Throughput, PDR and Delay as compared to other protocols (AODV, GPSR, DSR and DSDV).

III. SIMULATION SETUP

Table: 2 Simulation Scenario

Nodes	30
Sender	1,5,10, 15
Receiver	1,5,10,15
MAC Protocol	802.11
Terrain	1200x1200
Ad Hoc Multicast Routing Protocol	MAODV, PUMA
Simulation Time	600 Seconds
Group Size	1
Propagation Model	TwoRayGround
Simulator	NS-2.35

Table:2 above shows the simulation parameters used for simulation purpose. In a network, total number of mobile nodes are 30 out of which Sender node's density varies from 1 to 15 (nodes) and density of receivers varies from 1 to 15 (nodes). MAC layer protocol is IEEE 802.11, Ad Hoc Multicast Routing Protocols are MAODV and PUMA. Propagation model is TwoRayGround model, Mobility model is Random Waypoint model and network simulator NS-2 was used for simulation purpose.

Table:3 Sender vs Receiver

Sender vs Receivers	
Sender Node (s)	**Receiver Node (s)**
1	1,5,10,15
5	1,5,10,15
10	1,5,10,15

Table:4 H.264/SVC video streaming configuration

H.264/SVC video streaming Configuration	
Input Video	Foreman.yuv
Video Frame(s)	300
Frame Format	CIF
Resolution	352x288

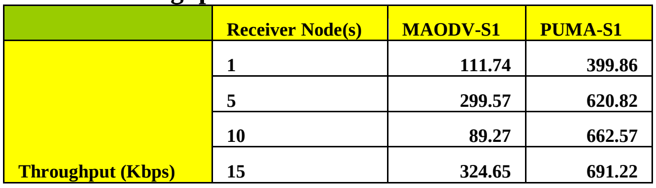
We used NS-2 for simulation of H.264/SVC video streaming using multicast routing protocols i.e. MAODV and PUMA under the QoS constraints. Sender/Receiver density varies from 1 to15 nodes. We did the performance evaluation on the basis of QoS parameters such as Throughput, Packet Delivery Ratio, Jitter and End-to-End Delay. We used video trace of foreman sequence [24] for input traffic that consists of 300 frames having CIF format with the resolution of 352x288. Following procedure was used to initialize the agents for simulation:

```
1. Init_nodes(n=30)
2. Set Sender: $S_n$, Receiver:$R_{n\ \{n=1,5,10,15\}}$
3. init_Group ( $S_{n,}$ $R_n$) {
       $S_{n->}$set dst_addr_ 0xE000000
       $S_{n->}$set set dst_port_ 100
     $R_{n->}$set set dst_port_ 100
       }
4. Init_App (Video) {
       $S_{n->App=Video}$
       $S_{n->}$Load_file(foreman)
       $S_{n->}$Set_Trace(on)
       }
5. Join ( group ) {
       set group [group]
       join-> group($R_n$)
       }
6. Leave ( group ) {
       get group [group]
       leave-> group($R_n$)
       }
```

IV. PERFORMANCE ANALYSIS OF MULTICAST PROTOCOLS

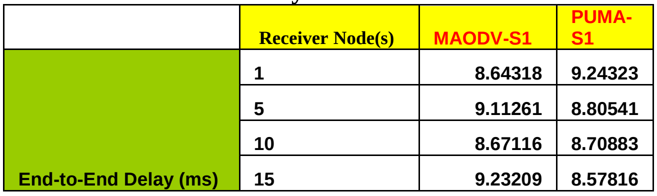
Performance Analysis-Sender Node=1

Table:5 Throughput- Sender Node-1



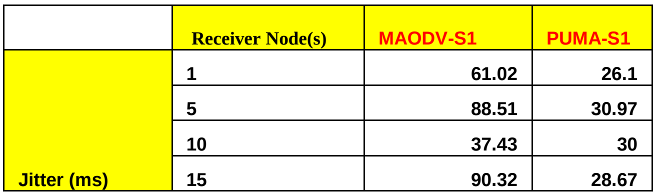
	Receiver Node(s)	MAODV-S1	PUMA-S1
Throughput (Kbps)	1	111.74	399.86
	5	299.57	620.82
	10	89.27	662.57
	15	324.65	691.22

Table:6 End-to-End Delay- Sender Node-1



	Receiver Node(s)	MAODV-S1	PUMA-S1
End-to-End Delay (ms)	1	8.64318	9.24323
	5	9.11261	8.80541
	10	8.67116	8.70883
	15	9.23209	8.57816

Table:7 Jitter-Sender Node-1



	Receiver Node(s)	MAODV-S1	PUMA-S1
Jitter (ms)	1	61.02	26.1
	5	88.51	30.97
	10	37.43	30
	15	90.32	28.67

Table:8 Packet Delivery Ratio-Sender Node-1

	Receiver Node(s)	MAODV-S1	PUMA-S1
Packet Delivery Ratio	1	18.43251089	83.65384615
	5	47.60522496	79.48717949
	10	18.287373	76.6025641
	15	55.87808418	73.3974359

Table:9 Routing Load-Sender Node-1

	Receiver Node(s)	MAODV-S1	PUMA-S1
Routing Load	1	6.42519685	2.195402299
	5	3.100609756	2.258064516
	10	6.468253968	2.305439331
	15	2.78961039	2.362445415

Table no. 5-9 above show the simulation results and performance comparison of MAODV and PUMA protocols using QoS parameters. There is only one sender and multiple receivers which vary from 1 to 15 nodes. In case of MAODV, with single receiver, Throughput is 111.74 Kbps, End-to-End Delay is 8.64318ms, Jitter is 61.02ms, PDR is 18.43251089 and Routing Load is 6.42519685. With 5 receivers, Throughput is 299.57 Kbps, End-to-End Delay is 9.11261 ms, Jitter is 88.51ms, PDR is 47.60522496 and routing load is 3.100609756. With 10 receivers, Throughput is 89.27 Kbps, End-to-End Delay is 8.67116 ms, Jitter is 37.43 ms, PDR is 18.287373 and Routing Load is 6.468253968. With 15 receivers, Throughput 324.65 Kbps, End-to-End Delay is 9.23209 ms, Jitter is 90.32 ms, PDR is 55.87808418 and Routing Load is 2.78961039.

In case of PUMA, with single receiver, Throughput is 399.86 Kbps, End-to-End Delay is 9.24323 ms, Jitter is 26.1ms, Packet Delivery Ratio is 83.65384615 and Routing Load is 2.195402299. Throughput is 620.82 Kbps, delay is 8.80541 ms, Jitter is 30.97 ms, PDR is 79.48717949 and Routing Load is 2.258064516 with 5 receivers. Throughput is 662.57 Kbps, End to End Delay is 8.70883 ms, Jitter is 30 ms, PDR is 76.6025641 and Routing Load is 2.305439331 with 10 receivers. Throughput is 691.22 Kbps, End-to-End Delay is 8.57816ms, Jitter is 28.67 ms, PDR is 73.3974359 and Routing Load is 2.362445415 with 15 receivers.

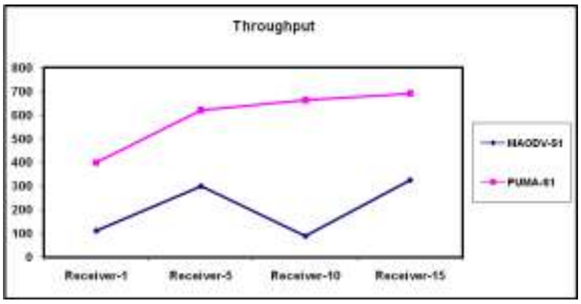


Figure:4 Throughput-Sender Node-1

Figure:5 shows that Throughput of PUMA is better than MAODV and it is gradually increasing w.r.t. to the density of receivers which vary from 1 to 15 nodes with single sender but it is unstable for MAODV.

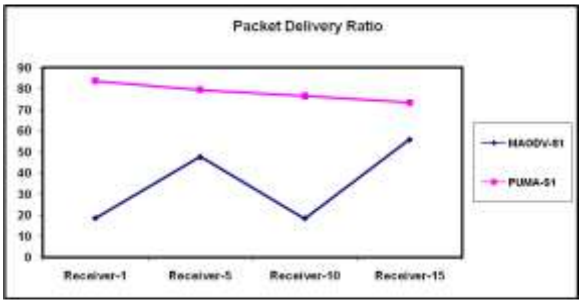


Figure:5 Packet Delivery Ratio-Sender Node-1

Figure:5 above shows the PDR of PUMA and MAODV. It is decreasing gradually for MAODV and there are variations in PDR for PUMA.

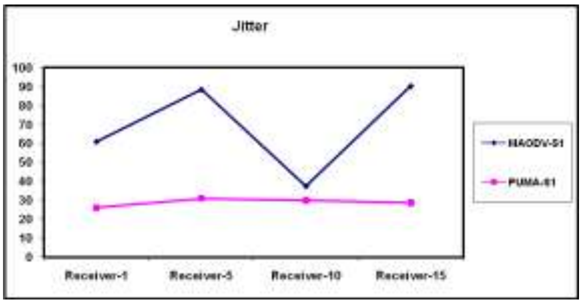


Figure:6 Jitter-Sender Node-1

Figure:6 above shows that value of jitter is approx. constant with little bit variations. In case of MAODV, it is varying w.r.t. each receiver.

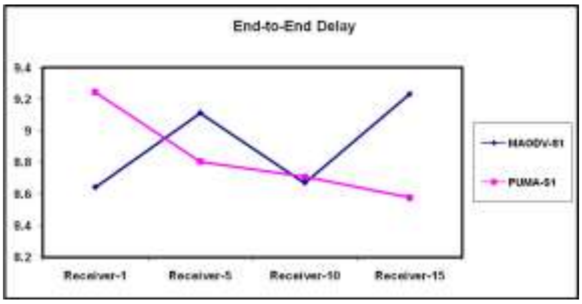


Figure:7 End-to-End Delay-Sender Node-1

Figure:7 above shows the End-to-End Delay which is increasing for MAODV but gradually decreasing for PUMA w.r.t. receiver density.

Figure:8 below shows that PUMA could manage the routing load as per receiver density but there are variation in routing load of MAODV.

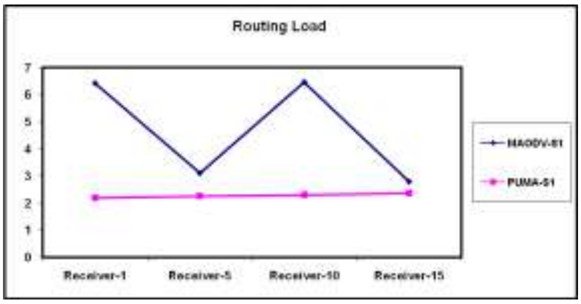


Figure:8 Routing Load-Sender Node-1

Performance Analysis-Sender Nodes-5, Receiver Nodes=1-15

Table:10 Throughput-Sender Nodes-5

	Receiver Node(s)	MAODV-S5	PUMA-S5
Throughput (Kbps)	1	388.13	451.84
	5	212.53	1125.31
	10	533.09	1455.12
	15	552.39	1421.37

Table:11 End-to-End Delay-Sender Nodes-5

	Receiver Node(s)	MAODV-S5	PUMA-S5
End-to-End Delay (ms)	1	8.92078	9.08142
	5	8.99029	8.55384
	10	9.05211	10.2928
	15	9.15993	10.7837

Table:12 Jitter-Sender Nodes -5

	Receiver Node(s)	MAODV-S5	PUMA-S5
Jitter (ms)	1	59.83	32.35
	5	37.54	51.13
	10	82.19	64.8
	15	82.11	54.97

Table:13 Packet Delivery Ratio-Sender Nodes -5

	Receiver Node(s)	MAODV-S5	PUMA-S5
Packet Delivery Ratio	1	16.16161616	20.70512821
	5	9.751359751	26.21794872
	10	27.7000777	33.26923077
	15	28.04972805	28.07692308

Table:14 Routing Load-Sender Nodes -5

	Receiver Node(s)	MAODV-S5	PUMA-S5
Routing Load	1	7.1875	8.969040248
	5	11.25498008	7.293398533
	10	4.610098177	5.959537572
	15	4.565096953	6.876712329

Table no. 10-14 above show the performance of MAODV and PUMA protocols using QoS parameters and there are 5 senders for multiple receivers. We can observe that in case of PUMA, variation in Throughput is directly proportional to the number of receivers but if density of receivers and senders are same, in that case, Throughput is slightly decreased. For MAODV, it is slightly decreasing for 5 receivers. For MAODV, Throughput using single receiver is 388.13 Kbps, End-to-End Delay is 8.92078 ms, Jitter is 59.83 ms, PDR is 16.16161616 and Routing Load is 7.1875.

With 5 receivers Throughput is decreased up to 212.53 Kbps, End-to-End Delay is 8.99029 ms, Jitter is 37.54 ms, PDR is 9.751359751 and Routing Load is 11.25498008.

With 10 receivers, Throughput is 533.09 Kbps, End-to-End Delay is 9.05211 ms, Jitter is 82.19 ms, PDR is 27.7000777 and Routing Load is 4.610098177.

With 15 receivers, Throughput is 552.39 Kbps, End-to-End Delay is 9.15993 ms, Jitter is 82.11 ms, PDR is 28.04972805 and Routing Load is 4.565096953.

For PUMA, Throughput using single receiver is 451.84 Kbps, End-to-End Delay is 9.08142 ms, Jitter is 32.35 ms, PDR is 20.70512821 and Routing Load is 8.969040248.

With 5 receivers Throughput is increased up to 1125.31 Kbps, End-to-End Delay is 8.55384 ms, Jitter is 51.13 ms, PDR is 26.21794872 and Routing Load is 7.293398533. With 10 receivers, Throughput is 1455.12 Kbps, End-to-End Delay is 10.2928 ms, Jitter is 64.8 ms, PDR is 33.26923077 and Routing Load is 5.959537572.

With 15 receivers, Throughput is 1421.37 Kbps, End-to-End Delay is 10.7837 ms, Jitter is 54.97 ms, PDR is 28.07692308 and Routing Load is 6.876712329.

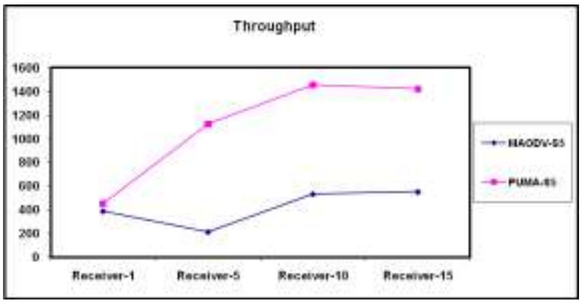


Figure:9 Throughput-Sender Nodes -5

Figure:9 above shows the Throughput of MAODV with some variations as compared to the Throughput of PUMA which is increasing w.r.t. density of receiver.

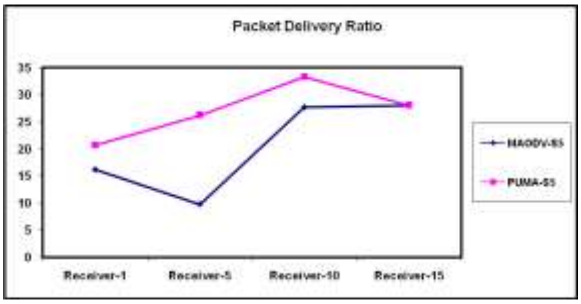


Figure:10 Packet Delivery Ratio-Sender Nodes -5

Figure:10 above shows the PDR of MAODV and PUMA which is increasing w.r.t. density of receivers.

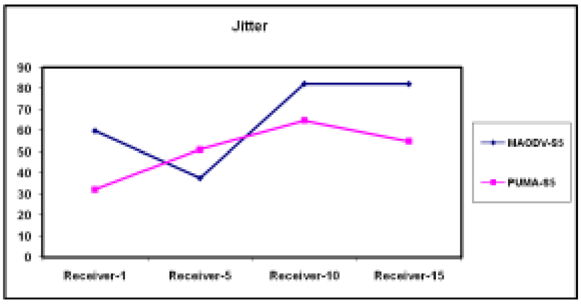


Figure:11 Jitter-Sender Nodes -5

Figure:11 above shows variations in Jitter for MAODV and PUMA. In case of MAODV, Jitter is increasing rapidly w.r.t. density of receivers. In case of PUMA, it is increasing gradually.

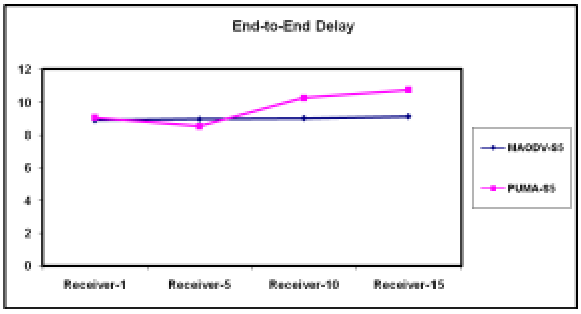


Figure:12 End-to-End Delay-Sender Nodes -5

Figure:12 above shows End-to-End Delay which remains approx. constant for MAODV but having some variations for PUMA w.r.t. receiver's density.

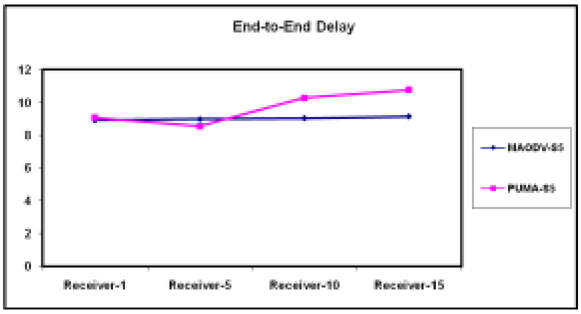


Figure:13 Routing Load-Sender Nodes -5

Figure:13 shows that Routing Load of MAODV is rapidly decreasing and it is also decreasing for PUMA with some little bit variations.

Performance Analysis-Sender Nodes=10

Table:15 Throughput-Sender Nodes-10

	Receiver Node(s)	MAODV-S10	PUMA-S10
Throughput (Kbps)	1	402.21	408.03
	5	205.62	1681.14
	10	237.11	2472.08
	15	514.29	2840.33

Table:16 End-to-End Delay-Sender Nodes -10

	Receiver Node(s)	MAODV-S10	PUMA-S10
End-to-End Delay (ms)	1	9.12459	9.96878
	5	9.36847	8.51165
	10	9.29884	9.44569
	15	9.10105	12.7848

Table:17 Jitter-Sender Nodes -10

	Receiver Node(s)	MAODV-S10	PUMA-S10
Jitter (ms)	1	56.01	26.86
	5	28.44	73.45
	10	34.31	108.97
	15	79.56	119.29

Table:18 Packet Delivery Ratio-Sender Nodes -10

	Receiver Node(s)	MAODV-S10	PUMA-S10
Packet Delivery Ratio	1	8.772221299	8.58974359
	5	4.136899817	18.81410256
	10	5.050672869	27.94871795
	15	11.3473999	30.51282051

Table:19 Routing Load-Sender Nodes -10

	Receiver Node(s)	MAODV-S10	PUMA-S10
Routing Load	1	12.39962121	23.45895522
	5	25.17269076	11.25383305
	10	20.79934211	7.902522936
	15	9.812591508	7.322478992

Table no. 15-19 above show the performance of MAODV and PUMA with 10 Senders. For MAODV, Throughput with single receiver is 402.21 Kbps, End-to-End Delay is 9.12459 ms, Jitter is 56.01 ms, PDR is 8.772221299 and Routing Load is 12.39962121.

With 5 receivers Throughput is decreased up to 205.62 Kbps, End-to-End Delay is 9.36847 ms, Jitter is 28.44 ms, PDR is 4.136899817 and Routing Load is 25.17269076.

With 10 receivers, Throughput is 237.11 Kbps, End-to-End Delay is 9.29884 ms, Jitter is 34.31 ms, PDR is 5.050672869 and Routing Load is 20.79934211. With 15 receivers, Throughput is 514.29 Kbps, End-to-End Delay is 9.10105 ms, Jitter is 79.56 ms, PDR is 11.3473999 and Routing Load is 9.812591508.

For PUMA, Throughput using single receiver is 408.03 Kbps, End-to-End Delay is 9.96878 ms, Jitter is 26.86 ms, PDR is 8.58974359 and Routing Load is 23.45895522.

With 5 receivers Throughput is increased up to 1681.14 Kbps, End-to-End Delay is 8.51165 ms, Jitter is 73.45 ms, PDR is 18.81410256 and Routing Load is 11.25383305.

With 10 receivers, Throughput is 2472.08 Kbps, End-to-End Delay is 9.44569 ms, Jitter is 108.97 ms, PDR is 27.94871795 and Routing Load is 7.902522936.

With 15 receivers, Throughput is 2840.33 Kbps, End-to-End Delay is 12.7848 ms, Jitter is 119.29 ms, PDR is 30.51282051 and Routing Load is 7.322478992.

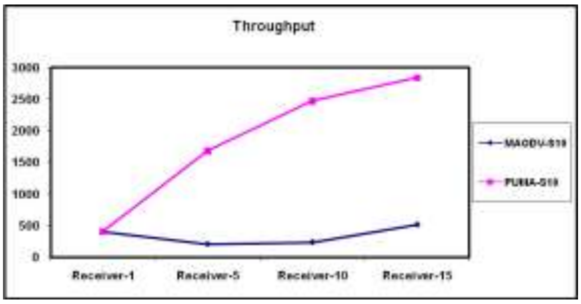


Figure:14 Throughput-Sender Nodes-10

Figure:14 above shows Throughput of MAODV which is increasing with some variations but it is rapidly increasing for PUMA w.r.t. receiver's density.

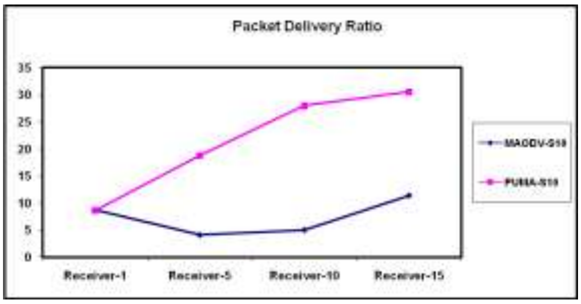


Figure:15 Packet Delivery Ratio-Sender Nodes-10

Figure:15 above shows PDR of MAODV which is increasing with little bit variations but it is rapidly increasing for PUMA w.r.t. receiver's density.

Figure:16 shows that variations in Jitter for MAODV and PUMA. It is increasing at constant level for PUMA and it has some variations for MAODV w.r.t. receiver's density.

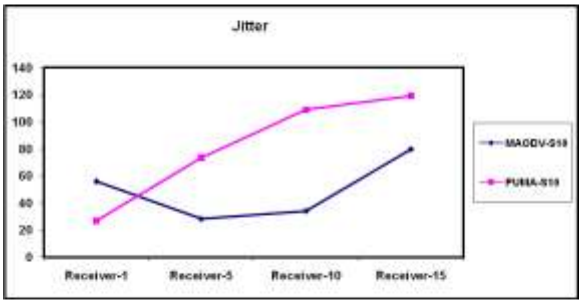


Figure:16 Jitter-Sender Nodes-10

Figure:17 shows Routing Load of MAODV and PUMA is decreasing with large scale variations. Figure:18 shows End-to-End-Delay of MAODV which remains approx. constant as compared to delay of PUMA which has some variations w.r.t. receiver's density.

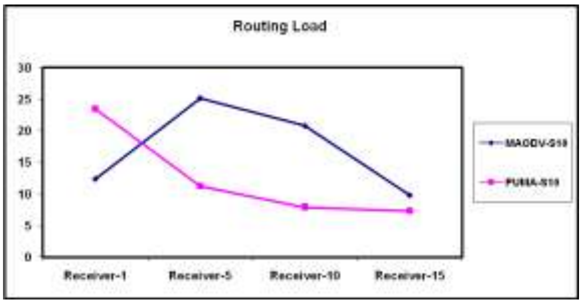


Figure:17 Routing Load-Sender Nodes-10

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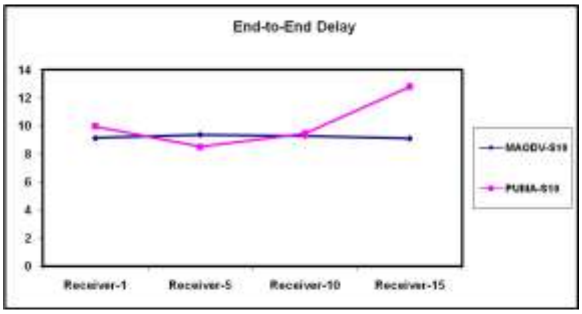

Figure:18 End-to-End-Delay-Sender Nodes-10

Performance Analysis-Sender Nodes-15

Table:20 Throughput-Sender-15

	Receiver Node(s)	**MAODV-S15**	**PUMA-S15**
Throughput (Kbps)	**1**	**191.18**	**375.81**
	5	**321.98**	**1582.09**
	10	**284.85**	**2769.85**
	15	**340.59**	**2911.18**

Table:21 End-to-End Delay-Sender Nodes-15

	Receiver Node(s)	MAODV-S15	PUMA-S15
End-to-End Delay (ms)	1	9.18632	8.27665
	5	8.92694	12.7847
	10	8.73005	13.1847
	15	8.70667	13.9543

Table:22 Jitter-Sender Nodes-15

	Receiver Node(s)	MAODV-S15	PUMA-S15
Jitter (ms)	1	33.44	23.02
	5	47.51	72.7
	10	42.45	113.83
	15	51.08	121.37

Table:23 Packet Delivery Ratio-Sender Nodes-15

	Receiver Node(s)	MAODV-S15	PUMA-S15
Packet Delivery Ratio	1	2.261200338	4.914529915
	5	4.57523246	12.43589744
	10	4.247675402	19.44444444
	15	5.082417582	20.64102564

Table:24 Routing Load-Sender-15

	Receiver Node(s)	MAODV-S15	PUMA-S15
Routing Load	1	45.22429907	42.14782609
	5	22.85681293	17.26116838
	10	24.54228856	11.4
	15	20.67567568	10.79710145

Table no. 20-24 above show the performance of MAODV and PUMA with 15 Senders. For MAODV, Throughput with single receiver is 191.18 Kbps, End-to-End Delay is 9.18632 ms, Jitter is 33.44 ms, PDR is 2.261200338 and Routing Load is 45.22429907.

With 5 receivers Throughput is increased up to 321.98 Kbps, End-to-End Delay is 8.92694 ms, Jitter is 47.51 ms, PDR is 4.57523246 and Routing Load is 22.85681293.

With 10 receivers, Throughput is 284.85 Kbps, End-to-End Delay is 8.73005 ms, Jitter is 42.45 ms, PDR is 4.247675402 and Routing Load is 24.54228856.

With 15 receivers, Throughput is 340.59 Kbps, End-to-End Delay is 8.70667 ms, Jitter is 51.08 ms, PDR is 5.082417582 and Routing Load is 20.67567568.

For PUMA, Throughput with single receiver is 375.81 Kbps, End-to-End Delay is 8.27665 ms, Jitter is 23.02 ms, PDR is 4.914529915 and Routing Load is 42.14782609.

With 5 receivers Throughput is increased up to 1582.09 Kbps, End-to-End Delay is 12.7847 ms, Jitter 72.7 ms, PDR is 12.43589744 and Routing Load is 17.26116838.

With 10 receivers, Throughput is 2769.85 Kbps, End-to-End Delay is 13.1847 ms, Jitter is 113.83 ms, PDR is 19.44444444 and Routing Load is 11.4.

With 15 receivers, Throughput is 2911.18 Kbps, End-to-End Delay is 13.9543 ms, Jitter is 20.64102564 ms, PDR is and Routing Load is 10.79710145.

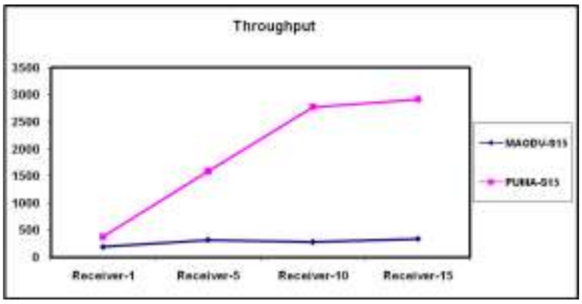

Figure:19 Throughput-Sender Nodes-15

Figure:19 above shows Throughput of MAODV which is quite less as compared to PUMA. In case of MAODV, it remains low with little bit variations. In case of PUMA, it is improving w.r.t. receiver's density.

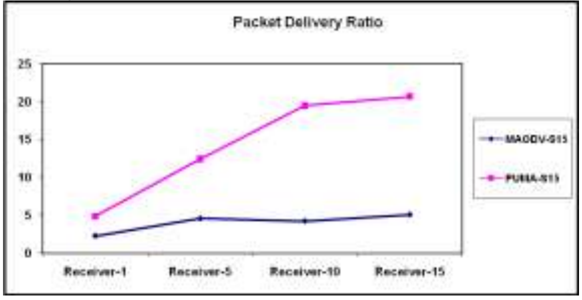

Figure:20 Packet Delivery Ratio-Sender Nodes -15

Figure:20 above shows PDR of MAODV which is less as compared to PUMA. PDR of MAODV has some variations but it is increasing for PUMA w.r.t. receiver's density.

Figure:21 below shows variations in Jitter for MAODV and PUMA. In case of MAODV, there are lot of variations but it remains less as compared to PUMA. In case of PUMA, it is increasing rapidly w.r.t. receiver's density which is quite higher than Jitter of MAODV.

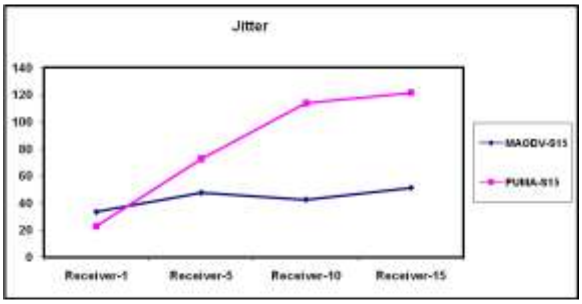

Figure:21 Jitter-Sender Nodes -15

Figure:22 below shows Routing Load of MAODV and PUMA and for both protocols it is decreasing in a constant manner but MAODV has higher load as compared to PUMA w.r.t. receiver's density.

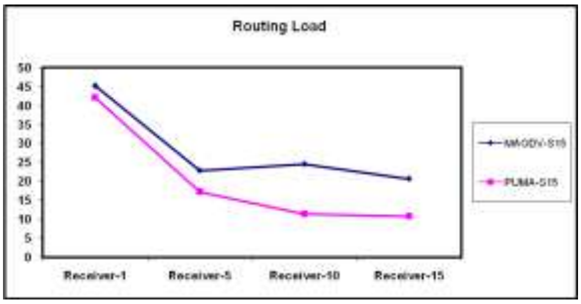

Figure:22 Routing Load-Sender Nodes -15

Figure:23 below shows End-to-End Delay of MAODV which is constantly decreasing as compared to PUMA w.r.t. receiver's density.

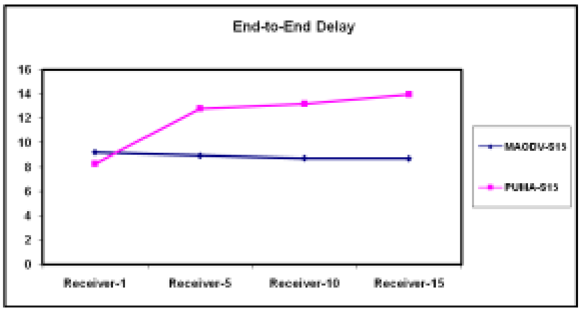

Figure:23 End-to-End Delay-Sender Nodes -15

V. CONCLUSION

In this research work, we investigated the performance of multicast routing protocols (MAODV, PUMA) using H.264/SVC video traffic under the QoS constraints. We used different simulation scenarios by varying the density of senders and receivers (1 to 15 nodes) and simulation results show the impact of these variations over the different QoS parameters i.e. Throughput, PDR, Delay, Jitter and Routing Load etc. In case of single sender, Throughput and PDR of PUMA is higher than MAODV w.r.t. receiver's density that varies from 1 to 15 nodes. Routing Load, Jitter and End-to-End Delay of PUMA is quite less as compared to MAODV. In case of 5 senders, there are variations in QoS parameters but still performance of PUMA is better than MAODV.

In case of 10 and 15 sender nodes, Throughput/PDR increases, Jitter and Delay both are compromised but routing load is reduced for PUMA as compared to MAODV. As per the simulation results, we can observe that PUMA protocol performed well because PUMA can reduce the extra control overhead and does not depend on any unicast protocol unlike MAODV. In case of MAODV, routing is affected by various factors i.e. high traffic load, maintenance of large multicast tree, frequent link breakages etc.

To encounter all these factors, scope of this research work can be extended to improve the performance of MAODV for high quality video transmission over multicast ad hoc networks. We will also consider the impact of Mobility and scalability over multicast routing protocols using multimedia streaming.

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