MULTIPATH VIRTUAL QUEUE MANAGEMENT SYSTEM FOR EFFECTIVE PACKET SCHEDULING IN MPLS NETWORKS

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Abstract
With the rapid development of communication and networking technologies VOIP has become an alternate to traditional telephony. These applications prefer timeliness in packet delivery. To perform load balancing, link utilization and to minimize the packet loss rate Multipath virtual Queue Management System for Effective Packet Scheduling in MPLS networks is proposed. The VoIP flows are dispersed into multiple available label switched paths to perform load balancing and link utilization. Virtual queues are maintained in all output ports to avoid queuing delay and HOL blocking. The proposed system ensures the arrival order of all the packets and plays back in the order of transmission. The performance of the proposed Virtual queuing system is compared with single path CSFQ queuing system with no virtual queue and Simulation results are proposed to show the efficiency of the proposed system.
Keywords: Virtual Queuing; Multipath Scheduling; Load Balancing; MPLS network; CSFQ; HOL; VoIP; packet reordering.

1. Introduction

Voice over IP (VoIP) is generally known as Internet telephony. Quality of Service (QoS) provisioning is very challenging task for these real time applications. This is because IP networks inherently suffer from network impairments such as packet loss, packet delay, and packet delay variation (jitter). QoS Performance relies on selecting best routing paths that have sufficient resources for all connections to be admitted and efficient resource utilization [Vinay Rishiwal *et al.* (2009)]. Queuing system has a vital role in improving the performance of packet scheduling.

Commonly used queuing disciplines are FIFO, LIFO and Priority. FIFO follows first-in first-out basis where as LIFO follows last-in first-out manner and Priority queue serves the packets in order their priority. Several queuing models like Poisson distribution model (M), Erlang distribution (E), General distribution (G), and General independent distribution (GI) are used to analyze the performance of queue. For example, the [M/M/1]:{infinity/infinity/FCFS} is a Poisson distribution arrival and distribution model with a single server, infinite queue length, infinite arrival process with FIFO queue discipline. This queue system is also simply referred to as the M/M/1 queue. Major matrix of standard quality assessment matrix [Hongli Zhang *et al.* (2011)] for VoIP QoS measurement is shown in Figure.1.

To perform load balancing and improve link utilization the proposed technique utilizes the Multiprotocol label Switching (MPLS) network. MPLS is an advanced packet-forwarding technique uses labels to make forwarding decisions [Hakim and Fouad (2006)]. Label switched path (LSP) is the routing path that starts with ingress Label switch router and terminates at egress LSR. The ingress nodes add the label for each incoming packet. The labels are detached from the egress border node, whenever the packet leaves the MPLS domain. With MPLS, the processing overhead required for routing at the intermediate nodes could be reduced, thereby improving their packet forwarding performance. In addition, the MPLS-Traffic Engineering (MPLS-TE) approach [Marc *et al.* (2007)] allows setting up explicitly routed Traffic Engineering-Label Switched Paths (TE-LSPs) whose paths satisfy a set of traffic engineering constraints, including bandwidth, throughput etc.

Link or node failures introduce additional overhead to reconfigure routing tables and find an alternative path for packet dispersion. Single path transmission selects one shortest path. This leads to load unbalancing and the path becomes more congested. To avoid this unbalancing situation and to utilize the entire available path a

Measuring item	MOS	R	Delay(ms)	Jitter(ms)	Loss(%)
Very satisfied	4.3-5	90-100	<130	<40	>0.4
satisfied	4．0-4.3	80-90			
Some users dissatisfied	3．6-4.0	70-80	130~400	40~60	0.4~1.0
many users dissatisfied	3.1-3.6	60-70	>400	>60	>1.0
Nearly all users dissatisfied	2．6-3.1	50-60			
Not recommended	1-2.6	0-50			

Fig. 1. VoIP QoS measurement.

Multipath virtual Queue Management System for Effective Packet Scheduling in MPLS networks is proposed in this paper.

2. Related Study

Several techniques have been proposed to implement Virtual output queue that can avoid HOL blocking and queuing delay [Nischal M *et al.* (2005)] [David K *et al.* (1998)] in a switching architecture. Virtual queuing based algorithm is introduced to asses switched packet delay and to avoid HOL blocking [Boussad Addad *et al.* (2011)]. The Virtual queue follows First in First out (FIFO) scheduling. Various delay metrics like intrinsic delays, nonsynchronization, over load condition are evaluated. This approach also considers the delay that occurs due to shared resources. The performance of the VoQ technique is measured for these delay metrics and shows VoQ technique is sutiable for packet switching architecture to reduce the packet delay.

Input/output contention-free switch architecture is designed with a virtual output queues [Ding Jyh *et al.* (2006)] (VOQ) to avoid Head-Of-Line problems. Small Timeto-leave Cell First (STCF) algorithm is proposed to make scheduling decision. It decides which output port the packet should be sent to, and making arbitration when more than one input ports request for the same output port. Service scheduling algorithms including FIFO, WFQ and strict priority queuing is also used for forwarding the packet from input ports to output ports according to the scheduling dispersing. HOL address cells are identified in request step to send immediate transmission requests.

Multipath Adaptive Forwarding Equivalence Class (MAFEC) algorithm is proposed [Laiquan and Jinkuan (2009)] to transmit the same-label-traffic into multiple available LSPs (label switch path). This technique tries to avoid routing oscillation and aims to increase efficient usage of network bandwidth. Fish network model is used to analyze and find multiple paths link-disjoint paths. The packets are transmitted on all available shortest LSP to perform link utilization.

Efficient Bandwidth Estimation Management is proposed for VoIP Concurrent Multipath Transfer [J.Faritha banu and Ramachandran (2012)]. The multiple paths for packet dispersion are computed using Grouping-based Multipath Selection and bandwidth on each path is elected based on Westwood approach. The packets are dispersed into multiple paths using SCTP protocol. This technique improves link utilization and performs load balancing. Bandwidth management technique for Multiprotocol Label Switched networks is proposed [Dongmei and Guangzhi (2008)] to allocate and share the bandwidth among many Label switched backup paths. Link usage information has to be distributed to all the nodes to estimate the amount of bandwidth to be shared. The technique identifies multiple paths between source and destination. The path failure or node failure utilizes the backup paths and bandwidth sharing among these paths increases network resource utilization.

Multipath dispersion introduces the out of order sequence delivery and causes additional resource consumption. To avoid side effects of reordering introduced by Concurent multipath transfer [Janardhan R. Iyengar *et al.* (2004)] have proposed an algorithm. This algorithm uses Virtual queue for each destination. Retransmission takes place from this virtual queue. The original play outs is not affected by this transmission.

Overly conservative congestion window growth at the sender is also reduced under the assumption of bottleneck queue on the end-to-end paths used in CMT is independent.

A reliable multipath routing for IEEE 802.16 wireless mesh networks is proposed (K. Valarmathi and Malmurugan (2011)] to perform interference load aware (ILA) routing. The source node selects multiple for the destination node. A value is associated with each path by evaluating QoS constraints. One path is notified as primary path and the alternate path is chosen from the set of multiple paths which has the second minimum value. In case of failure in alternate path, then source node chooses second alternate path that has next minimum value and this process continues. This technique tries to avoid congestion and packet losses.

3. Proposed System

3.1. *Virtual queuing*

Virtual queue is an imaginary FIFO (first-in–first-out) output buffer for each output port that holds k number of Virtual queue. Each virtual queue holds the Packets from particular flow (fi) and disperses the packets into multiple paths to achieve load balancing. In the proposed system each edge routers or ingress routers maintain multiple drop tail FIFO Virtual queues for each output interface. When the n numbers of multiple paths are selected for packet dispersion and k (k= n) number of virtual queue will be active for each port. Each virtual queue buffer holds VoIP packets for each label switched path (LSP).

The ingress router consults the load adapter to take forwarding decisions and the packet is stored in the appropriate output VQ. Queuing delay can be minimized by placing the incoming packet immediately in the appropriate queue. Each packet may also be directed to any output virtual queue, but one packet can leave from real queue. HOL blocking is eliminated by transmitting a packet from input port to virtual queue output port in any order. First packet is not held up with a packet.

The ingress router of proposed system is shown in the Figure. 2. with Virtual queue. Real queue follows round robin dispersion. Edge routers assign labels to each packet based on the flow rate and destination address. The core router maintains only one virtual queue for each output port. Load balancing is invoked and flows splitter splits the flows into n multiple paths in the ingress router. Core router disperses the packets into one specified path defined by the ingress router. The packets may arrive at out of order sequence in core routers. Packet reordering techniques is used at the destination node buffer to avoid out of order sequence.

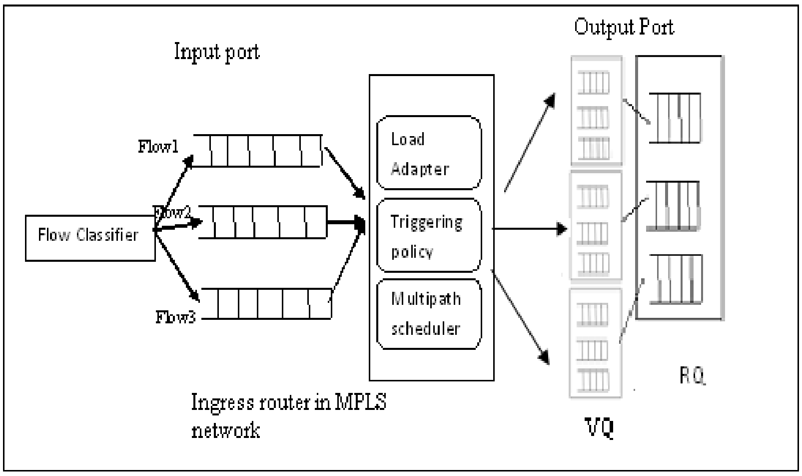

Fig. 2. MPLS ingress router with multiple Virtual Queue.

Flow classifier classifies the flows into VoIP flow and Non VoIP flow. Load adapter continuously evaluates the incoming flows to check for system balancing load condition. When the system becomes unbalanced, load adapter invokes Flow splitter and triggering policies [J.F.Banu and V.Ramachandran (2012)]. Flow splitter is used to split the flow of packets (fi) into multiple available parallel paths. The multiple paths are selected based on the given QoS constraints. Triggering policy replaces no dispersion policy with multipath routing. MPLS ingress router flow splitting for virtual queue is shown in Figure. 3.

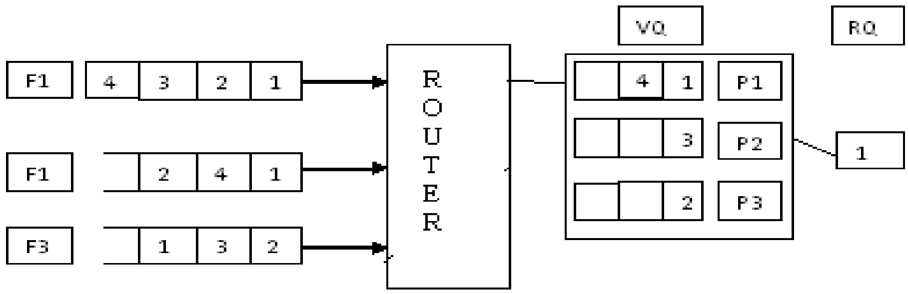

Fig. 3. MPLS ingress router Flow splitting.

Packets belonging to a flow f1 are dispersed in FIFO order to port1 of virtual queue. The packet can be placed in any of the available queue. Virtual queue 1 corresponds to path1 and virtual queue2 corresponds to path2 and so on. For example the first packet can be placed in the vq1 and second packet in vq3. Waiting time of a packet in an input queue can be eliminated by processing arrived packet immediately. Each packet may also be directed to any output virtual queue, HOL blocking is eliminated.

MPLS core router with virtual queue is shown in Figure.4. This core router also avoids HOL blocking. For example the second packet in the second queue which is destined for output 4 cannot reach that output port if there is no virtual queue system.

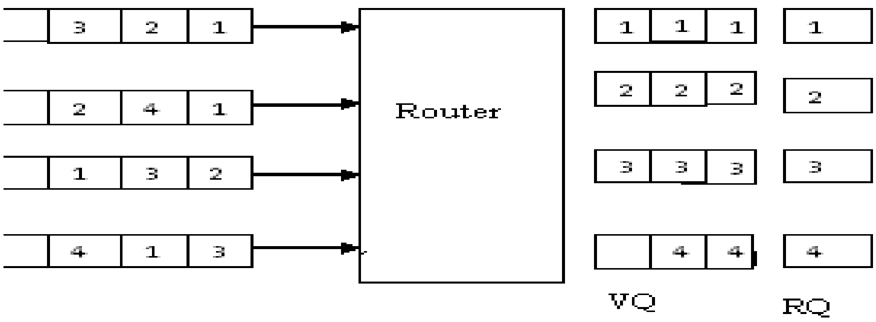

Fig. 4. MPLS core router with Virtual queue and HOL blocking.

3.2. ***Load adapter and triggering Policy***

Load adapter measures system load by using Buffer Occupancy Threshold (BOT) policy. When the queue occupancies of the active users exceed a threshold value, triggering policy is invoked. Queue occupancy threshold can be set to the ¾ of the total available buffer space [J.F.Banu and V.Ramachandran (2012)]. The triggering policy overrides the default routing policy (no dispersion policy) with multipath routing policy when the system is in unbalanced state. This multipath routing policy uses periodic round robin scheduling where the packets are dispersed into multiple label switched path which satisfies the given QoS constraints in a round robin fashion (cyclic manner) over the paths. Bandwidth and delay are the two QoS constraints considered in the proposed approach.

3.3. ***Multipath Routing***

To achieve load balancing and improve link utilization VoIP packets are dispersed into multiple disjoint paths. For a given source-destination pair multiple set of disjoint paths are computed in an MPLS network. Multipath routing increases fault-tolerance and reliability. MPLS router can split the same label traffic flow into different paths with the given traffic engineering constraint. QoS constraints like minimum delay and maximum bandwidth are considered for splitting a given flow dynamically into these multiple paths. In the proposed multipath routing MPLS ingress router evaluates the flow rate and destination address and inserts a label into each packet. Core routers do not maintain any per flow state information. They make forwarding decision based on their labels. Multipath routing tries to achieve load balancing by splitting the traffic into multiple paths as shown in Figure. 5.

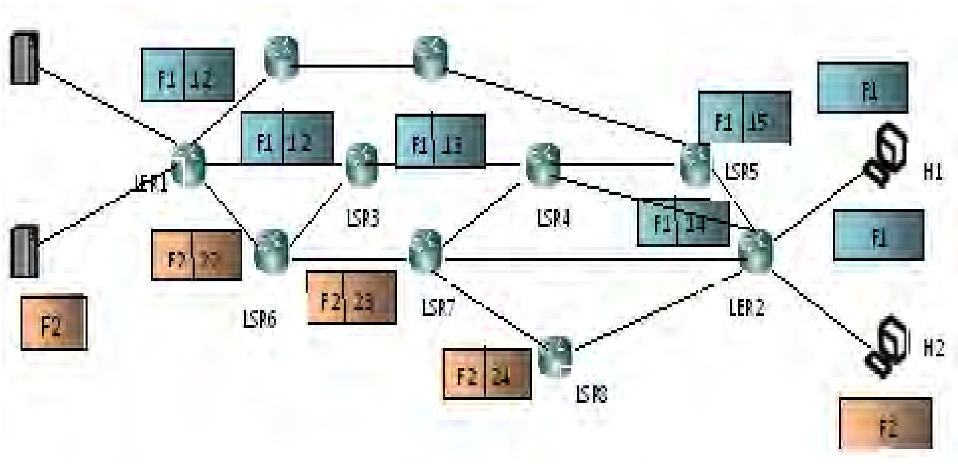

Fig. 5. MPLS multipath Routing .

Ingress router LSR1 receives packets from server1 (flow1) and inserts a label into these packets. LER1 divides the flow1 from server1 into two Label Switched paths (LSP) and distributes the packets concurrently. LSP1 for the flow1 follows LER1—LSR1—LSR2—LSR5—LER2 and LSP2 for the flow1 follows LER1—

LSR3—LSR4—LER2 and LSP1 for flow2 from server2 follows LER1—LSR6—LSR7—LSR8—LER2. Finally LER2 removes the labels and transmits the packets to host1 and host2. Algorithm for load balancing and multipath routing is shown in Figure .6.

Algorithm (For load balancing and multipath routing)
1. Find P, a set of disjoint loop less path from S to D
2. Find path p_i from the set of disjoint loop less path (P) such that $bw(p_n) = Bw_{req}(f1)$ and $d(p_i) = d_{req}(f1)$
3. Select k backup path from the set P { $p_1, p_2, p_3 \ldots P_k$ } where k is the maximum number of edge disjoint paths
Which statisfies the following bw and delay requirements

$$Bw(p_1) + Bw(p_2) + Bw(p_3) + \ldots\ldots Bw(p_k) = Bw_{req}(f1) \text{ and}$$
$$d(p_1) + d(p_2) + d(p_3) + \ldots\ldots d(p_k) = d_{req}(f1)$$

3. For load balancing
If Queue occupancy >= BOT
{
Split Traffic flow among all these k disjoint paths
Disperse the packets using round robin dispersion. }
else
{
Disperse into the a path p_i }

Fig. 6. Algorithm for load balancing and multipath routing.

3.4. *Packet reordering*

Packets are arrived in out of order sequence because of multi path dispersion, parallel paths in routers and load balancing. TCP generally preserves the ordering before delivery of entire message to the destination. In the proposed system packets are delivered using UDP / IP protocol. The ordering of packets becomes essential since multiple parallel paths and load balancing is used to disperse the packets. Simple and efficient reordering technique is used to recover from the out-of-order sequence, also identifies the packet loss and duplication at the destination.

Each packet is assigned with a sequence number at the Sender. The receiver receives the packet and checks whether the packets are in a continuous monotonic sequence number order. The receiver also assigns sequence number called receiver index R for the received packet and calculates the displacement d. For the duplicate packet and lost packets receiver will not assign an index. Consider a sequence of packets S and S = {1, 2 …… N} are transmitted to the receiver. Arrival sequence (AR) of packets at the receiver is recorded in the arrival buffer as in the order of their arrival. AR = {1, 2 …… N}. Receiver assigns receiver index as R = {1, 2, 3 ….. N}.

Displacement d is the difference between receiver index and arrival sequence. If d = 0 for each packet then no reordering required. If d > 0 packet is considered as late arrival and d < 0 packet arrived early. Lost packets and duplicate packets will not have receiver index. A packet is considered lost if it arrives after a threshold on the displacement of packets or if the corresponding sequence number is not there in the arrival buffer.

A packet is considered as duplicate if its sequence number is repeated in the arrival buffer. Displacement threshold is considered as d > 2. Figure.7. shows late arrival and early arrival and lost packets and packet reordering approach. Packets 10,12,13,14 are arrived earlier and packet 8 arrived late. Packet 12 is received twice and recognized as duplicate packet and packet 11 is considered as lost because it exceeds displacement threshold value 2.

Arrived Sequence (AR)	5	6	7	10	9	8
Receiver index (R)	5	6	7	8	9	10
Displacement (d)	0 (in order)	0 (in order)	0 (in order)	-2 (early)	0 (in order)	2 (late)

Arrived Sequence (AR)	12	12	13	14	11
Receiver index (R)	11	--	12	13	14
Displacement (d)	-1 (early)	Duplicate	-1 (early)	-1 (early)	3 (Lost)

Fig. 7. Packet reordering.

4. Simulation Result

The proposed technique is simulated with the network simulator (ns-2) [isi.edu]. The topology consists of three sender and 3 destination node. These nodes connected to 20 MPLS enabled label switched routers (LSRs). Different link bandwidth and delay are assigned between them. Both CBR and VoIP traffic with random exponential loss rate of 0.05. QoS metrics like received bandwidth (throughput) and packet loss rate are taken for evaluation. The proposed technique is compared with single path CSFQ dispersion routing strategy.

The throughput is measured for various time inter1vals by varying the load from 100Mbps to 700Mbps. Packet loss rate is measured by varying the load from 100Mbps to 800Mbps. The proposed system (MPVQ) attains good throughput and minimum packet loss rate when compared with single path Core Stateless Fair Queuing (SPCSFQ) is shown in figure. 8-9.

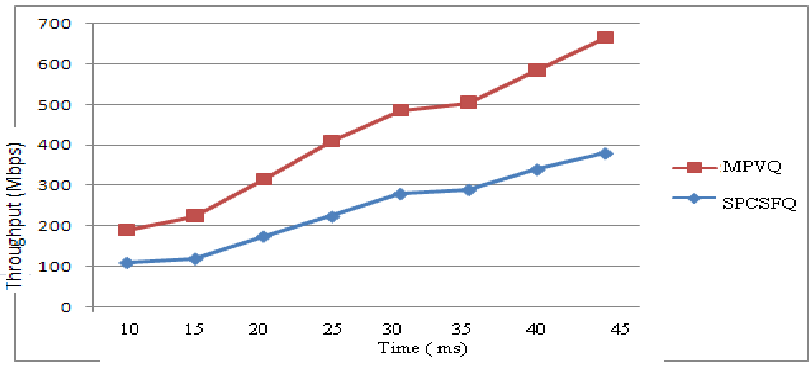

Fig. 8. Time Vs Throughput.

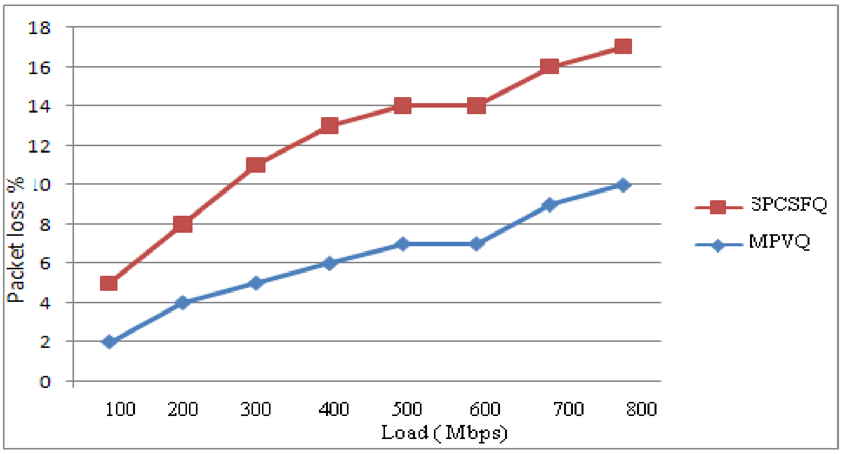

Fig. 9. Load Vs packet Loss Rate.

5. Conclusion

In this paper, Multipath virtual Queue Management System for Effective Packet Scheduling in MPLS networks is proposed that contains a flow classifier which classifies the flows as VoIP and non VoIP flows. Load adapter checks for the system load balancing and invokes flow splitter and triggering policies. Flow splitter splits the VoIP flows into multiple QoS guaranteed paths and stores the VoIP packets into the appropriate virtual output queue. Multiple Virtual queue for each selected path is active and avoids queuing delay and HOL blocking. The trigger handler invokes multipath dispersion to disperse the packets into round robin manner. The received packets are reordered to get continuous play out at the receiver. By various simulation results, it is shown that the proposed technique attains good throughput with less packet loss drop when compared with single path routing strategy.

References

[1] Banu,J.F. V. Ramachandran. (2012). *Multipath adaptive packet dispersion for voice applications*, ,J. Comput. Sci., vol.8, pp. 454-459. DOI:10.3844/jcssp.2012.454

[2] Boussad Addad, Saïd Amari, Jean-Jacques Lesage. (2011) . *A Virtual-Queuing-Based Algorithm for Delay Evaluation in Networked Control Systems*, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 58, NO. 9, pp. 4471- 4479.

[3] David K. Hunter, Meow C. Chia, Ivan Andonovic. (1998). *Buffering in Optical Packet Switches*, Journal of lightwave technology, vol. 16, no. 12, pp. 2081- 2094.

[4] Ding Jyh Tsaur, Hsuan-Kuei Cheng, Chia-Lung Liu, Woei Lin. (2006). *A Study of Matching Output Queueing with a 3D-VOQ Switch*, ICOIN 2006, LNCS 3961, pp. 429 – 439, Springer-Verlag.

[5] Dongmei Wang, Guangzhi Li. (2008). *Efficient Distributed Bandwidth Management for MPLS Fast Reroute*, IEEE/ACM Transactions on Networking, Vol.16.No.2, pp 486-495.

[6] Hakim Mellah, Fouad Mohammed Abbou. (2006). *Labled Burst Switching*, Journal of applied Sciences, pp. 6:1814-1817. DOI: 10.3923/jas.2006.1814.1817.

[7] Hongli Zhang, Zhimin Gu and Zhenqing Tian. (2011). *QoS Evaluation Based on Extend E-Model in VoIP*, ICACT2011, pp. 852-854.

[8] http://www.isi.edu/nsnam/ns/doc

[9] Janardhan R. Iyengar, paul D. Amer, Randall Stewart. (2004). *Retransmission policies for concurrent multipath transfer using SCTP multihoming*, ICON 2004 , vol.2, pp.713 – 719.

[10] J.Faritha banu, V. Ramachandran. (2012). *Efficient Bandwidth Estimation Management for VoIP Concurrent Multipath Transfer,International Conference on Computer Science and Engineering (ICCSE)*, Chennai, July 29, PP.37-42.

[11] K. Valarmathi , N. Malmurugan.(2011). *Reliable Multi Path Routing For 802.16 Wireless Mesh Networks*, Indian Journal of Computer Science and Engineering (IJCSE), Vol. 2 ,No. 6 , pp. 966 – 975.

[12] Laiquan Han , Jinkuan Wang. (2009). *An Adaptive MPLS Multipath Transmission Algorithm, International Conference on Research Challenges in Computer Science*, pp. 182- 186. DOI 10.1109/ICRCCS.2009.54

[13] Marc Portoles Comeras, Josep Mangues Bafalluy, and Marc Cardenete-Suriol. (2007). *Performance issues for VoIP call routing in a hybrid ad hoc office environment*, Proc, IEEE, 16th IST on Mobile and Wireless Communications Summit.,pp:1-5.

[14] Nischal M. Piratla, Anura P. Jayasumana, Abhijit A. Bare. (2005). *Reorder Density (RD): A Formal, Comprehensive Metric for Packet Reordering*, Networking , LNCS 3462, pp. 78 – 89.

[15] Vinay Rishiwal, S. Verma and S. K. Bajpai. (2009). *QoS Based Power Aware Routing in MANETs*, International Journal of Computer Theory and Engineering , vol. 1, no. 1, pp. 49-54.