Analysis of Bandwidth Utilization for Wireless Mesh Networks

Nagendra Sah, Neelam Rup Prakash, and Deepak Bagai

***Abstract*—Mobile Ad-hoc networks are characterized as networks without any physical connections. In these networks there is no fixed topology due to the mobility of nodes, interference, multi-path propagation and path loss. One particularly challenging environment for multicast is a mobile ad-hoc network (MANET), where the network topology can change randomly and rapidly, at unpredictable times.In this paper, it is proposed to analyze the possibilities of improving the quality of service in multicast routing by using Priority based Bandwidth Reservation Protocol (PBRP) for wireless mesh networks. The routing Protocol used here is On Demand Multicast Routing Protocol (ODMRP),DVMRP and PIM-DM. By simulation results, it is shown that the proposed protocol achieves high bandwidth utilization and throughput with reduced delay, when used in multicast routing protocols.**

***Index Terms*—Wireless mesh networks (WMN), quality of services (QoS), routing protocols.**

I. Introduction

Wireless mesh networks (WMN's) contains several stationary wireless routers which are interlinked by the wireless links. Wireless routers acts as the access points (APs) for wireless mobile devices. Through the high speed wired links, some wireless routers act as a gateway for internet. Wireless mobile devices transfer data to the corresponding wireless router and further these data's are transferred in a multi-hop manner to the internet via intermediate wireless routers. The popularity of WMN's is due to their low cost and auto-organizing features [1].

Multi-channel wireless mesh network architecture requires topology discovery, traffic profiling, channel assignment and routing. This includes static aggregation nodes similar to the wireless LAN access points. For the construction of multi-channel wireless mesh networks MCWMN, 802.11b interface hardware is used because it can handle the bandwidth problem. Every node in a multi-channel wireless mesh networks MCWMN includes multiple 802.11 complaint NIC's and it is tuned to a particular radio channel for long duration such as hours or days [2].

In case of high speed digital audio and videos, multimedia application requires the source of inflexible Quality of Service (QoS), when compared with traditional application. The purpose of proper Bandwidth allocation is essential for these conditions. The crucial factors for QoS in real time multimedia applications are the Bandwidth allocation and delay factors [3].

Manuscript received February 11, 2013; revised August 19, 2013.

The authors are with the PEC University of Technology, Chandigarh, India (e-mail: nagsah@yahoo.com).

The challenges faced in wireless media for Bandwidth allocation on multimedia application includes [4]

- Harmful effects such as Fading and co-channel interferences (CCI) causes distortion in channels.
- The resources such as Bandwidth and power are limited.
- The data rates in multimedia application are irregular.
- System efficiency and fairness are the service factors which are given more importance among individuals.

In this paper authors propose a new multicast protocol for Mobile Ad Hoc networks, called the Multicast routing protocol based on Zone Routing (MZR). MZR is a source-initiated on demand protocol, in which a multicast delivery tree is created using a concept called the zone routing mechanism [5].

In this paper, authors present a performance study of three multicast protocols: ODMRP, ADMR, and SRMP. Multicast Routing in Mobile Ad hoc NETworks (MANETs) is a recent research topic. Source Routing-based Multicast Protocol, (SRMP) is a new on-demand multicast routing protocol that applies a source routing mechanism and constructs a mesh to connect group members [6].

In this paper, authors focus on one critical issue in Mobile Ad hoc Networks (MANETs) that is multicast routing. In fact, optimal routes, stable links, power conservation, loop freedom, and reduced channel overhead are the main features to be addressed in a more efficient multicast mechanism [7].

In this paper, the authors describe the reliability of the On-Demand Multicast Routing Protocol (ODMRP) in terms of the delivery of data packets in response to the important role that multicasting plays in wireless mobile multi hop ad hoc networks. Using GloMoSim 2.0, the simulation results have shown that using ODMRP, the average miss ratio does not always increase with increasing the speeds of mobility of the mobile hosts in the ad hoc network. Instead, there is a "sweet spot" of values of the mobility speeds of the mobile hosts. In addition, the averages miss ratio decreases with increasing the number of multicast group members, which indicates that ODMRP has more packet delivery capabilities for denser multicast groups. [8]

In this paper, authors present a comparative performance evaluation of three general-purpose on demand multicast protocols, namely ADMR, MAODV, and ODMRP, focusing on the effects of changes such as increasing number of multicast receivers or sources, application sending pattern, and increasing number of nodes in the network [9].

In this paper, authors analyze the performance of multicast routing protocol PIM-SM to provide suggestions of improving this protocol. PIM-SM is preferred among the current intra domain multicast routing protocols. But it is not widely deployed in Internet till now [10].

DOI: 10.7763/IJIMT.2013.V4.456

In this paper, authors analyze the effective techniques to avoid congestion and losses in networks by multipath routing. Multiple shortest paths are discovered based on the combined routing metric and the source node chooses the path with minimum weight value as the primary path. The path with next minimum weight values are selected as back up paths. Initially the data transmission takes place using the primary path and during any fault, it can be switched over the backup paths [11].

II. Problem Statement

It is very difficult to improve the efficient routing in multicast transmission in wireless mesh networks due to bandwidth constraints. It is proposed if the band width utilization is improved by using the bandwidth reservation protocols between multi-nodes of multicast wireless mess network, then there should be efficient transmission between different nodes. In this simulation a priority based bandwidth reservation protocols is used [12].

The proposed protocol consists of two phases namely Bandwidth Request phase and Bandwidth Reply phase. In the Bandwidth Request Phase, a Bandwidth Request (BREQ) message is forwarded from the node that requests the admission of a new traffic flow to its destination. During this phase bandwidths are not reserved. The BREQ message consists of traffic flow specifications and the requested bandwidth.

Next in the Bandwidth Reply Phase, a Bandwidth Reply (BREP) message proceeds backwards, hop-by-hop, from the destination node to the node that originated the request along the path laid down by the corresponding (BREQ) message. The destination node precedes the reply according to the priority of traffic classes and reserves the bandwidth on the reply path.

In the Bandwidth Request Phase the bandwidths are not reserved and only the necessary messages are transmitted to the destination. The source is required to select the TFID of any new flow in such a way that the source, destination, TFID uniquely identifies the traffic flow in the network.

In this phase, the destination sends back to the source a BREP message and it is routed through the same path that has been enclosed by the BREQ message. This is obtained by using the list of intermediate node IDs included in the BREQ message. On receiving the BREP message, each node reserves the bandwidths according to the priority of the traffic.

If the nodes do not receive packets until the traffic flow is dropped for a particular amount of time TS, then the bandwidth remains allocated. The source generates probe packets to guarantee an established traffic flow state on each node in the path to prevent premature termination of the traffic flow. Probe packets are the messages which include the information about their traffic and these packets are discarded by the receivers in the MAC layer. The generation interval of the probe packets must be smaller than the TS. Generally, by transmitting the probe packets it consumes the bandwidth which is already reserved for the traffic flow in the data sub-frame.

A. *Two Ray Ground Model*

The Two Ray Ground model is also a large scale model. It is assumed that the received energy is the sum of the direct line of sight path and the path including one reflection on the ground between the sender and the receiver. It is shown that this model gives more accurate prediction at a long distance than the free space model [1]-[4]. The received power at distance d is predicted by:

$$P_r(d) = P_t\, G_t\, G_r\, h_r^2\, h_t^2 / d^4 L$$

where h_t and h_r are the heights of transmit and receive antennas respectively.

B. *Ricean and Rayleigh Fading Models*

These two models are fading models, meaning that they describe the time-correlation of the received signal power. Fading is mostly caused by multi-path propagation of the radio waves. If there are multiple indirect paths between the sender and the receiver, Rayleigh fading occurs. If there is one dominant (line of sight) path and multiple indirect signals, Ricean fading occurs [4].

C. *Shadowing Model*

The shadowing model of ns-2 realizes the log-normal shadowing model. It is assumed that the average received signal power decreases logarithmically with distance. A Gaussian random variable is added to this path loss to account for environmental influences at the sender and the receiver. The shadowing model consists of two parts. The first one is known as path loss model, which also predicts the mean received power at distance d, denoted by $Pr(d)$. It uses a close-in distance $d0$ as a reference. $Pr(d)$ is computed relative to $Pr(d0)$ as follows.

$$Pr(d0)/Pr(d) = (d / d0)\beta$$

β is called the path loss exponent, and is usually empirically determined by field measurement. The shadowing model extends the ideal circle model to a richer statistic model: nodes can only probabilistically communicate when near the edge of the communication range.

III. Multicast Routing Protocols

A. *On-Demand Multicast Routing Protocol (ODMRP)*

The On-Demand Multicast Routing Protocol (ODMRP) falls into the category of on-demand protocols since group membership and multicast routes are established and updated by the source whenever it has data to send. Unlike conventional multicast protocols which build a multicast tree, ODMRP is mesh based. It uses a subset of nodes, or forwarding group, to forward packets via scoped flooding. ODMRP consists of a request phase and a reply phase. When a multicast source has data to send but no route or group membership information is known, it piggybacks the data in a Join-Query packet. When a neighbor node receives a unique

Join-Query, it records the upstream node ID in its message cache, which is used as the node's routing table, and re-broadcasts the packet. The side effect of this process is to build the reverse path to the source. When a Join-Query packet reaches the multicast receiver, it generates a Join-Table packet that is broadcast to its neighbors. The Join-Table packet contains the multicast group address, sequence of pairs, and a count of the number of pairs. When a node receives a Join-Table, it checks if the next node address of one of the entries matches its own address. If it does, the node realizes that it is on the path to the source and thus becomes a part of the forwarding group for that source by setting its forwarding group flag. It then broadcasts its own Join-Table, which contains matched entries. The next hop IP address can be obtained from the message cache. This process constructs the routes from sources to receivers and builds the forwarding group. Membership and route information is updated by periodically sending Join-Query packets.

Nodes only forward (non-duplicate) data packet if they belong to the forwarding group or if they are multicast group members. The forwarding group nodes flood data packets, ODMRP is more immune to link/node failures (e.g., due to node mobility). This is in fact an advantage of mesh-based protocols.

B. *Distance Vector Multicast Routing Protocol (DVMRP)*

DVMRP is a distance vector routing protocol. It uses flooding and pruning to build the multicast tree. The routers in the leaf subnets have group membership information. When a router receives a flooded packet, it knows whether that packet will be useful for its subnet or not. In case there is no group member on the subnet, the leaf router sends a prune message to its neighboring routers. In addition, a leaf router can send a prune message through all interfaces except for the one on the reverse shortest path to the sender. When an intermediate router receives prune messages from all interfaces except for the reverse shortest path interface, it forwards the prune message upstream. This way, the unwanted branches of the spanning tree get pruned off. When a router sends a prune message, it maintains information about the (Source, Group) pair for which the prune message was sent. This state is used to prevent propagation of the data packets when they arrive at those routers.

DVMRP is a soft-state protocol in the sense that the state in the routers times out, and hence the process of flooding and pruning needs to be repeated periodically. However, if a member wants to join a group before the next flooding takes place and there is no host on the subnet currently subscribed to the group, DVMRP allows the corresponding router to send a graft message. The graft message propagates upstream using the reverse path forwarding interface until it reaches a router that is part of the shortest path tree. In fact, a graft message cancels the prune state at the relevant router.

C. *PIM-DM (Protocol Independent Multicast–Dense Mode)*

This is PIM operating in dense mode (PIMDM), but the differences from PIM sparse mode (PIM-SM) are profound enough to consider the two modes separately. PIM also supports sparse-dense mode, with mixed sparse and dense groups, but there is no special notation for that operational mode. In contrast to DVRMP and MOSPF, PIM-DM allows a router to use any unicast routing protocol and performs RPF checks using the unicast routing table. PIM-DM has an implicit join message, so routers use the flood and prune method to deliver traffic everywhere and then determine where the uninterested receivers are. PIM-DM uses source-based distribution trees in the form (S, G), as do all dense-mode protocols.

IV. Results And Discussion

The QUALNET-5.0 simulator has been used for proposed protocol. It has the facility to include multiple channels and radios. It supports different types of topologies such as chain, ring, multi ring, grid, binary tree, star, hexagon and triangular. The supported traffic types are CBR and MCBR. In this simulation, 20 mobile nodes are arranged in a topology of size 1500 meter x 1500 meter region. All nodes have the same transmission range of 250 meters. In our simulation, the speed is set as 5m/s.

TABLE I: Experimental Set-Up

Area	1500X1500 m^2
Transmission range	500 m
Number of nodes	200
Physical / Mac layer	IEEE 802.11 at 2 Mbps
Mobility model	Random waypoint model with no pause time
Maximum mobility speed	1-20 m/s
Simulation duration	500 s
Pause time	0
Packet size	512 bytes
Traffic type	CBR (Constant Bit Rates)
Number of packets	5/second
Number of multicast sources	1,2,5,10,15 nodes
Number of multicast receivers	10,20,30,40,50 nodes
No. of simulations	20

Performance matrices used:

1) Control packet load: the average number of control packet transmission by node in the network. Control packets include any of QUERY, REPLY, PASSREQ, CONFIRM, HELLOW and ACK packets.
2) Packet delivery ratio: the ratio of data packet sent by all the sources that is received by a receiver.
3) Data packet overhead: the number of data transmissions performed by the protocols per successfully delivered data packet.
4) Control packet overhead: the number of controlled transmissions performed by the protocols per successfully delivered data packet.
5) Total packet overhead: the total control and data overheads per successfully delivered data packet. This matrix represents the multicast routing efficiency.

The simulation environment for the proposed work consists of four models:

1) Network model
2) Channel model
3) Mobility model
4) Traffic model

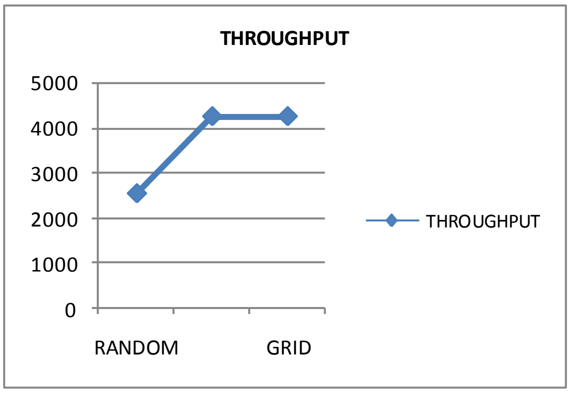

Fig. 4(a). Calculation of throughput (Bits/Sec).

In Different Placement Model
No of Channels-1
No of Nodes-20
Path Loss Model-Two Ray
Speed Range 0-10mps
Traffic Source-Cbr
Mobility Model-Random
Pause Time-30sec
Physical Layer Protocol-Phy 802.11b
Data Link Layer Protocol-Mac 802.11s
Channel Frequency-2.4mbps

This shows that throughput of server in uniform and grid placement model is more than random placement of nodes. This is because chances of data loss in random environment are more. Average throughput signifies the rate of packets communicated per unit time.

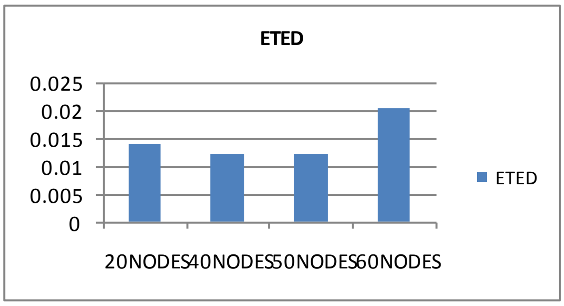

Fig. 4(b). End to end delay(s) for different nodes.

No of Channels-1
Path Loss Model-Two Ray
Speed Range 0-10mps
Placement Model-Random
Traffic Source-Cbr
Mobility Model-Random
Pause Time-30sec
Physical Layer Protocol-Phy 802.11b
Data Link Layer Protocol-Mac 802.11s
Channel Frequency-2.4mbps

Higher end-to-end delay values imply that the routing protocol is not fully efficient and causes a congestion in the network. The values of end- to- end delay for the protocol ODMRP fairly increases with no of nodes are increased.

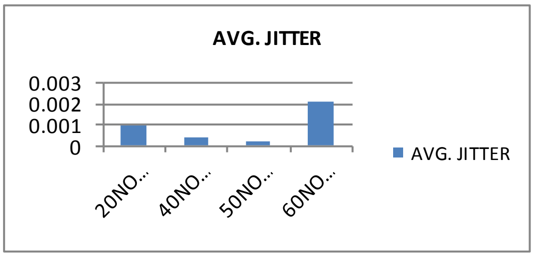

Fig. 4(c). Calculation of average jitter at diff nodes.

No of Channels-1
Path Loss Model-Two Ray
Speed Range 0-10mps
Placement Model-Random
Traffic Source-Cbr
Mobility Model-Random
Pause Time-30sec
Physical Layer Protocol-Phy 802.11b
Data Link Layer Protocol-Mac 802.11s
Channel Frequency-2.4mbps

Jitter is defined as the difference between the expected time of arrival of a packet and the actual time of arrival. Jitter is caused primarily by delays and congestion in the packet network. Jitter causes discontinuity.

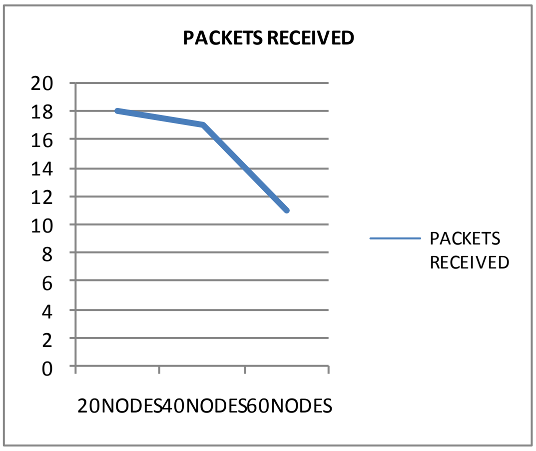

Fig. 4(d). Packets received at different node condition.

No of Channels-1
Path Loss Model-Two Ray
Speed Range 0-10mps
Placement Model-Random
Traffic Source-Cbr
Mobility Model-Random
Pause Time-30sec
Physical Layer Protocol-Phy 802.11b
Data Link Layer Protocol-Mac 802.11s
Channel Frequency-2.4mbps

In ODMRP, every source node will periodically send out route requests through the network. When the number of source nodes becomes larger, the effect of this causes congestion in the network and the data delivery ratio drops significantly. There is decline in packet delivery ratio as the multicast group increases. This can be attributed to collisions that occur from the frequent broadcasts through the network.

The performance of DVMRP, ODMRP and PIM-DM are investigated and analyzed based on the results obtained from the simulation. A number of experiments are performed to explore the performance of these protocols with respect to a number of nodes (randomly).

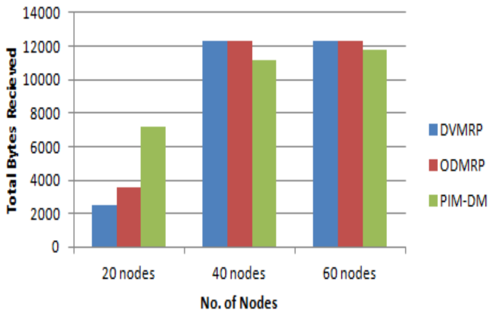

Fig. 4(e). No. of nodes VS total byte received.

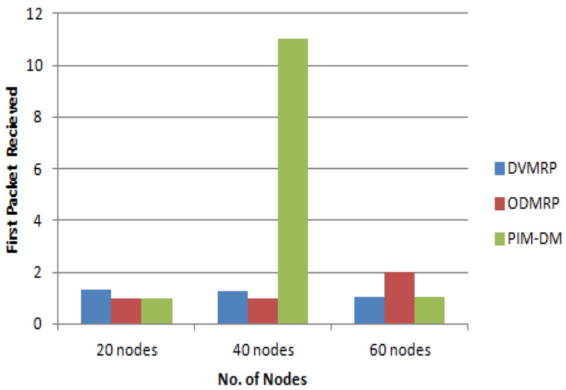

Fig. 4(f). No. of nodes VS first packet received.

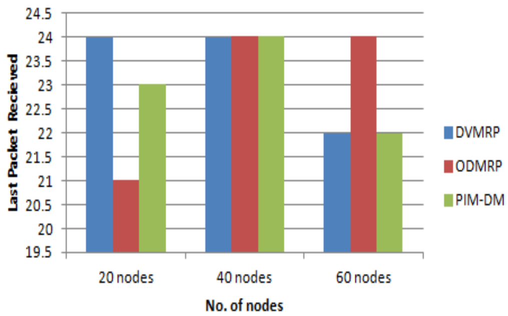

Fig. 4(g). No. of nodes VS last packet received.

From Fig. 4(e) to Fig. 4(j), it is observed that all protocols performance is affected by the increasing number of nodes in the network. Increased network traffic results in packet loss due to buffer overflow and congestion. When nodes are placed randomly, no. of bytes received at server increased by increasing no. of nodes for ODMRP as shown in Fig. 4(e). For DVMRP, bytes received increase from 20 to 40 nodes but after that remain same. The received bytes increase with no. of nodes for PIM-DM also. For ODMRP, the average ETED decreases but remains almost same. For PIM-DM firstly ETED is small but suddenly increase after that its ETED decreases. Fig. 4(f) and Fig 4(g) show the first and last packet received. Fig. 4(h) shows that Total Packet Received is highest for ODMRP and lowest for DVMRP. Fig. 4(i) shows that throughput is highest for ODMRP and lowest for DVMRP. For ODMRP, throughput increases from 40 to 60 nodes but after that falls for 20 nodes. The same thing happens for DVMRP and PIM-DM. For all kinds of traffic load, ODMRP outperforms other two protocols. ODMRP uses a forwarding group, to forward packets to receiver via scoped flooding. This path redundancy enables ODMRP suffer minimum data loss. The average ETED increases for DVMRP as no. of nodes increase as shown in Fig. 4(j).

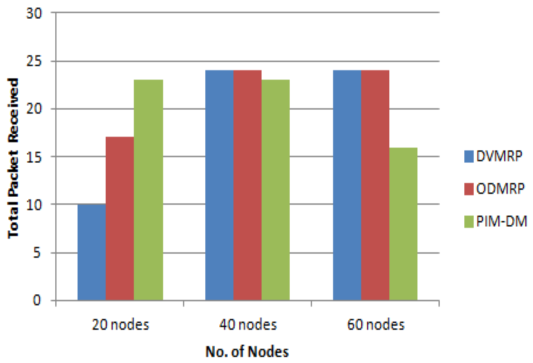

Fig. 4(h). No. of nodes VS total packet received.

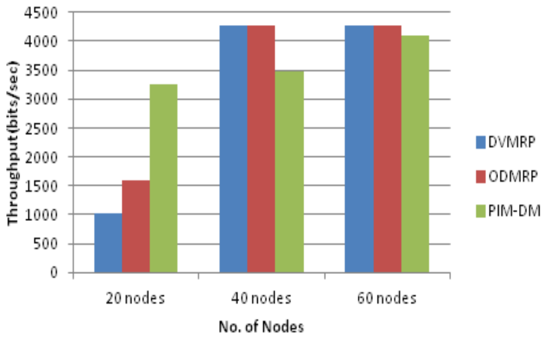

Fig.4(i). No. of nodes VS throughtput.

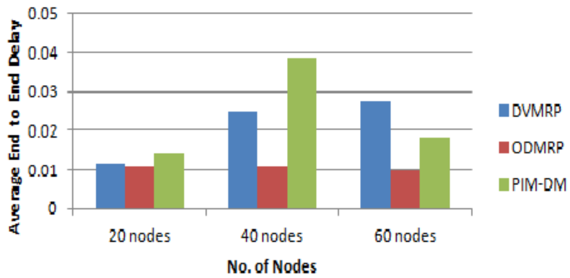

Fig. 4(j). No. of nodes VS average ETED.

V. Conclusion

By simulation results, it is seen that the proposed technique of bandwidth utilization has increased the throughput with reduced delay and overhead as compared to without using bandwidth utilization technique. Our results also indicate that on increasing the no of nodes in the network leads to congestion which further degrades the performance of the ad hoc network. Therefore a trade-off has been made between the no. of nodes and congestion. The results obtained are better as compared to the simulation done by using NS2 [12].

References

[1] L. Blondia, B. Moerman, and Demeester, "A cluster driven channel assignment mechanism for wireless mesh networks," in *Proc. 5th IEEE International Conference on Mobile Ad Hoc and Sensor Systems*, Oct. 2008.

[2] R. Gopalan and Chiueh, "Centralized channel assignment and routing algorithms for multi-channel wireless mesh networks," *Mobile Computing and Communications Review*, vol. 8, April 2004.

[3] K. Bur and C. Ersoy, "Ad hoc quality of service multicast routing," *Computer Communications*, vol. 29, no. 1, 2005.

[4] Z. Han and K. J. R. Liu, *Resource allocation for wireless networks: Basics, techniques, and applications*, Cambridge University Press, 2008.

[5] V. Devarapalli and D. Sidhu, "MZR: A multicast protocol for mobile ad hoc networks," *IEEE*, 2001.

[6] H. Moustafa and H. Labiod, "A performance comparison of multicast routing protocols in ad hoc networks" in *Proc. The 14m IEEE 2003 International Symposium on Persona1, lndoor and Mobile Radio Communication*, *IEEE*, 2003.

[7] H. Moustafa and H. Labiod, "A performance analysis of source routing-based multicast protocol (srmp) using different mobility models," *CNRS*, *IEEE*, 2004.

[8] A. Sobeih, H. Baraka, and A. Fahmy, "On the reliability of odmrp in mobile ad hoc networks," *IEEE*, 2004.

[9] J. G. Jetcheva and D. B. Johnson, "A performance comparison of on-demand multicast routing protocols for ad hoc networks," December 15, 2004.

[10] D. Li, J. P. Wu, K. Xu, X. P. Zhang, Y. Cui, and Y. Liu, "Performance analysis of multicast routing protocol PIM-SM," *IEEE*, 2005.

[11] K. Valarmathiand and N. Malmurugan, "Reliable multipath routing for 802.16 wireless mesh networks," in *Proc. Indian Journal of Computer Science and Engg*., vol. 2, no. 6, pp. 966-976, January, 2012.

[12] K.valarmathiand and N. Malmurugan, "A priority based bandwidth reservation protocol for wireless mesh networks," in *Proc. International Journal of Computer Science*, vol. 9, issue 1, no. 1, pp. 90-95, January, 2012.

Nagendra Sah was born in Jaynagar, India, on May 1, 1960. He is an assistant professor in PEC University of Technolgy (Formerly PEC-Deemed University), Chandigarh, India. He has done his B. Tech degree in Electronics and Communication Engg. From National Institute of Technolgoy, Warangal, Andhra Pradesh, India in 1986 and Master of Engg. Degree in Electronics Engg. From Panjab University, Chandigarh, India in 2005. He has teaching experience of about 18 years. Presently, he is working as Assistant Professor. He has published about 40 papers in national and international conferences and in international journals. His research is focused on the radio-system design, wireless communication and networking and modeling of mobile radio propagation and the development of simulation methods for a mobile radio channels.

Neelam Rup Prakash was born on March 3, 1965. She is an associate professor in PEC University of Technology, Chandigarh. She has done her B.E., M.E. and Ph. Ph. D. from Panjab University, Chandigarh. She has the teaching experience of 26 years. She has published about 50 papers in national and international conferences and in international journals. Her research is focused on Communication, Digital Design & Computer Aided Diagnostics.

Deepak Bagai was born on Nov. 13, 1963. He is an associate professor in PEC University of Technology, Chandigarh. He has done her B.E., M.E. and Ph. Ph. D. from Panjab University, Chandigarh. He has the teaching experience of 27 years. He has published about 50 papers in national and international conferences and in international journals. His research is focused on Communication Networks.