Congestion Avoidance in Wireless Mesh Network using improved PREQ frame in Hybrid wireless mesh protocol

Rahul V. Mane[1], Vijaykumar V. Patil[2]
[1] Department of Electronics &Tele-Communication Engineering, K.I.T's College of Engineering, Kolhapur, Maharashtra, 416234, India
[2] Asst. Prof. Department of Electronics Engineering, K.I.T's College of Engineering, Kolhapur, Maharashtra, 416234, India

Abstract- *The wireless technology is one of the main segment of mobile applications with mobility support at low deployment costs. And these, Wireless Mesh Network (WMN) is one of the technologies that supports mobile users for un-disrupted, reliable data connectivity, provides high bandwidth even in areas, where access of such services is difficult. Additionally, it features abilities like self-configuring, self-healing, and self-organizing. IEEE present a MAC standard for WMN enhancements named IEEE 802.11s for multi-hop networks. Within this standard, the required routing protocol called Hybrid Wireless Mesh Protocol (HWMP) is proposed for efficient utilization of resources to achieve high bandwidth at MAC layer. To enhance this protocol, a congestion avoiding protocol was proposed, which utilizes alternate paths just before the congestion state is reached. The proposed technique does not add any overhead, it utilizes path request frame, which is already part of standard. This paper explore simulation results of the proposed routing protocol against the existing HWMP protocol for packet delivery fraction, throughput and delay. The results indicate that the proposed technique significantly improves performance of IEEE 802.11s.*

Keywords- Wireless Mesh Network, HWMP,PREQ Frame Congestion Control, Congestion Avoidance.

I. INTRODUCTION

Hybrid Wireless Mesh Protocol is the integral routing protocol for IEEE 802.11s standard that include dynamic routing algorithms and effective in setting up reliable and flexible transmission paths. The major focus in designing this protocol was to make the network and devices technology independent such that devices that are not in each-other's communication area can also communicate effectively. This routing algorithm involve both reactive and proactive routing into the network. The reactive elements utilize radio metric for being compatible to reactive ad hoc on demand distance vector protocol. In its proactive form, the routing algorithm appear routing information for reaching root mesh point proactively. This routing protocol include features form Ad hoc On-demand Distance Vector (AODV) protocol.

In IEEE 802.11 standard, ad hoc mode nodes can connect each other without any central entity or coordinator such as an Access Point (AP). There are many interesting applications where ad hoc mode is not sufficient to fulfill the requirements, like support of internet connectivity and presence of client nodes. Therefore, both types of modes i.e. infrastructure and ad hoc are integrated in a new type of wireless network, named as Wireless Mesh Network. IEEE 802.11s inherently depends upon one of the IEEE 802.11 variants like a, b, g, and n for multi-hop WMN.

There are many applications which are efficiently supported by WMN. It is also used in building automation control, emergency and safety applications due to its self-healing, self-configuring and self organizing capabilities. WMN solutions provided by different organizations. WMN is one of the important technologies for next generation wireless networking due to some of its advantages over other wireless networks. WMN can be infrastructure backbone WMN client WMN , or Hybrid WMN.

HWMP protocol delivers reliable, dynamic and less congested transmission path. The major idea of executing new protocol is to communicate devices effectively which are not in a communication area to each other i.e. hard are anodes. This algorithm delivers both Reactive and Pro-active routing in the network. The reactive mode utilize on demand routing i.e. Ad-hoc Distance Vector Routing Protocol. In Proactive mode utilizes tree based data structure which has Root node maintain routing table to keep routes to all destination. The main limitation in HWMP protocol is insufficient to come up with congestion.

Congestion Control Mechanism apply when congestion present in the network. This system provides limit the flow of packets when congestion occurs. This contain operations which are monitoring, detection and then controlling of congestion. These methods are insufficient in more congested scenario. Only congestion signaling part is mention in HWMP where rest of congestion control technique is not specified. However, various congestion control mechanism are proposed in literature to settle this problem but anyway these methods are not sufficient to derive efficient network performance.

However Congestion Avoidance is better at congestion structure than congestion control mechanism which takes the decision when network is already experiencing congestion. When a queue size extend above threshold value then that node broadcasts the CCNF frame to immediate node. Then neighboring nodes find the new path to send their packet to destination and avoid the more congested path which is proposed in Congestion Avoidance Algorithm CA-HWMP. Thus the congestion is avoided.

Also In this paper, Modified PREQ in HWMP for Congestion Avoidance Mechanism is proposed to provide continuous transmission on a congested path until it rerouting to a new less congested path. When a packet transmitted from new path the old path will be deleted to avoid any further delay. This technique ensures performance in the network which increases the network throughput, packet delivery fraction and average delay.

II. RELATED WORK

Gang Feng, Fei Long, and Yide Zhang proposed a modification in hop-by-hop mechanism by including feedback mechanism in distributed manner. This technique needed two NICs on each node at the same time, which operates independently. The mechanism is first derived algorithm for end-to-end, then it is further derived for hop-by-hop congestion control to control source rate end to end. This algorithm works with the assumption of total knowledge of each flow on on each intermediate node. The controlling algorithm is responsible for monitoring incoming and outgoing transmissions and it performs computation on each relay node to sum all congestion states and maximum transmission rate for each flow. The intelligent part of it is that it chooses smaller value for maximum possible rate for transmission. The drawback of this mechanism is additional cost for extra NICs and increase in overhead due to continuous feedback mechanism. There is an additional processing and synchronization cost because of combined algorithms to control congestion on each node.[9]

Barbara Staehle, Michael Bahr, Deshang Fu, and Dirk Staehle, proposed “Intra-mesh Congestion Control for IEEE 802.11 s Wireless Mesh Networks.” There are different algorithm for intramesh congestion solving different issues using congestion notification. Total congestion control (TCC), Link selective congestion control and Path selective congestion control (PSCC) were presented which resolved some scenario but in some issues these algorithm not working well. In TCC algorithm when congestion at node on receiving congestion frame then total traffic is jamed. In LSCC algorithm on congestion scenario it limits the traffic for specific link by blocking data packets for specific node. In PSCC, congested node broadcast CCNF to limit the traffic for particular destination. The congested node provides this information by adding a destination address for a particular flow into CCNF. For the announcement of particular destination, this algorithm requires modification in the standard CCNF. On receiving modified CCNF, a node only blocks sending data for a particular destination, but it continuously receives data for that specific node. The scenario becomes more complex when CCNF frame is further broadcast to immediate node in a continuous chain. These algorithms rectify congestion problems in some scenarios of multi-hop WMN uses IEEE 802.11s MAC. [4]

Raniwala, A. De, P. Sharma, S. Krishnan, R. Tzi-cker Chiueh, presented "Globally fair radio resource allocation for wireless mesh networks," During this approach the protocol determines the resources distributed among the links under same collision domain and employs advanced topology discovery and max-min fair resource allocation technique to confirm lower congestion in the domain. A max-min fair is a technique of increasing resource share to a new flow by taking it from an existing flow having already a smaller share. In a single wireless domain, each link gets a share of present bandwidth proportional to the number of flows traversing it. In an irregular collision domain, where not all nodes can see the packets from other nodes, unnecessarily slows down their flow rate and creates congestion by reducing channel capacity. The proposed technique helps nodes in a collision domain evaluate the traffic in the domain perfectly and allocates resources accordingly. This technique is helpful because unlike symmetric collision domain, instead of allocating equal share of available resources, it distributes it based on queue build up. If a node sees a queue is building up, it decreases its channel capacity calculate and lowers its flow rate. On the other hand, if none of the nodes sees any queue increase, the channel capacity estimate increases and flow rate increases. [7]

Kishwer Abdul Khaliqa, Sajjad Hussainb, Amir Qayyuma, J¨urgen Pannek proposed "New data link layer encoding scheme for multi hop WMN" They use special feature of cut through switch that decreses delay in the network and also increases throughput reducing re-transmission in the network. This algorithm for some cases not works well. [2]

Fawaz A. Khasawneh**,** A. Benmimoune**,** Michel Kadoch **,** Mohammed A. Khasawneh proposed “Predictive Congestion Avoidance in Wireless Mesh Network.” In this approach, an

Enhanced Congestion Avoidance - HWMP (ECA-HWMP) is proposed which predicts the congestion in each link in the network by applying two statistical inspection methods which are Croston and Holt-Winter methods. The two methods rely on the historical data collected in advance to forecast the future data. Since ECAHWMP predicts the congestion before it really happens in the network, the overhead created by the congestion control signaling in HWMP protocol is reduced. However, the prediction process has some level of certainty (>95%) and in some cases (<5%) a congestion threshold will be reached and CCNF signals will be broadcasted. [1]

Kishwer Abdul Khaliq, Muhammad Sajjad Akbar, Amir Qayyum, Ehsan Elahi, Amer Zaheer proposed "Congestion Avoidance Technique for Hybrid Mesh Protocol". In this approach when a number of packet gets more than particular queue size level then the CCNF broadcast to show congestion in network. The neighboring node find the new path to send packet to destination on receiving the CCNF and to avoid the path that has already a congestion. Thus, the congestion is avoided. One of the added advantage of this mechanism is that it is not only helps avoiding congestion but also helps in load balancing. This approach gives weak response for interactive application. [3]

III. PROPOSED MECHANISM

Congestion control technique is used when congestion occurs into the network. Congestion Control has three operations monitoring, detection of congestion, processing of congestion control and control the flow of packets. When congestion occur packet drop from queue due to this performance of network is reduced and also increases the burden on a specific node. To avoid this problem they used Congestion Avoidance algorithm to avoid congestion before this occur i.e. comparing node queue level with specific threshold value to broadcast CCNF to its immediate node, but in congestion sensitive applications it is not a good idea because of it create extra packet overhead.

In our proposed technique, path selection is performed at MAC layer; instead of IP layer therefore we utilized new protocol for congestion avoidance using modified PREQ in HWMP for Congestion Avoidance Mechanism in the Wireless Mesh Network. Our proposed routing protocol Modified PREQ in HWMP for Congestion Avoidance Mechanism in the Wireless Mesh Network is the new approach in the current mandatory Protocol CA-HWMP for IEEE 802.11s monitor queue size at congested node. The basic variables used in the proposed mechanism are same as used in the CA-HWMP i.e. PREQ, PREP, PERR and RANN. In our Enhance approach routing protocol when volume of packet in the queue at node reaches specified value then it monitor the maximum threshold value and then broadcast the CCNF frame to its immediate node. All the immediate nodes, who send data to P^{th} node i.e. destination, will send new PREQ to search the new less congested path to the destination skipping the old paths through the node P. In current CA-HWMP protocol re-routing new path from congested path at this scenario packet will stop transmission on congested link due to this more delay introduced in the network to route from congested path to new path. This situation definitely degrades the throughput so for sensitive application like crisis and safety management it is inadequate to handle the congestion scenario. For that our new proposed algorithm is to transmit continuously packet on congested path until it reroute to a new path. When a packet transmitted from new path the previous path will be deleted to avoid any further delay. This leads to higher throughput in the network. For this we utilized sequence number to avoid flooding in the network. This algorithm enhances capability of network.

Considering a scenario given in figure1 in which node B and E are immediate neighbor of node A. Node A sends packet to node P, the desired path selected by its routing protocol HWMP is A-E-I-M-N-O-P. As proposed routing protocol monitor the queue size at every mesh node. At node I, there is congestion because of queue size come near above maximum threshold value, then routing protocol at node I, broadcast CCNF frame to its immediate nodes and CCNF forwarded to all whichever receive CCNF, i.e. when CCNF received at source A it sends PREQ for new path. Then PREQ forwarded to all and dropped by node I. When PREQ received at node P it sends PREP. PREP reaches source A from new path except node I. Now data flow will be ongoing through new path i.e. A-B-C-D-H-L-P. The packet that was queued because of no present any enhance routing congestion avoiding mechanism, will now forward to destination node using this newly less congested established path. This mechanism enhances throughput. This mechanism allows packet transmission on the rerouting path instead of existing path.

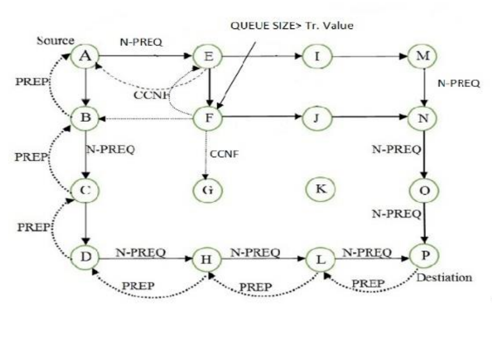

Fig -1: Modified PREQ in HWMP

IV. SIMULATION SETUP

For the detailed examination of Hybrid Wireless Mesh Protocol, Network simulator (NS3) provides 802.11s module in the WMN. This simulator is open source and provides new functionality of implementation of new enhanced protocols into it, because of this advantage we analyses our enhance routing congestion avoidance protocol, we implement successfully into mesh module of NS3 using C++.

For implementation and comparative study analysis of both protocols, we have implemented UDP On-off application which transmit packet at a constant bit rate. For simulation we have consider transmission rate from 150Kbps to 350Kbps on UDP transport protocol. For Mesh topology we use HWMP grid topology (x*y) where number of node enhances in both axis where distance between two nodes is 170m. Initially, we consider 4*4 grid then increase the value of x and y.

For our approach analysis we consider effect of application Transmission Rate on throughput. We have considered different scenario by changing number nodes in the HWMP grid for simulation of different routing path.

GENERAL SIMULATION PARAMETER

1. Operating System- Ubuntu 14.04.3 Desktop
2. NS 3 version -NS 3.24.1
3. Wi-Fi Standard- IEEE 802.11s
4. Routing Protocol at MAC- HWMP
5. No. of nodes- 4, 9, 16, 25
6. Max Queue Size- 65%
7. Packet size- 1024kB
8. Transport layer protocol-UDP
9. Traffic Flows- Constant Bit Rate
10. Tx. Rate- 150Kbps

V. SIMULATION RESULTS

Fig2 shows the throughput for this scenario. The simplest case is with 4 number of nodes, and transmission is simplest because all nodes are in the vicinity of one another. In the same scenario, the second case is with 9 mesh nodes and there is still less chances to use of alternate paths, and device rate is also 3 times greater than the application rate. Therefore throughput observed using both routing protocol is almost same. When mesh nodes are increased to 16, in case of both protocols, the availability of second best path also greater than previous case. The only possibility of packets drop from queue is, When queue becomes full. But if we continue to increase in number of relay nodes in grid, the graph shows the increasing throughput degradation behavior while using HWMP. The packet drop ratio increases when more nodes enter in network to communicate. When we added more nodes in network, the new entering nodes generate more data to send/share in the network. However, by increasing mesh nodes in the network, there is also a increase in control overhead because of exchange of control messages.

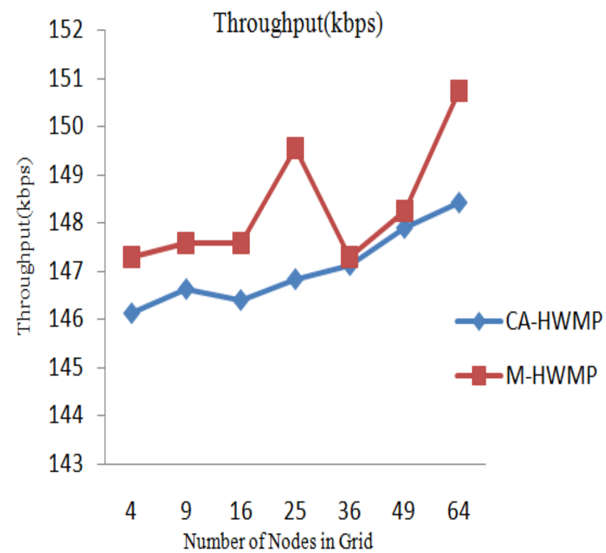

Fig -2: Throughput

The second evaluation parameter that we consider for evaluation of our proposed mechanism is Packet Delivery Fraction (PDF) to examine the network behavior on increasing data rate. This PDF is achieved by evaluate percentage receiving data-rate at receiving nodes. When the number of nodes increases in the grid, the PDF decreases due to increase of intermediate hops, contention for channel access and control overhead. In-spite these factors, with the increase in flows, the PDF decreases on relay nodes due to buffer overflow in absence of congestion control mechanism in HWMP.

The graph lines in Figure 3, presents no significant difference observed between both protocols when we have 4 and 9 nodes grid. With the increase in mesh nodes from 9 to 16 along 50% traffic flows, the M-HWMP PDF gain is greater than CA-HWMP due to the greater possibility of alternate paths. In case of 36 mesh nodes, though more nodes are available to disseminate data, however PDF gain in M-HWMP is better as compared to CA-HWMP. The simulation results show that some packets are dropped due to buffer overflow and some packet lost because of wireless reasons HWMP. With the use M-HWMP this PDF increases. In case of 64 mesh nodes, this PDF degradation is noticed. The reason is that packets drop from the queue due to greater difference between incoming and outgoing traffic rate. But the buffer overflow on relay nodes is not only reason, packets also drop due to wireless channel access, interference, packet collisions.

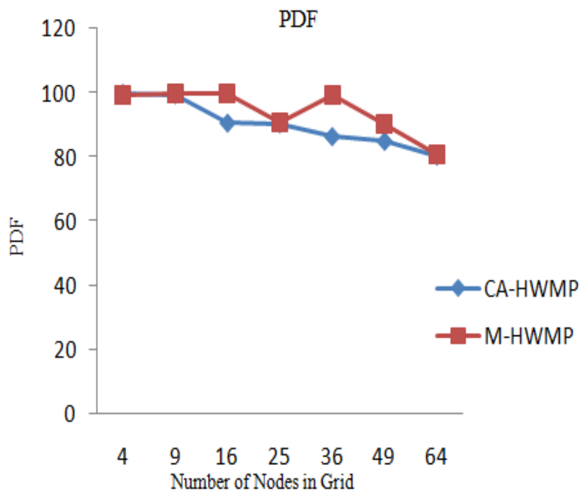

Fig -3: PDF

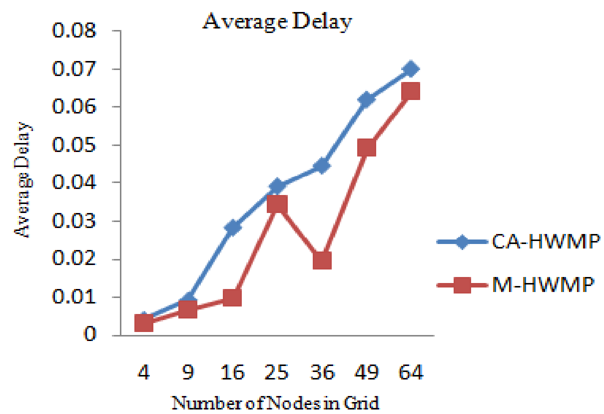

Fig -4: Average Delay

Figure 4 shows average delay. Our proposed algorithm outperforms than CAHWMP algorithm, since uninterrupted transmission on a congested path until it rerouting to a new path and after that path will be deleted when it gets a new path. Then it will surely help to reduce average delay as compared to CAHWMP algorithm. In CAHWMP congestion is avoided after the happening of congestion in the network due to this average delay is more.

VI. CONCLUSIONS

To handle congestion at the MAC layer, we proposed a congestion avoidance technique named Congestion Avoidance Hybrid Wireless Mesh Protocol (CA-HWMP). In this protocol, when node queue level reached to a specified threshold value, it broadcasts CCNF to its adjacent neighbors before reaching to congestion state. The nodes present in its neighbor reroute all traffic on congested node from alternate path. For comparison, we have choose our proposed approach using IEEE 802.11s WMN with its mandatory routing protocol i.e. HWMP. For showing evaluation, we used NS3 which is based on object oriented language C + + and a scripting language Python. We evaluated our proposed protocol through Packet delivery fraction and average end-to-end delay. We also observed this effect on the different node grids by gradually varying the environment from sparse to dense mode. From the comparison, it is concluded that M-HWMP performs better than CA-HWMP in term of greater throughput and PDF. However, M-HWMP offers minimal higher delay than CA-HWMP. The increased delay is caused due to selection of alternate path, which may not be the optimal one. However, it provide almost same delay due to congestion as compared to default protocol.

REFERENCES

[1] Fawaz A. Khasawneh, Abderrahmane Benmimoune, Michel Kadoch , Mohammed A. Khasawneh "Predictive Congestion Avoidance in Wireless Mesh Network," Future Internet of Things and Cloud (FiCloud), 2015 3rd International Conference on , vol., no., pp.108,112, 24-26 Aug. 2015.

[2] Kishwer Abdul Khaliqa,∗, Sajjad Hussainb, Amir Qayyuma,1, J¨urgen Pannekc Novel Data Link Layer Encoding Scheme for Multi-hop Wireless Mesh Network Procedia Computer Science 52 (2015) 665–669.

[3] Kishwer Abdul Khaliq, Muhammad Sajjad Akbar, Amir Qayyum, Ehsan Elahi, Amer Zaheer, Congestion Avoidance Hybrid Wireless Mesh Protocol (CA-HWMP) for IEEE 802.11s, Procedia Computer Science, Volume 32, 2014, Pages 229-236, ISSN 1877-0509.

[4] Barbara Staehle, Michael Bahr, Desheng Fu, and Dirk Staehle. Intra-mesh Congestion Control for IEEE 802.11 s Wireless Mesh Networks. In 21st International Conference on Computer Communications and Networks (ICCCN), 2012, pages 1–7. IEEE, 2012.

[5] Mohiuddin Ahmed and KM Arifur Rahman. Novel Techniques for Fair Rate Control in Wireless Mesh Networks. International Journal, 3, 2012.

[6] Desheng Fu, Barbara Staehle, Rastin Pries, and Dirk Staehle. On The Potential of IEEE 802.11 s Intra-mesh Congestion Control. In Proceedings of the 13th ACM international conference on Modeling, analysis, and simulation of wireless and mobile systems, pages 299–306. ACM, 2010.

[7] Raniwala, A.; De, P.; Sharma, S.; Krishnan, R.; Tzi-cker Chiueh, "Globally fair radio resource allocation for

wireless mesh networks," Modeling, Analysis & Simulation of Computer and Telecommunication Systems, 2009. MASCOTS '09. IEEE International Symposium on , vol., no., pp.1,10, 21 23 Sept. 2009.

[8] Ren Juan; Xu Hui; Qiu Zhengding, "Cross-Layer Congestion Control for Multi-Channel Wireless Mesh Networks," Wireless Communications, Networking and Mobile Computing, 2009. WiCom '09. 5th International Conference on , vol., no., pp.1,4, 24-26 Sept. 2009.

[9] Gang Feng, Fei Long, and Yide Zhang. Hop-by-Hop Congestion Control for Wireless Mesh Networks with Multi-channel MAC. In Global Telecommunications Conference, 2009. GLOBECOM 2009. IEEE, pages 1–5. IEEE, 2009.

[10] Nascimento, V.; Gomes, C.; Moreira, W.; Abelem, A., "CLM-TCP: TCP Congestion Control Mechanism Using Cross Layer for Wireless Mesh Networks." Parallel and Distributed Systems, 2008. ICPADS '08. 14th IEEE International Conference on , vol., no., pp.885,890, 8-10 Dec. 2008.

[11] Sumit Rangwala, Apoorva Jindal, Ki-Young Jang, Konstantinos Psounis, and Ramesh Govindan. Understanding Congestion Control in Multi-hop Wireless Mesh Networks. In Proceedings of the 14th ACM international conference on Mobile computing and networking, pages 291–302. ACM, 2008.

[12] Ashish Raniwala, D Pradipta, and Srikant Sharma. End-to-End Flow Fairness over IEEE 802.11-based Wireless Mesh Networks. In INFOCOM 2007. 26th IEEE International Conference on Computer Communications. IEEE, pages 2361–2365. IEEE, 2007.

[13] Tan, Kun; Qian Zhang; Feng Jiang; Xuemin Shen, "Congestion control in multi-hop wireless networks." Sensor and Ad Hoc Communications and Networks, 2005. IEEE SECON 2005. 2005 Second Annual IEEE Communications Society Conference on , vol., no., pp.96,106, 26-29 Sept., 2005.

[14] Mojtaba Seyedzadegan, Mohamed Othman, Borhanuddin Mohd Ali, and Shamala Subramaniam. Wireless Mesh Networks: WMN Overview, WMN Architecture. In International Conference on Communication Engineering and Networks IPCSIT, volume 19, 2011.

[15] S Badombena-Wanta and EO Sheybani. Mobile Communications for Development: Enabling Strategic and Low-cost e-applications for Rural and Remote Areas. In Wireless Telecommunications Symposium (WTS), 2010, pages 1–7. IEEE, 2010.

[16] Abdulrahman Yarali, Babak Ahsant, and Saifur Rahman. Wireless mesh networking: A key solution for emergency & rural applications. In Second International Conference on Advances in Mesh Networks, 2009. MESH 2009, pages 143–149. IEEE, 2009.

[17] Kai Shi, Yantai Shu, and Juan Feng. A MAC layer Congestion Control Mechanism in IEEE 802.11 WLANs. In Fourth International Conference on Communications and Networking in China, 2009. ChinaCOM 2009, pages 1–5. IEEE, 2009.

[18] Xudong Wang and Azman O Lim. IEEE 802.11 s Wireless Mesh Networks: Framework and Challenges. Ad Hoc Networks, 6(6):970–984, 2008.

[19] J Camp and E Knightly. The IEEE 802.11 s Extended Service Set Mesh Networking Standard. Communications Magazine, IEEE, 46(8):120–126, 2008.

[20] A Behrouz Forouzan. Data Communications & Networking (sie). Tata McGraw-Hill Education, 2007.

[21] Hidenori Aoki, Shinji Takeda, Kengo Yagyu, and Akira Yamada. IEEE 802.11 s Wireless LAN Mesh Network Technology. NTT DoCoMo Technical Journal, 8(2):13–21, 2006.

[22] Ian F Akyildiz, Xudong Wang, and Weilin Wang. Wireless Mesh Networks: A Survey. Computer networks, 47(4):445–487, 2005.

[23] Mihail L Sichitiu. Wireless Mesh Networks: Opportunities and Challenges. In Proceedings of World Wireless Congress, 2005.

[24] Roger Karrer, Ashutosh Sabharwal, and Edward Knightly. Enabling Large-scale Wireless Broadband: The Case for TAPs. ACM SIGCOMM Computer Communication Review, 34(1):27–32, 2004.