Impact Of Load Balancing Interference Routing Metric On Multi Channel Multi Radio Wireless Mesh Network

Mohammad Siraj[1*] *and Zeeshan* Abbasi[2]

[1]Department of Electrical Engineering, College of Engineering, King Saud University, Riyadh.
[2]University Polytechnic, Jamia Millia Islamia, New Delhi

Abstract. Wireless Mesh Network (WMNs) is a promising technology that has been accepted favorably by the Internet Service Providers (ISPs). ISPs use it to provide last mile broadband Internet connectivity to the end users. This popularity arises from the fact, that it inter operates well with diverse wireless systems and provides robust fault tolerance with a high degree of redundancy and reliability. Routing metrics plays a crucial part in the performance of WMN. When routing protocols are implemented, the routing metric is assigned to different paths. It calculates the optimum path to predict the best routing path. These are integrated in routing protocols to improve WMNs efficiency in terms of reliability, latency, throughput, error rate and cost. This paper compares the impact of using load balancing interference aware routing metric (LBIARM) on the performance of Multi-Channel Multi Radio WMNs (MCMR WMNs). The performance of LBIARM was evaluated by comparing it with popular standard metrics weighted cumulative expected transmission time metric and Hop Count metric. OPNET Modeler 17.5 PL1 was used as a simulation tool for implementation. Simulation results show the effectiveness of using LBIARM metric on MCMR WMNs.

1 Introduction

Wireless Mesh Networks are a promising wireless technology used for various applications like video on demand, healthcare systems, disaster and emergency, modern intelligent transport systems, public security systems, broadband internet for home and campus networking. Routing metrics is a crucial part of WMN routing protocols, which affects the performance of WMNs [1-9]. Due to the presence of static nodes and common wireless medium, it is a challenging task for researchers to design a best quality routing metric. Figure 1 shows the architecture of a WMN. IEEE 802.16 Mesh Networks comprises of two types of nodes. The two types of nodes are subscriber station (SS) and Base Station (BS). The SS is analogous to the terminal at the client end through which mobile subscribers access it via air interface. WirelessMan-OFDM is the air interface. The BS acts as an interface between the external and IEEE 802.16 Network.

*Corresponding author: siraj@ksu.edu.sa.

2 Related Work

Researchers have designed many routing metrics. Some of the popular are Expected Transmission Count (ETX) Metric [10], Expected Transmission Time (ETT) Metric[11], Weighted Cumulative Expected Transmission Time (WCETT) Metric [11], Load Aware Expected Transmission Time (LAETT) [14], Metric of Interference and Channel Switching (MIC)[12-13], Exclusive Expected Transmission Time (EETT)[15], Interference Load Aware (ILA) metric [16], Interference Aware Routing Metric (iAWARE)[17], Load Balancing Interference Aware Routing Metric (LBIARM) [18], Expected Dynamic Transmission Cost (EDTT) [19] and Physical layer Metric[20] for Internet of things[21] and Opportunistic routing metrics[22].
To evaluate the effect of routing metric on the performance of WMNs, we consider our metric with two popular metrics for our performance evaluation. These three metrics are briefly described below:

2.1 Hop Count Metric

The most common metric used in the multi-hop routing protocols is Hop-Count metric [10]. It is used in protocols like DSDV, DSR and AODV. Hop-Count metric finds route having the minimum number of hops. Hop-Count can outclass other metrics, which are dependent on load in high agility situations. The metric is very stable and has the isotonicity characteristic. As a result, least weight paths can be discovered proficiently. The weakness of this metric is that it does not address interference, channel diversity, varying load of the link and capacity of the load. It finds path having poor throughput and high packet loss ratio. This is because the links that are slower, take a lot of time to transmit packets.

2.2 Weighted Cumulative Expected Transmission Time (WCETT) Metric

The most WCETT was presented by Draves [16] to enhance the ETT metric in the multi radio mesh networks by taking into account the diversity of the channels. The WCETT metric of a path p is defined as follows:

$$WCETT_p = (1-\alpha) * \sum ETT + \alpha * MaxX_j \tag{1}$$

Where X_j = summation of links ETT values on channel j

$$X_j = \sum_{\text{hops on channel j}}^{n} ETT_i \quad 1 \le j \le k \tag{2}$$

Where,
α is a tunable parameter $0 \le \alpha \le 1$ which controls the preferences over the path length versus channel diversity.

WCETT is composed of weighted average of two components. The first term sums up individual link ETTs while the second term sums up the ETTs of every link of a given channel. This adds channel diversity to the routing metric causing low intra-flow interference. Using WCETT, multi radio wireless mesh network's performance is enhanced in comparison to ETX, ETT and Hop-Count metrics. WCETT metric is not isotonic and due to this, it can’t be used with link state routing protocols. Secondly, the inter-flow interference effects are not explicitly taken into account by WCETT. As a result of this, sometimes paths are created, which have high levels of interference.

2.3 Load Balancing Interference Aware Routing Metric (LBIARM)

LBIARM [20] is an enhancement of WCETT comprising of two components. The first component is same as WCETT component. The second part considers channel diversity.

$$LBIARM = (1-\alpha)\sum_{i\in p} ETT_i + \alpha \sum_{i\in p} ETT_i * N_i \quad (3)$$

Where N_i is the set of interfering links on link I and.

$$ETT = ETX * \frac{S}{B} \quad (4)$$

Where,
S = average packet size.
B = Bandwidth of the existing link.
α is a tunable parameter 0 ≤ α ≤ 1.

3 Performance Evaluation

The simulation setup to validate and evaluate various routing metrics, including LBIARM, Hop Count and WCETT in OPNET Modeler is discussed here. The three routing metrics namely Hop Count, WCETT and LBIARM are compared for a 4 X 4 grid mesh network as shown in Figure 1.

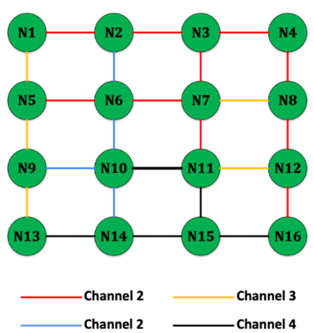

Fig. 1. 4x4 Grid Wireless Mesh Network with 4 channel assignment

In the simulated wireless mesh network, 16 static mesh nodes are deployed in a grid scenario in 800 x 800 m2 area. Identical distance is maintained between each one hop node pair. Similarly, the interference range is kept almost equivalent as all the mesh routers have same transmission strength. One of the mesh routers, which is centrally located in the network, was selected to act as a gateway node. Each of the mesh nodes has multi radio that was allocated to different channels. The same channel allocation scheme was extended for all the mesh routers as in [4]. That is, each mesh router had more than one interfaces, and these interfaces were allocated to different channels.
The source nodes send Constant Bit rate (CBR) traffic with UDP as the transport protocol. It consists of 500, 1000 and 1500 byte packets with a transmission rate of 20 packets/second. OPNET source code was modified to calculate LBIARM at each node. Interference traffic load was created by broadcasting HELLO messages at an interval of 1 second periodically to all neighbor nodes on channel i. Upon receiving this message, the neighbor nodes update the traffic load information of the corresponding nodes in their neighbor's table. Simultaneously, information of average packet buffered at the nodes is updated. For calculation of LBIARM, HELLO messages are also used. The value of parameter was taken as 0.3 for calculation of WCETT and LBIARM. This value was taken, as it was found that optimum value of WCETT

is when α =0.3. These simulations were executed on a Pentium XEON X5560 2.79 GHz 48 GB RAM. The simulation parameters are illustrated in Table 1.

Table 1. Simulation Parameters.

Parameter	**Value**
Network Scenario	Campus Network
Network Grid	800 X 800
Number of Nodes	16
umber of radios	1,2 and 4
Number of Channels	4
Packet Size	500,1000 and 1500 Bytes
Interference range	400 m
Traffic Model	Constant Bit Rate(CBR)
Transmission Power	10 mW
Queue size at Routers	50 Kbytes
Physical layer protocol	PHY 802.11g
CBR sender's rate	20 packets/sec
Tx. rate at Physical layer	54 Mbits/sec

The routing metrics are compared based on the following performance metrics.

- **Packet Delivery Ratio (PDR):** It is defined the ratio of total number of data packets that are received by the destination node to the total number of data packets transmitted by the source node.
- **End-to-end delay of data packets:** It is the time taken by the data packet to reach from source node to destination node.

Figure 2, shows the throughput comparison with multi radios. Initially, throughput was observed with the number of radios taken as 1. Then the number of radios were increased to 4. A marginal difference in throughput was observed between WCETT and LBIARM when single radio was chosen. When the number of radios was increased to 4, a substantial difference was observed between LBIARM and WCETT. This is because there is a heavy contention for the physical medium when multiple flows are directed towards single radio. Contention occurs at the link layer, which is the reason of delay at each hop. As the number of hops are increased, interferences increases leading to more contention due to the receive queue, which is very high and there is a buffer overflow. When more than one radio is used the time slots to send the packets also reduces and the minimal link satisfaction ratio increases, as a result network performance shows enhancement. It is observed that LBIARM selects higher performance paths. LBIARM achieves a throughput enhancement of 80% and 16% respectively over Hop Count and WCETT respectively for four radio scenarios.

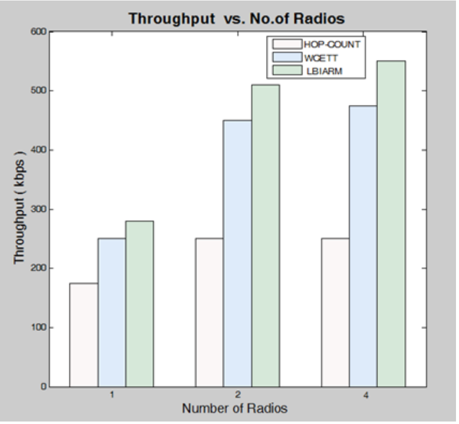

Fig 2. Throughput versus Radios

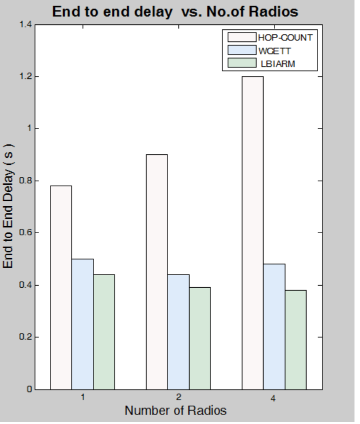

Fig 3. End to end delay versus radios

Figure 3, shows the comparison between an end-to-end delay versus multi radios. It is observed that as the numbers of radios are increased, end to end delay in Hop Count is increased whereas even after increasing number of radios, there is not much change in WCETT. This is because Hop Count has not been designed for multi radio. There is not much improvement in WCETT, as it does not recognize inter-flow interference. So, if inter-flow interference exists, the packets are routed towards gateway leading to a large queue. LBIARM has a shorter delay in comparison to others as it selects routes whose load is less than the channel capacity, thereby minimizing the delay time in queuing, collision and buffer overflow. When more than one radio is selected, it is observed that LBIARM can improve end to end delay by minimizing the latency by 80% and 16 % from Hop Count and WCETT respectively.

Figure 4, shows performance comparison between throughput and the packet size when packet size is varied from 500 to 1500. The simulation result shows that WCETT and LBIARM perform well when the packet becomes large. The improvement is around 80 % and 13 % from Hop Count and WCETT respectively.

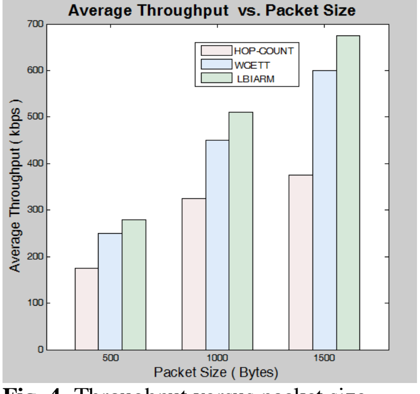

Fig. 4. Throughput versus packet size.

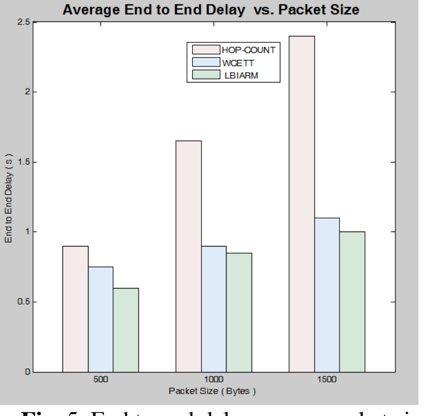

Fig. 5. End to end delay versus packet size.

Figure 5, shows performance comparison between end-to-end latency and the packet size when packet size is varied from 500 to 1500. LBIARM considers routing overhead in packet transmission. When data packet size is small, the overhead takes a higher percentage of the transmission time compared with large data size. Therefore, LBIARM performs much better with smaller packet size as compared to the larger packet size. There is an improvement in end-to-end delay as compared to Hop Count and WCETT. Delay improvement by for a large packet nearly by 71 % and 10 % from Hop Count and WCETT respectively for a four-radio scenario.

4 Conclusion and Future work

In this work, it is seen that the use of a load balancing interference aware routing metric enhances the performance of the network by minimizing the end-to-end delay, thereby increasing the throughput of the network. It is observed that the usage of a normal metric results in a larger end to end delay and a decreased throughput because of intra-flow interference, inter-flow interference and traffic load in the network. The load balancing interference aware routing metric takes into account intra-flow interference, inter-flow interference and traffic load. These parameters are very critical when the number of nodes increase. It will be very interesting to observe, how load balancing interference aware routing metric performs in WMN test bed.

References

1. M.Siraj and K.A. Bakar, "Link establishment and performance evaluation in IEEE 802.16 wireless mesh networks,". Int. J. Phys., vol.6 issue 136, pp.3189-3197, (2011)
2. M. Siraj "A Survey on routing algorithms and routing metrics for Wireless Mesh Networks", World Applied Sciences Journal, vol.30 issue 7, pp.870-886, (2014).
3. M. Siraj and K.A. Bakar, "Minimizing Interference in Wireless Mesh Networks Based Telemedicine System", Journal of Computer Science, Vol.8. Issue8, pp.1263-1271, (2012).
4. M. Siraj and K.A. Bakar, "To Minimize Interference in Multi Hop Wireless Mesh networks using load balancing interference aware protocol", World Applied Sciences Journal 18(9):1271-1278, vol.11 No. 3, pp 1652-1664, (2013).
5. M. Siraj, M. Shoaib and S. Alshebeili, "Performance enhancement of cognitive radio Wireless Mesh Networks by link scheduling and beamforming," Saudi International Electronics, Communications and Photonics Conference, pp. 1-6, (2013).
6. M. Siraj and Z. A. Abbasi, "An Efficient Video on Demand System over Cognitive Radio Wireless Mesh Networks," 2013 International Symposium on Computational and Business Intelligence, pp. 231-234, (2013).
7. M. Siraj and S. Alshebeili, "RPCRAN: A Routing Protocol for Cognitive Radio Ad hoc Networks", International Journal of Innovation and control Volume 9, Number 10, (2013).
8. M. Siraj and K.A. Bakar, "To Minimize Interference in Multi-Hop Wireless Mesh Networks Using Load Balancing Interference Aware Protocol", World Applied Sciences Journal, Vol.18. Issue9, pp.1263-1271, (2012).
9. Mohammad Siraj and Saleh Alshebeili "Performance Enhancement in multi hop Cognitive Radio Wireless Mesh Networks", International Journal of Innovation and control, Volume 9, Number 10, (2013).

10. De Couto, D. Aguayo, J. Bicket and R. Morris, “A High-Throughput Path Metric for Multi-Hop Wireless Routing,” in Proc. of the 9th annual international conference on Mobile computing and networking, pp 134 – 146, (2003).
11. R.Draves, J. Padhye and B. Zill. “Routing in multi radio, multi hop wireless mesh networks,” In proceedings of ACM MOBICOM.pp.114-128, (2004)
12. Y. Yang, J. Wang. and R. Kravets, “Designing routing metrics for mesh networks, Proc. WiMesh,” (2005)
13. Y. Yang, J. Wang. and R. Kravets.,” Interference-aware loop-free routing for mesh networks,” (2006).
14. H.Aiache, V. Conan, L. Lebrun and S. Rousseau, “A load dependent metric for balancing Internet traffic in Wireless Mesh Networks," Mobile Ad Hoc and Sensor Systems, pp.629-634, (2008).
15. W. Jiang, S. Liu, Y. Zhu and Z. Zhang, “Optimizing Routing Metrics for Large-Scale Multi-Radio Mesh Networks” Wireless Communications, Networking and Mobile Computing, pp.1550-1553, (2007).
16. D.M. Shila and T. Anjali, “Load-aware Traffic Engineering for Mesh Networks. Computer Communications and Networks,” pp.1040-1045, 2007
17. A.P. Subramanian, H. Gupta, S. Das, and J. Cao (2008). “Minimum Interference Channel Assignment in Multi-radio Wireless Mesh Networks,” IEEE Transactions on Mobile Computing, vol.7 issue 12, pp.1459-1473, (2008).
18. M. Siraj and K.A. Bakar, “A Load balancing Interference Aware Routing Metric (LBIARM) for multi hop wireless Mesh Network,”, Int. J. Phys. Sci., vol.7 issue 3, pp 456-461, (2012).
19. Cheng, H., Wang, C., Zhang, X., “An opportunistic routing in energy-harvesting wireless sensor networks with dynamic transmission power”. IEEE Access 7, 180652–180660p, (2019)
20. M. Abdullahi, K. Malekinasab, W. Tu and M. Bag-Mohammadi, "An Efficient Metric for Physical-layer Jammer Detection in Internet of Things Networks," IEEE 46th Conference on Local Computer Networks (LCN), pp. 209-216, (2021).
21. Islam, N.; Altamimi, M.; Haseeb, K.; Siraj, M. Secure and Sustainable Predictive Framework for IoT-Based Multimedia Services Using Machine Learning. Sustainability,13, 13128, (2021)
22. Mostafa Abdollahi, Farshad Eshghi, Manoochehr Kelarestaghi, Mozafar Bag-Mohammadi,Opportunistic routing metrics: A timely one-stop tutorial survey, Journal of Network and Computer Applications, Volume 171,102802, ISSN 1084-8045, (2020)