Journal of Theoretical and Applied Information Technology
30th June 2021. Vol.99. No 12

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

INTERFERENCE AND LOAD BALANCING ROUTING METRICS USED IN WIRELESS MESH NETWORK: NEW TREND AND CHALLENGES

BAHAA MUNEER ISMAEL[1], ASRI BIN NGADI[2], JOHAN BIN MOHAMAD SHARIF[3]

[1]School of Computing, Facility of Engineering, University Technology Malaysia, Johor Bahru, Malaysia
[1]College of computer science and information technology, University of Basrah, Iraq
[2]School of Computing, Facility of Engineering, University Technology Malaysia, Johor Bahru, Malaysia
[3]School of Computing, Facility of Engineering, University Technology Malaysia, Johor Bahru, Malaysia
E-mail: [1]bahaa_muneer@yahoo.com, [2]dr.asri@utm.my, [3]johan@utm.my

ABSTRACT

Wireless Mesh Networks (WMNs) is an integrated concept deployed for the data communication systems for Internet access. These networks need incorporate and effective data management, load balancing, interference management and traffic congestion mechanisms. Data routing in these network by using new and intelligent routing protocols based on routing metrics play vital role to increase the network performance. However, the WMN networks have suffered with load balancing, interference and other routing challenges because only one or two internet gateways deployed in these networks to access the internet. To fulfill these network requirements, there is pressing need to design more efficient routing protocol to deal the WMN networks and provide full network functionalities. The routing protocols are using different routing metrics or combination of some routing metrics such as inter-flow interference, hop count and load balancing for routing decisions. Therefore, a proficient routing metric is required to make routing protocol more effective. In this paper, we identified and reviewed many existing routing protocols based on interference, load balancing and hop count as their routing metrics. We discussed existing protocols based on their working, metrics and effectiveness. We anticipate that this research review paper would help the researcher to conduct innovative research incorporating with the existing routing protocols available in literature.

Keywords: *Wireless Mesh Network, Routing protocol, Routing Metric, Interference, Load Balancing*

1. INTRODUCTION

Wireless Mesh Networks (WMNs) have emerged area of research where it provides a best infrastructure option for massive network coverage, fast rollout, and as a low cost solution. Fairness and load balancing in WMNs have been considered one of crucial task due to high efficiency in terms of improving traffic congestion management, load balancing management and interference avoidance management. The concept of WMN has adopted for next generation due to its self-configuration, self-organization, and low cost services. Whenever, the link failure observed in these networks, it automatically establishes alternative path. WMN is specialized type of mobile networks and its architecture contains Mesh Router (MR), Internet Gateway (IG) and Mobile Client (MC). The MR are mostly static and equipped with multiple radios which perform the function of relaying traffic from IG to MC and from MC to IG. Whereas IG are MR but their functionality is more than MR in term of processing and buffer size. The MC are mobile nodes and they change their position frequently. Figure 1 shows the WMN architecture.

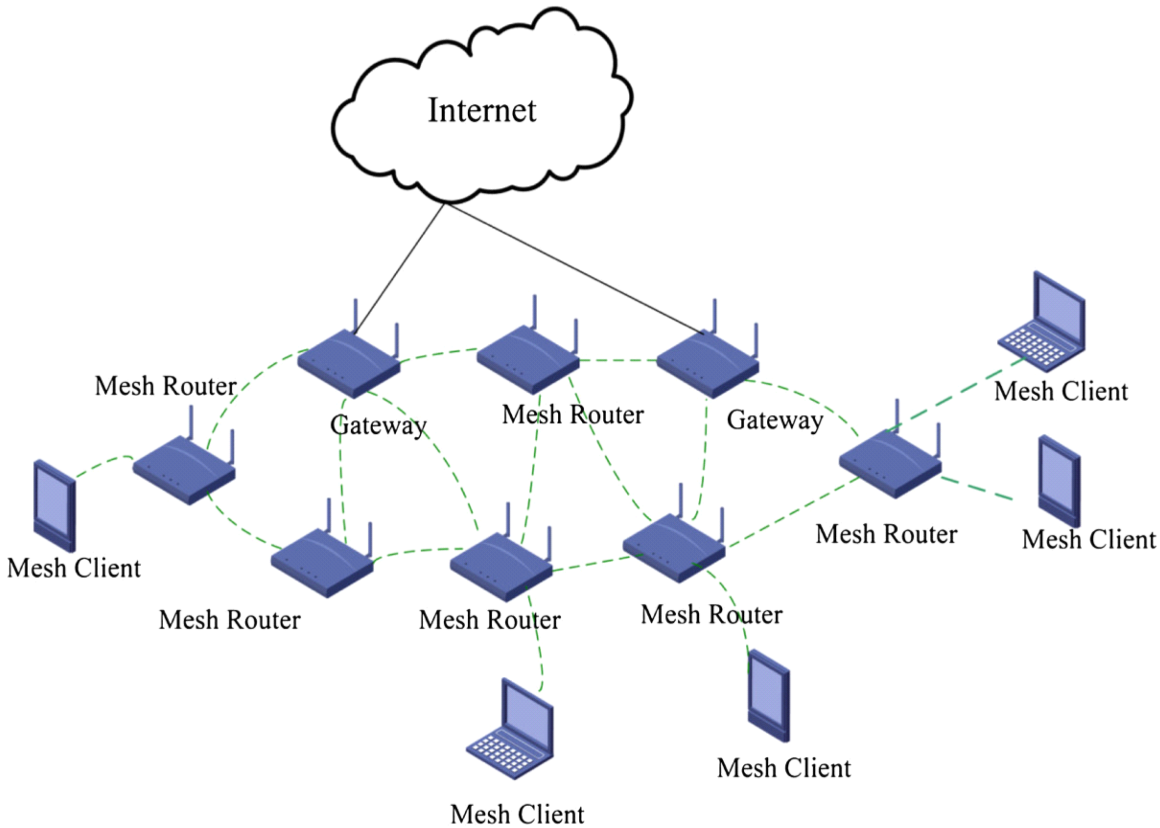

Figure 1: Wireless Mesh Network Architecture [1]

The WMN is a networking and multi-hop technique that is used to construct the new generation networks [2]. A decent routing protocol can find high-performance routes from origins to destinations. Routing protocols are categorized into three types: constructive, reactive, and hybrid. Static mesh routers benefit from constructive routing protocols, while mobile mesh clients benefit from reactive routing protocols. Since hybrid WMN involves both static mesh routers [3]. WMN is suitable for incorporating into emerging Internet of Things (IoT) networks. Traditional WMN's lifespan can be extended by using energy storage to solve energy constraints [4].

Routing metrics are critical for the reliability and performance of routing protocols, as well as the specification of network path performance in WMN. Routing metrics are most important for the formation, configuration, and conservation of wireless mesh network topology [5]. New technologies in the WMN provides high-bandwidth capabilities at a low cost services. In WMN, traffic is unbalanced and leads to overhead and more processing and also data traffic is congested and leads to packet loss, as well as affecting transmission performance. As a result, load balancing techniques are needed to boost routing efficiency. Mesh clients are computers used by consumers, such as a server or a smartphone. Mesh routers provide a connection between MC and IG. The IG are a form of MR that connects WMN and with Internet. Mobile users in WMN consumes more resources like bandwidth [6].

This paper reviews the routing protocols designed for WMN networks and their main routing metrics for routing decision. The latest protocols are evaluated in terms of their operation, routing metrics, features and limitations. The basic motive of any routing protocol is to increasing the network performance and maximized the network throughput. The other sub objectives of this paper are as follows:

- Review routing protocols of WMN to evaluate their performance.
- Discusses the used routing metrics in protocols.
- Discuss the protocols limitations and factors to design new protocols.

The rest of the paper is organized as follows: Section 2 presents the literature review in detail. Section 3

Journal of Theoretical and Applied Information Technology
30th June 2021. Vol.99. No 12

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

presents the discussion and technical comparison of discussed protocols. Section 4 concludes the paper with future direction.

2. LITERATURE REVIEW

This section discusses the brief overview of existing routing protocols used for load balancing and interference in WMN. This section identified the routing protocols and used metrics by different in WMN. First, this section presents the other routing metrics based protocols. Afterwards, this discussion is about routing metrics which are divided on the basis of interference and load balancing and hop count.

A. Different Methods based Routing Protocols for WMN

In [7], authors proposed a routing protocol designed to handle load balancing and interference. This protocol uses clustering technique to reduce current network problems. The proposed approach reduces end-to-end delays and also works for the route quality and life expectancy of nodes especially in heavy-duty bottlenecks situations. At the same time, it uses interference and queue information from the mesh station channel to address the existing challenges. The results of the simulations showed that the proposed protocol has exceeded in performance compared with existing routing protocols. The designed protocol is able to handle load balancing and interference of different IoT based WMN connections. The proposed solution implemented in WMN environment by choosing optimum routes on the network. The proposed scheme performs effectively. However, the complex routing metrics increases the overhead in networks.

Authors in [8], discussed the major challenge of WMNs because of the mobility of the mesh nodes. The protocols performance is based on consistency of the connections. An intelligent mechanism is required to solve these problems in WMN. Authors used machine learning prediction techniques to tackle this issue. They analyzed prediction methods such as Gaussian regression output, vector regression and multiple linear regression. This protocol is evaluated in simulation by using different scenarios with PCL-IDA-metrical and cross-layer routing for prediction. The results are also used to predict the consistency of the links that were implemented into OLSR routing protocol. The results showed that when the multiple linear regression technique is employed and evaluated the average delay, data throughput and packet loss. The overall results are better than non-prediction models with multiple linear regression model.

Authors in [9], discussed the routing protocols based on high fault tolerances and coverage areas in WMNs. The IEEE 802.11 based unlicensed band wireless devices are commonly used in these networks. However, IEEE 802.11-based WMNs suffered from data loss because of the hidden node issues. Authors designed a new Asymmetric Hidden Node Problem Aware Metric (AHAM) to alleviate this problem. AHAM has made a new possible flow possible to evaluate a source and destination path, which avoids the interfering of existing hidden nodes and current flows through hidden nodes on that path. This is because, when new flows are formed, the hidden node problem may asymmetrically affect the transmission between flows. AHAM aims to correctly estimate and compensate for the effect of hidden nodes on the fresh and present flows. Simulation results showed that, AHAM achieves high efficiency and compared it with previous assessments reported that is the efficiency and the level of network fairness maintained.

Authors in [10], addressed the existing problems like load balancing, scalability, mobility and power management. Authors in this paper suggested a new routing protocol which uses buffer occupancy for routing decision. The experiments result showed that the proposed protocol significantly improved network efficiency by tackle the load balancing and congestion. The proposed protocol evaluated in terms of various node densities with different data rates. The performance metrics of the proposed protocol and standard protocol are data generation, delay, jitter and full received messages. The results showed that the proposed protocol exceeds the standard AODV protocol with regard to pre-defined performance requirements, thereby allowing optimal use of all network resources and increasing the WMN overall performance.

Authors in [11], addressed the routing problems to achieve the best global network efficiency. An optimization DIAR method for finding successful roads in a WMN is proposed. With wireless networking evolving rapidly, networks of the next generation need to be delayed. For multiple concurrent information flows, DIAR aims to pick routes with minimal end-to-end delays. Interference is one of the reason for transmission failure, delay and bandwidth. The proposed protocol is used to balance the load and solve the optimization problem. Furthermore, DIAR takes complex network status into account by choosing various packet transmission paths and assessing the network condition when searching for a routing solution. We are eventually chosen as the option for the routes with the least delay. Simulation results showed that improved network efficiency could be achieved by DIAR. Every time the dynamic optimization of routes is found, DIAR finds such a complex situation and assesses network conditions. DIAR is better able to achieve network efficiency in various situations, as shown by the NS3 simulation results.

Authors in [6], proposed a Firefly Load Balancing Energy Optimized Routing (FLB-EOR) technology to address existing problems. The FLB-EOR protocol is optimized and handle load balancing for multimedia data with minimum EC in WMNs. Initially FLB is used to manage the multimedia congestion of data in WMN. Using FLB-EOR technology, the minimal load-weighting nodes for multimedia data transmission in the network are discovered, resulting in increased efficiency of performance and load balance. Using the gravity neighbor's selection algorithm, the closest neighbor to send data towards the destination after the minimal-weighting nodes. The distance between the nodes is determined in the gravitational neighbor-node selection and search the neighbor node to the destination. This helps to decrease energy use and improve the life of the network. The simulation carried out for FLBEOR to show that the LBE produces more accurate results than modern solutions.

Authors in [12], proposed a solution by using routing metric on the quality of links, which is based on the MAC and PHY features which includes usable bandwidth, the availability of the link, and loss data rate. This measurement enables interflow interference to be apprehended and the creation of bottlenecks to be avoided by the load. On the basis of the conflict diagram model, a method is established for assessing the path based on available bandwidth, interference with intra-flows. Finally, they introduced a routing protocol supporting this metric, which simulated the performance of this protocol compared to other known routing protocols. After comparison, the proposed protocol has achieved the significant performance in terms of retardation and throughput, particularly.

In [13], the authors proposed a protocol by using backup paths maintenance strategy via broadcasting reduction. Proactivity is given to backup paths that restrict the amount of broadcast required in the event of a breakdown. Path setup is one of two options: an interconnected routing information or a medicated ad-hoc HWMP approach. This protocol strives for maximum robustness to back-up paths that conflict with the previously developed main route, giving greater robustness than advanced back-up paths. This will allow their routing to withstand correlated node interruptions or localization. The results showed that the global connected status for topologies up to 100 nodes can be set up in less than 15 seconds, enabling trajectory creation without further diffusion. In less than 0.25 seconds even in the case of local information. The authors showed that the key objectives of their routing protocol are: building the main and backup route, trace path failures identification and the transfer of backup paths in the event of main path failure.

B. Interference and Load Balancing based Protocols

Authors in [14], proposed a novel routing protocol to minimizing end-to-end delay by using different routing metric including end-to-end delay, inter and intra interference and load balancing. End-to-end delay is computed based on Queuing delay (time taken for packet to be processed in the buffer) and transmission delay. After EED link metric calculation, each router calculates the multi-radio achievable bandwidth (MRAB) based on inter and intra interference of the link. Both EED and MRAB combine to make a novel path metric named as Weighted End-to-End Delay (WEED). By the combination of EED path metric and WEED link metric a highly throughput is achieved. The Problem with this approach is that it only considers the link/path interference and delay. But to select the least loaded gateway is also required to increase the network throughput and overall network performance because all the network traffic have passed by Internet gateway.

Authors in [15], proposed a novel routing protocol called Delay-Aware Routing Metric (DARM) for WMN by using different routing metric including packet loss, inter and intra interference, load balancing and channel switch delay. DARM considers the link transmission delay, channel switch delay and path transmission delay. DARM reduces the link transmission delay and effectively select the channel and reduces the channel switch delay. After selected the link DARM protocol selects the best path to reduce the path transmission delay. This approach works well when the paths are static. But this approach does not consider the load at gateway so the load balancing is not achieved by doing this technique.

Authors in [16], proposed protocol by using cross layer routing metric called Interference-aware Routing by Cross layer Routing (CLRF) that consider inter and intra flow interference and traffic load. CLRF comprised in two parts, first is load balancing which calculates the interflow interference and the load of mesh routers by using interference ratio, queue occupancy rate and channel utilization ratio. The second part is channel switching cost which checks the intra flow interference. By the combination of both these calculated values the CLRF chooses the path. The problem with this approach is that its only considers the load at mesh routers but the load at internet gateway does matter in the performance of wireless mesh networks.

Authors in [17], proposed a novel routing protocol called Reinforcement Learning-based Best Path to Best Gateway (RLBPR) for WMN. This protocol uses different routing metric to select best path and least loaded gateway. RLBPR uses Interference ratio, packet losses and load at gateway metric to select the best path and best gateway. In RLBPR the GW computes its load and then advertises its load in advertisement packet and each intermediate node updated its routing table. In RLBPR a source node sends packet to its neighbor to forward to best GW. Neighbor send feedback back to source and source node store this feedback to routing table. So by doing this source protocol received feedback with the already stored feedback. So next time it uses the best path. The problem with scheme is that when the network changes it will not perform well.

Authors in [18], proposed a novel routing protocol called Best path to Best Gateway (BP2BG) which used different routing metric to select best path and least loaded gateway. BP2BG used interference ratio, packet losses and load at gateway metric to select the best path and best gateway. In BP2BG the GW computes its load and then advertises its load in advertisement packet and each intermediate node updated its routing table. Each mesh router computes the Link Quality Metric (LQM) based on interference ratio of the link and expected link quality. After LQM computation, Path Quality (PQ) is computed based on LQM. BP2BG selects the best path to best gateway by combining the both path quality and load at gateway. The problem with this approach is that when any node found alternative best path it immediately switches to this path while other neighboring node may be used this path for transmission. By doing this the interference will occur so that the network performance decreases.

Authors in [19], proposed a novel routing protocol called Source based Routing Protocol (SBR) which used different routing metric e.g. packet losses, intra and inter interference and load at gateway to select the best path and best gateway. In this approach, source node decided the transmission path with least interference and to the least loaded gateway. Gateway computes it capacity (load) and advertise its load in advertisement packet. Mesh routers receive GW advertisement and update their routing table. Each mesh router calculates the intra and inter interference of the link and after this Path Metric (PM) is calculated based Link Metric (LM) by each mesh routers. SBR Algorithm used a novel routing metric based on PM and Gateway load. In SBR, when any node found best alternative path it will not switch to it because the neighboring node may send data by using this path. So its waits for some time and after this time it can be switched to this path. The problem with this approach is that when the network topology changes the SBR can't work properly so the network performance decreases. Table 1 shows the comparison of Interference and load balancing based routing protocols.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Table 1: A summary of Interference and load balancing based routing protocols

Scheme	Evaluation Routing Metric	Objective	Limitation
EED [14]	Intra and inter flow, load balancing, interference	To minimize queuing delay and transmission delay through interference.	Load balancing between mesh routers and internet gateway is not considered
DARM [15]	Intra-flow, inter-flow interference, channel switch delay	To minimize channel switching delay and transmission delay.	Not work well when topology changes and load balancing between the MR and IG is not considering
CLRF [16]	Intra and Inter-Flow interference, Load Balancing	To maximize traffic load by minimizing interference between channels and minimizing channel switching cost	Load balancing between Internet gateways is not considered.
RLBPR [17]	Intra and inter-flow interference, Packet losses and load at gateway is considered.	Maximizing throughput by using load balancing between gateways.	Not perform well when topology changes and load at MRs is not considered
BP2BG [18]	Intra and Inter-Flow interference, Load balancing between Gateways.	Maximizing Throughput by selecting the best shortest path to least loaded gateway.	Path switching technique between the best paths is not considered.
SBR [19]	Intra and Inter-Flow interference, Load balancing between Gateways.	Maximizing the throughput by decreasing the interference and packet losses.	When the topology changes not perform well

C. Hop Count based Protocol

Authors in [20], proposed a Hybrid Wireless Mesh Protocol-Expected Transmission Count (HWMP-ETX) routing for WMN. The proposed protocol combines reactive and proactive features of routing protocols. As reactive protocols work with AODV protocol. The WMN in HWMP-ETX composed of MR and MC. The mesh routers are proactively linked with each other. Mesh clients are frequently moving so they are reactively linked with each other. In reactive mode it works same as AODV works and in proactive mode it uses tree based protocol. HWMP combine the best features of ETX to send message and select the shortest path by using Dijkstra's routing algorithm between source and destination. However, this protocol does not consider the intra interference between paths.

Authors in [21], proposed the Wired-cum-Wireless WMN OLSR-ETX (W3-OLSR-ETX) for scalable networks. W3-OLSR-ETX used Expected Transmission Count (ETX) with OLSR. In ETX calculates the forward delivery and reverse delivery ratio of the node. After this it takes reciprocal of the product of forward delivery and reverse delivery ratio. The sum of ETX is used for path selection. Dijkstra's algorithm is adopted for select and find the shortest path. In this paper, ETX is used with OLSR routing protocol in wired-cum-wireless scenario. In ETX only the inter-flow interference is considered, and intra interference is not considered. When the number of nodes increases then the intra interference increases so the network performance decreases. This approach does not consider the other routing metric as well.

Authors in [22], proposed the Diversity based Review of Multipath Routing Metrics of Wireless Mesh Networks (DMRM) by using the inter and intra interference and link quality, and channel diversity metric. DMRM uses packet losses record traffic load of its own and interfering nodes and save this information in their locality table. When in first time the node send the hello packet is also send the Traffic load to each other. Whenever the route request is send than this information is also shared to get latest information about traffic load. Diversity Multipath Routing Protocol (DMRP) uses the DMRM metric to send message to each other. The problem with this approach is that it does not consider the load at gateway because every packet to internet by using the gateway. So to select the least loaded GW is also major concern in WMN.

Authors in [23], proposed the Load Balance Cross-layer protocol based on AODV (LBCL-AODV). LBCL works same like AODV and optimizes the route selection. The proposed protocol is using cross-layer knowledge like data delivery rate and node load. In route discovery phase, two kind of information is added from each participant node (node load and node delivery ratio). Based on these two information best path is selected. When the load on the selected route is increased from the predefined threshold value then route migration process will take place. In route migration process the route with heavy load is transferred to the route with least load. When any two nodes shifted their routes to the least loaded route then the congestion in the route will be occurred. So network performance will be decreased and other routing metric will also not be considered in this approach.

Authors in [24], proposed Load Balancing Interference Aware Routing Metric (LBIARM) which considers intra and inter flow interference, channel diversity and load balancing between the channels as routing metric. This approach has two components like ETT. First calculates the ETT of the link but the second component calculates the channel diversity. This is not considering in WCETT. Like WCETT, it also calculates the expected transmission time by sending probe packets but data packet is larger than the probes packet. So this expected transmission time is not achieving is real environment. And other problem with this approach is that it only considers the load balancing between channels not between Internet Gateways.

Authors in [25], proposed Weighted Cumulative Expected Transmission Time with Load Balancing (WCETT-LB) protocol for WMN. The WCETT only considers the load of mesh routers but in this approach it also considers the load at gateway. And in this proposed work the gateway is mobile to one hop and to avoid the packet loss due to mobility of gateway multipath mechanism is used. The gateway calculates two types of load, one from the internet to the mobile gateway and the other is from mesh router to mobile gateway. If the sum of both load is greater than the threshold value than half load will switch to the other gateway otherwise not. The problem with this approach is that its only considers the load at mesh routers and mobile internet gateway but not consider the interference and other routing metrics.

Authors in [26] [16], proposed Local Node Stability (LNS) based routing for WMN and uses inter-flow interference and channel utilization as routing metric. The LNS calculates the Link Quality Metric (LQM) for each link and then compare calculated LQM with the threshold value to identify the link node stability. If the calculated LQM value is less than threshold value, then it is acceptable link otherwise it is unacceptable link. LQM is calculated by adding interference ratio IR and link utilization CL of the link. By using this metric packet is send from source to destination with minimum packet loss and minimum delay. However, this protocol does not consider intra-flow interference and load balancing between the mesh routers and internet gateways. These factors also effected the network performance.

Authors in [27] [17], proposed active topology based routing approaches for WMN which selects the path based on utilize channel and unutilized channel. In this paper they proposed two types of active path. One is to select the packet through active path of utilized channels means the path is already created so there is no need to established but the disadvantage is that congestion on this path increases as a result packet losses increases. Second to select the path this is composed of unutilized channel. The advantage of this is that chance of congestion occurring is minimum so that packet losses is also minimum. The disadvantage of this is that complex routing algorithm is used to establish new path so it is more time consuming. The problem in both cases is that it only considers channel utilization as routing metric but other factors can also effect the network performance.

Authors in [28] [18], proposed a Multi-Radio Multi-Channel (MRMC) protocol based on isotonic metric for WMNs. The MED uses the expected available bandwidth by calculating the inter and intra flow interference. This strategy uses to calculate the physical and logical interference, load and noise comprehensively. MED calculate the expected transmission time through probe packets. But the size of probe packet is smaller than data packet and by sending probe packets networks overhead increases. So by doing this expected transmission time cannot correctly calculate. The Problem with approach is that it does not consider the load balancing between gateways as bottleneck can be created at gateway. Table 2 shows the comparison of hop count based protocols.

Table 2: A summary of the characteristic of Hop count based Routing Metric used in WMN

Scheme	Evaluation Routing Metric	Objective	Limitation
HWMP-ETX [20]	ETX and hop count	Select shortest path to reach Internet Gateway and maximizing throughput.	Not considered intra-flow interference between channels and load balancing between gateways.
W3-OLSR-ETX: Wired-cum-Wireless WMN [21]	ETX and hop count	Select shortest path by combining the best features of ETX and OLSR.	Intra Interference and load balancing between IG and MR is not Considered
DMRM [22]	Hop count, Intra and Inter-Flow Interference, Load Balancing.	Maximizing Throughput by load balancing between channels.	Load balancing between internet gateways in not considered.
LBCL-AODV [23]	Load balancing and transmission time.	Used load balancing factor with AODV to maximizing throughput.	Interference and load balancing between internet gateways is not considered.
LBIARM [24]	ETT, Intra and intra flow interference and Load balancing.	Used Load balancing factor with ETT to minimized transmission time.	Expected transmission time is calculated based on Probe Packets so it is not good Approach.
WCETT-LB [25]	ETT and load balancing between MR and IG.	To increase the throughput by managing the load between IGs and MR's.	Only load balancing is used Interference metric is not considered.
LNS [26]	Hop Count, Inter-Flow interference and link stability.	Maximizing the throughput by maintaining link stability.	Intra-Flow Interference and load balancing between the gateways is not considered.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3. DISCUSSION

After reviewing the various routing protocols based on interference and load balancing and hop count based discussed in the literature. It is found that each routing metric used in protocol has its own assumptions but these could not realistic WMN. Every protocol has its own merits and demerits which are discussed in Table 1 and 2. So, an efficient routing metric is needed which uses both routing metrics interference, load balancing and hop count to maximize the throughput and increase network performance.

4. CONCLUSION

This paper discussed the various routing protocols based on different strategies, load balancing, hop count and interference metrics for WMNs. We compared the characteristic of various routing protocols based on different routing metrics. In general, each routing protocol used one routing metric or combination of these. We concluded that feasible routing metric improves the WMN performance in terms of data delivery, less delay, high throughput and load balance. The feasible routing method increases the WMN network performance and maximized throughput. We anticipate that this interesting area could help the researchers to conduct innovative research by incorporating the existing routing protocols available in literature.

Future work: There are many studies in the literature

In the end, the issue of multi-channel radio allocation in WMN networks still needs further research. Some issues such as user mobility, QoS, productivity, and fairness are not being considered efficiently in terms of existing and available technologies and algorithms, so we need more research in WMN networks, especially in relation to Load balance, interference and fairness.

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