2014 1st International Congress on Computer, Electronics, Electrical, and Communication Engineering (ICCEECE2014)
IPCSIT vol. 59 (2014) © (2014) IACSIT Press, Singapore
DOI: 10.7763/IPCSIT.2014.V59.26

Routing Protocols for Wireless Mesh Networks: Performance Study

Shubat S. Ahmeda[1] and Reda K. Farhan[2]
[1]Department of Computer Engineering, University of Tripoli, Libya
[2]Department of Computer Engineering, Libyan Academy, Libya.

Abstract. Routing in WMNs is challenging because of the unpredictable variations in the wireless environments. However, there is two ways to enhance the performance of routing protocol in WMNs. One way is to improve the metric used in the selection path; the second way is to modify the routing algorithms by considering new characteristics of WMN. This paper reviews on various types of routing protocols that are used in wireless mesh networks. This paper simulated three routing metrics in OMNeT++ Simulation tool, with Optimized Link State Routing and Ad hoc On Demand Vector (AODV) routing protocols. The two routing protocols have been implementing in mesh wireless test bed consisting of up to 200 mesh nodes. The result of the simulation presents performance evaluations with regard to the network size and network load.

Keywords: Reactive Routing Protocol, Routing Metrics, Routing Protocols, WMNs.

1. Introduction

Wireless Mesh Networks (WMNs) play an important role in today communication. WMNs have low investment overhead and can be rapidly deployed; they can extend IP connectivity to regions unreachable by any single access technology. Some features like low-cost, easy network maintenance, robustness, and reliable service coverage allow WMN to take more portion of wireless communication in near future. A typical WMN consists of mesh routers, and mesh clients. Mesh routers have a wireless infrastructure and work with the other networks to provide a multi-hop internet access service for mesh clients. On the other hand, mesh clients can connect to network over both mesh routers and other clients [1]. WMNs combine concepts from a diverse set of existing and emerging wireless technologies, including cellular technologies, ad hoc networks, and sensor networks. The application of research results from these areas could greatly contribute to the development, implementation, and growth of wireless mesh networks. Routing is an important factor to forward the data packet from source to destination node. The choice of a routing protocol is highly dependent on the network size, node density, node mobility and traffic patterns. Therefore, flooding should be avoided if the network is large. Degree of mobility should be evaluated in order to design protocols adapted to the frequent change of routes. When the network is exposed to heavy traffic volumes, it is necessary to include load balancing techniques in the routing, in order to optimize network resource utilization and avoid congestion. The Wireless Mesh routing protocols can be divided into proactive routing, reactive routing and hybrid routing protocols. The processes of routing algorithm involve applying a routing metric to multiple routes, in order to select or predict the best route. A metrics is a property of a route consisting of any value used by routing algorithms to determine whether one route should perform better than another. To guarantee good performance, routing metrics must satisfy these general requirements are scalability, reliability, flexibility, throughput, load balancing, congestion control and efficiency. The routing metrics for mesh routing protocols are Hop Count, Expected Transmission Count (ETX), The Expected transmission time (ETT), Modified ETX Metric (mETX), Moving Average Expected Transmission count (AETX), Expected Link Performance (ELP), Expected Multicast Transmission Time (EMTT), Sum of Motivated Expected Transmission Time (SMETT), Statistical Estimate Routing Metric (SERM), The Weighed Cumulative ETT (WCETT), Metric of Interference and Channel-switching (MIC), Interference Aware (iAWARE) [2-9].

In this paper, firstly, we present in section 2 review of current Mesh routing protocols and its metrics, in order to provide a better understanding of the research challenges in WMN routing protocol. The remainder of the paper is organized as follows. Section 3 provides Performance evaluations comparing ETX and hop count metrics when used with the Optimized Link State Routing (OLSR) protocol under different WMN environments. In additional to that Ad hoc on Demand Distance Vector (AODV) routing protocol with ETT metric will be included in this comparison. Section 4 concludes this work.

2. Review of WMN Routing Protocols

Wireless Mesh Networks exhibit unique characteristics that differentiate them from other wireless and wired technologies. Therefore, existing routing protocols must be revisited in order to consider their adaptability to WMNs. The main differences relating to routing are: WMNs differ from wired networks due to the possibility of interference between disjoint paths. A fixed wireless backbone differentiates WMNs from other network types. WMNs differ from wired network as the link capacity can vary over time due to the very nature of wireless communications that are sensitive to surrounding interference. WMNs can benefit from the possibility of introducing channel diversity in the routing process, which is not possible in other wireless networks due to node mobility (MANETs) or energy constraints (WSNs). In WMNs, data transmission is primarily between the mesh clients and mesh routers. In general, the routing protocols may be categorized into proactive routing, reactive routing and hybrid routing protocols. In, proactive routing protocol; each node maintains one or more tables which have routing information to all other nodes within the network. Reactive routing protocol creates routes only when desired by the source node. The hybrid routing protocols combines both proactive and reactive routing protocols to transport the packets from the source to the destination. It takes both the advantages proactive and reactive routing protocols. Enhancing the performance of routing protocols can be achieved either by improving the metrics used in the selection path or modify the routing algorithms by considering new characteristics of WMN. Different studies have evaluated the performance of the various routing protocols [9], [10]. Most of the works have focused on enhancing existing routing protocols with new routing metrics more appropriate for WMNs. The fixed wireless backbone allows a better estimation of the link quality through regular measurements. It is also possible to introduce channel diversity in the network infrastructure so as to reduce interference and increase overall throughput.

Some of the recently used WMN routing protocols are summarized. Dynamic Source Routing (DSR): The source will check in its route cache whether there is a valid route to the destination. If there is a route, the source uses this route. If there isn't the source then generates a route request packet. The routing metrics for DSR protocol is Hop Count. An advantage of this protocol is that it does not require any periodic update so the node can conserve power making it suited for low powered devices. However its shortcomings are that it has no mechanisms for handling congestion from high traffic load. Not scalable as delay increases with network size [10]. SrcRR is a variation of DSR using the expected transmission time as a metric instead of the number of hops. The advantage of this protocol that it finds routes with high throughput rates. The disadvantage is that it is not scalable [11]. Link Quality Source Routing (LQSR): is an extension of DSR by adding some metrics to DSR. The metrics are Hop Count, Round-Trip Time latency, Packet Pair latency, expected transmission count. The advantage of this protocol is that it increases throughput since it considers the ETX metric. Its short comings are the same as its metrics overhead as the metrics use probe packets and not scalable. Multi radio-Link Quality Source Routing (MR-LQSR): The assumption is that if a node has multiple radios, they are turned to different non-interfering channels. It uses WCETT Metric instead of hope count as in LQSR. The protocol identifies all nodes in the wireless mesh network and assigns weights to all possible links. The link information including channel assignment, bandwidth and loss rates are propagated to all nodes in the network. Its advantages are similar to those found when using multiple radios: load balancing, tradeoff between delay and throughput as it considers channels with good quality. The disadvantage is that it is not scalable [12]. Ad hoc on Demand Distance Vector (AODV): Routes are set up on demand, and only active routes are maintained. It uses a simple request-reply mechanism for route discovery very similar to that of DSR. It uses the Expected Transmission Time (ETT) routing metric, which measures the expected time needed to successfully transmit a fixed-size packet on a link. The advantages of this protocol is that it reacts quickly to the topology changes and is loop free and avoids count to infinity problem. However is also has shortcomings such as, no routes are set up on demand, and only active routes are maintained. This reduces the routing overhead, but introduces some initial latency due to the on demand route setup. Also it is not suited for low powered devices. Furthermore packet delivery ratio drops dramatically when the number of connections increases [11]. Ad hoc On-demand Distance Vector-Spanning Tree (AODV-ST): uses a proactive strategy to discover routes between the mesh routers and the gateways, and a reactive strategy to find routes between mesh routers. AODV-ST supports ETT and ETX. The advantages of this protocol is that it reacts quickly to the topology changes However, its drawback, the packet delivery ratio drops dramatically when the number of connections increases [11]. Ad hoc on-demand distance vector with Directional Flooding (AODV-DF): can significantly reduce routing overhead and increases the performance by reduce the number of route request packets broadcast by using a restricted directional flooding technique [13]. Ad hoc On-demand Distance Vector- Multi Radio (AODV-MR): is improved AODV to work in Multi-Radio wireless mesh network. It assumes that each node has at least one common channel with neighbor. AODV-MR increases the network capacity because it causes lower degree of interference and contention due to distributed traffic across multiple non-overlapping channels. However, AODV-MR uses IAWARE as router path metric [14]. Optimized Link State Protocol (OLSR): is an optimization version of a pure link state protocol. Topological changes cause the flooding of the topological information. To reduce the possible overhead in the network protocol uses Multipoint Relays (MPR) by reducing the same broadcast in some regions in the network. The routing metrics for OLSR protocol is shortest path. The advantage is that it is suited for dense networks where the source and destination keeps changing constantly. The disadvantages are that bandwidth is wasted on topology control messages aggravated by increasing network size and no load balancing [10]. Destination Sequenced Distance Vector routing (DSDV): where each node maintains a routing table that contains the shortest path to every possible destination in the network and number of hops to the destination. The sequence numbers allows the node to distinguish stale routes from new ones and updates in the routing tables are done periodically to maintain table consistency. The routing table consisting of destination address, next node, metric (Hop count) and sequence number. The advantage of this is that DSDV guarantees loop-free paths and higher efficiency in route discovery as opposed to the latency experience in reactive protocols. The disadvantage is delivery ratio decreases with network size and does not provide load balancing [6]. Cluster head Gateway Switch Routing protocol (CGSR): is a multichannel operation capable protocol [15]. It uses DSDV as the underlying routing scheme. The DSDV approach is modified to use a hierarchical cluster head-to-gateway routing. A Wireless Mesh Network is divided into multiple clusters for load control. A cluster head estimates traffic load in its cluster. As the estimated load gets higher, the cluster head increases the routing metrics of the routes passing through the cluster. The advantage of this protocol is that it effectively balances the traffic load and outperforms the routing algorithm using the expected transmission time (ETT) as a routing metric. Scalable Routing using HEAT Protocol: is a fully distributed, proactive any cast routing algorithm. This protocol inspired by the properties of temperature fields. It assigns a temperature value to every node in the mesh network, new nodes are assigned a value of zero and gateway nodes are assigned a well-defined maximum value. This protocol determines the temperature of node based on distances to the available gateways and robustness of the paths towards these gateways. That is, a path providing multiple alternative delivery opportunities along its way to one of the gateways is preferred [16].

3. Performance Evaluations

3.1. Simulation Parameters

The simulation work that has been implemented is done in Objective Modular Network Test bed in C++ OMNeT++ Simulation tool, by supporting of the INETMANET Framework [17]. INETMANET Framework supports wireless and mobile network simulation. The simulation implementation has been into three phases, Initialization Phase, Running Phase, and Simulation output and analyzing Phase. The purpose of the initialization phase is to setup the network based on a given Network Description (NED) file with support of Omnetpp.ini configuration file to configure and assign or modify the network compound's parameters and simple modulus's parameters. Before the initialization phase is started, some parameters values should given, i.e. total number of mesh nodes, number of mobile hosts, number of radios, radio bit rate, radio sensitivity, the radio transmitter power, some UDP applications, simulation time, and the routing protocol type. By the end of this phase, the network is initialized. All mesh nodes took their positions uniformly as a grid in the simulation area of size 1000m x 1000m and whole system parameters are determined and preloads. These nodes are establishing connection with each other. There is no other background traffic. . Hop count is the most commonly used metric in wireless network has been compared with ETX metrics for Optimized Link State Routing protocol. Simulations were run in order to observe the influence of network size and network load on the performance of each routing metric. Ad hoc on Demand Distance Vector routing protocol with ETT as default metric has been included in this comparison.

The performance parameter figures that have been measured were defined as follows:

Throughput (bits/s):- Throughput is the measure of the number of packets successfully transmitted to their final destination per unit time.

Average end-to-end delay: - It represents the time that spent by the packet to reach to the destination. The average end-to-end delay can be calculated by summing the times taken by all received packets divided by their total numbers.

3. Normalized Routing Load (NRL):- It is the number of transmitting routing packets per delivery data packets. (NRL = number of routing packets/ number of received packets).

ETX metric of the link has been calculated by

$$ETX = \frac{1}{df \cdot dr} \quad . \tag{1}$$

Where df is the probability that a packet successfully reaches the receiver, while dr is the probability that an ACK is successfully received by the sender.

ETT metric can be calculated by

$$ETT = ETX \times \frac{S}{B} \quad . \tag{2}$$

Where S is the packet size and B is the link bandwidth.

3.2. Simulation Results

In the first scenario, the impact of the network size on the performance of each routing metric has been investigated, the number of mesh nodes change from 25 to 200 nodes. The results obtained consist of an average over all the flows. Figure 1 and figure 2 represent an average end to end delay and throughput for the two Routing Protocols with different routing metrics; it appears that Hop Count (HC) and ETX for OLSR protocol performs similarly in terms of end-to-end delay and throughput; AODV routing protocol provides slightly lowest an average end to end delay and lowest throughput. Figure 3 represents normalized routing load for the two routing protocols with different matrices, the normalized routing load for AODV protocol increases with the network size. This is due to the flooding mechanism used for route discovery by this protocol. In this figure OLSR routing protocol performs better.

In the second scenario, the impact of network load on the performance has been investigated by progressively increasing the number of flows from 10 to 40 for a network composed of 40 nodes uniformly scattered over the simulation area. Figure 4, Figure 5 and Figure 6 show the average end-to-end delay, the throughput and the normalized routing load for the two Routing Protocols with different routing metrics. When the number of data flows is small which means the transmission involves only a subset of nodes, the results for all the (routing matrices) protocols are quite similar. On the other hand, when the network load increase, performance figures show that ETX achieve a better traffic in terms of average end to end delay and throughput by forwarding the traffic flows to less congested areas.

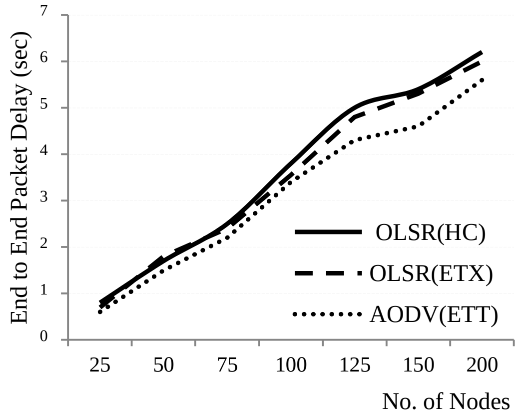

Fig.1: Average End to End Packet Delay for network size.

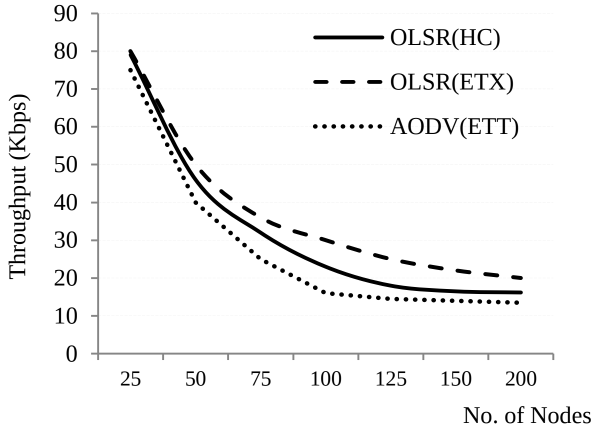

Fig. 1: Throughput for different network size.

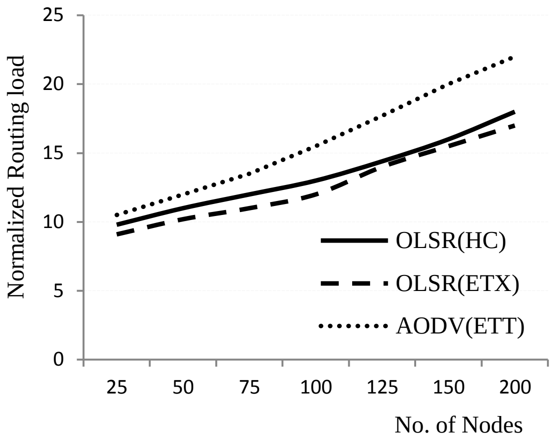

Fig. 2: Normalized Routing Load for different network size.

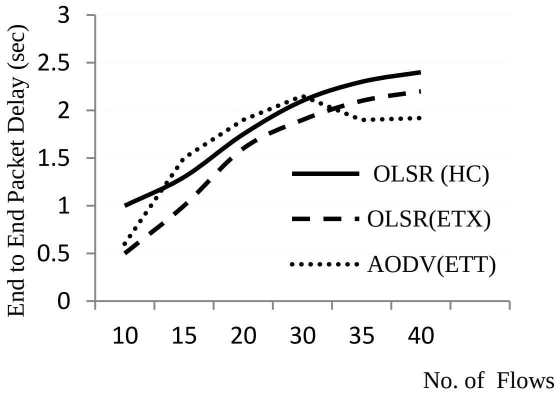

Fig. 4: Average End to End Packet Delay for network load.

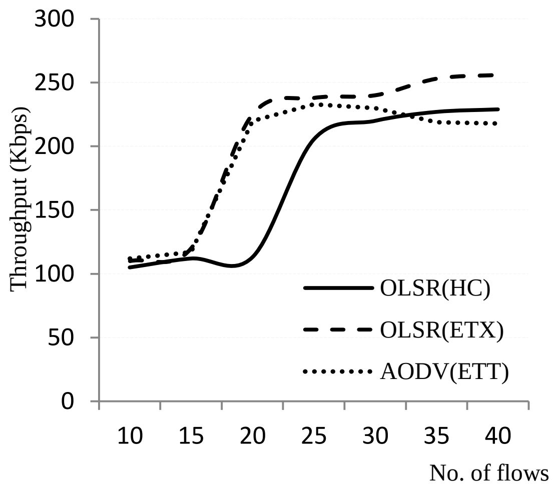

Fig. 5: Throughput for different network load.

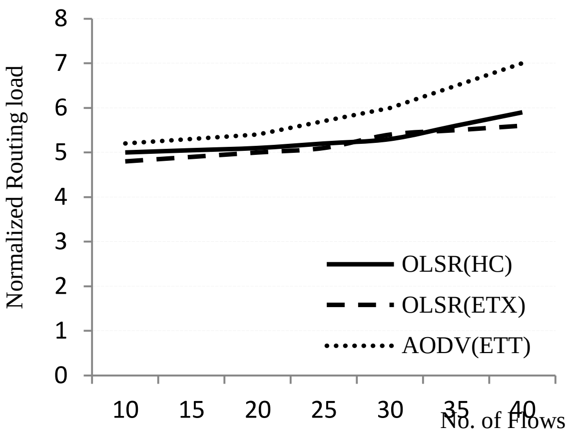

Fig. 6: Normalized Routing Load for different network load.

4. Conclusion

WMNs are a promising technology for next generation wireless networking, the backbone of WMNs provides good solution for users to access the Internet anywhere anytime. In this paper, reviews on various types of routing protocols that are used in wireless mesh networks have been presented. In order to ensure good performance of the routing protocol, routing metrics must satisfy scalability, reliability, flexibility, and throughput, load balancing, congestion control and efficiency. Two well known routing protocols (OLSR and AODV) with different routing metrics have been implementing in mesh wireless test bed consisting of mesh nodes varying from 25 up to 200 nodes. Performance comparison is done with regard to the network size, network load. It has been demonstrated that OLSR protocol with ETX metric improves the overall performance in all the considered scenarios.

5. References

[1] I. F. Akyildiz, X. Wang and W. Wang, "Wireless Mesh Networks: A Survey," *Computer Networks Journal*, vol. 47, pp. 445-487, March 2005.

[2] Y. Yang, J. Wang, J. and R. Kravets, "Designing Routing Metrics for Mesh Networks," in *Proc. of the First IEEE Workshop on Wireless Mesh Networks*, 2005.

[3] A. P. Subramanian, M. M. Buddhikot, and S. C. Miller, " Interference Aware Routing in Multi-Radio Wireless Mesh Networks, " in *Proc. of IEEE Workshop on Wireless Mesh Networks*, Sept. 2006, pp. 55-63.

[4] Y. Hu, S. Yang, D. Wang, L. Zhang, "SMETT: A new Routing Metric for Multi-radio and Multi-channel Wireless Mesh Network," in *Proc. of IEEE International Conference on Wireless Communication, Networking and Mobile Computing*, *2006*.

[5] M. Rahman, S. Azad, and F. Anwa, "Integrating Multiple Metrics to Improve the Performance of a routing Protocol over Wireless Mesh Networks," *International Conference on Signal Processing Systems*, Malaysia, 2009. pp. 784-767.

[6] Entezami, F.; Ramrekha, T.A.; Politis, C.; , "An enhanced routing metric for ad hoc networks based on real time testbed," *Computer Aided Modeling and Design of Communication Links and Networks (CAMAD), 2012 IEEE 17th International Workshop on* , vol., no., pp.173-175, 17-19 Sept. 2012.

[7] Ashraf, U.; Abdellatif, S.; Juanole, G.; , "An Interference and Link-Quality Aware Routing Metric for Wireless Mesh Networks," *Vehicular Technology Conference, 2008. VTC 2008-Fall. IEEE 68th* , vol., no., pp.1-5, 21-24 Sept. 2008.

[8] Xin Zhao; Jun Guo; Chun Tung Chou; Misra, A.; Jha, S.; , "A high-throughput routing metric for reliable multicast in multirate wireless mesh networks," *INFOCOM, 2011 Proceedings IEEE* , vol., no., pp.2042-2050, 10-15 April 2011.

[9] E. Alotaibi, B. Mukherjee, "A survey on routing algorithms for wireless Ad-Hoc and mesh networks," *Computer Networks Journal*, vol. 56, no.2, pp. 940- 965, February 2012.

[10] S. Siva Nageswara Rao, "A Survey: Routing Protocols for Wireless Mesh Networks," *International Journal of Research and Reviews in Wireless Sensor Networks*, vol. 1, no. 3, pp 43-47, September 2011.

[11] K. Ramachandran, et. al., "On the Design and Implementation of Infrastructure Mesh Networks," in *Proc. of the IEEE Workshop on Wireless Mesh Networks*, 2005, pp. 4-15.

[12] R. Draves, J. Padhye, and B. Zill, "Routing in Multi- Radio, Multi-Hop Wireless Mesh Networks," in *Proc. 10th ACM Mobi-Com International Conference*, Philadelphia, 2004, pp. 114-128.

[13] K, Dong-Won kum, Anh-Ngoc Le, You-Ze Cho, Keong Toh, In-Soo Lee, "An Efficient On-Demand Routing Approach with Directional Flooding for Wireless Mesh Networks", Journal of Communications and Networks, Feb 2010, vol. 12, pp. 67 – 73.

[14] A. A. Pirzada, M. Portmann, and J. Indulska, "Evaluation of Multi-Radio Extensions to AODV for Wireless Mesh Networks ," in *Proc. of the 4th ACM International Workshop on Mobility Management and Wireless Access*, 2006, pp. 45-51.

[15] K.P. Vijayakumar , P . Ganeshkumar and M. Anandaraj ," Review on Routing Algorithms in Wireless Mesh Networks," International Journal of Computer Science and Telecommunications, vol. 3, no. 5, May 2012.

[16] R. Baumann, S. Heimlicher, and B. Plattner, ETH Zurich, "Routing in Large-Scale Wireless Mesh Network Using Temperature Fields", IEEE Network, vol.22, 2008.

[17] A. Varga, "The OMNeT++ Discrete Event Simulation System," in *Proc. of the European Simulation, Czech* Republic, *2001*.

S**.** Ahmeda has received his BSc in Computer Engineering from Department of Computer Engineering, University of Tripoli, Libya in 1989 and his M. Sc and Ph. D. from Department of Electrical and Electronics Engineering, University of Nottingham, UK in 1992 and 1996. Since October 1997 to August 1999 he worked as Laboratory administration manager in Industrial Research Center, Tripoli. Since September 1999 he worked as a Lecturer, assistant professor, associate professor and currently he is working as a professor in department of Computer engineering, University of Tripoli. His research interests are in target tracking algorithm, Network security, Routing Protocol for Ad Hoc Network and Wireless Mesh Networks.

Reda Farhan. Was awarded Undergraduate Degree in Computer Engineering in Computer Engineering from Department of Computer Engineering, Tripoli University, Tripoli, Libya in 2005. Currently he is postgraduate student at Electrical and Electronics Engineering Department Libyan Academy, Tripoli, Libya.

Currently Lecturer at the Zawia College for Computer Technologies, Zawia, Libya. His area of interest is Routing protocol for Ad hoc Networks.