IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-7, Issue-5, May 2019 E-ISSN: 2347-2693

Delay-Based Routing Mechanism for Load Balanced Routing in Wireless Mesh Networks

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DOI: https://doi.org/10.26438/ijcse/v7i5.501506 | Available online at: www.ijcseonline.org

Accepted: 17/May/2019, Published: 31/May/2019

***Abstract*—**The tremendous growth in usage of internet technology has led to the development of various wireless networks. One of the wireless networks that have gathered lot of attention is Wireless Mesh Network (WMN). WMN is being preferred because of its numerous advantages such as better coverage area, communication with other networks, low energy consumption, cost effectiveness, increased network capacity and is compatible with all IEEE 802.11 standards. However there are several challenges degrades the network performance. Normally WMNs adopts shortest path algorithm for route establishment and most of the existing algorithms are not fully accounting the factors that impacts network performance, which in turn introduces unbalanced load distribution issues in the WMN. The design of a novel delay-based link quality metric is given in this paper which utilizes the real-time statistics from the wireless driver to consider the wireless contention, congestion, and channel loss. The proposed delay metric is additive in nature and introduce less routing overhead compared to existing mechanisms. Simulation results illustrate that the proposed DBL-AODV protocol significantly enhances the performance of the network by reducing the routing overhead and the routes having high delay are avoided from the process of packet forwarding compared to the standard protocol.

***Keywords*—**Delay, Load balancing, AODV,WMN

I. Introduction

WMN is a multi-hop wireless network comprising of Mesh Gateway (MG) connected to wired systems. Mesh Routers (MR) forwarding the traffic to Internet Gateway and Mesh Clients (MC) are the end users. Mesh nodes are tiny radio transmitters which operate similar to that of a wireless router. These nodes deliver the packets as per the destination even when the nodes are not directly connected. Thus mesh network is reliable even when one of the nodes is not effective. WMN [1] has advantage over Mobile ad hoc network (MANET) by providing high broadband internet access in which clusters of stationery mesh routers with each one supporting multiple radios. Some wire connected MRs behaves as internet gateways (IGWs) to other MRs and provides internet connection.
Features of WMN: Wireless mesh network is a multi-hop wireless network. This provides connectivity even to the users in the non-line of sight conditions and hence increases the throughput. In this way they provide reliable communication than the cellular networks. WMNs exploit IEEE 802.11 radio technology and are easily integrated with the other wireless networks such as wireless sensor, cellular, wireless fidelity (Wi-Fi), WiMedia, worldwide interoperability for microwave access (WiMAX) etc. through the mesh routers which are equipped with multiple interfaces.

WMNs have highly adaptable network architecture, easier deployment and configuration, robust and reliable service coverage, lower operation cost and require less installation time. They are self-configuring; the network spontaneously includes a new node into the existing structure without the involvement of a network administrator. They are self-healing; the network automatically identifies the most secure and the fastest path to transmit the data, even if the nodes fail. As more and more nodes are installed in the network, the network becomes wider and faster. WMN can also be used for wide variety of applications such as transport systems, wireless sensor network, surveillance system, broadband home networking, building automation, health and medical system, community and neighbourhood networking.

Some of the basic routing metrics in wireless mesh networks are: Hop count is the basic routing metric which determines the path with minimum number of nodes between the source and destination. It is the simplest routing metric and is commonly used with AODV, DSR, DSDV routing protocols. However it doesn't take into consideration the transmission rate and packet loss.

Expected Transmission Count (ETX) is the number of transmissions required to successfully transmit a unicast packet on a link. The ETX of a path is the total summation of ETX of each link along that path. The ETX of a link is measured by

$$ETX=1/((D_f \times D_r)) \quad (1)$$

where, D_f is the forward packet delivery ratio. D_r is the reverse packet delivery ratio. This routing metric considers only the packet drop ratio and do not consider transmission rate.

ETT is defined as the time required to successfully transmit a packet at the MAC layer. It is an extension of ETX and considers average size of the packet and bandwidth of the link

$$ETT=ETX \times S/B \quad (2)$$

where, S is the average packet size and B is the bandwidth. This routing metric increases the network throughput and doesn't consider the traffic-load and interference of a link.

WCETT routing metric is an extension form of ETT. The WCETT metric of a path say 'p' is defined by

$$WCETT(p) = (1-\propto)\sum_{link \in p} ETT_l + \propto \times max_{1\le c \le k} X_c \quad (3)$$

where, $\propto$ is the tunable parameter ranging between 0 and 1.X_c is the total summation of the links that are on channel 'c', 'k' describes different channels used in transmission path. WCETT has all the advantages of ETT except isotonicity. This routing metric considers intra-flow interference and doesn't take into account inter-flow interference. Metric of interference and channel switching (MIC) considers intra-flow interference, inter-flow interference and also supports load balancing. Since MIC is an improvement over WCETT, it considers the isotonicity of the path.

The MIC is a combination of two components, IRU and CSC.The MIC for a path p is defined by

$$MIC(p) = \frac{1}{(N \times \min(ETT)_{link})} * \sum_{link\ l \in p} IRU_1 + \sum_{node\ i \in p} CSC_i \quad (4)$$

where, N is the total number of nodes in the network.

Since wireless mesh networks are a type of packet switching networks, the routing protocol directs the packets from their source to their final destination through intermediate nodes. Several routing protocols exist for these types of networks [1]. Each protocol adopts a routing strategy. Based on these routing strategies, the mesh routing protocols are characterized into Proactive routing, Reactive routing and Hybrid routing protocols.

Low Capacity, management of the traffic and gateway nodes and end to end fairness problem are the major issues in the employment of WMNs. In order to reduce the existing challenges in WMNs load balancing plays a vital role. The entire paper is organized as below. The related work is discussed in Section 2. The suggested novel routing scheme is defined in section 3. The simulation results, performance comparison and analysis are presented in section 4. Lastly we have drawn inference in section 5.

II. RELATED WORK

In [2], authors have described a load balancing Multipath protocol MM-AOMDV. This protocol takes the advantages of multipath routing protocol in order to decrease the Route Discovery overhead. MM-AOMDV determines less congested routing paths bearing higher probability of transmission using metrics like load on the channel, remnant energy at node and channel access contentions. Thus, MM-AODV sets off route maintenance procedure less number of times compared to AOMDV.

The authors [3] have proposed a novel traffic predicting multipath routing algorithm called MRATP which comprises three important tasks such as multipath routing, congested discovery and load balancing. The results obtained show that MRATP performs effectively when compared with other algorithms due to its high scalability, better adaptability, desirable success ratio, robustness and lower end to end delay.

A prediction based adaptive load balancing (PALB) mechanism [4] has been proposed for MANETs. The PALB mechanism operates on wavelet analysis. The prediction of network traffic permits minimum congestion in traffic by adaptive distribution of traffic load among multiple disjoint paths thereby reducing packet dropping probability and end-to-end packet delay which in turn balances the network's energy consumption.

Adriana Hava et.al [5] has presented a novel load balancing algorithm that enhances QoS measures of videos in Wireless Mesh Networks. This novel mechanism achieves load balancing across the nodes by constantly evaluating the performance at WMN nodes and forwarding traffic to less congested nodes in the WMN. It employs a novel hybrid hierarchical architecture which is an amalgamation of centralized and distributed approach. The simulations performed depict that the proposed solution achieves better results over the classic approach.

The authors Huaiyu Wen et.al [6] has proposed a cross layer routing protocol for load balancing. The optimal path is discovered by using packet delivery rate and node load as performance parameters and by considering default hop count metric and cross-layer data of MAC layer. The main drawback of the proposed protocol is that it fails to achieve a high throughput while keeping a minimized end to end delay.

The mechanism in [7] employs routing and MAC scheduling to provide rigorous time delays for delay-sensitive traffic. The routing is implemented in MAC layer of the IEEE 802.16 mesh network using its specific features. The next hop node is determined by every node of the network on its own by utilizing pseudo-random election algorithm in coordinated distributed scheduling of the standard IEEE 802.16. Thus the algorithm renders itself scalable by working in a distributed manner and the possible path loop is avoided by developing a loop cancelling mechanism.

Interference Delay Aware (IDA) Routing Metric [8] is the integration of Cumulative inter-flow Load Interference (CLI), Channel Switching Load Cost (CSLC) and Estimated Transmission Delay (ETD).
CLI considers the interflow interference caused by the interfering nodes and is defined as

CLI (P) = $\sum_{link^c_{x,y\epsilon p}} CLI^c_{x,y} = \sum_{link^c_{x,y\epsilon p}} \sum_{j\epsilon | N^c_x \, U \, N^c_y|} LT^c_j$ (5)

where, $link^c_{x,y\epsilon p}$ =Link between Node x and y over a channel 'C' for path 'P'

U N^c_y = union of interfering nodes $x \, and y$ respectively within two hops during transmission.

LT^c_j = Transmission time required by the Node j to carry traffic load through channel 'C' and is defined by

$$LT^c_j = \frac{TL^c_j}{B} \quad (6)$$

where, TL^c_j =Queue length

S=Packet size

B=Bandwidth

Channel Switching Load Cost (CSLC) considers the intra flow interference within two hops. It is given by

$$\text{CSLC(P)} = \sum_{node \ j\epsilon p} LC_j \quad (7)$$

LC_j =Intra-flow interference factor of node j.

In our work we have proposed a modified AODV protocol called Delay Based Load Balancing Ad-hoc on Demand Protocol (DBL-AODV), which considers response time of all nodes along the path as a routing metric for route discovery.

III. DELAY BASED LOAD BALANCING AODV PROTOCOL

The DBL-AODV protocol performs the following modifications to the existing protocol during routing:

- Route selection is based on the hop count and response time
- Whenever response time increases, packets are routed via alternate paths
- Based on the response time RREQ packets are considered or discarded

Delay Based Load Balancing AODV Protocol (DBL-AODV) is a modification of the standard AODV protocol. It uses response time as routing metric to opt the best path to the destination. The proposed method finds end-to-end delay for all the available paths to the destination during route discovery. The source node broadcasts RREQ towards the destination node. If route request message reached in the neighbour node or rely node, this node has to find the delay of the route request and it updates in routing table and checks its sequence number to find the freshness of route request. Sequence number is updated in its own routing table by rely nodes. The destination node finds the overall delay and it to be updated in route reply message. The path with higher delay indicates that it is heavily loaded and the path with least delay indicates the path is not congested. Once the source node gets a route reply, it selects the best route having minimum delay and avoiding packet transmission via congested route thus increasing the overall performance of the WMN. The flow chart of the DBL-AODV is as shown in Figure 2.

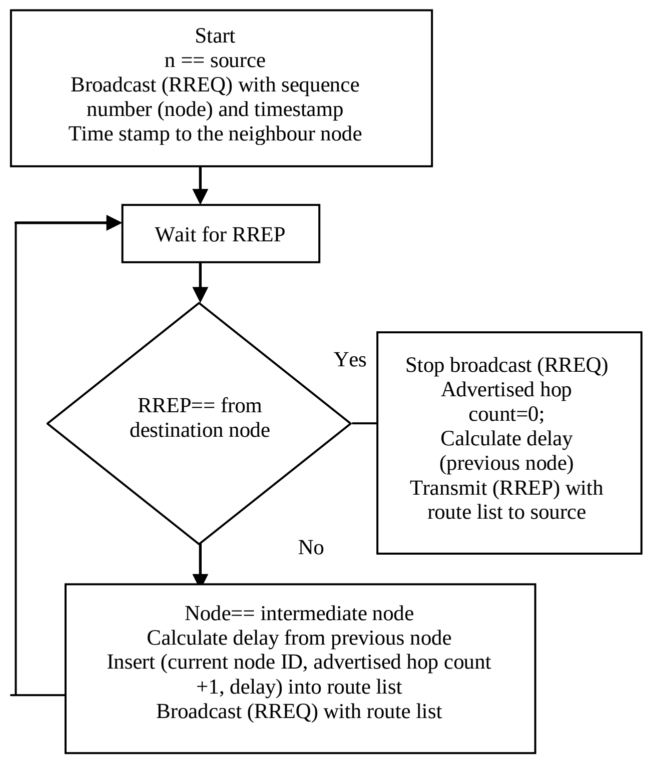

Figure 2. Flow Chart of DBL-AODV Protocol

The delay at every node in WMNs is an aggregation of different delays like input queuing delay, transmission delay, propagation delay, retransmission delay, processing delay and output queuing delay. The network delay analysis involves splitting of packet delay into a series of node delays where delay at each node is defined as the difference in interval of packet arrival at a node and the next node. Thus, the equation below determines that the nodal delay can be decomposed into its component delays as shown.

$$\tau_{nodal} = \tau_{proc} + \tau_{queue} + \tau_{trans} + \tau_{prop} \quad (8)$$

The processing delay τ_{proc}at each node is explained as the period of time exploited by a node for detecting errors, searching a feasible link for further transmission based on destination address and time for interpreting packet header while a packet is being processed. Although the processing appears complicated, this kind of delay is normally insignificant in contrast to other time delays. The time utilized for placing a packet into the communication media is the transmission delay $\tau_{trans}$and the below equation represents the computation of the same.

$$\tau_{trans} = \frac{L}{R} \quad (9)$$

where L represents packet length in bits and R gives the rate of transmission in bits per unit time. The time duration expended by a packet in a queue for allowing the transmission of other packets moving across the same link is called queuing delayτ_{queue}.The queuing delay $\tau_{queue}$and the transmission delay $\tau_{trans}$are relatedby the following equation.

$$\tau_{queue} = \tau_{trans} * L_{queue} \quad (10)$$

whereL_{queue} denotes the average length of queue and it relies on load factor.Load factor is described as the ratio of attempted link transmission to the maximum rate of link transmission. For a load factor of less than 0.5, the typical mean queue length will be less than 1. The queue length increases when the load factor exceeds 1. The transmission delay is the significant constituent of the node delay for a rarely loaded link. However, queue delay prevails for a densely loaded link.

The propagation delay $\tau_{prop}$is defined as the duration that a signal utilizes for propagating from one node to the other via communication medium. It is derived by the following equation.

$$\tau_{prop} = \frac{d}{s} \quad (11)$$

$$\tau_n = \sum_{i \in n} (2D_i + E_i) + \tau_{WRj} + \tau_p \quad (12)$$

where, τ_n represents response time of the RREP packet n
i denotes a node on the path n
D_i represents internal delay in node i precluding the extra delay added.
τ_{WRj} is the delay in generating RREP packet in response to RREQ packet.
τ_p represents the propagation delay.
Internal Delay is given by

$$N_i = \tau_R + \tau_{Proc} + \tau_{Fi} + \tau_p \quad (13)$$

where $\tau_R$represents RREQ/ RREP packet receiving delay
τ_{Proc} is the processing time of a packet
τ_{Fi} stands for the packet forwarding time in node i.

IV. PERFORMANCE EVALUATION

We conducted a number of simulations to evaluate the effectiveness of the proposed algorithm over standard AODV protocol. The performance of the DBL-AODV and standard AODV are compared in terms of throughput, total number of packets received, end to end delay and jitter.
The simulation environment consists of 25, 36, 49, 64 and 81 node densities which are placed randomly in a 1500m x 1500m area. The traffic is generated from three sources and traffic type chosen is Constant Bit Rate with each packet having size of 512 bytes. The simulations are run over 300 seconds.
The other parameters used for performance analysis are listed in Table 1.

Table 1. Mesh Network parameters in simulation

Parameter	Value
Protocols	AODV, DBL-AODV
No. of Nodes	25, 36, 49, 64, 81
Radio type	802.11b Radio
MAC Protocol	802.11s
Antenna Model	Omni-directional
Path Loss Model	Two ray propagation
Traffic Type	CBR
No. of CBR	3

In the simulation, the performance of DBL-AODV is evaluated and compared with Ad hoc On-demand Distance Vector routing protocol (AODV).From Figure 4 it is observed that AODV gives lesser throughput since packets are forwarded through the shortest path irrespective of the load along the path whereas the DBL-AODV considers the response time as a parameter for route selection. Based on the response time proposed protocol changes the route discovery process. In DBL-AODV packets are forwarded through the path having lesser response time and lower hop count among the all available paths to the destination. Hence proposed protocol gives higher throughput as compared to the AODV protocol. From the Figure 3, it is also observed that when node densities increase, the performance of the AODV decreases but DBL-AODV yields higher throughput. For lower node densities, the performance of the proposed protocol is increased by 5% but for higher node densities, the performance of the DBL-AODV is increased by 15% compared to AODV protocol which is even true for total number of packets received. From Figure 5, it is seen that end to end delay for DBL-AODV is lesser than the AODV protocol since it avoids the packet transfer through the highly congested path. For the higher node densities, delay is very much less than the AODV protocol. This is even same for the Jitter.

Table 2. Throughput Comparison

Node Density	AODV	DBL-AODV
25	296406	301138
36	187938	218924
49	125380	286159
64	86255.1	159105
81	111987	138974

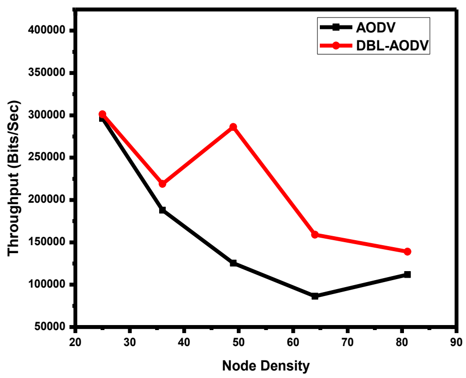

Figure 3. Variation of throughput v/s node densities

Table 3. Total Messages Received

Node Density	AODV	DBL-AODV
25	21707	21788.7
36	13702	15707
49	9180.33	17725.5
64	6314	11410
81	8197	10000.3

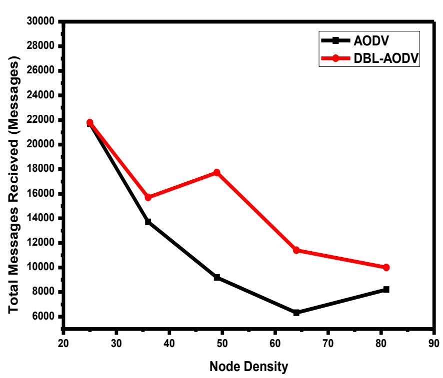

Figure 4. Variation of total messages received v/s node densities

Table 4. End to End Delay Comparison

Node Density	AODV	DBL-AODV
25	3.8457	2.43911
36	3.48773	2.98289
49	1.50114	1.45233
64	0.73018	0.6242
81	2.70725	1.0865

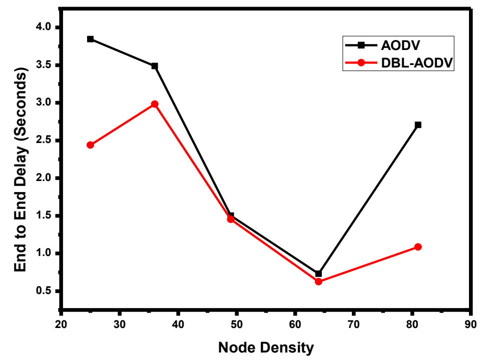

Figure 5.Variation of End to End Delay v/s node densities

Table 5. Jitter

Node Density	AODV	DBL-AODV
25	0.01224	0.01107
36	0.02336	0.01284
49	0.03944	0.00509
64	0.067	0.05347
81	0.05494	0.00713

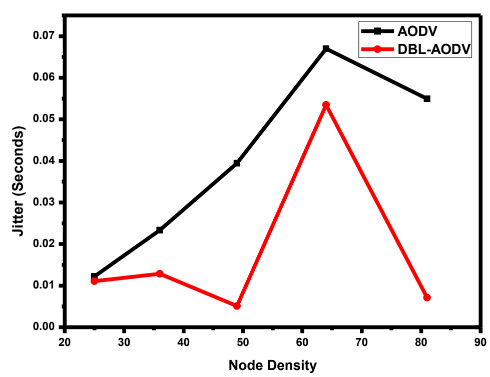

Figure 6.Variation of Jitter v/s node densities

V. CONCLUSION AND FUTURE SCOPE

In this work, DBL-AODV protocol is proposed which balances the load in the network by considering delay as the routing metric while performing the route discovery process. The DBL-AODV routing protocol adopts the best route with possible minimum delay and hop count, thereby overcoming the limitations of the existing multipath routing protocol. From the results it is clearly evident that DBL-AODV outperforms AODV in terms of throughput, total number of packets received, delay and jitter. The overall performance of the wireless mesh network is improved by around 5% for lower node density and around 15% for higher node density as compared to the standard AODV protocol.

ACKNOWLEDGMENT

This work is supported by the Technical Education Quality Improvement Program Phase III with the World Bank assistance. The authors would like to thank the State Project Facilitation Unit, Directorate of Technical Education, Government of Karnataka, National Project Implementation Unit, MHRD, New Delhi for their support and encouragement.

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