Optimized Route Calculation for Wireless Mesh Network

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ABSTRACT
A proactive routing protocol CL-OLSR (cross-layer based optimized link state routing) by using a brand-new routing metric CLM (cross-layer metric) is proposed. This protocol, senses link quality impact factors of bandwidth, node load, packet / link delivery rate and interference trough cross-layer operation mechanism. The metric is taken as a basis of route calculation and to optimize the route selection. Additionally, finding energy of nodes in the network. The simulation results are presented showing that the proposed CL-OLSR protocol improves the network throughput to a large extent; also reduce the end-to-end delay.

Keywords
Route Selection, Optimisation, Cross layer Design, Routing, Proactive Routing.

1. INTRODUCTION
Wireless mesh network (WMN) is a novel kind of distributed broadband network architecture, of which the key idea is that every node in the network can be the access point and the router at the same time [1]. WMN has excellent robustness, and self-organization, scalability which can support rapid deployment and installation, achieve high-speed routing and high-bandwidth transmission, and can be applied to wideband local area networks, transport medical system networks, metropolitan area networks, and other scenes. At present, many domestic and foreign research institutions and related companies are carrying on extensive researches about the WMN technology, and the relevant standards are actively being customized.

Traditional hierarchical network design approach is not effective for WMN. Due to the openness of the wireless channel and time-variability of channel parameters, the hierarchical design method can not guarantee the utilization of network resources and quality of service (QoS) requirements of users. The traditional minimum hop based routing protocol [2] has the flaws that it can not effectively control congestion, has poor fairness, and can not realize load balance. Hence, using the cross layer idea to implement new routing protocols and improve the performance of WMN is the main point of this paper. The new protocol can meet the requirements of load balance and fault tolerant routing, and increase the network capacity while providing a certain QoS guarantee.

The rest of the paper is organized as follows. Section 2 points out the research issues and ideas of this paper on the basis of the current research situation of related works. Section 3, describes the cross layer based optimized link state routing (CL-OLSR) protocol in detail and also describes about network cross layer model. In Section 4, the performance and the route calculation of CL-OLSR route protocol, and proposes new metric called cross layer metric, makes performance is analysed and the simulation results are presented. Finally, this paper is concluded and the future research work is proposed.

2. RELATED WORK
In recent years, the research approach of integrating cross-layer design idea into the Wireless Mesh Network routing protocol design has made obvious progress, which can increase utilization of network resources to a large extent and enhance Qos guarantee to users which obtains the recognition of more and more scholars and research institutions.[2] proposes taxonomy of cross layer routing metric for WMNs with respect to routing parameters, i.e., transmission rate, inter-flow interference, intra-flow interference, congestion, and channel diversity. Taxonomy also opens the door up for new research areas in the design of cross layer routing metrics for MCMR radio WMNs for high throughput IP connectivity. ; [7] proposes integrated metrics based Extended Dynamic Source Routing method (EDSR), which uses cross-layer design to provide frame delivery rate, extra bandwidth and node load of MAC layer for network layer routing algorithm, thus improving the throughput rate and load balance capability of network and satisfying users' QoS requirements by the promotion of network's overall performance;[8] proposes a QoS-aware Routing with Congestion Control and Load Balancing protocol (QRCCLB), which, by introducing cross-layer operation, takes DSR routing protocol in Ad Hoc network as prototype and can make the network traffic bypass the network's business hotspot, thus achieving the effect of congestion control and load balance; [9] proposes a Capacity-Aware Routing (CAR) Protocol, which adopts Bottleneck Link Capacity (BLC) as routing metric. This metric can increase network throughput and reduce end-to-end delay to some extent by cross-layer operation of considering link interference and link load and other link quality information;

The routing protocols have the following common features. These routing protocols are all improved based on existing On-Demand Routing protocols of Ad-Hoc network, like DSR, AODV. But for WSN, the network node is relatively fixed. Only node failures, as well as joining and leaving and the uncertainty of wireless links will result in changes in network topology as in[4]. The rate of change of network topology is far below the arrival rate of data flow and main business in Wireless Mesh Network is the Internet business with certain delay requirement. Based on the network environment, Yelling Yang et al. have come up with conclusion in [11]: proactive hop-by-hop routing protocol is more suitable for Wireless Mesh Network. These routing protocols have jumped out of the traditional route of taking minimum hop as routing metric and introduced the idea of cross layer design. But there is a lack of overall(systemic) knowledge for cross layer design of Wireless Mesh Network in which the implementation process is complex and the practicality is low.

Based on the above analysis, this paper designs an Cross-layer based proactive routing protocol (CL-OLSR) for Wireless Mesh Network based on Optimized Link State Routing protocol (OLSR). CL-OLSR makes use of a brand-new routing metric CLM. This routing metric takes into account four cross-layer factors: node available bandwidth, node balance, link delivery rate and link interference by introducing cross-layer operation mechanism and environmental cognition idea. The effect of these four impact factors on the link quality are optimizing the route selection to a larger extent, hence improving network throughput and achieving the goal of load balance.

3. CL-OLSR PROTOCOL

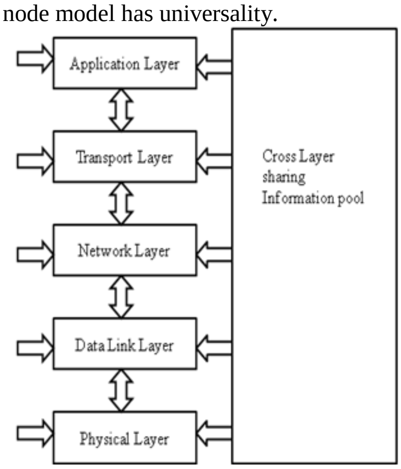
CL-OLSR protocol and OLSR protocol use the same operation mode. The executing process of the whole protocol can be divided into four sub-operations: neighbor discovery, MPR selection, MPR information distribution and route calculation. CL-OLSR exchanges information with other nodes through distributed cooperative mechanism in the neighbor discovery phase. Then this information is used independently to make inference about link state. CL-OLSR completes MPR information distribution, MPR selection, route calculation and optimization selection according to results, thus realizing load balance. Therefore, the following description focuses on network using cross-layer design mechanism, for route optimized selection and optimized route calculation.

3.1 Network Cross-Layer Design

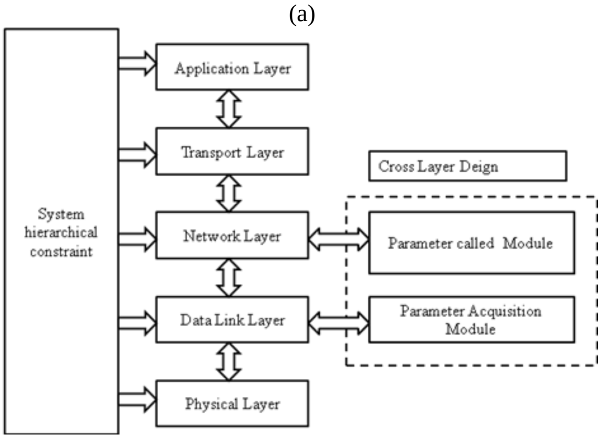
First we give the network model: Consider a Wireless Mesh Network consisting of *N* wireless access points, here the Wireless Mesh Network can be denoted by a directed graph *G* (*V, E*), where *V is* the set of vertices in the graph, $\forall v \in V$ denotes a MAP in network, *E* is the set of direct edges and $\forall e_{ij} \in E$ denotes that there is a directed path from v_i *too* v_j . Following assumptions are made:

1) The network topology is designed and MAP no longer has its location moved after deployment.
2) Each MAP is homogeneous, equipped with multiple wireless adapters and can communicate through multiple channels simultaneously.
3) Each MAP node has additional cross-layer information sharing pool and two cross-layer design models, one is parameter called module and other is parameter acquisition modules, as shown in Figure 1(b).

Node model uses cross layer information sharing design, as shown in Figure 1(a). Every layer of node shares acquired node inner information and environment information in information sharing pool. Different protocol layer takes desired information from sharing pool according to the protocol rules of this layer as input parameters of decision-making algorithm. Different optimization criteria of every layer require different inference methods which require different sharing information as decision parameters. Figure1(b) shows the Node model, which relaxes the strict requirements of hierarchical structure while maintaining the separation rules between layers and allowing algorithms of different layers to share state information of network. This benefits layer inner, layers inter operation optimization and the integrated optimization of overall performance of network. There, this node model has universality.



(a)



(b)

Figure 1: Cross-layer design in CL-OLSR

The environment state information of sensed in data link layer and network layer node which is shared in information pool through parameter called module. As Figure 1 (b) shows two important models of cross layer that are, parameter acquisition module which is engaged for collecting link quality-related information from this node to other adjacent nodes on the data link layer, including node bandwidth, node balance and link delivery rate and interference. Parameter called module is engaged for providing data interface of various statistics information for network layer routing protocols. When making route selection, network layer gets various statistics information from information sharing pool and uses heuristic methods to makes inference for link state. Then the results are taken as a basis for route selection.

4. CL-OLSR ROUTE CALCULATION

4.1 CLM Routing Metric

Every node in network senses cross-layer information as shown in Figure 1(b) to obtain information of node available bandwidth and node load that represents node state and information of link delivery rate and link interference that represents link state. Cross-layer information is shared in the way that Figure 1(a) shows and this information is recorded in the node's neighbor table. Nodes interact and share with each other through neighbor discovery. Every node periodically broadcasts a "HELLO" packet according to the currents neighbor table to achieve state information exchange between neighbor nodes. And further nodes detect and update the state information of surrounding neighbors.

For ∀v∈V, consider the following two performance parameters: node available bandwidth and node load; for $\forall e_{ij} \in E$, onside the following two performance parameters: link/packet delivery rate and interference. This algorithm combines performance parameters of node into performance parameters of downstream edge on its path. For $\forall e_{ij} \in E$, there are four following performance parameters:

1) Bw_ϵ denotes node available bandwidth of upstream node v_i of direct edge e_{ij} where e is used instead of e_{ij}. Following is similar.
2) $Load_\epsilon$ denotes node load of upstream node v_i *of* direct edge e_{ij}.
3) PDR_ϵ denotes link delivery rate from node v_i *to* v_j *on* direct edge e_{ij}.
4) LI_ϵ denotes link interference of direct edge e_{ij}.

These four performance parameters can be obtained through cross-layer mechanism, the definition of which is as follows:

Definition 1: Bw_ϵ represents the bandwidth surplus extent of upstream node v_i of direct edge e_{ij}. all MAP are homogeneous, therefore basic data bandwidth is the same,

$$BW_\epsilon = \frac{Bw_{available(i)}}{Bw_{basic}} \quad (1)$$

Among them $Bw_{available(i)}$ denotes available bandwidth of v_i and Bw_{basic} denotes basic data bandwidth of MAP. In practical application, if the basic data bandwidth of MAP is different, then Bw_ϵ should be multiplied by a weighting factor to reflect basic data bandwidth situation.

Definition 2: $Load_\epsilon$ represents busyness extent of upstream node v_i of direct edge e_{ij}.

$$Load_\epsilon = \frac{Q_{wait(i)}}{Q_{max(i)}} \quad (2)$$

Among them $Q_{wait(i)}$ denotes the number of data packets waiting to be sent in sending queue. $Q_{max(i)}$ denotes maximum length of waiting queue. In practical application scenario, representational contents of node load should be made appropriate adjustments according to specific circumstances.

Definition 3: PDR_ϵ represents data transmission efficiency of direct edge e_{ij} , defined as frame delivery rate from node v_i to node v_j on edge e_{ij} ,

$$PDR_\epsilon = \frac{F_{rev(j)}}{F_{sent(i)}} \quad (3)$$

Among them, $F_{rev(j)}$ denotes the number of frames successfully received by v_j $F_{sent(i)}$ denotes the number of overall frames sent by v_i. Here, only when the MAC layer perfectly receives frames sent by the neighbor nodes, then a frame is successfully received. If a complete frame can't be correctly received due to collision or the wrong checksum of a received frame, then frame is said to be lost.

Definition 4: LI_ϵ represents the interference extent of direct edge e_{ij} to its surrounding nodes,

$$LI_\epsilon = \frac{|IS(e)|}{ISN} \quad (4)$$

Among them, IS(e) denotes the node set in network which may have interference with wireless transmission on direct edge e_{ij} . |IS (e)| denotes the number of nodes in this set. In this paper, each node in network monitors surrounding network in its own channel and records the node set which has used the current channel to transmit in a period of time. IS(e) takes the intersection of the node sets recorded by v_i and v_j corresponding to the channel used by direct edge e_{ij}.ISN denotes the number of nodes contained by the largest IS(e) set in network, the value of which can be estimated according to specific network environment.

According to definition 1 to 4, CLM is defined as follows:

Definition 5: For any directed edge e_{ij} in graph:

$$CLM(e) = \alpha . (1 - Bw_\epsilon) + \beta . Load_\epsilon + \gamma . (1 - PDR_\epsilon) + \delta . LI_\epsilon \quad (5)$$

Among them, α, β, γ and δ are weight factor and satisfy $|\alpha| + |\beta| + |\gamma| + |\delta| = 1$. The value of α, β, γ *and* δ are decided by specific network environment and application.

The designing of CL-OLSR protocol for WMN is based on optimized link state routing (OLSR) protocol. CL-OLSR based on refines the idea of cross-layer design, and proposes a brand-new routing metric CLM applicable to WMN. This routing metric takes into account four cross-layer factors: node available bandwidth, node balance, link delivery rate, and link interference by introducing the cross-layer operation mechanism. Through considering these four factors, the route selection is optimized to a larger extent, the network throughput is improved and the goal of load balance is achieved. Compared with the on-demand routing, CL-OLSR is a proactive routing protocol of hop-by-hop forwarding, which is more suitable for static topological properties of WMN, and satisfies the requirements of low delay of the traffic flow.

CL-OLSR senses the information of the node available bandwidth, node balance, link delivery rate, link interference, and node state, and switches node state through the distribution method. CL-OLSR exchanges sensed information through the distributed cooperative mechanism in the neighbor discovery phase. CL-OLSR makes inferences about the link state through this information, then calculates route and optimizes selection according to the inference results, thus realizing the load balance. Finally, calculating the energy utilized by nodes and making the route calculation more optimized.

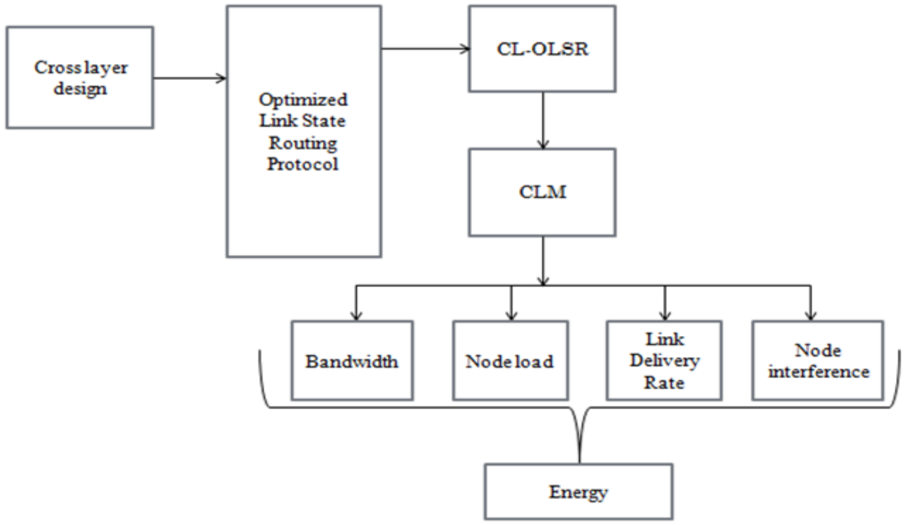


Figure 2: The figure above shows, the entire four impact factor for Optimized Route Calculation.

5. CL-OLSR ROUTE IMPEMENTION

CL-OLSR routing protocol, based on OLSR routing protocol, integrated with CLM in cross-layer design as routing metric can greatly improve the accuracy and optimization of final route selection under the premise of Capacity-Aware Capacity- Aware Channel almost no increase in maintenance costs. In the CL-OLSR, in each node n's neighbour table (each table entry records a one hop neighbours' related information, including link type and the two-hop neighbours' that this hop can connect to, etc.), each table entry (one-hop neighbours node corresponding to this table entry is denoted by neighbours) is added a field to record a corresponding CLM weight of directed links from n to neighbours (link type is one-hop neighbours node of one-way link and corresponding CLM weight is set to infinity) shown in figure3.

Similarly, in each node n's MS table (each table entry records related information of one MPR Selector node), each table entry (the MPR Selector corresponding to this table entry is denoted by ms) is added a field to record corresponding CLM weight of directed links from n to ms. As the node topology table contains MS table information of all nodes in the network, so each table entry of topology table adds corresponding field that records corresponding CLM weight information. Thus, in the last routing operation calculation, Dijkstra algorithm can be used to calculate the optimal path between the source and destination node according to CLM weight information of neighbours table and topology table. Among them, the update mechanism of CLM weight field in MS table plays a crucial role in the stability of routing. If every round of protocol operation recalculates CLM weight field of every table entry in MS table to reflect the current quality of corresponding link.

Then these updated link quality information will be broadcasted to the entire network with topology control packet, so each node in the network will adjust routing table accordingly in route calculation operation after this round so that the following network traffic migrates from current load heavy path to path of lighter load. The results of this operation is that in the next round of protocol, the lighter load paths become congested due to traffic concentration while the heavier load paths become idle due to traffic migration. So the network traffic will migrate again to the previous path.

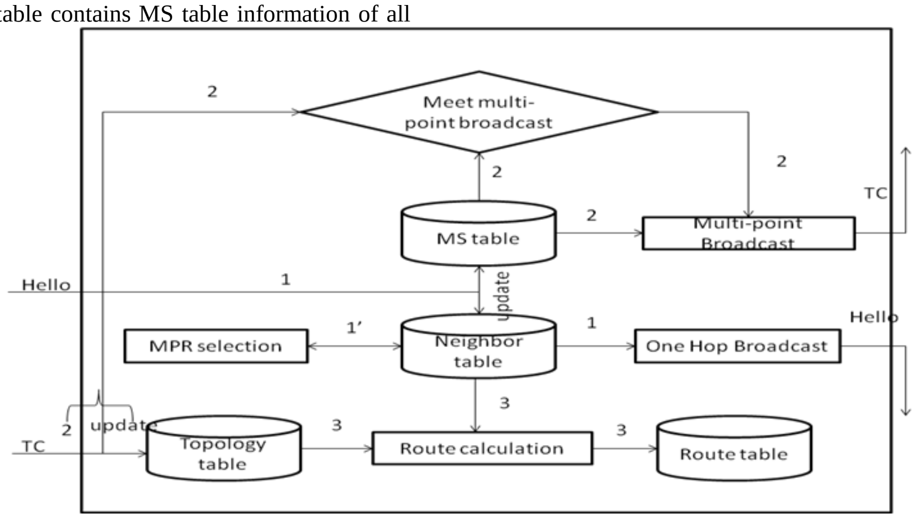


Figure 3: CL-OLSR route protocol executing schematic diagram

The pseudo code of this algorithm is as follows:

1. Route absorber(&MS table) /*regularly executed, update CLM weight in MS table

2. if MS.seq == sequence /*Ms.seq records the version number of MPR Selector set. Whenever node adjusts MPR Selector set according to the received HELLO packet, this value increases by 1. Sequence is a global variable which records version number that algorithm executes last time.*/

3. return; /*if node's MPR Selector set doesn't change, do nothing*/

4. else

5. *{* for each MS ITEM in MS table /*MS ITEM has multiple attribute values corresponding to each field of table entry in MS table.*/

6. *{* calculate CLM weight of directed path from current node to MS ITEM.ms, denoted by CLM New /*MS ITEM.ms denotes MPR Selector node in this table entry.*/

7. if | CLM New - MS ITEM. CLM |> threshold /*MS ITEM. CLM denotes the value of CLM weight filed in this table entry, threshold is a pre-set threshold. */

8. MS ITEM.CLM = CLM New; *}*

9. sequence = MS.seq; *}*

10. *}*

6. RESULTS AND ANALYSIS

NS2 simulation software is used to carry out simulation test on CL-OLSR routing protocol. Simulation experiment has been extended to support multiple adapters and multiple channels configuration. And by using method of corresponding C++ object in Tcl script. The topology used by the simulation is shown in Fig. 2. There are total 15 network nodes. In simulation, node transmission range is 250 m, the interference range is 50m and the distance between adjacent nodes is 170 m, and totally the distance is 550m, highest antenna range is 1.5m. The motion range is 1000 m* 1000 m, simulation time is around 80sec. Figure 4 shows the topology of network.

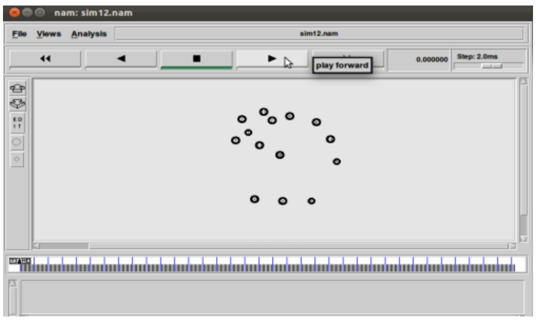


Figure 4: Shows simulation topology in NAM traces (network animator).

The simulation experiment randomly generates 5 CBR data flows where data packet size is 512 bytes. Then the transmission rate of data flow is changed from 2 packets/sec increasing to 29 packets/sec and take transmission rate as parameters of measuring network load. The data flow in the network is shown in Figure 5. Then the end to end delay of the network using CL-OLSR protocol is analysed initially at 0sec the delay is large, this is due to packets take some time initially to transmit i.e at 0sec and gradually start transmission in the network, so end to end delay is calculated depending upon time taken by a packet to reach the destination node. The experimental results are shown in Figure 6.

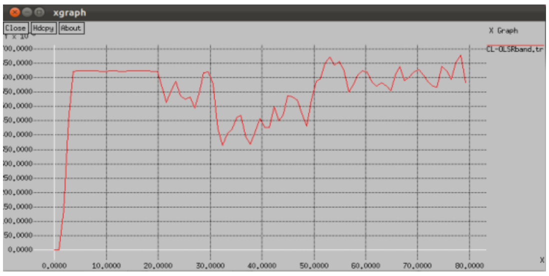


Figure 5: Bandwidth vs time graph of CL-OLSR protocol

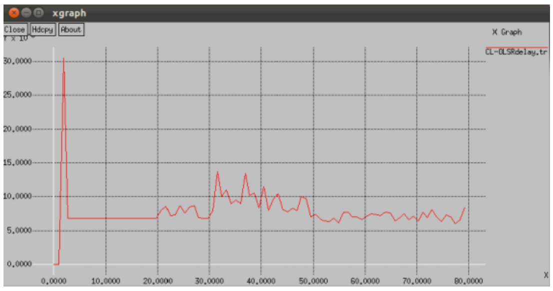


Figure 6: End to End delay of CL-OLSR protocol

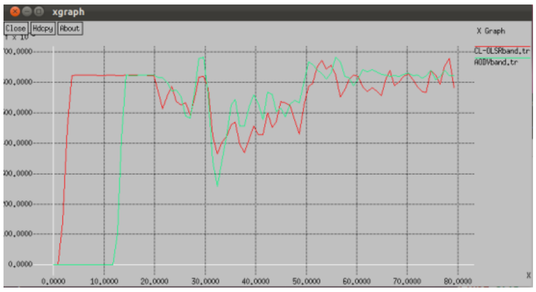


Figure 7: Bandwidth analysis of CL-OLSR and AODV protocols

CL-OLSR effectively uses the network bandwidth and improves network throughput and transmission rate. CL-OLSR's performance has been greatly improved compared with AODV. The analysis is shown in Figure 7 and Figure 8 shows the analysis of end to end delay of both protocols. It can be seen from simulation results that although there is interference and packet loss on the wireless links, but CL-OLSR selects the path of light node load, low packet loss and weak wireless interference to transmit data by monitoring the link quality. CL-OLSR effectively uses the network bandwidth and improves network throughput and transmission rate. CL-OLSR's performance has been greatly improved compared with AODV. It can be seen from Figure 9 that when the data transmission rate is 12packets/sec, the network throughput of CL-OLSR is 1.22 times,1.25 times that of

AODV while the average end-to-end delay of CL-OLSR is 0.78 times and 0.62 times of AODV.

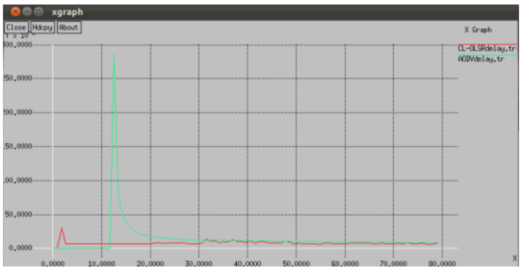


Figure 8: End to End delay analysis of CL-OLSR and AODV protocols

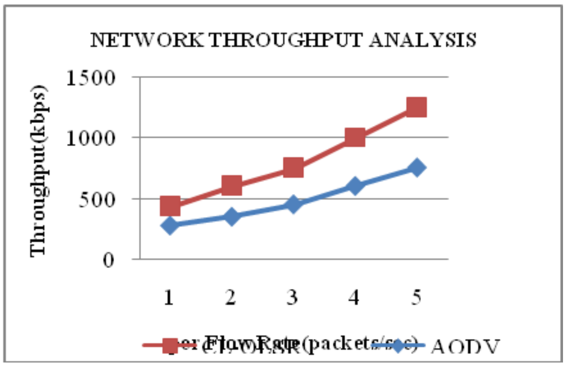


Figure 9: Network throughput analysis of CL-OLSR and AODV protocol.

The main reason of above performance difference is that CL-OLSR fully considers the impact of link quality factor on route effect: node bandwidth, node current load, and link/packet delivery rate and interference. CL-OLSR can avoid the wireless links of poor quality, high interference in current network, so the impact of network load increase on the performance of CL-OLSR is not obvious. AODV don't take into account or just simply consider these issues, so when the network load increases, the packet loss and interference increase. And when node gets overloaded, routing protocols don't have corresponding mechanism to adjust the route, so the impact of network load is more obvious.

7. CONCLUSION

A cross-layer based proactive routing protocol CL-OLSR based on OLSR routing protocol for WMN is proposed in this paper. This protocol exploits a brand-new routing metric called CLM, which takes into account four impact factors: the node bandwidth, the node load, the link/packet delivery rate, and the link interference, through the cross-layer operation mechanism in route calculation. Finally analysing the energy utilised by all four impact factors. Thus the effect of route selection is optimized. Simulation experiment results demonstrate that CL-OLSR dramatically improves the network performance, efficiently increases the network throughput, reduces the end-to-end average delay, and achieves load balancing route results to some extent.

Future work: The determination of the feasible weight of these factors in route selection integrated metrics is our future focus.

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