Load Balance Routing Protocol in Wireless Mesh Network based on Cross-layer knowledge (use style: *paper title*)

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Huaiyu Wen *(Author)*
line 1 (of *Affiliation*): School of Computer Science and Engineering
line 2: University of Electronic Science and Technology
line 3: Chen Du, China
line 4: e-mail: wenhuaiyu@163.com

GuangChun Luo *(Author)*
line 1 (of *Affiliation*): School of Computer Science and Engineering
line 2: University of Electronic Science and Technology
line 3: Chen Du, China
line 4: e-mail: wenhuaiyu@163.com

***Abstract*—Wireless mesh network (WMN) is a new kind of distributed broadband network and has drawn great attention since it has good scalability, robustness and self-organization. However, routing protocols in traditional wireless networks such as wireless sensor network (WSN) and Ad Hoc network cannot be directly used in WMN, such as those minimum hops based routing protocols that have poor performance in WMN. To provide a routing protocol suitable for WMN, a load balance routing protocol in WMN is proposed based on cross-layer knowledge and takes Ad Hoc On-demand Distance Vector Routing (AODV) as a prototype, namely Load Balance Cross Layer based AODV (LBCL-AODV). In this protocol, not only the hop counts in AODV are considered, but also cross-layer information is used as metric to optimize route selection through using node load and packet delivery rate performance parameters. WMN always suffers from the load unbalance problem which degrades the network performance. To solve this problem, a load dynamically migration method is proposed which can migrate the traffic from busy routes to empty paths. The simulation results show that LBCL-AODV can reduce the end-to-end delay, increase the delivery rate and achieve the load balance.** *(Abstract)*

Keywords-component; cross-layer; load balance; load migration (key words)

I. Introduction *(Heading 1)*

With the rapid development of wireless communication technology, various wireless networks appear and are applied into production and life. Among all the wireless networks, WMN is a new kind of distributed broadband network and has drawn great attention since it has good scalability, robustness and self-organization [1, 2]. WMN has also evolved into the next generation wireless communication technology [3].

WMN are consisted of two kinds of nodes: mesh routers and mesh clients. And mesh routers can establish the backbone network and connect to the public Internet. After the backbone is formed, it can provide mesh clients with multi-hop wireless Internet access. In this scene, the routers and the clients can both form multi-hop wireless network. WMN differs from traditional WLAN network in their network access way. In WLAN, every client must share an AP (Access Point) to access Internet and communicate with each other via the AP [4]. So in WLAN, the AP becomes a bottleneck when the traffic becomes heavy. However in the WMN, every device can act as the client and router at the same time. Each node can receive packets and forward packets as a router. In this way, clients can form multi-hop routes. When the traffic is heavy, WMN can dispatch traffic through other nodes while in the WLAN the AP suffers from congestion and the overall network performance is degraded. The multi-hop manner is inherited by WMN from Ad Hoc network. But the traffic in WMN is largely composed by Internet traffic while in Ad Hoc network much traffic are nodes' communication which makes their network protocols different.

WMN combines the advantages of WLAN and Ad Hoc networks to form a distributed multi-hop wireless architecture. Due to the differences and relationships of WMN and traditional wireless networks, the existing protocols of WLAN and Ad Hoc networks cannot be directly used in WMN [5]. Therefore, new routing protocols for WMN should be developed to satisfy the characteristics of WMN such as the node's stability. Due to the openness of wireless channel and time-variability of channel parameters, hierarchical design method can't guarantee the utilization of network resources and QoS requirements of user service [6]. Traditional routing protocols based on minimum hop suffer from high congestion, poor fairness and load unbalance. But due to the similarity of WMN and Ad Hoc network, routing protocols in Ad Hoc network can be improved to adjust to the requirements in WMN [7][8]. Therefore, LBCL-AODV is proposed in this paper to optimize the route selection for WMN using cross-layer knowledge such as node load and delivery rate. LBCL-AODV inherits the route discovery mechanism and is also an on-demand routing protocol in which nodes don't have to know the global knowledge of network [9]. Moreover, as time passed, some nodes will have to deal with much traffic which may cause network congestion. This phenomenon can be reflected by the value of cross-layer metric the node load or the packet delivery rate [10][11]. LBCL-AODV monitors the traffic on nodes and moves the traffic from one route to another by checking the variation of cross-layer metric. When a node forward too

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many packets, the node will be marked too heavy and the protocol will choose another route to deliver the packets. Therefore, LBCL-AODV combines the cross-layer information with AODV to provide a routing protocol for WMN with good throughput and load balance result.

The rest of the paper is organized as follows. In Section 2, the cross-layer metric and the LBCL-AODV algorithm are presented. In Section 3, the performance of LBCL-AODV is evaluated through simulation experiments. Finally, we conclude and discuss future work in Section 4.

II. LBCL-AODV Protocol

LBCL-AODV inherits the route selection mode of AODV protocol. When a source node needs to communicate with another node for which it has no routing information in its table, the path discovery process is initiated. The route discovery also contains two steps: reverse path setup and forward path setup. LBCL-AODV exchanges information with other nodes in the path setup phase. This information contains the cross-layer knowledge and the protocol uses this message to complete the route selection which can reduce the end-to-end average delay and improve the overall throughput. The load balance mechanism in LBCL-AODV can further reduce the traffic congestion and make the network load distribute evenly over the whole network.

A. *Route Setup (Heading 2)*

The route setup includes three steps: path discovery process, reverse path setup and forward path setup. When a source node needs to communicate with another unknown node, the path discovery process is initiated. Then the source node broadcast a route request (RREQ) packet to its neighbors. The cross-layer information is added by special module in the RREQ packets.

To decide whether a route is good, the cross-layer information is collected and after the path discovery step, the node load and packet delivery rate are obtained. Then the LBCL-AODV uses these two cross-layer performance parameters to calculate the routing metric . The route metric is used as the route decision function to optimize the route selection as Eq. (1).

$$C = \frac{1}{\mu}\left\{ \alpha \frac{\sum_{i=1}^{n-1} L_i}{n-1} + \beta \frac{\sum_{i=1}^{n-1} D_{i,i+1}}{n-1} + \lambda \frac{H - H_{std}}{H_{std}} \right\}$$

1. 節點的負載比率
2. 節點的延遲

In the formula above, L_i is the node load of node i and $\sum_{i=1}^{n-1} L_i/(n-1)$ is the average node load on route r and α is the variable parameter of L_i ; $D_{i,i+1}$ is the delivery rate from node i to node $i+1$ and $\sum_{i=1}^{n-1} D_{i,i+1}/(n-1)$ is the average packet delivery rate on route r and β is the variable parameter of $D_{i,i+1}$. Our goal is to avoid the "hot" route. Therefore, the average route load and delivery rate are exploited to reflect busy condition of traffic on the route. The third item is the hop count rate with the weighting factor λ . H represents the hop count number and H_{std} is the pre-defined standard hop counts by user or administrator to make time also an factor to be considered in the route selection. The operation of average value avoids the situation in which the route has not much traffic but a node on the route provide high values accidentally.

Route with the smallest C value will be selected as with the protocol in AODV. Because the route need high packet delivery rate, the value of β is negative. And α, β, λ satisfies the equation $|\alpha| + |\beta| + |\lambda| = 1$. To sum up, a route with high packet delivery rate, low work load and low hop counts will be selected with a higher probability.

In some situation, a node on a particular route may have high work load and low packet delivery rate due to the device performance. Although the route is not so busy at all, the poor performance node will be become the bottleneck of the route and the route will become congested on this point to deliver more traffic. The follow Eq. (2) is used to determine whether a route is useful or not.

$$U = \prod_{i=1}^{n-1}(L_i - L_{max}) \prod_{i=1}^{n-1}(D_i - D_{min}) \prod_{i=1}^{n-1}(H - H_{max}) \qquad (2)$$

In Eq. (2), L_{max} indicates the maximum value of node load L_i and L_i is set to when it satisfies $L_i \ge L_{max}$; D_{min} indicates the minimum value of node packet delivery rate D_i and D_i is set to D_{min} when it satisfies that $D_i \le D_{min}$; H_{max} indicates the maximum value of route hop counts H and H is set to H_{max} when it satisfies that $H \ge H_{max}$. U can be added in the corresponding item of the decision function C . The decision function will be off when the value of U is zero. In other words, a route with a smallest value of C will be selected when U is not zero. We can set C to C_{max} when U is zero. In this way, the route can be selected using cross-layer information which can decrease end to end delay, increase throughput and improve the whole network performance. And with the check of bottleneck node, time is saved and the whole traffic distribution in network is more even.

B. *Node Load Migration*

To further make the workload even in the network, a load balance strategy is proposed here. In some situation, one route is used too much and the traffic is very heavy on this route. When the whole traffic on one route reaches the traffic threshold value, the load migration will be induced.

When the traffic of one route is beyond the threshold T_{thres} , the route is labeled as R_{busy} . The traffic is calculated in a time period Δt .The route with least traffic in this period is labeled as R_{empty} . When the migration happens, the traffic on R_{busy} will decrease and the traffic on R_{busy} will increase. The traffic amount on route R_{busy} is labeled as T_{busy} and the traffic amount on route R_{empty} is labeled as T_{empty} in certain time period Δt . To avoid the situation in which both the two routes are busy and no migration is needed, the traffic on the empty route should be at least less than on the busy route which satisfies $T_{busy} - T_{empty} \geq \psi$. The value ψ is set according to the different applications. The procedure can be described as follows.

- For route $R_1, R_2, \cdots R_i \in R$
- In time Δt ,traffic $T_1, T_2, \cdots T_i \in T$, decision function $C_1, C_2, \cdots C_i \in C$
- The max T_i labeled as T_{busy} corresponding C_{busy} , the min T_j labeled as T_{empty} corresponding C_{empty}
- If satisfies $T_{busy} - T_{empty} \geq \psi$, then $C_{busy} = \frac{1}{\mu_{busy}} C_i$, $C_{empty} = \frac{1}{\mu_{empty}} C_j$, satisfies . $\mu_{empty} \succ\succ \mu_i \succ\succ \mu_{busy}$

After these procedures, the traffic will be gradually attracted to the empty route and make the network load more even. This can benefit the alleviation of congestion problems on the busy routes which can further improve the network throughput.

III. Simulation Results

NS2 simulation software is used to carry simulation tests on LBCL-AODV to verify its performance. Simulation experiment has been extended to support multiple adapters and multiple channels configuration. And by calling lookup() method of corresponding C++ object in Tcl script, pointer pointing to cross-layer object is obtained, and then cross-layer access mechanism is realized through this pointer.

In the simulation, the performance of LBCL-AODV is tested and compared with Ad hoc On-demand Distance Vector route protocol (AODV) in addition to OLSR protocol. Two important network performance parameters are used to weigh the performance of these routing protocols: network throughput and end-to-end average delay. And the load balance mechanism is experimented and compared in the simulation.

The simulation is performed for a network of 100 nodes distributed in a square . Node transmission range is 150. Only the nodes within each other's transmission range can communicate with each other. The network connectivity follows the unit disk graph. The wireless link bandwidth is 2Mbps and the data is generated by CBRGEN generator. The simulation tests are supposed for static network for the static characteristic of mesh network.

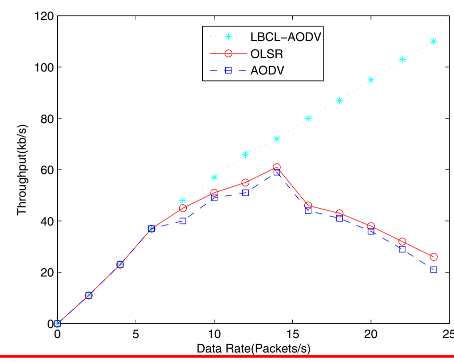
Through a variety of simulation experiments values of parameters, when the value of α is 0.3, the value of β is 0.2, the value of λ is 0.5, LBCL-AODV protocol can achieve the best performance result. It can be seen from the result that the parameter of shortest path takes half the proportion of the routing metric which reflects the necessity of cross-lay information metric.

In the simulation, the number of connections is preset to 5. And the source nodes and destination nodes are selected randomly and the simulation starts randomly. It can be seen from the results that when the data transmission rate is 5Packets/s, the three routing protocols are similar. When the data rate is low, the network is not congested and nearly no packets will be lost using the different routing protocols.

For AODV and OLSR, when the network load increases, packet loss phenomenon will happen sometimes. So when the data rate is 18Packets/s, the throughput of AODV and OLSR will decrease and the corresponding curve down casts as shown in Fig.1. The throughput of LBCL-AODV increase constantly as the cross-lay metric is considered. It can be seen form the figure that when the data transmission is 18Packets/s, the network throughput of LBCL-AODV is 1.73 times that of OLSR, 1.82 times that of AODV while the average end-to-end delay of LBCL-AODV is 0.75 times that of OLSR, 0.67 times that of AODV as shown in Fig. 2.

Through the simulation experiments, the rationality of LBCL-AODV is verified. Through combing the cross-lay parameters with the distance parameter, the network performance is improved greatly. The node load and packet delivery rate are considered that the network is improved and

the average end-to-end delay is decreased. And through the load migration mechanism, the traffic can be transferred from the "hot" routes to "cold" routes to realize the network load balance. This further can benefit the alleviation of congestion in the network hot area.



前面為介紹到 OLSR
，在最後面需要效能量測時才拿出來比較。

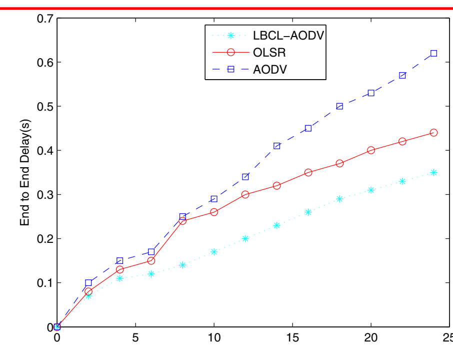


Figure 2. Average End-to-End Delay Comparison.

IV. CONCLUSION

In this paper, we have proposed a routing protocol LBCL-AODV for WMN. In traditional routing protocols for WSN or Ad Hoc networks, only the time metric hop count for evaluate a routing protocol is considered. In LBCL-AODV, however, the cross layer information of MAC layer is combined with the time metric used in network layer. Through the exploitation of node load and packet delivery rate, the protocols are more suitable to the practical network scene which reduces the average end-to-end delay and increases the throughput. Also a load balance mechanism is used in which network traffic can migrate from busy nodes to other relative empty nodes dynamically. In this way, the node load is distributed across the whole network. The congestion can be controlled further. As a result, LBCL-AODV can have a good load balance result. And how to reduce the end-to-end delay while keeping high throughput is still our future work.

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