Based on the Cross Layer Integrated Metric and Change of the Trigger Mechanism WMN Routing Protocol Design and Simulation

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Abstract
To improve the throughput and transmission quality of routing protocols for Wireless Mesh Networks, this paper presents a cross-layer routing protocol MCL-AODV for the wireless Mesh backbone networks. The protocol takes the quality of MAC layer link, node queue congestion degrees and wireless transmission distance into account through the cross-layer operating system, to optimize the routing selection process by creating a new composite routing metric and reduce the routing overhead of management control by changing the trigger mechanism of HELLO message. Simulation results show that MCL-AODV protocol reduces the average routing overhead and end-to-end delay, improves network throughput and packet delivery ratio.
***Keywords: Wireless Mesh Networks; Across-layer design; trigger mechanism of HELLO message*.**

1. Introduction

Wireless Mesh Network (WMN) is a new type of distributed broadband access network system, which combines the advantages of the Ad hoc networks and wireless LAN, WMN routing protocols have become an effective means of wireless broadband access, and have become a hot research topic .[1-2]
WMN routing protocols have mostly evolved from the Ad Hoc network routing protocols, “the minimum hops” has been the routing criterion to select the route, the route finding process is relatively simple and can respond quickly to routing changes caused by the movement of the network nodes. But the minimum hops routing is likely to cause some of the critical path local congestion, and non-critical path is idle in a long time, resulting in a waste of network resources, and reducing the network capacity [3-4]; WMN backbone network node mobility is relatively smallest route, it does not need to respond quickly to network changes; in addition, the radio channel has openness and variability, the traditional network hierarchical design is not an effective method for wireless network design [5-6].
This paper propose a routing protocol MCL-AODV for WMN backbone network based on cross-layer composite criterion and changing the routing of HELLO messages trigger mechanism. The protocol considers the quality of MAC layer link, the node queue congestion degrees and the wireless transmission distance link performance through the cross-layer operating mechanism, to create a cross-layer composite routing metric to optimize the route selection process; Meanwhile, by changing the HELLO message trigger mechanism, reduce overhead of routing control in order to lower the consumption of network bandwidth to improve overall network performance. The simulation results show that, MCL-AODV to some extent, improves data packet delivery ratio and network throughput, reduces the average end-to-end delay and average routing overhead.

2. MCL-AODV cross-layer composite routing metric

The cross-layer routing of MCL-AODV calls the information of MAC layer through a parameter calling modules at the network layer, it makes the network layer aware MAC layer link quality and node queue state as much as possible, design cross-layer composite routing metric to avoid the routing performance degradation when the parameters in MAC layer changes.

2.1Description of the problem

WMN backbone network model abstracted into a two-dimensional plane graph without direction G (V, E), where: V is the set of vertices of the graph G, N = | V | represents the total number of network nodes, v ∈ V is any route node; E is the set of edges of a graph G, e (i, j) ∈ E is a wireless link between any two nodes v_i and v_j.

2.2 Cross-layer composite routing metric design

(1) node availability FR (i): represents MAC layer interface queue utilization of the upstream end node vi in e (i, j). Lwait (i) and Ltotal (i) in Formula (1) are packets length waiting to be sent and the total length of interface queue in MAC layer interface queue buffer of vi.

$$FR(i) = 1 - \frac{L_{wait}(i)}{L_{total}(i)}, \quad \text{where } 0 \le FR(i) \le 1 \qquad (1)$$

(2) The transmission success rate TR (i, j): represents MAC frame transmission success rate from the node vi to the node vj in e (i, j). F is the number of retransmissions when transmit a frame successfully in e (i, j), when F is greater than the maximum number of retransmissions Fmax specified by a network ,the value of TR (i, j) is 0, when the data frame did not retransmit, the value of TR (i, j) is 1. In the ideal case, transmit one RTS and DATA frame respectively can complete the transmission of a data frame, then the transmission number is F +2.

$$TR(i,j) = \begin{cases} 0, & F\max < F \\ 1 - \dfrac{F}{F+2}, & F\max \ge F > 0 \\ 1, & F = 0 \end{cases} \qquad (2)$$

(3) Link performance VE (e): reflects the comprehensive performance of node availability FR (i) of upstream node vi in e(i,j) and the MAC frame transmission success rate Tr (i, j) in the wireless link (i, j). In formula (3), α is the weight coefficient of the FR (i) and TR (i, j) considering the comprehensive performance of the link, this paper sets α the value of 0.5.

$$VE(e) = (1-\alpha) * FR(i) + \alpha * TR(i,j) \qquad (3)$$

In order to prevent the fluctuating of wireless routing, calculate the value of VE (e) every T seconds (T for 5 seconds), and make the VE (e) of the two adjacent time periods for smoothing processing. $VE(e)_{old}$ and $VE(e)_{cur}$ are parameters value of the link performance in e (i, j) on the current time cycle and the previous time cycle, $VE(e)_{avg}$ is the parameters average value of link performance after smoothing processing. λ is the weight coefficient of $VE(e)_{old}$ and $VE(e)_{cur}$ considering the comprehensive performance of the average link . Set λ the value of 0.7 , focus on the preferences of $VE(e)_{cur}$ in the current time period.

$$VE(e)_{avg} = \lambda VE(e)_{cur} + (1-\lambda) VE(e)_{old} \qquad (4)$$

(4) Composite routing metric: select an optimal path considering the distance length of each hop node, and multiple constraints routing is an NP problem [7], so we give heuristic definition of complex routing criterion RM. In formula (5), and are default index, the paper sets = 2、 = 0.22; Dist(i,j) is the distance between node vi and vj in wireless link e (i, j); is the average overall performance of the link (i, j).

$$RM(e) = \frac{Dist(i,j)^{\theta}}{[VE(e)_{avg}]^{\omega}} \qquad (5)$$

For any path p in the graph G, the composite routing metric is the sum of all the criterion values of links in the path p , i.e. RMp=∑RMe,where e ∈P. MCL-AODV routing mechanism can be described as follows: For a given source node S and destination node D, all the path from S to D is composed of a collection R, if R is not an empty set, then we choose path p as the routing from S to D to meet the smallest value of RMp.

3. The realization of MCL-AODV simulation

There are two aspects of the improvement of MCL-AODV based on AODV, the first is using a new cross-layer composite routing metric to choose the route in routing discovery process; the second is change the trigger control right of HELLO message from the network layer to the MAC layer. The simulation of MCL-AODV is realized in NS2 [8-9].

3.1MCL-AODV route discovery

MCL-AODV use the same reactive route discovery mechanism with AODV , but the routing metric is not “the minimum number of hops "but a new cross-layer composite routing metric RM proposed by this paper,. The implementation method is:

(1) Increase the interworking of information between the MAC layer and the network layer;

. (2) Add a parameter acquisition module in the MAC layer, calculate and update the VE(e)avg values in intervals of time T (the routing table update period is used in this paper) , and uploaded to the network layer;

(3) Add a parameter called module in the network layer, receive the VE(e)avg values from the MAC layer, calculate composite routing criterion RM value combined with a single hop distance ;

(4) Add a new the routing criterion RM field in RREQ and RREP packets, and add RM table entries in the routing table.
In order to realize inter-layer access between the network layer and the MAC layer, the implementation process is as follows:

(a) Add a head file mac-802_11.h in mcl-aodv.h :
include <mac/mac-802_11.h>

(b) Declare a MAC layer access object and set friend class in MCL-AODV class of mcl-aodv.h:
Mac802_11 * mymac; / / declare the MAC layer access is mymac
friend class Mac802_11; friend class MAC_MIB; / / set Mac802_11 and MAC_MIB to the MCL-AODV friend class.

(c) modify the command () function in mcl-aod v.cc , add the following code:

```
int MCL-AODV :: command (int argc, const char * const
* argv) {. . . . .
else if (strcmp (argv [1], "set-mac") == 0) {mymac =
(Mac802_11 *) TclObject :: lookup (argv [2]);
if (mymac == 0) {fprintf (stderr, "MESPAgent:% s
lookup% s failed. \ n", argv [1], argv [2]);
return TCL_ERROR;} else return TCL_OK;}. . . . . . }
```

(d) Initialize the MAC layer access object mymac in mcl-aodv.cc:

```
MCL-AODV :: MCL-AODV (nsaddr_t id): Agent (PT_
MCL-AODV) {mymac = 0;}
```

(e) Add two lines of code in the tcl script

```
set rt ($ i) [$ node_ ($ i) agent 255]
$ rt ($ i) set-mac [$ node_ ($ i) set mac_ (0)]
```

(f) Access MAC layer parameters with the object mymac in MCL-AODV protocol:

```
void MCL-AODV :: recv (Packet * p, Handler *)
{. . . . . . u_int32_t RTSFailureCount; u_int32_t
ACKFailureCount;. . . . . .
RTSFailureCount = mymac->
macmib_.getRTSFailureCount ();
ACKFailureCount = mymac->
macmib_.getACKFailureCount ();
float Le = 0.0;
Le = 2 / ((float) RTSFailureCount + (float)
ACKFailureCount
+2);
      . . . . . . }
```

3.2MCL-AODV route maintenance

MCL-AODV use the same route maintenance mechanism with the AODV, that is the use of HELLO messages trigger routing updates to reduce latency. But HELLO messages triggered routing updates will also increase the control overhead of routing protocol management. Therefore, in order to reduce the transmission delay and minimize routing control overhead in the same time, MCL-AODV use the idea of cross-layer design, put the generation and delivery mechanism HELLO message on the MAC layer [10], HELLO frame is sent to the neighbor node by the MAC layer in a certain period of time (HELLO packet transmission period HELLO_INTERVAL),the link information of neighbor node is collected and uploaded to the network layer by the cross-layer mechanism .

4. Simulation performance analysis

Simulation platform used by this article is Redhat9.0 + NS2.34, and the experiment scene is 30 nodes of WMN's backbone network relatively stationary distributed in the region of 1550 1360 square meters in a 6 5 matrix form, the vertical, horizontal distance of adjacent nodes are 170m; the traffic types is CBR, each source sent 8 data packets per second, the numbers of service stream were 3,6,9,12,15,20, each simulation time is 120S. The routing protocols have be simulated are AODV, RM-AODV, CLAODV and MCL-AODV, and RM-AODV is a protocol which change the single-hop routing criterion of AODV and use cross-layer routing criterion proposed in this article, CLAODV is a routing protocol which change the HELLO message mechanism ,proposed in reference literature[6]. The purpose of the simulation is to analyze and compare the network performance in packet delivery ratio, average end-to-end delay, average routing overhead and throughput.

(1) Packet delivery rate: the ratio of the number of data packets successfully received by the destination node to the data packet number sent by the source node, it reflects the reliability of network transmission, the higher of the Packet delivery rate, the higher reliability of network transmission.

Packet delivery rate of the above four protocols in the simulation experiment with the increase in network traffic changes are shown in Figure 4.Seen from the figure, packet delivery rate of four protocol networks all achieve 100% when the network load is light; The packet delivery rate drop when the network load increase, but decline of MCL-AODV is smallest; the downward trend of other protocols is closed.

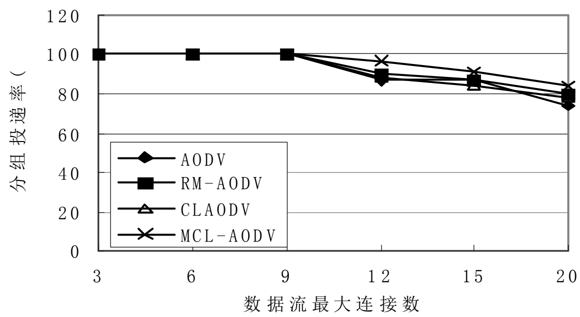

Figure 4 packet delivery ratio comparison

(2) the average end-to-end delay: the ratio of the sum of the delay of all the data packets received by the destination terminal to the number of packets successfully received, it reflects the effectiveness of the routing protocol. The smaller the average end-to-end delay, the faster a data packet transmitted from the source reach the destination node. Figure 5 shows the change of average end-to-end delay with the increment of network traffic of the four different protocols in simulation experiment. Seen from the figure, the average end-to-end delay is small when the service traffic is light and not obvious different; when the service traffic exceeds a certain value, the increment of the average delay is large, but the increment of MCL-AODV is relative the minimum.

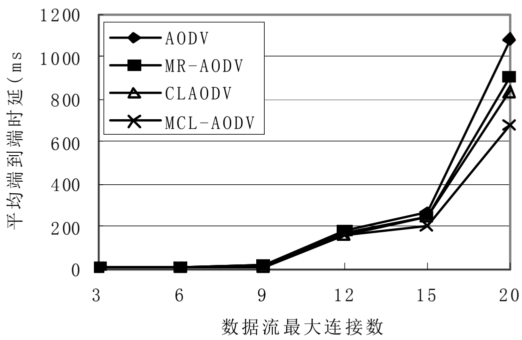

Figure 5 Comparison of average end-to-end delay

(3) The average cost of the route: the ratio of the control packets and the number of packets reached the destination node successfully in the data transfer process; it reflects the efficiency of the routing protocol to transmit data. The average routing overhead is smaller, the higher the efficiency of the routing protocols to transfer data. Figure 6 shows the change of average routing overhead of the four different protocols with the increment of network traffic in the simulation experiment. Seen from the figure, the average routing overhead is small and the difference is not obvious when the business traffic is light; the average routing overhead has increased significantly when traffic continues increase, but the increment of average routing overhead of MCL-AODV protocol is the smallest.

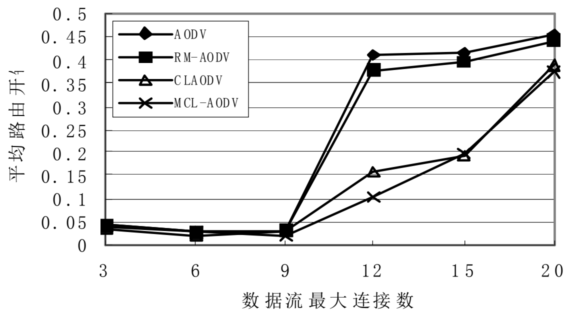

Figure 6 Average routing overhead comparison

(4) The average throughput: the number of data packets transmitted successfully in the unit time, it is an important indicator that reflects the overall performance of the network, the greater the average throughput, the better the performance of the network. The throughput in simulation experiment is the average throughput of network count in the every 0.5s. Figure 7 shows the change of average throughput with the increase of network traffic variation. Seen from the figure, the average throughput of the network traffic increase with the network traffic variation, but the increment of MCL-AODV is the largest , the increment of AODV is relatively the minimal.

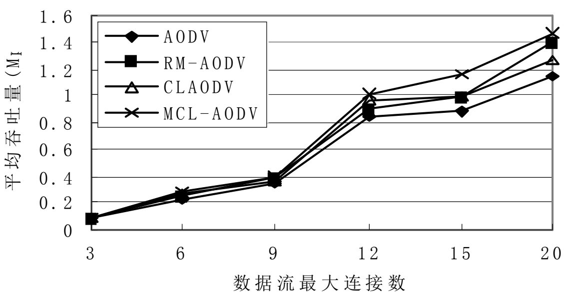

Figure 7 throughput comparison

Seen from the above simulation results, MCL-AODV can reduce the average routing overhead, and the end-to-end delay, and can improve network throughput and packet delivery ratio.

5. Conclusion

This paper propose a routing protocol MCL-AODV, which is based on cross-layer composite criterion and change HELLO messages trigger mechanism ,for WMN backbone network . The simulation results show that compared with AODV, RM-AODV and CLAODV, MCL-AODV routing performance is better than the other three, in particular, is significantly better than the AODV. MCL-AODV improves data packet delivery ratio and network throughput to some extent, reduce the average end-to-end delay and average routing overhead, achieved load balancing effect to some extent.

The focus of our future research work is to consider the impact of cross-layer optimization design and extend MCL-AODV protocol to multi-channel to reduce the mutual interference between the nodes, and improve the utilization of wireless network resources further.

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