A Multi-MAC Based Multi-Channel OLSR for Wireless Ad hoc Network

Zheng Xiang
Scholl of Information Science & Technology
Southwest Jiaotong University
Chengdu, China
xz3_83@163.com

Xuming Fang
Scholl of Information Science & Technology
Southwest Jiaotong University
Chengdu, China
xmfang@home.swjtu.edu.cn

***Abstract*—Wireless Ad hoc network is one of the hottest research fields in the past few years. Since the routing protocol and multi-channel usage are very important to the performance of Wireless Ad hoc Network, there's a need to co-design the two issues. This paper firstly gives an overview of single-channel OLSR protocol, and then a multi-MAC based multi-channel OLSR protocol is proposed. Through simulation and comparison, we observe that the wireless Ad hoc network using multi-channel OLSR protocol outperforms the one using single-channel OLSR protocol.**

Keywords- multi-channel, OLSR, wireless Ad hoc network

I. INTRODUCTION

Wireless Ad hoc Network[1], which became one of the research hotspots at the end of 1990's, has a lot of advantages such as infrastructureless, low hardware cost and flexible deployment. Since wireless Ad hoc network is a multi-hop network, routing protocol is introduced to be in charge of packet forwarding. Without routing protocol, any packet destined to any other node that is more than one-hop away from originated node cannot be delivered, thus the network throughput drops sharply. In addition, the traffic type in the network is becoming more and more diversified, e.g. voice, video and background data, therefore, a high bandwidth and better QoS for the traffic are required. Unfortunately, Ad hoc network was previously a proprietary network based on low link bandwidth and failed to satisfy the requirement mentioned above. In order to change this situation, IEEE802.11 standard was introduced as the MAC and PHY layers for wireless Ad hoc network to provide a higher bandwidth[2]. As we know, IEEE802.11b can achieve a raw bit rate at about 11Mb/s while IEEE802.11a/g can achieve a raw bit rate at about 54Mb/s. Although the raw bit rate seems to be sufficient for the traffic at first glance, the actual usage can only reach 40% at most, and of course the bandwidth is insufficient when the network becomes saturated. According to IEEE802.11 standard, there are 3 orthogonal channels in IEEE802.11b/g and 12 orthogonal channels in IEEE802.11a. Based on intuition, if we can use all the channels simultaneously, a better network performance would be achieved.

Above discussion shows that the routing protocol and the channel usage both have huge impact on wireless Ad hoc network performance. Therefore, there is a need to co-design the two issues in order to achieve better network performance. This paper first gives an overview of singe-channel OLSR which is proposed in IEEE802.11s[3] draft, and then a multi-MAC based multi-channel OLSR is proposed followed by performance evaluation, finally a conclusion is drawn.

II. OVERVIEW ON SINGLE-CHANNEL OLSR

OLSR is a routing protocol specifically designed for wireless Ad hoc network. It is a table driven, proactive routing protocol, i.e. every node in the network exchanges topology information of the whole network periodically and establishes a routing table in order to do packet forwarding. One advantage of proactive routing protocol is that it has a short forwarding delay because forwarding route is established before packet is sent, but it also has a disadvantage of relatively low reaction to topology change. Moreover, exchanging control message periodically and establishing static routing table will consume much network bandwidth and node's resource. Therefore, a mechanism called Multipoint Relays (MPR) is introduced in OLSR to minimize control message flooding. According to MPR, one node only exchanges control message with part of its neighbor nodes, thus control message flooding is reduced and the network bandwidth and node's resource are saved effectively. The procedure of OLSR can be summarized as follows: nodes obtain some network information such as local link state, neighbor nodes state by periodically exchanging control message, e.g. Hello message. The information is then saved in the node to create a routing table which contains the routes to all the other nodes in the network. Finally, packet forwarding can be carried out.

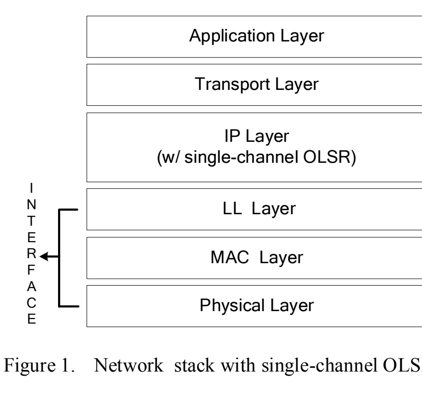

Figure 1. Network stack with single-channel OLSR

Figure 1 is a wireless Ad hoc network protocol stack with single-channel OLSR. This network protocol stack is similar to that in WLAN because IEEE802.11 standard is introduced to wireless Ad hoc network as MAC layer and PHY layers. The biggest difference between them is that a single-channel OLSR is included in wireless Ad hoc network to do multi-hop packet forwarding. Whenever OLSR receives a packet from upper layer, it will look up the routing table to determine the next hop of this packet; Whenever OLSR receives a packet from lower layer, it will first check the IP header to determine whether the destination of this packet is this node. If hit, then OLSR handles this packet to upper layer, otherwise looks up the routing table to do packet forwarding.

TABLE I. CONTROL MESSAGES IN OLSR

Message	Details
MID	Advertise the main interface address and other interface address of the node
HELLO	Exchange information only between neighbor nodes
TC	Advertise a node's MPR Selector Set

TABLE II. OLSR DATABASE IN EACH NODE

Information	Details
Interface Association Set	main interface and other interfaces for each node in the network
Link Set	State of links to neighbor nodes
Neighbor Nodes Set	State of neighbor nodes
2-hop Neighbor Nodes Set	State of 2-hop neighbor nodes
MPR Set	State of MPR nodes
MPR Selector Set	State of MPR Selector nodes
Topology Set	Topology information of the network

Table 1 and Table 2 are the control messages and node's database in OLSR respectively. Based on the control messages and the database, every node can calculate the routing path to all the other nodes in the network using iteration algorithm, thus a routing table is established to do packet forwarding. Whenever network information is refreshed, the routing table can also update itself accordingly to adapt to the topology change of the network.

III. RELATED WORK ON MULTI-MAC BASED MULTI-CHANNEL ARCHITECTURE

There are several literatures discussing multi-MAC based multi-channel architecture. Ashish et. al.[5] proposes an architecture which can be used in the scenario where a spanning tree is already formed before NIC assignment. Under this architecture, parts of the whole NICs in a node are assigned to communicate with their father node while other NICs can simultaneously transmit packets to its child nodes. Pradeep et. al. [6] gives another solution to multi-MAC based multi-channel issue, which assigns X of the available NICs at each node statically to X channels whereas the remaining NICs can frequently switch between any of the remaining channels. Although the references mentioned above made great contribution to multi-MAC based multi-channel issue, they have some flaws which cannot be ignored. Firstly, the architecture proposed in [5] can only deal with the situation where the spanning tree is formed in advance of NICs, which may not be feasible when all nodes are treated equally like in mobile Ad hoc Network. Secondly, the solution in [6] consists of some NICs that need to switch between different channels, therefore a high switching delay can be expected. Finally, the documents dealing with multi-MAC based multi-channel issue usually focus on the problems such as channel assignment, modification to MAC layer and so on, but rarely take traffic factor into consideration. In this paper, we start with a different perspective in hope of finding a solution mainly concerning the relationship between multi-channel and traffic.

IV. MULTI-MAC BASED MULTI-CHANNEL OLSR

Although single-channel OLSR can function well in most situations, it still needs to be improved due to some reasons. First, control message flooding exists in the whole network since OLSR is a table driven, proactive routing protocol. A lot of network bandwidth is consumed even if MPR is used to minimize flooding, thus routing overhead is very high in the network. Second, single-channel OLSR manipulates only one network interface (NIC), which means control packet and data packet are buffered and transmitted on the same NIC. Since control packet possesses part of the buffer and transmission time, the probability that data packet is dropped due to timeout increases, and of course throughput of the network decreases. Third, QoS is poorly guaranteed because single-channel OLSR is not able to distinguish between different traffic from application layer, therefore, the scenario where single-channel is used is limited. To address the flaws discussed above, we propose a routing protocol called multi-MAC based multi-channel OLSR.

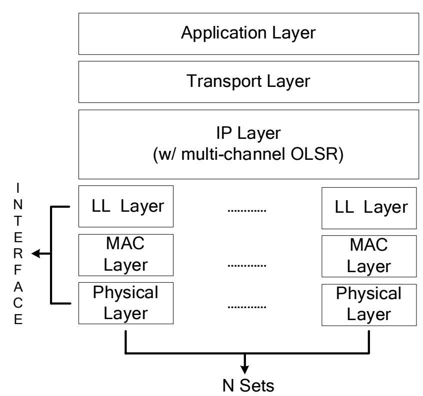

Figure 2. Network stack with multi-channel OLSR

Figure 2 is a wireless Ad hoc network protocol stack with multi-channel OLSR. Multi-channel OLSR has following three improvements over single-channel OLSR:

- The number of network interface (NIC) increases from one to N (N>1). Each NIC operates independently and is bound to a unique channel. Therefore, the collision field in the network is broken into multiple ones, and packets of different types can avoid contention as well as collision, thus higher network throughput is achieved.

- The number of interface queue also increases as NIC increases in the node. Whenever OLSR receives a packet from upper layer, it will put the packet into different queues according to its traffic type. Since data packet and control packet will be put into different queues, the probability that packet is dropped because of not enough space decreases. Therefore, node's forwarding ability is improved and packet delivery ratio increases.
- Traffic Aware Interface Distribution (TAID) mechanism is introduced in multi-channel OLSR. TAID can distribute traffic between different NIC dynamically according to traffic types. For instance, when VBR traffic requires more bandwidth in a node, TAID will assign more NICs for VBR traffic, thus bandwidth that VBR traffic possesses increases and QoS is accordingly guaranteed better.

V. PERFORMANCE EVALUATION

In order to compare the performance of multi-channel OLSR with that of single-channel OLSR, we conducted a simulation using NS2[7]. Due to the requirements of multi-channel OLSR, we extended NS2 by creating more than one NIC and introducing TAID for every node.

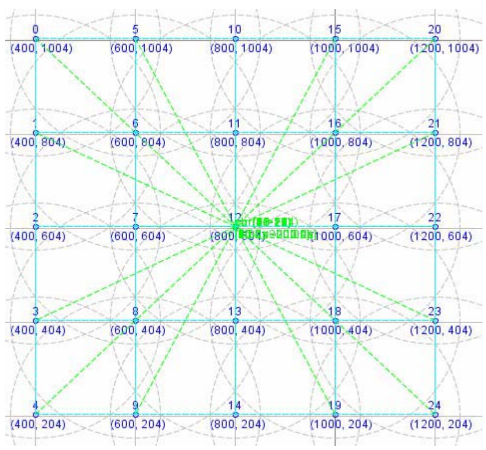

Figure 3. Simulation topology

There is something to notice: as this is a preliminary simulation for multi-channel OLSR, we only implemented a simple TAID at this stage, which uses one NIC for control packet and the other NIC for data packet. Figure 3 is the simulation topology: 25 static nodes distribute in a 5×5 grid topology, each node can only communicate with its one-hop away nodes. The simulation time is 100s, during which the number of CBR stream in the network increases by one every 10s and finally reaches 10. For each CBR stream, the packet length is 1000 bytes and generating rate is 512 Kbytes. All the CBR streams stop at 95s. We change the MAC transmitting rate from 1Mb/s to 11Mb/s according to IEEE802.11 specification and then observe the packet delivery ratio (PDR) and the average end to end delay (Avg. Delay) for each MAC transmitting rate.

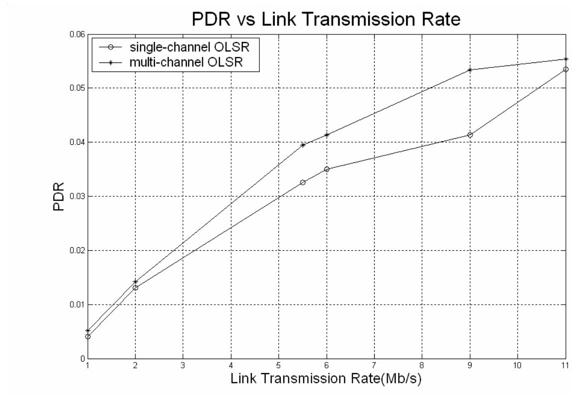

Figure 4. PDR vs MAC transmitting rate

TABLE III. PDR DETAILS

MAC Layer Transmitting Rate(Mb/s)	PDR w/ single-channel OLSR	PDR w/ multi-channel OLSR	PDR gain
1	0.0041	0.0052	26.83%
2	0.0131	0.0142	8.40%
5.5	0.0326	0.0395	21.17%
6	0.0350	0.0413	18.00%
9	0.0413	0.0534	29.30%
11	0.0535	0.0554	3.55%

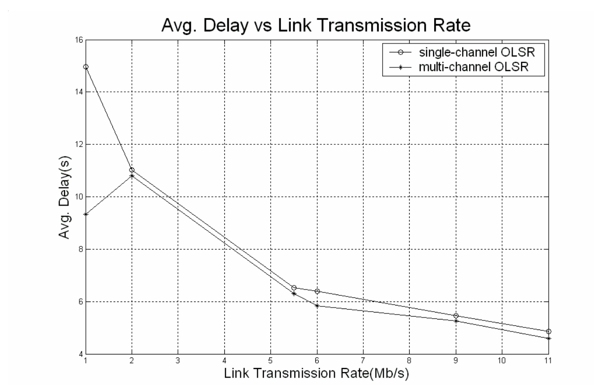

Figure 5. Avg. delay vs MAC transmitting rate

Figure 4 shows PDR as MAC transmitting rate increases. We observe that PDR of the network using single-channel OLSR and that using multi-channel OLSR both increases as MAC transmitting rate increases. In addition, PDR under multi-channel OLSR always outperforms the one under single-channel OLSR. The explanation for the PDR figure is as follows: In multi-channel OLSR, control packet and data packet are buffered in different queues. Therefore, the probability that data packet is dropped due to control packet buffered in the same queue decreases, and the forwarding ability of the node improves as well as PDR of the network increases. Table 3 shows the details of PDR. The last column illustrates the PDR gain under multi-channel OLSR over the one under single-channel OLSR. As we can see, although PDR jitters at some points, it is still relatively high.

TABLE IV. AVG. DELAY DETAILS

MAC Layer Transmitting Rate(Mb/s)	Avg. Delay w/ single-channel OLSR (s)	Avg. Delay w/ multi-channel OLSR (s)	Avg. Delay gain
1	14.9589	9.3393	37.57%
2	11.0338	10.7970	2.15%
5.5	6.5226	6.3045	3.34%
6	6.3991	5.8365	8.79%
9	5.4511	5.2679	3.36%
11	4.8660	4.5894	5.68%

Figure 5 plots packet average end to end delay against MAC transmitting rate. Similarly, we observe that packet average end to end delay of the network using single-channel OLSR and that using multi-channel OLSR both decreases as MAC transmitting rate increases. Moreover, packet average end to end delay under multi-channel OLSR always outperforms the one under single-channel OLSR. The explanation for the packet average end to end delay figure is as follows: In multi-channel OLSR, data packets are buffered in a unique queue different from control packet. Therefore, the time during which data packet is buffered in the queue decreases, and packet average end to end delay decreases accordingly. Table 4 shows the details of packet average end to end delay. The last column gives the Avg. Delay gain under multi-channel OLSR over the one under single-channel OLSR. As we can see, although Avg. Delay gain is relatively small, time sensitive traffic can benefit from such tiny progress.

VI. CONCLUSION

This paper proposes a multi-MAC based multi-channel OLSR. Through simulation, we find that network using multi-channel OLSR outperforms the one using single-channel OLSR in many aspects such as PDR and packet average end to end delay. Although multi-channel has some flaws, for example, more hardware cost and a more complex traffic distribution algorithm due to TAID, it still achieves a better network performance by increasing a relatively low overhead. In our future work, we will continue to research the multi-channel protocol, which not only covers OLSR, but also relates to AODV or DSR. Besides, since the types of traffic in internet are increasing, different traffic needs different QoS. We will do a deeper research on the topic of “Traffic Aware” by simulation and analysis in hope of designing a multi-channel routing protocol which can guarantee better QoS for each traffic.

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