MANET 기반의 IEEE802.11에서 Gray Zone 문제 해결을 위한 전송률 설정
(Transmission Rate Setting for the Gray Zone Problem in IEEE802.11 based MANETs)

Abstract In wireless ad-hoc networks, one of the reasons that increase the data packet loss rate is gray zone effect. The gray zone effect can happen when broadcasting control packets with lower rate while transmitting the data packets with such higher rate or the same PHY data rate. In this case, nodes are able to find valid routes but some data packets may not reach the destination, which causes the high packet loss rate. Most research efforts so far have attempted to modify the routing protocol to take the gray zone effect into consideration. This method, however, could have a detrimental performance owning to its high computational complexity. In this paper, by adjusting the suitable broadcast rate and data transmission rate, we can obtain higher throughput than the original way. By simulations, we show that our simple approach can improve throughput significantly.

Key words: mobile ad-hoc networks, gray zone effect, broadcast rate, unicast rate

1. Introduction

MANETs are wireless networks where mobile nodes communicate with each other without infrastructure and using multi-hop paths. MANETs have received a lot of attention since they enable mobile nodes to communicate each other through shared radio medium without any infrastructure. This feature has urged many researchers to study MANETs. IETF (Internet Engineering Task Force) MANET working group makes a great effort to standardize routing protocol for MANETs, and currently four routing schemes have been issued as Request for Comments (RFCs). Several research projects to implement RFC MANET routing protocols as open-sources are also underway[1,2].

When working and experimenting with such open sources in the real environment where IEEE 802.11b/g/a is used as the Medium Access Control (MAC), the system sometimes suffers low throughput although a path is definitely found between a
source and a destination. One of the reasons is the negative effect of the celebrated gray zone problem [3,4]. Gray zone effects are caused by the discrepancy between communication range of data packets, and that of control packets to find paths.

Generally speaking, packets with longer length or higher modulation rate are likely to be lost. Control packets which are used to find communication path are transmitted via broadcast MAC frame, for which the basic modulation rate, that is a low rate, is usually chosen. Further the size of a control packet is shorter than that of a data packet. Thus the communication range for a control packet can be longer than that of a data packet as shown in Fig. 1. As a result, a found path can include a longer link than the communication range of data packets. Moreover, in the communication gray zone, the link quality will be low. Therefore the node tends to choose the fragile link instead of strong link to enhance better throughput. Consequently, limiting the gray zone problem is expected to increase the network performance and decrease packet loss rate.

Until now, a number of solutions have been proposed to alleviate the gray zone effect even though they are so complicated for practical settings as described in Sect. 2. In case of IEEE 802.11, broadcast rate is usually set to low quantities (e.g. 1Mbps or 2Mbps) so as to support legacy terminals. However, not mandatory since IEEE 802.11 standard only describes that broadcast frames should be transmitted at one of the basic rates which are preset for all stations in the Basic Service Set (BSS). Currently, most IEEE 802.11 products support higher rates. Therefore, we believe that it is reasonable for all nodes to support higher broadcast rates, such as 5.5 Mbps and 11 Mbps in IEEE 802.11b. Higher transmission rate for broadcast frames is expected not only to close the gap of transmission range between broadcast frame and unicast frame but also to shorten the occupancy of channel by themselves. Thus the efficiency of channel utilization will be improved.

The rest of the paper is organized as follow. Sect. 2 describes related work on mitigating the communication gray zone problem in wireless networks. Sect. 3 provides the background materials of our method. We will verify the effectiveness of the setting by simulations in Sect. 4. The last section concludes this paper.

2. Related work

In wireless links, frames with larger size and/or higher modulation rate are likely to be lost. In the case of IEEE 802.11, for broadcast frames, a modulation rate is chosen from BSS basic rate set, and it is typically set to a low value, for example 2Mbps, which is used as support legacy terminals. For unicast frames, a higher modulation rate is often used to utilize wireless links efficiently. In MANET routing protocols, control messages to find communication paths are usually conveyed on broadcast frames. On the other hand, unicast frames are often used for data messages since most existing applications are based on unicast communication. Further, in general the size of control messages tends to be shorter than that of data messages. Therefore, control messages reach farther than data messages.

All the above-mentioned factors cause gray zone problem. Gray zone is the area inside the communication range of control messages and outside that of data messages as shown in Fig. 1. If a node happens to choose another node in its gray zone as a next hop, it will suffer from bad link quality. In particular, hop count based routing schemes, such as DSR (Dynamic Source Routing) [5], AODV (Ad hoc On Demand Distance Vector) [6], OLSR (Optimized Link State Routing) [7] intend to minimize the number of hops. This nature increases the risk of including fragile links into the found paths, which leads to low throughput. Consequently, limiting the gray zone
problem is expected to increase the network performance and decrease the amount of packet lost.

So far some schemes have been proposed to cope with the gray zone problem by concentrating in choosing bidirectional links, that is, by using strong links instead of fragile links. This is because fragile links cause re-routing process, which create a large amount of overhead. In [3], the authors propose three schemes, namely: exchanging neighbor sets, N-consecutive hello messages, and SNR (Signal to Noise Ratio) threshold for control messages. In exchanging neighbor sets, each node broadcasts hello messages containing its neighbor set, so that it can recognize which neighbor has a bidirectional link with itself. In N-consecutive hello messages, one node accepts another as a neighbor with a stable link only after receiving at least N consecutive hello messages. In SNR threshold for control messages, a node accepts only control messages which are received with signal quality over preset SNR threshold, i.e. via a strong link.

The work in [4] focuses on the path discovery procedure in AODV, and RREQ (Route Request) ACK (Acknowledgment) is newly introduced. After receiving RREQ, a node returns RREQ ACK to the RREQ sender. This increases the possibility of using strong links instead of fragile links compared with the original AODV protocol.

In [8], by not only testing the hardware indoor but also doing the simulation, the authors compare AODV and SAODV (Secure AODV) routing protocol and come to the conclusion that SAODV can achieve better performance by preventing control message tampering and data dropping problem in both TCP and UDP cases, which is better than using the SNR threshold method to reduce the width of the gray zone effect as the work in [3].

In all the above works, AODV is significantly modified, and/or every time control message is received, its SNR quality should be investigated. On the other hand, our simple proposal shown in Sect. 3, achieves high throughput without implementing any additional function to MAC and/or routing protocol.

3. Our novel approach

To reduce the complexity of other methods mentioned above in Sect. 2, we attached special importance to a simple approach that can reduce gray zone to enhance throughput by only adjusting the modulation rate for unicast frame and broadcast frame. For the short explanation in our paper, from now, we defined modulation rate for broadcast frame as broadcast rate, modulation rate for unicast frame as unicast rate, respectively. According to gray zone communication definition which was illustrated in Fig. 1, using the normal setting which set broadcast rate less than unicast rate could cause gray zone to occur. However, if broadcast rate is set higher than or equal to unicast rate, gray zone is possibly reduced. To show the concept of our simple approach, we run a simple example simulation which has two nodes and changed the distance of two nodes. In what follows, we use QualNet 4.5 as a network simulator, IEEE 802.11 standard as MAC layer protocol, OISR protocol as our routing protocol and use CBR (Constant Bit Rate) to feed the traffic of the network. For each setting in the environment of fading channel, we run the simulation 100 times that considered as real experiment and received the result which we illustrated in Fig. 2. Gray zone phenomenon occurrence does not only depend on the difference of transmission rate but also on the packet size. So in our example, we changed both to investigate the logic of our method.

Before rate control, gray zone effect is defined as the distance between the performance graph of line a and line b with rate setting corresponding to the
case of broadcasting 128 bytes of message at 1 Mbps and the case of unicasting 512 bytes of message at 2 Mbps, respectively. After rate control, reduced gray zone effect then becomes the distance between the performance graph of line a1 and line b1 which rate setting corresponding to the case of unicasting 512 bytes of message at 1 Mbps and the case of broadcasting 128 bytes of message at 2 Mbps, respectively. (It’s easy to see that the role of rate have been changed conversely.) As illustrated in Fig. 2, the gap of communication gray zone has been reduced to about 65m.

From this point of view, we realized that in order to reduce the gap of communication gray zone effect, there is a comfortable and simple way which involves only setting the modulation rate for broadcast frame higher than for unicast frame. The performance is evaluated via in-depth simulation over various scenarios whose results will be discussed in subsequent section.

4. Simulation results

The implementation of IEEE 802.11 in Qualnet 4.5 is always set to 2Mbps for all broadcast rate and unicast rate. For the ease of presentation as illustrated in Fig. 3 and Fig. 4, we consider this setting case as “default” case. The legend “ARF” is denoted the case of the method “Auto Rate Fallback.” We also use the legend “B11U5.5” as the case of broadcast rate with 11 Mbps and unicast rate with 5.5 Mbps, and similarly for the others cases. So, the legend “B11Uauto” denotes the case of broadcast rate at 11 Mbps and unicast rate automatically adjusted. We summarized this setting parameters in table 1.

<table>
<thead>
<tr>
<th>Simulator</th>
<th>QualNet 4.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation area</td>
<td>1,500m×1,500m</td>
</tr>
<tr>
<td>Simulation time</td>
<td>300s</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>50</td>
</tr>
<tr>
<td>Number of sections</td>
<td>15</td>
</tr>
<tr>
<td>Application layer protocol</td>
<td>CBR</td>
</tr>
<tr>
<td>Routing protocol</td>
<td>OLSR</td>
</tr>
<tr>
<td>PHY-MODEL</td>
<td>PHY802.11b</td>
</tr>
<tr>
<td>Fading model</td>
<td>Rayleigh</td>
</tr>
<tr>
<td>Mobility model</td>
<td>Random Waypoint</td>
</tr>
</tbody>
</table>

We ran simulation 100 times in different environments to achieve the high confidence and plot all the given figures with confidence interval of 95%. By simulation, we confirm that successfully reducing the gray zone effect makes the network more stable and increases throughput.

4.1 The effect of gray zone in the cases of mobility speed and packet size changed

Fig. 3 shows packet arrival ratio characteristics acting as a function of packet size in the case of fading channel and mobility model. In this case, mobility speed of 2 m/s which is equal to 7.2 km/h is assumed to be the walking speed. Changing packet size afforded us the opportunity to investigate the effect of packet size on the arrival ratio of the network. As the figure illustration, when packet size is increased, packet arrival ratio decreases. At packet size of less than 500 bytes, the setting of B11Uauto achieved the best result of approximately 90% packet arrival ratio. When packet size is increased above 500 bytes, the setting of B11U5.5 achieved best performance. In general, the two cases of setting B11U5.5 and B11Uauto yielded better packet ratio than other cases. This once again confirmed that our method was reasonable. By setting the broadcast rate higher than unicast rate, we can enhance throughput as well as achieve better packet arrival ratio.

When sending long packets, B11Uauto becomes less dominated than B11U5.5. This can be explained by the effect of ARF in the network. Since ARF...
cannot differentiate the cause of data transmission failure, sometimes, it makes bad judgments and decreases the unicast rate continuously. Hence, operating with such low rate makes the network performance to be low.

4.2 The effect of gray zone in the case of changing the density of the network

We realized that choosing a rate depends on the distance between nodes which implies that rate adaptation depends on the density of node in the network. Therefore, we created a general rule that was capable of adjusting rate based on node density showed in Fig. 4.

In Fig. 4, we observed that when varying the size of the simulation areas, which means varying the density of network, there is a relationship between the nodes’ communication ranges and throughput of the network. When the network density is decreased, throughput decreased as intuited. The set of broadcast rate with 11 Mbps and unicast rate with 5.5 Mbps is much more scalable and dominating than the others.

When the area is increased to 2,500m×2,500m, throughput severely decreased and the optimal throughput was achieved with broadcast rate 5.5Mbps and unicast rate 5.5Mbps. We also conclude that with the simulation area up to 3,000m×3,000m, the optimal setting is 2Mbps broadcast rate and 1Mbps unicast rate.

Therefore, with all of these above-mentioned simulation results and observations, we again strongly confirm that in order to reduce the gap of communication gray zone problem, there is a comfortable and simple way which involves only setting the broadcast rate higher than or equal to unicast rate. And it is also worth considering the relationship between the distance between nodes and data rate for suitable case.

5. Conclusion

Gray zone is a network area in which nodes can receive broadcast messages but not data packets. Therefore, the nodes use invalid route in its neighbor table which makes the packet loss rate high. Until now, there are many researches coping with gray zone problem by concentrating on modifying the routing protocol AODV. Such method could have a detrimental performance owning to theirs high computational complexity while our method is simple to deploy. By the simulations with our method, we show that by choosing the optimal option rate, our approach can achieve better performance than the traditional method.

References
