Opportunistic Routing Protocols in Wireless Ad Hoc Networks Using Directional Antennas

Zhi YIN\textsuperscript{a,*}, Mi WEN\textsuperscript{a}, Chunming YE\textsuperscript{b}

\textsuperscript{a}Department of Computer and Information Engineering, Shanghai University of Electric Power, Shanghai 200090, China
\textsuperscript{b}Business School, University of Shanghai for Science and Technology, Shanghai 200093, China

Abstract

MORE (MAC-independent Opportunistic Routing & Encoding) could increase network throughput by using network coding. On the other hand, directional antenna has better power efficiency and introduce the possibility of space diversity. In this paper, the authors try to combine directional antenna with opportunistic routing protocols and tried to use Network Simulator version2 to simulate it. The results show that there is an optimal lobe width for each particular circumstance and that under this optimal condition the throughput of opportunistic routing with directional antenna is much higher.

Keywords: Opportunistic Routing; Directional Antenna; Throughput

1 Introduction

The application of wireless ad hoc networks has been booming for recent years. There are a lot of techniques ensuring the system work well, among which routing protocol is very important one [1]. As newly emerged routing protocols, opportunistic routing protocols have specific advantages against traditional routing protocols in that they can utilize routes with relatively low link probability in wireless mesh networks to obtain higher throughput. Previous research has proved opportunistic routing protocols such as ExOR (Extremely opportunistic Routing) [2][3] can outperform traditional routing protocols by a large scale, yet it has certain drawbacks and can still be modified with new elements such as network coding. Furthermore, MORE (Mac-Independent Opportunistic Routing & Encoding) [4] is a new protocol based on ExOR but has better architecture which enable the protocol to be independent with MAC layer. It has also combined the routing with network encoding to achieve better performance for the system.

*Project supported by the National Nature Science Foundation of China (No. 60903188).Project supported by the National Natural Science Foundation, China(No. 71271138), and the Humanities and Social Sciences Planning Fund of Ministry of Education (No.10YJA630187),
*Corresponding author.
Email address: yzzhizhi@163.com (Zhi YIN).
On the other hand, while opportunistic routing significantly improves the average progress per transmission over unicast routing by leveraging the opportunistic receptions of multiple potential forwarders in wireless mesh networks, not every node contributes equally in a transmission. By concentrating the beam energy at a particular direction, directional antennas may further improve the performance of opportunistic routing in multi-hop wireless networks. Compared with traditional omnidirectional antenna, directional antenna has less lobe width and higher gain. It also has longer transmission distance and can repress backward signals. These characters make it a better choice when combined with wireless routing protocols. However, more research are needed to find out whether directional antenna can suit with opportunistic routing protocols and under what condition can these two work perfectly with each other.

In [5], the writers derive an analytical model which allows the incorporation of various node distribution models, radio channel models and antenna models to evaluate the average progress per transmission. It is found that a directional antenna with high directional property does not always improve the performance of opportunistic routing and an optimal beam width exists for each particular network. When compared to the case of omnidirectional antenna, a directional antenna with optimal beam width and direction settings can achieve 30 to 50% performance gain, in terms of average progress per transmission, under typical network configurations. Moreover, such performance gain can be as high as 100% for radio propagation environments where the packet reception probabilities fall off slowly with distance.

In this paper, we will further investigate the improvement of throughput in wireless mesh networks brought by MORE and directional antenna. Moreover, NS2 is used to simulate the wireless network transmission progress. The rest of this paper is organized as follows. In Section 2, we present some preliminary knowledge about the opportunistic routing and directional antenna. In section 3, the scheme of MORE and the effects of directional antenna are illustrated. In section 4, we present our evaluation results. Finally, we conclude the paper in section 5.

2 Preliminary

In this section, we give the network model, and review the impact of directional antenna and multirate on anypath routing algorithm design.

2.1 Routing protocols in wireless Ad hoc networks

Ad hoc network is a self organized network without infrastructure. As the position and movement of the nodes are both random, the topology of network is dynamic. Therefore, the key point for ad hoc network is the designing of an effective routing protocol which could to adaptive to the change of the topology.

Current Ad hoc routing protocols could be divided into to categories: table-driven routing protocols and source-initiated on-demand routing.

Table-driven routing protocols are directly transplanted from the wired networks. For this kid of protocols, every node in the network maintains one or multiple tables to store the routing information of all nodes, and keeps consistence between the routing and changing topology by broadcasting. Typical routing protocols such as DSDV (destination-sequenced distance-vector routing), CGSR (cluster head gateway switch routing) and WRP (wireless routing protocol) are
of this category.

Although the table-driven routing protocols could obtain the routing information very quickly, it may cause the signal congestion and higher power consumption due to the frequent broadcasting. Therefore, source-initiated on-demand routing is currently more welcomed. For this kind of protocols, the node does not need to maintain all the routing information as in table-driven routing protocols, it only initiate a routing protocol process before the source node needs to set up a transmission link. The often used AODV (Ad hoc on-demand vector routing), DSR (dynamic source routing) and TORA (temporally ordered routing algorithm) are all of this category.

2.2 Opportunistic routing protocols in wireless Ad hoc networks

The opportunistic routing protocols try to improve the network through in two aspects. First, the reliability of single-hop transmission is increased by allowing choosing multiple relay nodes other than one relay node. Second, in any case there may exist a less hops routing, it is used to substitute for the initial routing which might have more hops.

2.3 Directional antennas

Early works in wireless Ad hoc networks generally assume that omnidirectional antennas are used. However, there has been more and more studies about using directional antennas in wireless networks. As shown in Fig. 1, Directional antennas can focus the energy in the demanding area and thus improve the power efficiency. Moreover, it introduces space diversity and decreases the interference compared with traditional omnidirectional antennas.

![Fig. 1: The model of directional antennas.](image-url)
3 Opportunistic Routing Protocols in Directional Wireless Ad Hoc Networks

3.1 MORE protocol

MORE (MAC-independent Opportunistic Routing & Encoding) is based on the ExOR (Extremely Opportunistic Routing) but introduces the intra-flow random network coding to reduce the chance of repeat packets.

Since the network coding was proposed in around 2000 [6]-[10], it has been proved to be an effective method to approach the upper bound of network capacity. Especially in wireless environment, the unreliable link and broadcasting nature is very suitable for network coding. Furthermore, the performance of network coding is highly affected by network data flow pattern, which is just the function of routing protocol. Therefore, combining network coding with routing protocol will further improve the throughput of the network. Katti proposed MORE protocol invoked by the above function. Combining MAC layer independent routing and network coding, MORE has advantages in two aspects: first, it is transparent to MAC layer; second, it is compatible with the current wireless protocols such as 802.11. A typical process of MORE is shown in Fig. 2.

![Fig. 2: The process of MORE protocol.](image-url)
3.2 Effect of directional antenna

Directional antennas can focus the energy in the demanding area and thus improve the power efficiency. However, when combined with opportunistic routing protocol, it does not always increase the protocol efficiency. Actually, there exists different optimal beam width for different topology. Except for the beam width, the node density and the propagation environment will also affect the performance of the protocol, which will be proved in the following section.

4 Simulation Results and Analysis

In this section, using NS2 as simulation tool, we compare the performance of AODV and MORE. Furthermore, we compare the performance of MORE protocol with different antenna beam width.

First, Fig. 3 compares the packet loss rate. It can be seen that the throughput of MORE is about 27 packets/s, which is about 68.75% higher that AODV. On the other hand, Fig. 4 illustrates the relationship between throughput and beam width. It can be seen that the throughput increases at first and begin to decrease after reaching the peak. E.g., when the beam width is 90°, the throughput is higher than omnidirectional case; while when the beam width decreases to 60°, it becomes worse. When we see more details in the simulation, the problem for narrower beam width is that many node cannot receive the broadcasting packets in this case, which cause the degradation of the system performance.

5 Conclusion

This paper introduced the characters of opportunistic routing protocol MORE and directional antenna. The combined use of opportunistic routing protocol and directional antenna is simulated through NS2 software and the results are analyzed. It could be seen that combination of opportunistic routing and directional antenna brings a lot of advantages for wireless Ad hoc networks. We still look forward to future research on this topic and hopefully their will be more achievements in this area.
Fig. 4: The comparison of AODV and MORE.

References


