Chapter XXIII
Ad Hoc Networks Testbed Using a Practice Smart Antenna with IEEE802.15.4 Wireless Modules

Masahiro Watanabe
Mitsubishi Electric Corporation, Japan

Sadao Obana
ATR Adaptive Communications Research Laboratories, Japan

Takashi Watanabe
Shizuoka University, Japan

ABSTRACT

Recent studies on directional media access protocols (MACs) using smart antennas for wireless ad hoc networks have shown that directional MACs outperform against traditional omini-directional MACs. Those studies evaluate the performance mainly on simulations, where antenna beam is assumed to be ideal, i.e., with neither side-lobes nor back-lobes. Propagation conditions are also assumed to be mathematical model without realistic fading. In this paper, we develop at first a testbed for directional MAC protocols which enables to investigate performance of MAC protocols in the real environment. It incorporates ESPAR as a practical smart antenna, IEEE802.15.4/ZigBee, GPS and gyro modules to allow easy installment of different MAC protocols. To our knowledge, it is the first compact testbed with a practical smart antenna for directional MACs. We implement a directional MAC protocol called SWAMP to evaluate it in the real environment. The empirical discussion based on the experimental results shows that the degradation of the protocol with ideal antennas, and that the protocol still achieves the SDMA effect of spatial reuse and the effect of communication range extension.

INTRODUCTION

Ad hoc networks (Jurdak, 2004) are the autonomous system of mobile nodes which share a single wireless channel to communicate with each other. The previous works on ad hoc networks assume the use of omni-directional antennas that transmit or receive signals equally well in all directions. Traditional MAC protocols, such as IEEE 802.11 DCF (Distributed Coordination Function) (ANSI/IEEE. Std, 1999), are designed for omni-directional antennas and cannot achieve high throughput in ad hoc networks because that waste a large portion of the network capacity.

On the other hand, smart antenna technology may have various potentials (Lehne, 1999). In particular, it can improve spatial reuse of the wireless channel, which allows nodes to communicate simultaneously without interference. Furthermore, the directional transmission concentrates signal power to the receiver, which enlarges the transmission range. Thus, it can potentially establish links between nodes far away from each other, and it prevents network partitions and the number of routing hops can be fewer than that of omni-directional antennas.

However these potentials smart antennas may have, a sophisticated MAC protocol is required to take advantage of these benefits in ad hoc networks. Recently, several directional MAC protocols, typically modifications of IEEE 802.11 DCF, have been proposed for ad hoc networks including our proposed MAC protocol called SWAMP (Takata, 2004). SWAMP provides both spatial reuse of the wireless channel and communication range extension by two types of access modes that utilize the directional beam effectively, and it contains a method of obtaining the location information of its neighbors.

For the real use to wireless devices, it should be evaluated the performance of proposed MAC protocol due to the effects of actual antenna pattern included both side-lodes and back-lobes, and actual propagation condition included realistic fading. So this time, we have developed a testbed for validation of the real environment, which is based on ESPAR antenna and IEEE802.15.4/ZigBee wireless module, and has the interface to GPS (Global Positioning System) for utilizing location information MAC protocol. And we embedded SWAMP into this testbed and evaluated in the actual environment

This paper summarizes SWAMP protocol and overview of testbed. In addition, we analyze the experimental result of SDMA and wider range communication due to SWAMP.

BACKGROUND

Directional MAC Protocols

Various MAC protocols using smart antennas or directional antennas, typically referred to as directional MAC protocols, have been proposed for ad hoc networks.

Ko et al. (2000) propose DMAC (Directional MAC) in which all frames are transmitted directionally except for the CTS (Clear To Send). Choudhury et al. (2002) propose MMAC (Multi-hop RTS MAC), which involves the multi-hop RTS (Request To Send) to take advantage of the higher gain obtained by directional antennas. These protocols, however, need various additional mechanisms to provide the location information and to forward the RTS.

In (Fahmy, 2002; Nasipuri, 2002) and (Takai, 2002), RTS is transmitted omni-directionally in order to find the receiver in case location information is not available. Each node estimates the direction of neighboring nodes for pointing the beam with AOA (Angle of Arrival) when it hears any signal. Because these protocols employ at least one omni-directional transmission, it limits the coverage area provided by directional transmissions and do not exploit one of the main benefits of directional antennas, i.e., the increase of the transmission range, either.

Ramanathan (2001) proposes circular directional transmission of periodic hello packets to obtain node information that is located farther away than the omni-directional transmission range. Korakis et al. (2003) proposes circular RTS, which scans all the area around the transmitter to find the addressed receiver and to tackle the deafness and the hidden-terminal problem arisen from directional transmissions. Bandyopadhyay et al. (2001) develops additional frames in order to determine the neighbor topology by recording the angle and signal strength under consideration of propagation conditions. Although these schemes attempt communication range extension, circular transmission increases the delay and incurs large control overhead.

In mobile ad hoc evaluation, Ramanathan (2005) shows a directional MAC testbed and simulation results, but not including actual experimental results. Although Nishida (2005) evaluated AODV (Ad hoc On demand Distance Vector routing) protocol based on IEEE802.11b DCF with omni-directional antennas in the experiment, not used directional antennas.

SWAMP

SWAMP (Smart Antennas Based Wider-range Access MAC Protocol) is a MAC protocol for ad hoc networks using smart antennas based on IEEE 802.11 DCF, which utilizes the directional beam effectively to increase the spatial reuse and extend the transmission range.

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