Energy-Efficient Wireless Communication based on Directional Transmission from Mobile Access

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Abstract

The radio front-end (RF) is a major power consumer on mobile systems. In particular, the power amplifier (PA) is the most power-hungry component for wireless transmission. We aim at significantly reducing the energy consumption by the PA in 802.11 interfaces by using directional antennas, or *directional transmission*, without changing the network infrastructure or protocol. Our solution is called *BeamSwitch*, based on a single RF chain with multiple directional antennas and one omni-directional antenna BeamSwitch dynamically select the best antenna during active wireless transceiving without disrupting the communication. Using simulation based on Qualnet and the power model of a commercial 802.11 transceiver, we show that BeamSwitch reduces energy per bit transmission by more than one third without negative impact on communication quality. We will demonstrate a prototype of BeamSwitch based on the Rice WARP platform with three directional antennas.

1. Introduction

Energy consumption of mobile devices is increasingly important because they have to deliver more services subject to slowly increasing battery and heat dissipation capabilities. Wireless interfaces are among the most power hungry components, especially when they are transmitting. The high transmission power is primarily due to the power amplifier, which boosts the signal to be sent through the antenna. Emerging wireless standards with high data rates usually require higher linearity in the power amplifier, which leads to lower efficiency of the power amplifier and is likely to further increase its percentage contribution to the total power consumption.

Our solution, BeamSwitch, shows that directional communication based on directional antennas can be used to reduce transmission power for mobile systems. BeamSwitch is standard-compliant. A BeamSwitch-equipped mobile system dynamically detects the need of direction change and rapidly selects the right directional antenna for transmission using information from incoming frames to itself or its peers. In case of any change in direction, BeamSwitch employs an efficient antenna selection algorithm to select the best directional antenna; it will resort to the omni-directional antenna when it deems directional transmission risky. Our simulation based on Qualnet and a realistic power model shows that BeamSwitch reduces energy per bit by 32% and 41% for 5.5 Mbps and 11Mbps FTP traffic, respectively, even under extreme end device mobility.

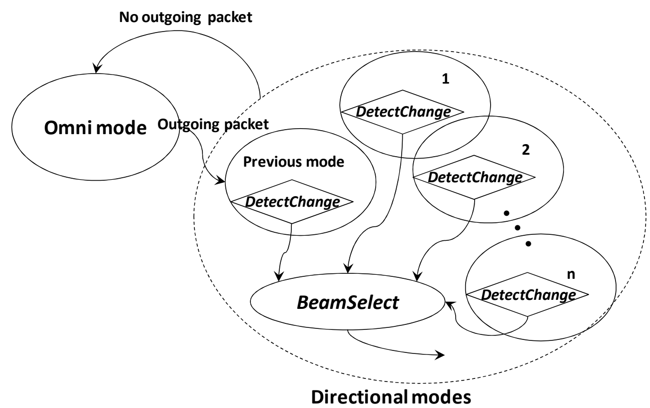

Figure 1: Algorithm overview of BeamSwitch that operates in one of many modes, one omni and *n* directional, in which a different antenna is employed

BeamSwitch is drastically different from other technologies based on antenna arrays, such as beam forming and multiple-input/multiple-output (MIMO). BeamSwitch employs directional antennas in the antenna array and only uses a single antenna at a time. As a result, BeamSwitch only requires a single RF chain at a time, leading to significant reduction in energy per bit transmission that is beyond the reach of MIMO and beam forming technologies. BeamSwitch is also complementary to the use of directional transmission for vehicular mobility, such as *MobiSteer* [1], which treats direction selection as a hand-off problem.

We propose to demonstrate an efficient implementation of BeamSwitch with three directional and one omni-directional antennas. We will show that our prototype can detect the change in direction and select the best antenna without disrupting communication even under extreme end device mobility.

2. Design

The algorithm of BeamSwitch is illustrated in Figure 1. BeamSwitch operates in one of the multiple modes, one omni-directional and multiple directional, depending on which antennas it is using. When there is no outgoing frame, BeamSwitch stays in the omni-directional mode. Only when there is an outgoing frame, BeamSwitch will attempt to find

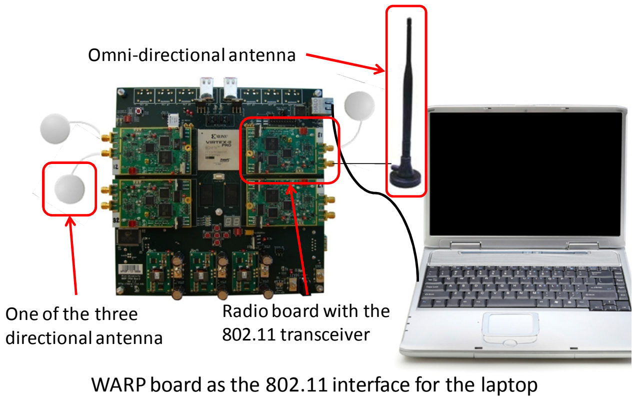

Figure 2: BeamSwitch prototype with three directional and a single omni-directional antennas to be used in the demo

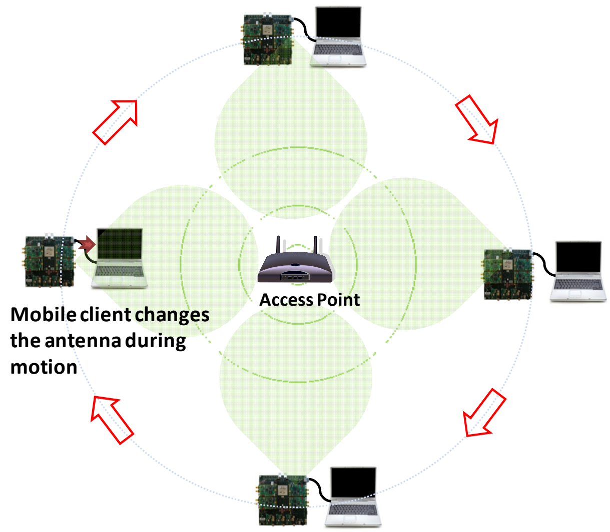

Figure 3: BeamSwitch enables a moving mobile client to select the best antenna without disrupting communication

the best directional mode (*BeamSelect*). When operating in a directional mode, BeamSwitch analyses RSSI information of each incoming frame to detect direction change (*Detect-Change*).

3. Implementation and Demo Setup

We have implemented a prototype of BeamSwitch based on the Rice Wireless Open-Access Research Platform (WARP) [2], as shown in Figure 2, and connected it to a laptop as an 802.11 interface through an Ethernet cable. The prototype employs three directional antennas to cover all directions in directional mode. While ideally BeamSwitch only needs a single RF transceiver and employs a switch to select one antenna from many, our prototype employs two RF transceivers because the RF switch on the WARP board only have two ports. However, only one RF transceiver is active at a time.

Our demonstration setup includes two WARP boards: one as the interface for the mobile client and the other for the access point. Only the WARP board for the mobile client implements our BeamSwitch prototype, described above. As illustrated in Figure 3, the mobile client will communicate with the access point in our demo while moving freely; BeamSwitch will enable it to select the best antenna without disrupting the communication. We will demonstrate continuous video/audio stream. The applications will run on the laptops and use WARP as the 802.11 interface to transceive frames. The mobile client will also display the antenna selection and RF activities in the BeamSwitch prototype to highlight the effectiveness of our direction selection and change detection techniques.

4. Demo Requirements

The demo will employ two WARP boards, two laptop computers, and a number of antennas. We will need the following equipments:

- We will need two tables, one for AP and the other for the mobile client. Ideally, the table for the client should stand on wheels because we will be moving the client to demonstrate BeamSwitch
- To provide a realistic channel for the demo, two tables need to be at least three meters apart
- Required setup time boards requires 30 to 45 minutes
- We will need at least four power outlets for two WARP boards and two laptop computers

5. Acknowledgements

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6. References

[1] V. Navda, A. P. Subramanian, K. Dhanasekaran, A. Timm-Giel, and S. Das, "MobiSteer: using steerable beam directional antenna for vehicular network access," *in Proc. of MobiSys 2007,* pp. 192-205, June 2007.

[2] WARP, "http://warp.rice.edu/," 2008.