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An Efficient method to improving performance on long range in Distributed Hybrid Wireless Networks

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Abstract—In the Hybrid wireless network on distributes system play a vital role now a day but using distributed system in hybrid wireless network, we propose a new Distributed Cooperation and Diversity combining framework. Our focus is on heterogeneous networks with devices equipped with two types of radio frequency (RF) interfaces: short-range high-rate interface (e.g., IEEE802.11), and a long-range low-rate interface (e.g., cellular) communicating over urban Rayleigh fading channels. Within this framework, we propose and evaluate a set of distributed cooperation techniques operating at different hierarchical levels with resource constraints such as short-range RF bandwidth. We propose a Priority Maximum-Ratio Combining (PMRC) technique, and a Post Soft-Demodulation Combining (PSDC) technique. We show that the proposed techniques achieve significant improvements on Signal to Noise Ratio (SNR), Bit Error Rate (BER) and throughput through analysis, simulation, and experimentation on our software radio test bed. Our results also indicate that, under several communication scenarios, PMRC and PSDC can improve the throughput performance by over an order of magnitude.

Key terms: - Diversity, cooperation, hybrid wireless networks.

I. INTRODUCTION

WIRELESS communication networks are enabling an ever increasing set of applications. The service quality and scalability of these applications is limited by fundamental constraints. These include a scarce radio-frequency spectrum, signal propagation effects, such as fading and shadowing, resulting in areas with limited coverage and the small form factor of mobile devices with limited energy capacity and antenna diversity. Recently, due to the increasing demand of mobile services such as mobile cloud computing and video streaming, improving the robustness and throughput of cellular systems has become more critical. Many technologies including dynamic power control, adaptive coding and modulation, smart antennas, have been proposed or adopted, never-the less the cooperation gain on the mobile client side has not been exploited yet. To improve the spectrum efficiency, one of the solutions used by operators is to deploy additional base stations [1], but this strategy is ineffective and costly. In this paper, we propose to explore a new communication model, where multiple mobile nodes cooperate with each other and with the base stations. We will investigate communication strategies that exploit the channel diversity across a set of cooperating mobile nodes equipped with multiple radio interfaces. A short-range radio interface is used by the cooperating nodes to combine the long-range radio interface signals and boost its performance.

Currently, most smartphones are equipped with a WiFi interface besides their cellular interface. The high speed local network makes the distributed cooperation with a small group of nearby users possible. But very little research has been done for distributed wireless systems with multiple types of air interfaces and considering the unique characteristics of each interface. With the increased hardware integration, faster computation, and high user's density, the cooperation between nearby devices is becoming possible and even necessary given the increased demand for bandwidth.

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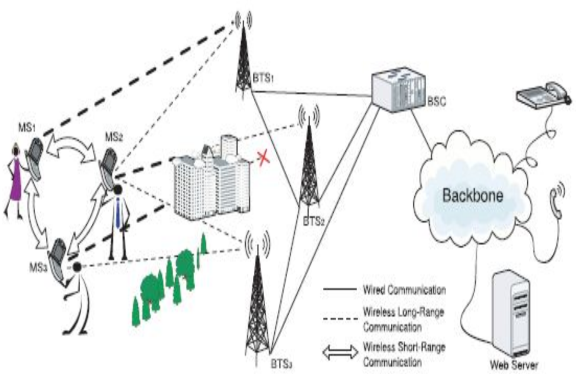
RF-channel diversity is general mechanisms to improve the robustness and efficiency of wireless communication systems and have been studied for many years [2], [3], [4]. Many existing technologies, such as MIMO, require multiple antennas to be collocated at the same device. Due



to the minimum spatial separation (0:4_ [4]) and high cost of RF front ends, however, it is impractical to implement these schemes on a single small form factor device such as a cell phone [5]. Furthermore, the existing diversity techniques introduced in the past (e.g., Maximum Ratio Combining (MRC) and Generalized Selective Combining [6], [2], [4]) were designed for antennas that are wired to a central combiner and not restricted by the local communication limitations.

Unlike traditional diversity paradigms, our approach combines the physical layer information from multiple distributed receivers in heterogeneous wireless network, as well as accounting for the constraints on the local network bandwidth, computation, and energy consumption. It exploits both the antenna gain and the channel independence. We show that this type of cooperation can significantly improve the Signal to Noise Ratio (SNR), Bit Error Rate (BER), and throughput even with reasonably limited short range bandwidth. It leads to an improved coverage, capacity boost, and reduction of interference. To the best of our knowledge, it is the first to consider a heterogeneous architecture to combine multiple long-range links at the physical layer for diversity purpose.

Distributed cooperation framework—Hierarchical Priority Combining strategy, which allows multiple levels of cooperation depending on the channel conditions and resource constraints. It consists of three levels of combining techniques: Predemodulation Combining, Post Soft Demodulation Combining, and Decode-and-Forward. We also propose an implementation of Predemodulation Combining technique, called Priority Maximum Ratio Combining (PMRC), and an implementation of Post Soft-Demodulation Combining technique. We show that an order of magnitude improvement of the SNR, outage probability, BER, and throughput can be achieved, even with a limited short-range bandwidth. We also show that most of the benefit of the traditional single device

Maximum-Ratio Combining can be exploited by PMRC or PSDC with the contribution from a small group of neighboring nodes. In addition, we demonstrate the practicality of PSDC by implementing it on a USRP/GNU radio test bed and experimentally confirm substantial gains for channels with moderate fading.

II. FORMAL APPROACH

We consider a hybrid network where the mobile nodes are equipped with two radio interfaces: a long-range, low data rate cellular interface, and a short-range, high data-rate interface. Our study is in the case where the long-range communication happens on quasi-orthogonal channels and is mainly limited by shadowing, and channel fading caused by multipath propagation and mobility. These are critical problems in cellular communication as they result in dead signal areas and localized poor system performance. Our cooperation strategy intends to make use of the RF front ends of a group of geographically separated devices. This cooperation operates at the physical-link layer, and it is transparent to applications. Therefore, the existing applications would have an improved performance without requiring any awareness or modifications. In this paper, the proposed protocol and analysis are based on only single master node. Multiple master nodes are possible by allowing each node as the master node concurrently, but more advanced protocols need to be developed to handle the collision and delay.

III. EXISTING SYSTEM

The existing diversity techniques introduced in the past (e.g., Maximum Ratio Combining (MRC) and Generalized Selective Combining .In the case where the long-range communication happens on quasi-orthogonal channels and is mainly limited by shadowing, and channel fading caused by multipath propagation and mobility.

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These are critical problems in cellular communication as they result in dead signal areas and localized poor system performance. Our cooperation strategy intends to make use of the RF front ends of a group of geographically separated devices. This cooperation operates at the physical-link layer, and it is transparent to applications.

IV. PROPOSED SYSTEM

The continuous improvements of the physical/link-layer between a mobile station (MS) and one or multiple base stations (through various coding, modulation, and antenna technologies). We propose a distributed cooperation framework—Hierarchical Priority Combining strategy, which allows multiple levels of cooperation depending on the channel conditions and resource constraints. It consists of three levels of combining techniques: Predemodulation Combining, Post Soft-Demodulation Combining, and Decode-and-Forward. We also propose an implementation of Predemodulation Combining technique, called Priority Maximum Ratio Combining (PMRC), and an implementation of Post Soft- Demodulation Combining technique. We show that an order of magnitude improvement of the SNR, outage probability, BER, and throughput can be achieved, even with a limited short-range bandwidth. We also show that most of the benefit of the traditional single device Maximum-Ratio Combining can be exploited by PMRC or PSDC with the contribution from a small group of neighboring nodes. In addition, we demonstrate the practicality of PSDC by implementing it on a USRP/GNU radio testbed and experimentally confirm substantial gains for channels with moderate fading.

V. DISTRIBUTED COOPERATION FRAMEWORK

Consider the scenario depicted in Fig. 1: there are a group of three nearby mobile users each with a cellular phone or mobile station, and base stations or base transceiver stations (BTS). The base stations are controlled by the base station controller (BSC), which dictates the carrier frequencies, communication power and rate, etc. The base stations are also connected to the backbone which leads to the telephone network and the Internet. Communication between mobile stations and base stations is through long-range low data-rate links. Due to obstructing objects and the distance to the base station, they suffer from the typical channel fading and path loss (attenuation) that impair urban cellular communication. In contrast, mobile stations can also communicate with each other through short-range high data-rate links. Because of the short distance, their communications are fast and stable. Here, we consider a simple topology with single hop communications. For example, a base station BTS1 is communicating with a mobile station MS1 and another mobile station MS2 in the vicinity through long-range low datarate links; the links from MS1 to MS2, from MS2 to MS3, and from MS3 to MS1 are short-range high data-rate links. With cooperation, the long-range cellular signals are 1) independently received at each of the three nodes, 2) relayed through the high speed local wireless network, and 3) combined at the destination node. This cooperation can significantly improve the Signal to Noise Ratio, Bit Error Rate, and throughput. It leads to improved coverage and a system capacity boost. Furthermore, it reduces interference as the base stations do not have to increase their transmission power to overcome the channel fading in order to reach mobile nodes. For the proposed cooperation strategy to be used in practice, other mechanisms need to be developed to address the important issues of security, privacy, incentives mechanisms to encourage cooperation and enforce fairness. In this paper, we focus on evaluating the potential of distributed diversity mechanisms.

VI. HIERARCHICAL PRIORITY COMBINING

In this part, we introduce a distributed cooperation framework—Hierarchical Priority Combining. It incorporates three levels of combining: Decode-and-Forward, Post Soft-Demodulation, and Predemodulation. We first outline the three combining techniques used in HPC; then describe the proposed HPC protocol; followed by the performance analysis. Decode-and-forward: If at least one of the assisting nodes can demodulate the packet and verify its integrity, then the decoded packet can be relayed to the master node through its short-range link. This level of combining uses the minimum local bandwidth, but can only be used when the overall signal strength is high, and the mobile nodes are experiencing strong uneven fading or shadowing. This could be the case when a group of people are in motion, e.g., inside a car, a bus, or a train. A similar idea has been discussed in [20]. The main difference in our research is that we are considering to relay the packet through a different interface rather than reinjecting it back to the same channel with a different coding scheme. This approach, in

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our opinion, is more realistic from system's perspective, however it requires a different analysis.

Post soft-demodulation combining: At this level, the signal received by each of the assisting nodes has incorrectable errors. However, it is already strong enough for demodulation. In this case, some of the assisting nodes with the strongest received signals send the soft-decision output of the demodulator to the master node for bit-level combining (Refer Section 2.4 for more detail of soft-decision values).

Cooperation at this level can be very efficient at correcting errors when the signal strength is relatively high. This is still a suboptimal diversity combining technique but has the advantage of requiring only a moderate short-range communication bandwidth. Predemodulation combining: At this level, some of the assisting nodes transmit the sampled down-converted RFsignal to the master node. We introduce Priority Maximum Ratio Combining as the potential candidates for Predemodulation Combining. In PMRC, only the assisting nodes with the strongest SNR relay their received signals to the master. The master then combines its received signal with other gathered signals. Signal combining at this level gives the best error correction capability, but communicating the digitized waveform information requires a large local bandwidth. Therefore, it is more appropriate for the scenarios where the long-range radio signal is extremely weak and experiences strong fading, but the local short range links is fast and stable. The HPC protocol dynamically decides which of the above three combining techniques to use at the time of the reception of the packet. Intuitively, Predemodulation Combining takes all the information of the originally received signals among the cooperative nodes, so it should perform the best in error correction, but it also requires a huge amount of local bandwidth. Decode-and-Forward Combining and Post Soft-Demodulation Combining can be taken as the lightweight version of Predemodulation Combining as it either sends the complete demodulated data or partially demodulated data with soft-decision values. The advantage of Decode-and-Forward Combining is that it uses a minimal amount of local bandwidth, but requires a node to have a strong signal reception in order to independently and successfully decode the packet. Post Soft-Demodulation Combining, on the other hand, performs better due to the freedom of using soft-decision values from multiple sources compared to Decode-and- Forward Combining. To achieve the best performance while still minimizing the local bandwidth usage, our HPC strategy uses the received signal quality to decide which combining technique to adopt for each packet.

There are many possible ways to cooperate, but the proposed HPC strategy has the benefit of being effective and easy to implement due to its simplicity and hierarchical structure. The HPC cooperation protocol runs in two phases. Phase I is a very short period, within which the nodes exchange information with each other about the quality of received signal. In Phase II, each node decides if and what level of combining information it will send to the master. In the following, we provide a high-level description of the protocol.

VII. CONCLUSION

In this paper, we introduced a framework for distributed cooperation and diversity over two radio interfaces. We proposed a Priority Maximum-Ratio Combining technique, and a Post Soft-Demodulation Combining technique that leverage distributed diversity while limiting the local communications. We analyzed and compared PMRC and PSDC in terms of SNR gain, outage probability, bit error rate, throughput, and delay. Our analytical and experimental results show that the cooperation between devices with a combination of cellular and short-range air interfaces is a promising approach to increase network capacity and mitigate the effects of channel fading and shadowing. It allows robust communications with an order of magnitude weaker signal for typical scenarios (e.g., five cooperating nodes and two actively assisting nodes). This type of cooperation also opens several directions of future research on security for a realistic use of the proposed mechanisms and also distributed cooperation framework—Hierarchical Priority Combining strategy, which allows multiple levels of cooperation depending on the channel conditions and resource constraints.

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