Implementation of Backhaul Rate Allocation in Uplink SC-FDMA using Greedy Algorithm

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Abstract—A cellular system where mobile terminals transmit in the uplink to base stations (BSs) using single carrier frequency division multiple access (SC-FDMA), to consider multi cell processing among BSs. Received signals are first quantized on a per-subcarrier basis and then forwarded to the serving BS on a backhaul with limited rate. With the aim of maximizing the network throughput, a) design an efficient composite signal representation and b) propose a rate allocation algorithm for the backhaul. Using a closed-form expression of the achievable throughput in the presence of quantization noise, an iterative greedy algorithm for the backhaul rate allocation is developed, where at each iteration the selection of signal to be exchanged as the one providing the maximum network throughput increase per backhaul bit. In order to determine how many quantization bits are used for each received signal, consider either a static bit allocation with a fixed number of bits, or a dynamic bit allocation (which ensures a predetermined network percentage throughput loss with respect to the unquantized case). In an LTE scenario, it is seen that the proposed bit allocation methods flexibly adapt to channel and backhaul conditions and yield similar performance, hence the static approach is preferred due to its lower complexity.

Key words: Resource Allocation and Interference Management; MIMO Systems; 3.5G And 4G Technologies; Broadband Mobile Communication Systems; Cellular Technology

I. INTRODUCTION

In telecommunications, 4G is the fourth generation of cellular wireless standards. It is a successor to the 3G and 2G families of standards. In 2008, the ITU-R organization specified the IMT-Advanced (International Mobile Telecommunications) requirements for 4G standards, setting peak speed requirements for 4G service at 100 Mbit/s for high mobility communication (such as from trains and cars) and 1 Gbit/s for low mobility communication (such as pedestrians and stationary users). A 4G system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to laptop computer wireless modems, smart phones, and other mobile devices. Facilities such as ultra-broadband Internet access, IP telephony, gaming services, and streamed multimedia may be provided to users. Pre-4G technologies such as mobile WIMAX and first-release 3G Long term evolution (LTE) have been on the market since 2006 and 2009 respectively, and are often branded as 4G. The current versions of these technologies did not fulfill the original ITU-R requirements of data rates approximately up to 1 Gbit/s for 4G systems. Marketing materials use 4G as a description for Mobile-WiMAX and LTE in their current forms. IMT-Advanced compliant versions of the above two standards are under development and called LTE Advanced and Wireless MAN-Advanced respectively.

ITU has decided that LTE Advanced and Wireless MAN-Advanced should be accorded the official designation of IMT-Advanced. On December 6, 2010, ITU announced that current versions of LTE, WIMAX and other evolved 3G technologies that do not fulfill "IMT-Advanced" requirements could be considered "4G", provided they represent forerunners to IMT-Advanced and "a substantial level of improvement in performance and capabilities with respect to the initial third generation systems now deployed." The approaching 4G (fourth generation) mobile communication systems are projected to solve still-remaining problems of 3G (third generation) systems and to provide a wide variety of new services, from high-quality voice to high-definition video to high-data-rate wireless channels. The term 4G is used broadly to include several types of broadband wireless access communication systems, not only cellular telephone systems. One of the terms used to describe 4G is MAGIC—Mobile multimedia, anytime anywhere. Global mobility support, integrated wireless solution, and customized personal service. As a promise for the future, 4G systems, that is, cellular broadband wireless access systems have been attracting much interest in the mobile communication arena. The 4G systems not only will support the next generation of mobile service, but also will support the fixed wireless networks. This article presents an overall vision of the 4G features, framework, and integration of mobile communication.

Contributions. Paolo Baracca [1] et al has proposed a Design a SC-FDMA cellular system using CoMP with a rate-limited backhaul and to save backhaul rate, different BSs may use the same received signal quantized with different bits. A framework is proposed by the following steps

First, Initialization of MT signal generation Conversion of data from serial to parallel M-ary modulation of PSK and QAM M-ary modulation for producing Apply FFT operation and mapping Apply IFFT operation Adding Cyclic Prefix Conversion of data from parallel to serial Signal transmits through on AWGN channel Second, Conversion of data from serial to parallel Remove Cyclic Prefix Applying FFT operation and demapping. Applying IFFT operation Demodulation of PSK and QAM Conversion of data from parallel to serial

Furthermore, Cooperation among BSs is allowed thanks to a RNC which is connected to each BS by a zero latency and error free backhaul link. Hence, there is no direct connection between BSs. We also assume that detection and decoding are distributed, i.e., BS j e J decodes all and only the messages sent by the MTs in K(j).
II. SYSTEM MODEL

SC-FDMA cellular system using CoMP with a rate-limited backhaul. Received signals are first quantized on a per-subcarrier basis and then forwarded on the backhaul to other BSs. To save backhaul rate different BSs may use the same received signal quantized with different bits. Hence, an efficient method for sending various bit representations of a given signal is proposed. Combining reconstructed a MSE. BS serving a given MT is able to increase the desired MT signal strength relative to ICI. With the aim of maximizing the MSE compared:

\[ s = 0, \ldots, S - 1 \]

With reference to MT \( k \in K \), indicate with \( N(k) \) the set of subcarriers allocated to MT \( k \). Then, indicate with \( Kn = k \in K : n \in N(k) \) the set of MTs transmitting on subcarrier \( n \). Note that, as we are assuming single antenna devices, at most one MT is transmitting within each cell (i.e., for each set \( K(j) \)) on a given subcarrier: hence, no interference arises among the MTs anchored to the same BS. According to SC-FDMA, the transmission performed by MT \( k \) is organized into data blocks, each composed by \( N(k) \) symbols. The power available at each MT is assumed to be unitary. The sequence of statistically independent and identically distributed complex symbols transmitted by MT \( k \) is first transformed by a unitary \( N(k) \)-size DFT to obtain a signal which, in turn, is mapped onto subcarriers \( N(k) \). Let \( X(k) n \), \( n \in N \), be the sequence obtained after this mapping. Note that \( X(k) n = 0, n /\in N(k) \), whereas we assume that \( X(k) n \sim \mathcal{CN}(0, 1), n \in N(k) \); in fact, the Gaussianity of \( X(k) n \) is verified only if \( N(k) \) is sufficiently large. Finally, this sequence is transformed by a unitary \( N \)-size inverse DFT (IDFT) and, after the addition of a cyclic prefix, transmitted onto the channel.

B. Concepts Involved:

1) Backhaul Infrastructure

Cooperation among BSs is allowed thanks to a RNC which is connected to each BS by a zero latency and error free backhaul link. Hence, there is no direct connection between BSs. And also assume that detection and decoding are distributed, i.e., BS \( j \in J \) decodes all and only the messages sent by the MTs in \( K(j) \). The exchange of received signals among the BSs on the backhaul follows a two phase scheme. In the first phase, BS \( j \) quantizes \( Y(j) n \) for the subcarriers belonging to a subset of \( k \in \mathcal{K}(j) \) \( N(k) \) and a representation of the quantized values is forwarded to the RNC. In the second phase, the RNC sends the bits to the intended BSs.

2) System Implementation:

An important backhaul rate reduction results if a suitable composite representation of the quantized signals is used. In fact, BS \( j \) may quantize the signal on subcarrier \( n \) for two BSs \( i1 \) and \( i2 \) using \( b(i1,j)n \) and \( b(i2,j)n \) bits. However, considering that both quantized signals are sent to the RNC and are obtained from the same signal \( Y(j)n \), we can provide both quantization representations with fewer bits than \( b(i1,j)n + b(i2,j)n \). For instance, if \( b(i1,j)n = b(i2,j)n \), only one of the two signals is sufficient to reconstruct both and thus only one can be sent to the RNC. Note that if we were to represent a given signal with the maximum number of bits required by the other BSs, we would increase the backhaul rate in some links during phase two.

C. Throughput Maximization:

1) Bit Switching Algorithm:

The bit loading algorithm proposed in the previous section can find the optimal Solution for a fixed rate allocation. However, it starts from zero allocation state and requires large computational effort to achieve the final full rate allocation state. Meanwhile the final rate allocation is likely to be non-optimal due to the greedy nature of the algorithm. To achieve the global optimality, an exhaustive search is required, which is of course not practical for a large-scale system. In this section, a so-called bit switching algorithm is
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considered that can find more efficient power allocation for the target $t$. The idea is that, instead of increasing rates iteratively from zero, it starts with the full rate allocation $k = R_{\min} + 8k$. The initial rate allocation could be any feasible solution. If $t$ is not optimal, there must exist a better allocation $0$ with $n;k$. In fact switching bits from a subcarrier to a more suitable subcarrier of one MS. Since the rate target is already fulfilled, $k = R_{\min} + 8k$, the switching is only among subcarriers of one MS. The criterion of bit switching is such that the overall sum power should be reduced. The required transmit power on link $(n; k)$ can be calculated by current rate allocation, it first calculates and saves the cost/bonus of increment/decrement on subcarrier $n$ and on subcarrier $n; 8n$. If the bonus is larger than the cost bits are switched. In another words, keeping the sum rate of MS unchanged bits are switched between a subcarrier pair. If the sum power is to be decreased.

2) Gradient Based Algorithm:
Even though the proposed greedy bit loading algorithm in the previous sub section has linear complexity, it needs to compute the optimal beam forming Algorithm Greedy bit loading algorithm. Vector, power vector and BSC for each of $NK$ candidate rate assignments, which is computationally intense. With the motivation of further reducing the computational effort and avoiding extensively executing Algorithm, a gradient based power updating algorithm is proposed. The gradient method is similar to in the sense that every link is tested with bits increment while keeping the rates of all other links unchanged. Since the optimal link is found by calculating the sum rate power gradient algorithm is only executed once at each iteration instead of $NK$ times in Algorithm. To reach the final rate targets of all MSs as soon as possible, the optimal link is chosen such that it has the maximum gradient of the sum rate power function.

3) Greedy Algorithm:
The idea of the greedy bit loading algorithm is that at each iteration, bits are added to the optimal link while the rates of interfering users are kept unchanged, so that the total power increment in the system is minimum. The iteration continues until all MSs Reach their rate targets. At every iteration, the considered problem is a fixed-rate problem that can be optimally solved by Algorithm. The iteration of the algorithm is initialized from zero iteration $t$, the algorithm tests with an allocation such that rate on link $(n; k)$ has increment and others are kept fixed. Obviously there are $NK$ such candidate allocations. To obtain the current best link, algorithm is executed $NK$ times each for one of the candidates. The sum power of rate target is denoted by $(n;k)$.

IV. RESULTS

A. Network Formation:

![Fig. 1: Network Information](image)

Shows that the formation of Network, where consider a base station and mobile terminal and network formation is based on the principal of Poisson distribution.

B. SC-FDMA Transmission:

![Fig. 2: SC-FDMA Transmission](image)
The SC-FDMA error probability is compared with BPSK, QPSK and both 16 & 64 bit QAM.

C. Power Spectral Density:

![Fig. 3: Power Spectral Density](image)
Calculation of power spectral density with respect to maximum backhaul rate. Threshold comparison of each
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(IJSRD/Vol. 3/Issue 02/2015/494)

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user is plotted here. Threshold point considered here is 60. When the signals of users crosses blow the threshold then it will be considered as the detected spectrum and will be allocated to the preferred user.

D. Sub Channel Creation:

![Sub Channel Creation](image)

Fig. 4: Sun Channel Creation
Average network throughput using SBA and DBA and the number of bits are conveyed by sub-channels.

E. Throughput Analysis:

![Throughput Analysis](image)

Fig. 5: Throughput Analysis
Average network throughput with maximum backhaul rate and the throughput analysis is done based on the comparison with proposed and existing scheme.

V. CONCLUSION

Determine CoMP for uplink of cellular system where MTs transmit by using SC-FDMA. detection and decoding are distributed same time at each BSs and constraint on the number of bits exchanged on the backhaul scheduling of backhaul transmission is developed effectively by resource allocation algorithm. The Future work will be on the development of both Static Bit Allocation (SBA) and Dynamic Bit Allocation (DBA) to sharing the unquantized subcarrier signal.

REFERENCES