Particle swarm optimization based precoder in CoMP with measurement data

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I. Extended Abstract

Coordinated multipoint (CoMP) schemes have been identified as one of the key technologies for mitigating inter-cell interference (ICI) in future communication systems [1], [2]. Under this framework, both coordinated beamforming/scheduling and the more advanced joint processing between base stations (BSs) are included. In the downlink, coordinating BSs to improve the capacity was initially proposed in [3]. A subset of joint processing CoMP is a joint transmission approach where the user data and the channel state information (CSI) needs to be available at all the coordinating BSs, such that simultaneous transmission of user data can be performed coherent or non-coherently from one or more BSs. With this approach ICI is mitigated, as other BSs aid the transmission of useful signals instead of introducing interference. In the coordinated beamforming/scheduling approach, the user data is only available at the serving BS. However, the CSI of all the users are shared between the BSs such that ICI can be controlled based on user scheduling and beamforming.

To realize the gains of joint transmission CoMP in a frequency division duplex system, the users need to feedback the CSI, typically to its serving BS, such that it is aggregated at a central coordination node (CCN) for jointly mitigating interference via precoding. The aggregated CSI knowledge is used create the precoding weights consisting of power allocated beamforming weights that needs to be available at the corresponding BSs in the backhaul when transmitting to the users involved in joint transmission CoMP. Under the assumption of perfect channel knowledge, perfect synchronization among BSs and negligible delays, the theoretical gains with joint processing CoMP are substantially larger than with coordinated beamforming. How much of these gains can be preserved under more realistic assumptions is addressed to some extent in this work.

Joint transmission CoMP is very sensitive to CSI errors. When users are moving fast, obtaining reliable CSI at the transmitter can be very difficult. In practice, the CSI obtained at the CCN is imperfect. The imperfection is primarily due to prediction errors and quantization errors. The process of feeding back the CSI to the BS, aggregating the CSI at the CCN and making the precoding weights available at the corresponding BS in the backhaul introduces delay in this closed loop system. With delay introduced in the system, outdated

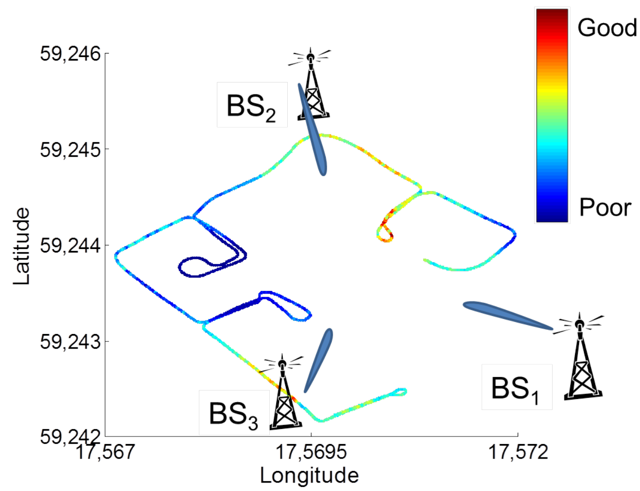

Fig. 1. Prediction errors were generated based the statistics of this drive route measurements from a suburb in Kista, Sweden.

CSI can easily diminish the promising gains of CoMP. Hence, the estimated channel needs to be predicted well in advance to account for the delays in the system. Furthermore, the mobility of users poses stringent constraints on the predicted channel. The prediction errors are introduced when there is a mismatch between the true channel and the predicted channel. To feedback the CSI, the users need to quantize the amplitude and the phase of the channel. With finite number of bits being used to feedback the CSI, quantization of real channel coefficients results in lossy compression.

In this work, we evaluate the performance of different precoders under more realistic conditions where the CSI feedback is imperfect due to prediction and quantization errors. As a first step we consider full feedback where the aggregated channel matrix is full. In this paper, we focus on two precoders that provided the best results as we show later in our simulation results. A robust linear precoder (RLP) based on automatic control feed-forward (RLP-ACFF) is used [4]. This precoding algorithm acts on the estimates of the uncertainty of the predicted channel. The other precoder that is considered here is a particle swarm optimization (PSO) based precoder, that was primarily designed to work under limited feedback and limited backhaul constraint [5]. The movement of a flock of birds or a shoal of fish as a swarm, was found to be performing optimization, from which PSO was dervied [6]. PSO is a stochastic algorithm, where the birds or particles are mapped to the precoding weights, fly in the search space, aiming to optimize a given objective. In this work, the precoders are optimized towards maximizing the sum rate under per BS power constraint.

In our simulations, we considered two BSs with inter-site distance of 500 m with two users moving at fast pedestrian speed of 5 kmph. Wiener filter is used to estimate the channel 8 ms in the future. This corresponds to the duration of time taken for feedback and backhaul delays, including the processing time of channel prediction, precoding design and other delays before actual data transmission. The prediction errors are generated from the statistics of the drive route measurements as shown in Fig. 1. More details can be found in [7]. The phase of each complex channel is quantized with 5 bits while the amplitude is assumed to be perfectly estimated. The 3GPP pathloss model for urban environment was used [8]. The following scenarios were considered. Scenario 1: Both users are in their respective cells, close to the cell-edge. Scenario 2: Both users are at a distance of 125 m from their serving BS. Scenario 3 (not shown): one user is located at the cell edge while the other user is 125 m from its serving BS. To compare the performance of the precoders with other reference algorithms, coordinated scheduling (denoted as CS in the figures) and frequency division multiple access (FDMA) are considered. With coordinated scheduling, the whole bandwidth is allocated to the user with the highest instantaneous channel gain from one BS, while the other BS is silenced. With FDMA, the entire bandwidth is disjointly and equally divided between the users. The performance of the precoders and other algorithms for interference mitigation in terms of the average sum rate versus the cell-edge signal-to-noise ratio (SNR) are as shown in Fig. 2 and 3. The SNR at the cell-edge is defined as the reference value for one user located at the cell-edge. The algorithms were considered for perfect and imperfect CSI. It can be observed that PSO performed the best in both the scenarios for all the SNR regions. At low SNRs at the cell-edge, the errors in the channel were dominated by prediction errors, while at high SNRs, the quantization errors dominated the performance. It can also be observed that the choice of the precoder plays an important role in preserving the gains for joint transmission CoMP compared to coordinatd scheduling. Other algorithms considered in this study are captured in [7].

PSO is robust against imperfect CSI due to prediction errors and quantization errors. More bits can be allocated to improve the user data rate, however, this is at the expense of using more feedback resources. A Wiener filter was used for channel prediction, however a Kalman filter can be used to improve the prediction. The performances of these algorithms with sparse aggregated channel matrix (limited CSI) and imperfect channel knowledge needs to be investigated.

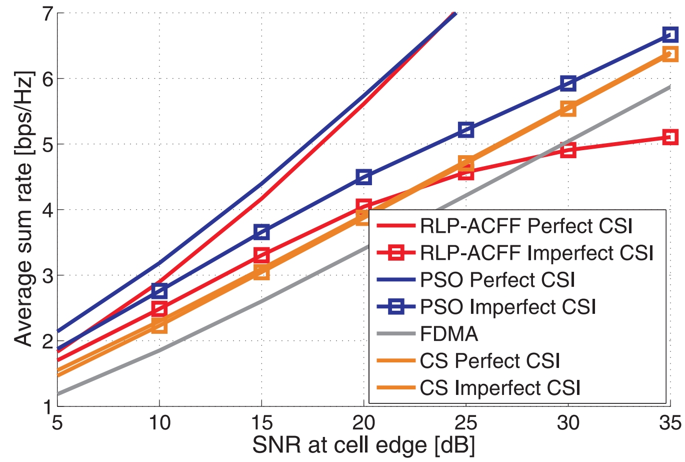

Fig. 2. Scenario 1: Both users are in their respective cells, close to the cell-edge.

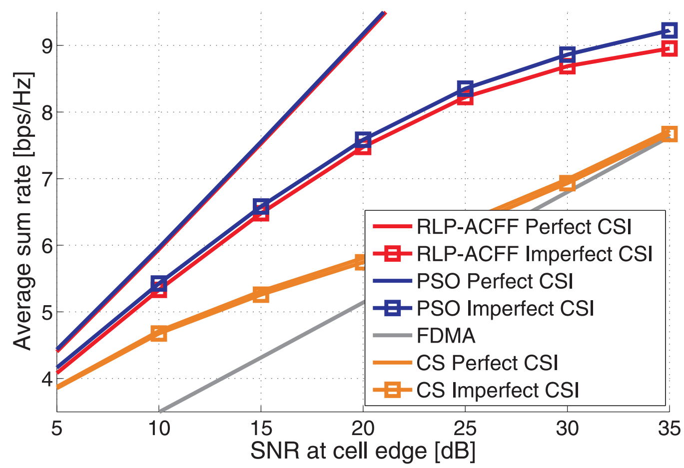

Fig. 3. Scenario 2: Both users are at a distance of 125 m from their serving BS.

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