Coordinated Multi-Point (CoMP) Adaptive Estimation and Prediction Schemes using Superimposed and Decomposed Channel Tracking

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***Abstract*—Performance of future wireless technologies will depend heavily on cooperation between different transmission/reception nodes in the access network. CoMP (Coordinated Multi-Point) transmission increases the cell edge user performance by reducing the inter-cell interference. UEs (User Equipments) simultaneously receive data from multiple base stations (eNBs) grouped into a joint transmission cluster. Clustering choices need to be optimized by joint use of CoMP adaptive channel estimation and prediction schemes for energy efficiency and capacity improvements. In this paper, various multi-point (multi-eNB) channel estimation/prediction schemes are proposed and analyzed to improve the joint transmission set clustering accuracy. Multi-point CIRs (Channel Impulse Responses) can be tracked either by superimposed or decomposed methods. The latter scheme tracks each multipath component of every CoMP measurement set member and yields more accurate estimates, however leads to significantly higher computation complexity as opposed to the superimposed tracking which tracks the overall CIR. Therefore, UEs need to dynamically switch between the two schemes depending on the serving cluster size and recently observed CoMP characteristics. It is shown that increasing the channel estimation/prediction filter size yields significantly more capacity and energy efficiency improvements for UEs served by larger clusters. It is also demonstrated that the serving eNB can maximize the performance gains by setting the channel prediction range equal to observed system delay between the multi-point CSI reports and data transmission.**

I. Introduction

Capacity and spectral efficiency of the cellular systems need to be increased in order to meet the increasing mobile data demand from users. Some of the proposed options that increase the capacity of cellular networks are listed in [1] as using more spectrum, increasing the number of transmit/receive antennas, using dedicated beams to serve the users, and enabling small cell deployment. However, none of these methods address inter-cell interference issue, which is the actual bottleneck for spectral efficiency, especially for LTE and beyond systems that have full frequency reuse. CoMP is listed as one of the key features and work items for LTE-A systems to improve cell edge performance, system throughput, received SINR and spectral efficiency by mitigating and exploiting the inter cell interference [2].

Accuracy of the joint transmission clustering decision is the key performance determining factor in CoMP networks in terms of both downlink capacity and access network energy efficiency [3]. Therefore, channel estimation schemes utilized by the user and prediction schemes chosen by the serving eNB are very crucial to avoid incorrect and outdated multi-point channel feedback and improve the performance of CoMP systems. In [4], a thorough comparison of various channel estimation schemes is provided and it is shown that reduced rank LMMSE (Linear Minimum Mean Squared Error) has the highest computation complexity followed by regular LMMSE and downsampled CIR estimators, respectively. Channel prediction methods tackle outdated CSI feedbacks and when fading channel prediction methods are used jointly with adaptive transmission schemes; major performance gains can be obtained compared to non-adaptive transmission schemes utilizing outdated channel feedbacks as demonstrated in [5]. Joint utilization of channel estimation and prediction schemes in MIMO OFDM systems is demonstrated in [6] using AR (auto-regressive) Kalman filters. It is shown that the unnecessary increase of AR degrees yield minor performance gains which is not enough to compensate for the significant increase in estimation/prediction computation complexity.

In our previous work [7], we proposed channel estimation filters adapted according to UE's CoMP parameters, where the UE changes the estimation filter lengths according to the serving CoMP cluster size and the likelihood of each measured point being included in the joint transmission cluster on the upcoming TTI (Transmission Time Interval). In [8], we proposed a novel multi-point channel feedback reporting method, where the UE performs down-selection on the joint transmission set for the upcoming TTI to reduce the clustering accuracy burden on the serving eNB. However, to the best of our knowledge, comparison of decomposed and superimposed channel tracking methods in CoMP networks is not studied in existing literature.

Some distinct contributions of this paper to the existing CoMP literature are listed as follows:

- Comprehensive study is provided for CoMP adaptive switching/fallback between the superimposed versus decomposed channel estimation schemes to balance the clustering accuracy versus the channel estimation computation complexity trade-off.
- Effects of estimation/prediction filter length increases on CoMP performance are presented and characterized according to users being served by various cluster sizes.
- Multi-point channel estimation and prediction framework is presented to tackle the CoMP system delays and inaccurate measurements using a comprehensive approach.

The rest of the paper is organized as follows. Sec. II presents the CoMP cellular system model used in our study. Sec. III describes the multi-point channel estimation and prediction schemes, Sec. IV provides the simulation results, performs a comparative analysis on decomposed versus superimposed channel estimation/prediction schemes in CoMP networks and Sec. V concludes the paper.

II. CoMP Cellular System Model

A. CoMP Joint Transmission Procedures

Definition of downlink CoMP is explained initially in 3GPP 36.814 [9] as dynamic coordination among multiple spatially separated transmission points. CoMP coordinating set, N_{Coop}, is the overall master set of points that have logical/physical links enabling them to exchange channel feedbacks and/or user payloads to perform downlink joint transmission or make scheduling decisions in the access network over certain time - frequency resources. CoMP joint transmission set, N_{JT}, is a subset of N_{Coop} and contains the points that are directly participating in user plane data transmission over the same resource blocks to the UE as shown in Fig. 1. CoMP measurement set, N_{meas}, includes the points about which the UEs are required to report measured link qualities and CSI (Channel State Information) feedback.

Inter-eNB deployment and joint processing/joint transmission schemes for FDD transmission are considered in this work. Serving eNB acts as the anchor point of the CoMP transmission. Contents of the CoMP measurement set are sent to the UE as part of downlink control plane signaling along with the measurement IDs, and density/periodicity of the CSI-RS (Channel State Information Reference Signal). CSI-RS inserted into the resource blocks enable the UEs to perform multi-point channel estimation for all the members of the CoMP measurement set, N_{meas}. Serving cell makes the clustering decision depending on the consolidated multi-point CSI feedback and a subset of the CoMP measurement set is chosen as the CoMP transmission set, N_{JT}. User plane payload coming from the PDN-GW (Packet Data Network-Gateway) targeted for a specific UE is then transferred by the serving eNB to all the chosen members of the CoMP transmission set over logical/physical links. Members of N_{JT} perform cross-point scheduling and jointly transmit the data to the scheduled UE using the specified time/frequency resources.

B. Spatial Channel Model and Threshold based Clustering

CoMP capable UEs perform multi-point measurements for the eNBs that are included in the CoMP measurement set, $n \in N_{meas}$, unless otherwise is specified by the serving eNB. Actual measured received power from eNB n by user i at TTI t is expressed as

$$P_{RX}(n,t,i) = P_{TX}(n) - PL(n,i) - P_{Fading}(n,i,t), \quad (1)$$

where $P_{TX}(n)$ is the transmitted power from eNB $n \in N_{meas}$, $PL(n,i)$ is the large scale pathloss observed between user i and eNB n according to the UMa (Urban Macro) propagation model explained in [10], and $P_{Fading}(n,i,t)$ is the time-varying power loss observed due to small scale fading at TTI t according to the model in Section 4.1.2. Channel impulse response (CIR) between every UE and eNB radio link, (n,i), is modeled independently to have unbiased joint transmission clustering decisions and formulated as

$$h_{n,i}(t,\tau) = \sum_{l=1}^{L} A_l(t) e^{j2\pi f_{d_l} t} e^{j2\pi f_c \tau_l} e^{j\phi_l} \delta(\tau - \tau_l), \quad (2)$$

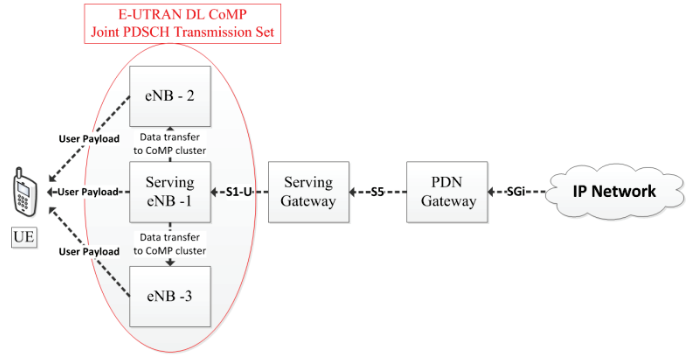

Fig. 1. User plane data flow for downlink inter-eNB CoMP joint transmission.

TABLE I. Simulation Parameters

Parameter	Assumption or Value
Cellular layout	Hexagonal grid with wrap-around
UE distribution	Uniform random distribution
Pathloss model	Urban macro [10]
Number of sites: size(N_{meas})	19
Carrier frequency (f_c)	2110 MHz
Downlink bandwidth (W)	10 MHz
LoS shadowing (σ_{LoS})	4 dB
NLoS shadowing (σ_{NLoS})	6 dB
Channel sampling density (η)	42.6
Number of multipath components (L)	6
Pedestrian UE receiver velocity (v)	6 km/h
Transmission power (P_{TX})	20 W

where L is the total number of multipath components and f_c is the carrier frequency. A_l, f_{d_l} and ϕ_l represent the time varying amplitude, Doppler frequency and additional phase shifts observed at the delay tap τ_l, respectively. Multi-point complex CIR samples formulated in (2) are obtained using Winner SCME model explained in [11] according to the input parameters shown in Table I. Spatial channel sampling density η is defined as the number of spatial samples per half wavelength $\lambda/2$. Channel samples, $t \in [1,..,T]$ are obtained with a 1 ms granularity to synchronize with the scheduling decisions that are performed every TTI at the serving eNB. As a result, η is tuned according to the receiver velocity to generate 1 channel sample for every TTI. Instantaneous downlink received signal power fluctuation at each channel sample due to small scale fading is found by

$$P_{Fading}(t) = 10\log_{10}\left[\left(\frac{\left|\sum_{l=1}^{L} h(t,\tau_l)\right|}{2}\right)^2\right]. \quad (3)$$

Serving eNB will need to adapt to the received power fluctuations due to small scale fading every TTI to update N_{JT}. Due to the transmission through noisy channel and scarce structure of CSI-RS for multi-point channel estimation demonstrated in [1], the system is vulnerable to channel estimation errors. Joint transmission clustering decisions also suffer from the CoMP system delays due network topology constraints, feedback consolidation and processing procedures at the serving eNB. As a result, serving eNB performs the threshold-based CoMP transmission set clustering decisions based on the incorrectly estimated and outdated multi-point downlink received power measurements

$$P_{RX\_err}(n,t,i) = P_{RX}(n,t-\Delta,i) + P_{err_{n,i}}(\mu,\sigma), \quad (4)$$

where Δ is the delay observed in milliseconds during the CSI exchange and feedback processing, and $P_{err_{n,i}}(\mu,\sigma)$ models the effect of channel estimation errors on received power measurements for each link as a Gaussian random variable with mean μ and standard deviation σ expressed in dB scale. To balance the trade-off between the CoMP access network energy efficiency and user perceived downlink capacity, serving eNB performs threshold based clustering decisions as shown in [12]. Best member of N_{meas} is found every TTI by

$$n_{Best}(i,t) = \arg\max_{n}\{P_{RX_{err}}(n,i,t)\}, \quad (5)$$

and eNBs yielding downlink received power values that are within a certain network defined threshold ∇_{NW-JT} compared to the best measured eNB are added to the CoMP joint transmission set for user *i* at TTI *t* as

$$n \in N_{JT}(i,t) \; if \; |P_{RX_{err}}(n_{Best},i,t) - P_{RX_{err}}(n,i,t)| \leq \nabla_{NW-JT}. \quad (6)$$

It can be seen from (4) and (6) that both the cluster size, $N_C(i,t) = size(N_{JT}(i,t))$, and the contents of the joint transmission set will be impacted by reported CSI feedbacks due to multi-point channel estimation errors and system delays.

C. CoMP Performance Metrics for Time-varying Channels

Assuming the receiver UEs perform perfect phase adjustment of multi-point sinusoidal crests, the received downlink power from the CoMP cluster N_{JT} is calculated by

$$P_{JT}(i,t) = \sum_{n \in N_{JT}} P_{RX}(n,i,t). \quad (7)$$

Downlink capacity perceived in bits/sec at each user location, *i,* can be expressed by adapting Shannon's capacity formula to CoMP joint transmission schemes using (7) as

$$C(i,t) = W(i,t)\log_2\left(1 + \frac{P_{JT}(i,t)}{\sum_{n \in N \setminus N_{JT}(i)} P_{RX}(n,i,t) + P_{noise}}\right), \quad (8)$$

where $W(i,t)$ is the assigned frequency bandwidth to user *i.* Advantages of receiving cross-point scheduling from larger clusters in terms of downlink capacity is clear from (8), however the cellular access network energy efficiency should also be considered for comprehensive performance analysis.

Total power consumption in Joules/sec for a single base station using CoMP is calculated according to Table II as

$$P_{Comp} = N_{\frac{PA}{sector}}\left(\frac{P_{TX}}{PA_{eff}} + P_{SP}\right)(1 + C_C)(1 + C_{BB}) + P_{BH}. \quad (9)$$

Signal processing and backhauling power consumptions are modeled as quadratic functions of the CoMP cluster size as

$$P_{SP-CoMP} = 58(0.87 + 0.1N_C + 0.03N_C^2)\ \text{W}, \quad (10)$$

TABLE II. COMP POWER CONSUMPTION PARAMETERS [11]

Parameter	Assumption or Value
Power amplifier efficiency (PA_{eff})	0.38
Cooling losses (C_C)	0.29
Battery backup losses (C_{BB})	0.11
Pilot density (p)	8/168
CSI signalling overhead (q)	8
Subcarrier spacing (Δf)	15 kHz
Power amplifiers per sector ($N_{PA/sector}$)	1
OFDM symbol period (T_S)	66.7 µsec

$$P_{BH} = \frac{2pqN_c^2 / T_s}{100 \text{ Mbits/sec}} 50 \text{ W}, \quad (11)$$

respectively. Overall CoMP access network energy efficiency while serving the user *i* can be derived using (8) and (9) as

$$EE(i,t) = \frac{C(i,t)}{N_C(i,t)P_{CoMP}(i,t)}. \quad (12)$$

Possible technical challenges of CoMP systems due to channel estimation errors and system delays can be induced from (8) and (12) as follows:

- Inaccurate multi-point CSI feedbacks can exclude a potential joint transmission point from the CoMP cluster unnecessarily. This decreases both the energy efficiency of the access network and the user perceived quality of service in terms of received downlink data rates.
- Inclusion of an incorrect point in the CoMP joint transmission cluster increases the downlink data rates slightly; however, this causes significant bits/Joule energy efficiency losses since the increased power consumption of the access network is not compensated by an equal amount of downlink capacity gain for the served UEs.

III. CHANNEL ESTIMATION AND PREDICTION SCHEMES IN COMP NETWORKS

A. Decomposed CIR Estimation

UEs can track each multipath delay tap $l \in L$ of every CoMP measurement set member $n \in N_{meas}$ individually and perform channel estimation separately for each path. Smoothened CIR at each path is then merged to report multi-point CSI feedback for all $n \in N_{meas}$. This method is called the decomposed channel estimation and tracking. CIR at a particular delay tap *l* between the user *i* and CoMP measurement set member $n \in N_{meas}(i,t)$ is estimated by using a weighted sum of the currently observed channel sample at TTI *t* and previously estimated $M_{UE} - 1$ CIR samples as

$$\tilde{h}_{n,i}(t,\tau_l) = \sum_{m=0}^{M_{UE}-1} w(m)\hat{h}(t-m,\tau_l), \quad (13)$$

where the weight coefficients *w(m)* are stored in a user defined filter of length M_{UE}. A detailed representation of (13) for an auto-regressive MMSE channel estimator is formulized as

$$\tilde{h}_{n,i}(t,\tau_l) = [(R_h(\Delta t,\tau_l) + \sigma_{noise}^2 I_{M_{UE}xM_{UE}})^{-1} r_h(\Delta t,\tau_l)]^H \hat{\boldsymbol{h}}_{t,\dots,t-M_{UE}+1;\tau_l}. \quad (14)$$

The regularized time domain CIR autocorrelation function component, $R_h(\Delta t,\tau_l)+\sigma^2_{noise}I_{MxM}$, is formed using the variance of the channel estimation error at a particular path of the CIR and the delay-cross power density formulated by

$$R_h(\Delta t=M_{UE}-1,\tau_l)=E[h(t-M_{UE}+1,\tau_l)h(t,\tau_l)^*]. \quad (15)$$

It should be noted that the autocorrelation vector, $r_h(\Delta t,\tau_l)$, between the most recent channel sample $h(t,\tau_l)$ and M previously estimated channel samples is equal to the first column of the regularized CIR autocorrelation matrix in (14).

Multipoint channel estimation filter takes a weighted sum of the M_{UE} most recent CIR realizations given by

$$\widehat{\boldsymbol{h}}_{t,\dots,t-M+1;\tau_l}=\left[\hat{h}(t,\tau_l)\dots.\hat{h}(t-M_{UE}+1,\tau_l)\right]^T \quad (16)$$

to smoothen the CIR estimate at time t and delay tap l. Autoregressive coefficients of the multi-point channel estimation filter shown in (14) are formed using the MMSE criterion, where the more recently measured channel estimates are given higher weights as $w(j)>w(k)\ \ \forall\, j<k$. This is due to the decreasing nature of the CIR autocorrelation function in time domain which has a peak at $R_h(\Delta t=0,\tau_l)$.

B. Superimposed CIR Estimation

An alternative multi-point channel estimation method can be utilized by tracking the superimposed time-varying CIR coefficients instead of separate CIR realizations at each path. Although this approach yields less accurate CSI estimates compared to decomposed multipath tracking, multi-point channel estimation complexity of the UE will be decreased significantly. Superimposed CIR estimate at TTI t is found by

$$\tilde{h}_{n,i}(t)=[(R_h(\Delta t)+\sigma^2_{noise}I_{M_{UE}xM_{UE}})^{-1}r_h(\Delta t)]^H\widehat{\boldsymbol{h}}_{t,\dots,t-M_{UE}+1}, \quad (17)$$

where the superimposed CIR samples that are used as inputs to the channel estimation filter are expressed as

$$\widehat{\boldsymbol{h}}_{t,\dots t-M+1;\tau_l}=\left[\sum_{l=1}^{L}\hat{h}(t,\tau_l),\dots,\sum_{l=1}^{L}\hat{h}(t-M_{UE}+1,\tau_l)\right]^T. \quad (18)$$

Conversion between the delay-cross power density expressed in (15) and the time auto-correlation function is formulated by

$$R_h(\Delta t)=\int_{l=1}^{L}R_h(\Delta t,\tau_l)\,d\tau_l. \quad (19)$$

Filter coefficients in (17) are formed using the superimposed CIR samples and the time auto-correlation function instead of the decomposed CIR samples and delay-cross power densities.

C. Multi-Point CIR Prediction

Multi-point channel estimation procedures performed by the UEs are enough to tackle the channel estimation errors; however CoMP system delays still create performance degradations due to outdated CSI feedbacks. As a result, serving e-NB should perform channel prediction procedures using the CIR estimates reported by the UE to predict how the multi-point CIRs will change at the time of the joint data transmission. Multi-point channel prediction is performed by

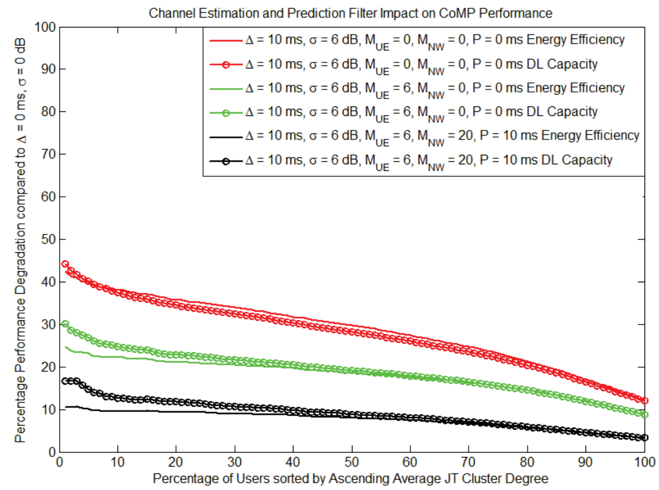

Fig. 2. Performance improvement of CoMP systems due to multi-point channel estimation and prediction schemes.

$$\breve{h}_{n,i}(t+p)=\sum_{\substack{m=1\\p>1}}^{p-1}\breve{h}_{n,i}(t+p-m)w(m)\ +\ \sum_{m=p}^{M_{NW}}\tilde{h}_{n,i}(t+p-m)w(m), \quad (20)$$

where $\breve{h}_{n,i}$ and $\tilde{h}_{n,i}$ represent the predicted CIR samples by the serving eNB and the estimated CIR samples by the UE, respectively, and $p\in[1,\dots,P]$ represents the prediction range in terms of number of TTIs. The prediction filter length used by the serving eNB is denoted by M_{NW} to avoid confusions with the channel estimation filter length. It is assumed that the CIR prediction filter is larger than prediction range, $M_{NW}>P$, to track the time-varying behavior of the CIRs accurately.

Serving eNB performs the prediction at P steps using (20) by updating the filter inputs, predicted CIR autocorrelation matrix and filter coefficients at every step. Currently predicted CIR sample replaces the most outdated CIR sample for the filter input at each step p. Prediction filter coefficients are generated similar to the estimation filters shown in (17), however the regularized CIR autocorrelation component from (14) is altered to replace σ^2_{noise} by ε. Diagonals of the CIR autocorrelation matrix are summed with epsilon to make sure the matrix is invertible. Regularization process for the prediction filter does not reuse the variance of the channel estimation errors since the CIR samples used by serving eNB are already estimated by the UEs for CSI feedback reporting.

IV. Simulation Results and Performance Analysis

Inaccurate CoMP transmission conditions are simulated with $\Delta=10$ ms and $P_{err}(\mu=0\text{ dB},\sigma=6\text{ dB})$. The UEs which do not have any CIR estimation or prediction mechanisms, $M_{UE}=0$ and $M_{NW}=0$, suffer up to 45% energy efficiency and capacity degradation compared to the perfect clustering conditions having no estimation errors or systems delays, $P_{err}(\mu=0\text{ dB},\sigma=0\text{ dB})$ and $\Delta=0$ ms. Performance of the schemes which only use multi-point channel estimation methods is compared to the schemes which use CIR estimation and prediction methods jointly and the results are demonstrated in Fig. 2. CoMP access network energy efficiency and downlink capacity performance degradation of the systems which only use multi-point channel estimation schemes without prediction, $M_{UE}=6$ and $M_{NW}=0$, reach

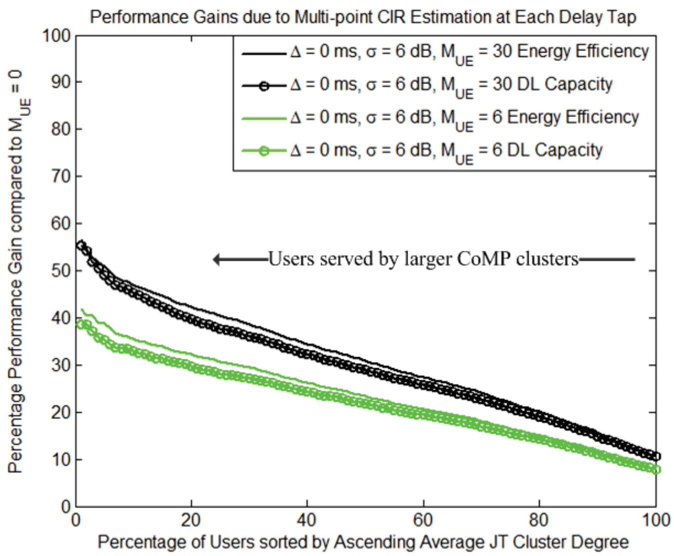

Fig. 3. Decomposed multi-point channel estimation scheme.

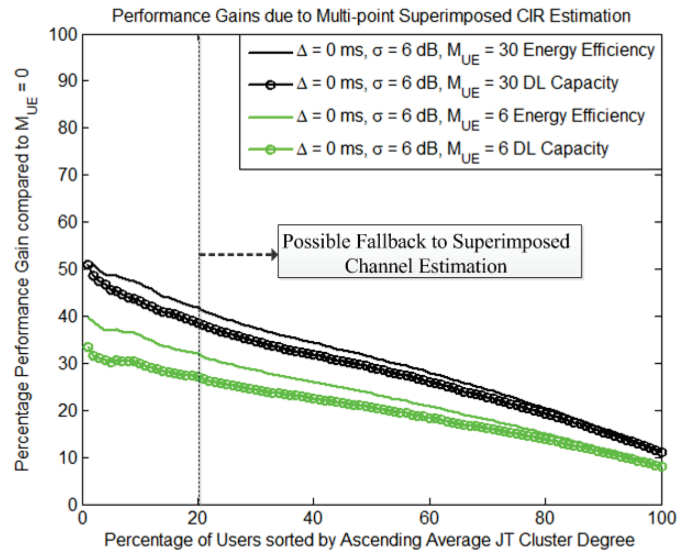

Fig. 4. Superimposed multi-point channel estimation scheme.

around 25% and 31%, respectively, compared to the perfect clustering conditions. However, when the serving-eNB complemented the multi-point CIR estimation schemes by performing prediction according to the estimated CIR samples using $M_{UE} = 6$, $M_{NW} = 20$, and $P = 10$ ms, energy efficiency and downlink capacity percentage performance degradation reduced to 11% and 17%, respectively, compared to the ideal clustering conditions. It should be noted that the CIR prediction range P is set to the system delay observed in the channel to maximize the performance gains due to prediction. It is shown in Fig. 2 that increasing filter lengths enhances the CoMP performance metrics more significantly for users with higher $N_C(i)$ as opposed to users being served by smaller CoMP transmission clusters. As a result, the UEs and serving e-NB should adapt the estimation filter length M_{UE}, prediction filter length M_{NW}, and the prediction range P according to the served UE's CoMP characteristics.

Both decomposed and superimposed estimation schemes are simulated for low mobility conditions, $v = 6$ km/h, where the serving eNB is assumed to form the joint transmission clusters using the UE estimated multi-point CIR samples without any delay encountered as shown in Figs. 3 and 4. Multi-point CIR estimation scheme that tracks each tap individually using $M_{UE} = 30$ yields energy efficiency and downlink capacity percentage performance improvements up to 56%; whereas multi-point superimposed CIR estimation scheme yields up to 51% improvement compared to CoMP schemes lacking any receiver memory span, $M_{UE} = 0$. It may seem like tracking the CIR samples and the time-varying auto-correlation functions separately for each multipath component is a better performing scheme as opposed to schemes that only track the superimposed CIR using the overall time correlation functions. However, storing CIR at each delay tap for each CoMP measurement set member and forming individual auto-correlation functions for each multipath component places a huge computational burden on the UE. Hence, UEs should choose to switch dynamically between the two channel estimation schemes depending on the recently observed CoMP characteristics and computation complexity versus clustering accuracy trade-off in CoMP systems.

The details of the actual types of multipoint channel estimation used by the wireless device, and the techniques for adaptively determining which method to use under which circumstances may include a variety of details and techniques described as follows:

- Wireless device may be configured to use decomposed channel estimation only for points (sites) that are recently added to the CoMP measurement set. In this case, superimposed channel estimation may be used for all points in the CoMP measurement set which have been members of the CoMP measurement set for at least a certain predetermined amount of time, while decomposed channel estimation may be used for any points which have been members of the CoMP measurement set for less than the predetermined amount of time.
- Decomposed channel estimation may be used when the wireless device is receiving downlink CoMP joint transmission from a large cluster (e.g., more than a certain predetermined number) of cells, $\mu_{N_c} \geq N_{Threshold}$, while superimposed channel estimation may be used when the wireless device is receiving downlink CoMP joint transmission from a smaller cluster of cells as shown in Figs. 4 and 5.
- Decomposed channel estimation can be preferred only for points that have received power values close to a joint transmission cluster threshold, ∇_{NW-JT}, while superimposed channel estimation may be used for CoMP measurement set members which have received power values that are outside of the predetermined range of the joint transmission cluster threshold as shown in Fig. 6. This method makes sure that the UEs increase the channel estimation computation complexity only for the critical points that require extremely accurate CSI feedback for joint transmission set clustering decisions.

It should be noted that the above mentioned exemplary techniques for adapting the channel estimation technique dynamically may be used individually or in combination, as desired. Other techniques may be used alternatively or in addition, as we described thoroughly in the patent filing [14].

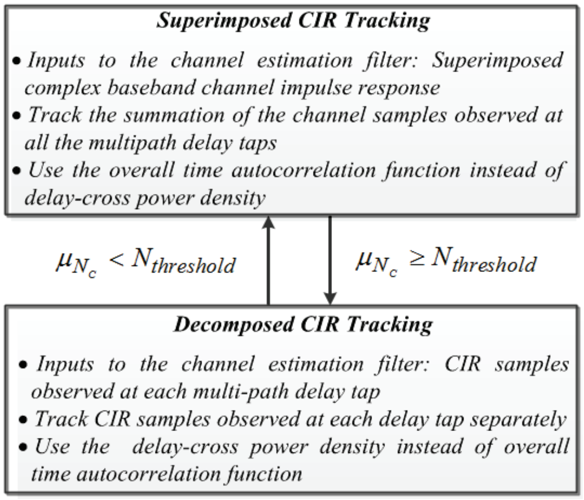

Fig. 5. CoMP joint transmission cluster size adaptive switching between decomposed and superimposed channel estimation schemes.

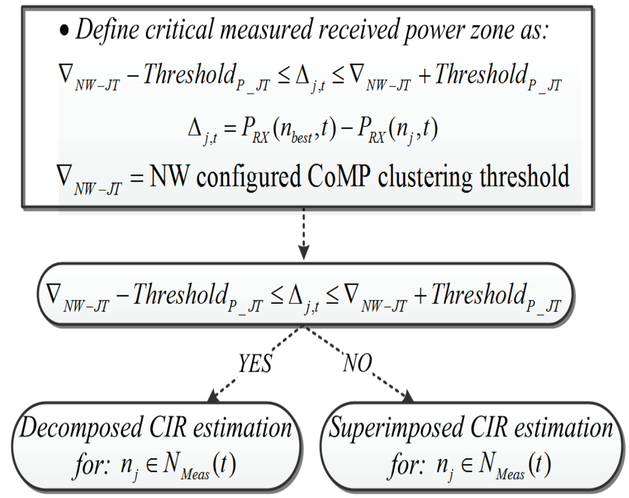

Fig. 6. Downlink received power adaptive switching between decomposed and superimposed channel estimation schemes.

V. Conclusions and Future Work

Channel estimation errors and system delays, which cause inaccurate CoMP joint transmission clustering decisions, are tackled using a holistic approach where UEs perform multi-point channel estimation and serving e-NB performs multi-point channel prediction procedures. Energy efficiency and capacity gains of choosing decomposed CIR estimation over superimposed tracking is only around 1-2% when all the user locations are considered, however gains reach up to 10% when the top 1% of the UEs being served by largest CoMP joint transmission clusters are considered. To balance the channel estimation complexity versus the performance gain trade-offs, UEs that are being served by larger clusters should use decomposed CIR estimation and tracking, and fallback to superimposed tracking method when the cluster size decreases. Alternative schemes for CoMP adaptive switching between the channel estimation techniques can be implemented by using decomposed CIR estimation tracking only for the points that have received power values which are close to the joint transmission cluster threshold or for the points that are recently added to the CoMP measurement set.

Thus in general, wireless devices should utilize more accurate but computationally more complex decomposed channel estimation technique when the difference in CSI feedback accuracy is more pronounced and has a more significant effect on overall device and CoMP network performance, while the wireless device may utilize slightly less accurate and less computationally complex superimposed channel estimation technique when the difference in CSI feedback accuracy is less pronounced and has a less significant effect on overall CoMP system performance. In other words, by adaptively and dynamically selecting and switching channel estimation technique(s) depending on the relative importance of increased clustering accuracy the wireless device may provide excellent overall multipoint cellular performance in terms of and efficiency. Using the proposed methods for switching between decomposed and superimposed channel estimation schemes, UEs balance the optimal trade-off between CoMP capacity and energy efficiency performance gains versus computation complexity.

Future work will focus on utilizing CoMP adaptive channel estimation scheme switching method jointly with the CoMP adaptive filter length choices explained in the patent filings [7] and [8]. Decomposed channel estimation scheme will be further enhanced to have various filter lengths for each multipath component of every CoMP measurement set member.

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