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On a User-Centric Base Station Cooperation Scheme for Reliable Communications

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***Abstract*—In this paper, we describe CoMP2flex, a user-centric base station (BS) cooperation scheme that provides improvements in reliability of both uplink (UL) and downlink (DL) communications of wireless cellular networks. CoMP2flex supports not only cooperation of two BSs with same direction of traffic but also cooperation of two BSs serving bidirectional traffic. The reliability performance of CoMP2flex is shown with numerical simulations and analytical expressions. We quantify and numerically validate the performance of the greedy BS pairing algorithm by comparing maximum weight matching methods, implemented as the Edmonds matching algorithm for weighted graphs.**

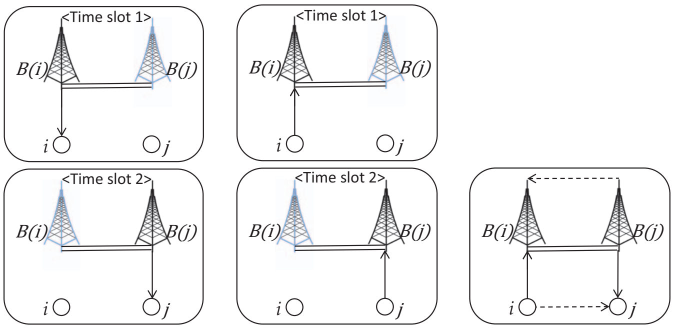
***Index Terms*—CoMP, BS cooperation, reliable communications, stochastic geometry.**

I. INTRODUCTION

Enhancing the reliability of communication, even enduring low data rate, is one of the 5G wireless system design factors [1]. Previously, many researchers have focused on the downlink (DL) traffic due to its greater volume compared to the uplink (UL) traffic. Recently, UL traffic has increased because of new mobile applications and the massive growth of Internet-of-Things (IoT) applications. Many IoT applications have an intensive UL traffic by their sensing and monitoring characteristics [2]. For this reason, enhancing the reliability of UL transmission as important as that of DL transmission.

Increasing the number of base stations (BSs) per area, *network densification*, is one way to increase the reliability. By taking advantage of multiple proximate and interconnected BSs, a BS cooperation in same transmission direction is considered in terms of coordinated multipoint transmission (CoMP) [3]–[6]. CoMP can increase the reliability performance, however, CoMP considers cooperation between the BSs with the same direction of traffic.

In [7], [8], a cooperation scheme for serving cross directional (UL and DL) traffic simultaneously utilizing separated half duplex BSs is proposed and investigated, and is termed CoMPflex: CoMP for In-Band Wireless Full-Duplex. The limitation of [7], [8] is that the traffic is assumed always cross directional. In general, the cooperative BSs could serve the same or opposite direction of traffic. This means that the reliability might be improved if the network can support both CoMP and CoMPflex according to the traffic. In this paper, we propose CoMP2flex, a user-centric base station (BS) cooperation scheme that provides improvements in reliability of both uplink (UL) and downlink (DL) communications of wireless cellular networks. The proposed CoMP2flex can support not only cooperation of two BSs with same direction of traffic but also cooperation of two BSs serving bidirectional traffic. We will show that the reliability performance of CoMP2flex by analytical expressions and numerical simulations. We quantify and numerically validate the performance and complexity of the greedy BS pairing algorithm by comparing the Edmonds matching algorithm for weighted graphs, one of maximum weight matching methods.



(a) Dynamic Cell Selection for DL-CoMP (b) Coordinated Scheduling for UL-CoMP (c) CoMPflex

Fig. 1: Different BS cooperation modes of CoMP2flex.

The paper is organized as follows. In Section II, we describe the system model of the proposed scheme. The reliability analysis of proposed scheme is given in Section III, and its numerical results are presented in Section IV. The paper is concluded in Section V.

II. SYSTEM MODEL OF CoMP2flex

We propose a combined CoMP and CoMPflex (CoMP2flex) BS cooperation scheme, which can support not only cooperation of two BSs with same direction of traffic but also cooperation when the BSs serve opposite directions of traffic. We consider a pair of cooperating BSs. They are interconnected via a wired connection (double solid line in Fig. 1). If both BSs serve DL traffic, dynamic cell selection (DCS) is used (Fig. 1a). DCS serves one user in a cell first, and then serves the user in the other cell. If both BSs serve UL traffic, CoMP reception with coordinated scheduling is used, i.e., only one user in one cell will transmit and the user in the other cell will transmit later (Fig. 1b). Lastly, if the BSs serve cross directional traffic, one BS will operate in DL (DL-BS) and the other in UL (UL-BS), or vice-versa (Fig. 1c). The UL-BS uses side information sent from the DL-BS through the wired backhaul, for interference cancellation.

To quantify the performance of CoMP2flex, we assume that the BSs are randomly distributed with density λ_{B}, resulting in a homogeneous Poisson point process (PPP) [9]. The mobile stations (MSs) are associated with the nearest BS, and each BS serves one MS using the same resource at a time. We assume that each MS, independently of one another, selects its transmission direction with a certain probability δ. We can define a random variable T for the traffic direction, $\Pr\{T = \mathrm{DL}\} = \delta$ and $\Pr\{T = \mathrm{UL}\} = 1-\delta$. The traffic asymmetry of the network can be adjusted by changing δ. A single frequency and Rayleigh fading channel with unit mean power is assumed. $\ell(r) = r^{-\alpha}$ is the path-loss function with path loss exponent α. The default transmit power of uplink users is P_{M}. BSs transmit with constant power P_{B}. A downlink (uplink) signal-to-interference-plus-noise ratio (SINR) requirement is denoted by β_{D} (β_{U}). The term σ^2 is additive white Gaussian noise. The transmission is successfully received if the received SINR is greater than or equal to the target threshold value. Each BS can cooperate with an adjacent BS paired by an algorithm explained in the next subsection.

A. BS Pairing Algorithm

For pairing the BSs, we use two different methods. The first method is a greedy pairing algorithm, which operates as follows: Given a BS deployment, the algorithm starts with a BS chosen uniformly at random. It then lists all neighboring BSs and selects the closest one, in terms of Euclidean distance. These two BSs are then considered a *pair*. The algorithm then select the next unpaired BS, lists its unpaired neighbors, and pairs it with the nearest one. When there are no more BSs that can be paired, the algorithm terminates. Assuming there are n BSs, an upper bound on the complexity is $n(n-1)$,which is of order $O(n^2)$. To be simple, we restrict the candidate BSs to the BSs sharing the same edge, so called Delaunay neighbors. Each BS only needs the knowledge about its Delaunay neighbors, i.e., it is a local method.

The second method is the Edmonds matching algorithm [10]. This algorithm needs the knowledge of the entire network, i.e., it is a global method. In this method, the network is modeled as a weighted planar graph $G = (V, E)$, where the vertex set V contains the BSs, and E is the edge set, representing connections between the BSs. There is an edge $e \in E$ if and only if the BSs represented by the endpoints of e are adjacent in the deployment. The *weight* of an edge e, $wt(e)$, is the distance between the BSs. The goal of the Edmonds matching algorithm is to find a maximal matching (i.e., containing as many edges as possible), while minimizing the total weight. Note that in this case, the distance between the typical BS and its paired BS might be quite high, since the algorithm looks at the entire network.

Our motivations for studying this algorithm are twofold: First, for planar graphs, there exist implementations with complexity $O(n^{\omega/2})$, where $\omega < 2.38$ is the exponent of the best matrix multiplication algorithm [11]. Therefore, the exponent satisfies $\omega/2 < 2.38/2 = 1.19$, which is lower than in the greedy method. Second, we will use the Edmonds matching algorithm to validate the greedy pairing algorithm.

Based on the system model presented in this section, we will derive the analytical forms of the transmission success probabilities in UL and DL representing reliability in the next section.

III. RELIABILITY ANALYSIS

In this section, we investigate the reliability performance of CoMP2flex by deriving analytical expressions for the transmission success probabilities in UL and DL. For the analytical tractability, we assume that all BSs in the network can schedule the one *active* mobile station (MS) either UL (UL-MS) or DL (DL-MS) in each Voronoi cell. We further assume that the spatial distribution of MSs follows the another independent PPP with the density λ_{B}.

A. UL Success Probability in CoMP2flex Network

The success probability of transmission of a typical UL user $\mathcal{U}$ at a typical BS $B(\mathcal{U})$ in CoMP2flex $p_{\mathrm{U}}^{\text{CoMP2flex}}$ can be expressed as follows:

$$\begin{aligned} p_{\mathrm{U}}^{\text{CoMP2flex}} &= \mathbb{E}\left[\Pr\left[\frac{g_{\mathcal{U},B(\mathcal{U})}\ell(r)\,P_{\mathrm{M}}}{I^{\psi}_{B(\mathcal{U})} + I^{\varphi}_{B(\mathcal{U})}} \geq \beta_{\mathrm{U}}\right]\right] \qquad (1)\\ &= \mathbb{E}\left[\Pr\left[g_{\mathcal{U},B(\mathcal{U})} \geq \frac{\beta_{\mathrm{U}} r^{\alpha}}{P_{\mathrm{M}}}\left(I^{\psi}_{B(\mathcal{U})} + I^{\varphi}_{B(\mathcal{U})}\right)\right]\right], \end{aligned}$$

where $g_{i,j}$ denotes the gain of the channel at j from i, and I_i^{ψ} and I_i^{φ} denote the aggregate interference at node i from DL-BSs and UL-MSs, respectively. The transmission distance between the typical user and the typical BS is denoted by r, and r is random variable with pdf as $f(r) = 2\pi\lambda_{\mathrm{B}} r \exp\left(-\pi\lambda_{\mathrm{B}} r^2\right)$ [12]. By using the fact that $g_{\mathcal{U},B(\mathcal{U})}$ is exponential random variable with unit mean (due to the Rayleigh faded channel), (1) can be expressed as:

$$\begin{aligned} p_{\mathrm{U}}^{\text{CoMP2flex}} &= \mathbb{E}_r\left[\mathbb{E}_{I^{\psi}_{B(\mathcal{U})}, I^{\varphi}_{B(\mathcal{U})}}\left[\exp\left(-s\left(I^{\psi}_{B(\mathcal{U})} + I^{\varphi}_{B(\mathcal{U})}\right)\right)\right]\right]\\ &= \mathbb{E}_r\left[\mathbb{E}_{I^{\psi}_{B(\mathcal{U})}}\left[\exp\left(-sI^{\psi}_{B(\mathcal{U})}\right)\right]\mathbb{E}_{I^{\varphi}_{B(\mathcal{U})}}\left[\exp\left(-sI^{\varphi}_{B(\mathcal{U})}\right)\right]\right]\\ &\approx \int_0^{\infty} \mathcal{L}_{\mathrm{U}}^{\psi}(s)\,\mathcal{L}_{\mathrm{U}}^{\varphi}(s)\,2\pi\lambda_{\mathrm{B}} r \exp\left(-\pi\lambda_{\mathrm{B}} r^2\right) dr, \qquad (2) \end{aligned}$$

where $s = \frac{\beta_{\mathrm{U}} r^{\alpha}}{P_{\mathrm{M}}}$, and $\mathcal{L}_{\mathrm{U}}^{\psi}(s)$ and $\mathcal{L}_{\mathrm{U}}^{\varphi}(s)$ are the Laplace functionals of the interference from DL-BSs at the typical BS and the interference from UL-MSs at the typical BS, respectively. The interference from DL-BS is coming from outside of the pair. Assuming independence of the channels from different interfering DL-BSs and independence of the distances from different interfering DL-BSs, and using moment generating function of exponential distribution, $\mathcal{L}_{\mathrm{U}}^{\psi}(s)$ can be expressed as:

$$\begin{aligned}\mathcal{L}_{\mathrm{U}}^{\psi}(s) &= \mathbb{E}_{I^{\psi}_{B(\mathcal{U})}}\left[\exp\left(-\frac{\beta_{\mathrm{U}} r^{\alpha}}{P_{\mathrm{M}}} I^{\psi}_{B(\mathcal{U})}\right)\right] \\ &= \mathbb{E}_{g_{i,B(\mathcal{U})}, r_{i,B(\mathcal{U})}}\left[\exp\left(-\frac{\beta_{\mathrm{U}} r^{\alpha}}{P_{\mathrm{M}}} \sum_{i\in\Phi^{\psi}} g_{i,B(\mathcal{U})} r_{i,B(\mathcal{U})}^{-\alpha} P_{\mathrm{B}}\right)\right] \\ &= \mathbb{E}_{r_{i,B(\mathcal{U})}}\left[\prod_{i\in\Phi^{\psi}} \mathbb{E}_{g_{i,B(\mathcal{U})}}\left[\exp\left(-\frac{P_{\mathrm{B}}}{P_{\mathrm{M}}} g_{i,B(\mathcal{U})} \beta_{\mathrm{U}} r^{\alpha} r_{i,B(\mathcal{U})}^{-\alpha}\right)\right]\right] \\ &= \mathbb{E}_{r_{i,B(\mathcal{U})}}\left[\prod_{i\in\Phi^{\psi}} \frac{1}{1+(P_{\mathrm{B}}/P_{\mathrm{M}})\beta_{\mathrm{U}} r^{\alpha} r_{i,B(\mathcal{U})}^{-\alpha}}\right], \end{aligned} \tag{3}$$

where $r_{i,B(\mathcal{U})}$ denotes the distance from ith BS in the interfering BS set Φ^{ψ} to the typical BS $B(\mathcal{U})$. We assume that the set Φ^{ψ} follows PPP with density $\lambda_{\mathrm{B}}^{\psi}$. To approximate the density $\lambda_{\mathrm{B}}^{\psi}$, we further assume that entire DL-BSs have cooperation BSs. The average node density of DL-BSs is $\delta\lambda_{\mathrm{B}}$. DL-BSs are either CoMP BSs or CoMPflex BSs. A pair of BSs can be CoMP BSs when both BSs serve DL traffic, hence the node density of CoMP BSs is $\delta^2\lambda_{\mathrm{B}}$. The rest of DL-BSs are CoMPflex BSs, hence their node density is $\delta(1-\delta)\lambda_{\mathrm{B}}$. Only half of CoMP BSs can be simultaneously active due to adopting DCS mode. So, $\lambda_{\mathrm{B}}^{\psi}$ is equal to $0.5\delta^2\lambda_{\mathrm{B}} + \delta(1-\delta)\lambda_{\mathrm{B}} = \left(\delta - 0.5\delta^2\right)\lambda_{\mathrm{B}}$. In case of the typical BS having the DL-BS as pair, the interference from the paired DL-BS to the typical UL-BS is cancelled. Hence the interference at the UL-BS is coming from DL-BSs not paired to it. Assuming the paired BS is the nearest DL-BS, the distance to the nearest *interfering* BS is the distance to the second nearest DL-BS. The second nearest distance distribution is given as [13]:

$$f(d) = 2(\pi\lambda)^2 d^3 \exp\left(-\pi\lambda d^2\right). \tag{4}$$

Using (4), $\lambda_{\mathrm{B}}^{\psi}$, and probability generating functional (PGFL) of PPP [9], (3) can be expressed as:

$$\begin{aligned}\mathcal{L}_{\mathrm{U}}^{\psi}(s) = \int_0^{\infty} \exp\left(-2\pi\lambda_{\mathrm{B}}^{\psi} \int_t^{\infty} \frac{(P_{\mathrm{B}}/P_{\mathrm{M}})\beta_{\mathrm{U}} r^{\alpha} x^{-\alpha}}{1+(P_{\mathrm{B}}/P_{\mathrm{M}})\beta_{\mathrm{U}} r^{\alpha} x^{-\alpha}} x dx\right) \cdot \\ 2(\pi\lambda_{\mathrm{B}})^2 t^3 \exp\left(-\pi\lambda_{\mathrm{B}} t^2\right) dt, \end{aligned} \tag{5}$$

where t is the distance to the nearest interfering DL-BS (second nearest BS). For brevity, $r_{i,B(\mathcal{U})}$ is changed as x.

In a similar way, we can obtain $\mathcal{L}_{\mathrm{U}}^{\varphi}(s)$. The interfering MS set will be denoted Φ^{φ} and it is assumed as PPP with density $\lambda_{\mathrm{B}}^{\varphi}$. To approximate the density $\lambda_{\mathrm{B}}^{\varphi}$, we assume that all UL-BSs serving UL-MSs are paired. The average node density of UL-MSs is $(1-\delta)\lambda_{\mathrm{B}}$. A pair of UL-MSs can be CoMP MSs when both MSs have UL traffic, hence the node density of CoMP MSs is $(1-\delta)^2\lambda_{\mathrm{B}}$. The rest of UL-MSs are CoMPflex MSs, hence it is $(1-\delta)\delta\lambda_{\mathrm{B}}$. Only half of CoMP MSs can be simultaneously active due to adopting coordinated scheduling. So, $\lambda_{\mathrm{B}}^{\varphi}$ is equal to $0.5(1-\delta)^2\lambda_{\mathrm{B}} + (1-\delta)\delta\lambda_{\mathrm{B}} = 0.5\left(1-\delta^2\right)\lambda_{\mathrm{B}}$. To sum up, the interferer densities can be quantified as follows:

$$\lambda_{\mathrm{B}}^{\psi} = \left(\delta - 0.5\delta^2\right)\lambda_{\mathrm{B}}, \tag{6}$$

$$\lambda_{\mathrm{B}}^{\varphi} = 0.5\left(1-\delta^2\right)\lambda_{\mathrm{B}}. \tag{7}$$

Then $\mathcal{L}_{\mathrm{U}}^{\varphi}(s)$ can be expressed as:

$$\mathcal{L}_{\mathrm{U}}^{\varphi}(s) = \exp\left(-2\pi\lambda_{\mathrm{B}}^{\varphi} \int_r^{\infty} \frac{\beta_{\mathrm{U}} r^{\alpha} y^{-\alpha}}{1+\beta_{\mathrm{U}} r^{\alpha} y^{-\alpha}} y dy\right), \tag{8}$$

where y denotes the distance from interfering UL-MSs to the typical BS. It is assumed that the interfering UL-MSs are located at a distance larger than r. Using (2), (5), and (8), we can evaluate the UL transmission success probability for CoMP2flex.

B. DL Success Probability in CoMP2flex Network

Following the same lines as $p_{\mathrm{U}}^{\mathsf{CoMP2flex}}$, we can obtain the analytical expression for the DL transmission success probability for CoMP2flex $p_{\mathrm{D}}^{\mathsf{CoMP2flex}}$ as follows:

$$p_{\mathrm{D}}^{\mathsf{CoMP2flex}} \approx \int_0^{\infty} \mathcal{L}_{\mathrm{D}}^{\psi}(s)\, \mathcal{L}_{\mathrm{D}}^{\varphi}(s)\, 2\pi\lambda_{\mathrm{B}} r \exp\left(-\pi\lambda_{\mathrm{B}} r^2\right) dr, \tag{9}$$

where $s = \frac{\beta_{\mathrm{D}} r^{\alpha}}{P_{\mathrm{B}}}$ and the Laplace functionals of the interference from BSs $\mathcal{L}_{\mathrm{D}}^{\psi}(s)$ and MSs $\mathcal{L}_{\mathrm{D}}^{\varphi}(s)$ are

$$\mathcal{L}_{\mathrm{D}}^{\psi}(s) = \exp\left(-2\pi\lambda_{\mathrm{B}}^{\psi} \int_r^{\infty} \left(\frac{\beta_{\mathrm{D}} r^{\alpha} x^{-\alpha}}{1+\beta_{\mathrm{D}} r^{\alpha} x^{-\alpha}}\right) x dx\right), \tag{10}$$

$$\mathcal{L}_{\mathrm{D}}^{\varphi}(s) = \exp\left(-2\pi\lambda_{\mathrm{B}}^{\varphi} \int_r^{\infty} \frac{(P_{\mathrm{M}}/P_{\mathrm{B}})\beta_{\mathrm{D}} r^{\alpha} y^{-\alpha}}{1+(P_{\mathrm{M}}/P_{\mathrm{B}})\beta_{\mathrm{D}} r^{\alpha} y^{-\alpha}} y dy\right). \tag{11}$$

The distance from the interfering DL-BSs to the typical DL-MS x cannot be closer than r as shown in [12]. We further apply this distance restriction to the distance from the interfering UL-MSs to the typical DL-MS y to approximate. With path-loss exponent $\alpha = 4$, (10) and (11) are further simplified as follows:

$$\mathcal{L}_{\mathrm{D}}^{\psi}(s) = \exp\left(-\pi\lambda_{\mathrm{B}}^{\psi} \sqrt{\beta_{\mathrm{D}}} r^2 \arctan\left(\sqrt{\beta_{\mathrm{D}}}\right)\right), \tag{12}$$

$$\mathcal{L}_{\mathrm{D}}^{\varphi}(s) = \exp\left(-\pi\lambda_{\mathrm{B}}^{\varphi} \sqrt{\frac{P_{\mathrm{M}}}{P_{\mathrm{B}}}\beta_{\mathrm{D}}} r^2 \arctan\left(\sqrt{\frac{P_{\mathrm{M}}}{P_{\mathrm{B}}}\beta_{\mathrm{D}}}\right)\right). \tag{13}$$

IV. PERFORMANCE ANALYSIS

A. Success probability vs. SINR threshold

We quantify the reliability performance of CoMP2flex, where the analytical results of (2) and (9) are compared with numerical simulations using the greedy pairing algorithm. For comparison, we also present the performances of CoMP-only network, where BS cooperation happens only if two serving BSs have the same traffic direction, and CoMPflex-only network, where BS cooperation happens only if two serving BSs have the cross traffic direction. We also compare the greedy pairing algorithm with the Edmonds matching algorithm, in terms of reliability and complexity. For the numerical simulations, the parameters used are shown in Table I.

The reliability performances in UL of CoMP2flex, CoMP-only and CoMPflex-only are shown in Fig. 2. We see that the analytical curve and simulation follow the same trend, and that the performances of CoMP-only and CoMPflex-only are lower than CoMP2flex. This is because in CoMP2flex,

TABLE I: Simulation parameters.

Parameter	Description	Simulation Setting
S	Size of observation window	150 km
λ_B	BS density	0.02 BS/km^2
σ^2	Noise power at MS and BS	-174 dBm
α	Path loss exponent	4
β	SINR thresholds	$-15, -10, \ldots, 15$ dB
P_B	BS transmission power	40 dBm
P_M	MS transmission power	20 dBm
δ	DL/(UL+DL)	0.5
W	System bandwidth	1 Hz
N	Simulation iterations	10000

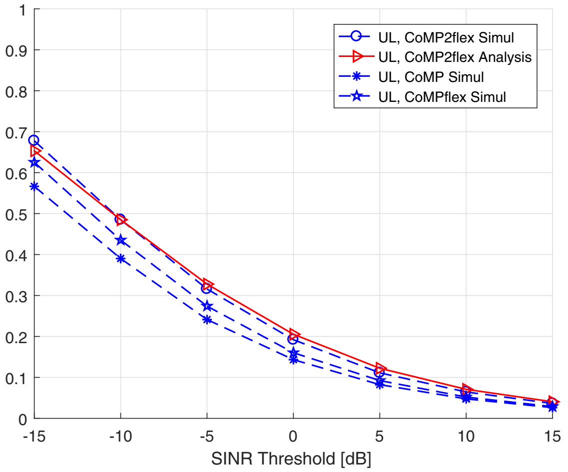


Fig. 2: UL Success Probability vs. SINR threshold.

the paired BSs use interference cancellation, yielding a better performance than CoMP-only, and protect the transmission by time sharing in case of both paired BSs serving the same traffic direction, yielding a better performance than CoMPflex-only scheme. For the reliability in DL, shown in Fig. 3, the analytical and simulation curves again follow the same trend. Note that in this case, since there is no interference cancellation between MSs (in contrast to UL), CoMP2flex and CoMP-only schemes have similar performance. But, still the better performance is shown compared with CoMPflex-only scheme because there is no protection mechanism in CoMPflex-only mode but CoMP2flex has it.

The small gap between the analytical and simulation curves can be explained from the analytical model assuming PPP deployment of the MSs, while this is not the case in the simulation, since each MS is deployed inside the cell of its BS as pointed in [14].

B. Comparison of the two matching algorithms

In this subsection, the performance of the two pairing algorithms, Greedy matching and the Edmonds matching algorithm defined in Section II-A, is compared in terms of reliability in UL and DL, in the CoMP2flex scheme. The comparison is shown in Fig. 4, where we see that for both UL and DL, the greedy algorithm gives a slightly higher performance than Edmonds matching. This is because how the BSs are paired in the two algorithms: in the greedy one, each BS is paired to the *closest* BS, while in the Edmonds matching, the goal is to have as many BSs as possible paired, while at the same time minimizing the overall distance.

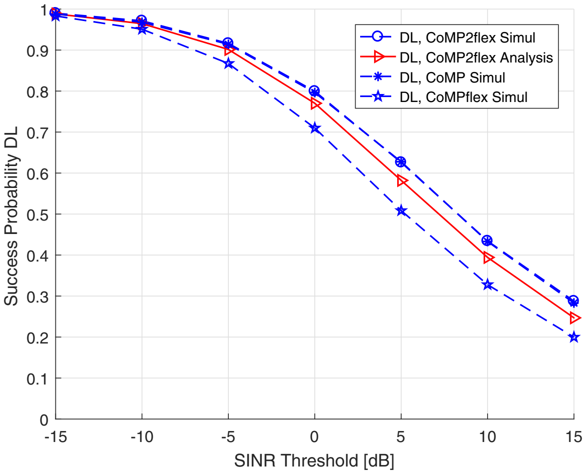


Fig. 3: DL Success Probability vs. SINR threshold.

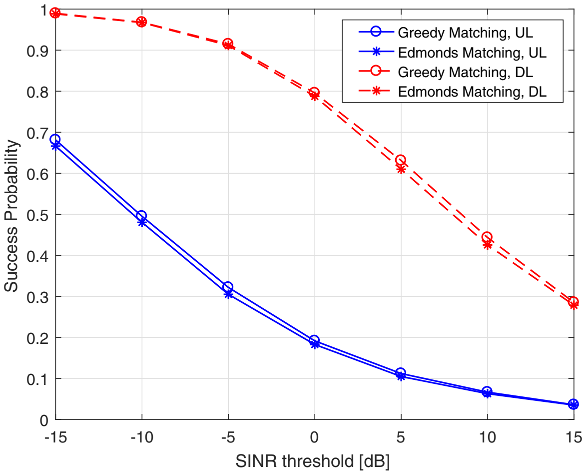


Fig. 4: Success Probability in UL and DL vs. SINR threshold, comparing greedy and Edmonds matching, for CoMP2flex.

We also compare the time in seconds required to run the two pairing algorithms, for a range of BS densities, shown in Table II. The computations were done on a Quad-core 2.7 GHz computer with 16 GB RAM, running Windows 10 64 bit, and using Matlab R2016b. We see that the greedy method is much faster than the considered implementation of the Edmonds algorithm, which has a reported cubic complexity [15].

From the comparison, we can conclude that using the greedy algorithm gives a performance at least as good as the Edmonds one, an observation which validates the method. Also, in the greedy algorithm, each BS needs only knowledge of its neighbors, compared to the Edmonds algorithm.

TABLE II: Time comparison for the two matching algorithms.

BS density λ_B	Greedy alg.	Edmonds alg.
0.0020	0.0005	0.0678
0.0115	0.0027	2.2543
0.0210	0.0050	6.8409
0.0305	0.0074	15.9043
0.0400	0.0100	24.9267

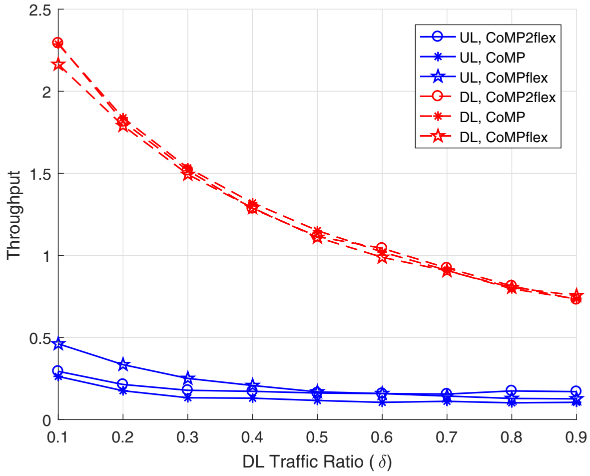


Fig. 5: Throughput in UL and DL vs. DL Traffic Ratio.

C. *Throughput vs. DL Traffic Ratio*

Even though we design the proposed CoMP2flex aiming increasing the reliability, a throughput or spectral efficiency is important performance metric. The throughput of CoMP2flex is compared with, CoMP-only and CoMPflex-only schemes in both UL and DL traffic directions as a function of DL traffic ratio (δ), in this subsection. The throughput is measured in units of bits per seconds (bps) per Hz. In the cases of CoMPflex and CoMP-only schemes, since the BSs use time sharing (only on cooperating BS in each CoMP pair is operating at a given time), the throughput is degraded by half if the directions of traffic are same. The throughput performance of CoMP2flex, CoMPflex-only and CoMP-only is shown in Fig. 5. The target threshold is assumed as 10 dB. In this figure, we observe that in both UL and DL, all three schemes follow a similar trend. Furthermore, they have a higher performance for UL-intensive traffic (for $\delta \to 0$), which follows from the BS-BS interference cancellation.

For the DL direction (dashed curves), CoMP2flex and CoMP-only are of similar performance, owing to the time sharing. With low δ, the performance of CoMPflex-only is the lowest.

For the UL direction (solid curves), CoMPflex-only has higher performance than the other two, from the BS-BS interference cancellation. With high δ, the performance of CoMP2flex becomes superior.

V. CONCLUDING REMARKS

This paper has presented analytical expressions and numerical results on a reliability of a BS cooperation scheme, CoMP2flex, as well as comparing it with a variant of CoMP using time sharing and its origin CoMPflex. We can conclude that the impact of BS-BS interference cancellation benefits of CoMP2flex, suggesting it be suitable for cooperation in cross directional traffic and its time sharing nature brings the benefits in the cooperation of same directional traffic. We have also compared two pairing algorithms, one where each BS needed only knowledge of its neighbors, and the other one, the Edmonds matching algorithm, requiring full knowledge of the network. It was observed that the performance attainable using these two algorithms are similar, which validates the greedy algorithm used for the BS pairing. It could be interesting to investigate the other CoMP modes to increase throughput performance of CoMP2flex.

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