Coordinated Scheduling and Power Control for Downlink Cross-tier Interference Mitigation in Heterogeneous Cellular Networks

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***Abstract*—In heterogeneous cellular networks, the deployment of low-powered picocells provides user offloading and capacity enhancement. The expansion of a picocell's coverage by adding a positive bias for cell association can maximize these effects. Under this circumstance, downlink cross-tier interference from a macro base station to pico mobile stations in the expanded picocell range deteriorates those pico mobile stations' performance significantly. In this paper, a coordinated scheduling and power control algorithm is proposed, whereby the macro base station reduces its transmission power for those victim pico mobile stations in the expanded picocell range only on a set of resource blocks to minimize performance degradation at the macro base station. First, the transmission power level is calculated based on the mobile stations' channel condition and QoS requirements. Then, a set of resource blocks is determined by solving a binary integer programming to minimize the sum of transmission power reduction subject to victim pico mobile stations' QoS constraints. To reduce computational complexity, we utilize a heuristic algorithm, i.e., max-min greedy method, to solve the problem. Through system level simulations, we show that average and 5%-ile throughputs of victim pico mobile stations are significantly improved.**

I. INTRODUCTION

As smartphones and tablet PCs are widely spread throughout the world, mobile data and video traffic demand has been increasing considerably [1]. To accommodate the higher cellular capacity demand, heterogeneous cell deployment is considered as an efficient approach compared to macro-cellular based solutions [2]. The cellular network structure consisting of different types of base stations (BSs) is often known as a heterogeneous cellular network, and it is implemented by deploying low-powered BSs such as pico BSs (PBSs), femto BSs, or relay BSs in a relatively unplanned manner within the macro BS (MBS) transmission coverage. These overlaid small cells are known to provide spatial diversity and cell splitting gains. In the 3rd Generation Partnership Project (3GPP) standardization, heterogeneous cellular networks (HetNets) have been discussed as one of the key network models for 4G Long Term Evolution Advanced (LTE-A) systems.

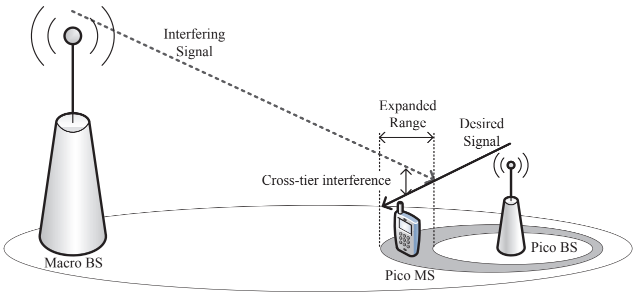

Fig. 1. Example of an interfered PMS by an MBS which is associated with a PBS by cell range expansion

Since PBSs are deployed by the operators and are directly connected to the operators' core network, they have advantages over femto- and relay BSs for the purpose of capacity improvements. Femto BSs are usually deployed by users at home and they are connected to the core network via public ISPs such as cable or DSL. Therefore any cooperation between an MBS and a femto BS or between femto BSs is hard to be expected. In case of relay BSs, the frame structure tends to be complicated in order to provide a wireless connection channel between the superordinate MBS and relay BSs. On the other hand, PBSs have no restrictions to exchange signalling messages with MBSs and they can operate independently to MBSs. Therefore, from now on, we will focus on HetNets consisting of macro- and picocells.

Unlike conventional homogeneous cellular networks with only MBSs, of which the downlink transmit power is the same (5 W $\sim$ 40 W), there exists a transmit power gap in HetNets as the downlink transmit power of PBSs ranges from 100 mW to 2 W. This transmit power difference creates a new interference pattern along with the traditional cell association procedure (initial access or handover).

In homogeneous cellular networks, a target MBS that an MS is associating with is determined by the received downlink signal strength. The MBS from which the MS experiences the strongest downlink signal strength is selected as the serving MBS. Taking only the path loss into account, the nearest one is selected as the serving MBS, and this decision is also appropriate for the uplink transmissions.

In HetNets, however, MSs tend to associate with an MBS rather than a PBS even if they are located closer to that PBS, due to the large transmit power gap. This phenomenon brings

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three adverse effects. First, those mobile stations denoted as macro mobile stations (MMSs) need to spend more uplink transmit power than the case where they are associated with a PBS. Second, the higher uplink transmit power from these MMSs causes the strong cross-tier interference toward a PBS. Lastly, there will be an MS load imbalance between an MBS and a PBS.

To resolve this, *Cell Range Expansion (CRE)* [3] as illustrated in Figure 1 has been introduced where a positive offset is added to the received signal strength from a PBS so that the coverage of a PBS is virtually expanded to accommodate more MSs denoted as PMSs, which achieves load balancing and uplink cross-tier interference mitigation. However, from the perspective of PMSs in the expanded range denoted as ER-PMSs, the strong downlink signal strength from an MBS becomes the dominant interfering signal. As a result, those ER-PMSs would experience serious throughput degradation by downlink cross-tier interference from an MBS toward them after handover (or initial access).

In the 3GPP LTE-A system, *Almost Blank Subframe* (ABS) has been introduced whereby an MBS transmits no data signals during some temporal subframes except for essential control signals in order to reduce cross-tier interference toward PMSs, and has been studied in [4]. Similarly the authors in [5] discuss transmit power silencing (no data transmission) on some frequency resource blocks (RBs). Since MBSs are known to cover a larger area and accommodate more users than PBSs do, transmit power nulling needs to be triggered very carefully as MBSs' achievable rates are completely zero during those subframes even though it can completely achieve the cross-tier interference cancelation. In [6], the authors investigate MBSs' throughput gain by allowing low power transmissions to MBSs during ABS subframes. In [7], a transmit power reduction scheme at an MBS is proposed, whereby the MBS's transmit power level is determined by ER-PMSs' required signal-to-interference plus noise ratio (SINR) values. However, as transmit power levels are restricted down to certain values over all RBs, macrocells' throughput can be deteriorated.

In this paper, we propose a coordinated scheduling and power control algorithm for heterogeneous cellular networks, which tries to minimize the number of RBs that will be used for interference coordination with low transmit power. In Section III, we first calculate the available downlink transmit power level on each RB that an MBS could reduce down to while satisfying MMSs' QoS SINR requirements. Then, a set of RBs is selected for coordination so that the QoS rate requirements of ER-PMSs are guaranteed by solving an optimization problem using binary integer programming. We evaluate our proposed scheme through system level simulations in Section IV.

II. SYSTEM MODEL

The network model considered in this paper is a heterogeneous downlink cellular network consisting of 1 MBS and P PBSs deployed inside the MBS's coverage. Let $\mathcal{K}^m$, $\mathcal{K}_l^p$ and $\mathcal{K}_{ER}^p$ denote sets of MMSs, PMSs in the l^{th} PBS, and ER-PMSs in overall picocells, respectively. The corresponding cardinalities are represented as following: $|\mathcal{K}^m| = K^m$, $|\mathcal{K}_l^p| = K_l^p$, and $|\mathcal{K}_{ER}^p| = P$. For the simplicity of explanation, we consider only 1 target MBS and each picocell is assumed to have one ER-PMS, i.e., P ER-PMSs in total. The total bandwidth B is divided into N resource blocks with a set $\mathcal{N}$ and simultaneously allocated by both the MBS and PBSs to their associated MSs. The noise power spectral density is N_0, and the averaged channel gain between a BS and an MS over a resource block including path loss, shadowing, and fast fading is assumed to be acquired $a\ priori$ via channel state information feedback.

The received signal-to-interference plus noise ratio (SINR) of an MMS i on the n^{th} resource block without coordinated power control can be expressed as

$$SINR_{i,n}^m = \frac{P_m|h_{i,n}^m|^2}{\sum_{l=1}^P P_p|h_{i,n}^{p_l}|^2 + N_0\frac{B}{N}} \tag{1}$$

where P_m and P_p denote the equally distributed power on a resource block which is calculated by dividing the total transmit power of MBS (P_m^{tot}) and PBS (P_p^{tot}) by the number of total resource blocks N, respectively, and $h_{i,n}^k$ is the average channel gain from the BS k ('m' for the MBS, 'p_l' for l^{th} PBS) to the MS i on resource block n which includes path loss, shadowing, and fast fading. The power of additive white Gaussian noise is calculated by multiplying the noise power spectral density N_0 by the bandwidth of a unit resource block B/N. When the coordinated scheduling and power control is applied, for resource blocks with lower transmit power, we replace the equal power P_m with the new transmit power value $\overline{P}_{m,n}$ ($\overline{P}_{m,n} \leq P_m$). We assume the unused portion of downlink transmit power at the MBS is not re-allocated to other resource blocks in order to prevent additional interference toward normal PMSs. The SINR of a PMS j in a PBS l on the n^{th} resource block can be expressed in two forms as

$$SINR_{j,n}^{p_l} = \frac{P_p|h_{j,n}^{p_l}|^2}{P_m|h_{j,n}^m|^2 + \sum_{l'=1,l'\neq l}^P P_p|h_{j,n}^{p_{l'}}|^2 + N_0\frac{B}{N}} \tag{2}$$

and

$$\overline{SINR}_{j,n}^{p_l} = \frac{P_p|h_{j,n}^{p_l}|^2}{\overline{P}_{m,n}|h_{j,n}^m|^2 + \sum_{l'=1,l'\neq l}^P P_p|h_{j,n}^{p_{l'}}|^2 + N_0\frac{B}{N}} \tag{3}$$

where P_m can be replaced by the new transmit power $\overline{P}_{m,n}$.

From the SINR, the achievable rate for an MMS i in the MBS can be calculated using the Shannon formula as

$$R_i^m = \sum_{n=1}^N \alpha_{i,n}^m \frac{B}{N}\log_2(1 + SINR_{i,n}^m), \tag{4}$$

where $\alpha_{i,n}^m$ is a scheduling indicator function which indicates whether the resource block n is scheduled to the MS i in the MBS, and can be either 0 or 1. In case of a PMS j in a PBS l, the rate can be expressed in a similar way as the MMS case by

$$R_j^{p_l} = \sum_{n=1}^{N} \alpha_{j,n}^{p_l} \frac{B}{N} \log_2(1 + SINR_{j,n}^{p_l}). \tag{5}$$

III. PROPOSED COORDINATED SCHEDULING AND POWER CONTROL

In this section, we describe how the proposed algorithm operates. In the first subsection, for each RB the best pair of an MMS and its required transmit power is selected in a way that the cross-tier interference can be minimized while each MMS's QoS SINR requirement is satisfied. Then, in the second subsection, among overall RBs we selectively choose only a subset of RBs that will be actually utilized for coordinated scheduling and power control by solving an optimization problem where the sum of the reduced transmit power at the MBS is minimized while ER-PMSs' QoS rate requirements are satisfied.

A. MMS & Transmit Power Determination

When the MBS wants to allocate the transmit power $P_{m,n}$ lower than the equal power P_m on RB n, two issues need to be considered - which MMS will be scheduled on that RB and if $P_{m,n}$ meets the requirement of the MMS. Suppose that each MMS has a minimum required SINR level as a QoS requirement, the transmit power $P_{m,n}$ needs to satisfy the following equation:

$$\frac{P_{m,n}|h_{k,n}^{m}|^2}{\sum_{l=1}^{P} P_p |h_{k,n}^{p_l}|^2 + N_0 \frac{B}{N}} \geq \gamma_{k,req} \quad \forall k \in \mathcal{K}^m, \forall n \in \mathcal{N} \tag{6}$$

where $\gamma_{k,req}$ denotes the SINR requirement for the MMS k. When the MBS lowers its transmit power for cross-tier interference mitigation, the transmit power should be determined so as to satisfy the above SINR requirements.

From (6), we can calculate the required transmit power $P'_{k,n}$ that the MBS needs to allocate for an MMS k when the MMS is scheduled on a resource block n as

$$P'_{k,n} = \frac{\sum_{l=1}^{P} P_p |h_{k,n}^{p_l}|^2 + N_0 \frac{B}{N}}{|h_{k,n}^{m}|^2} \cdot \gamma_{k,req} \quad \forall k, n. \tag{7}$$

Given pairs of MMS and required transmit power on each RB, the best MMS k_n^* is selected for which the MBS can achieve the lowest transmit power on RB n while the selected MMS's SINR requirement is satisfied, as shown in (8). Therefore the cross-tier interference from the MBS to ER-PMSs can be minimized. Obviously, an MMS in a better channel condition and/or with a lower SINR requirement is likely to be selected for coordinated power control.

$$\begin{aligned} k_n^* &= \arg\min_{k \in \mathcal{K}^M} \; P'_{k,n} \quad \forall n \\ &= \arg\min_{k \in \mathcal{K}^M} \left(\frac{\sum_{l=1}^{P} P_p |h_{k,n}^{p_l}|^2 + N_0 \frac{B}{N}}{|h_{k,n}^{m}|^2} \cdot \gamma_{k,req} \right) \end{aligned} \tag{8}$$

Following the selected MMS k_n^*, the transmit power $\overline{P}_{m,n}$ that the MBS can reduce down to for RB n is determined as

$$\overline{P}_{m,n} = P'_{k_n^*,n} = \frac{\sum_{l=1}^{P} P_p |h_{k^*,n}^{p_l}|^2 + N_0 \frac{B}{N}}{|h_{k^*,n}^{m}|^2} \cdot \gamma_{k^*,req}. \;\; \forall n \tag{9}$$

Additionally, the power margin $\tilde{P}_{m,n}$ which is the transmit power difference between P_m and $\overline{P}_{m,n}$ is defined as

$$\tilde{P}_{m,n} = P_m - \overline{P}_{m,n}. \;\; \forall n, \tag{10}$$

B. Coordinated RB Selection for ER-PMSs

In Section III-A, we have discussed how to determine a pair of MMS (8) and reduced transmit power (9) on each RB. Since it is better for the MBS to minimize the number of RBs on which reduced transmit power will be applied for ER-PMSs, we will discuss in this section how to determine a subset of overall RBs that will be actually used for coordination.

As a first step, the improved achievable rate $\overline{R}_{j,n}$ of ER-PMSs ($j \in \mathcal{K}_{ER}^p$) on each RB is calculated based on lower MBS transmit power $\overline{P}_{m,n}$ by

$$\overline{R}_{j,n} = \frac{B}{N} \log_2(1 + \overline{SINR}_{j,n}^{p_l}), \;\; j \in \mathcal{K}_{ER}^p, \forall n \tag{11}$$

where p_l indicates the PBS index that the PMS j is associated with.

Then, using the power margin $\tilde{P}_{m,n}$ in (10) and the improved achievable rate $\overline{R}_{j,n}$ per RB in (11), the coordinated RB selection problem can be formulated for which the sum of the transmit power margins is minimized:

$$\underline{\alpha}_{Coord}^{m*} = \arg\min_{\underline{\alpha}_{Coord}^{m}} \sum_{n=1}^{N} \tilde{P}_{m,n} \cdot \alpha_{Coord,n}^{m} \tag{12a}$$

$$\text{subject to} \;\; \sum_{n=1}^{N} \overline{R}_{j,n} \cdot \alpha_{Coord,n}^{m} \geq R_{j,req} \quad j \in \mathcal{K}_{ER}^p \tag{12b}$$

$$\sum_{n=1}^{N} \alpha_{Coord,n}^{m} \leq N \tag{12c}$$

$$\alpha_{Coord,n}^{m} \in \{0, 1\} \quad \forall n \tag{12d}$$

$$\tilde{P}_{m,n} \geq 0 \;\; \forall n \tag{12e}$$

where $\underline{\alpha}_{Coord}^{m}$ and $R_{j,req}$ denote a scheduling indicator vector expressed by $[\alpha_{Coord,1}^{m}, \alpha_{Coord,2}^{m}, \cdots, \alpha_{Coord,N}^{m}]$ and the QoS rate requirement of an ER-PMS j, respectively. The objective is to minimize the impact of transmit power reduction at the MBS, i.e., MBS throughput degradation, while guaranteeing QoS requirements to MMSs (7) and ER-PMSs (12b). The formulated problem may not entail feasible solutions when one or more ER-PMSs are in deep fading even with lower MBS transmit power or require much higher data rates than they can achieve with coordinated power control so that the number of coordinated RBs exceeds the total number of RBs N. Therefore we assume the RE-PMSs do not experience severely faded channel and their rates can be modified along with achievable rates with lower MBS transmit power, so that infeasible solution cases are excluded for further discussions.

To find an optimal solution to the above problem, exact methods such as *Branch-and-Bound* can be considered utilizing linear programming (LP) relaxation in which the problem is transformed into a general linear programming by relaxing the integer variables, and branches are generated by integer

Algorithm Max-min Greedy RB Allocation

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Initialization: $\alpha^m_{Coord,n} = 0\ \forall n \in \mathcal{N}$, $R_{j,ach} = 0\ \forall j \in \mathcal{K}^p_{ER}$.
while $\frac{R_{j,ach}}{R_{j,req}} \le 1$ (QoS rates are not satisfied) do
    Find the least satisfied ER-PMS $j^*$:
        $j^* = \arg\min_{j} \frac{R_{j,ach}}{R_{j,req}}\ \ \forall j \in \mathcal{K}^p_{ER}$.
    Find the best RB index $n^*$ for the ER-PMS $j^*$:
        $n^* = \arg\max_{n'} \overline{R}_{j^*,n'}\ \ \forall n' = \{n' \in \mathcal{N} : \alpha^m_{Coord,n'} \neq 1\}$
    Update $\alpha^m_{Coord,n^*} = 1$.
    Update $R_{j,ach} = R_{j,ach} + \overline{R}_{j,n^*}\ \ \forall j \in \mathcal{K}^p_{ER}$.
end while
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approximation of the real-number solution. Although Branch-and-Bound methods prevent us from examining all the possible combinations of possible solutions, they still cannot guarantee a solution in polynomial time. As a consequence, we propose a greedy-based algorithm to find a suboptimal solution to the above optimization problem which shows a good tradeoff between performance and computational complexity in Table II.

The Algorithm above represents pseudocode of how the proposed algorithm works. In order to reduce the computational complexity, our strategy is to divide user scheduling and resource block allocation separately based on max-min fairness. For each iteration until all ER-PMSs' QoS rates are satisfied, first we select an ER-PMS of which the degree of QoS satisfaction is the lowest. The degree is represented by a ratio of an achieved rate to a required rate, i.e., $\frac{R_{j,ach}}{R_{j,req}}$ where $R_{j,ach}$ denotes the achieved rate and is expressed as $\sum_{n=1}^{N} \overline{R}_{j,n} \cdot \alpha^m_{Coord,n}$. Second, after choosing a target ER-PMS, we find an RB index on which the target ER-PMS can achieve the highest rate increase. In case the selected RB index has been chosen by other ER-PMSs already, the next best RB index needs to be examined. As a last step, the coordinated scheduling indicator $\underline{\alpha}^m_{Coord}$ and each ER-PMS's achieved rates are updated accordingly.

C. Resource Allocation for Unselected RBs

At the MBS, after selecting RBs which will be scheduled to MMSs (8) with lower transmit power (9) for ER-PMSs, for the rest RBs the transmit power at the MBS is recovered to original equal power P_m and those RBs are scheduled to MMSs by any scheduling policy (e.g., proportional fairness). At PBSs, the same policy is applied to the rest RBs while selected RBs from Section III-B are scheduled to the ER-PMS.

IV. PERFORMANCE EVALUATION

In this section, the performance of the proposed scheme is evaluated through system level simulations. The system level simulator has been developed based on the LTE downlink system level simulator in [8].

TABLE I
SYSTEM LEVEL SIMULATION PARAMETERS

Simulation Parameter	***Value***
Carrier frequency	2.0 GHz
System bandwidth	10 MHz
Subframe duration	1 ms
Antenna configuration	SISO
Channel model	Typical Urban (TU)
Inter-site distance	750 m
Noise power spectral density	-174 dBm/Hz
Scheduling algorithm	Proportional fairness
Traffic model	Full buffer
Macro BS transmit power	40 W (46 dBm)
Macrocell path loss model	$128.1 + 37.6\log_{10} R$ (R in km)
Macrocell shadowing model	Log normal fading with std. 10 dB
Macro BS antenna gain	15 dBi
Number of MMSs per sector	50
Pico BS transmit power	250 mW (24 dBm)
Picocell path loss model	$140.7 + 36.7\log_{10} R$ (R in km)
Picocell shadowing model	Log normal fading with std. 6 dB
Pico BS antenna gain	5 dBi
Number of PMSs per picocell	15 (including 1 ER-PMS)

For simulations, a heterogeneous network topology is generated with 1 three-sectored MBS and 2 or 4 outdoor PBSs which are uniformly distributed within each MBS's sector. Each PBS is equipped with an omnidirectional antenna. As a co-channel configuration, the system bandwidth is fully accessed by both MBS and PBSs with equally distributed power unless coordinated scheduling and power control is applied. Two range expansion offsets are evaluated - 4 dB and 8 dB. The minimum required SINR of MMSs is 5 dB, and the target rate of ER-PMSs is 0.5 Mbps. The detailed simulation parameters are described in Table I most of which are adopted from 3GPP standard documents [9], [10], [11].

To evaluate the performance, we compare the following schemes:

- No Coordination (NC): No cross-tier interference coordination is applied. The transmit power on each RB at the MBS is P_m.
- Coordinated Power Control only (CPC): Given the value n and power margins, the MBS selects n RBs on which power margins are minimum. The values of n is discussed in Table II.
- Coordinated Scheduling & Power Control (CSPC): The proposed scheme is applied.

Table II shows the number of RBs used for CSPC using branch & bound (B&B), CSPC using proposed max-min greedy algorithm (MMG), and CPC using MMG. Compared to the optimal solution, the proposed heuristic algorithm allocates about 10% more RBs in average. Based on the number of RBs used for CSPC (MMG) as a reference, we choose the smallest positive integers which are greater than the number of RBs in CSPC (MMG) as the value n for CPC (MMG).

Table III shows the average and 5th percentile user throughput of ER-PMSs and overall PMSs (regular PMSs + ER-PMSs) for different simulation scenarios. Observations from simulations can be summarized as follows:

- *Average throughput of ER-PMSs*: In NC case, about 30% average throughput degradation is observed by increasing an RE offset whereas having more picocells degrades the performance about 10%. For CPC and CSPC, the throughput degradation rate is about 5%. The target rate of 0.5 Mbps (= 0.0524 bps/Hz) is achieved for both CPC and CSPC, however CSPC achieves about 150% higher throughput than CPC does by utilizing less RBs in average.
- *5%-ile throughput of ER-PMSs*: For both NC and CPC in common, 5%-ile of ER-PMSs experience 70% to 75% performance degradation from ER-PMS average throughput which would cause a serious fairness problem. In CSPC, those 5%-ile users are guaranteed 60% to 70% of average throughput, and more importantly the performance gap between the target rate and 5%-ile throughput is less than 10% except for the worst case, i.e. 4 picocells & 8 dB offset, where 18% degradation occurs.
- *Average & 5%-ile throughput of overall PMSs*: The possible performance degradation in PMS average throughput by prioritizing ER-PMSs is insignificant. In 5%-ile PMS throughput, ER-PMSs' throughput improvement increases the fairness among overall PMSs. Compared to NC and CPC, CSPC provides about 20% and 50% throughput gains in 4 dB and 8 dB offsets, respectively.

V. CONCLUSION

In this paper, we have investigated cross-tier interference mitigation using coordinated scheduling and power control among macro- and picocells. The proposed scheme, first, determines the candidate MMS and available transmit power per RB that the MBS can reduce down to, based on MMSs' channel condition and SINR requirements. Then, a group of RBs that will be used for coordination is determined by solving an optimization problem whereby the total power reduction at the MBS is minimized while ER-PMSs' required rates are satisfied. To reduce the computational complexity, we have introduced a max-min greedy algorithm to solve the optimization problem. Through system level simulations, we have shown that the proposed scheme could significantly improve the average throughput of ER-PMSs as well as the user fairness among PMSs.

TABLE II
AVERAGE NUMBER OF RBS USED FOR COORDINATION

Num. of picocells & RE offset	***Avg. number of RBs used***		
	CSPC (B&B)	***CSPC (MMG)***	***CPC (MMG)***
2 picocells & 4 dB	2.12	2.4	3 (=$\lceil 2.4 \rceil$)
2 picocells & 8 dB	2.9	3.3	4 (=$\lceil 3.3 \rceil$)
4 picocells & 4 dB	3.4	3.8	4 (=$\lceil 3.8 \rceil$)
4 picocells & 8 dB	4.1	4.5	5 (=$\lceil 4.5 \rceil$)

TABLE III
THROUGHPUT COMPARISON

Cases	***Schemes***	***ER-PMS throughput [bps/Hz]***		***PMS (overall) throughput [bps/Hz]***	
		Avg.	***5%-ile***	***Avg.***	***5%-ile***
2 picos, 4 dB	NC	0.049	0.015	0.133	0.041
	CPC	0.051	0.018	0.134	0.042
	CSPC	0.072	0.053	0.135	0.052
2 picos, 8 dB	NC	0.033	0.007	0.138	0.035
	CPC	0.048	0.013	0.136	0.037
	CSPC	0.067	0.049	0.137	0.052
4 picos, 4 dB	NC	0.046	0.014	0.127	0.038
	CPC	0.054	0.015	0.126	0.036
	CSPC	0.079	0.048	0.125	0.040
4 picos, 8 dB	NC	0.030	0.006	0.133	0.031
	CPC	0.050	0.008	0.128	0.033
	CSPC	0.074	0.043	0.130	0.047

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