Co-Primary Spectrum Sharing for Denser Networks in Local Area

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Abstract—**This work investigates co-primary spectrum sharing problem in the local area indoor dense deployment scenario. A spectrum sharing method and relevant mechanism are designed to achieve flexible spectrum usage amongst multiple operator networks. This proposed solution improves spectrum efficiency by making small cells more flexibly and efficiently utilize whole spectrum resources via intra operator spectrum allocation and inter-operator spectrum coordination. Intensive system level simulations give a detailed verification of the performance of this spectrum sharing approach.**

Keywords- small cell; co-primary spectrum sharing; denser network.

I. INTRODUCTION

Telecommunication Industry has been investigating future requirements for wireless communications of year 2020. One of the key requirements is 1000 fold increase from now for traffic volume for future network [1]. This has been accepted for many experts as one of the target for designing 5G system. In order to meet the high demand, together with other technologies, it is commonly believed by both academia and industry that cellular network will go to denser cell deployment and small cell in local area is becoming one of the focus for 5G cellular system. Many front research activities have started to develop solutions for future small cell deployment e.g. denser deployment or ultra dense network (UDN) [2].

Nevertheless, there are still plenty of challenges for denser small cell deployment. Since small cells are probably deployed by subscribers without any prior network planning, new challenges of interference management emerge in co-channel overlaid networks with the large scale deployment of small cell. In [3], the simulation results show that small cell to small cell interference becomes an important issue for indoor coverage when private femtocells are densely deployed, where only authorized users are allowed to connect to a privately accessible femtocell. Therefore, in denser deployment of small cells, one focus is studying and specifying the solutions to mitigate the interference among small cells.

On the other hand, from spectrum sharing perspective, denser network provides new challenges for flexible and efficient spectrum usage, especially when small cells belonging to multiple networks or multiple operators massively deployed in the same geographic area.

In literature, spectrum sharing amongst multiple operators is often known in the name of inter-network spectrum sharing, which mainly appears as inter system/service sharing [4]. Generally relevant study has basically been based on primary/secondary approach from traditional cognitive radio regime. As an example of above study, ASA (authorized Shared access) or LSA (Licensed Shared Access) was demonstrated and under standardization in Europe [5]. However, another direction which has attracted more interests gradually is co-primary spectrum sharing, which is a new spectrum access model with two or more primary license holders [6]. Basically there is some previous study on inter-network sharing especially on macro cell scenarios. In [7], the authors study flexible spectrum sharing between two operators in the scenario that the two operators' macro networks share the same spectrum band and locate in the same geographic area with only relative displacement. With only the downlink of the UMTS FDD system based on CDMA considered, the authors model the spectrum sharing rule by making the new added users achieve the targeted CIR threshold. The results show how the performance varies with different displacement. In [8] the authors model the inter-operator dynamic spectrum sharing problem as a non-zero sum game, and design a utility function, optimized by two different ways: distributed and centralized, based on Nash Equilibrium (NE) and Pareto Optimal (PO), respectively. However to the best of our knowledge, little study has paid any special attention to co-primary sharing in denser deployment of small cells in a local area scenario.

Based on this observation, we are motivated to propose a co-primary spectrum sharing mechanism for denser deployment of small cells in local areas. By making the overall spectrum resource available to all small cells belonging to different operators in the same local area, we break down the "hard wall" built by traditional fixed spectrum allocation schemes and improve the spectrum efficiency. Also, a simple but effective coordination mechanism is designed to provide QoS guarantee for each individual operator's network.

The rest of this paper is organized as follows. In section II, co-primary spectrum sharing model is presented. In section III,

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we give a comprehensive description of our spectrum sharing method and mechanism. In section IV, simulation layout and results are provided. Finally, section V summarizes the conclusions.

II. Co-Primary spectrum Sharing model

Co-primary spectrum sharing refers to a new spectrum access model that the regulator allocates a part of spectrum not exclusively to a single operator but jointly to several potential users (operators) with the obligation to use it collectively under fair conditions and subject to certain rules. The exact usage conditions (policies) would have to be laid down in a mutual agreement and the entire model would be subject to permission by the national regulator. Such a new mode was already initially discussed e.g. by the German Regulator (formerly RegTP) regarding allocation of 3.5GHz band for Fixed BWA in 2004/5. A similar concept was also created by the FCC 2007 rules for a novel "light licensing" scheme in the 3650-3700 MHz band which for example resulted to the creation of the IEEE 802.11y standard. The relevant spectrum is generally named as spectrum pool in the literatures.

Co-primary sharing access mode together with cognitive radio access procedures can enable higher peak data rates for the end users as well as higher capacity. Such shared spectrum usage seems especially beneficial and appropriate for small cell deployments because these are usually more isolated than large macro cells. The local area deployments among different operator networks are very much location dependent. It may not be most favorable to have static spectrum allocation/coordination policies or rules among different operators, which is applied commonly over the whole network area. Figure 1 illustrates system architecture for co-primary sharing.

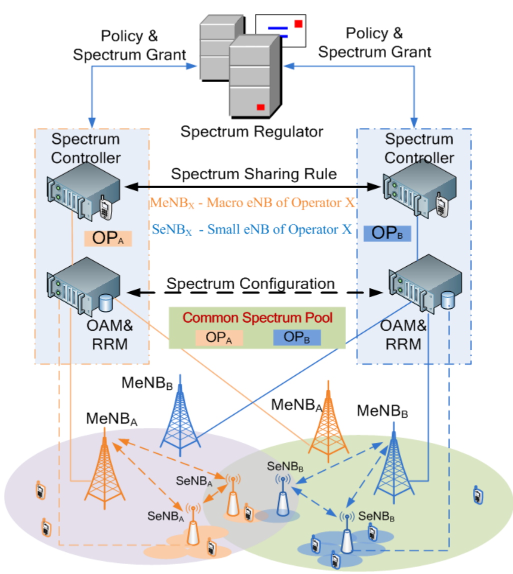

Fig. 1. System architecture for co-primary spectrum sharing

As illustrated in Fig. 1, spectrum regulator allocates a part of spectrum jointly to several potential operators. Each operator owns a spectrum controller, connecting to OAM and then to all its small cells in the targeting area. In practice, this entity may be maintained by the operator. The spectrum controller within one operator is responsible for coordination on spectrum sharing policies, rules or conditions among multiple operators in the same geographic area. With different approaches, spectrum controller may have other functions e.g. guiding on spectrum allocations for some cells of the same operator, or determining the principle for intra-operator sharing.

III. Co-primary Sharing method and mechanism

In this section, we give an overall description of proposed method for co-primary sharing scenario. Relevant mechanism is also proposed here from system implementation perspective.

We focus on the local area denser deployment scenario, where small cells from multiple operators were independently deployed in the same local area such as a residential or office building. According to most of deployment cases in current operator networks, macro cell is assumed to operate on another spectrum band, so its impact on small cell could be neglected.

It is also assumed here a small cell can communicate with its neighbors within the same operator network within a region via air interface or via ideal backhaul. We understand in the future network, it is quite possible with that feature within a small area or a cluster of denser networks. On the other hand a UE can only identify any small cell within the same operator network via reference signal means or other new means, but cannot identify other operator's small cells.

A spectrum pool consists of certain number of component carriers (CC), which is used for minimum granularity for resource allocation in spectrum sharing scenarios. Basically all the co-primary sharing operators can utilize this spectrum pool. With carrier aggregation technology, small cells with high traffic demand may operate on more than one component carriers.

Based on agreements amongst operators, the whole spectrum pool is divided into some spectrum parts which are dedicated used by one operator respectively, and other spectrum parts which are used in a shared manner by operators. For simplicity, here and following we assume there are two operators participating co-primary sharing. Generally the number co-primary sharing operators is very limited so above assumption is reasonable and also easy to extend to more operators. Fig. 2 shows spectrum pool for case of two operators. As agreed beforehand between two operators, the left blue part and the right green part is allocated to two operators respectively, not allowing counterpart operator's utilization. The middle part of spectrum is basically shared between cells from two operators.

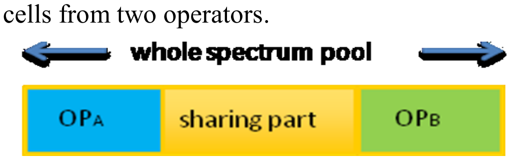

Fig. 2: Spectrum pool for two operators

One of the challenges for co-primary sharing is coordination between operator networks. Generally it is possibly for operators to reach an agreement on sharing rule, principle or policy. However trust between operators are unclear for even future systems, so it may not be most favorable to have extensive/comprehensive coordination among different operators, as this may increase difficulty of interface btw operators and in addition operators may not be willing to distribute sensitive information on their networks. Therefore minimize coordination signaling amongst different operators' network is favorable for co-primary sharing.

Based on above considerations, firstly small cells from two operators broadcasts a reference signal or beacon signal with the same and predefined transmit power setting on a separated channel/band which e.g. is for delivering control information for cognitive purpose. The channel could also be one of the channels in the spectrum pool and in that case there should be possible some time break for traffic data transmission. As mentioned above, UE can only identify reference signals or beacon signals from own operator network but estimation on total interference from other operator networks is feasible at UE. Then based on estimation results of total interference from other operator networks of from UE, a small cell will know well the impact from other operator networks and report to its spectrum controller. The spectrum controller or a cluster head of some small cells then sorts all the small cells under its control based on reported impact from other operator networks and then selects certain number of small cells with highest interference from other operator networks. Those small cells are allocated to dedicated spectrum part of the operator and not allowed to use sharing spectrum part. In this way, small cells closer to small cells from other operator network would have better separation in frequency from inter-operator perspective.

Remained small cells in the same operator networks are free to utilize spectrum resources as long as they do not occupy other operator's dedicated spectrum part as agreed beforehand between operators.

Next step is spectrum allocation within an operator. All the small cells from one operator can join the allocation of dedicated spectrum part. Of course some priority may be defined for those selected small cells. On the other hand operator would carry out spectrum allocation on sharing spectrum part independently from other operators, however only small cells not selected in the first step participate allocation procedures.

In future small cell deployment uncoordinated nature requires the small cell network to be self-organized, self optimization and cognitive as much as possible, distributed and scalable spectrum allocation schemes with the ability to minimize system signaling overhead and avoid reconfiguration storms seems to be preferred by individual operator for the future network deployment.

Advanced approach for spectrum allocation is preferred as long as constrains for the approaches are feasible in practical system. In our approach, we propose to use distributed approach based on graph or clustering for small cells. The basic principle is to color the small cells or clustering the small cells. The same color painting on small cells or small cells belonging to the same cluster generally have better separation or decouple with interference from each other if they reuse the same resources. The signaling between neighboring cells are related to occupied resources and neighboring relation information e.g. ANR (Automated Neighbor Relation) in 3GPP so that graph based on clique information or clustering information within the same operator network is available at each small cell.

The basic spectrum sharing method is summarized as following:

- Operators agree on spectrum sharing principle: dividing whole spectrum pool into dedicate spectrum parts Z_i for each operator respectively where i is index of operator and sharing spectrum part Z_0
- Small cells broadcast reference signals or beacon signals
- Each small cell estimates impact from all the other operator networks without identifying specific sources
- Spectrum controller or cluster head of small cells selects some small cells with highest total interference from all the other networks based on report from subordinated small cells; the set of those small cells is denoted as Φ_i, and $\Phi_i \in \Omega_i$ where Ω_i is the set of all small cells under the spectrum controller or cluster head within the operator network
- Advanced spectrum allocation procedures based on graph or clustering approach are carried out independently from operator network to operator network: dedicated spectrum part is allocated to all the small cells within the same operator network, i.e. $Z_i \Rightarrow \Omega_i$; sharing spectrum part is allocated to unselected small cells from same operator network, i.e. $Z_0 \Rightarrow \{\Omega_i - \Phi_i\}$

IV. Simulation Results

In this section, our co-primary spectrum sharing method is evaluated by static system level simulations. The simulation setting is based on basic LTE specifications [9] [10]. In each snapshot, location of base stations and user terminal is regenerated randomly.

The considered traffic model is full buffer, which aims to give an insight for the worst case of system performance. The link level capacity curve follows the proposed modified Shannon formula in [11]. Error vector magnitude (EVM) is used to account for imperfect implementation of Radio Frequency (RF) components.

We model the local indoor dense deployment scenario as a single floor dual-stripe model recommended by 3GPP [10], as illustrated in Fig. 3. There are 5 rooms with 10m x 10m size in each row and 2 operators will deploy small cells in these rooms. For simplicity of simulations, we assume that small cells only provide access to the authorized UEs.

It is assumed one operator can deploy at most one small cell inside a room, so there are at most two small cells from two operator networks in a room. For purpose of simplicity, macro cells are assumed to operate on an isolated spectrum band from these small cells and then not taken into account in the simulation. The detailed simulation setting is listed in Table I.

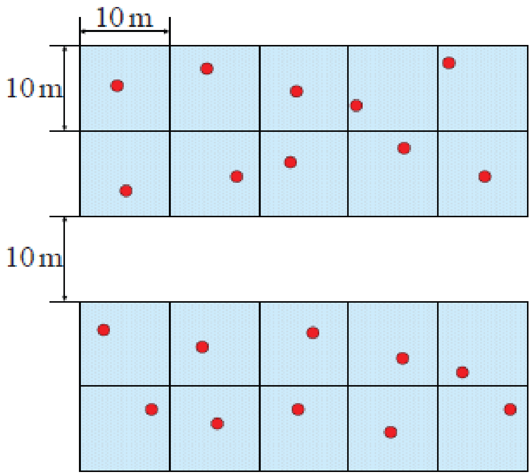

Fig.3. Deployment Scenario (Dual stripe, single floor)

TABLE I. SIMULATION SETTING

eNB Tx Power	13dBm / CC
Carrier frequecy	3.5 GHz
Number of operators	2
Spectrum pool	12 CCs, 10 MHz each
EVM	5%
Shadowing std. deviation	4 dB, in same room
	8 dB, in different rooms
UE to BS min distance	2 m
Penetration loss	5dB, inner wall; 10 dB outer wall
Layout	Dual-stripe, single floor
Room size	10m x 10m

As cell density level may have much impact on system performance for local area, a parameter overlap ratio is used in our simulation, which is defined as the ratio of the number of rooms with both operators' small cells versus the number of total rooms.

In our simulations, two baseline schemes are used for comparison purpose. Baseline 1 is the case that total spectrum pool is shared between two operators directly and no other actions or adjustment, that means each small cell use all the channels in the spectrum pool. The scheme is denoted as 'reuse 1' in the following figures. Baseline 2 is the case that two operators orthogonally occupies one half of the spectrum pool and no overlapping in frequency, and each cell use all the carriers within its operator's half part; which means there is no interference between two operators and conflict only comes from intra-operator. This scheme is denoted as 'ortho' in the following figures.

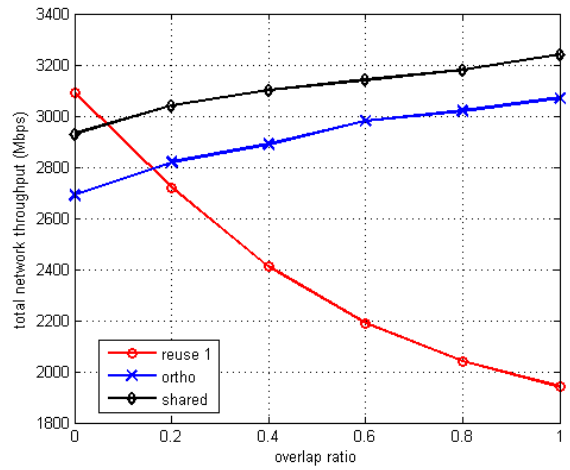

Fig. 4: total network throughput versus overlap ratio

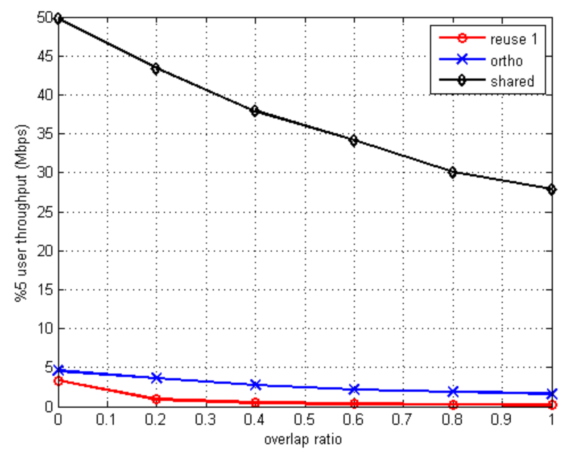

Fig. 5: %5 user throughput versus overlap ratio

Fig. 4 and Fig.5 provides simulation results for total network throughput and cell edge user throughput versus different network overlapping situations. Our method is denoted as 'shared' in the legend. In the simulation, four component carries are reserved for each operator beforehand, and four small cells from each operator are selected to mainly utilize those carriers.

From Fig. 4 we can see that total network throughout generally increases with higher cell density for two schemes expect for reuse 1 case thanks to more cells deployed. That also verifies cell densification is a good approach to cope with traffic volume requirement. The heavy loss from reuse 1 in higher cell density case is mainly due to lack of any interference mitigation approach, which degrades cell throughput much. The performance achieved by the proposed spectrum sharing method is always better than the two baselines. This is reasonable because the proposed spectrum sharing method accommodates both operators' small cells with more spectrum access opportunity than other schemes.

Especially in low overlapping case the gain over 'ortho' could be above ten percentage but gap will reduce gradually when two networks overlap more and more heavily.

On the other hand, as Fig. 5 shows, from cell edge performance perspective, the gain from our method is pretty huge. That mainly comes from a dedicated spectrum allocation for some selected small cells which avoids very high interference from other operator networks. Meanwhile, the approach used in intra-operator sharing with neighboring information has also promoted the performance for worse cells.

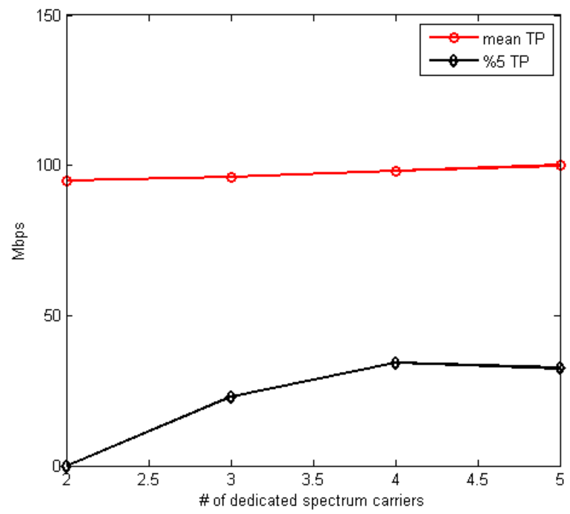

Fig. 6. Throughput performance with different number of dedicated spectrum carriers when overlap ratio is 0.6

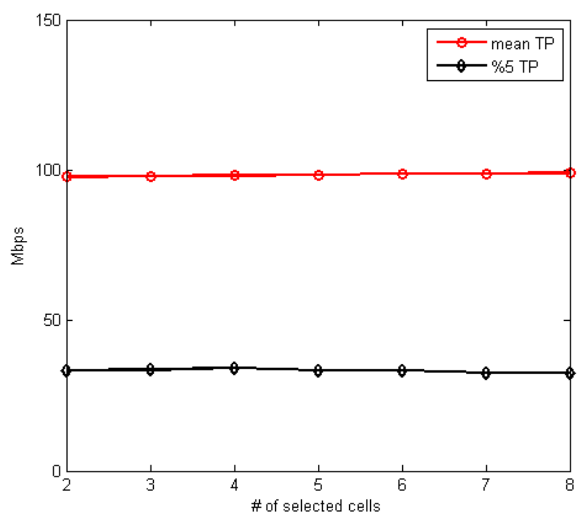

Fig. 7: Throughput performance with different number of selected cells when overlap ratio is 0.6

Although reservation on some spectrum parts and some selected small cells' utilization provide more space for spectrum access as mentioned above, how much dedicated spectrum part and how many selected cells should be configured for our method is an interesting issue. Fig.6 and Fig.7 then reveal the effect of various amounts of dedicated spectrum part and numbers of selected small cells per operator. From Fig. 6 with given overlap ratio of 0.6, mean throughput value slowly goes with the increase of the number of dedicated spectrum carriers, but coverage performance will stop improvement and goes down after specific point. This is because too much dedicated spectrum will give up more opportunities for reuse resources in inter-operator manner. One can also observe from Fig. 7 that, with fixed dedicated spectrum part, impact from changing the number of selected cells is limited. That implies that in this medium density level (overlap ratio of 0.6) configuring suitable amount of dedicated spectrum part makes more sense than letting more cells avoid inter-operator interference.

V. CONCLUSIONS

In this paper, we propose a co-primary spectrum sharing method for multiple operator networks in local area denser deployment. At the same time a realistic system framework is formulated to guarantee reliable and efficient communications within a denser network. The proposed mechanism is easy to configure and operate with very less signaling overhead and be implemented in practice system. The simulation results show that the proposed method is beneficial for the system performances in terms of the system throughput, and also cell edge throughput with a quite wide and robust parameter range.

For future research, we are currently extending this work to consider adaptive adjustment on amount of sharing spectrum part. Meanwhile solutions taking into account fairness among small cells will be also developed based on model of this paper.

REFERENCES

[1] B. Raaf, W. Zirwas, K. Friederichs, etal, "Vision for Beyond 4G Broadband Radio Systems," IEEE PIMRC'2011, Sep. 2011.

[2] EU METIS project deliverable D1.1, Scenarios, requirements and KPIs for 5G mobile and wireless system, Apr 2013.

[3] S. P. Yeh, S. Talwar, and S. C. Lee, WiMAX femtocells: a perspective on network architecture, capacity, and coverage, IEEE Communications Magazine, pp. 58-65, Oct. 2008.

[4] Ian F. Akyildiz, Won-Yeol Lee, Mehmet C. Vuran, and Shantidev Mohanty, "A survey on spectrum management in cognitive radio networks", IEEE Communication Magazine, Apr 2008.

[5] Marja Matinmikko, Marko Palola, Harri Saarnisaari etal, "Cognitive radio trial environment: first Authorised Shared Access (ASA) based live spectrum sharing demonstration,"IEEE MVT'2013, Jun 2013.

[6] EU METIS project deliverable D5.1, Intermediate description of the spectrum needs and usage principles, August 2013.

[7] M. K. Pereirasamy, etal, "Dynamic inter-operator spectrum sharing for UMTS FDD with displaced cellular networks", IEEE WCNC'2005, pp. 1720-1725, Apr. 2005.

[8] H. Kamal, M. Coupechoux, and P. Godlewski, "Inter-operator spectrum sharing for cellular networks using game theory," in Proc. IEEE PIMRC., 2009, pp. 425–429, 2009.

[9] 3GPP TR 36.814, Evolved Universal Terrestrial Radio Access (E-UTRA) – Further advancements for E-UTRA physical layer.

[10] 3GPP contribution R4-092042, "Simulation assumptions and parameters for FDD HeNB RF requirements", 2009.

[11] Mogensen, P. E. etal, "LTE Capacity Compared to the Shannon Bound", IEEE VTC'2007, Spring 2007.