Intercell Interference Coordination (ICIC) for LTE small cells: A practical solution

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Contents

Executive summary

Small cell networks are designed to exploit the spatial reuse of RF resources. This is with the objective of maximizing the average bandwidth that a User Equipment (UE) can receive. For this reason, network operators are constantly pursuing higher cell densities, augmenting the spectral efficiency in the process but also raising the interference levels under which these networks must operate. It is precisely in these high interference scenarios that techniques like Intercell Interference Coordination (ICIC) become fundamental to the correct functioning of the network.

ICIC reduces the interference level suffered by LTE users at the cell edge, thus improving the signal-to-noise-ratio of their data channels and allowing the network to operate in a cleaner RF environment. This is achieved by allowing individual cells to closely coordinate their scheduling decisions with their immediate neighbouring cells. This paper describes the ICIC solution from Node-H, which is based on a Soft Frequency Reuse (SFR) approach supported by decentralized HeNB coordination over the 3GPP-standard X2 interface. Node-H's ICIC mechanism has been built to guarantee the stability of the LTE air interface thanks to its tight coordination between RRM and SON procedures. It accentuates inter-operability between HeNB vendors thanks to the use of standard procedures and it provides the network operator with flexible configuration options to define how ICIC shall operate.

Introduction

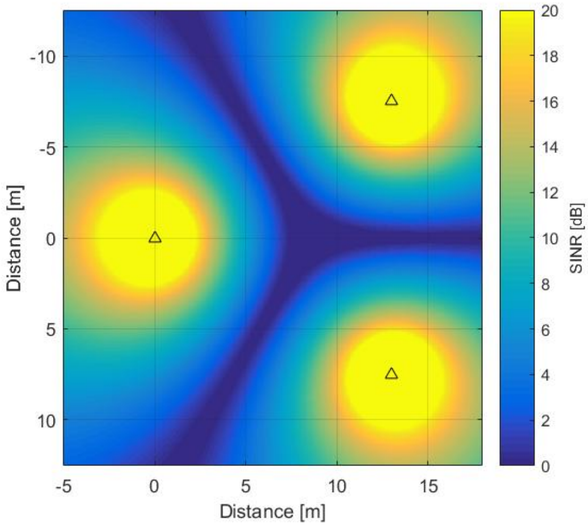

Figure 1: Sample map of the average SINR in the PDSCH of a LTE small cells network without ICIC.

Small cell networks are deployed following a full frequency reuse approach. The small coverage area of each cell enables a geographical reuse of licensed spectrum much higher than that offered by the more traditional macro and picocells. Consequently, the spectral efficiency per unit of area (measured in $bps/Hz/m^2$) offered by small cell networks is unparalleled and represents today the only technology capable of satisfying the ever increasing data demand.

However, dense small cell deployments are not free of challenges [1]. From an interference viewpoint, a full frequency reuse means that every cell acts as an aggressor onto its neighbour cells. Whereas interference may not be critical for User Equipments (UEs) near the cell centre, this is certainly not the case for the more vulnerable cell-edge UEs. Indeed, despite the robustness and efficient coding schemes that LTE has to offer, high density deployments of small cells can raise the interference-plus-noise floor to unbearable levels at the cell edge (see Figure 1). Fortunately, LTE's physical layer in the radio interface provides a natural mechanism for neighbour cells to coordinate the allocation of orthogonal resources to their UEs. All that remains is for SON algorithms to apply such coordination mechanisms in a manner that boosts the performance of cell-edge UEs.

The methodology described above is known as Intercell Interference Coordination (ICIC) and it has long been considered as fundamental to guarantee the success of LTE small-cells [2]. Although ICIC can diminish the data rates experienced by Cell-Centre (CC) UEs, such penalty is worth paying in exchange for the QoS boost that Cell-Edge (CE) UEs obtain. The industry wide interest that ICIC raises is reflected in the numerous institutions that have contributed to the standardization of ICIC methods [3] [4].

Node-H ICIC solution: The method

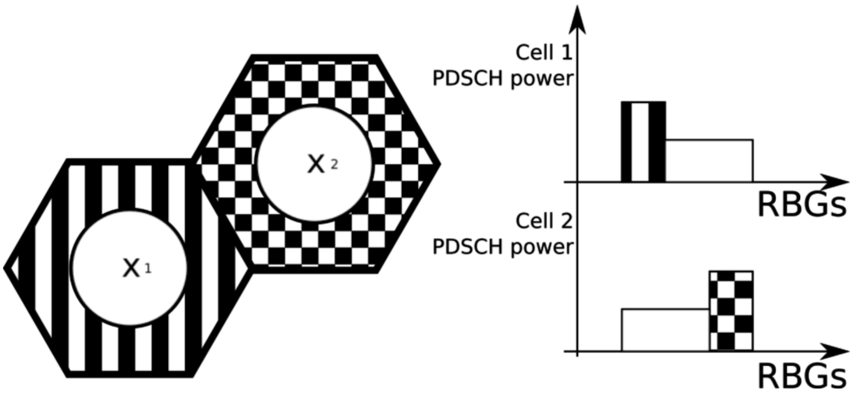

Figure 2: Sample PDSCH power allocation between two neighbour small cells.

The SON layer of Node-H's LTE stack includes a **decentralized** ICIC algorithm that allows HeNBs to cooperate in a manner that minimizes the interference levels at the cell edges. The ICIC strategy of Node-H acts in the frequency and power domains, thus enabling HeNBs to coordinate not only the spectrum chunks allocated to the data channels of cell-edge UEs but also the transmit power with which these channels are transmitted. Node-H's solution is based on a **Soft Frequency Reuse** (SFR) approach and is intended to improve the Signal-to-Interference-and-Noise Ratio (SINR) of the Physical Downlink Shared Channel (PDSCH). This approach reduces the HARQ retransmission rate of the PDSCH, thus effectively resulting in a higher data rate.

The objectives described above are achieved in two stages: First, by exchanging radio load information between neighbour HeNBs. And second, by selecting an optimal radio resource allocation based on the exchanged information. During the first stage, neighbour HeNBs exchange Relative Narrowband Tx Power (RNTP) information within standard **LOAD INFORMATION** messages over the X2 interface [5]. Consequently, Node-H's ICIC algorithm is interoperable with HeNBs from multiple standards-compliant vendors. This information is then analysed by Node-H's SON layer, which uses it to select the cell-edge Resource Block Groups (RBGs) that would cause the least interference onto its neighbour HeNBs, while also satisfying the Quality of Service (QoS) guaranteed to cell-edge UEs.

Internally within each HeNB, all of the above requires a well-structured management of the frequency and power resources allocated to cell-centre and cell-edge UEs. Furthermore, timely signalling of RRC and MAC resources is necessary to guarantee that the transitions between cell-edge and cell-centre are executed as smoothly as possible. Node-H's ICIC achieves this **cross-layer** objective by closely coordinating the scheduler decisions with those taken at the SON level.

Node-H's solution allows mobile network operators to provision HeNBs with a **static configuration** for ICIC purposes. In addition, a **self-configuration** mode is also available. The static configuration mode allows operators to specify which resource blocks and which transmit power shall be used for cell-edge UEs. Such an approach can be useful in enterprise deployments, wherein the HeNB locations and other parameters are planned beforehand. On the other hand, self-configuration of ICIC resources is a must in residential environments, where the operator has no control over HeNB locations or other random scenario changes. This allows HeNBs to take ICIC decisions autonomously and adapt to the immediate needs of their surroundings.

Node-H ICIC solution: The performance

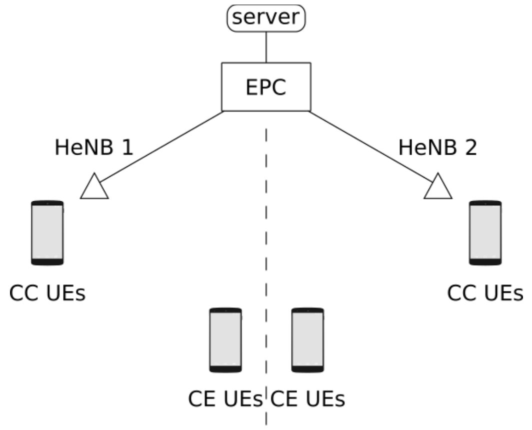

Figure 3: Network architecture for ICIC performance evaluation

This section illustrates and quantifies the benefits that the ICIC technology from Node-H can bring to a small-cells network. To measure this, Node-H's approach to ICIC has been evaluated in a shielded and cabled test-bed under different RF conditions and configuration settings. Then numerical results of the data rates for Cell-Centre (CC) UEs and Cell-Edge (CE) UEs have been obtained.

The capacity gain that ICIC provides depends strongly on the network topology and on the geometry of each particular scenario. For illustration purposes, this paper shows the performance of Node-H's ICIC algorithm in a heavily interfered scenario with two HeNBs (see Figure 3). Within this setup, the IP testing tool *iperf* [6] has been used to monitor the end-to-end TCP capacity between UEs and a central server. Table 1 summarises other relevant test parameters.

Table 1: Scenario characteristics for ICIC throughput test

Iperf	**Protocol**	TCP
	Simultaneous transfer to all UEs	yes
ICIC	**Number of ICIC sub bands**	2
	PDSCH power boost for cell-edge UEs	3 dB

ICIC is intended to improve data rates in situations of high-interference (e.g. hyper dense co-channel networks). It is precisely in those scenarios, where the low SINR levels diminish the throughput attainable by the UEs, that ICIC can bring the most benefits to the overall network capacity. Performance figures for such a scenario are illustrated in Figure 4. Here, the small cells are close together that they mutually interfere with each other, therefore massively impacting the UEs' experience. During testing, the attenuation between UEs and HeNBs was kept constant. Activating ICIC in this scenario, allowed both cells to immediately coordinate their power levels and resource allocations to cell-edge UEs. As a result, interference levels dropped for both cell-edge and cell-centre UEs, resulting in a 28% gain for the cell edge UEs and a net 15% gain of the overall network capacity.

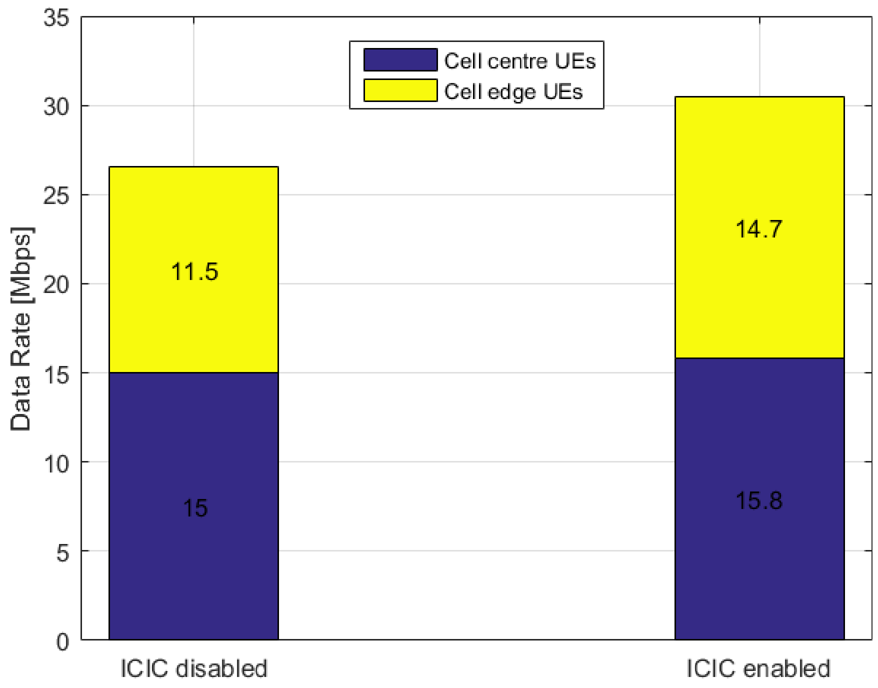

Figure 4: Measured UE data rates in a heavily interfered network with two cells.

Conclusion

This paper has described Node-H's ICIC mechanism, which is based on a **Soft Frequency Reuse** (SFR) approach. This procedure schedules cell-edge UEs in the least interfered Resource Blocks. In addition, it boosts the power with which data channels are transmitted to cell-edge UEs. This methodology counteracts RF interference and reduces capacity losses at the locations in which UEs are more vulnerable. In order to maximize the effects of this interference avoidance in a network-wide manner, neighbouring LTE cells use the **standard X2 interface** to dynamically coordinate their frequency allocation decisions. These procedures would not be possible without Node-H's careful **cross-layer design**, which guarantees that SON and RRM decisions are properly coordinated on every single subframe. The design paradigm pursued by Node-H for a **decentralized** ICIC emphasizes **inter-operability** and **3GPP-compliant** procedures for a **scalable** and efficient LTE network deployment.

Contact Node-H at info@node-h.com to learn more about this and other Node-H SON solutions for LTE small-cells.

Works Cited

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