# LTE Uplink CoMP Trial in a HetNet Deployment

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***Abstract*— Low power remote radio units (RRU:s) are identified as one of the key components to increase the capacity of cellular networks in dense areas with high traffic demands. When the traffic is clustered in hotspots they are also feasible to, combined with high power macro RRU:s, form a heterogeneous network (HetNet). The inherited centralized architecture with RRU:s opens for advanced coordination features between sites. One such promising coordination feature is uplink CoMP (Co-ordinated Multi Point). This paper shows results from a recent full scale CoMP trial on release 8 3GPP Long Term Evolution (LTE). It is demonstrated that best uplink reception (in a micro node) can be decoupled from best downlink transmission (from a macro node), enabling improved uplink bitrate with maintained downlink bitrate. Furthermore, with joint reception a significant uplink reception macro diversity gain is achieved. In the tested scenario on a 10 MHz band the total improvement is in the order of 6 Mbps in the macro-micro transition area.**

***Keywords- E-UTRA, LTE, CoMP, HetNet***

## I. INTRODUCTION

To support the predicted future demands on wireless broadband capacity, there is a need for network densification in some areas. With a heterogeneous network deployment, the densification can be tailored to the capacity needs by covering hotspots with low power nodes. Release 10 of 3GPP LTE defines a variety of node types to enable a capacity increase where the users are and where data traffic is consumed [1]. Where good backhaul is available, one such node type with promising potential is a low power RRU [2]. With several RRU:s connected to the same eNB (enhanced Node B) a centralized architecture is achieved. This centralized architecture enables fast inter-cell and inter-site coordination features such as CoMP and joint reception.

CoMP has been studied for cellular systems for a while [3] showing promising results both in simulations and pre-standard macro network trials [4]. Uplink CoMP requires no specific terminal support and is feasible already within Release 8 LTE standard. In HetNet deployments, uplink CoMP has an additional advantage, where the uplink/downlink power imbalance can be mitigated by decoupling the downlink transmission node from the uplink receiving node [5].

This paper presents results from a field trial with commercial Release 8 LTE terminals and a full scale HetNet deployment. The tests were performed in February 2012.

The paper is organized as follows: in Section II the UL CoMP feature in the context of HetNet deployment is described. The trial network and measurement method are described in section III. The results are presented in section IV and finally conclusions are drawn in section V.

## II. HETNET AND UL COMP

In cellular HetNet deployments there are access nodes (LTE eNB) with different power capabilities. This is illustrated in Fig. 1 where a low power node is deployed within the coverage of a high power macro node. Highest Reference Signal Received Power (RSRP) is typically used for cell selection in LTE, which also is the best node to connect to for downlink. The exception is when cell selection offset and range expansion is used [6]. The coverage of a cell in a HetNet deployment depends on the difference in power between the macro and low power node, illustrated with filled circles in Fig. 1. For the uplink, however, performance is limited by the transmit power capability of the terminal, which is independent of node power. The best uplink connection is then given by the lowest path loss, illustrated with the dashed circle in Fig. 1. Note that there is a transition zone where best uplink differs from best downlink. This is referred to as the uplink/downlink imbalance which is a typical property of a HetNet deployment.

With uplink CoMP, the uplink can be received and combined from several nodes. With selection combining the uplink is always received using the cell with the lowest path loss. In the transition zone, the high power macro node can transmit in downlink, at the same time as the low power node can receive uplink transmission. The uplink/downlink is then decoupled and the uplink/downlink power imbalance mitigated.

In addition to the decoupling advantage the ordinary CoMP advantage applicable also apply to the HetNet deployment. With soft combining, uplink transmission can be received in both the macro node and the low power node to be jointly decoded, achieving macro diversity gain around the cell edge. With Interference Rejection Combining (IRC) receiver the additional information can also improve the interference suppression.

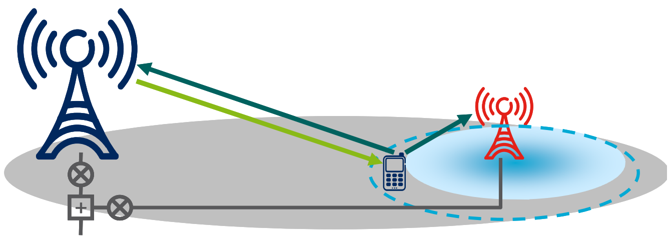

Fig. 1. Uplink CoMP in HetNet.

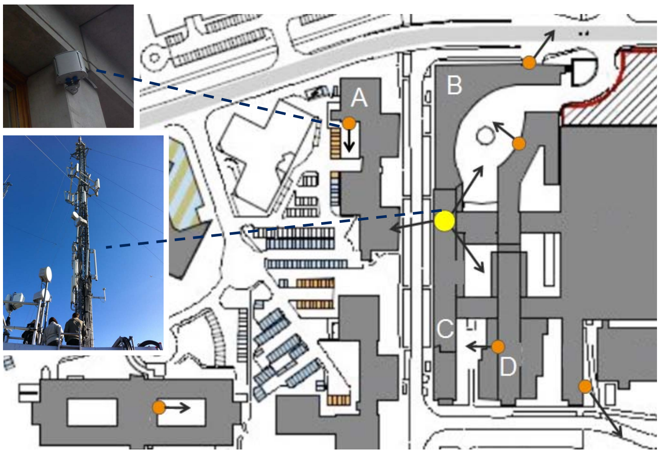


Fig. 2. Trial network.

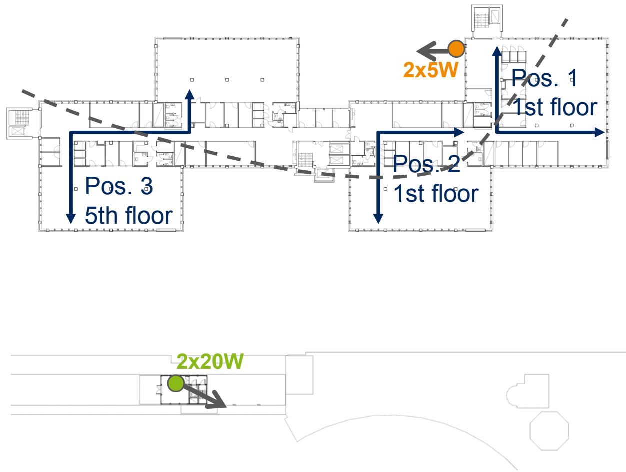


Fig. 3. Test area in building A.

## III. TRIAL NETWORK AND MEASUREMENTS

### A. CoMP Prototype

The radio access network is based on one commercial Release 8 eNB, modified with prototype software and equipped with RRUs. The use of RRUs, connected over Common Public Radio Interface (CPRI), makes it possible to co-locate the digital units of all cells in a single eNB cabinet. The micro cell RRUs are connected with dedicated fiber to the eNB, which is located at the macro site. Low-latency interconnect between the digital units facilitates sharing of antenna data between the cells. This setup makes reception combining from all cells in the whole trial network possible.

The prototype software for UL CoMP includes a variety of receiver algorithms. Antenna combining can be performed either by maximum ratio combining (MRC), or interference rejection combining (IRC). Note that, since all cells in the trial network have two receive antennas, antenna combining by MRC or IRC is always performed, even if a single cell is used for reception. All results presented in this paper are obtained with IRC combining, but since there is no interference included in the measurements, MRC is expected to give equal performance.

The UL CoMP prototype can employ different strategies for selecting which antennas to combine. In this paper we use the term *soft combining* to refer to the case when antenna data from more than one cell is combined. The prototype supports both MRC and IRC combining of up to 3 cells (6 antennas). The term *selection combining* refers to the case when antenna data from a single cell is used, namely the cell with the lowest path loss to the terminal. Note that this cell does not have to be the same cell as the one used for downlink.

The uplink power control is unchanged. The power is targeting a received signal strength in the downlink connected cell independent of if a higher power is received in a micro cell. This leaves room for improvement, but on the other hand the uplink results are more straight forward to compare with the same transmitted power independent of receiver algorithm.

The used terminal is a commercial Release 8 LTE category 3 dongle connected to a laptop.

### B. Network Deployment

The trial network is a full scale HetNet deployment with a three sector macro site above roof tops and six micro sites mounted on walls at around 4 m height, see Fig. 2. The macro cell power is 2x20 W and the micro cell power 2x5 W resulting in a 6 dB power difference and corresponding transition zones with difference in best uplink and downlink access node. Both the macro and the micro antenna are cross polarized with 68º horizontal half power beam width (HPBW). The macro antenna has a narrow vertical beam of 7º HPBW while the micro antenna has a wider beam 65º HPBW to cover all floors in the buildings resulting in difference in antenna gain, 17 and 8 dBi respectively. The network is very densely planned considering the frequency band. A capacity limited densely planned network is also expected to be an interesting scenario where to deploy micro RRU:s. The network characteristics are summarized in TABLE I.

TABLE I. NETWORK CHARACTERISTICS

| Parameter | Value |
|---|---|
| Access | LTE Release 8 |
| Frequency band | 10 MHz @ 800 MHz (band 20) |
| Number of macro sites/cells | 1/3 |
| Number of micro RRU:s | 6 |
| Macro to micro distance | 60-200m |
| Macro antenna height | 30 m |
| Micro antenna height | Around 4 m |
| Macro power | 2x20 W |
| Micro power | 2x5 W |
| Macro antenna gain | 17 dBi |
| Micro antenna gain | 8 dBi |

### C. Test Area and Test Positions

The tests were all done with the terminal indoor, where the majority of the broadband traffic is expected to be consumed. All the results presented in this paper are with the terminal in the same building, house A in Fig. 2. Only two cells were involved in the tests, one macro sector and one micro cell. The micro cell was the one mounted on the wall of house A and the macro sector the one pointing upwards towards house B in Fig. 2. The distance between the used micro antenna and the macro antenna was 80 m.

Both house A and house C, where the macro antenna was deployed, are seven floors high. The distance from the macro to house A was only 30 m resulting in very good indoor coverage by the macro cells. Therefore the macro sector pointing towards house A was turned off during the tests to create additional test positions in house A with limited, not maximum, bitrate in uplink.

Results from three indoor positions or walk routes are presented in this paper, see Fig. 3. They all cover the handover border between the macro and the micro cells and an area well into both cells. Positions 1 and 2 are both on the first floor while position 3 is on the fifth floor. Uplink results, which are of main interest for uplink CoMP, are presented for all three positions, while downlink results are presented for position 1 only.

This case study with a single micro deployment and a limited number of test positions will not give any useful absolute results, such as throughput performance for LTE with CoMP. However, the CoMP impact can be studied by comparing with and without the feature for each test position.

### *D. Logging and Used Measures*

The tests were performed with a dongle terminal connected to a laptop. Data was uploaded or downloaded with continuous file transfer (full buffer load). The laptop was placed on a trolley that was pushed at slow walking speed back and forth from well inside the macro coverage, passing the cell border, to well into the micro coverage. The three positions according to Fig. 3 were walked three turns each for each test case while collecting measurements.

Collected measures were RSRP for both cells and Layer 1 throughput including HARQ retransmission. The RSRP measures were logged every 160 ms. A geometry measure is calculated for every sample according to:

$$Geometry = RSRP_{macro} - RSRP_{micro} \text{ [dB]} \quad (1)$$

as a measure of the radio distance to the cell edge for best downlink cell selection as described in section II. The RSRP measure is quantized in dB-units resulting in a geometry also quantized in dB.

For each geometry sample a correlated layer 1 throughput is calculated as the sum size of all acknowledge transmissions during the 160 ms period as:

$$Thp = \frac{\sum TFS_{acked}}{0.16} \text{ [bps]} \quad (2)$$

where $TFS_{acked}$ is the transport format size in number of bits for acknowledge HARQ transmissions.

The throughput samples for each position have been binned according to their correlated geometry measure. For each geometry dB unit an average throughput and its 95 percent confidence interval is calculated and presented.

The same geometry correlated throughput is used for both uplink and downlink.

## IV. RESULTS

### *A. Uplink Improvement*

In Fig. 4, 5 and 6 the uplink layer 1 (L1) average throughput as a function of geometry (radio distances to handover border) are shown for the test positions 1, 2 and 3 respectively. The statistical confidence is indicated by 95 percentile confidence intervals. For each test position three cases are tested and compared:

- *No CoMP*; ordinary single cell uplink reception according to cell selection from handover.
- *CoMP selection combining*; best received signal in uplink on the two antennas selected from either macro or micro.
- *CoMP soft combining*; uplink joint reception in both macro and micro from all four antennas.

In all three positions there is a significant gain from uplink CoMP, both from selection combining and macro diversity joint reception. The gain is present for a large range of geometry in all cases, minimum from handover border at equal RSRP (0 dB geometry) up to 10 dB higher macro RSRP.

Looking at the gain from selection combining, blue lines compared to black lines in Fig. 4, 5 and 6, it is expected to be present in the transition zone as described in section II from handover border (a geometry of 0 dB) up to equal path loss (a geometry of 6 dB). In all three test positions CoMP selection combining shows gain in this transition zone proving the uplink decoupling gain from downlink cell association.

Looking at the additional gain from soft combining, red lines compared to blue lines in Fig. 4, 5 and 6, it is expected to be largest at equal path loss (a geometry of 6 dB) and decrease the larger the path loss difference is. In general this is supported by the results.

The gain from UL CoMP varies between test positions both regarding amount of improvement and geometry range. There are also differences in gain from selection combining and soft combining. The difference between test positions is caused by a combination of handover behavior, radio channel conditions and small unintended test execution variations. The later can be walk route variations and changes in surrounding indoor obstacles, such as people present in the building.

The handover behavior depends on handover hysteresis and filtering in combination with walking speed and direction. If the walk route passes the handover border with sharp RSRP difference or if it is more soft and with varying strongest cell has impact. This handover impact is illustrated in Fig. 7 where the position 1 no-CoMP test case bitrate results are separated into macro and micro connected samples. There are macro and micro samples up to 3 dB into the neighbor cell from handover filtering. The hysteresis (a3 offset) was set to 1 dB and the

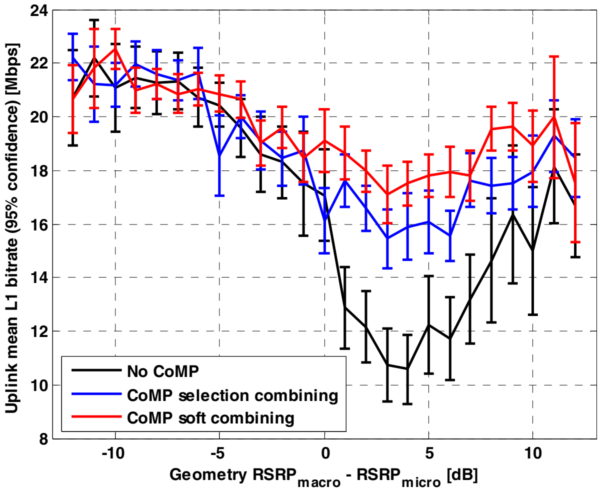


Fig. 4. Uplink bitrate as a function of Geometry in test position 1.

remaining additional 2 dB is from filtering and delay. The cell specific throughput results follow different trends dependent on path loss and radio channel to respectively cell. The combined throughput (blue line in Fig. 7.) goes from the micro only to the macro only as the fraction of samples from macro increases gradually further into the macro cell.

The relatively large variation on soft combining gain between test positions is expected to be caused by radio channel conditions in combination with antenna. This depends on multipath propagation and polarization which can differ significantly not only between test positions but also within each walk route depending on windows, walls, reflections and indoor obstacles.

### B. *Downlink Impact*

Uplink CoMP joint reception is not expected to have any impact on downlink. Downlink tests without CoMP and with soft combining CoMP were done in test position 1. Layer 1 downlink throughput as a function of geometry is shown in

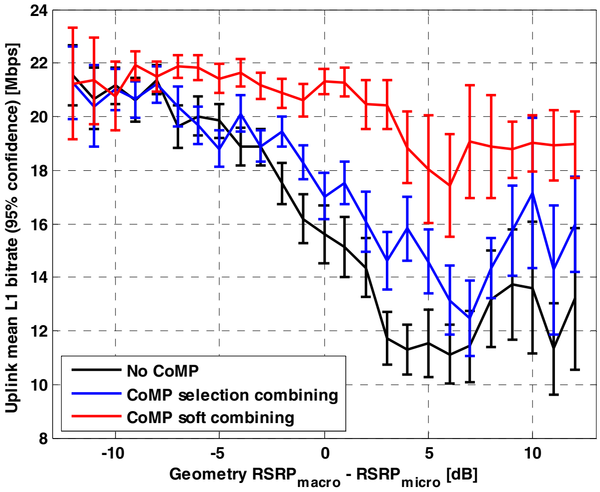


Fig. 6. Uplink bitrate as a function of Geometry in test position 3.

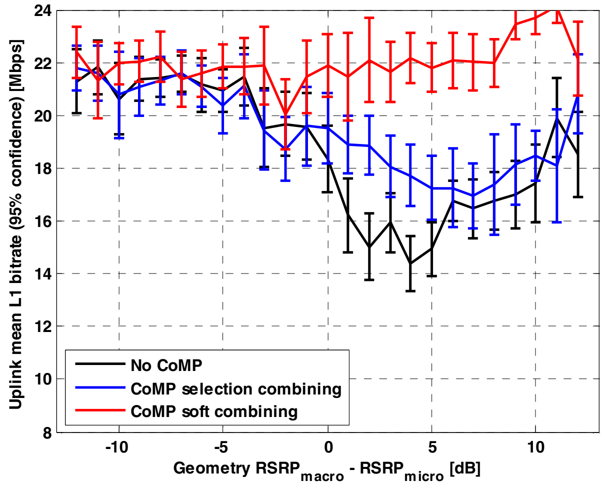


Fig. 5. Uplink bitrate as a function of Geometry in test position 2.

Fig. 8.

The difference in downlink bitrate is small and mainly within 95 percentile confidence interval. This in contrast to range expansion that can improve uplink in HetNet but that comes at the cost of degraded downlink [6]. This verifies that uplink CoMP can be applied without downlink bitrate loss and that uplink reception can be decoupled from downlink transmission by CoMP.

### C. *Assessment of Uplink Bitrate Improvement*

To quantify the uplink improvement the layer 1 bitrate difference between no CoMP and the two uplink CoMP receiver algorithms respectively have been extracted. This is done per binned geometry value and for all three test positions. The results are shown in Fig. 9.

This comparison emphasizes some of the observations made in section IV.A. The selection combining improvement is mainly in the transition zone. These results indicate around 3 Mbps improvement in the geometry range 1 to 4 dB. The

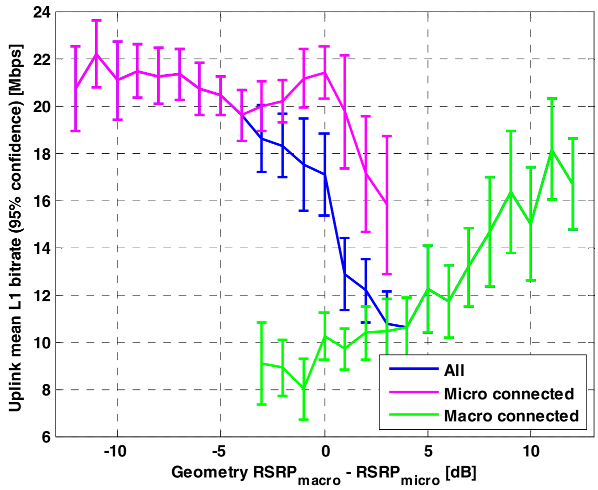


Fig. 7. Uplink bitrate per cell association for no CoMP in test position 1. Illustrating the effect of hysteresis and filtering in the handover decision.

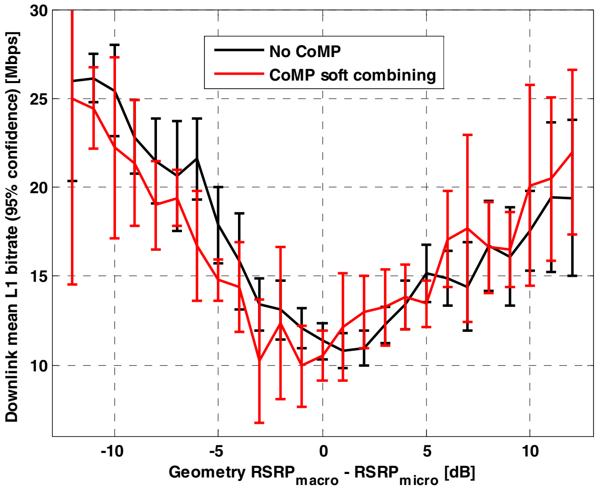


Fig. 8. Downlink bitrate as a function of Geometry for position 1.

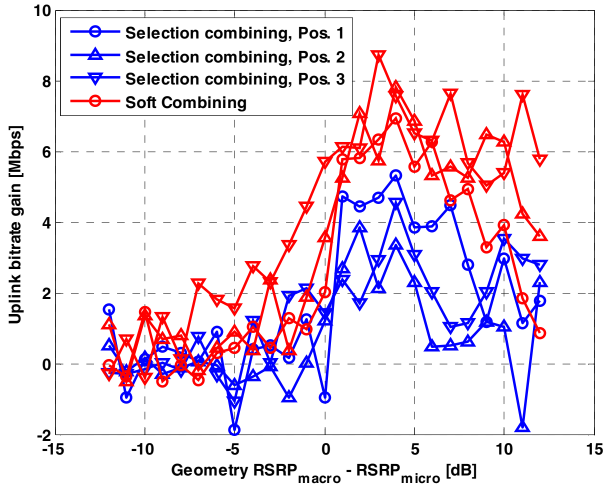


Fig. 9. Uplink bitrate Improvement as a function of Geometry.

additional soft combining gain is largest further into the macro cell around where the path loss to macro and micro is equal, at a geometry of 6 dB. The combined improvement is around 6 Mbps in the geometry range 0 to 8 dB.

The improvement outside this range varies more between the test positions and probably depends on mobility and radio channel conditions as discussed in section IV.A.

The absolute improvement is rather equal in all test positions despite the difference in base-line no CoMP performance. For example, without CoMP at 5 dB geometry position 2 shows around 15 Mbps (see Fig.5) while position 3 only shows 11 Mbps (see Fig. 6). But in both test positions soft combining CoMP gives around 6 Mbps improvement. This indicates that absolute improvement is rather constant leading to that the relative improvement is larger the worse the non-CoMP base-line is. It is left for further studies with more varying base-lines to verify this.

## V. CONCLUSION

A full scale HetNet LTE trial network has been deployed based on LTE commercial eNB and RRU:s and with commercial terminals. With prototype features it is demonstrated that uplink CoMP can be applied with Release 8 version of the LTE standard.

With an uplink selection combining feature it is shown that uplink reception in micro site can be decoupled from downlink transmission from macro site mitigating the HetNet uplink downlink power imbalance. In the transition zone where lowest path loss differs from strongest downlink an uplink improvement of around 3 Mbps is observed on the deployed 10 MHz.

With an uplink joint reception feature, it is shown a significant macro diversity combining gain on top of the decoupling improvement. The total uplink bitrate improvement is observed to be around 6 Mbps in the macro-micro transition area. This improvement comes without any degradation in downlink.

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