LTE HetNet Trial - Range Expansion including Micro/Pico Indoor Coverage Survey

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***Abstract* —Adding low power nodes is one option to meet the increased mobile broadband traffic demands. In the resulting heterogeneous network (HetNet) with different node power levels, range expansion is a key feature to improve uplink as well as to increase the coverage of micro/pico nodes. In this paper measurement results from a trial with Release 8 terminals and system verify that range expansion can improve uplink bit rate at a limited cost in downlink bit rate. Also, the macro versus micro/pico indoor coverage is assessed by scanning three office buildings. Coverage using a 2x1 W pico node is assessed to 75 percent of the coverage with a 2x5 W micro node. Range expansion can increase the indoor coverage with 1.5 to 4 percentages per dB.**

Keywords – LTE, HetNet, Range Expansion, measurement, trial network, Release 8

I. Introduction

Wireless broadband is a success and the packet data traffic in the networks is increasing. To support the predicted future demands there is a need to increase network capacity. It is identified that network densification, e.g., adding more sites, has a large potential to increase the capacity. With low power nodes creating heterogeneous networks the densification can be tailored to better meet capacity and service coverage needs [1].

3GPP LTE defines a variety of low power node types and supporting features to enable increase in capacity where the users are and where data traffic is consumed [2]. Outdoor street level deployment of 1 to 5 W nodes with omni or wide beam antennas is an interesting alternative. This can improve the capacity in areas with high traffic density within the covering macro network. To improve capacity and service coverage it is essential that low power nodes pick up enough traffic from the macro layer [3]; especially indoor coverage is of large interest since a large fraction of broadband traffic is expected to be consumed indoor.

Range expansion is one feature that can improve the coverage of micro and pico nodes at the same time as the uplink is improved. This comes at the cost of downlink performance degradation.

In this paper a HetNet trial network is presented where micro cells are deployed on street level below a macro site above roof top. The network is built with LTE Release 8 components, eNB and UEs. Indoor coverage is scanned in three office buildings, including the impact of range expansion and micro/pico node power.

For heterogeneous networks with low-power base stations such as pico cells, the question is how large share of the traffic the pico nodes can offload from the macro layer. In this context such question is addressed in terms of to what extent the different nodes provide (indoor) coverage.

Concept of range expansion is described in Section II; deployment and setup of heterogeneous trial network is described in Section III, and measurement setup in Section IV. Results are presented in Section V and the paper is concluded in Section VI.

II. HetNet, Power and Range Expansion

In cellular HetNet deployments there are access nodes with different downlink transmission power capabilities. The uplink UE transmission capability is the same for the whole network. This is illustrated in Fig. 1 where a low power node is deployed within coverage of a high power macro node. For downlink, the best node to connect is the one with highest RSRP (Reference Signal Received Power); illustrated with filled circles in Fig. 1. The best uplink connection is lowest path loss, illustrated with a dashed circle.

There is a transition zone where best downlink differs from best uplink. The size of this transition zone depends on the downlink power difference. With range expansion, illustrated with the arrow, cell selection can be adjusted between best uplink and best downlink (and even beyond). With increased range expansion, uplink bit rate can be improved and the low power node coverage and traffic uptake increased [1]. This comes at the cost of reduced downlink bit rate.

Range expansion is supported by Release 8 LTE with the parameter cellIndividualOffset [6].

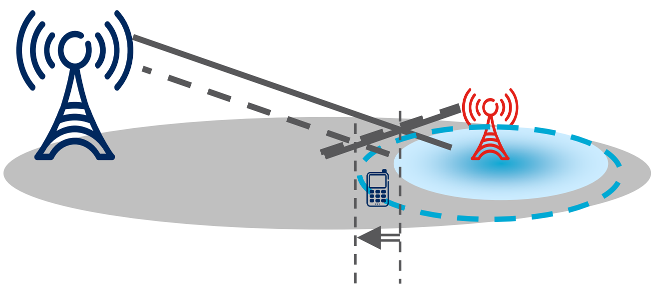

Figure 1. Power imbalance and range expansion.

III. TRIAL NETWORK

The trial system is 3GPP LTE Release 8 compliant and operates on 10 MHz bandwidth at 800 MHz (band 20).

The heterogeneous network consists of one three-sector macro site, five outdoor micro sites and one indoor in a courtyard with glass roof. Micro cell antennas (2x5 W, 8 dBi) are deployed at building facades about five meters above ground and the three-sector macro site (2x20 W, 17 dBi) is deployed at a radio tower about 30 meters above ground. The macro to micro distance ranges from 60 to 200 m. Both the macro and the micro antenna are cross polarized with 65º horizontal half power beam width. The macro antenna has a narrow 7º vertical half power beam width while the micro antenna has a wider vertical beam of 67º to cover all floors in the buildings. Approximate antenna directions and site locations are depicted in Fig. 2.

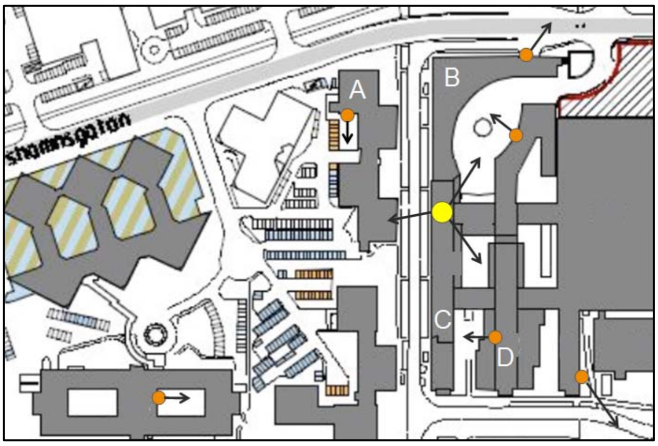

Figure 2. HetNet trial network deployment overview. Yellow and orange circles represent macro site and outdoor micro cells, respectively.

Indoor environment in House A-C consists of a mix of open office areas, stairways, meeting rooms and corridors with office rooms attached. Indoor walls typically consist of a mixture of glass, concrete and drywalls. Windows and indoor glass walls are normally of non low-emission type.

IV. MEASUREMENT SETUP

Measurements were conducted using a 3GPP LTE Release 8 compliant UE (Category 3) and Rhode & Swartz TSMW Universal Radio Network Analyzer connected to a laptop running Ascom TEMS Investigation for data collection.

Measurement setup is depicted in Fig. 3. Data was collected at pedestrian speed to enable good spatial resolution in the measurement logs.

V. RESULTS

A. Indoor Coverage

Reference Signal Received Power (RSRP) measured by the scanner in House C is depicted in Fig. 4. Rightmost samples in traces shown in Fig. 4 are located beneath macro cell antenna tower.

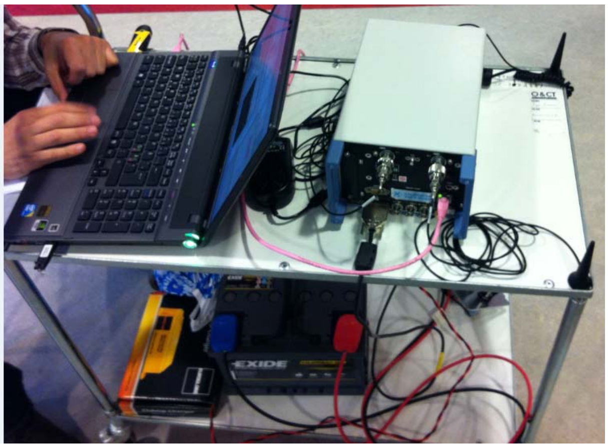

Figure 3. Measurement setup overview. UE in top-left corner, scanner with its antennas (one activated) in middle and to the right, respectively.

Considering macro cell only, Fig. 4 (right), RSRP distribution for floor 1 to floor 6 is rather similar. Floor 7 (i.e. elevator, ventilation equipment) shows significantly higher RSRP since this floor is very near antenna lobes of macro cells. Low RSRP samples in mid area of the building structure are gathered in the stairways of building C (concrete structure, few windows).

In general, the outdoor 2x5 W micro cell located at facade of building D as seen in Fig. 5, provides very good indoor coverage in major parts of building C. As expected, we have high signal strength at nearby floors, but also good signal strength up to floor 7; see Fig. 4 (left).

Given that the micro cell is located ~5 m above ground and with approximately 67º vertical half power beam width, only ~3 dB in signal strength is lost due to the high-floor elevation.

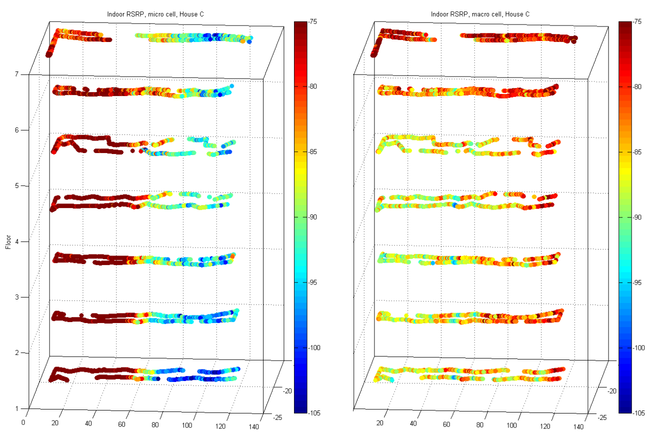

Figure 4. Indoor RSRP in Building C, floor 1-7. Micro cell RSRP (left), macro cell RSRP (right)

There is an obvious shadowing effect on the micro cell caused by the lower building located between building C and building D; see Fig. 5.

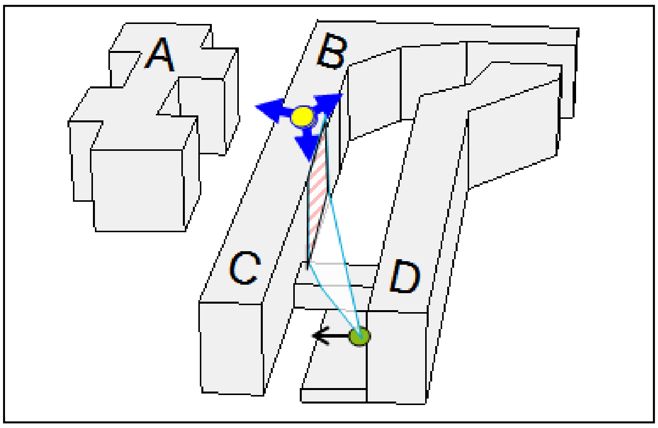

Figure 5. Macro cell located on the roof of building B; micro antennas are mounted on facade adjacent buildings A (hidden in this view) and D. Building between C and D constitues attenuation of micro cell signal in C-areas near building B.

Shadowing typically reduces RSRP up to 30 dB, and as expected, is more emphasized for lower floors and in part of building furthest away from micro cell. See Fig. 6.

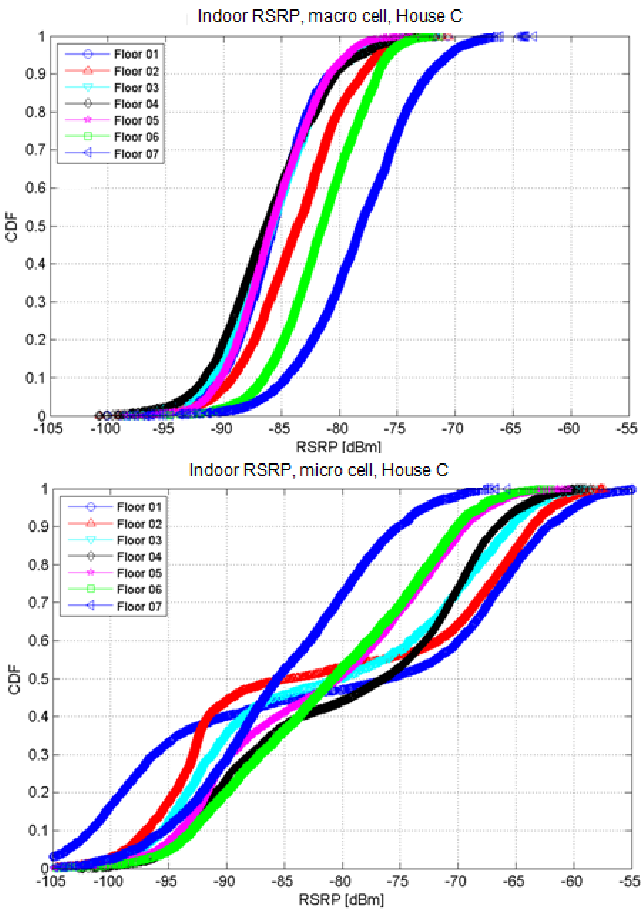

Figure 6. Indoor RSRP in Building C, floor 1-7. Micro cell RSRP (top), macro cell RSRP (bottom).

In Fig. 6 (bottom), micro cell RSRP distribution is evenly distributed for floors not affected by shadowing, whereas the s-shape for other floors is caused by addition of two separate RSRP distributions; one containing RSRP values from "non-shadowed" areas near the micro cell antenna, and one representing low RSRP values from "shadowed" regions further from micro antenna. In the shadowed group, RSRP is generally lower for lower floors.

Considering indoor coverage in building A as depicted in Fig. 7, as expected, macro cells provide best RSRP in parts of the building facing the corresponding antennas. In areas closer to the micro cell, i.e. at the opposite side of the building compared to where macro cells are dominating, highest RSRP is naturally achieved in the forward direction of the micro cell. Similarly to observations from building C, the outdoor micro cell covers more or less equally good coverage at all floors.

Reflection and backscattering from facade on the opposite side of the micro antenna brings coverage at areas above and back of micro antenna where it according to the antenna's 65° horizontal half power beam width should not provide any significant coverage.

Straightforward implications from the analysis considering 2x5 W micro cells are that indoor coverage will suffer if e.g. 2x1 W pico cells are used within same deployment strategy.

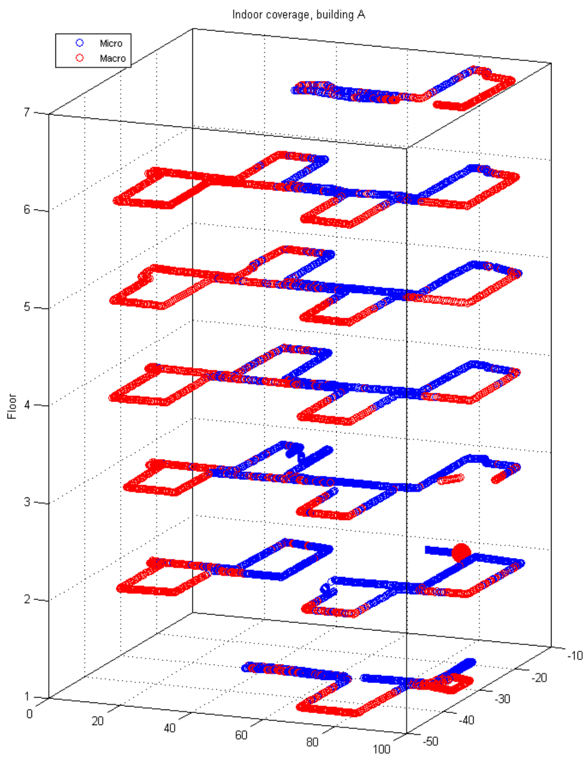

Figure 7. Micro and macro indoor coverage in building A. Red markers represents physical positions where 2x20 W macro cell provides best RSRP and blue markers represents areas served by 2x5 W outdoor micro cell. The micro cell is deployed at floor 2, shown as red sphere with blue tail indicating antenna direction.

B. Range Expansion

Indoor micro versus macro coverage in building A is shown in Fig. 7. With a 2x5 W micro cell the building is to a large extent covered by the micro despite the close macro site. Range expansion can, as described in section II, further increase the micro cell coverage.

A trial in building A to measure the link bit rate impact of range expansion has been performed. A UE was moved around the border between the micro and macro cell measuring Layer-1 bit rate and correlated RSRP measures. A geometry measure defined as the difference between macro and micro cell RSRP is used as a radio distance measure to the cell border. The trial was done with two parameter settings; one using best downlink RSRP handover (i.e. zero dB range expansion) and one using a 4 dB range expansion. 4 dB was selected to leave room for proper handover measurement and filtering. The UE reports RSRP down to 6 dB below strongest cell which also is according to specifications [4]. 4 dB is less than the macro-micro power difference of 6 dB and is then less than best uplink lowest path loss cell selection as described in section II.

Uplink bit rate as a function of geometry is shown in Fig. 8 including 95 percent confidence interval from the collected samples. As expected, uplink bit rate is improved significantly by connecting to the micro cell in the transition zone in the range 0 to 4 dB geometry. This demonstrates that range expansion can be applied on Release 8 of LTE. There is also a smaller improvement in the range 2 dB outside the transition zone. This improvement comes from the handover filtering; a 1 dB handover hysteresis (a3offset) was used.

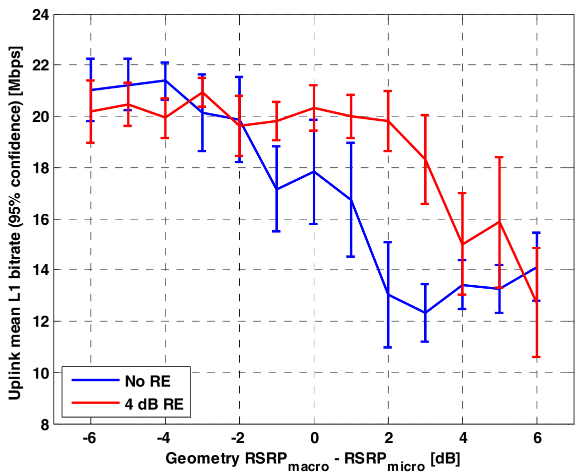

Figure 8. Uplink bit rate as a function of geometry.

In Fig. 9, downlink bit rate as function of geometry is shown. As expected, downlink is degraded by range expansion in the transition zone. The impact of handover filtering is seen as the smaller improvement with no range expansion for a geometry between 0 and 2 dB.

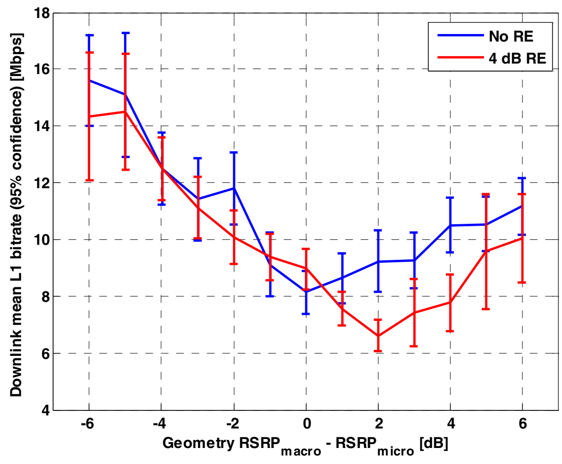

Figure 9. Downlink bitrate as a function of geometry.

In addition to uplink bit rate gain there is also an improved low power node coverage gain from range expansion. This has been investigated for all three buildings and also for range expansion offsets beyond what is possible with Release 8 by using RSRP scanner measurements. The fraction of building coverage as a function of range expansion is shown in Fig. 10. Range expansion up to 20 dB is included even though it is not feasible with existing LTE standard.

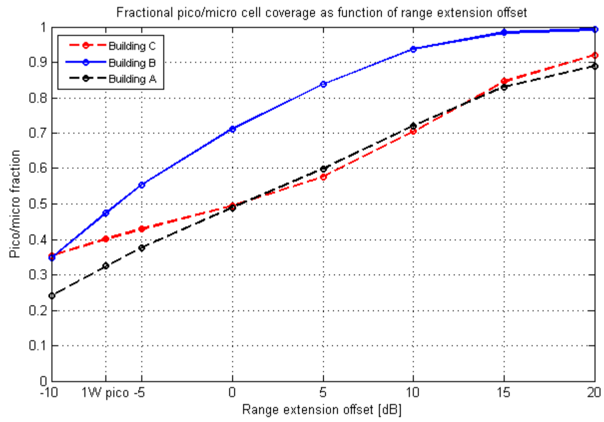

Figure 10. Relative micro/pico indoor coverage as a function of range expansion.

There are differences between the buildings depending on building shape and micro antenna position and direction. Also the macro antenna positions and directions have an impact. The micro cell coverage of building B is larger than that of building A and C, 70 percent compared to 50 percent. Also the coverage increase from a 5 dB range expansion is larger for building B than for building A and C. But for a 10 dB range expansion it is similar for all buildings, around 20 percentages. In average, this corresponds to around 2 percentages increase in micro cell coverage per dB increased range expansion.

Coverage for alternative low power node power capabilities can also be extracted from the same results. For example a 2x1 W pico cell corresponds to a negative range expansion of 7 dB, as marked in Fig. 10. The indoor coverage of an outdoor deployed 2x1 W pico cell will be significantly smaller than from the 2x5 W micro cell. House B will be covered to around 48 percent by a 2x1 W pico compared to the 70 percent coverage with a 2x5 W micro.

All the three studied buildings are close to the macro site. It is expected that micro cell coverage for similar buildings and micro antenna deployment will be larger the further away from the macro site the building is. However, the range expansion and power level impact is expected to be similar resulting in around 2 percentages increase of coverage per dB.

C. *Indoor attenuation*

Considering RSRP distributions from selected areas in building B (floor 4 and 5) as shown in Fig. 11, RSRP from areas facing inner yard ("front") where outdoor micro cell is deployed is significantly higher than RSRP from areas further inside the building ("back").

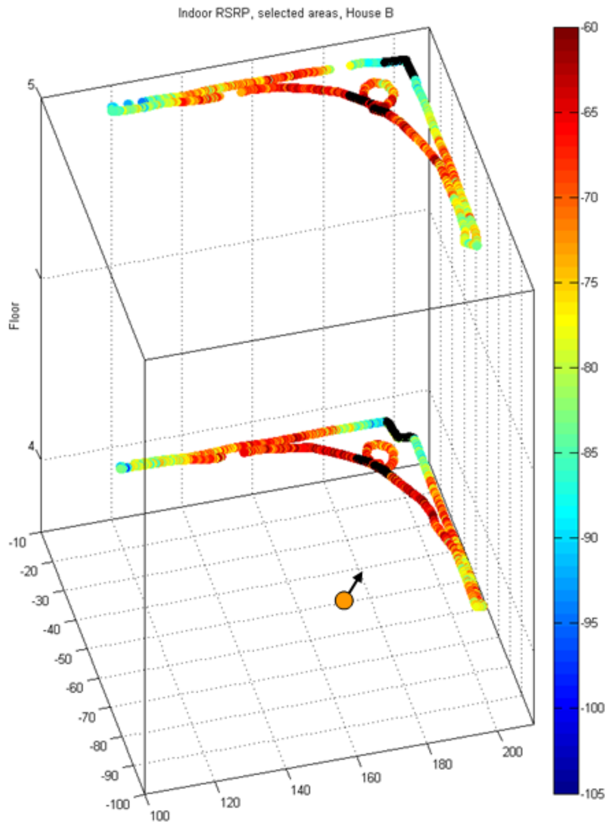

Figure 11. Selected areas on floor 4 and 5in building B. Micro cell schematicaly depicted by orange sphere is depoyed on floor 2 about 5 m above ground, see also Fig. 1.

Fig. 12 shows that back areas in median have typically 18 to 23 dB lower RSRP and that the back-area attenuation is ~5 dB higher at floor 5.

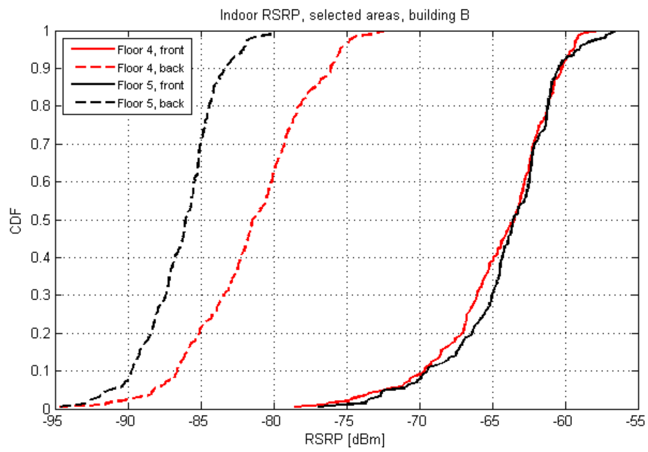

Figure 12. RSRP distribution for selected areas in building B.

Assuming 3 to 5 dB signal attenuation due to the building glass facade and considering that the distance between front and back areas is about 30 m, we get an average building attenuation of ~0.5 dB/m indicating good alignment between current measurement analysis and ITU models [5].

VI. CONCLUSIONS

It is demonstrated that range expansion can improve uplink bit rate. This comes at the cost of downlink bit rate as expected. A range expansion around 4 dB is feasible with LTE Release 8 UEs leaving room for handover filtering within the 6 dB neighbor cell reporting window.

With the used 65° vertical half power beam width antenna the micro cells cover the seven floor office buildings well. Micro versus macro node indoor coverage increases around 2 percentages per dB range expansion for the three studied micro deployments.

With 2x1 W pico nodes instead of 2x5 W micro nodes the indoor coverage of the low power node would be reduced with around 20 to 35 percent.

Average building attenuation indicates good alignment between current measurements and ITU models.

REFERENCES

[1] S. Parkvall, E. Dahlman, G. Jöngren, S. Landström and L. Lindbom, "Heterogeneous network deployments in LTE", in *Ericsson Review*, #2 2011.

[2] 3GPP, "Further advancements for E-UTRA physical layer aspects" TS 36.814 v9.0.0.

[3] S. Landström, H. Murai and A. Simonsson, "Deployment Aspects of LTE Pico Nodes", in *Proc. of ICC Workshop on HetNet*, 2011.

[4] 3GPP "E-UTRA, Requirements for support of radio resource management", TS 36.133 v8.16.0.

[5] ITU, "Guidelines for evaluation of radio interface technologies for IMT-Advanced", Rep. ITU-R M.2135 (2009).

[6] 3GPP "E-UTRA, Radio Resource Control (RRC); Protocol specification", TS 36.331 v8.16.0.