Time Reversal for 5G mm-wave overlay networks

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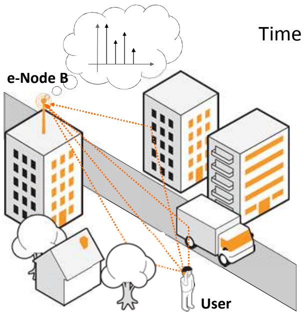
Context & Motivation

Thanks to its focusing properties, Time Reversal (TR) [1] has been identified as a promising signal processing techniques for green communications and has been evaluated over realistic green scenarios [2][3][4]. However, TR needs several transmit antennas to obtain good performance and, as a closed-loop technique, TR needs channel knowledge and therefore increases Medium Access Control (MAC) layer complexity.
This poster presents results of TR PHYsical (PHY) layer application at 60 GHz with a limited number of transmit antennas and a cross-layer analysis at 5 GHz[5].

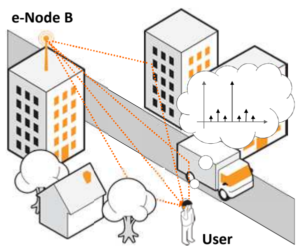
Time Reversal Principle [1][4]

Time (multipath) and spatial focusing signal processing technique



- The e-Node B estimates the CIR[1]
- The CIR is time-reversed and used to prefilter the signal

[1] Channel Impulse Response



Step 1 : Sounding

Step 2 : Focusing

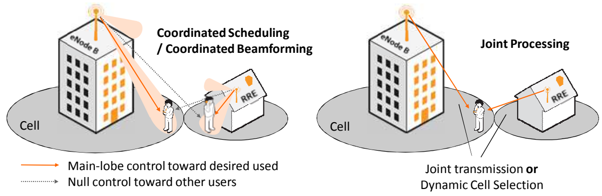
Without Time Reversal :
$$y(t) = x(t) * h(t,\tau) + n(t)$$

$$h_{eq}(t,\tau) = h^*(t,-\tau) * h(t,\tau) = R_h(t,\tau)$$

With Time Reversal:
$$y(t) = x(t) * R_h(t,\tau) + n(t)$$

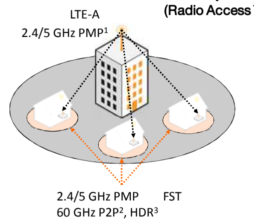
Green Scenarios [2][3]

LTE-A CoMP
(Long-Term Evolution-Advanced Coordinated MultiPoint)



The LTE-A CoMP technique reduce border-cell interference.

Simple and multi-RAT HetNets
(Radio Access Technology Heterogeneous Networks)



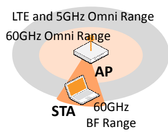
GLB CQI Metric evaluation → Air interface selection → Air interface implementation

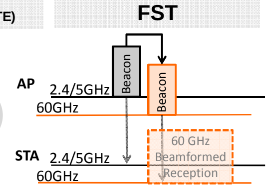
Multi-RAT HetNets are investigated as green scenarios to provide seamless connectivity under QoS[4] constraints

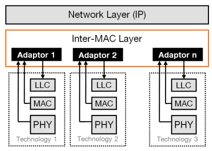
Multi-RAT Channel Quality Indicator (CQI) metrics combined with a Multiple Interface Management select the most green technology upon each radio link :
→ **Green Link Budget Metric (GLB)**

Multi-RAT radio link set up :
→ **Fast Session Transfer (FST)**
Wi-Fi @ 2.4/5 /60 GHz switching
→ **Inter-MAC : L2.5 layer**
→ **ANDSF[4] (Wi-Fi/LTE)**

ANDSF (Wi-Fi/LTE) | **FST** | **L2.5 Layer**







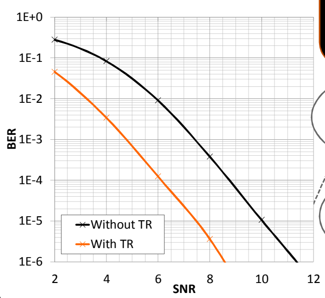
[1] Point-to-MultiPoint
[2] Point-to-Point
[3] High Data Rate
[4] Quality of Service
[5] Access Network Discovery and Selection Function

TR performance for small cells [6]

@ 5 GHz –IEEE802.11.ac
Large space channel model (indoor/outdoor)
- 802.11ad VHT[1] OFDM[2] PHY MCS[3] 1
  → Bandwidth size : 80 MHz
  → Datarate : 58.5 Mbps

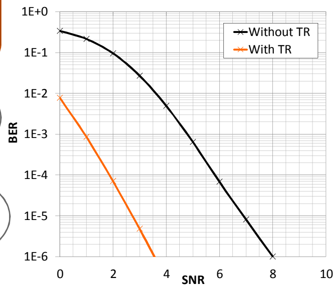
@ 60 GHz - IEEE802.11.ad & IEEE802.15.3c
- Line of Sight (LOS) propagation
- 802.11ad DMG[4] PHY MCS 15
  → Bandwidth size : 2640 MHz
  → Datarate : 1386 Mbps

BER[3] performance is enhanced with > 2 transmit antennas



@ 5GHz : 2.9 dB gain (BER = 10^{-6})

@ 60GHz : 4.4 dB gain (BER = 10^{-6})

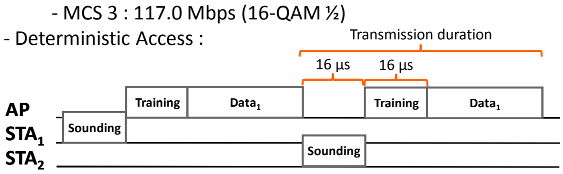


[1] Very High Throughput [2] Orthogonal Frequency Division Multiplex [3] Modulation and Coding Scheme [4] Directional Multi Gigabit

TR Cross-layer analysis @5 GHz [5]

Applying TR necessitates channel knowledge at the transmitter, and then induces overhead and additional power consumption. To validate the green nature of TR, it is necessary to evaluate its Energy Efficiency (EE) considering additional control frames generated (sounding).

Simulation parameters :
- Large space channel model (indoor/outdoor)
- 2 transmit antennas
- 802.11ad VHT OFDM PHY
  → Bandwidth size : 80 MHz
  → Datarates (of Data field) :
    - MCS 1 : 58.5 Mbps (QPSK ½)
    - MCS 2 : 87.8 Mbps (QPSK ¾)
    - MCS 3 : 117.0 Mbps (16-QAM ½)
- Deterministic Access :



Improving
$$EE = \frac{\text{Number of data bits transmitted}}{\text{Required transmission energy}}$$

Reducing
$$\left(\frac{E_{db}}{N_0}\right) = SNR_{dB} - 10 \cdot \log_{10}(\mu)$$

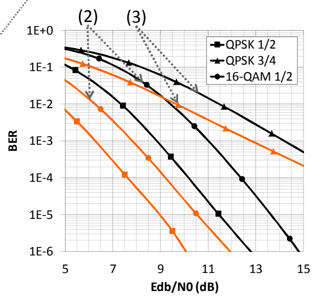
$$\mu = \frac{N_{DBPS} \cdot N_{DS}}{W \cdot T}$$

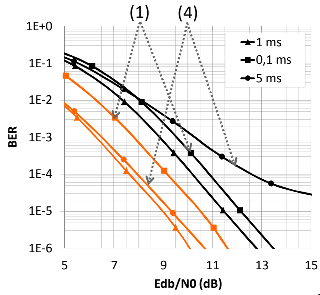
Number of Data Bits per OFDM Symbol; Number of DataSymbol in the data field; Transmission bandwidth size; Transmission duration

Reducing the required SNR corresponding to the desired QoS
→ Frequent sounding (short data field) (1)
→ Using Time-Reversal

Improving the spectral efficiency
→ Increasing modulation (2) or coding scheme (3)
→ Increasing the datafield size (4)

TR with only 2 transmit antennas increases EE





[1] M. Fink, "Time reversal of ultrasonic fields. Part I: Basic principles," IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, vol. 39, Sept. 1992.
[2] I. Siaud, A.M. Ulmer-Moll, "Multi-RAT selection : from use cases to CQI metrics (part I)", Green Touch BCG and GTT projects, Stuttgart meeting, Nov. 2012.
[3] I. Siaud, A.M. Ulmer-Moll, "Multi-RAT Link Adaptation Techniques for Green Convergent Networks" ICT FP7 MiWeba Workshop co-located with IEICE SDR conference, 23-th October Osaka Japan.
[4] M.-A. Bouzigues, I. Siaud, M. Hélard and A.-M. Ulmer-Moll, "Turn Back the Clock : Time Reversal for Green Radio Communications," *IEEE Vehicular Technology Magazine*, vol. 8, no. 1, pp. 49-56, Mar. 2013.
[5] M.-A. Bouzigues, I. Siaud, M. Hélard and A.-M. Ulmer-Moll, "On the use of Time-Reversal for Packet Switching in Green Communications," *1st International Workshop on GReen Optimized Wireless Networks (GROWN'13)*, Lyon, France, pp. 124-128, 7 Oct. 2013.
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