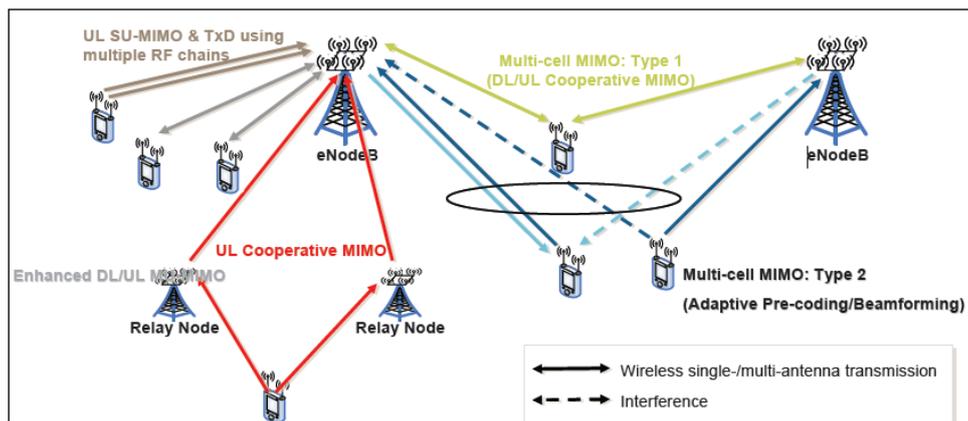


# Final Report: Internet on Trains

## Background

Multiple-Antenna System has become one of the key features that are expected to enable the next generation wireless systems to reach data rates of up to 1Gbps [1]. Using N antennas at both the transmitter and the receiver ends, it has been shown that it is possible to multiplex up to N data streams [2]. Using repeaters (amplify and forward), relays (detect and forward) and distributed antenna systems (DAS), the principle can be extended into cooperative- or networked-MIMO

The LTE-Advanced standard include advanced MIMO options up to 8x8 in DL and 4x4 in UL, coordinated multiple point transmission and reception (CoMP) and relay nodes (RN) [3] (for illustration see figure below).



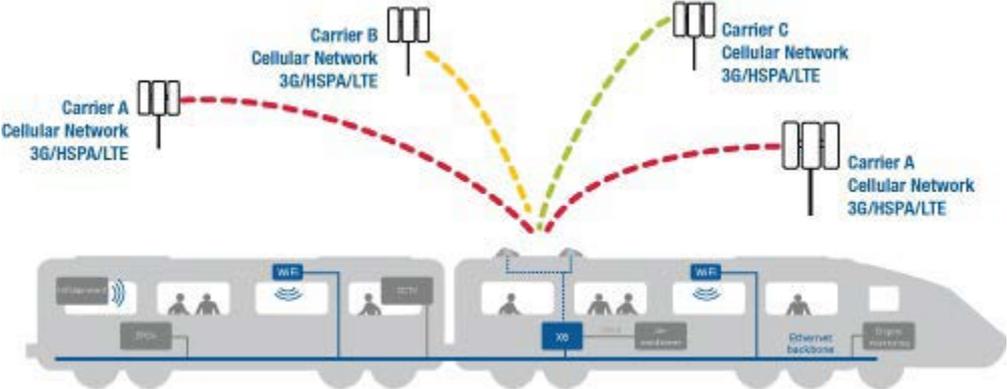
However, even though the area of multiple antenna communication has been thoroughly investigated since the beginning of the 90-ties there are still a number of open issues concerning its implementation both at the base station [4] as well as the terminal side [5]. A major issue is still the channel rank for various environments: in the event that the channel is not full rank it may not be possible for the system to multiplex the desired number channels regardless of the number of antennas deployed at the base or in the terminal [6].

Radio repeaters have been used extensively in both 2G and 3G all around the world but with few exceptions [7] its installation is typically based on single antennas for reception and transmit. With the commercial introduction of MIMO in HSPA, LTE and LTE-Advance, a paradigm shift will probably be introduces and we may soon see repeaters with perhaps up to 8 antennas servicing the cell.

## Passenger Internet on Board Trains

One scenario for which it is easy to envision the full use of MIMO and repeaters is the provisioning of speech and passenger internet onboard trains. Today the most common solution is that the speech provided with the help of simple 2G/3G onboard amplify-and-forward repeater systems. On the other hand, passenger internet is today, by most train operators in Europe, provided through

Icomera’s system solution that enables simultaneously connectivity with multiple radio carriers at different frequencies, standards and by different operators. The system then aggregates all of the received capacity on an IP level into one “big pipe” which is then through a WiFi system distributed in the train. Using standard HSPA technology, this combination of carriers results today in an aggregated channel of up to 100Mbps.



100Mbps throughput to 500 passengers inside an X-2000 is a good enough solution today but probably not when a service like e.g. individual HDTV is being required. Assuming that 50% of the passengers in a 5-10 years time frame will require access to at least 4Mbps services from the outside world we may estimate that each high speed train, travelling at +300km/h will need to be connected with at least 1Gbps.

**Participants:** Icomera, Tele 2, Ascom, DeltaNode, Rohde&Schwartz and Wireless@KTH

**Results:**

**Our** results show that MIMO may perform well on trains and reach higher rank in the above described radio channel, given that the inter-element distances are correctly chosen dependent on the base station-to-train distance.

During measurement of the 2X2 MIMO system it was also found that the condition number (CN), was less than 15 for 65% of the track covered by LTE (see Fig. 5). Hence, the measurements indeed confirm that it is possible to achieve MIMO performance using antennas mounted on the roof of a fast moving train, in LoS with

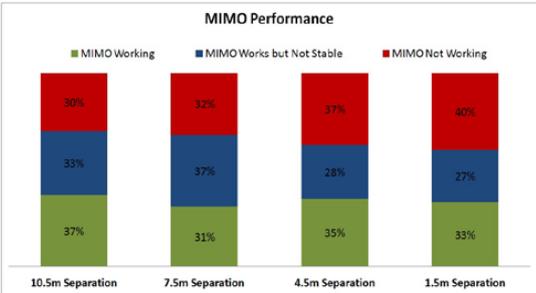


Figure 5. MIMO performance statistics for various inter-antenna distances

## Publications:

1. Alasali M. LTE MIMO Performance Measurements on Trains. 2012. Trita-ICT-EX, 2012:206. MSc Thesis, KTH School of ICT, Communication Systems (CoS), 2012
2. Alasali M, Beckman C. LTE MIMO performance measurements on trains. In: 2013 7th European Conference on Antennas and Propagation (EuCAP): . 2013 7th European Conference on Antennas and Propagation, EuCAP 2013; Gothenburg; Sweden; 8 April 2013 through 12 April 2013. New York: IEEE; 2013. p. 2327-2330. Proceedings of the European Conference on Antennas and Propagation
3. Alasali M, Beckman C. LTE MIMO Performance Measurements on Board Passenger Trains. In: . KVA, Royal Academy of Sciences, Frescati, Stockholm 11-12 November 2013. 2013.