Rel10: Carrier Aggregation and MU MIMO

Outcome from SAMURAI project

FP7-INFO-ICT-248268 Project: SAMURAI
Spectrum Aggregation and Multi-User MIMO: Real-World Impact

Presentation to IWPC/NGMN workshop, Washington, June 2012
Outline

• What is Samurai
• Key results from the project
  – MU MIMO in LTE systems
  – Carrier Aggregation
  – Joint MU MIMO and CA results
  – Test challenges for MU MIMO and CA
• Conclusions
European research

- Europe devotes part of its research effort to *Information and Communication Technology*
  - Overall budget for ICT within the 2007 – 2013 period: ~9000 M€
- SAMURAI is one of the sponsored project
  - 3 years project ending in Sep. 2012
  - 4.6 M€ budget
  - [http://www.ict-samurai.eu](http://www.ict-samurai.eu)
SAMURAI project in a nutshell

• 7 partners:
  – Agilent Technologies (project coordinator)
  – Intel Mobile Communications
  – Sequans Communications
  – Nokia Siemens Networks
  – EURECOM research center
  – Aalborg University
  – Budapest University

• Main research topics
  – MU-MIMO and CA in context of LTE/LTE-ADV
  – Industrial aspects and academic-type of research jointly developed.
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MU-MIMO in LTE Systems

*Theoretical aspects*

- **TM background**
  - Rel8 (TM5): not performing well
    - Fixed codebook precoding, wideband PMI feedback, large residual multi-user interference
  - Rel10 (TM9): more suited to MU-MIMO
    - Dynamic switch between SU and MU-MIMO
    - Higher granularity feedback, flexible codebook

- **MU-MIMO – yes, but not enough…**
  - Type and accuracy of feedback information are crucial for the reliability and performance of MU-MIMO systems
  - Interference-aware receiver is essential for robust performance to remove residual interference

- **Samurai contributions**
  - Develop and evaluate specific receivers (IRC and Interference Aware (IA) receiver)
  - Improve post processing SINR calculation to report accurate CQI (taking into account MU interference and receiver performance)
  - Develop proof of concept

No practical MU-MIMO deployments yet!

Type and accuracy of feedback information are crucial for the reliability of MU-MIMO systems LTE systems.
For any CQI value, best MU-MIMO performance/complexity trade-off with IRC and Samurai IA receiver.

For any CQI value, poor performance/complexity trade-offs with conventional MF and Max Log MAP.
MU-MIMO in LTE Systems

*Proof of concept*

- **Goal:** demonstrate the feasibility and performance of MU-MIMO using advanced receiver techniques
- **Platform:** Eurecom OpenAirInterface
  - Software defined radio
  - Open-source implementation of LTE Rel8
- **Performance evaluation on Express MIMO boards and Agilent PXB channel emulator ongoing**
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Carrier aggregation

RF aspects from UE perspective

- **DL CA**
  - Inter-band CA
    - Bands separated by duplexers, multi-feed antennas or quadplexers
  - Intra-band CA
    - Contiguous case (e.g. B38, B40, B41) supported by wider IF bandwidth
    - Non-contiguous case (e.g. B25) may be supported in a similar way to inter-band CA by use of external or RFIC–internal signal splitter

- **UL CA**
  - Four possible architectures described in TR36.912
  - Contiguous CCs using wider IF → simplest architecture
  - Inter-modulation is potential issue for certain band combinations
  - SAR and peak power not generally an issue, total power is constrained
  - For non-contiguous case, impact on front-end costs (and size) and overall power consumption is significant (for handheld devices)

- **Samurai contributions**
  - Investigate various RF and BB architectures to support CA (more details available on request)
3GPP have defined or are proposing a large number of scenarios for LTE as shown (Rel10/11)
   - Raises test challenges
Location of spurs and risk of self-blocking must be considered case-by-case
Prioritization must be carrier/market driven
   - Bands and band combination, bandwidth, numbers of CC, etc.

Sequans has CA chipset under development
   - Available in Q1 2013 for trial, supporting most scenarios (more details available on request)
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Joint MU MIMO and CA results

DL CA scenario

- Configuration
  - DL 2x20 MHz CA with 4x2 MIMO transmission schemes per CC
  - Fixed-rank or rank-adaptive SU/MU-MIMO adaptation algorithms are compared (Rel10)

- Conclusion
  - In a CA (DL 2x20MHz) scenario, gain at cell and user level is seen in heavily loaded cells when using MU-MIMO rank-1 combined with SU-MIMO rank-1
  - In full buffer traffic conditions, the achieved average cell throughput gain is in the order of 13%
  - In bursty traffic load conditions the average user throughput gain is up to 20%, depending on the cell load
Joint MU MIMO and CA results

UL CA scenario

- **Configuration**
  - UL 2x20 MHz CA with 4x1 MIMO transmission per CC
  - MU-MIMO can be combined with the multi-cluster UL scheduling scheme and load adaptive power control

- **Conclusion**
  - When combined with multi-cluster scheduling, MU MIMO provides 55% gain in average user throughput gain in medium-high traffic load scenarios
Outline

- European sponsored research; What is Samurai
- Key results from the project
  - MU MIMO and receiver
  - Carrier Aggregation
  - Joint MU MIMO and CA results
  - Test challenges for MU MIMO and CA
- Conclusions
Test: RF and protocol interactions challenge

- 2G/3G technologies
  - RF engineers relied on physical layer (PHY) test equipment
- 4G technologies
  - RF analysis alone is not capable of providing a complete picture because:
    - eNBs can tell user equipment (UE) to change data rate, or retransmit data etc… every millisecond
    - This interaction between eNB and UE happen in medium access control (MAC) layer, which is protocol layer
- New Challenge
  - RF engineers need visibility into the protocol layer to understand why RF test is not behaving as expected

Combination of 89600 VSA and a NEW 89600 Wireless Link Analysis (WLA) Software greatly simplify this new challenge!
Test: Dimensionality challenge

- Combinatorial challenge
  - RF tests are defined for a given band
  - LTE already has already about 30 bands, 6 bandwidths
  - With CA, the number of test cases increases dramatically if all combinations have to be explored
  - LTE-ADV: Multi-x:
    - bands, carriers, users, modes, in a multi-radio context

- Challenge from simultaneous transceiver chains
  - EVM for multiple transmit
  - Spur management
  - Self-blocking
  - MIMO support raises antenna issues
    - E.g. decorrelation properties

→ Increase in different dimensions leads to exponential growth in # test cases

- Samurai Contribution:
  - Develop building blocks for wideband, multi-mode test equipments
  - Sort out most significant scenario for early CA deployment
Conclusion

• Main outcomes from Samurai project
  – From a system perspective: CA and MU-MIMO are complementary features of LTE-A
    • Provide clear performance benefits, and can be combined in both DL and UL transmission schemes
    • The achievable gain depends on the deployment scenario, traffic load in the network and the UE capabilities (receiver interference management and measurement feedback quality)
  – From a device perspective
    • Better to start with 2 DL CC, and 1 UL CC
    • Interference aware receiver would become a must
  – From the test equipment perspective
    • LTE-A raise new technical challenges that could be overcome
    • Main challenge is on sorting the scenarios among all the possibilities offered by the standard
  – Feasibility demonstrated on open-air interface prototype
    • …and by actual products from industrial project partners