Multiple-Access Space-Time Coding Test-bed

The Multiple-Access Space-Time Coding Testbed (MASCOT) project develops, analyses, and implements concepts and techniques for Multi-User Multiple-Input Multiple-Output (MU-MIMO) wireless systems. It aims at bringing the full benefits of MU-MIMO communications to systems such as cellular, broadband wireless access, wireless local area, and ad-hoc networks.

At A Glance: *MASCOT*

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Duration: *01/2006 – 12/2008*

Total Cost: *€3,97m*

EC Contribution: *€3,09m*

Main Objectives:

The key objective of the MASCOT Project is to develop, analyse, and implement generic techniques for Multi-User Multiple-Input Multiple-Output (MU-MIMO) wireless systems. The first part of the project is dedicated to developing robust (with respect to propagation conditions) space-time codes, baseband transceiver algorithms, and methods for link adaptation, retransmission, and scheduling which are suitable for MU-MIMO systems. Particular emphasis is put on hardware implementation and complexity constraints. We investigate information-theoretic performance limits of MU-MIMO systems under realistic propagation conditions and we study the tradeoffs between different MIMO gains in the multi-user context. The ultimate goal is the implementation and testing of selected MU-MIMO techniques on the MIMO testbed of ETH Zürich.

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Technical Approach

The MASCOT Project is structured in three technical workpackages (WP), corresponding to the main research fields. Research ranges from space-time code design and transceiver algorithms in WP1, the development of reference designs and hardware implementation of selected algorithms in WP2 to information-theoretic limits analysed in WP3. Two additional workpackages are dedicated to project management (WP5) and dissemination, standardization and training (WP4).

- WP1: **Space-Time Code Design and Baseband Transceiver Algorithms**: The objective of WP1 is to develop and investigate space-time codes and transceiver algorithms for MU-MIMO communications, with particular emphasis on its suitability for efficient hardware implementation. Core research topics are the design of multi-user space-time codes, link layer adaptation, packet transmission scheduling, and baseband transceiver algorithms.
- WP2: **VHDL Library of Reference Designs and Testbed Integration**: The most promising candidate algorithms and architectures developed in WP1 are implemented in hardware as VHDL library of reference designs. Selected algorithms are evaluated, optimized, and demonstrated applying the real-time MIMO testbed at ETH Zürich which is extended to multi-user operation during the course of the project. The reference designs will be pro-actively marketed and may be licensed to interested third parties within WP4.
- WP3: **Performance Limits**: This WP addresses fundamental performance limits of MU-MIMO systems leading to profound understanding of the basic design tradeoffs. Early milestones in WP3 will provide WP1 with criteria for algorithm and code design. Information-theoretic performance limits of MU-MIMO systems are investigated and system design guidelines are developed for cellular and ad-hoc networks.

State of the Art

The following system-level simulation results (taking into account channel properties, physical-layer, and traffic models) were obtained at Iospan Wireless Inc. (now Intel Corp.), where a cellular broadband MIMO system for fixed Broadband Wireless Access (BWA) was developed by some of the MASCOT researchers. Figure 1 illustrates the short-term average throughputs achievable in the downlink in a 2MHz channel with various antenna configurations ($T \times R$ denotes a setup with T antennas at the mobile and R antennas at the base station) across the cell area. The throughput is colour-coded. By going from the 1 × 1 case (not shown here) to the 1 × 2 case, we obtain increased coverage and slightly higher throughput. This increase in coverage is due to the spatial transmit diversity gain realised by space-frequency coding. In the 2 × 3 case, we obtain a further improvement in coverage and a significant increase in throughput which is due to a 2-fold spatial multiplexing gain.

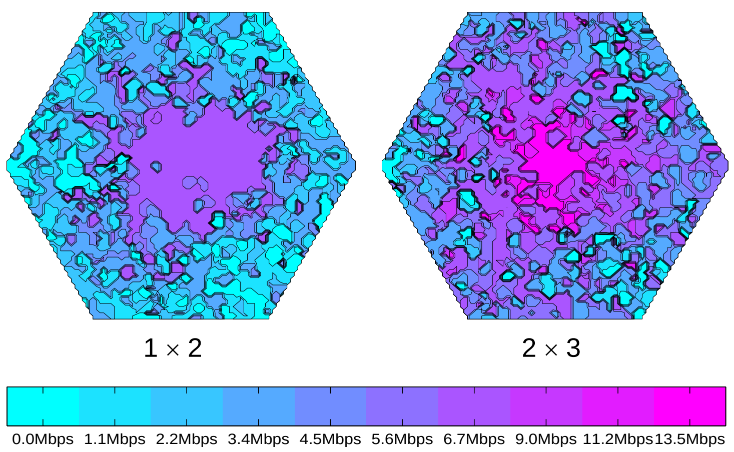

Figure 1: Colour-coded throughput in a MIMO cellular system

Key Issues

While Figure 1 shows that MIMO is capable of achieving significant throughput and link reliability gains in multi-user environments and under real-world propagation conditions, various open issues remain. Engineers designing MU-MIMO systems (in cellular setup as well as ad-hoc mode) face the following questions:

1. What is the system capacity?

2. What are the user capacity and link reliability?

3. How many users can simultaneously be reliably supported with MU-MIMO communications?

4. What are the coverage improvements achieveable through MU-MIMO?

5. What must be altered in the existing cellular infrastructure to deploy MIMO?

6. Can MU-MIMO be implemented in a practical system (computational complexity)? What is the cost?

7. How flexible and scalable are MU-MIMO wireless networks?

8. Can we upgrade current standards and systems to MU-MIMO?

9. Under what channel conditions are MIMO gains realisable?

10. What is the optimal antenna array configuration at the base station and the subscriber unit?

These questions are relevant to all wireless systems employing MIMO techniques, e.g. high-speed WLANs (IEEE 802.11n, including ad-hoc mode), cellular systems (3GPP long term evolution), and BWA systems (IEEE 802.16). MASCOT addresses these questions using a generic approach applicable to all these systems.

Results

Space-time codes are developed which behave robustly under varying propagation conditions. These are coupled to base-band transceiver algorithms, link adaptation, retransmission, and scheduling. Much attention is given to hardware implementation and complexity constraints. This provides partial answers to questions 1–4, and 6–10. The most promising algorithms are implemented in hardware and tested. The key deliverable is a library of VHDL reference designs for MU-MIMO systems. This library may be made available for commercial licensing. We expect that this activity yields partial answers to questions 6–10. Finally, we investigate performance limits and tradeoffs of MU-MIMO systems under realistic propagation conditions. This will partly answer the questions 1–5, 7, 9, and 10.

Expected Impact

Results will be contributed to scientific journals, conferences, and standards, e.g. IEEE 802.11n. MASCOT strengthens the European Information Society 2010 objectives by targeting scalable data rates for wireless broadband access and stable link quality for multiple users.