

Future Embedded System Education

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Necessity is the Mother of Invention

Definition of a complex system

- The whole is more than the sum of its parts
- The problem is too **heterogeneous** and too **complex** to be understood by an individual

Conclusion

- The solution of the problem ultimately requires the interaction of various disciplines

■ Internet of Things: Cognitive Wireless Networks

... must sense or be cognitive of the environment

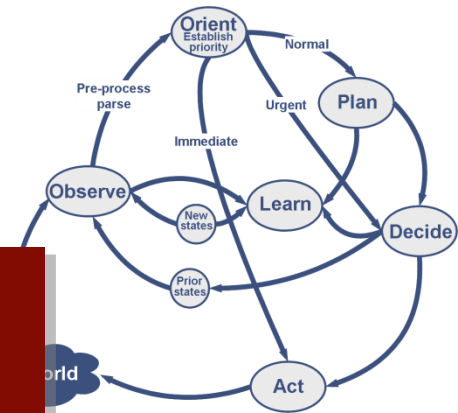
- other user interference, multi-path, noise, etc.
- time-variations

We need a “new system theory”

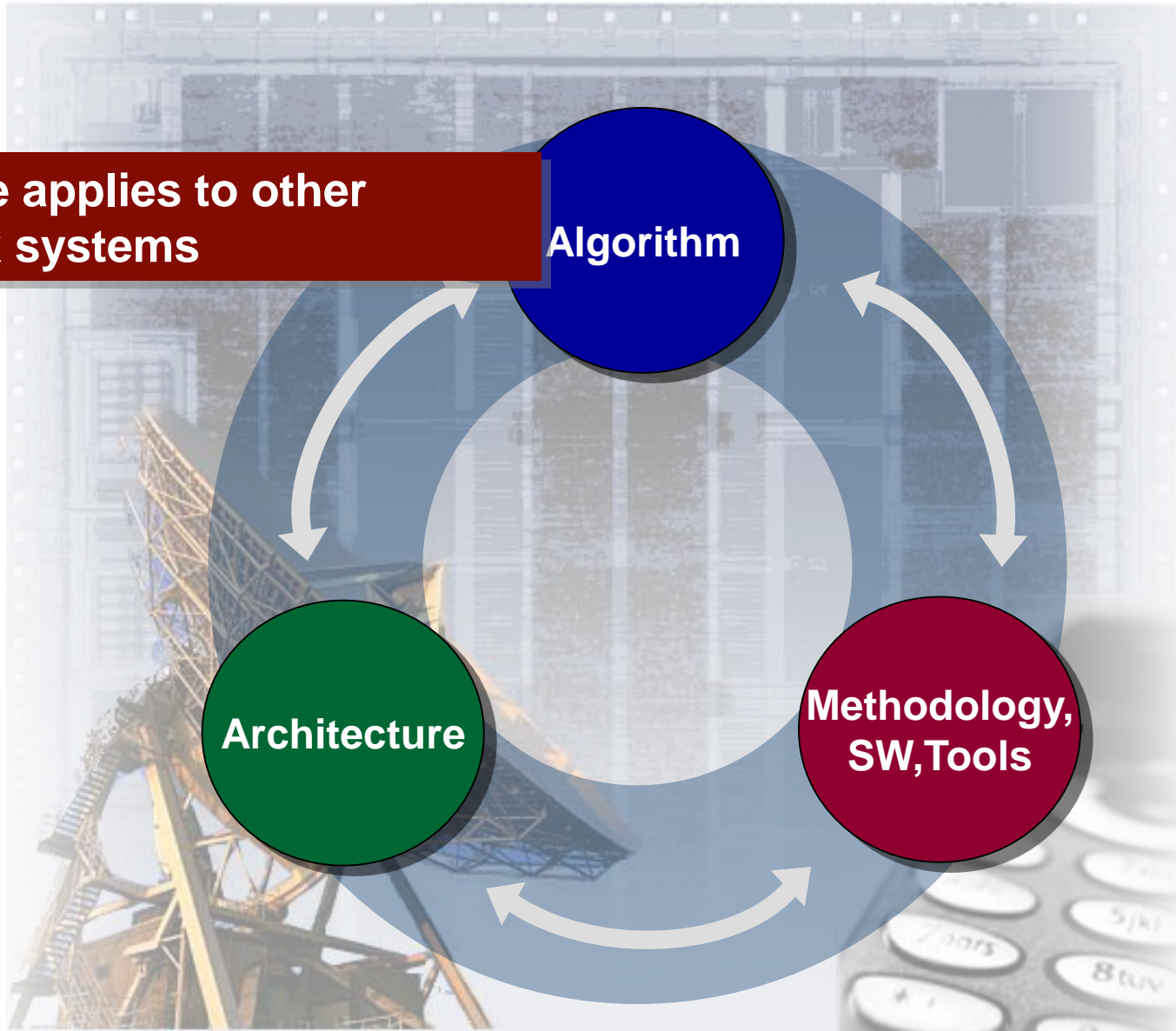
(Nothing is more practical than a good theory)

These radios find the best protocol, frequency band, and transmission mode” leveraging the three driving forces

- Semiconductor technology
- Machine learning and advanced optimization
- Networked system theory



Principle applies to other complex systems



Involvement of Alari Courses

- **Algorithm for Wireless Communications (Meyr)**
 - Class room teaching
 - Lab based on Mathlab
- **Design of embedded Processor (Leupers, Meyr)**
 - Class room teaching
 - Lab based on „LISA Porcessor designer“ (Synopsys)

Design - Methodology

**Mathematical Theory and Experiment
are complementary**

Design - Methodology

Mathematical theory provides bounds

- 1 Estimation and detection theory used to systematically derive (optimum) receiver structures

➔ Synthesis

- 2 Mathematical analysis used to compute performance bounds

➔ Analysis

Design Methodology

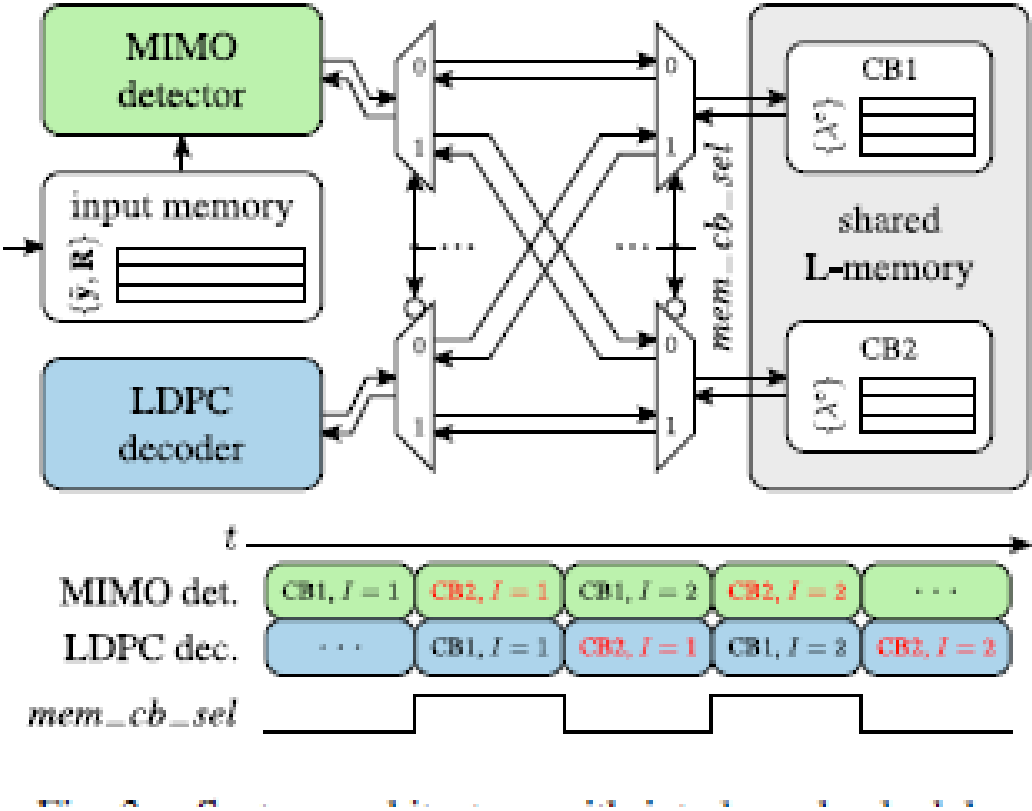
Computer simulation is used to

- 1 Obtain numerical performance data**
 - **Detection Loss**
 - **Implementation Loss**
- 2 Validate a design
(conformance to standards)**
- 3 Verify correctness of implementation
(verification) against testpattern**

Design Methodology

- **Optimal receiver structures must be systematically derived by solving an optimization problem because**
 - We obtain fundamental insight into receiver algorithms. (It is not only interesting to know „how“ but also „why“)
 - we can demonstrate that the ad-hoc conceived algorithms are special cases of the systematically derived algorithms
 - we obtain practical receiver algorithm as the result of approximations to the optimization problem

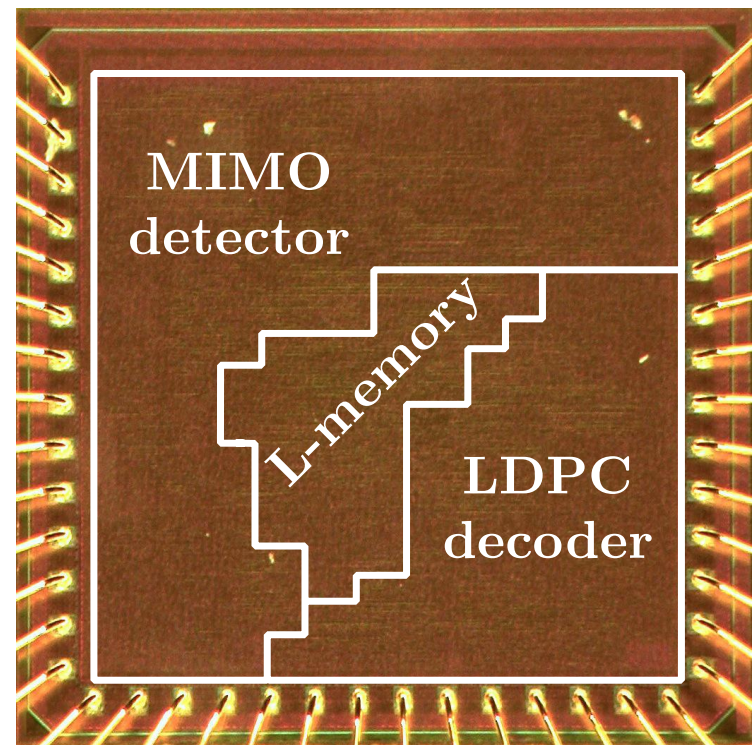
Iterix: Iterative MIMO Decoder and Detector Chip



³ Borlenghi et al., A 2.78mm² 65nm CMOS Gigabit MIMO Iterative Detection and Decoding Receiver, ESSCIRC 2012

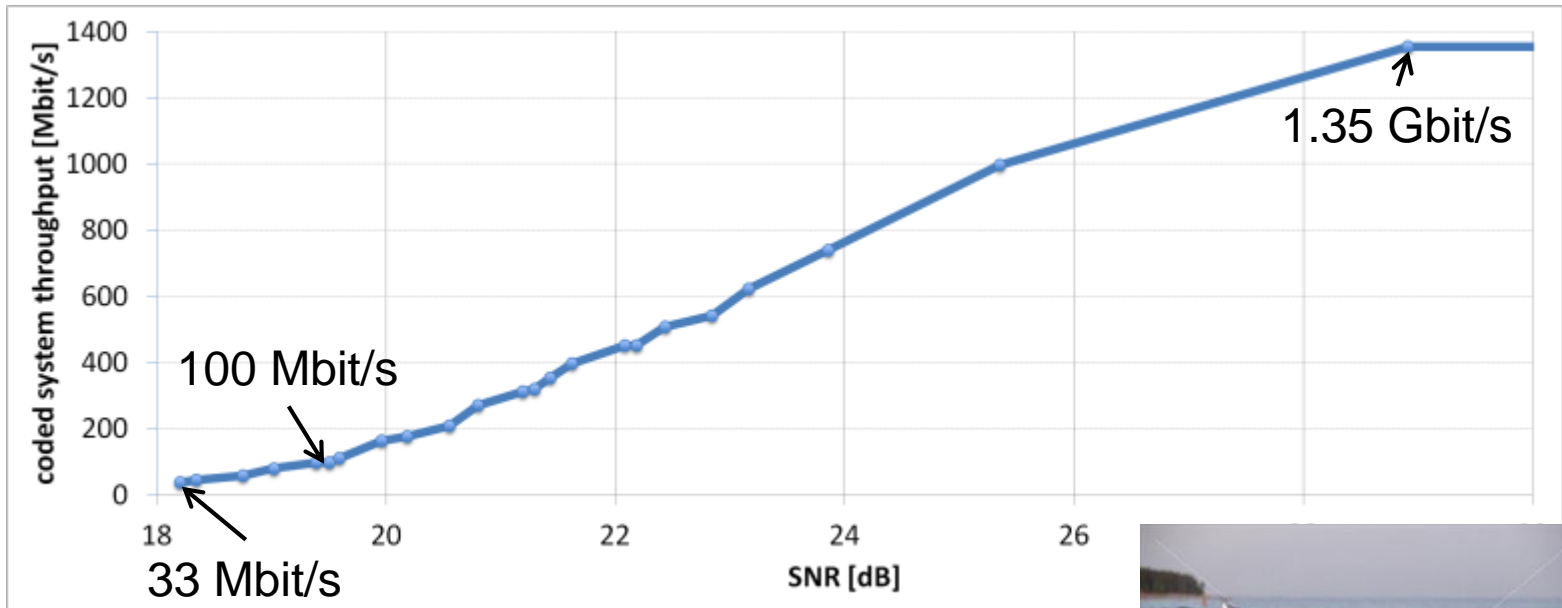
Implementation Results

- **First silicon implementation of MIMO IDD baseband³**
- **Core area: 2.78 mm² (1.58 MGE) in low-power 65 nm technology**
 - Detector (5 SDs): **872 kGE (55%)**, 140 to 145 kGE / SD
 - Decoder: **447 kGE (28%)**
 - LLR memory: **210 kGE (13%)**
- **Runtime flexibility**
 - {2x2, 3x3, 4x4} antennas
 - {4, 16, 64} QAM
 - All 802.11n LDPC codes
- **Max. frequencies @ 1.2 V**
Detector: **135 MHz**
Decoder: **299 MHz**
- **Avg. power (4x4, 64 QAM)**
Detector: **175 to 245 mW**
Decoder: **120 to 140 mW**
- **Max. throughput > 1 Gbit/s**

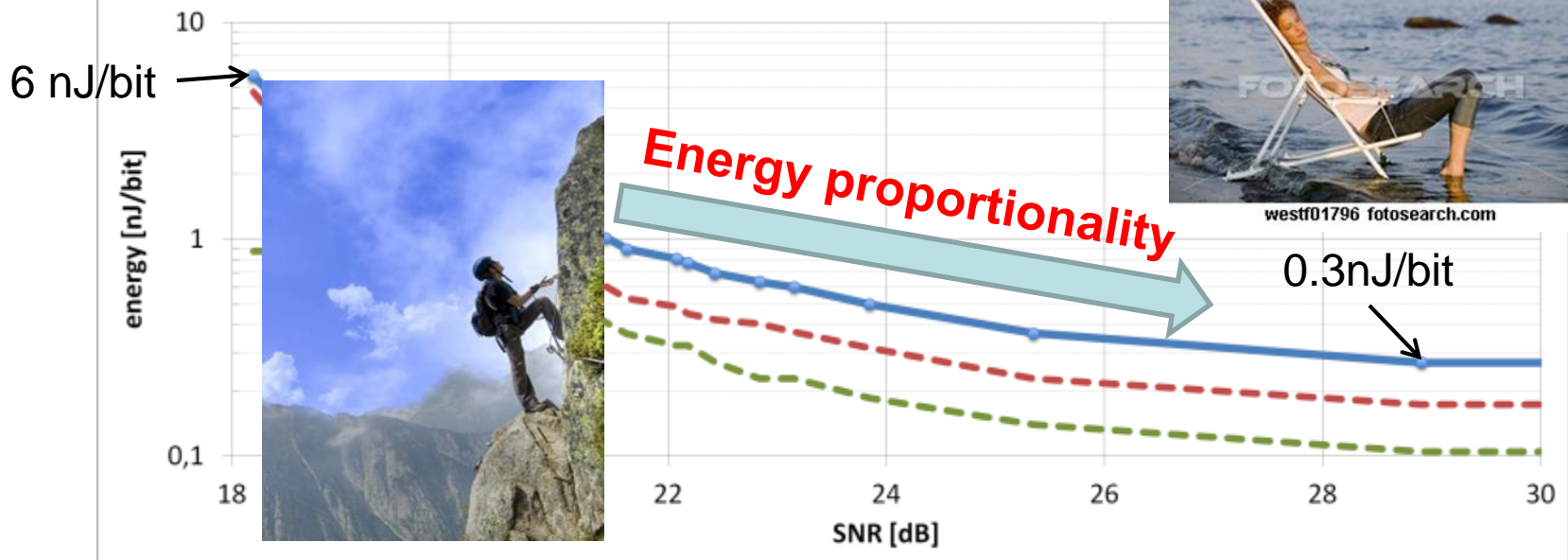


³ Borlenghi et al., *A 2.78 mm² 65 nm CMOS Gigabit MIMO Iterative Detection and Decoding Receiver*, ESSCIRC 2012

Throughput and Energy Efficiency



westf01796 fotosearch.com



Summary

- **Still too much „additive“ teaching**
- **Eliminate some courses of little relevance today**
- **Teach more problem solving skills**
- **Use case studies to show the interplay of knowledge areas**
- **Do not overload the curriculum with fashionable soft-skill courses**

Thank you

- **People (“the human nature”)**
- **Identify an attractive goal and define a “win-win” situation for the participating disciplines**
- **Management structure**
 - Administration
 - Leadership
- **Joint lab**