Future Embedded System Education

Alari Nano-Tera Workshop , June 25, 2014

Heinrich Meyr

Grand Professor, Center for Advancing Electronics TU Dresden

cfaed CENTER FOR ADVANCING ELECTRONICS DRESDEN

RWTH AACHEN UNIVERSITY

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

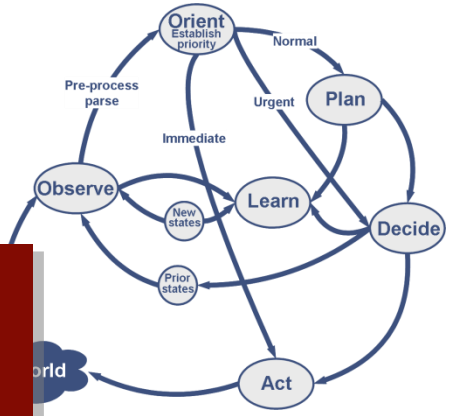
Conclusion

- 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



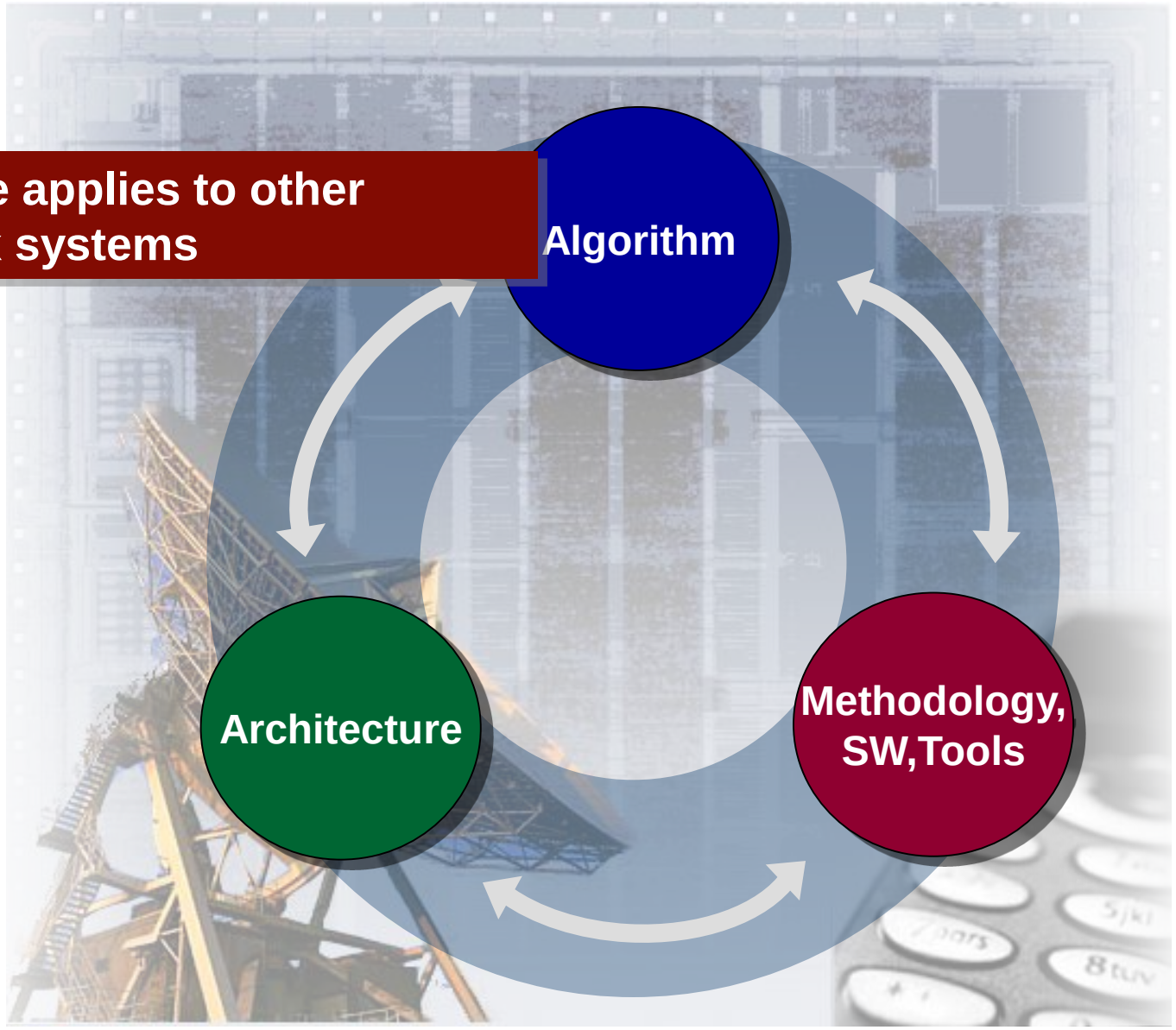
We need a "new system theory"

(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)

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**

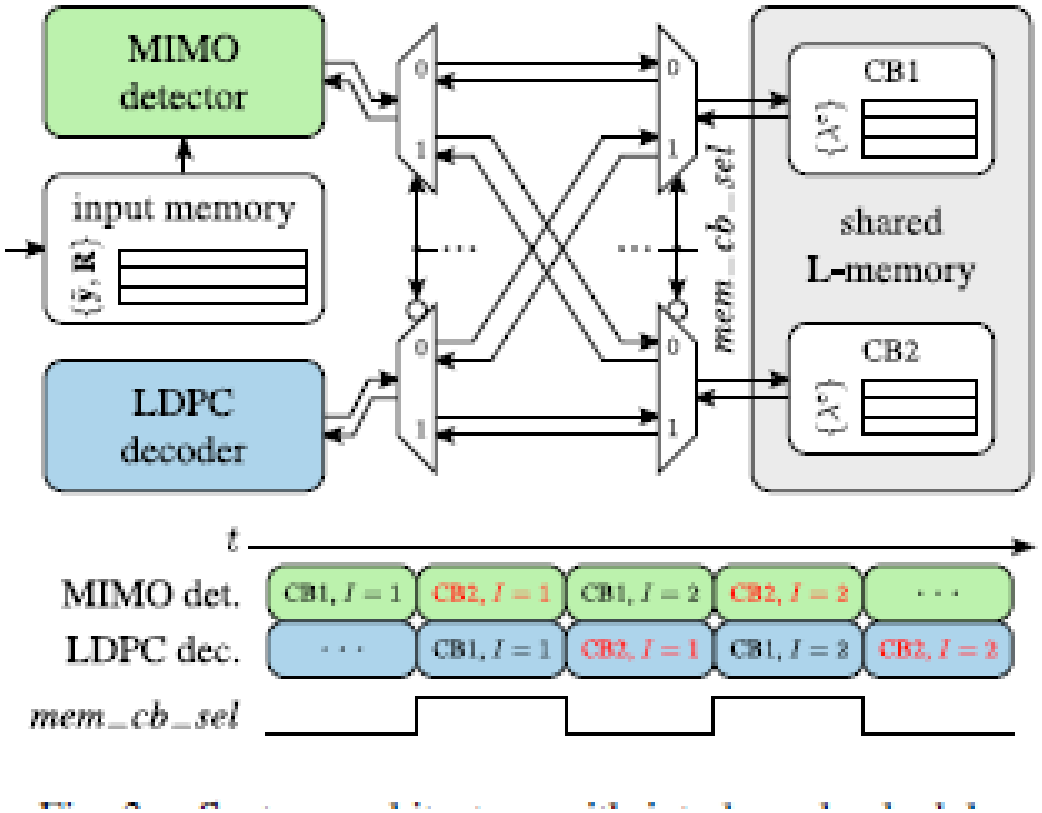
2. **Validate a design (conformance to standards)**

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



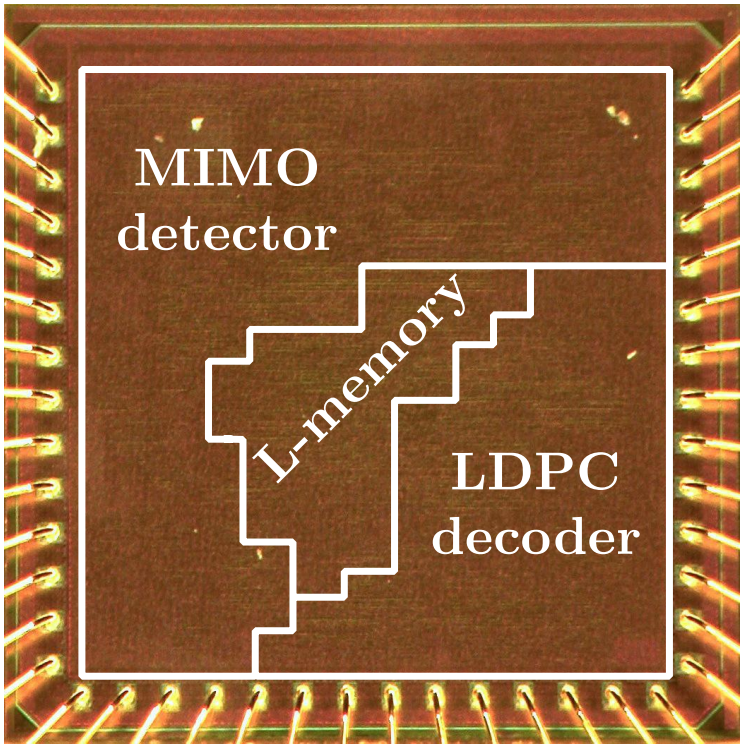
[3] Borlenghi et al., *A 2.78 mm² 65 nm CMOS Gigabit MIMO Iterative Detection and Decoding Receiver*, ESSCIRC 2012

Implementation Results

- **First silicon implementation of MIMO IDD baseband[3]**
- **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**

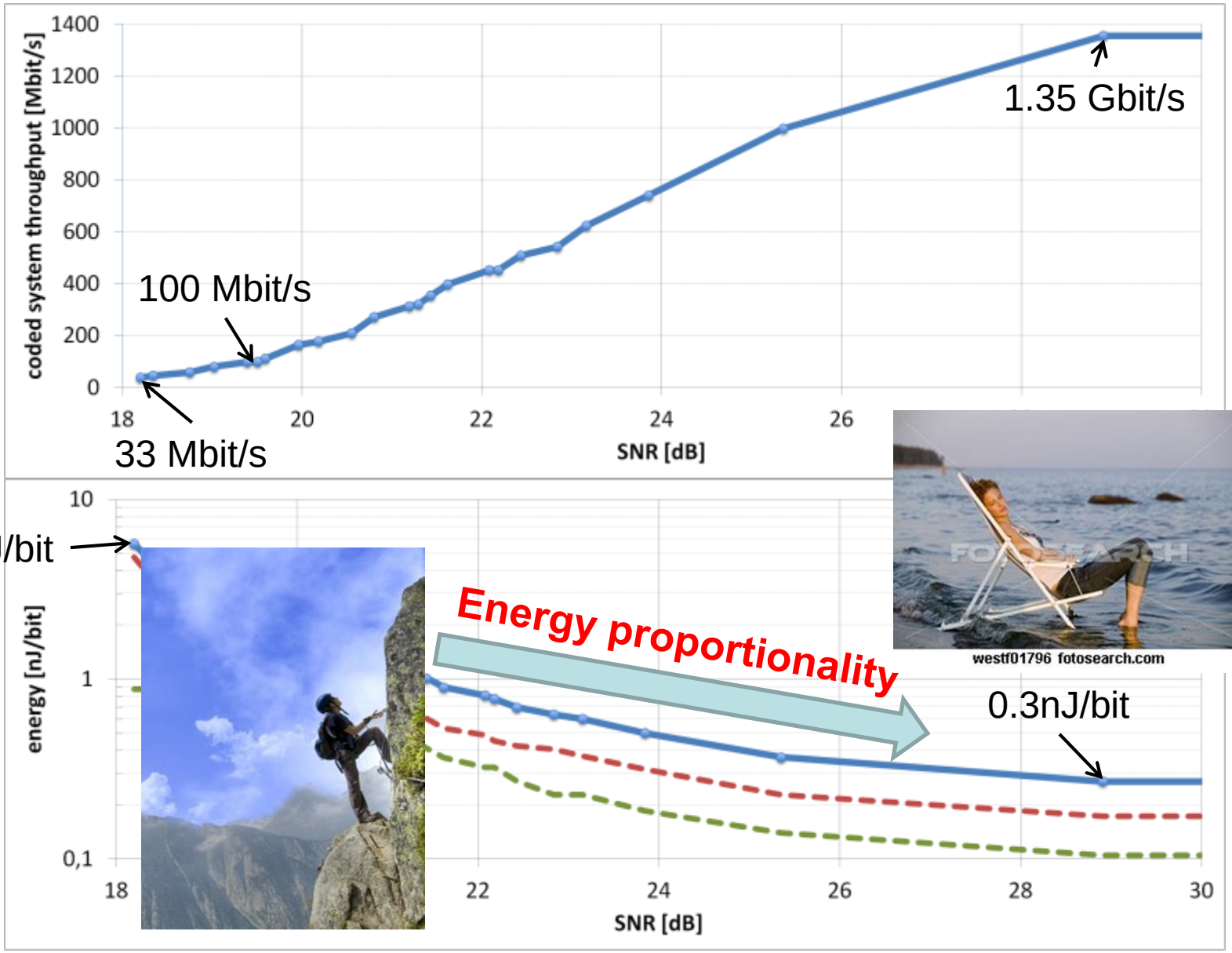
  Detector: **135 MHz**
  Decoder: **299 MHz**
- **Avg. power (4x4, 64 QAM)**

  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



4x4 64-QAM, block length 1944, code rate 1/2

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**