Embedded System Design and Modeling

Introduction to Embedded Systems Design

What are Embedded Systems?

- Embedded System (Marwedel): Embedded systems are information processing systems embedded into enclosing products.
- Cyber-Physical Systems (Lee & Seshia): A CPS is an integration of computation with physical processes whose behavior is defined by both cyber and physical parts of the system
- Key points:
  - there is a physical process to be controlled
  - there is some computational device who controls it
  - the processing is **close** to the physical process:
    - spatially: done right there (embedded)
    - behavioral: dedicated / specific to a particular process

What are Embedded Systems?

- Synonyms (more or less):
  - Embedded Systems
  - Internet of Things (IoT)
  - Industrial Internet
  - Systems of Systems
  - Industry 4.0
  - Internet of Everything (IoE)
  - Smart

  $\approx$ Cyber-Physical Systems

Found everywhere

- Embedded systems are everywhere:
  - Automotive (Transportation industry)
  - Telecommunications
  - Medicine
  - Consumer electronics
  - ...

Common characteristics

- Embedded systems share common characteristics:
  - must be **dependable**
    - reliability: probability that a system will not fail
    - maintainability: probability that a failed system can be repaired
    - safety: does not cause any harm even in worst-case conditions
    - security: allows authentication and confidentiality of data
  - must be **efficient**
    - low power consumption
    - low weight
    - low cost
    - no unnecessary resources used

Common characteristics

- Embedded systems share common characteristics:
  - must satisfy strict timing constraints
    - most embedded systems operate in real-time
  - must be fault-tolerant

Embedded systems vs PC

- Aren't embedded systems just "small PC's"? No.

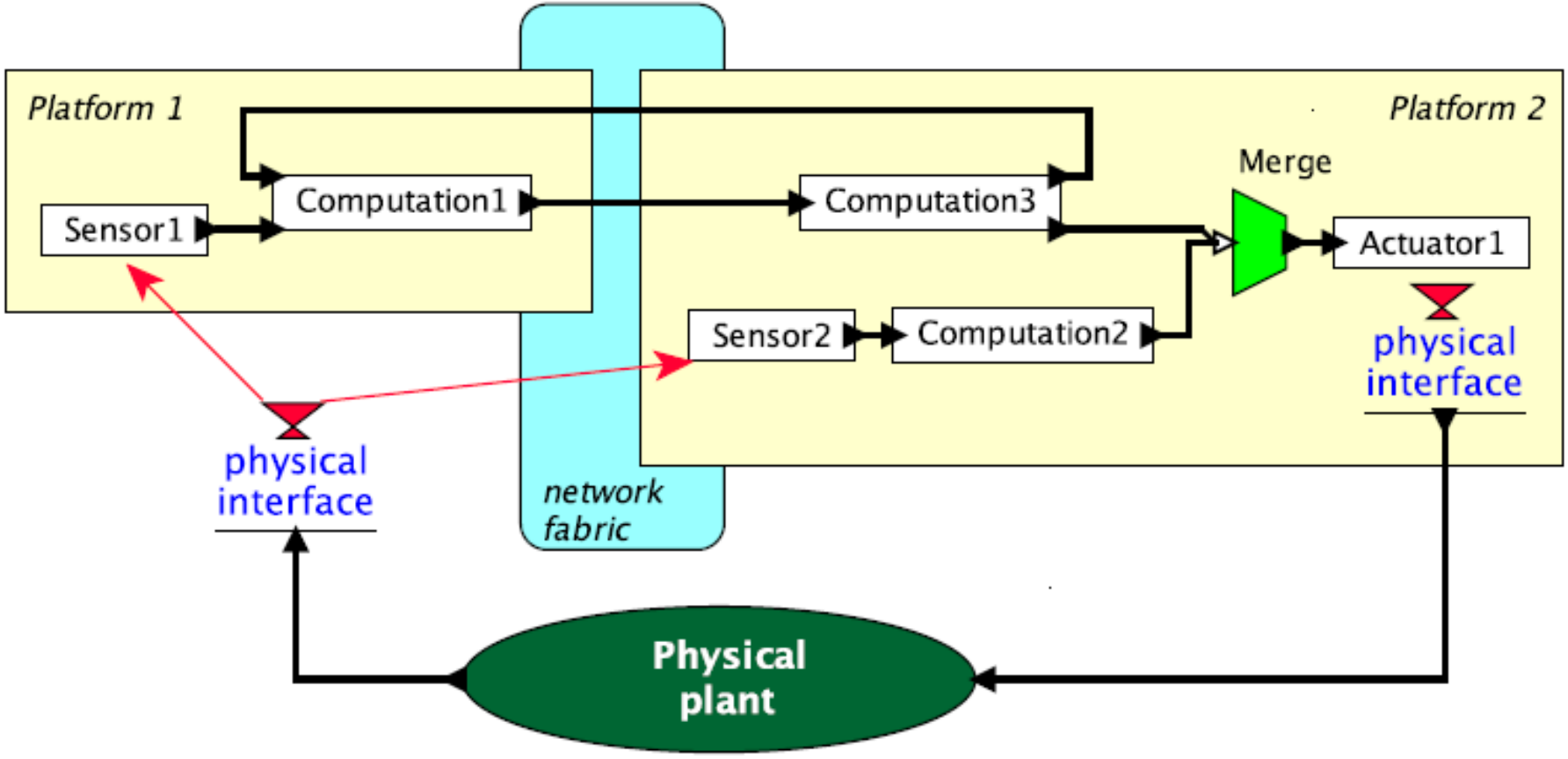
	Embedded	PC-like
Architectures	Frequently heterogeneous very compact	Mostly homogeneous not compact (x86 etc)
x86 compatibility	Less relevant	Very relevant
Architecture fixed?	Sometimes not	Yes
Model of computation (MoCs)	C+multiple models (data flow, discrete events, ...)	Mostly von Neumann (C, C++, Java)
Optim. objectives	Multiple (energy, size, ...)	Average performance dominates
Real-time relevant	Yes, very!	Hardly
Applications	Several concurrent apps.	Mostly single application
Apps. known at design time	Most, if not all	Only some (e.g. WORD)

Figure 1: Embedded Systems vs PC

- Image from Marwedel 2011

Structure of an embedded system

- Typical structure of an embedded system (CPS)



- Image from Lee&Seshia 2017

Structure of an embedded system

- Main components:
  - the physical process (known as the “plant”)
  - sensors: acquire information from the process
  - actuators: act on the process
  - computation: may be split between different devices
  - communications: between separate devices

The design process

- Iterative:
  - Modeling
  - Design
  - Analysis
  - ... and iterate again.