



# Cyber-Physical Systems: Fundamentals

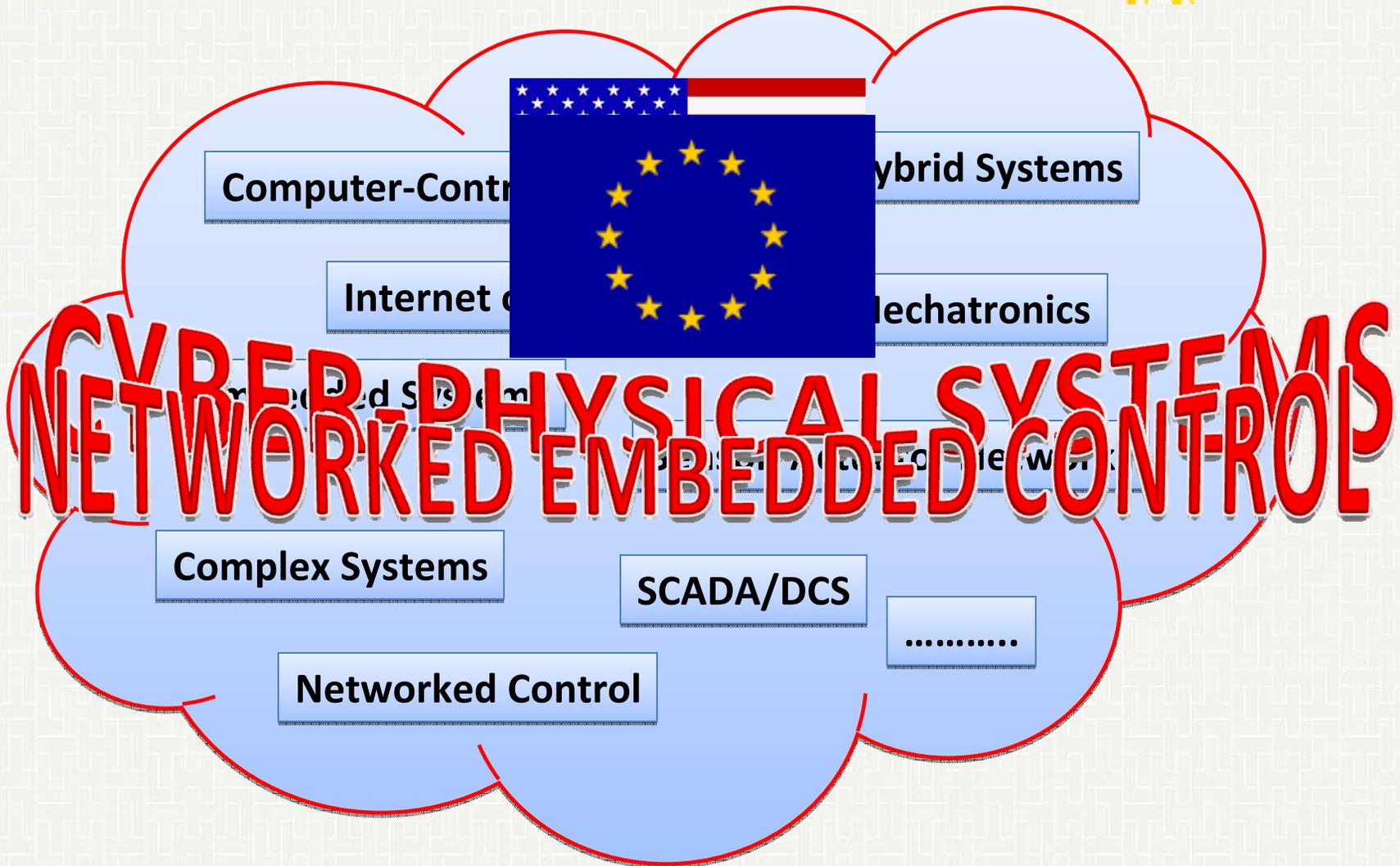
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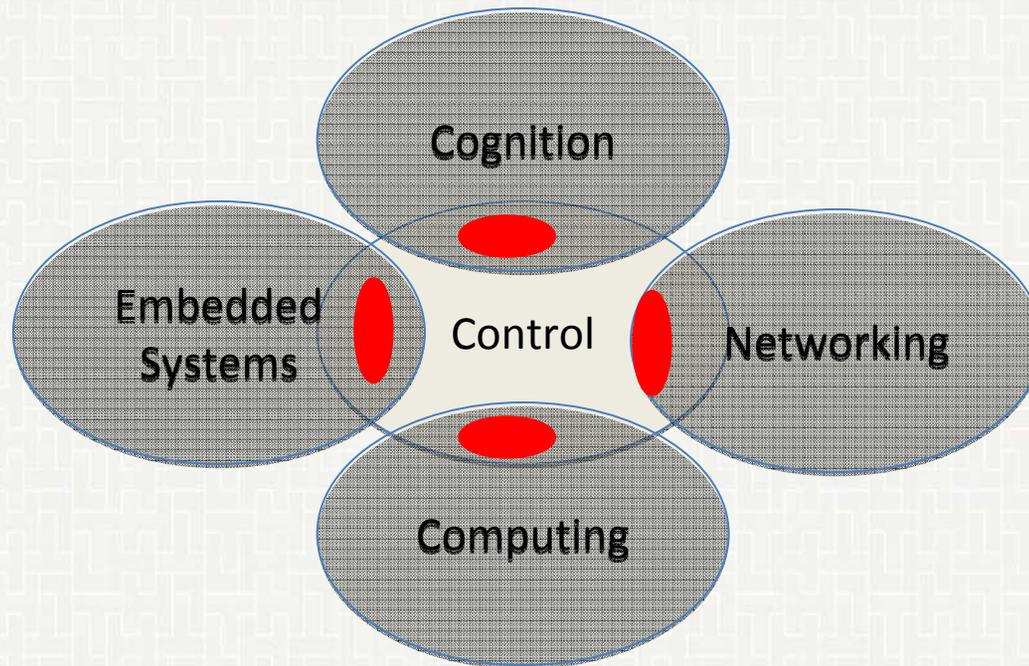
Nothing new ....



# So what is the difference?

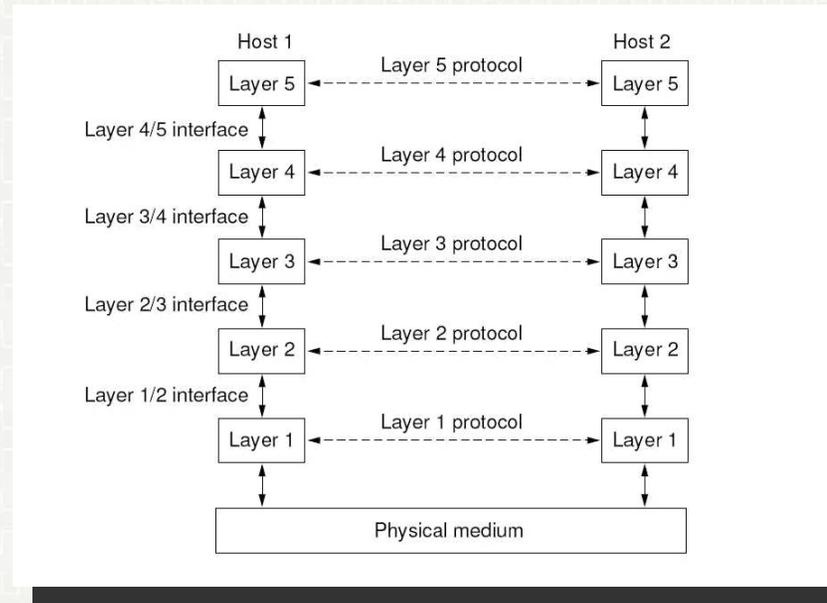
- Increased pervasiveness
- More autonomy
  - Higher complexity
  - Mixed criticality
  - More software
  - Large variations in use cases
- More network-centric
  - Distributed and decentralized
- More sensor-centric
- Several Models of Computation must be combined
- Increased power-awareness
  - Sensor networks -- laptops -- server farms

# A General Theory for CPS?



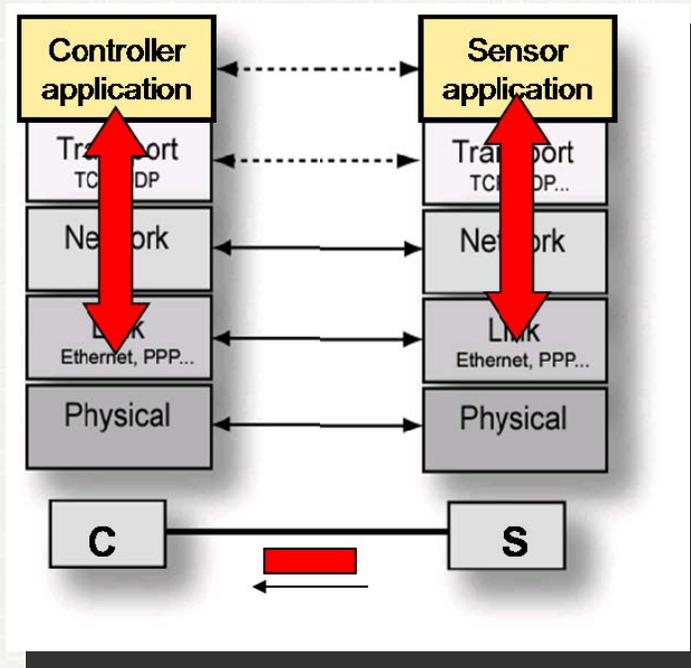
- CPS is the combination of several theories from different disciplines
- The new is found in the overlaps → co-design!
- However, we must keep in mind of that our engineers and students are not superhumans → packaging!!

# To layer ....



- The layered ISO/OSI stack is one of the major reasons for the success of the Internet - separation of concerns
- Layered architectures are needed also in other areas
  - Software
  - Control

# ... or not to layer?



- However, in resource-constrained applications cross-layer designs are necessary in order to meet non/extra-functional properties
  - Timeliness, power consumption, ....
  - Integration of concerns

# Excellent Prospects for Control

- Static worst-case designs increasingly difficult
  - Hardware advances (multi/manycore, MPSoC, NoC, ReMPSoc, ....)
  - Process variability
  - ➔ **Feedback**
- Need for adaptivity
  - Changes in load/traffic
  - Changes in usage patterns, objectives
  - ➔ **Feedback**
- Power and temperature control
  - DVS, DPM, temperature control, temperature gradient control
  - Embedded systems, multicore, server farms
  - ➔ **Feedback**



# What about Safety-Critical Systems?

- In many cases control systems
- Due to the feedback errors in the space domain are natural
- Control system designed using
  - Numerous approximations
    - Model reduction, linearization, .....
  - Verified through extensive simulations
  - Large safety margins when selecting, e.g., sampling periods
- **Why is it then so unthinkable to use feedback also at the implementation level?**



# Robotics as CPS

- Industrial robots are standard in manufacturing today (CPS)
  - Still rather inflexible
- Mobile robots, alone or in teams, is a very active research area (CPS)
  - Mainly passive interaction with the environment



# Mobile Manipulation

- Industrial robotics + mobile robotics
- One or several arms mounted on a moving platform
- From reconfigurable robot cells to applications that require close coordination between arm control and platform motion (interacting forces and friction)
- Applications:
  - Shop assistant
  - Service robots in assisted living
  - The Robot "HandyMan"
  - Complex manufacturing
- Tremendous challenges for robotics, control, and embedded systems

