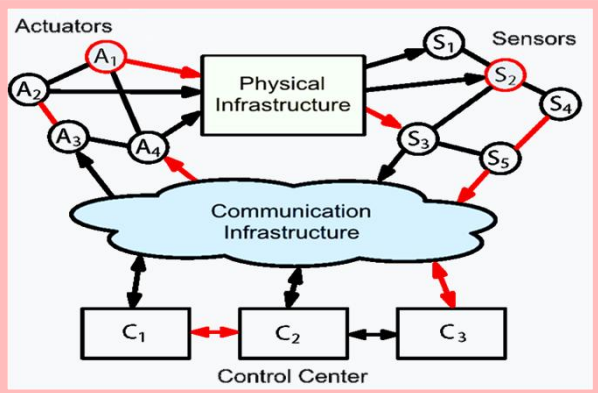
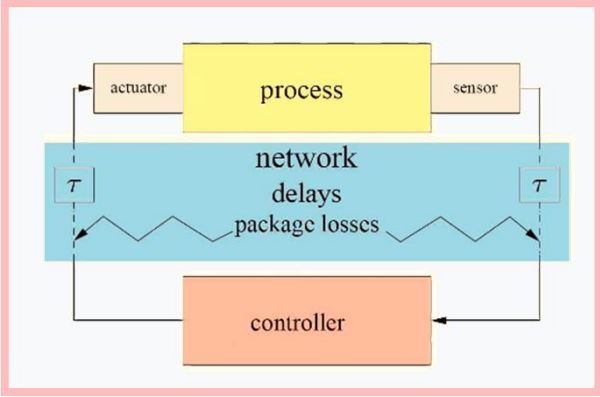
Advanced Networking and Security Research Lab
Affiliated with the University of Tehran & Deakin University

Networked Control Systems

Control & IoT

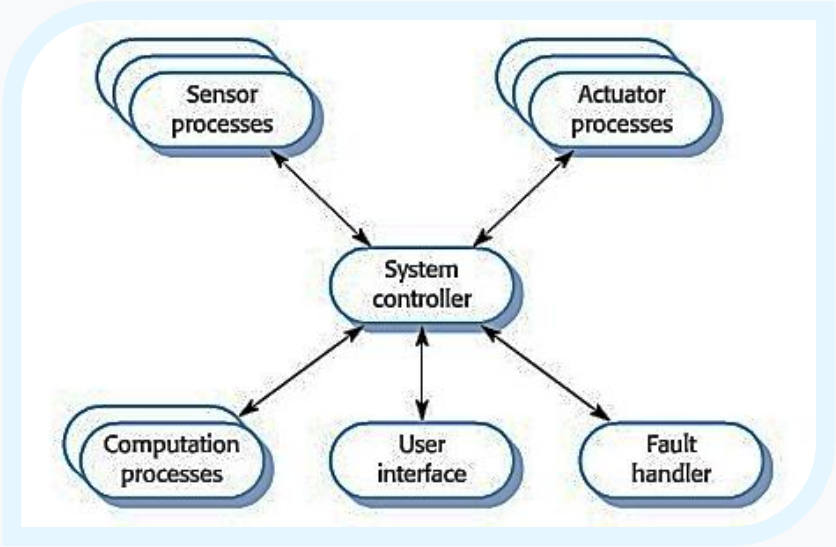




Dr. Farivar

Aug. 2017

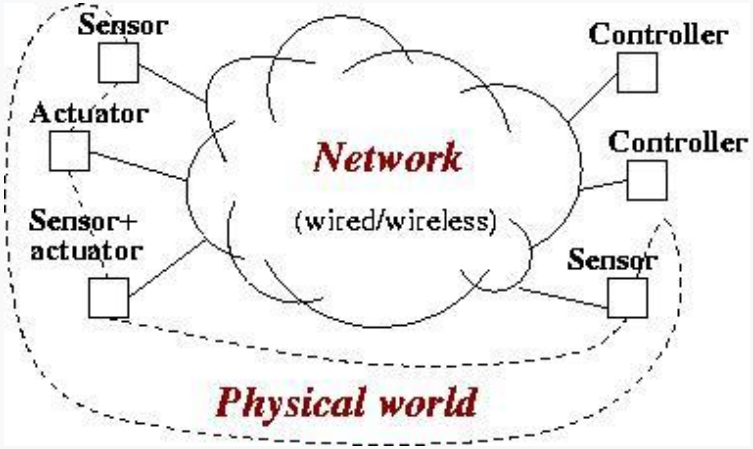
Motivation

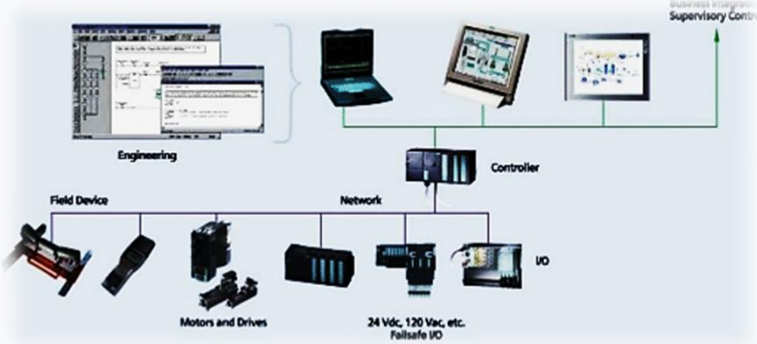


Centralized Control System

- High computational complexity
- Distribution of sensors over vast geographical region
- Long delays & Loss of data
- Harder to adapt to large-scale systems
- It is not robust to interactions between subsystems

Motivation





Decentralized / Distributed Control System

- Large-scale system is decomposed into N subsystems.
- Geographical distribution
- Constraints
- Measurements availability, weak coupling between the sub-systems,etc.
- Scalability, Robustness, Adaptability, and Computational Efficiency.

Motivation

- Technological Advances in Wireless Communication
- Decreasing in Cost and Size of Electronics

The system are distributed with communicating over network.

Networked Control System (NCS)

Motivation

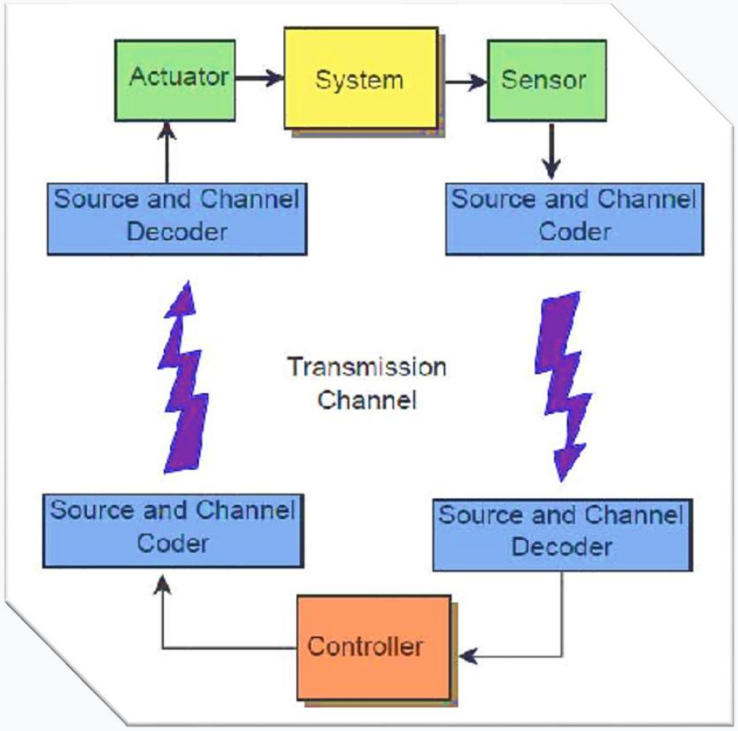
Networked Control System (NCS)

Problems

It may effect the control process;

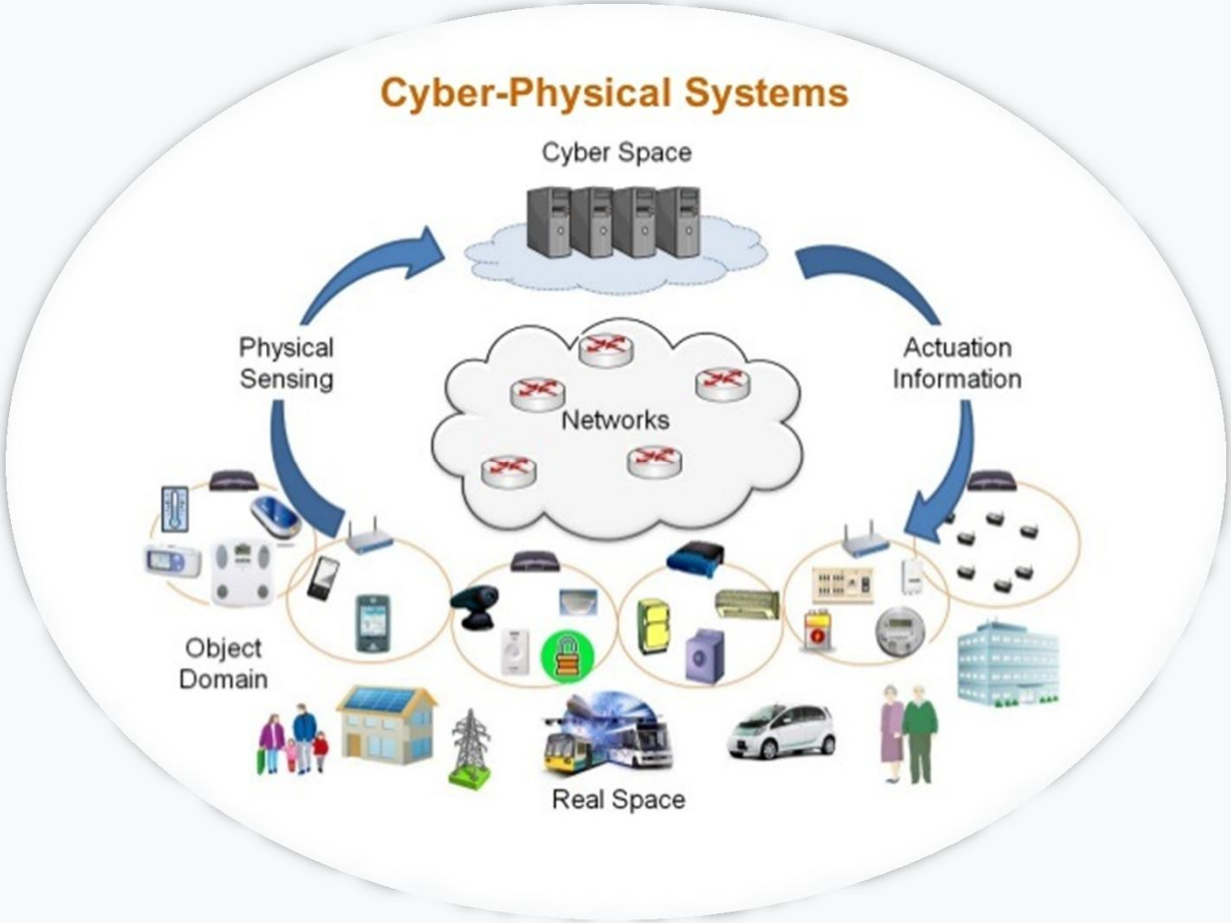
- Destabilizing the control
- Deteriorating the performance

- Time Delay,
- Packet Losses (dropouts),
- Quantization,
- etc.



Motivation

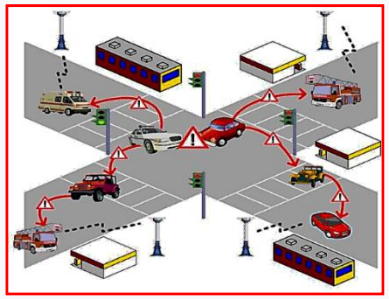
Applications for Decentralized / Distributed NCS

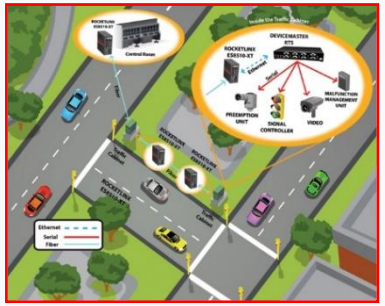


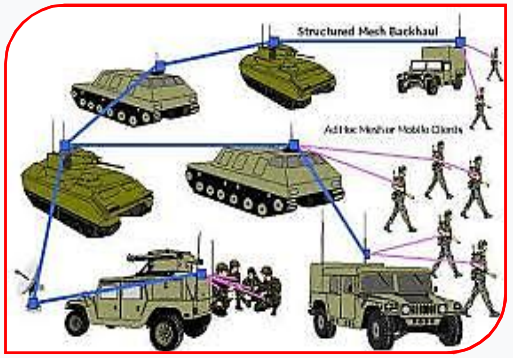
Motivation

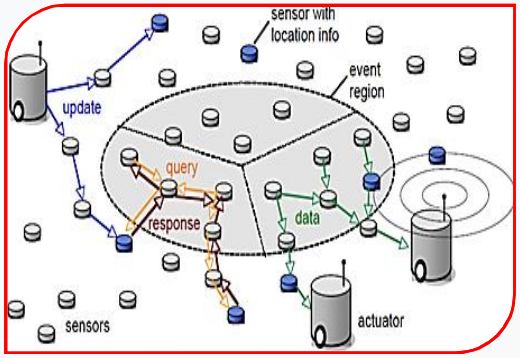
Applications for Decentralized / Distributed NCS

- Traffic Networks
- Mobile Control Applications
- Water Transportation Networks
- Distributed Energy Resources and Micro-grids
- etc.







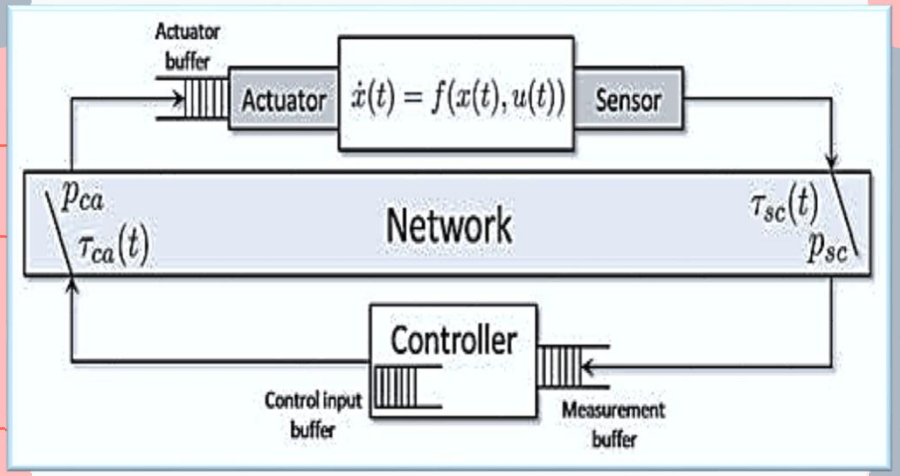


Control & IOT (Networked Control Systems)

Control of Cyber Physical Systems

✓ Advantages

- Cheap
- Fast
- Easier to distribute over vast geographical areas.



✗ Disadvantages

- Not free of charge
- Limitations of communication networks

Models of Packet Dropouts

Stochastic Models

1. Bernoulli

$$\Pr(\theta_k = 0) = p \text{ and } \Pr(\theta_k = 1) = 1 - p$$

2. Markov Chain

$$\Pr(\theta_k = 0 | \theta_{k-1} = 1) = p \text{ and } \Pr(\theta_k = 1 | \theta_{k-1} = 0) = q$$

3. Poisson

$$\Pr(N_{[t,t+\tau)} = k) = \frac{e^{\lambda\tau}(\lambda\tau)^k}{k!}$$

Deterministic Models

1. Time averages

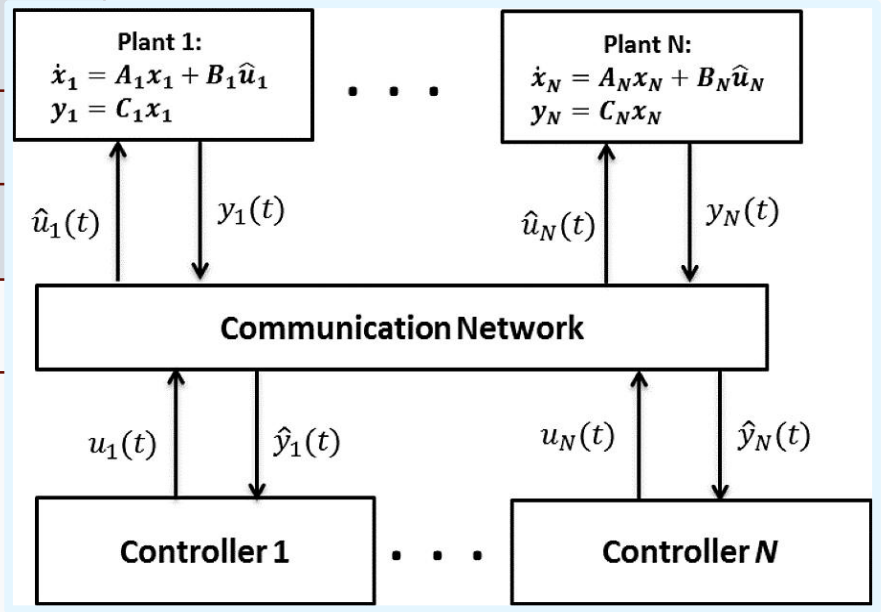
$$\eta := \lim_{T\to\infty} \frac{1}{T} \sum_{k=k_0}^{k_0+T-1} (1 - \theta_k), \ \forall k_0 \in \mathbb{N}$$

2. Arbitrarily drops (the worst case)
The number of consecutive packet drops is bounded and integer

Decentralized / Distributed Control Systems

Decomposition & Decentralization of Large-Scale Systems

- State- Space Model
  - Input/Output-Oriented Model
    - Decoupled
    - Input Decentralized
    - Output Decentralized
  - Interaction-Oriented Model



Decentralized / Distributed Network Control

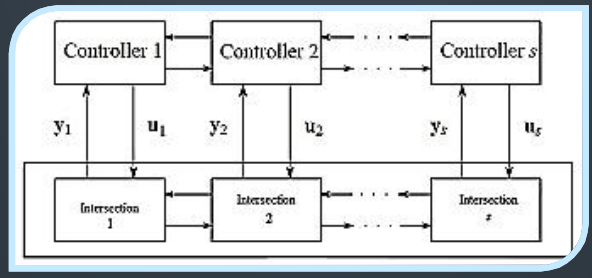
Decomposition & Decentralization of Large-Scale Systems

Decentralized Controllers

Controllers can not exchange information between each other.

Distributed Controllers

Controllers can exchange information with each other.



Decentralized / Distributed Network Control

Graph Representation of Decentralized Controllers

Block diagonal matrix

Controllers can access only the output to generate the control signal.

(Fully decentralized controllers)

Nearly Block diagonal

Controllers can have access to several outputs.

(Quasi-decentralized controllers)

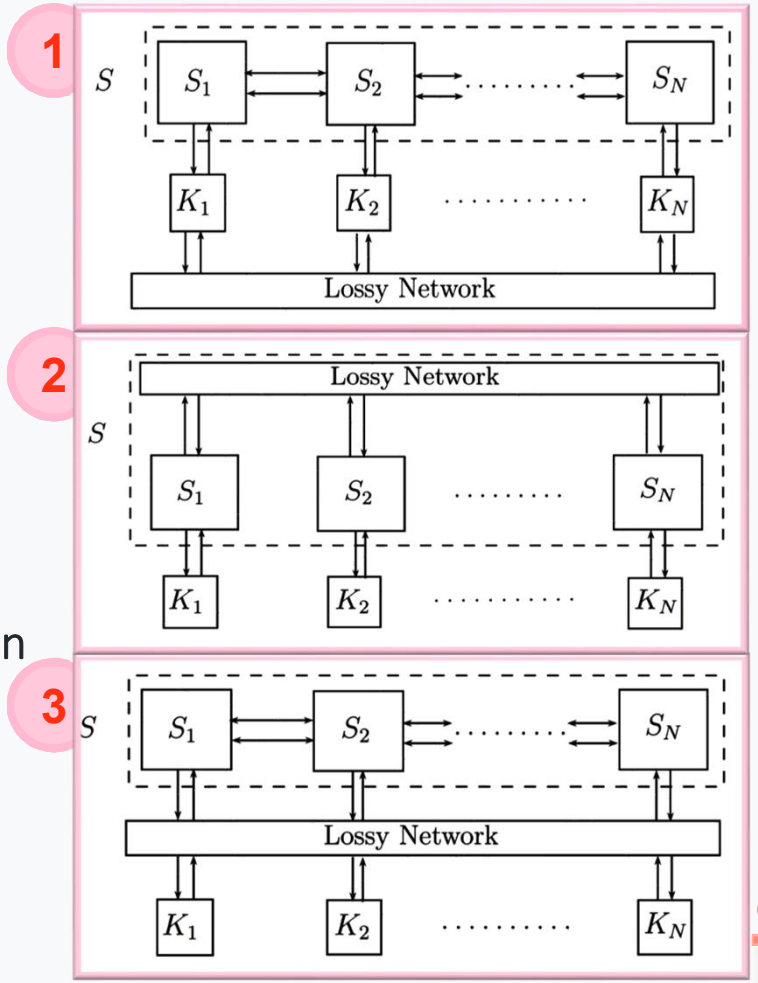
Decentralized / Distributed Network Control

Configurations of Decentralized/Distributed NCS

① Controllers communicate with the subsystems through a network.

② The systems interact with each other through a network.

③ Controllers exchange information through a network.



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