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BASICS OF SENSOR NETWORKS

Dr. H. K. Verma

Distinguished Professor (EEE)
Sharda University, Greater Noida

(Formerly: Deputy Director and Professor of Instrumentation
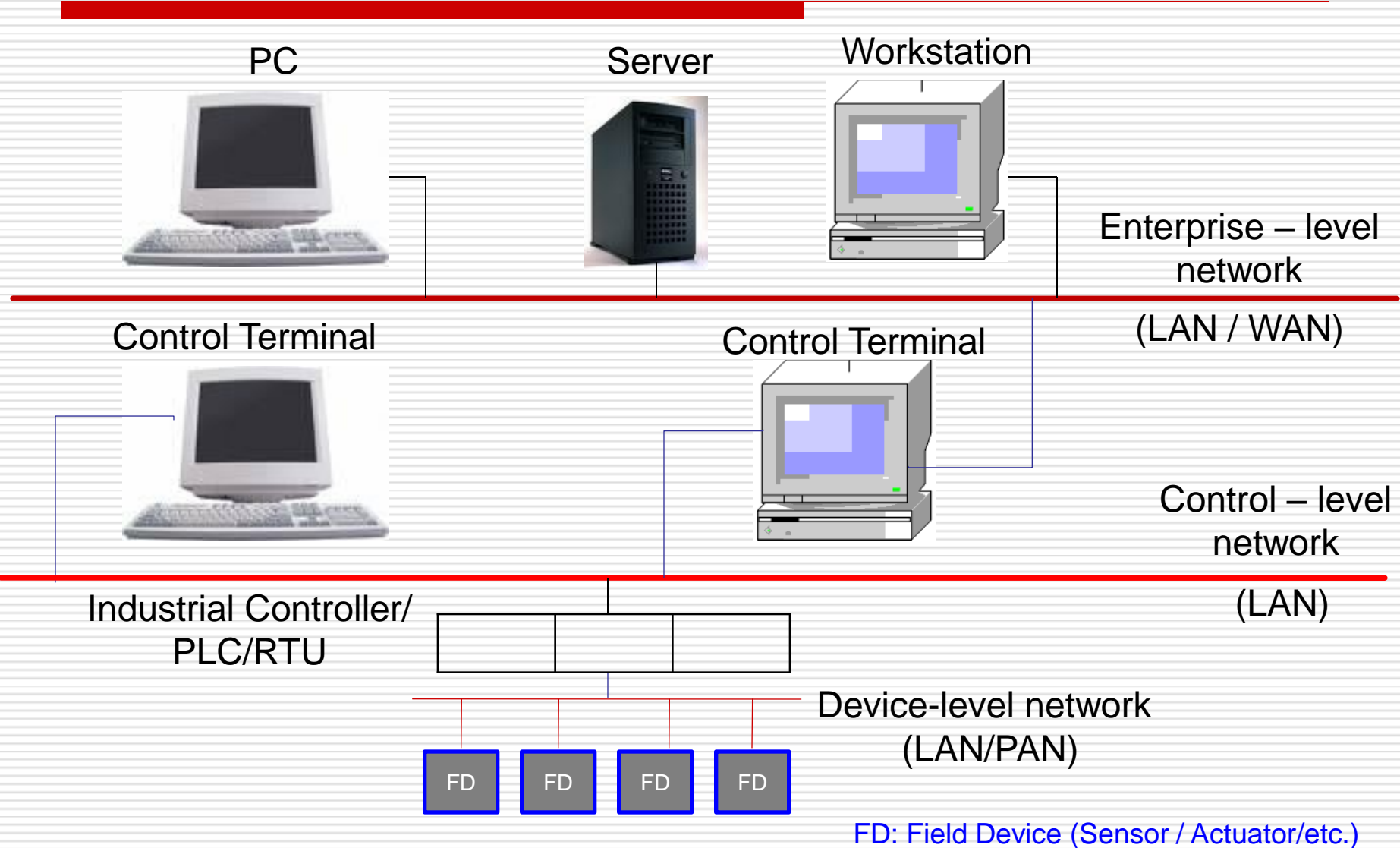Indian Institute of Technology Roorkee)

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1. Industrial Data Networks

2. LAN Topologies

3. Device Level Networks

4. 7-Layer OSI Model of Communication System

5. Networking of Sensors

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Industrial Data Communications

❖ Communication among computers/ servers/ work-stations

❖ Communication between computer and peripherals

❖ Communication between computer and intelligent instruments

❖ Communication among field devices (Factory-floor or field communications) using:
  ➢ Transducer networks or Sensor networks, or
  ➢ Field-device networks or Device-level networks, or
  ➢ Sensor and actuator networks, or
  ➢ Factory-wide networks

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Hierarchy of Industrial Data Networks

PC

Server

Workstation

Enterprise – level network

(LAN / WAN)

Control Terminal

Control Terminal

Control – level network

(LAN)

Industrial Controller/ PLC/RTU

Device-level network (LAN/PAN)

FD   FD   FD   FD

FD: Field Device (Sensor / Actuator/etc.)

Data Networks in Industry

❖ **Enterprise Network**

Network of the PCs, workstations and servers in Offices and the control terminals (PCs) in Control Room.

❖ **Control-Level Network**

Network of the control-terminals (PCs) and industrial controllers (PLCs), which are either in Control Room or on Factory Floor.

❖ **Device-Level Network**

Network of a controller/PLC/RTU in Control Room with its field devices (Sensors, Actuators, etc.) on Factory Floor.
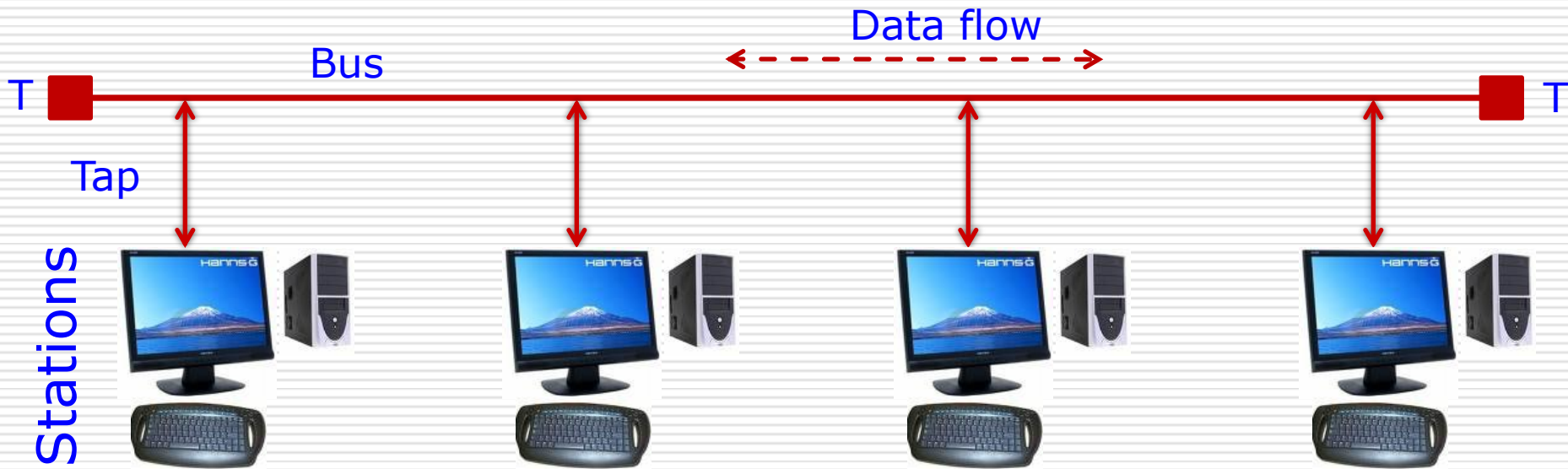
LAN Topologies

❖ Basic Topologies

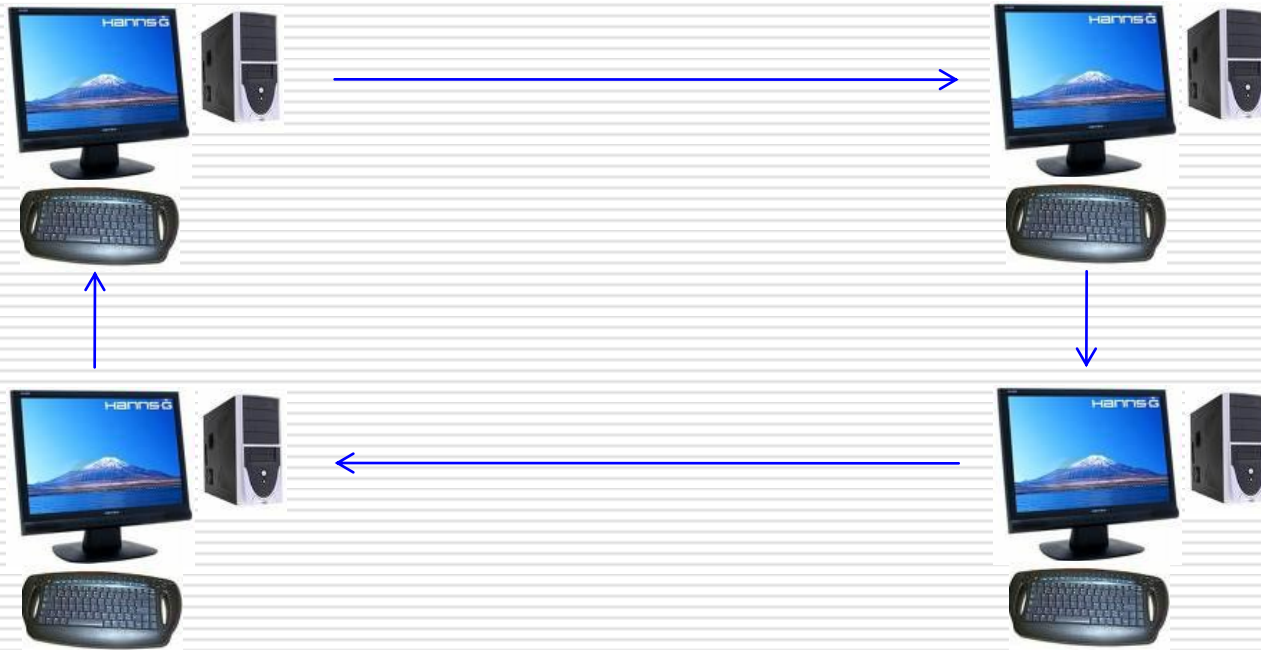   1. Point-to-Point
    2. Multipoint

❖ Multipoint Topologies

    1. Bus
    2. Ring
    3. Star
    4. Tree
    5. Mesh

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Bus (or Multidrop)Topology

- ❖ Bus is a linear transmission medium
- ❖ Data flow is bidirectional
- ❖ Stations connected through taps taken from bus
- ❖ Terminator (T) absorbs signal, thus avoids echos

Ring (or Loop)Topology

- ❖ Nodes (computers) are connected in tandem (series) to form closed loop
- ❖ Data flows through nodes (computers)
- ❖ Data flow is unidirectional
- ❖ Each node acts as a repeater
- ❖ It receives a data on one link and transmits bit-by-bit on other link

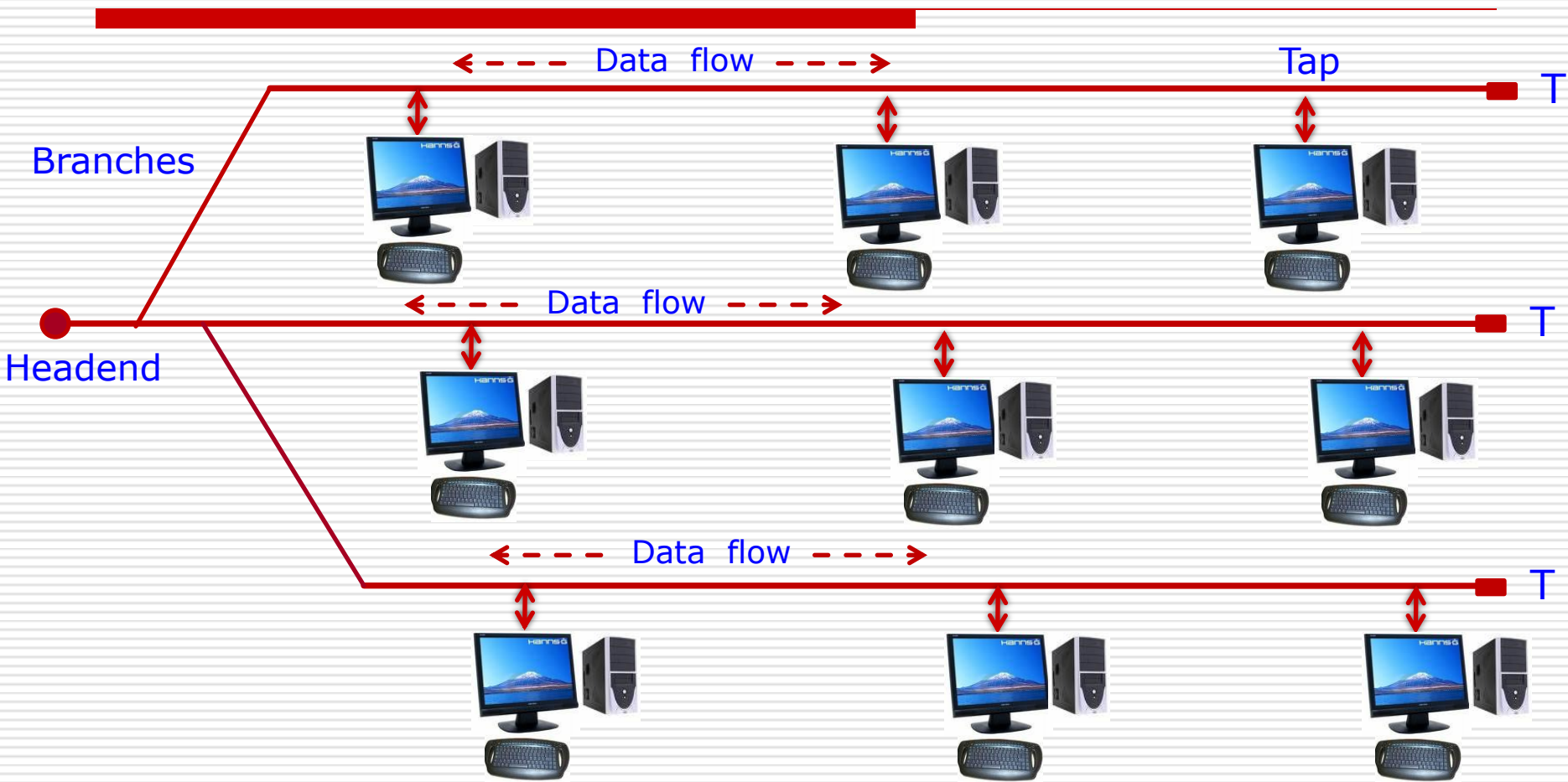# Star Topology

Central node

- ❖ Network comprised of many point-to-point circuits
- ❖ Central node: Hub or switch
- ❖ Hub: Operates in broadcasting mode
- ❖ Switch: Operates as frame-switching device

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Tree Topology

Data flow

Tap

T

Branches

Data flow

T

Headend

Data flow

T

❖ Generalization of bus topology

❖ Each branch may have further branches

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Mesh (or Fully Connected) Topology
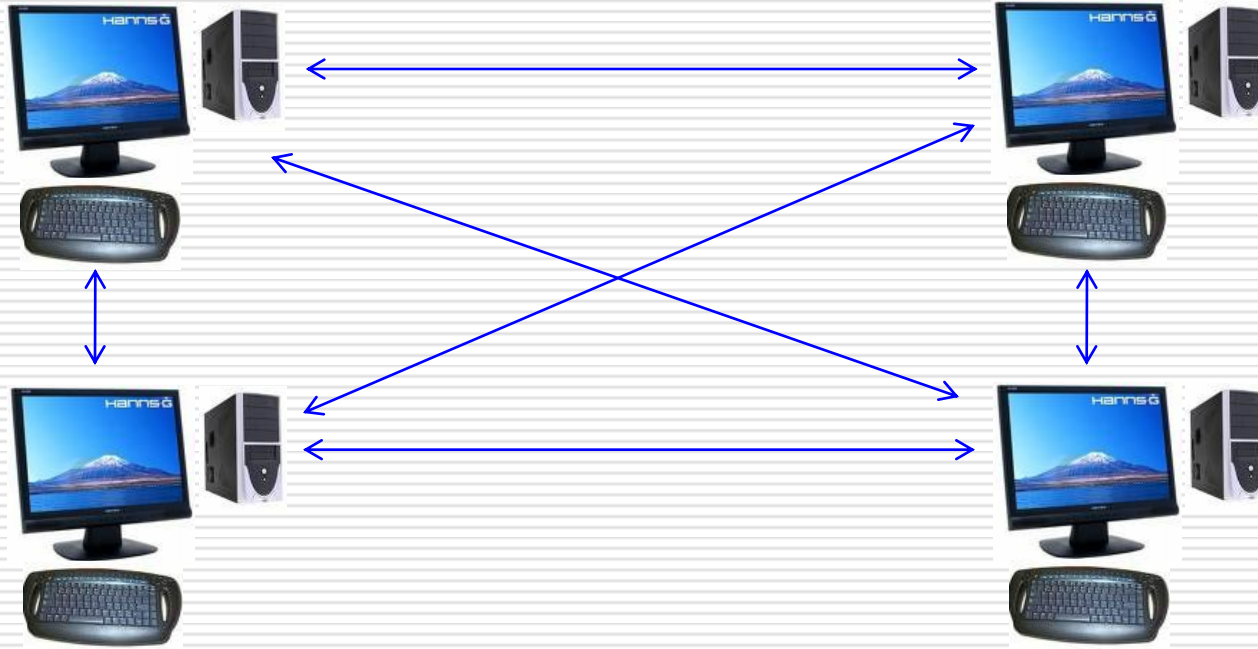
- ❖ Each station has a bidirectional link to every other station
- ❖ Less traffic problems, high reliability, high security
- ❖ Large no. of links: n(n-1)/2 links for 'n' nodes
- ❖ Each station must have n-1 I/O ports

Device–Level Wired Network

Control – level network

(Ethernet)

Industrial Controller/
PLC/RTU

Device-level network

FD   FD   FD   FD

FD: Field Device (Sensor / Actuator/etc.)

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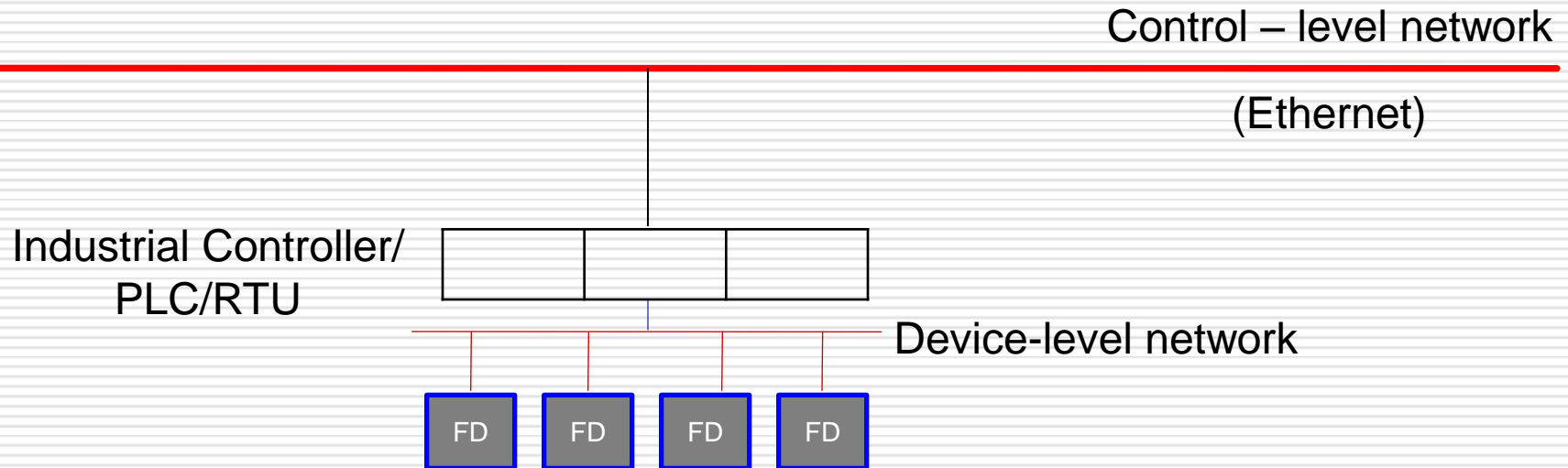
Device–Level Wireless Network

Control – level network

(Ethernet)

Industrial Controller/
PLC/RTU

Access Point

Device-level network

FD   FD   FD
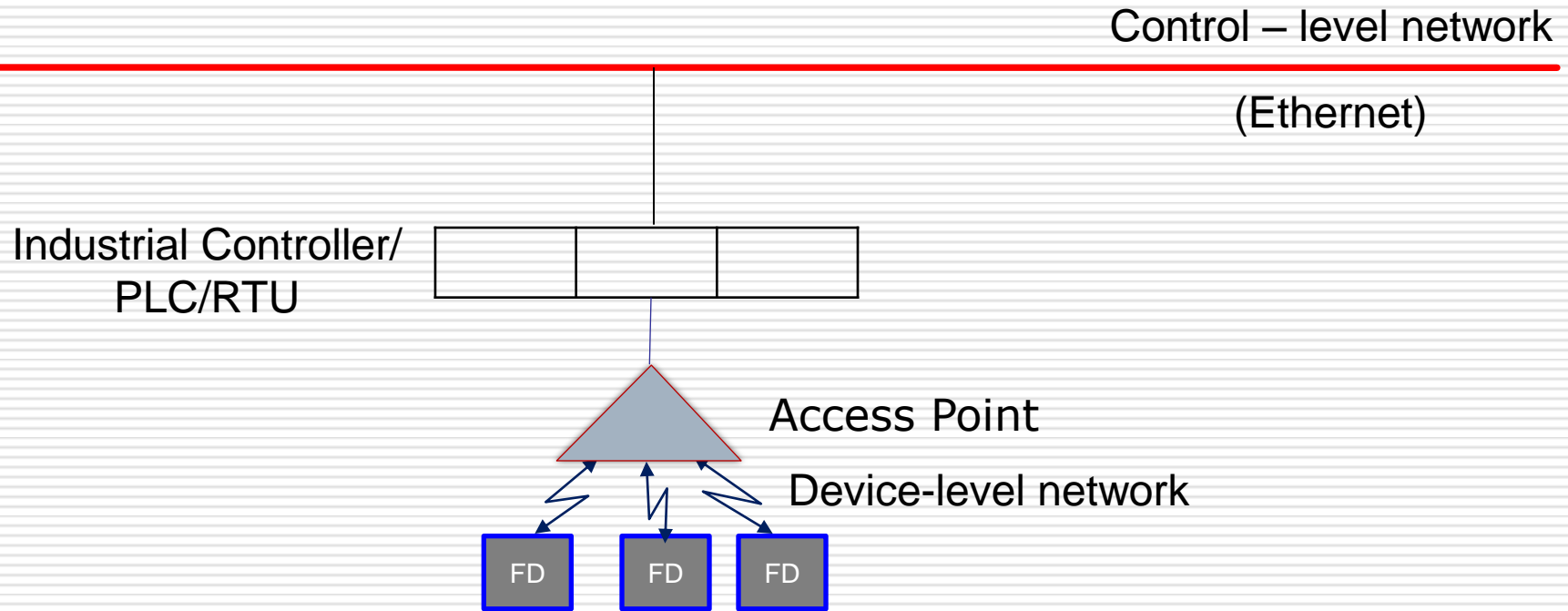
FD: Field Device (Sensor / Actuator/etc.)

Special Requirements of Device Level Networks

❖ Low latency or small end-to-end delay

❖ Low bandwidth or data rate

❖ High data security

❖ High network security

❖ Low power consumption or long battery life (for wireless networks only)

Technologies/Protocols for Device-Level Networks

Technologies/Protocols for Wired Networks

- ❖ RS422
- ❖ RSR485
- ❖ MODbus
- ❖ Foundation Fieldbus
- ❖ HART
- ❖ CAN
- ❖ LON
- ❖ BACNet

Technologies/Protocols for Wireless Networks

- ❖ Zigbee
- ❖ Wi-Fi
- ❖ Bluetooth
- ❖ Wireless Fieldbus

7-Layer OSI Model of Communication Systems

❖ "Open System Interconnection" model

❖ Prepared and issued by International Standards Organization

❖ Reference model of communication systems

❖ Defines functions of a communication system in 7 layers

❖ For use as reference or model "to identify and classify the various functions of a given communication system"

❖ Not a standard or set of prescriptions for a communication system to adhere to

❖ For any **communication system**, layers 1 and 7 are essential, while some middle layers may be absent

❖ A **communication protocol** or standard may not define all the 7 layers, it may define as few as one layer.

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Data Transfer Between Systems

Application Layer		Application Layer
Presentation Layer		Presentation Layer
Session Layer		Session Layer
Transport Layer		Transport Layer
Network Layer		Network Layer
Data-Link Layer		Data-Link Layer
Physical Layer		Physical Layer

Comm. System #1

Comm. System #2
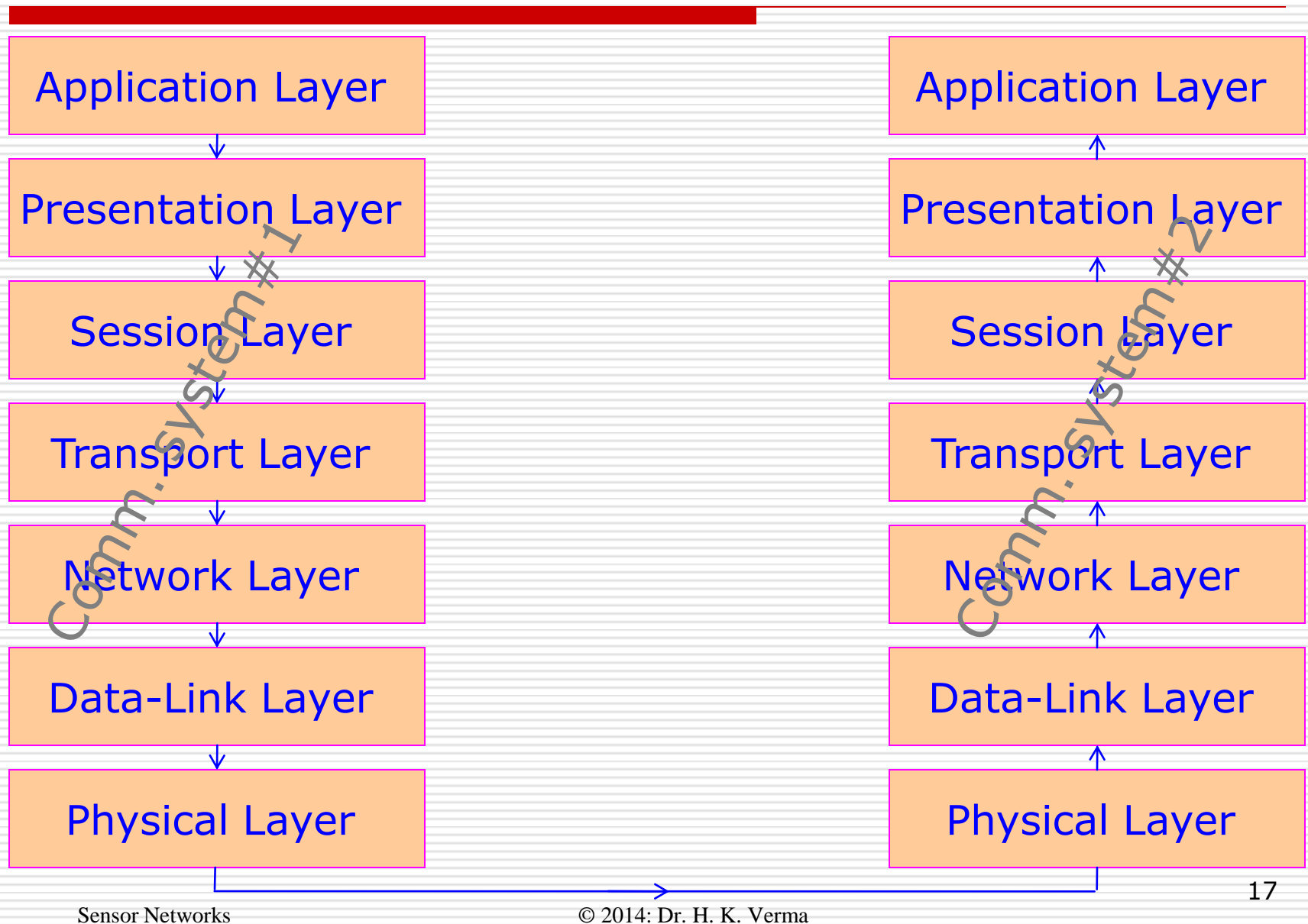
Functions of Seven Layers

Layer	Function
Application Layer	Application Programs
Presentation Layer	Data Presentation (Encryption, Compression, Data Formatting)
Session Layer	Inter-Application Dialogues
Transport Layer	Addressing
Network Layer	Network Routing
Data-Link Layer	Medium Access Control, Frame Format
Physical Layer	Comm. Medium, Connectors, Data-to-Signal Conversion,

Signal

Networking of Sensors
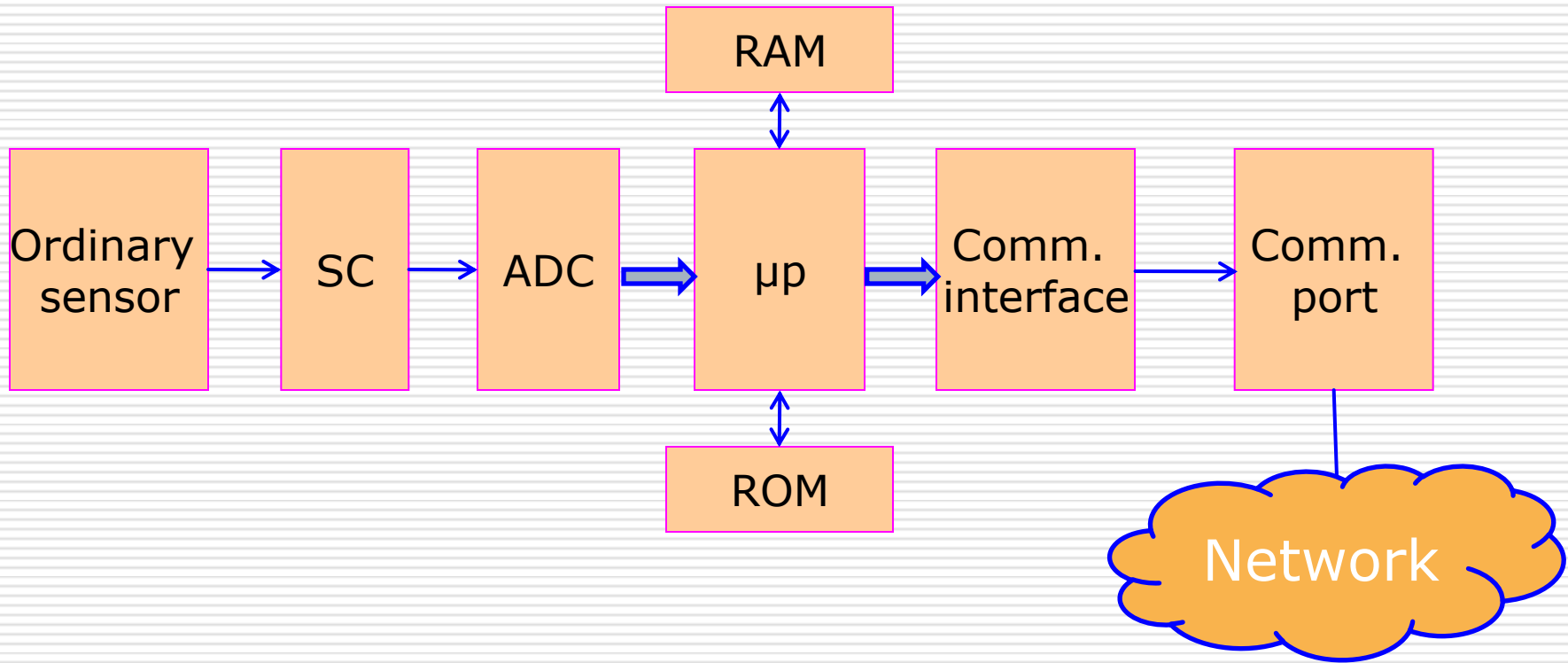
Four Situations:

Situation A – Ordinary Sensor + SC + MPU + Interface

Situation B – Network Sensor + Nothing

Situation C – Smart Sensor + Custom Interface

Situation D – Smart Sensor + IEEE 1451 Interface
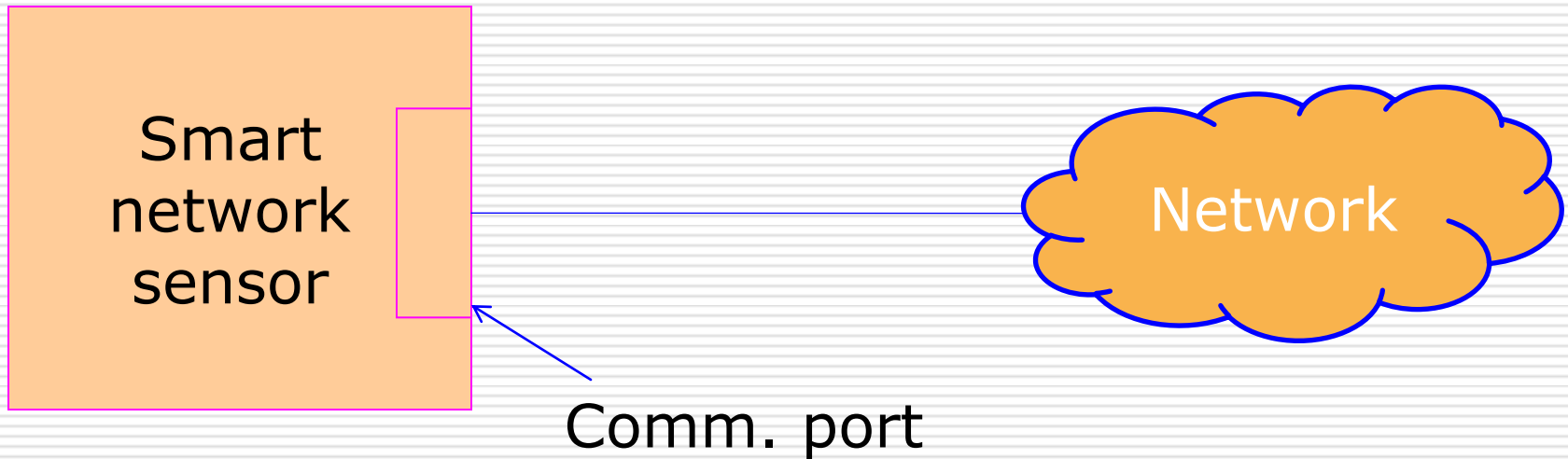
Situation A: Ordinary Sensor+SC+MPU+Interface

```
                        ┌──────────┐
                        │   RAM    │
                        └────┬─────┘
                             ↕
┌──────────┐   ┌──────┐   ┌──────┐   ┌──────┐   ┌──────────┐   ┌──────────┐
│ Ordinary │→  │  SC  │→  │ ADC  │⇒  │  µp  │⇒  │  Comm.   │→  │  Comm.   │
│  sensor  │   │      │   │      │   │      │   │interface │   │   port   │
└──────────┘   └──────┘   └──────┘   └──────┘   └──────────┘   └────┬─────┘
                             ↕                                       │
                        ┌──────────┐                            ╭────┴────╮
                        │   ROM    │                            │ Network │
                        └──────────┘                            ╰─────────╯
```

Advantage   Disadvantages
❖ Flexibility   ❖ Cumbersome
                                   ❖ Only expert can do
                                   ❖ Expensive

Situation B: Network Sensor + Nothing

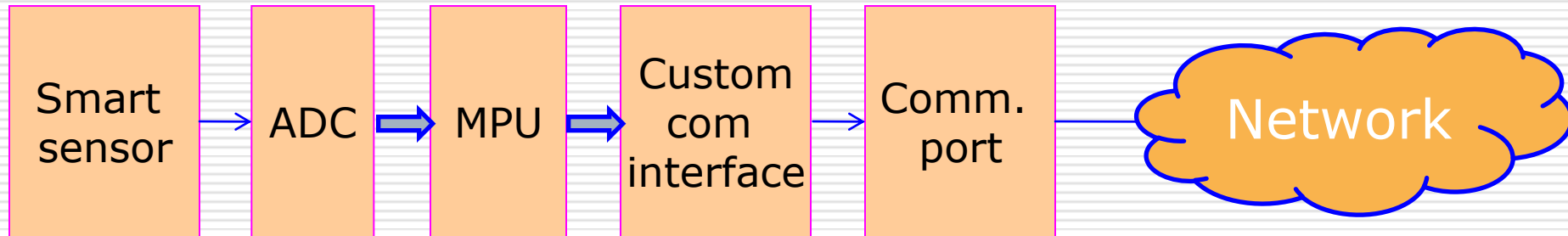Smart network sensor

Comm. port

Network

Advantages
- ❖ No other component needed
- ❖ Simple plug-&-play
- ❖ Fast
- ❖ No expertise required

Disadvantage
- ❖ No flexibility of network protocol
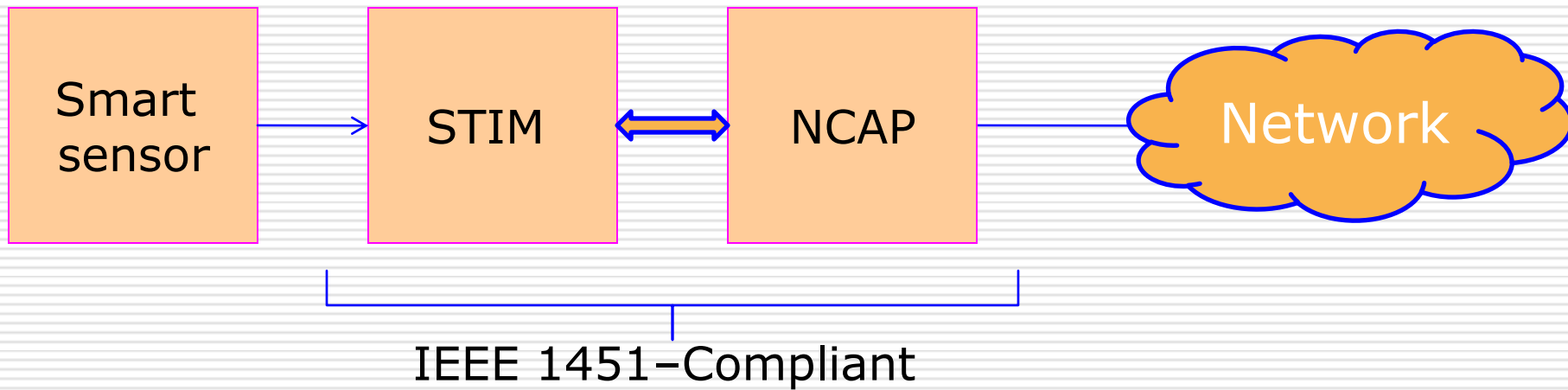
Situation C: Smart Sensor + Custom Interface

| Smart sensor | → | ADC | ⇒ | MPU | ⇒ | Custom com interface | → | Comm. port | — | Network |

Advantage
- ❖ No SC required

Disadvantages
- ❖ Cumbersome
- ❖ Only expert can do

Situation D: Smart Sensor + IEEE1451 Interface

```
┌──────────┐     ┌──────────┐     ┌──────────┐          ╭─────────────╮
│  Smart   │ ──▶ │   STIM   │ ◀══▶│   NCAP   │ ───────  │   Network   │
│  sensor  │     │          │     │          │          ╰─────────────╯
└──────────┘     └──────────┘     └──────────┘
                 └──────────────────────────┘
                     IEEE 1451–Compliant
```

Advantages
* ❖ No SC required
* ❖ Flexibility of network protocol

Disadvantage
* ❖ Needs STIM & NCAP