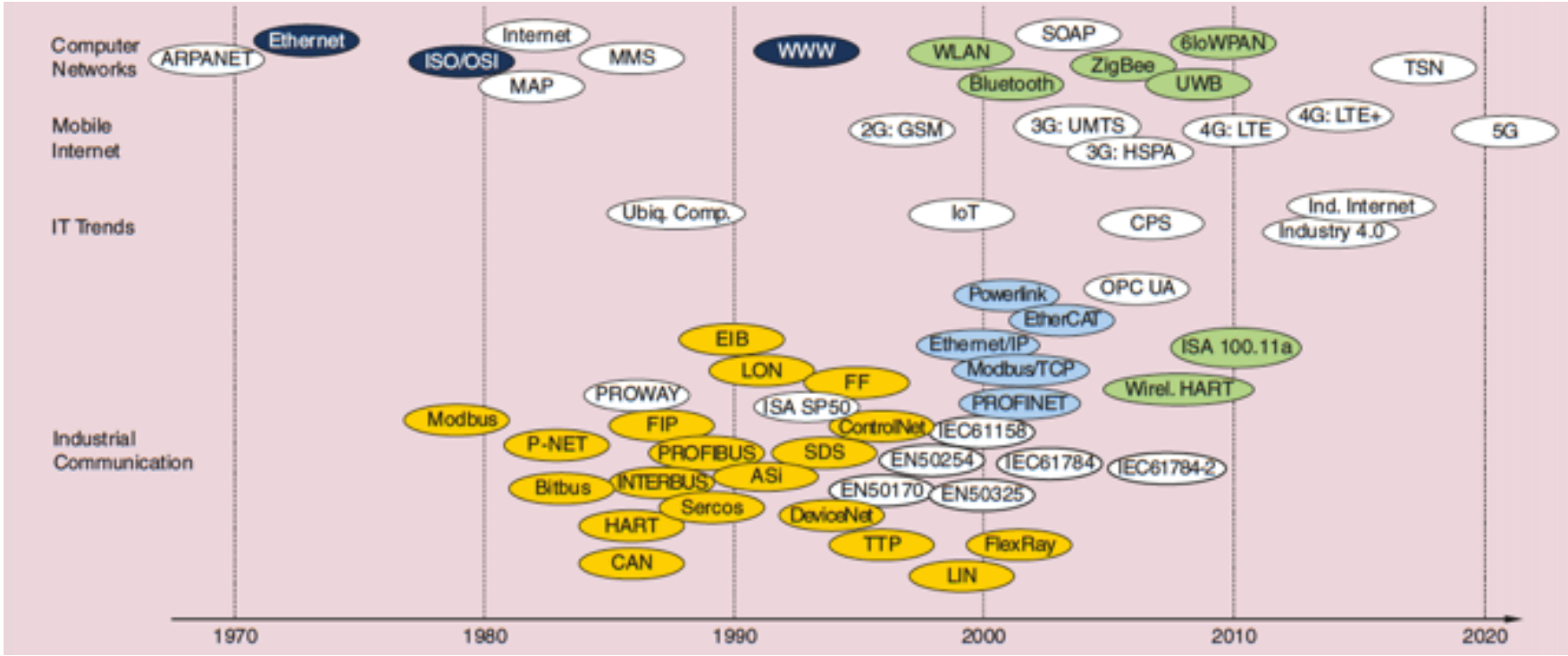
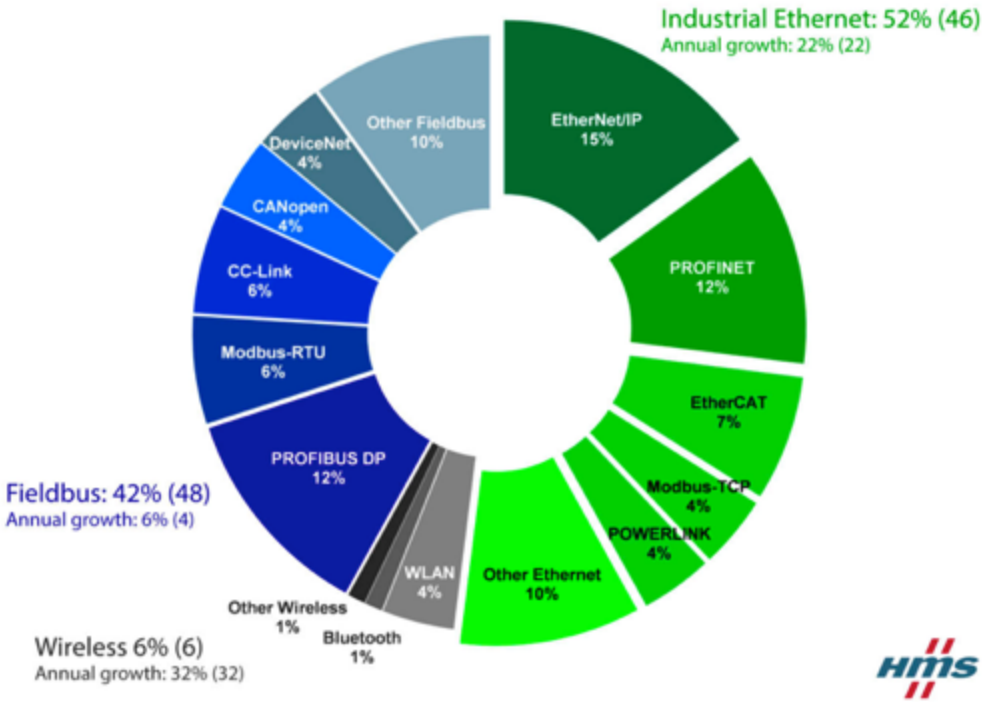
Bits over cables….

Communication Technologies @ I4.0



M. Laeger, T. Sauter, and J .Jasperneite, The Future of Industrial Communication, IEEE Industrial Electronics Magazine, 2017

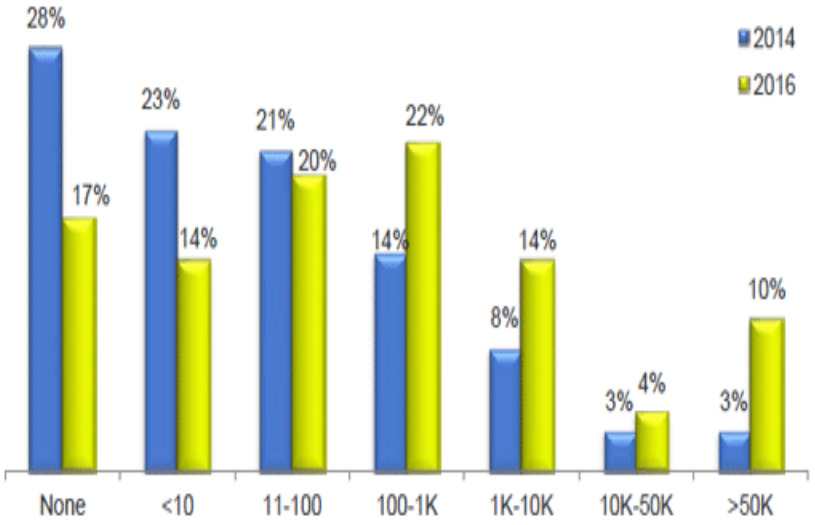
Industrial Communication Technologies – Market Share

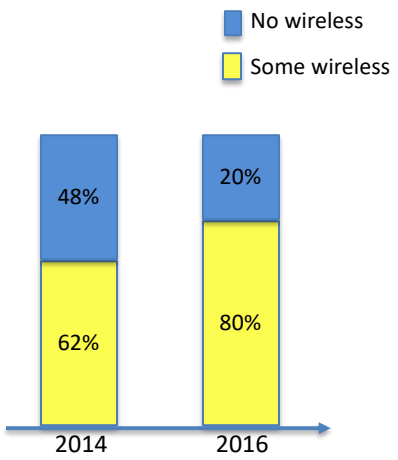


www.automazioneindustriale.it

Wireless is Gaining Momentum

Wired connectivity (Ethernet, field bus technology, etc.) is just fine for IIoT but wireless is on the hype

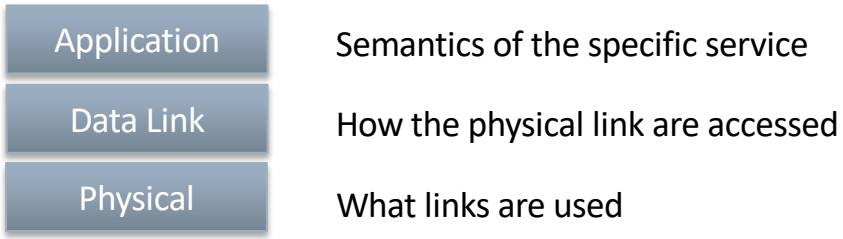




ON World/ISA Survey, Nov.2016 - 180 industrial end users, systems integrators, and service providers

Fieldbus Generalities

- Mainly targeting the interconnection of control devices and field devices (sensors/actuators)
- Short frequently-exchanged messages
- Tigth requirements in terms of delay and determinism



Short Digression on Channel Access

- Problem
  - To share a single communication medium (in our case a IEEE 802.15.4 frequency channel)
- Solutions
  - Scheduled access ("I Tell You when to Talk")
    - Transmissions on the channel are sequential with no conflicts
    - Polling schemes
    - Centralized scheduling schemes
  - Random access ("You Decide when to Talk but be Wise in Recovering from Collisions")
    - Transmission are partially uncoordinated and can overlap (collision)
    - Conflicts are resolved using distributed procedures based on random retransmission delay

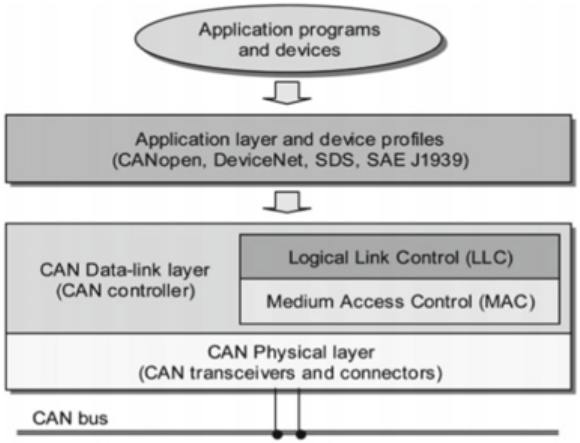
Scheduled vs Random Access

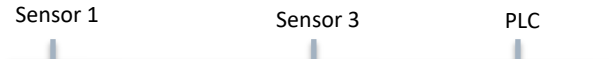
- Scheduled Access (e.g., GSM, Bluetooth, Wifi PCF)
  - PROs:
    - "guaranteed" performance (bounded delay/throughput)
  - CONs:
    - Coordination required (central node, synchronization, etc.)
- Random Access (e.g., WiFi DCF, Ethernet)
  - PROs:
    - Easy to implement
    - Opportunistic access to the resources
  - CONs:
    - Only "Statistical" guarantees on performance
    - Poor performance under heavy traffic (collisions kick in)

Fieldbus Example: the CAN Bus

- Connectivity based on shared physical bus
- Everybody receives everything transmitted on the BUS

Rate: 1 [Mb/s]





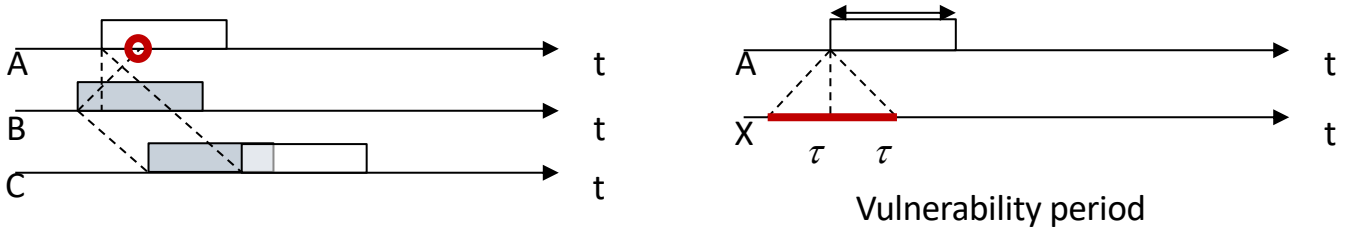
CSMA to arbitrate collisions

Fieldbus Example: The CAN bus

- Carrier Sensing Multiple Access

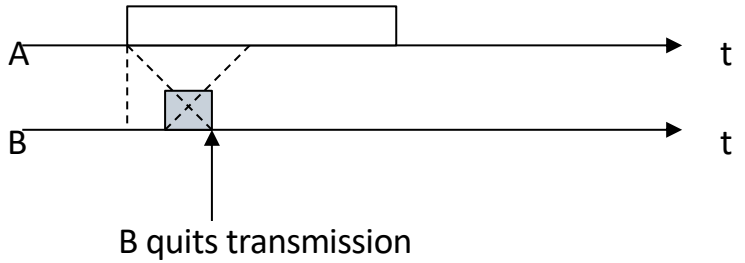
sense the BUS before transmitting; if BUS free transmit otherwise refrain and try later

- Collissions

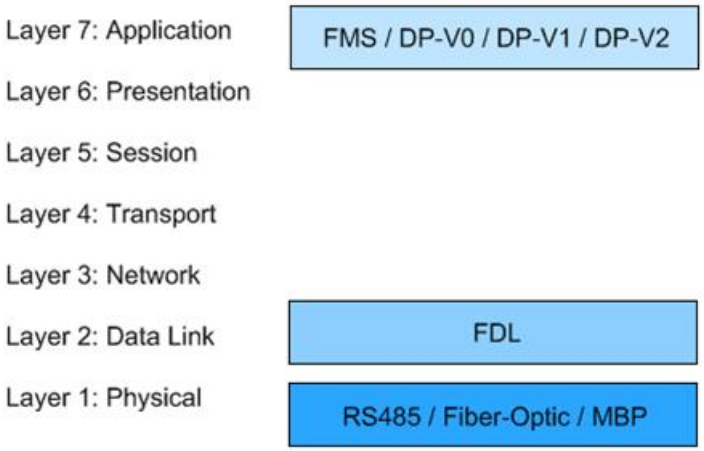


BUS Arbitration

- Each message has a priority (Lower identifier field means higher priority)
- Each station monitors its own transmission and the status of the BUS
- If a transmitting station overhears another transmission on the channel at higher priority, then quits (e.g., B in the figure)

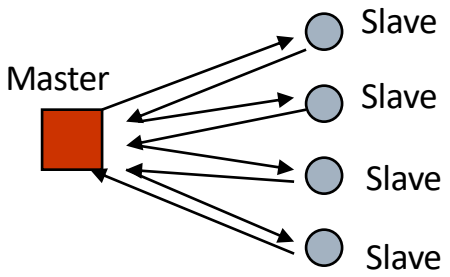


Other Fieldbus technologies - PROFIBUS



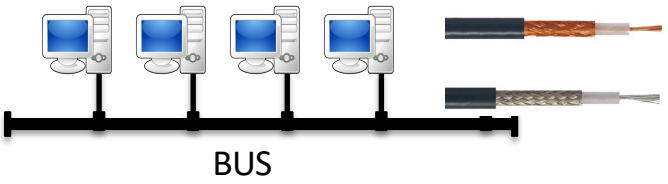
Rate: up to 12 [Mb/s]

BUS access managed through polling
Master station «tells» who can talk

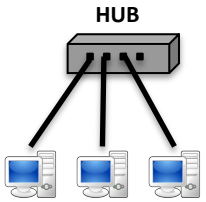


Ethernet Timeline

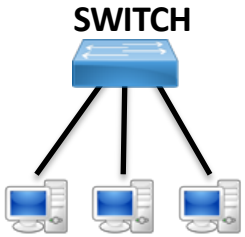
- 1976: Physical shared bus Xerox (1976), then ratified within IEEE 802.3 WG, coax cables, 1Mb/s



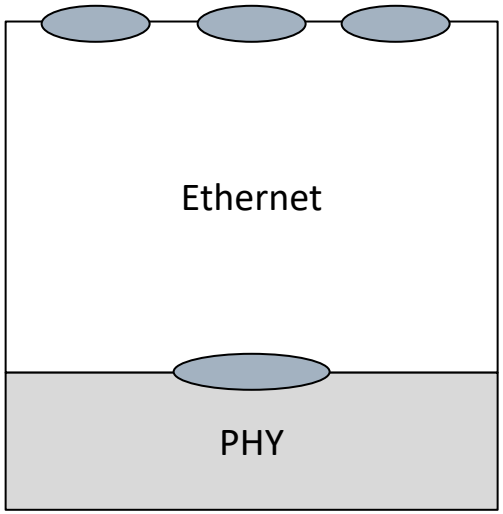
- 1990-2000: Star-like topologies with hub/repeatrer (90'-00'), twisted pairs, up to 1Gb/s



- 2000-Now: Fully switched/Full Duplex topologies, twisted pairs, fibers, up to 100Gb/s



Ethernet



Multiplexing
Frame filtering
Multiple Access

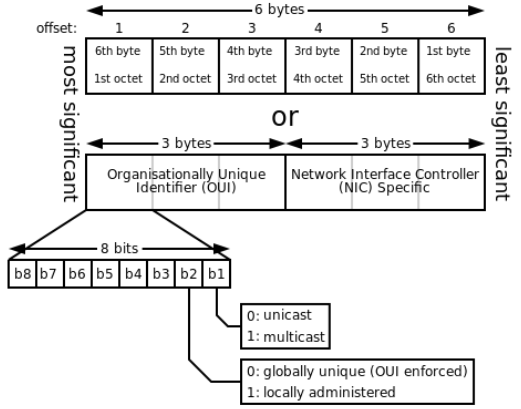
TX/RX

Ethernet Frame

- Synch preamble-Sync (x7 *10101010*)
- Frame Delimiter- FD (*10101011*)
- 48-bits Addresses
- Type: multiplexing field (e.g., IP has Type=0800)
- Data field
- Frame Check Sequence – FCS for error checking

MAC Addresses

- Used for filtering purposes
- First 3 bytes set the manufacturer
- Last 3 bytes identify the interface
- «All-ones» address used for broadcast



48-bit MAC address

00	0C	42	28	79	45
00000000	00001100	01000010	00101000	01111001	01000101

broadcast

FF:FF:FF:FF:FF:FF

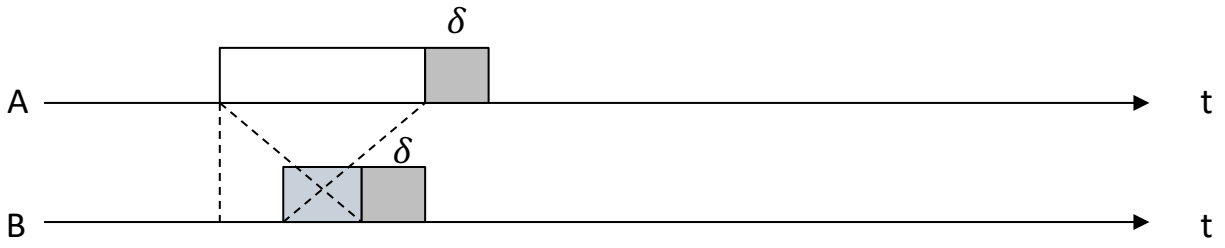
CSMA/CD

- Carrier Sensing Multiple Access

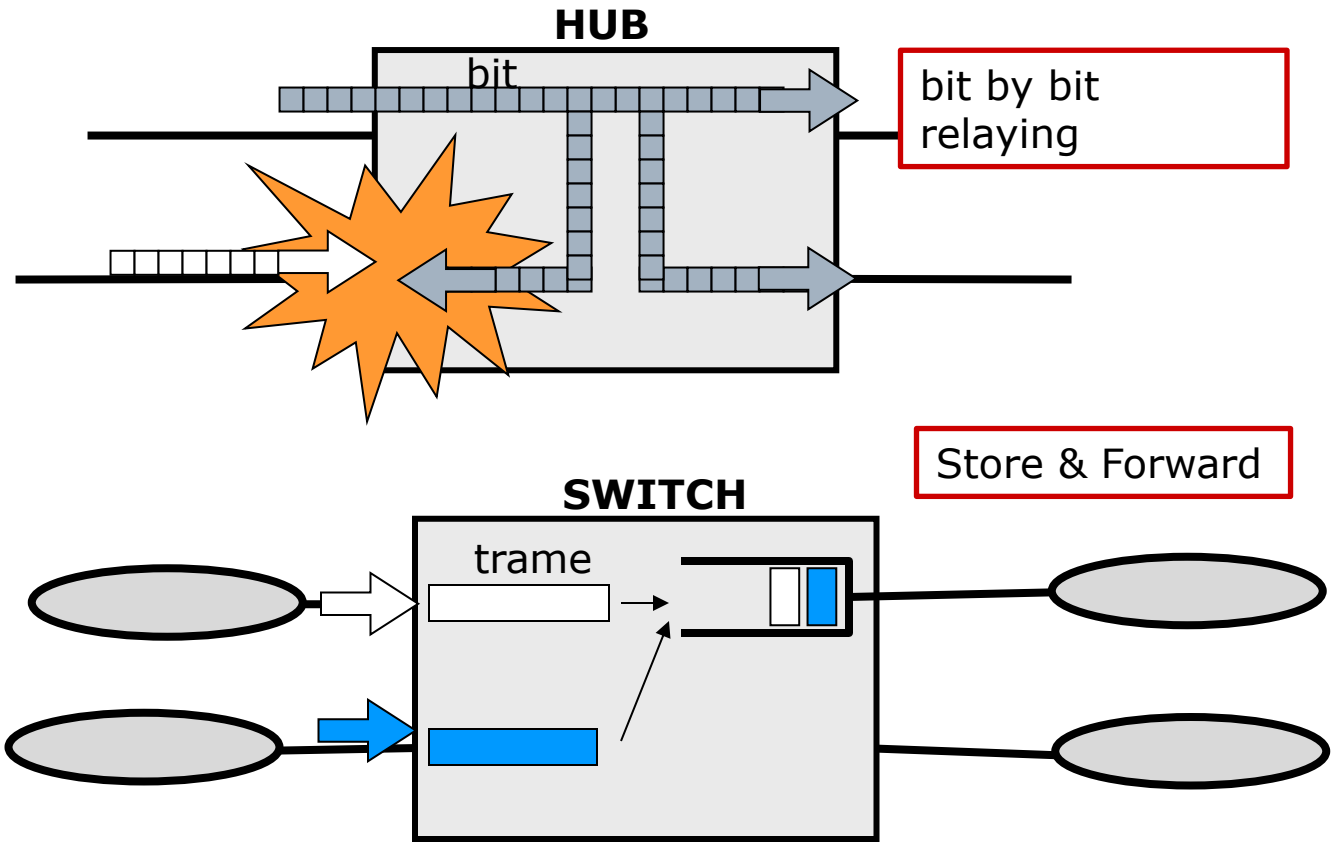
sense the BUS before transmitting; if BUS free transmit otherwise refrain and try later

- Collision Detect

If collision detected all the transmissions are aborted after a while

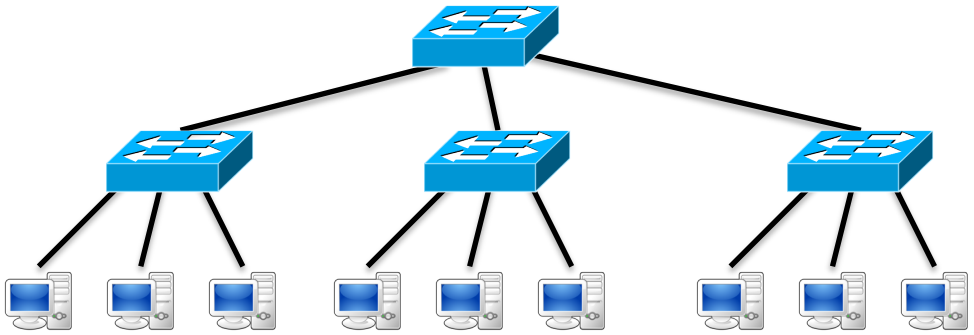


Hub and Switches

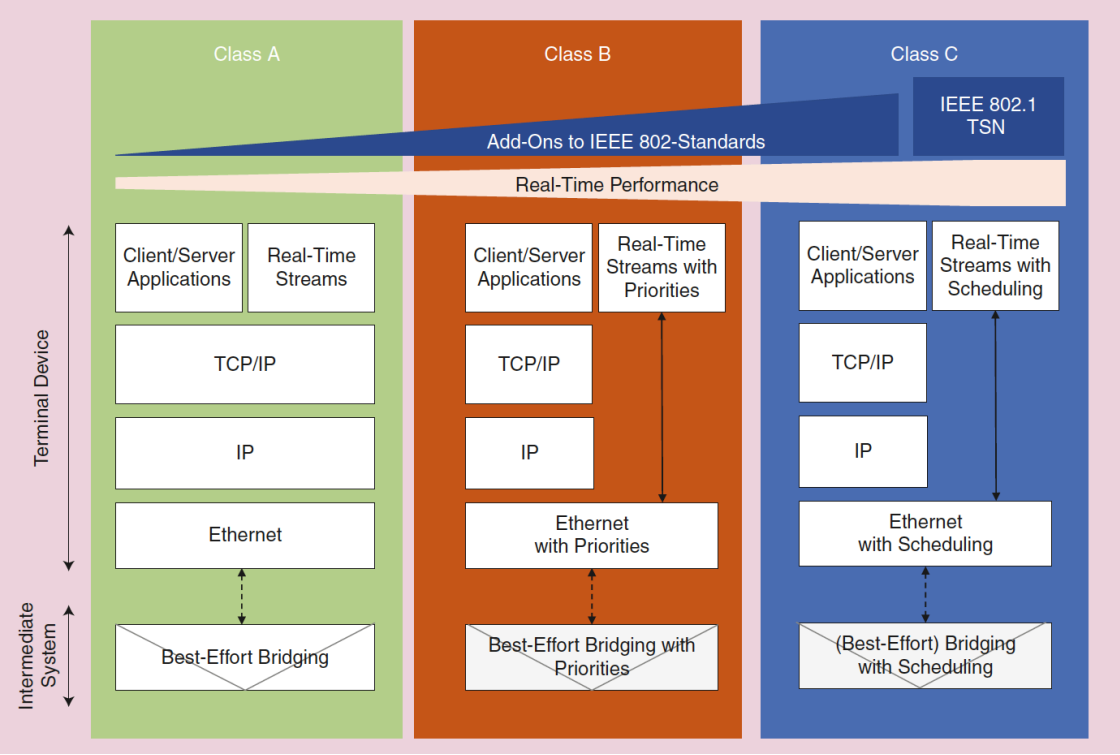


Fully Switched LANs

- No more collisions
- No more CSMA-CD



Ethernet @ Industry 4.0



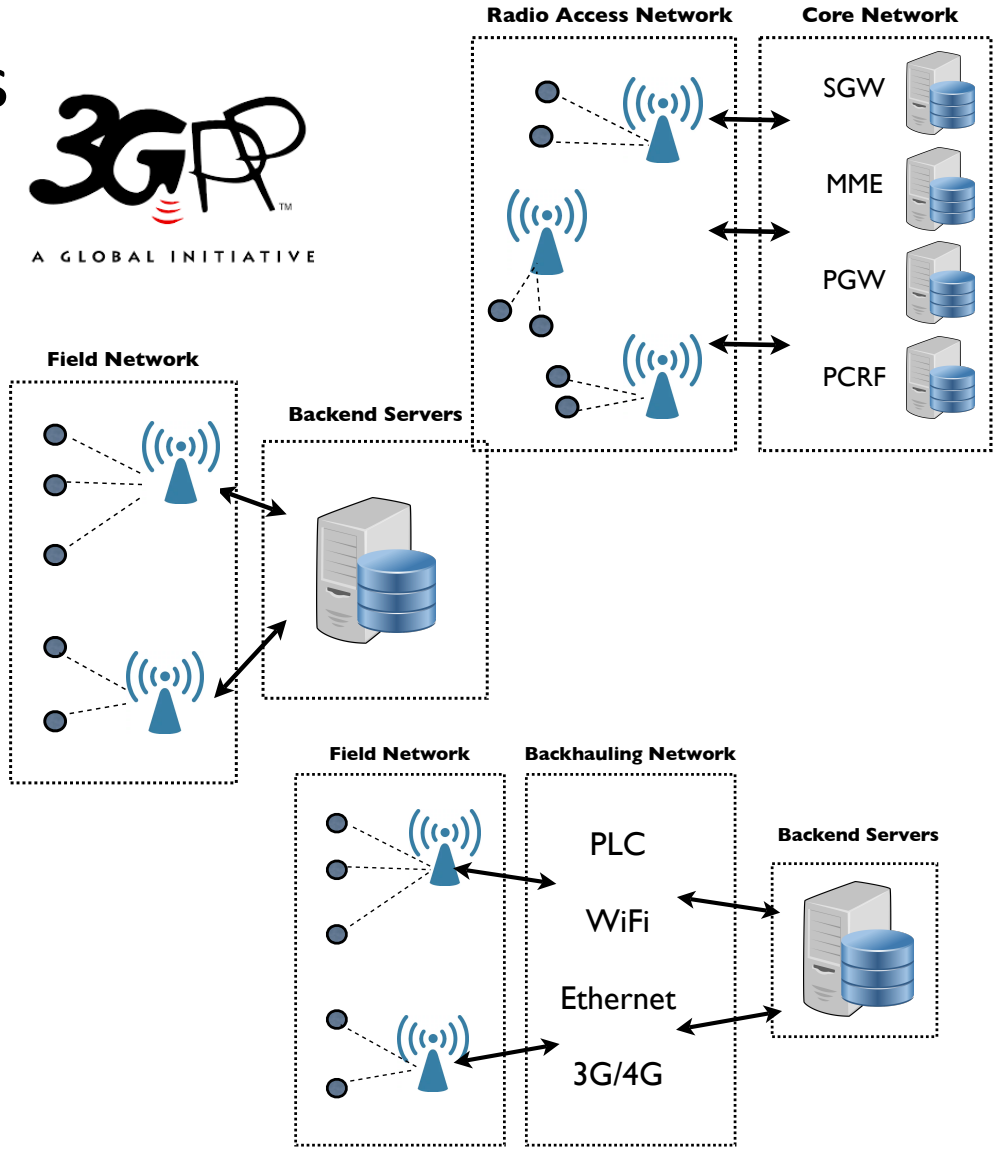
- Class A: MCT around 100[ms]
  - Ethernet/IP
  - Foundation Fieldbus
- Class B: MCT around 10[ms]
  - Profinet
- Class C: MCT around 1[ms]
  - EtherCAT
  - Profinet IRT
  - Ethernet Powerlink

M. Wollschlaeger, T. Sauter, J. Jasper, *The Future of Industrial Communications*, IEEE Industrial Electronics Magazine, 2017

Bits in the Air…

The Race to the Smart object

- Mobile Radio Networks
  - RAN and CN Evolutions
- Cellular IoT Operators
  - Low Power Long Range Technology
- Capillary Multi-hop Networks
  - Short/medium range + backhauling



Connectivity Offer