Wireless networks for industrial applications. Current solutions and future trends

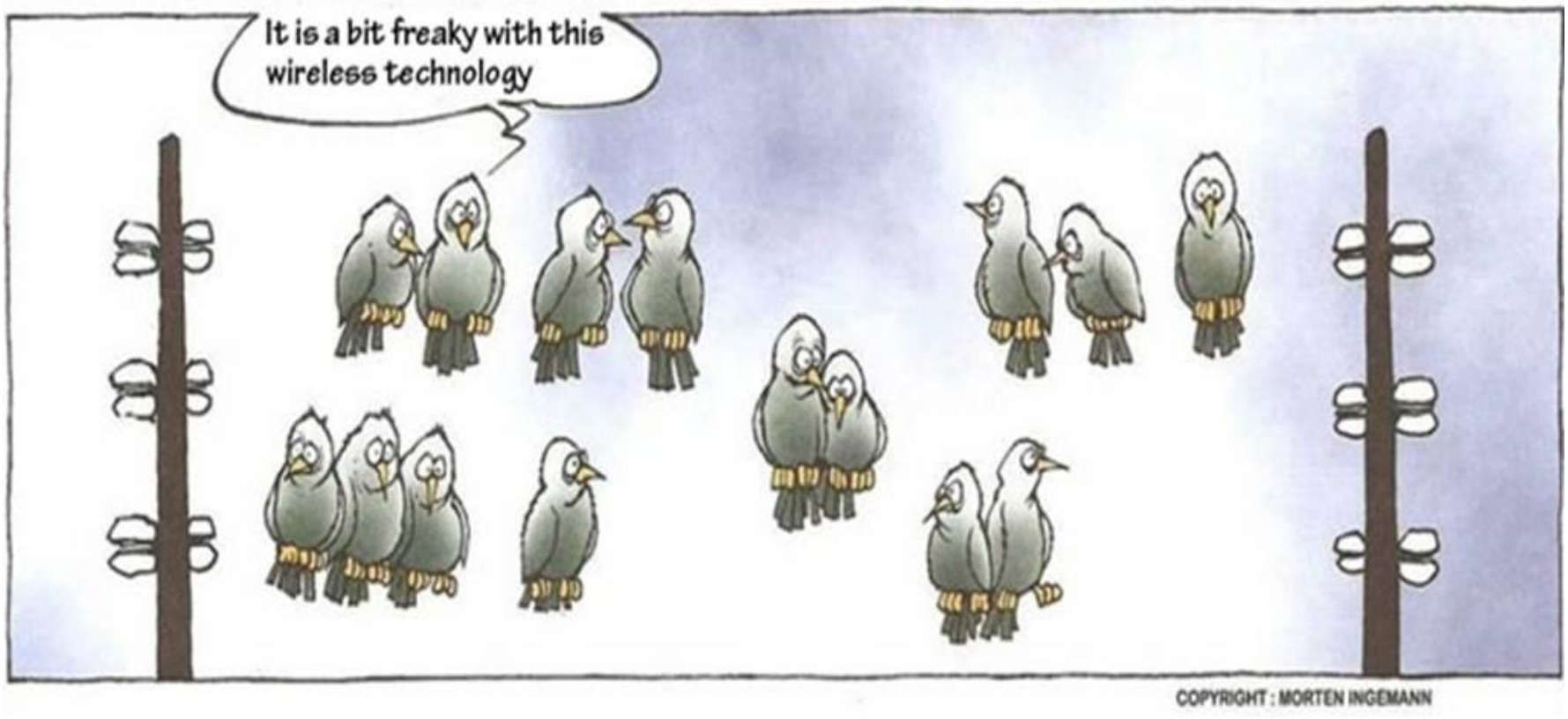
Who am I?

- Associate Professor of electronics with the Department of Information Engineering at the University of Brescia
- ES3 research group

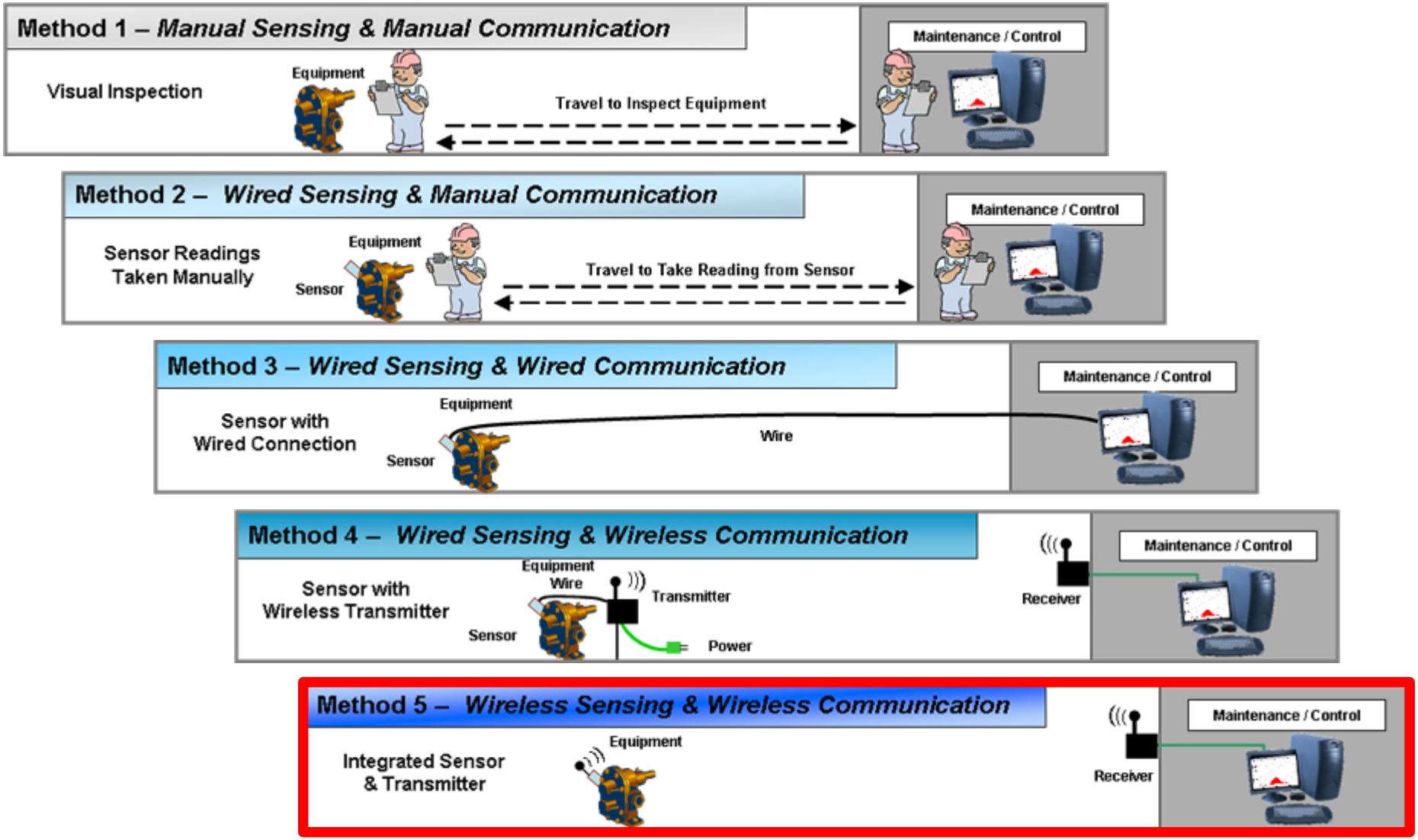
Member of:

- IEC-TC65, WG17 on Smart Grids for industry
- IEC-SC65C, WG16 on Wireless Fieldbus and WG17 on Wireless coexistence
- IEEE-IMS-TC37, on measurements for networking
- IEEE-IES-TCFA, on Technical Committee on Factory Automation

From wires to wireless…



Monitoring industrial equipments: past, present and future!



Industrial communication data delivery model

Process Data

represent the state of the plant

short and urgent data items

... motor current, axle speed, operator's commands, emergency stops,...

-> Periodic Transmission of Process Variables

Since variables are refreshed periodically, no retransmission protocol is needed to recover from transmission error.

Message Data

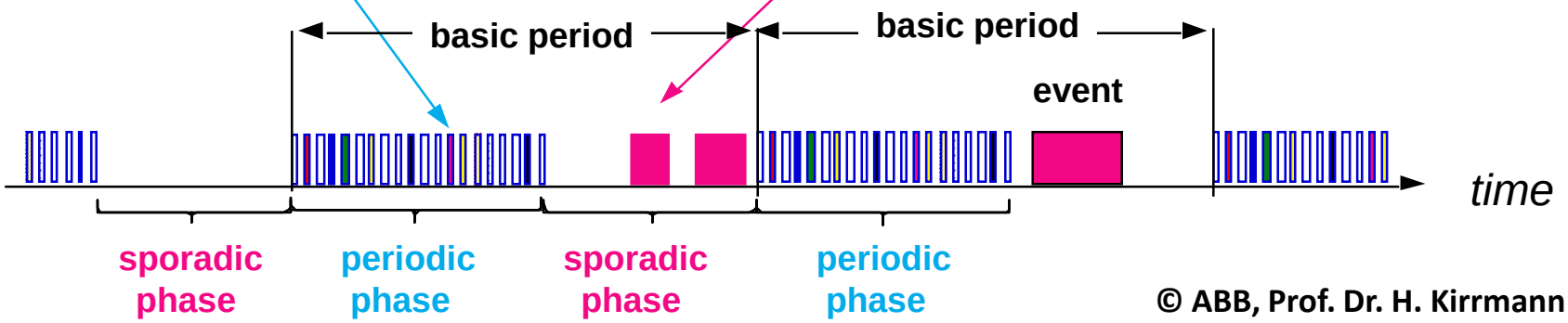
represent state changes of the plant

infrequent, sometimes lengthy messages reporting events, for:

- Users: set points, diagnostics, status
- System: initialisation, down-loading, ...

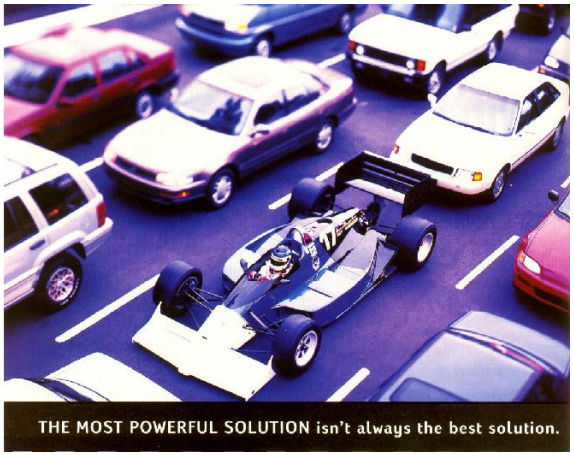
-> Sporadic Transmission of Process Variables and Messages

Since messages represent state changes, a protocol must recover lost data in case of transmission errors



Industrial communication data delivery model

- Raw Throughput: not really important!
- Real time: capability to respect time deadline
- At least three different kind of communications exist in industrial automation applications:
  - Periodic data communication, also known as **Real Time Cyclic** (RTC) data (process data)
  - Aperiodic data communication, also known as **Real Time Acyclic** (RTA) data (sporadic data, e.g. alarms, event notification…)
  - Non-time-critical communication, also known as **Best Effort** (BE) data (configuration, parametrization, diagnistics…)
- RTC and RTA traffic typically have payload size in the order of 10-100 B, whereas BE traffics may require sending large chunks of data



RT requires limiting the rate at which frames can be transmitted on a link and limiting their size (previous bandwidth allocation)

Why wireless now?

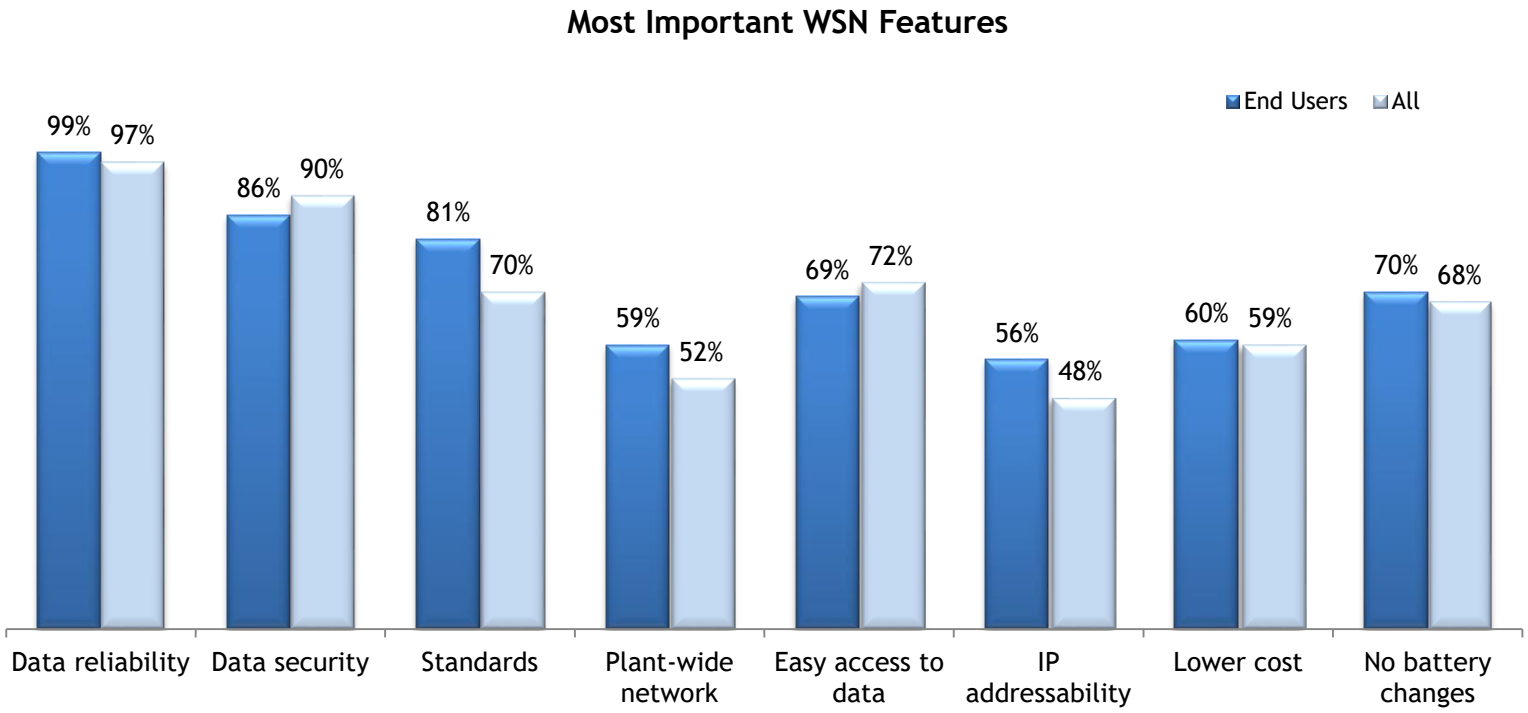
- Wireless isn't new. Why all the recent interest about it in process industries?

- Consider what happened with cell phones. Cellular technology was available for at least a decade before it was widely adopted, but the large size and short battery life of early phones made them impractical for most people. Once those problems were solved, adoption increased exponentially.

- Something similar has happened with wireless technology for **process automation** and more recently for **factory automation**. It wasn't hard to see the potential benefits, but users were reluctant to put wireless to work in their plants until concerns about security, battery life, standards, and communication reliability were addressed.

Most Important WSN Features

- By far, **data reliability** is ranked as the most important WSN feature, followed by **security** and then **standards**.



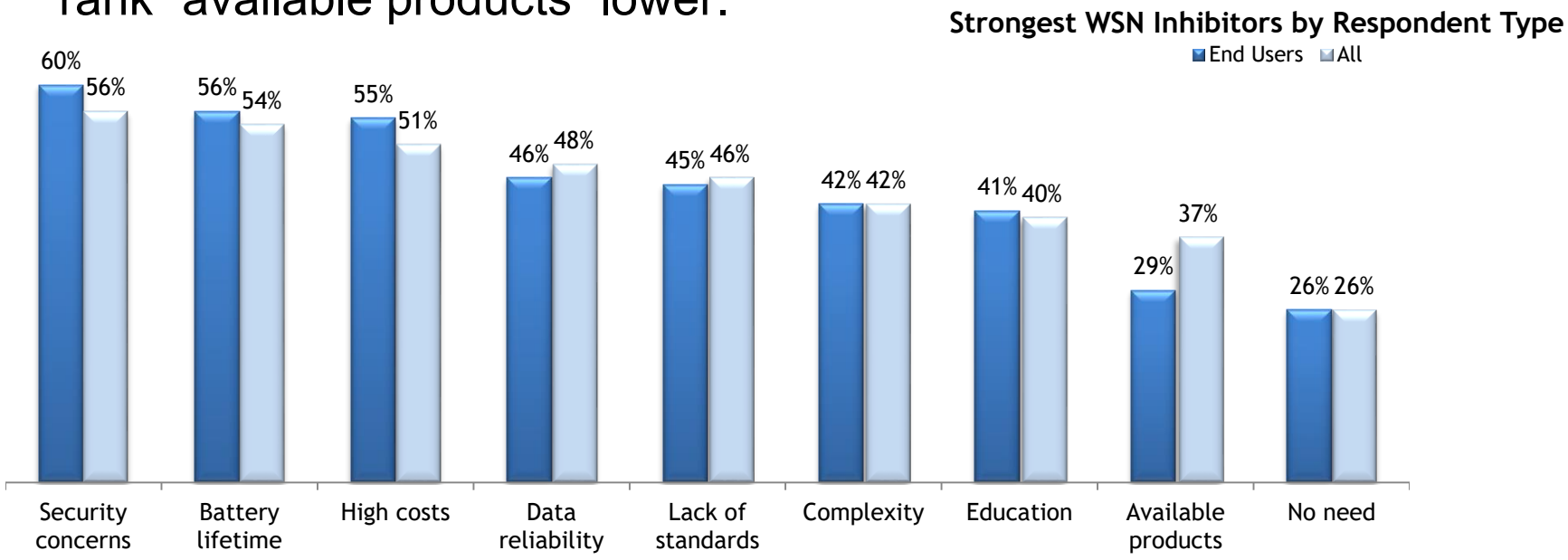
n= 216

Source: ON World

*Q: On a scale from 1-5 (1= Least important, 5=Most important), how important are the following considerations to you for a wireless sensor system (or do you think each is for your customers)? Chart shows the percent indicating each is “Important” or “Most Important.”

Adoption Inhibitors

- The strongest inhibitors are **security**, **battery lifetime** and **high costs** with data reliability dropping significantly as a concern compared with previous 2010 survey.
- End users rank security and costs higher than all respondents and rank “available products” lower.



n= 216

Source: ON World

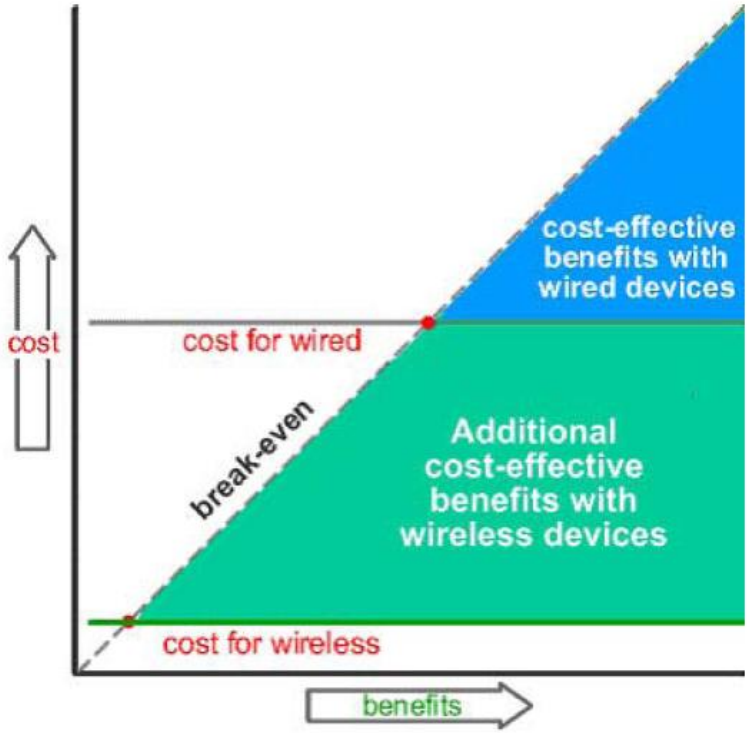
*Q: On a scale from 1-5 (1= Least inhibitor, 5= Strongest inhibitor), how would you rate the following as potential inhibitors that are preventing more widespread adoption of wireless sensor network technology today? Chart shows the percent indicating each item is an “Inhibitor” or “Strongest Inhibitor.”

Wireless advantages

- The more you know about the process, physical assets, and overall operations of your plant, the safer and more profitable your business can become.
- So, why aren't more plants "measuring up"?
  - Too often, the **cost or difficulty of adding new measurements** has outweighed the perceived benefits.
  - With traditional "wired" technologies, distance or complexity can make connecting the measurement point to a control system impractical or cost-prohibitive.
  - Wireless technology removes the barriers of traditional wired field solutions and gives you **unprecedented access to data** that was previously out of economic or technical reach.
  - Lower installation costs are only part of the equation. Even more important is **what you can do with the additional information**. Wireless technology also empowers mobile workers to do their job more efficiently by giving them remote access to the information they need.

Wireless advantages

- A smart wireless measurement point can be added for only a small fraction of the cost for wired installations.
- This dramatically lowers the economic barrier to adding new measurement points. Information that was too expensive to collect in the past is now readily available to help you improve your operation.



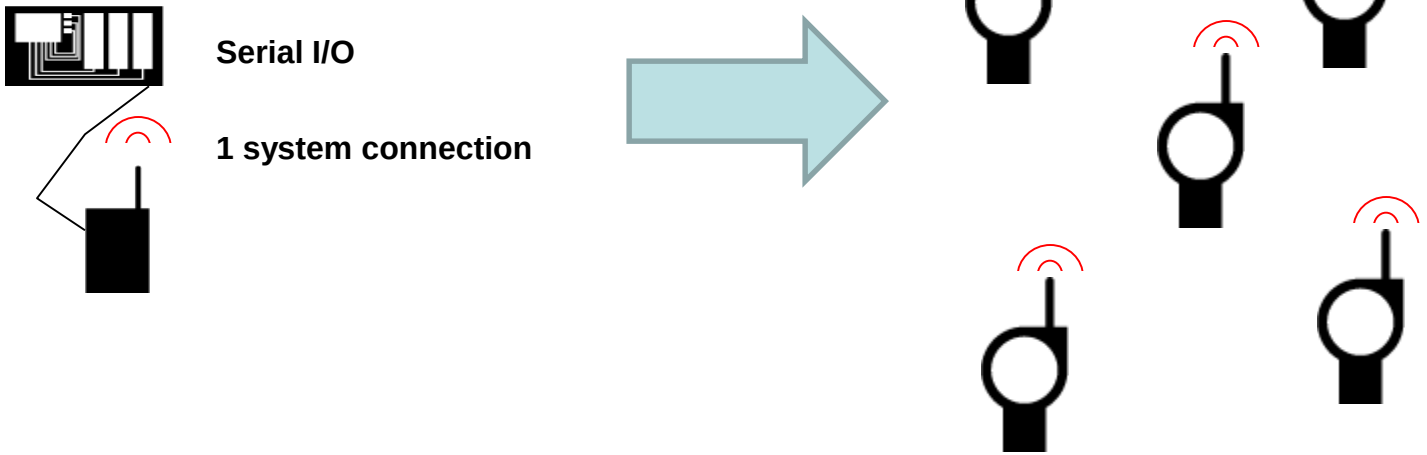
Implement Incrementally

Once the network is in place just :

- Install the next field device
- Add a data point (e.g. using OPC/Modbus)

- Additional devices strengthens the network

It’s just that easy!



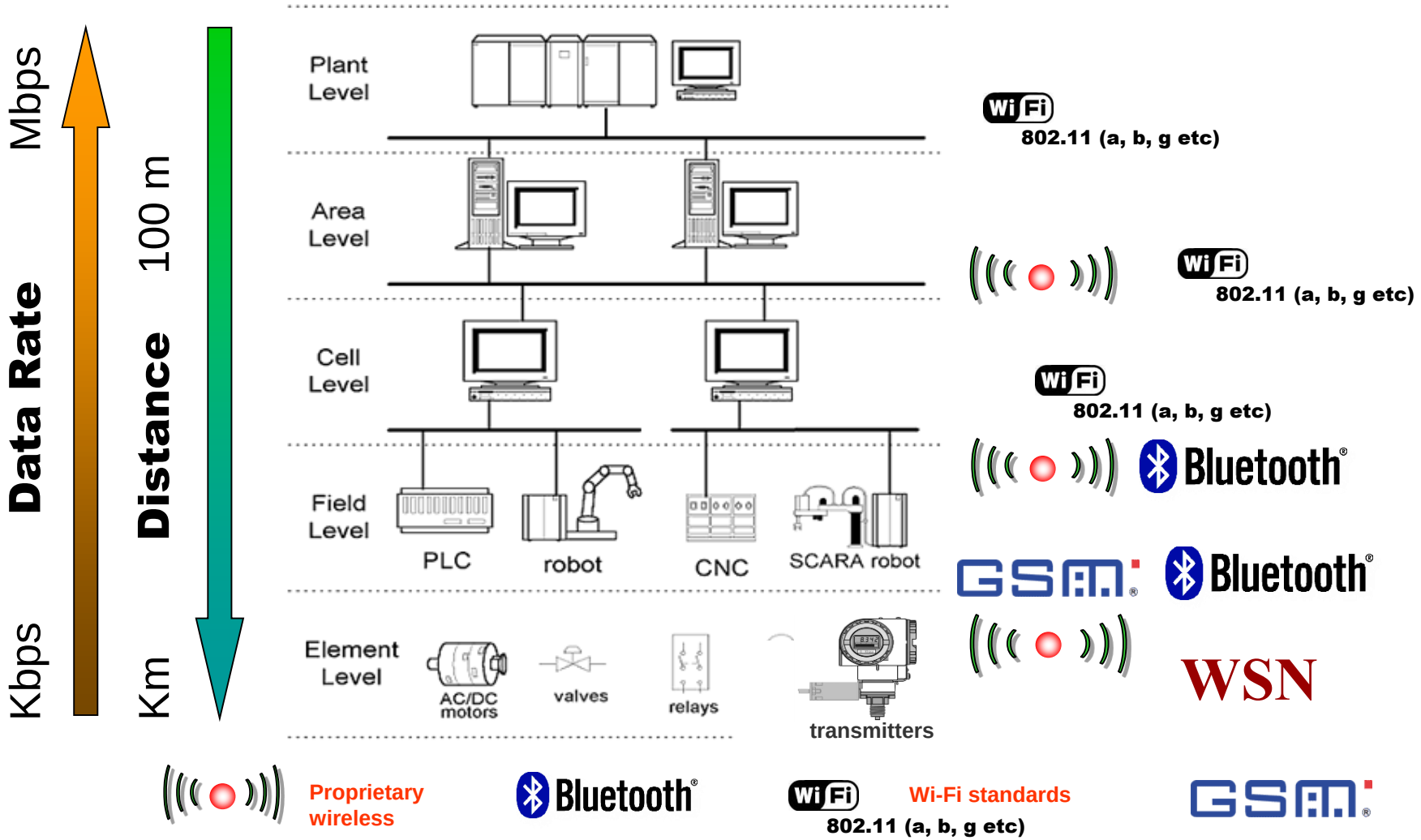
Monitoring or Control?

- Process monitoring
  - Hard to reach / expensive to install locations
  - Full access to multivariable devices
- Asset Management
  - Condition monitoring
  - Configuration database
- Control
  - Open loop
  - Closed loop
    - Where appropriate for wireless

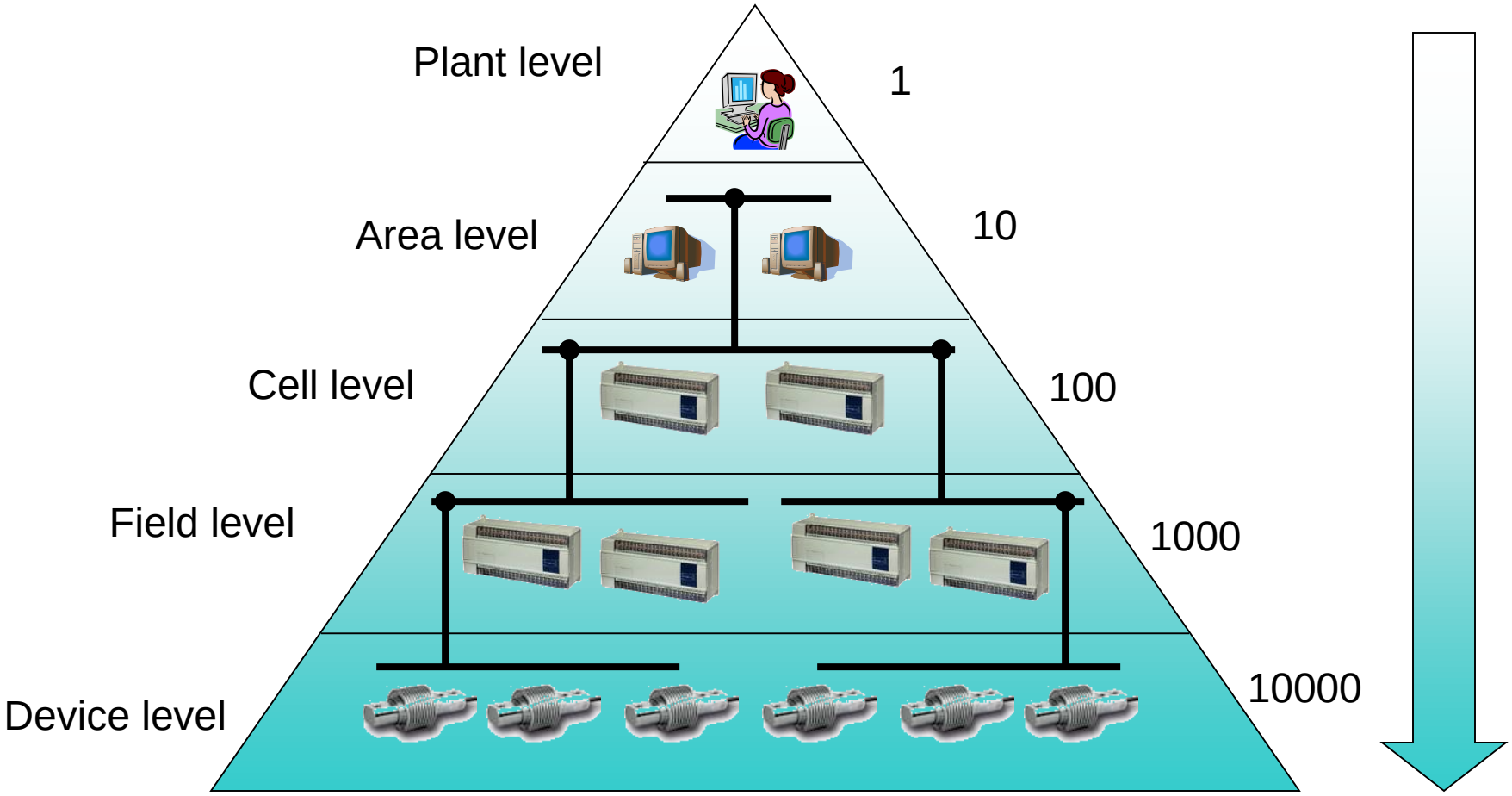
Type	Class	Description
Safety	0	Critical
Control	1	Closed Loop regulatory control
	2	Closed loop supervisory control
	3	Open loop control
Monitoring	4	Alerting
	5	Data logging and Up/Download

What kind of wireless applications?

- There is no One Size Fits All!!

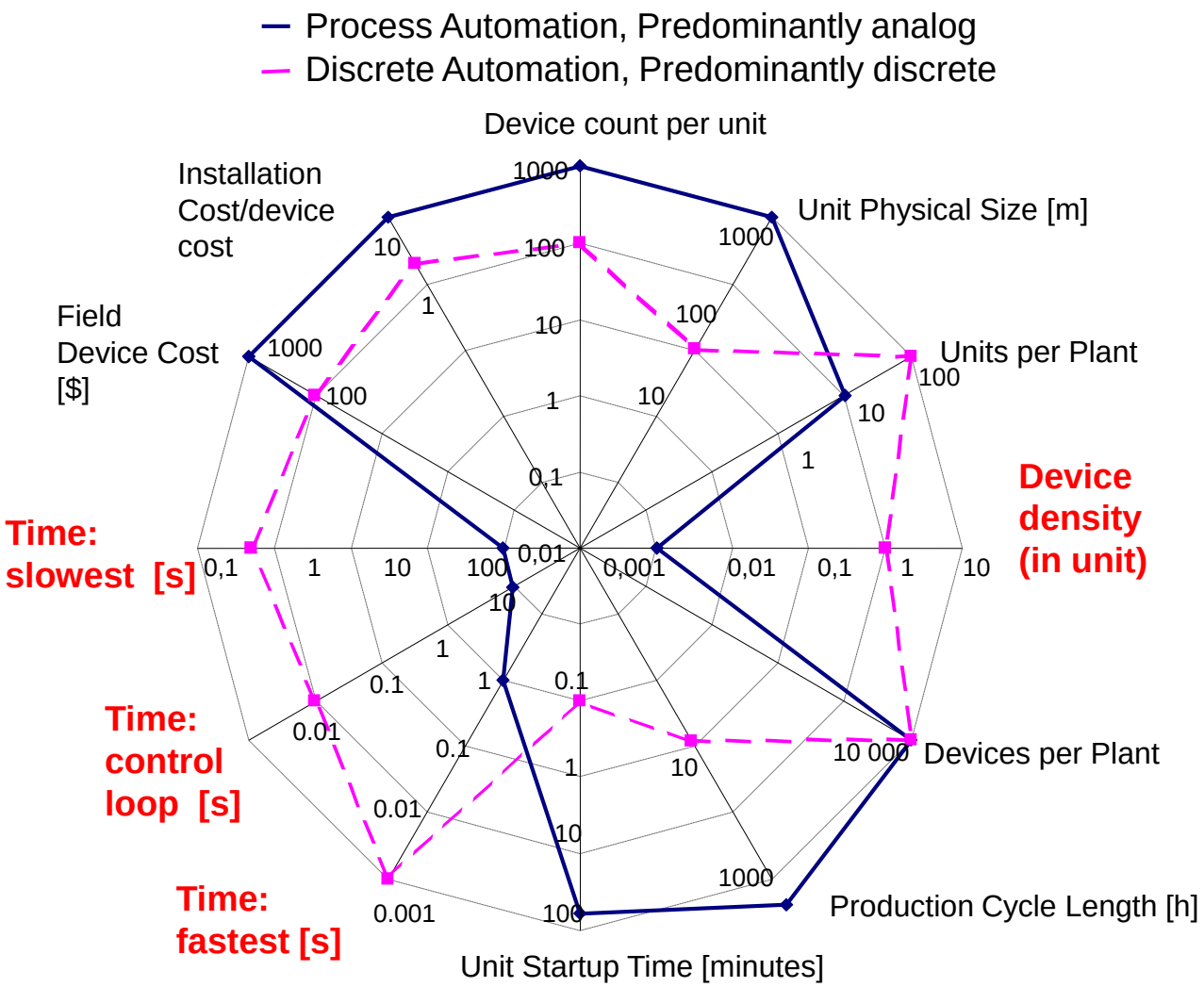


Where are the cables?



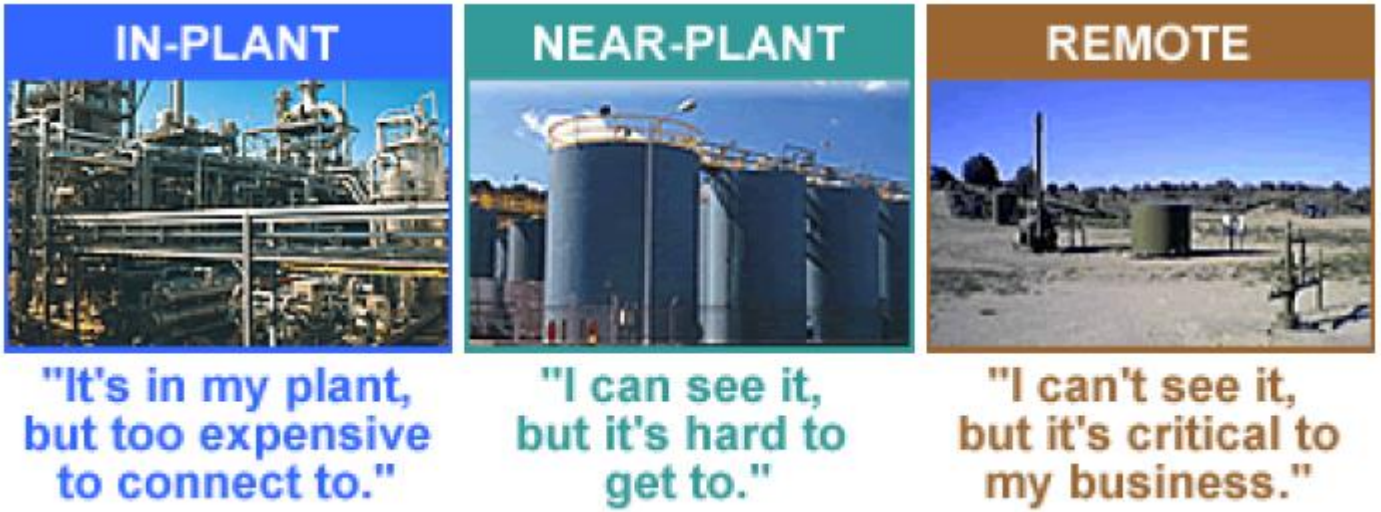
Resuming: FA vs PA…

- Similar requirements … but very different values (log graph)!
- There is no ONE-SIZE-FITS-ALL!



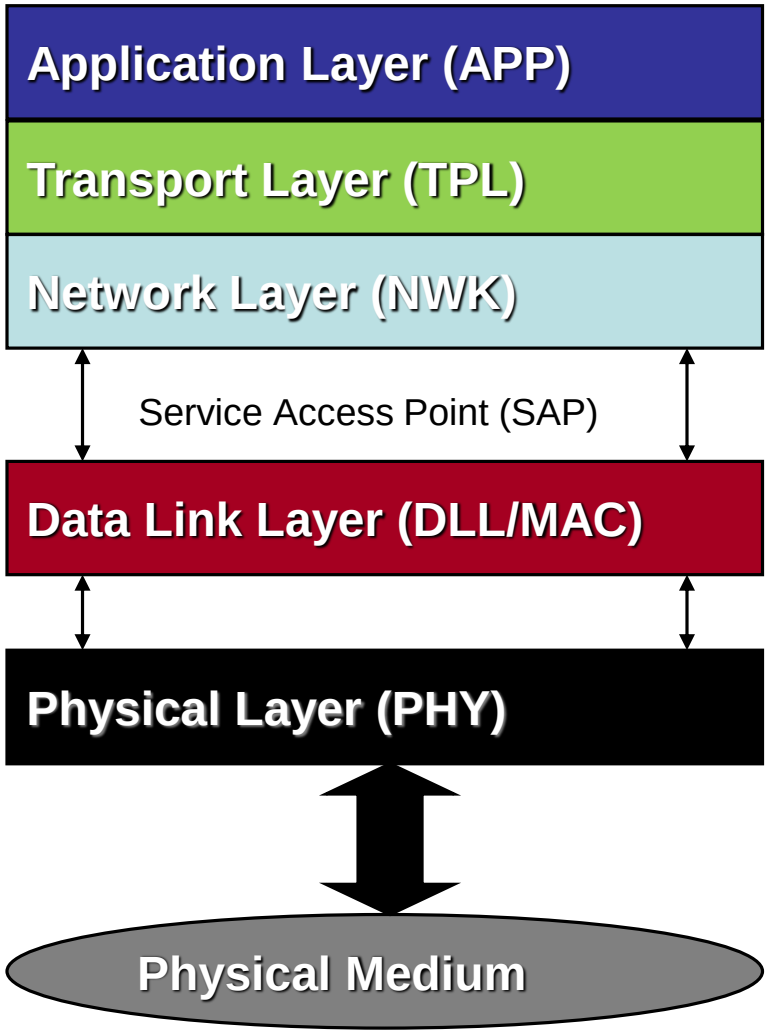
Wireless applications in Process Automation

- No single wireless technology delivers all these benefits in every situation.
- That's because there are so many different potential applications, each with a different requirement and a different "best" solution.
- As an example, consider the following three common types of process-automation applications for wireless technology.



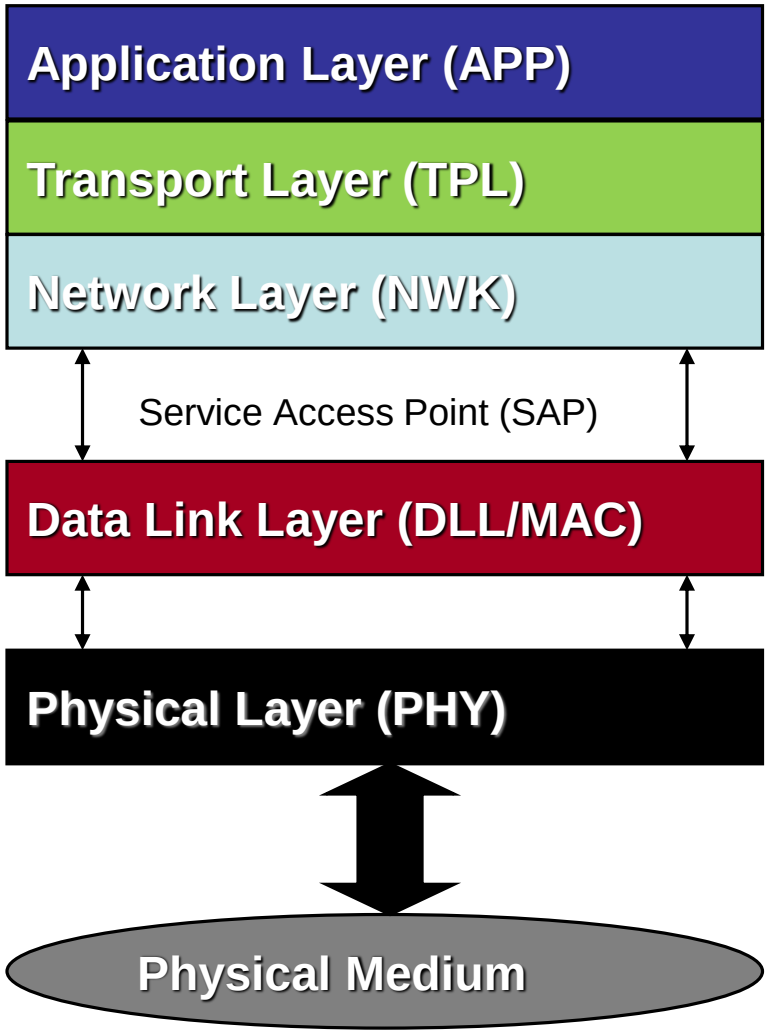
Communication Protocol Stack

- Stack
  - Layered, abstract description for network protocol design
- Layer
  - Collection of related functions
  - Provides services to the layer above it
  - Receives service from the layer below it.



Communication Protocol Stack

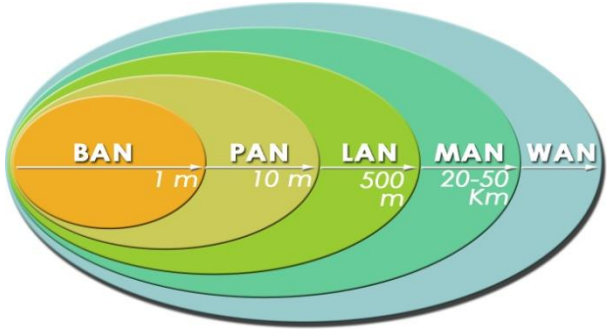
- The APP affects interoperability
  - Profiles can be defined
- The DLL/MAC affects (timing) performance and coexistence
  - It decides when to transmit
- The PHY affects coverage, throughput and coexistence



Communication standards

Metropolitan networks - Wireless **MAN** (WMAN)

- WiMAX
- Cellular (GPRS, EDGE, UMTS…)



Local networks - Wireless **LAN** (WLAN)

- WiFi, HIPERLAN
- DECT

BAN: Body
PAN: Personal
LAN: Local
MAN: Metropolitan
WAN: Wide Area Network

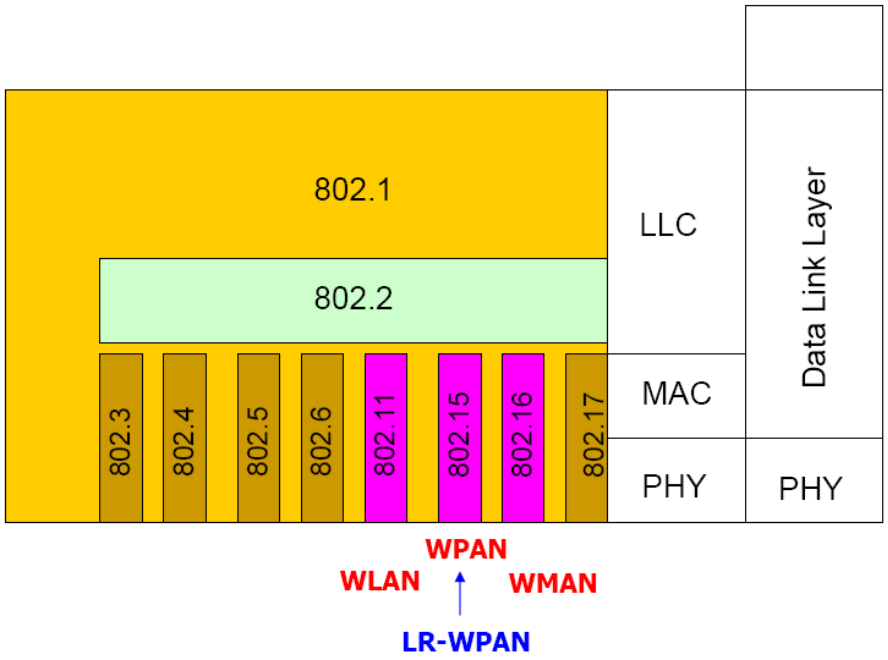
Short range networks - Wireless **PAN** (WPAN)

- Bluetooth, ZigBee, Z-Wave, WiBree, nanoNET, UWB, Wireless USB, WirelessHD, ISA100, WirelessHART, RFID, 6LoWPAN, WirelessFirewire, …….

Communication standards

IEEE standardization efforts

Defines PHY and MAC



- ***IEEE 802: LAN/MAN Stds***
  - ***IEEE 802.1: High Level I/F***
  - ***IEEE 802.3: ETH***
  - ***IEEE 802.11: WLAN***
  - ***IEEE 802.15: WPAN***
  - ***IEEE 802.16: WMAN***
  - ***IEEE 802.18: Radio Reg.***
  - ***IEEE 802.19: Coexistence***
  - ***IEEE 802.20: Mobile BWA***
  - ***IEEE 802.21: Media Independent Handoff***
  - ***IEEE 802.22: Wireless Regional Area Networks***

Wi-Fi

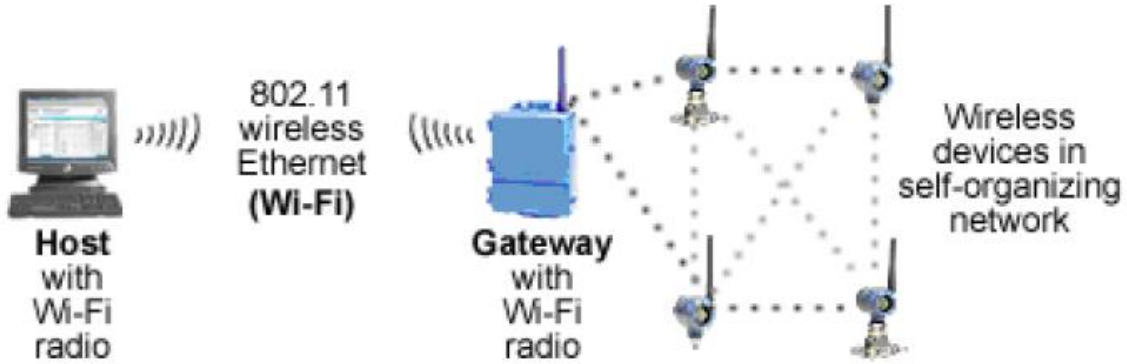
Wi-Fi (not an abbreviation)

- Wi-Fi Alliance, IEEE 802.11: WLAN “de facto” standard
- IP technology compatible, defines PHY and MAC
- Amendments: mesh (802.11s), security (802.11i), QoS (802.11e), …
- Mobile (802.11r) and high throughput variants (802.11ac/ad) exist

Standard	Frequency	Raw rate (Mb/s)	Range (metri)
802.11 legacy	2,4 GHz, IR	2	(pochi metri)
802.11a	5 GHz	54	20-40
802.11b	2,4 GHz	11	50-100
802.11g	2,4 GHz	54	50-80
802.11n	2,4 GHz, 5 GHz	450	Fino ai 120-180
802.11ac	5 GHz	2340	100
802.11ad	60 GHz	6750	60-100
802.11ah	900 MHz	347	Km

Wi-Fi in the plant

- Many plants already use Wi-Fi to allow workers to access important applications or send email without physically connecting their PC or laptop to the plant LAN.
- Beyond these office-type applications, however, Wi-Fi can also provide access or serve as a "backbone" transport medium for process-related networks.
  - For example, you might use Wi-Fi to link an isolated area of the plant to a central control room – especially where distance or barriers like rivers or highways make a wired connection too expensive or impractical.
  - Or you could use it to link a self-organizing network of low-power, short range devices to a host system or wired LAN.



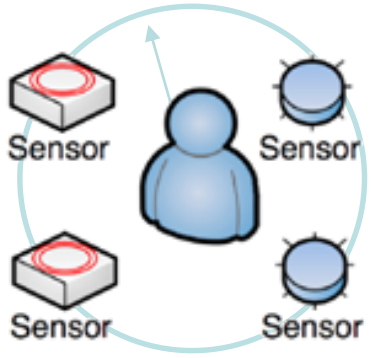
PAN networks

WirelessPAN – IEEE 802.15

- 802.15.1
  - Bluetooth
- 802.15.4 (low-rate PAN)
  - ZigBee, WirelessHART, 6LoWPAN, ISA100, …
- Others: Body Area networks, Visible light communications, etc.

IEEE 802.15
Wireless Personal Area Network (WPAN) Working Group

- ***Task Group 1: WPAN/Bluetooth ™***
- ***Task Group 2: Coexistence***
- ***Task Group 3: WPAN High Rate***
- ***Task Group 4: WPAN Low Rate***
- ***Task Group 5: WPAN Mesh***



~10m

Comparison

Technology	Wi Fi 802.11	Bluetooth® 802.15.1	ZigBee™ 802.15.4
Target application	Web, Email, Video	Voice, Cable replacement	WSN
Flash size	1MB+	250KB+	25KB - 70KB
Battery life (days)	0.5 - 5	1 - 7	100 - 1,000+
Basic network	32 / …	7 / …	255 / 65535
Throughput (kbps)	11,000+	1000	20 - 250
Range (m)	1 – 100+	1 - 100+	1 – 75+
Advantage	Speed, flexibility (IP)	Price, convenience	Low power, simple

The WirelessHART role

- Initiative launched by HCF in November 2004. Standard in September 2007.
- IEC approved (Committee 65C WG 16).

- Objective:

  Establish a wireless communication standard for process automation, in particular for IN PLANT applications

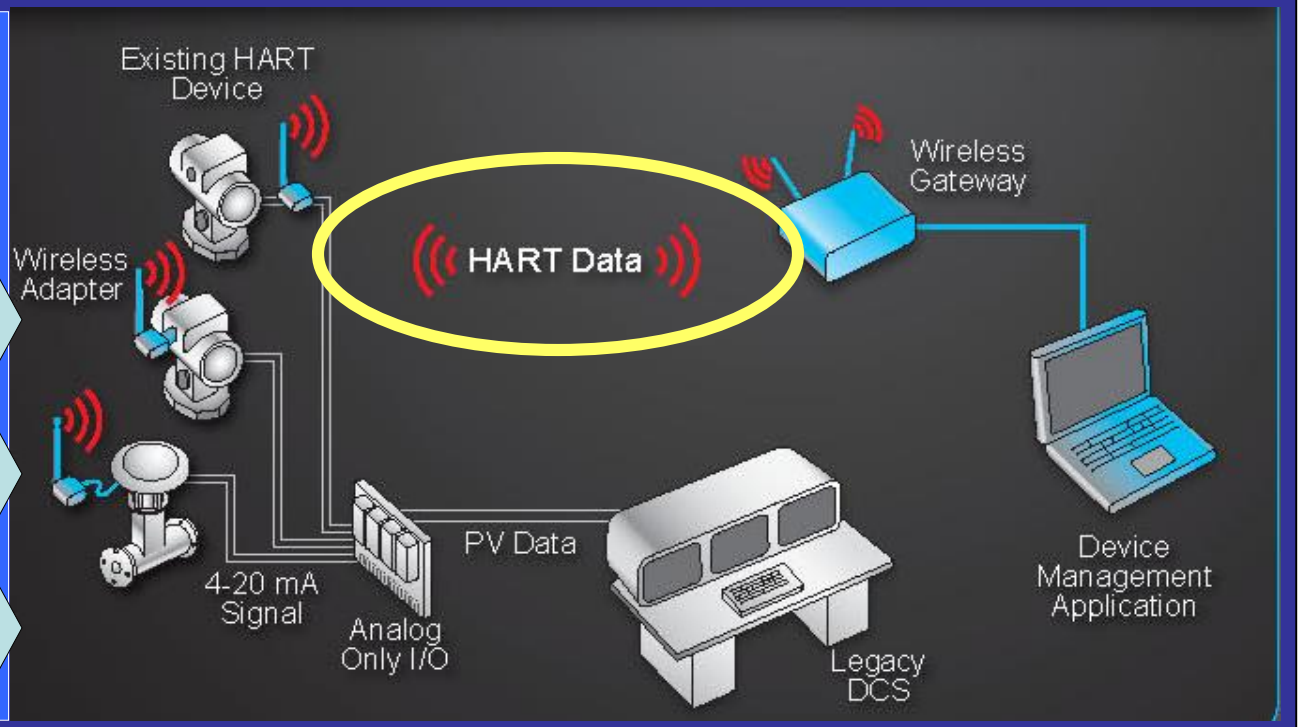
- *Wireless***HART:** wireless extension to **HART** protocol
  - An open and interoperable standard
  - As easy as using wired **HART** (they share upper layers)
  - Enable wireless access to *existing* **HART** devices
  - Use the same configuration, maintenance, diagnostic tools and procedures
  - Require little additional training

The WirelessHART role: major use case

Wireless Connection to existing legacy HART Devices

Wireless Access to HART Device Information

- Easy Access to Intelligent Device Information
- Enabled by Wireless Adapter
- Device Status, Diagnostics, Configuration and more

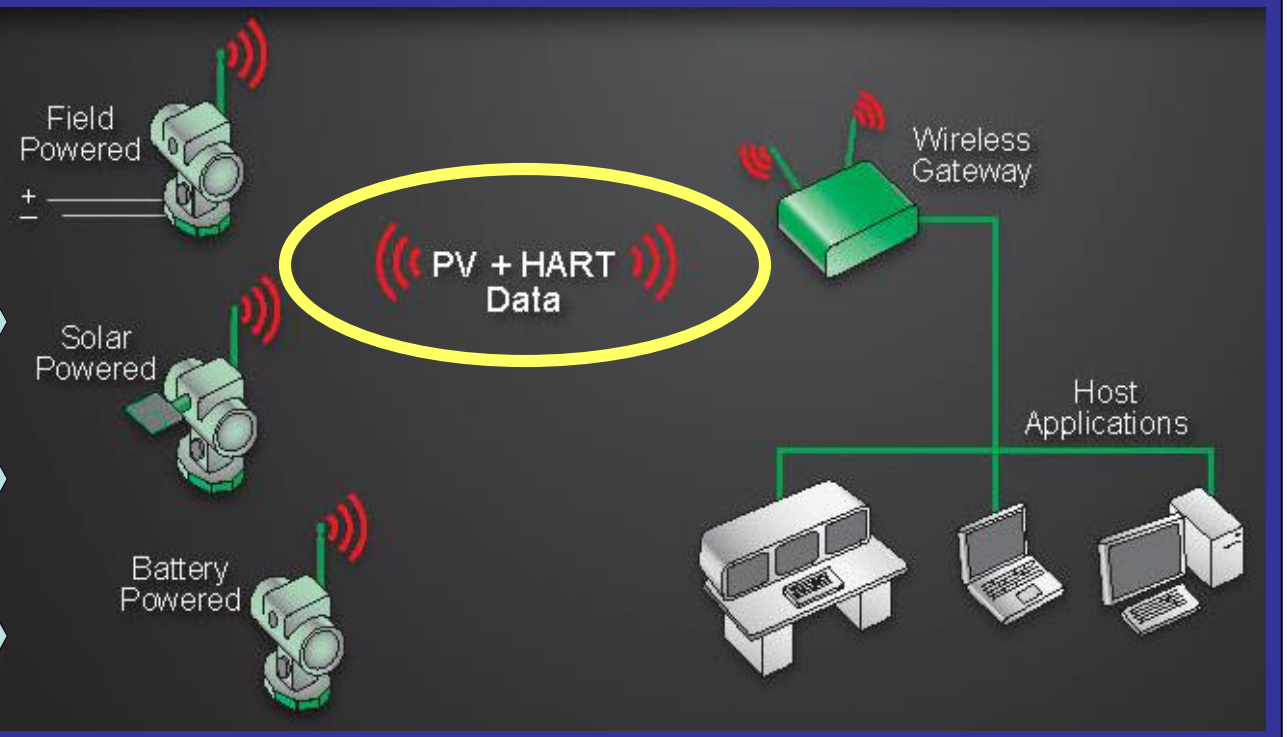


The WirelessHART role : enable new class of devices

A brand new wireless fieldbus and wireless devices!

Wireless Access to Additional Process Measurements

- Wireless Gateway Connection to Plant Systems
- Minimal Installation Cost - No Wires
- Battery, Solar or Field Powered Devices



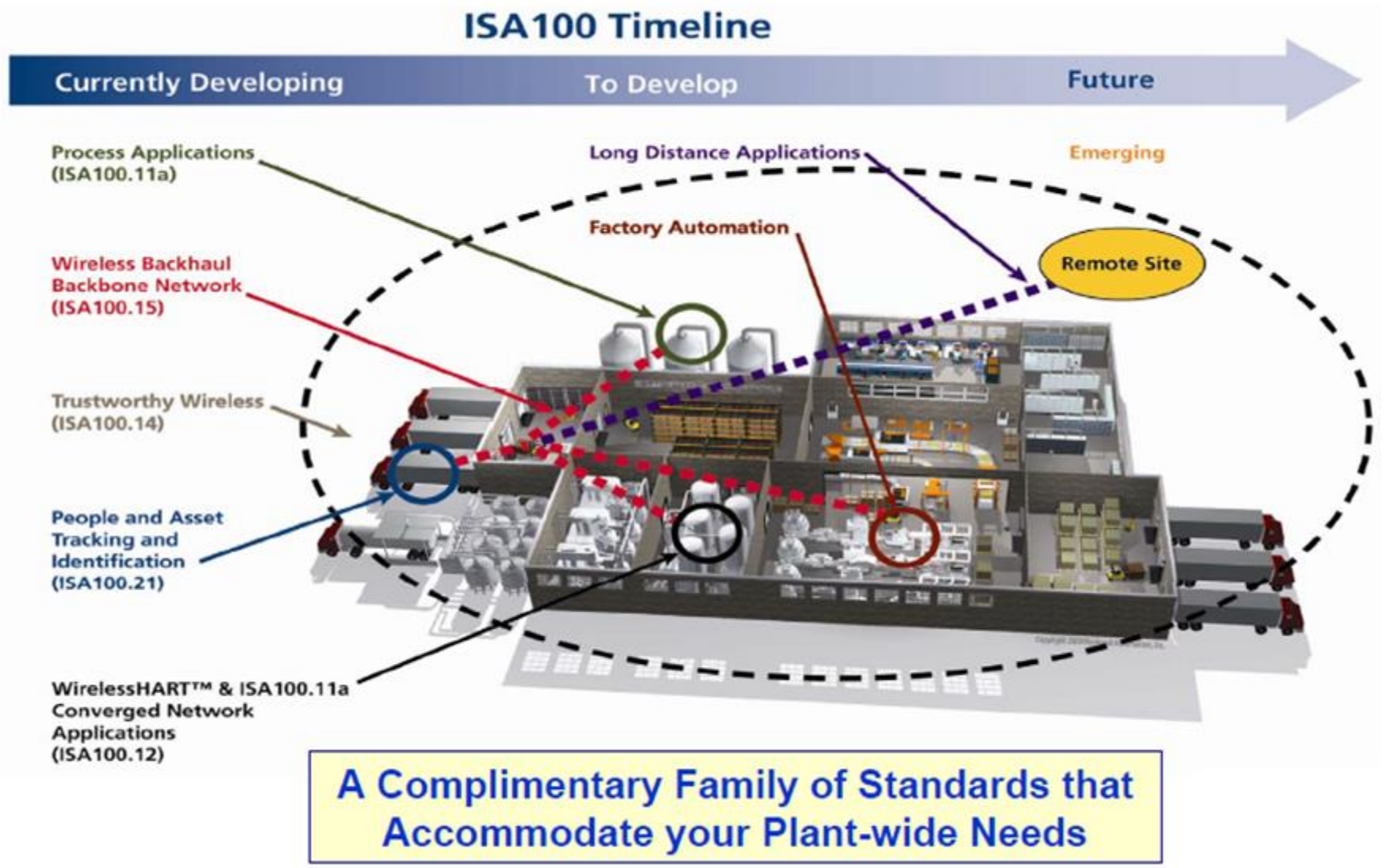
The ISA100.11a role

- What is the ISA100 Committee?
  - ✓ The ISA100 committee is part of ISA and was formed in 2005 to establish standards and related information that will define procedures for implementing wireless systems in the automation and control environment with a focus on the field level.

- The committee is made up of over 400 automation professionals from nearly 250 companies around the world with a variety of industrial backgrounds

- ISA100: Family of Standards, designed to Accommodate all the Plant Needs. Areas of Coverage Identified: to date;
  - ✓ **Process Automation (Process Focus)**,
  - ✓ Factory Automation (Discrete Focus),
  - ✓ Transmission and Distribution (Long Distance Focus),
  - ✓ RFID (Industrial Tagging Focus)

The ISA100.11a role



The ISA100.11a role

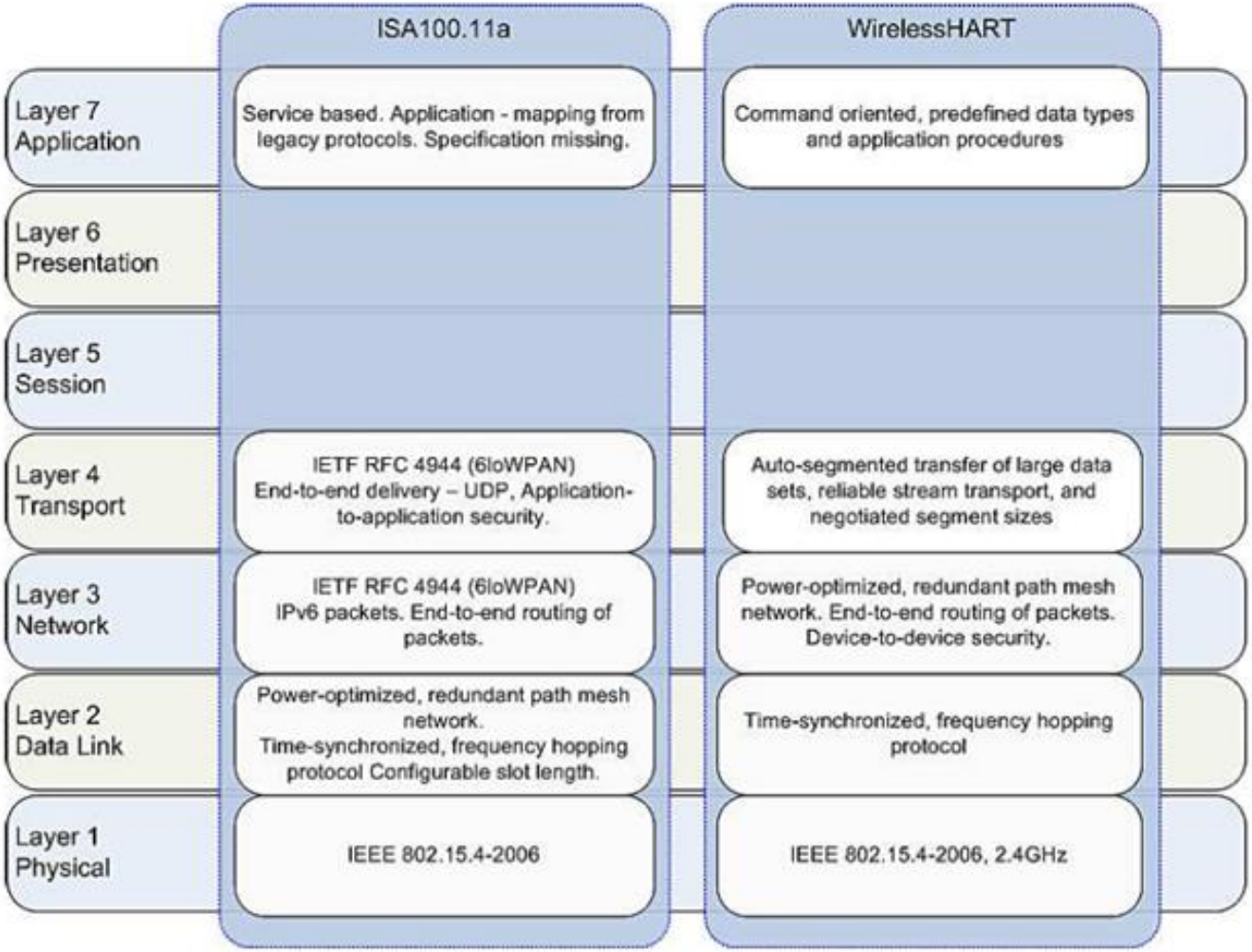
- This standard defines all specifications including security and management; for wireless devices serving application classes 1 through 5 for fixed, portable and moving devices.
- The ISA100.11a standard addresses performance needs for periodic monitoring and process control where latencies on the order of 0,1-1,0 s can be tolerated (with optional behavior for shorter latency).

- Scope of this standard:

AN INDUSTRIAL WIRELESS AUTOMATION STANDARD FOR PROCESS PLANTS

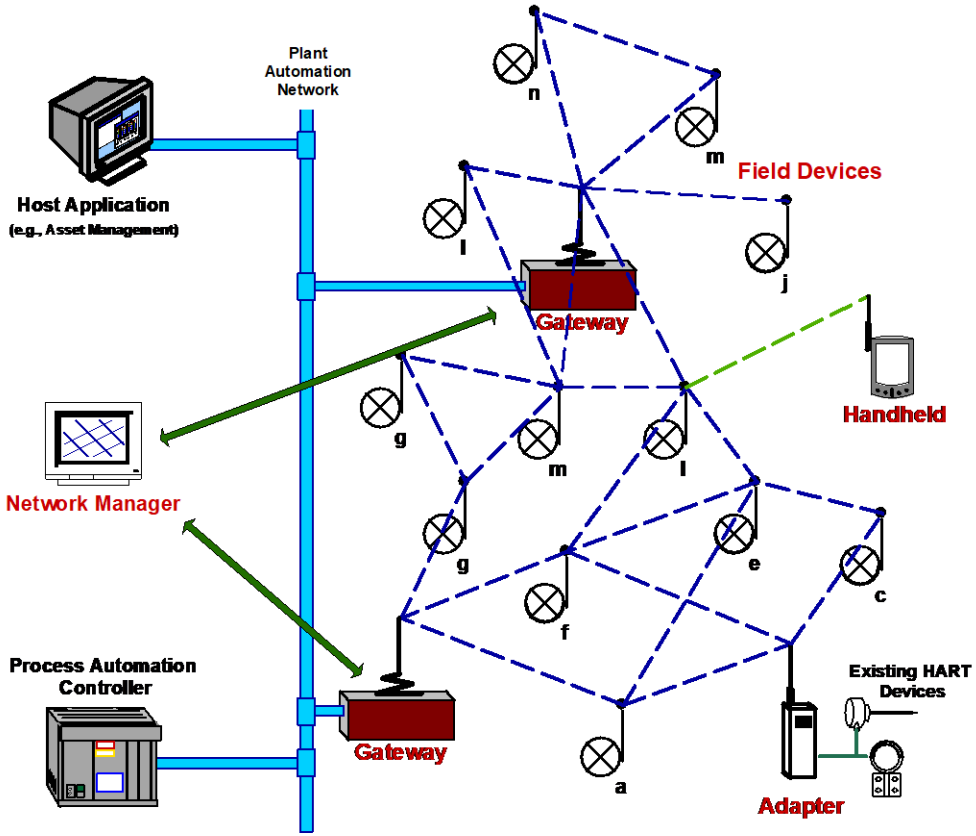
Comparison

- Very similar approach…



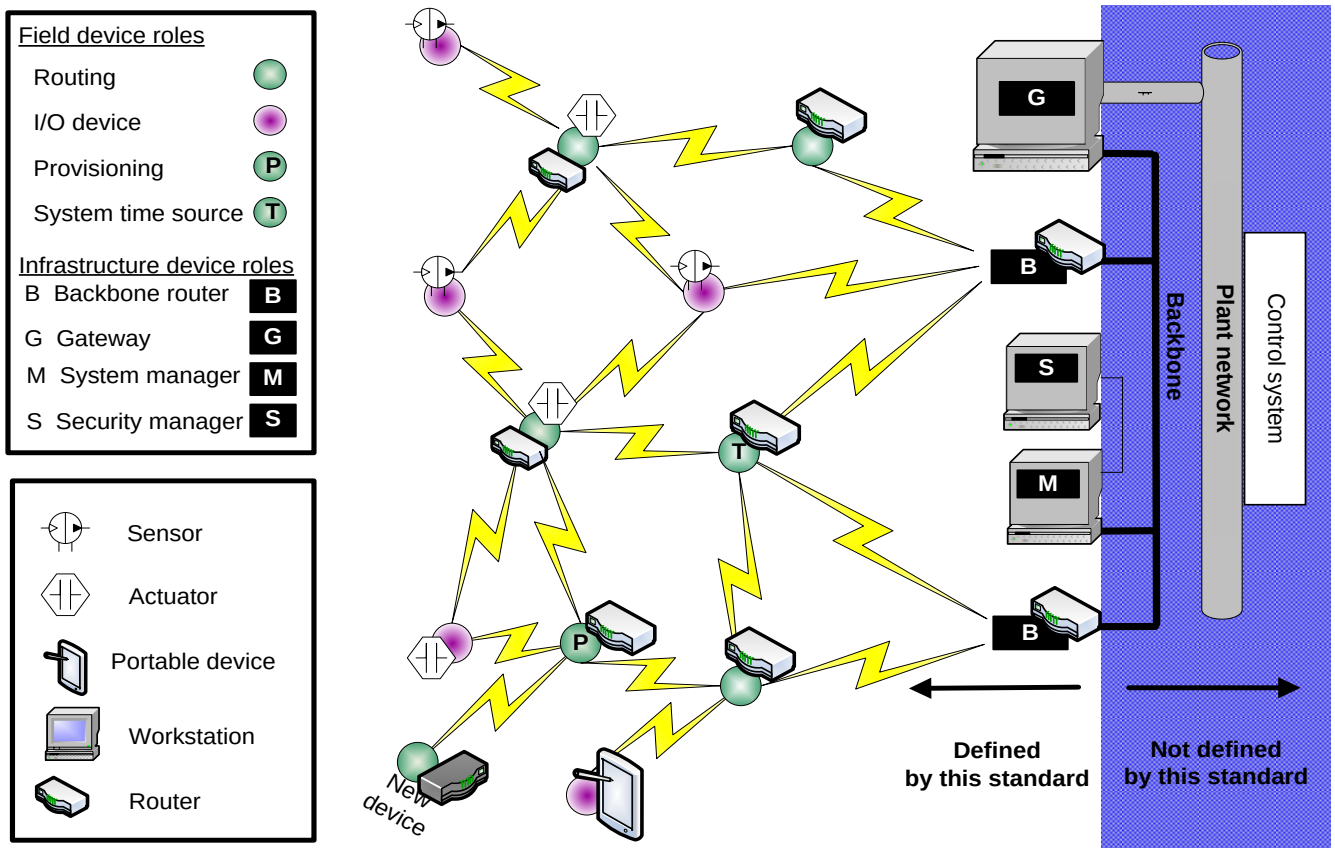
WirelessHART - Architecture

- The basic elements of a WH network include field devices, gateway, security and network manager.
  - Every network includes at least one gateway.
  - While redundant network managers are supported, there is only one active network manager per network.
  - Gateways may include one or more access points.



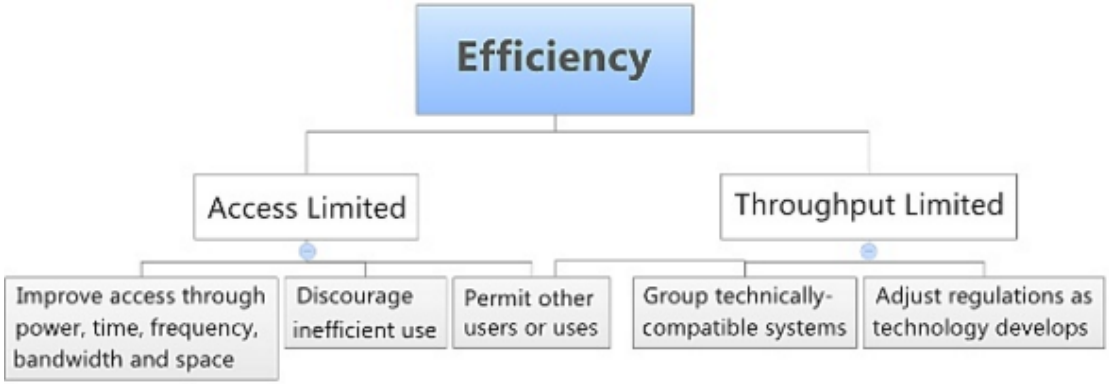
ISA100.11a – Architecture

- Circular objects: field devices (sensors, valves, actuators, etc.)
- Rectangular objects: infrastructure devices that communicate to other network devices via an interface to the network infrastructure backbone



Broadband systems

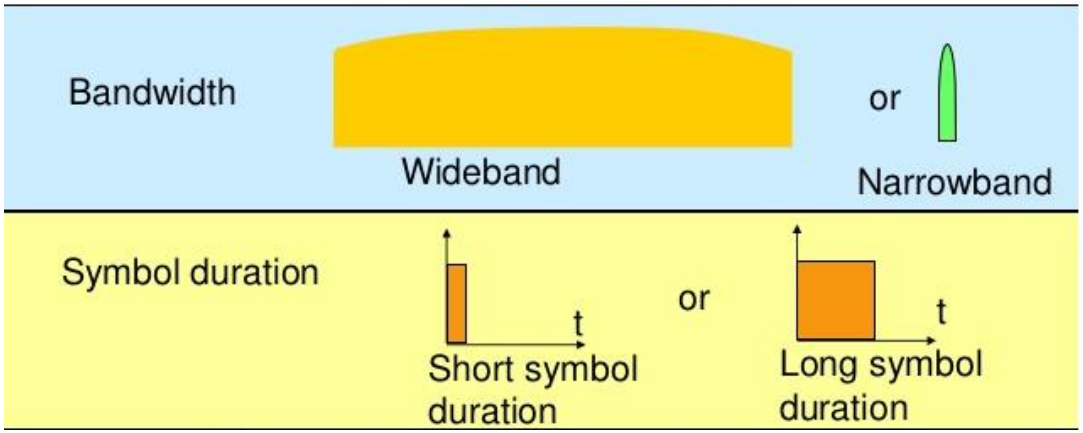
- Broadband systems usually counteract interference and noise by means of DSSS approach
- The main drawback of using a coding gain solution is the very low spectrum efficiency.
  - you send a lot of redundant data in the coding to compensate for the higher noise floor.



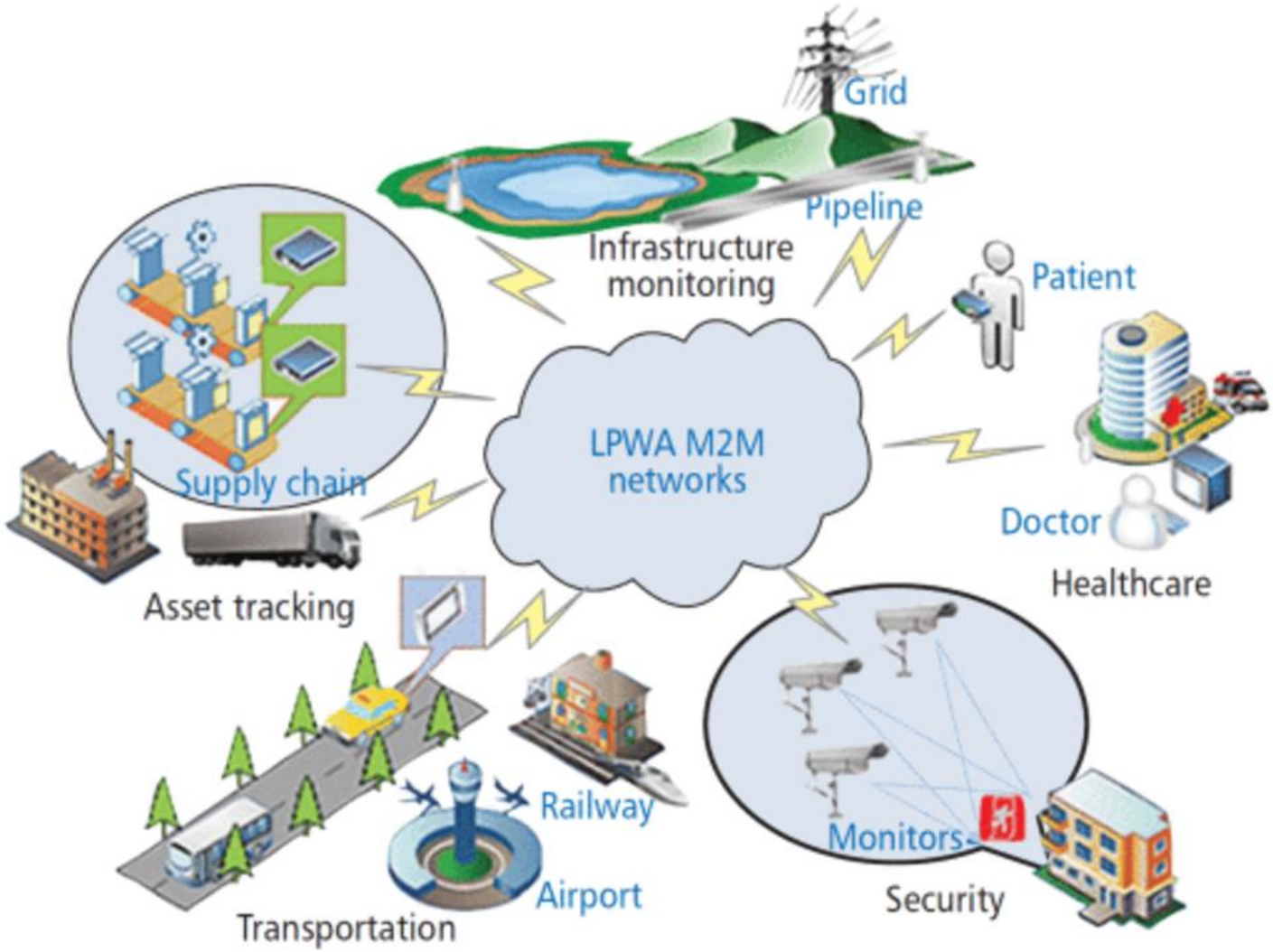
Trading higher receive sensitivity for less spectrum efficiency (higher bandwidth) by spread spectrum goes against regulatory requirements and worldwide industry practice for better spectrum utilization.

Narrowband systems

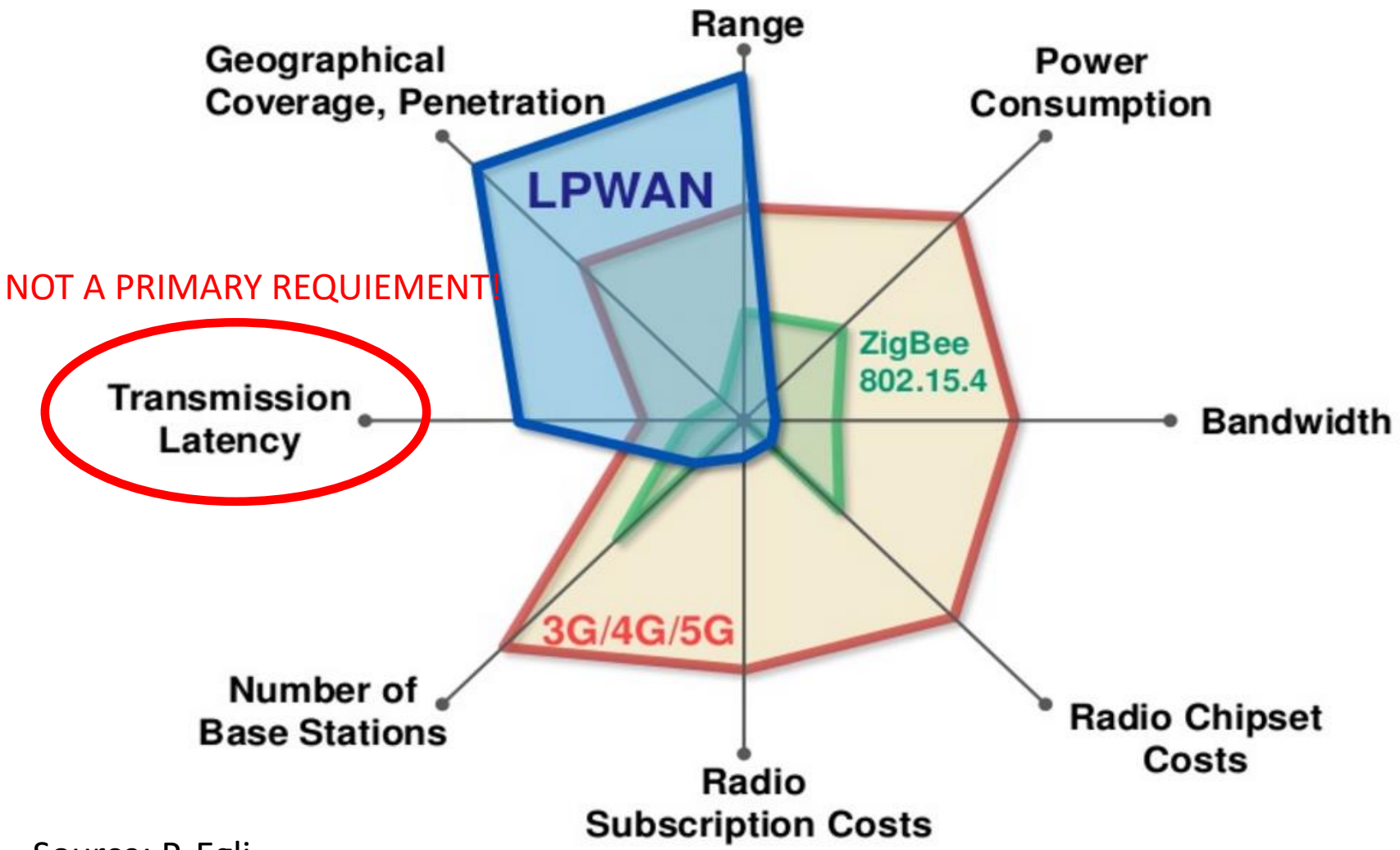
- Narrowband have low rates, that could mean very long time on air, which will in turn reduce the battery lifetime.
- Having very long telegrams also increases the probability of interference and collisions with other wireless systems.
- … but narrowband systems offer better SENSITIVITY and SPECTRUM EFFICIENCY!



LPWAN INTENDED APPLICATIONS



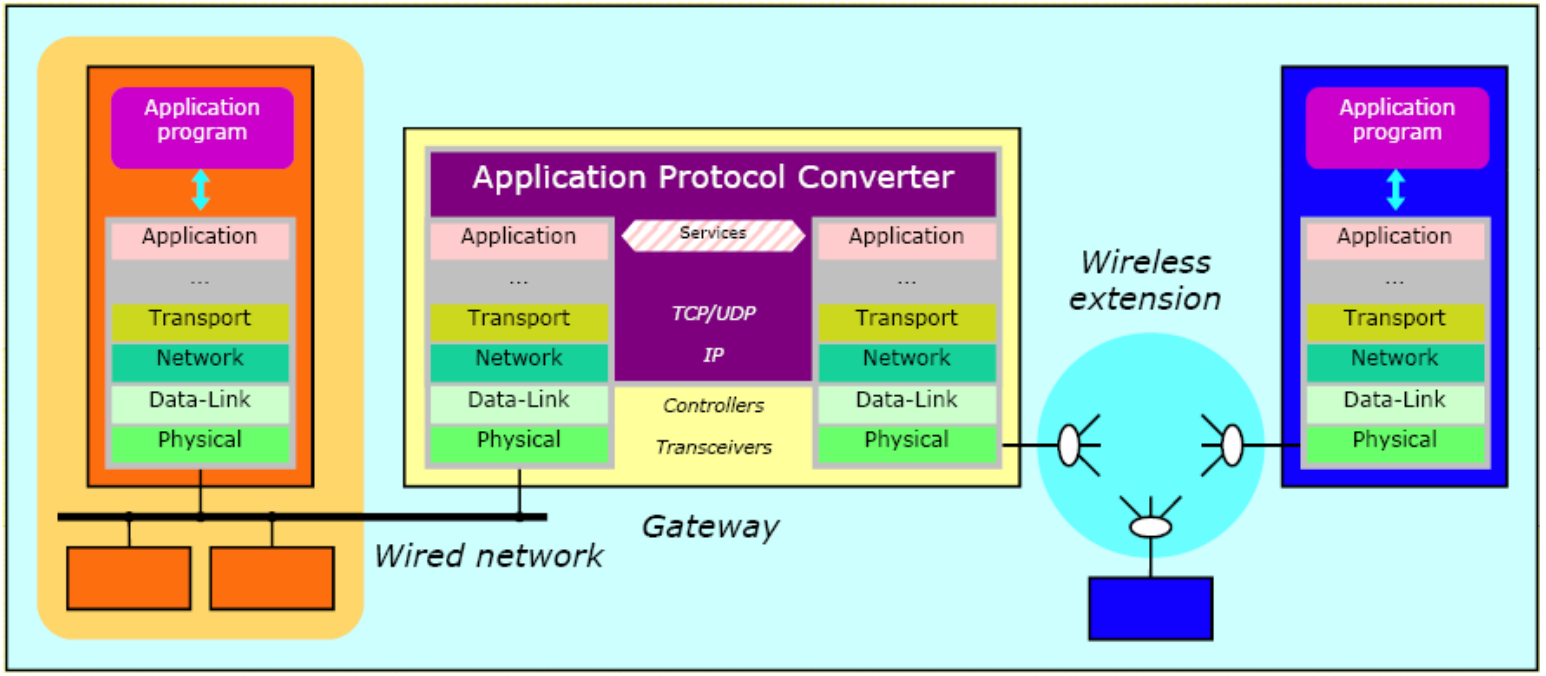
No one-size-fits-all…



Source: P. Egli

Interconnection on ApplicationLayer (Gateway)

- Fully compliant with the protocol stacks of both networks
  - Transparent flow of application layer PDUs
  - Most versatile concept
- May operate as proxy
  - More services than a gateway
  - represents parts of a network as if they were a single node



Thank you


THANK YOU
GRACIAS
ARIGATO
SHUKURIA
DANKSCHEEN
BIYAN
SHUKRIA
TINGKI
YAQHANYELAY
TASHAKKUR ATU
SUKSAMA
EKHMET
MEHRBANI
GRAZIE
KOMAPSUMNIDA
JUSPAXAR
GOZAIMASHITA
EFCHARISTO
BOLZÏN
MERCI
SPASSIBO
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SNACHALHUYA
CHALTU
WABEEJA
MAITEKA
YUSPAGARÀTAM
HUI
GUI
HÀTUR
UNALCHÉESH
SPASIBO
DENKAUJA
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MAAKE
TAVTAPUCH
MEDAWAGSE
AGUYJE
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