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Wireless Sensor Networks for Industrial Applications

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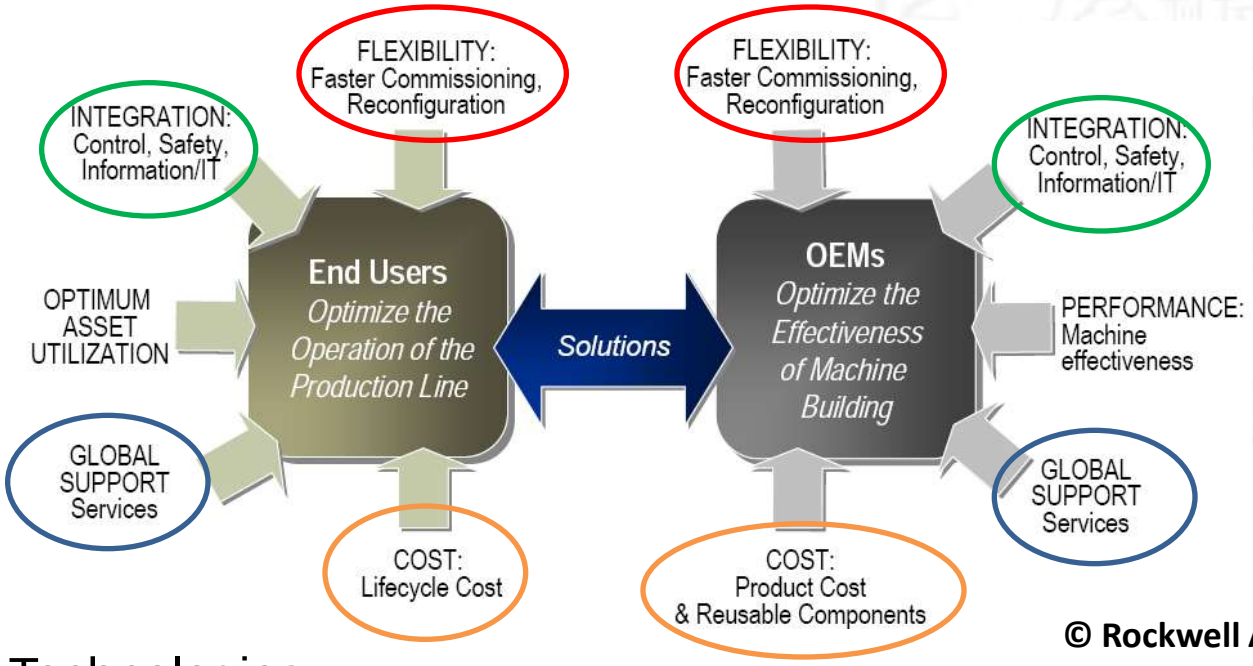
Manufacturing and technology drivers today

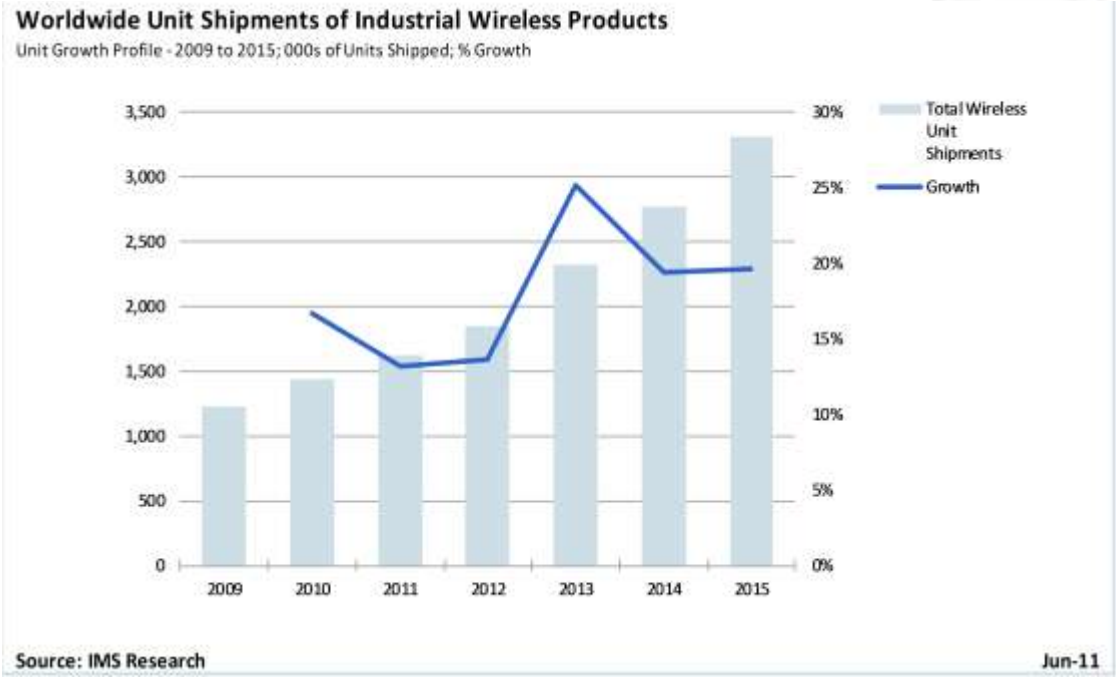
- Many common drivers for OEMs and End Users:



- Five Key Technologies:
  - Control/Diagnostics (Prognostics, Autonomous systems…)
  - Electronics (Smart devices…)
  - Materials (Nanocoatings…)
  - Software (Vertical integration…)
  - Communications: WIRELESS

Industrial Networks Go Wireless!

- In a recent study, IMS Research estimated that the overall industrial wireless market would grow at an average annual growth rate of 18% to the end of 2015.
- That's certainly well above the average rate we'd consider "normal" for industrial automation products (more typically 5-8%)



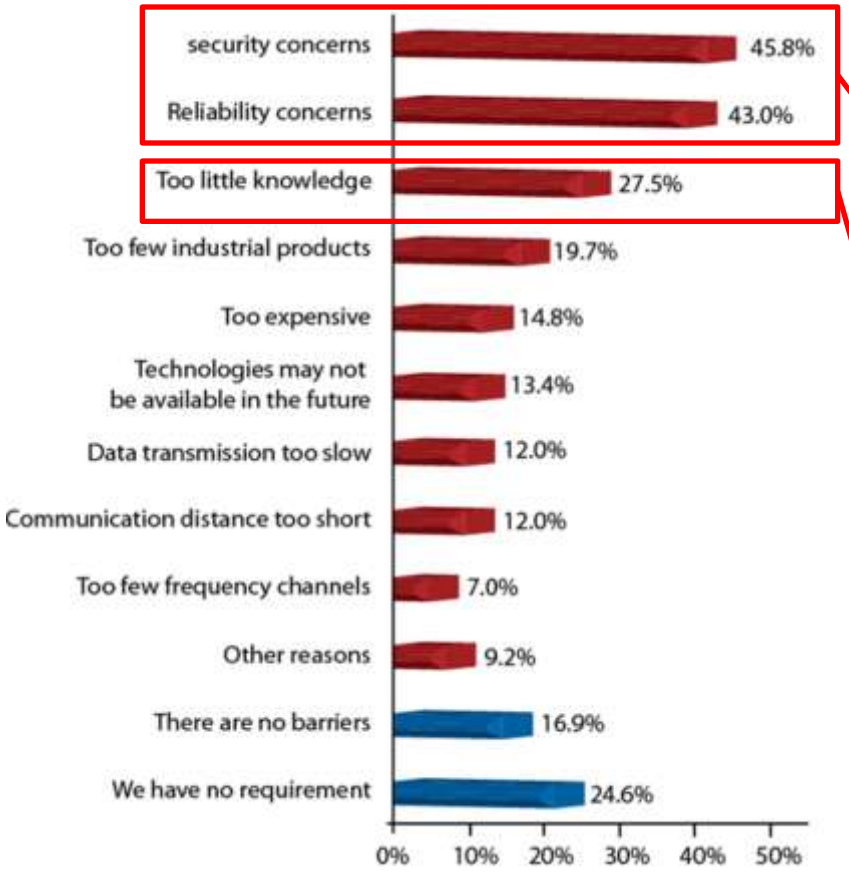
Why wireless now?

- Wireless isn't new, also in industrial automation (for niche applications). Why all the recent interest about it?
  - 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 industrial 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.

Inhibitors

- Nevertheless, nowadays there is still confusion about actual wireless technology capabilities and “psychological” inhibitors.



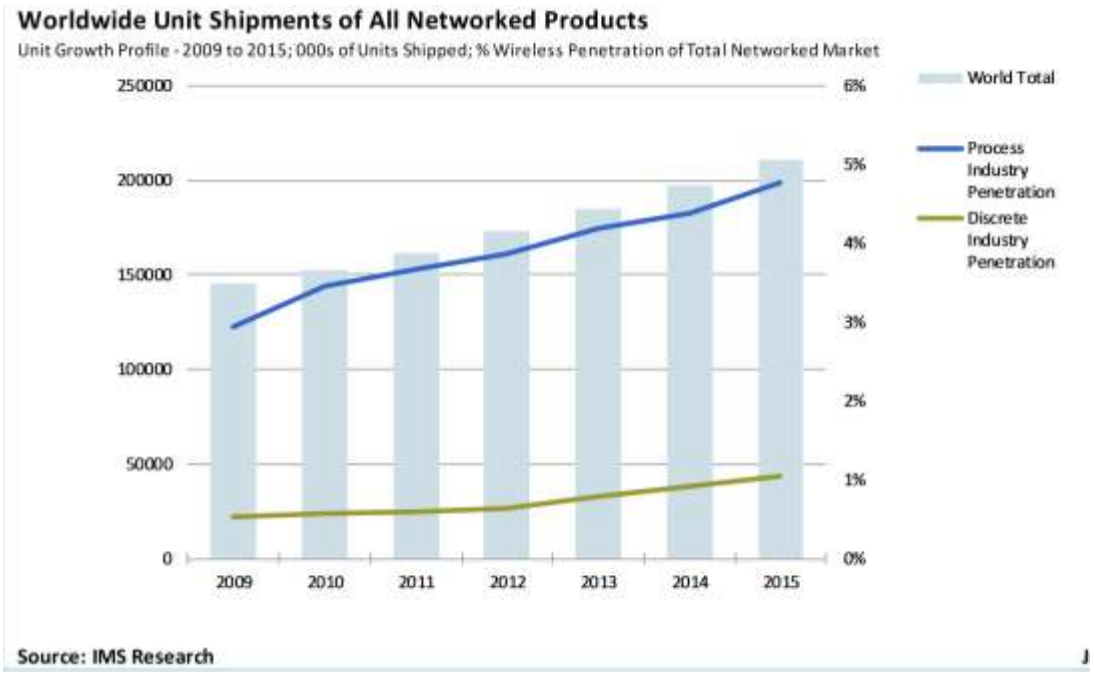
Challenges for the academic world:

- New control theory
- New design and verification tools
- New communication solutions
- Knowledge transfer between academy and industry

J. Morse, “Market Pulse: Wireless in Industrial Systems: Cautious Enthusiasm“, Embedded Systems, Winter 2006.

Market penetration

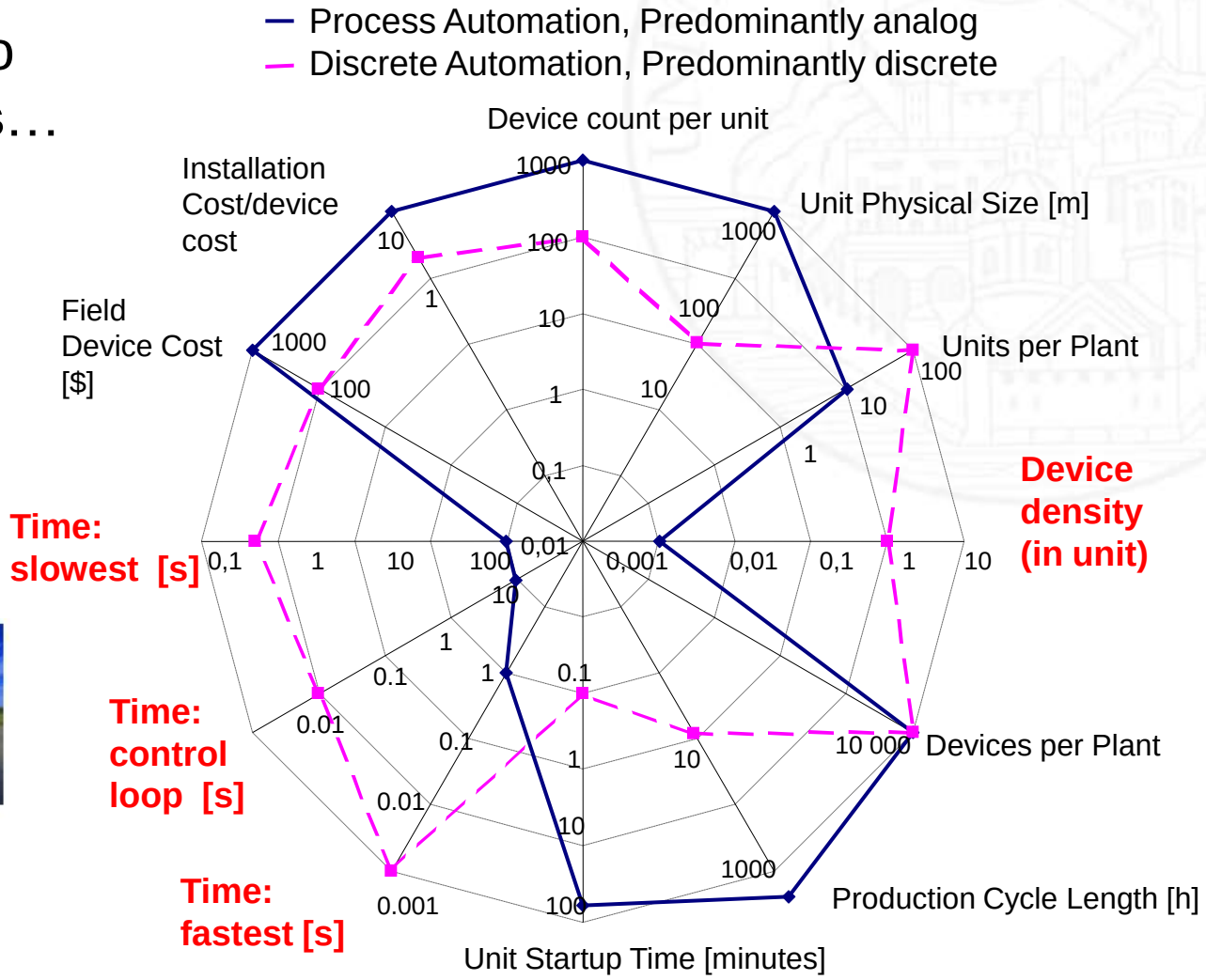
- However, the above statistics don't tell the whole story. The growth forecast for the relative market sizes of wireless products sold to discrete and process industries varies significantly:



- ✓ For example, in 2009 – a tough year for process equipment in general – unit shipments of wireless process measurement instruments **doubled**.
- ✓ The story for discrete automation is quite different. A wide variety of products targeted at this space do currently exist, but penetration within the market is **much lower**.

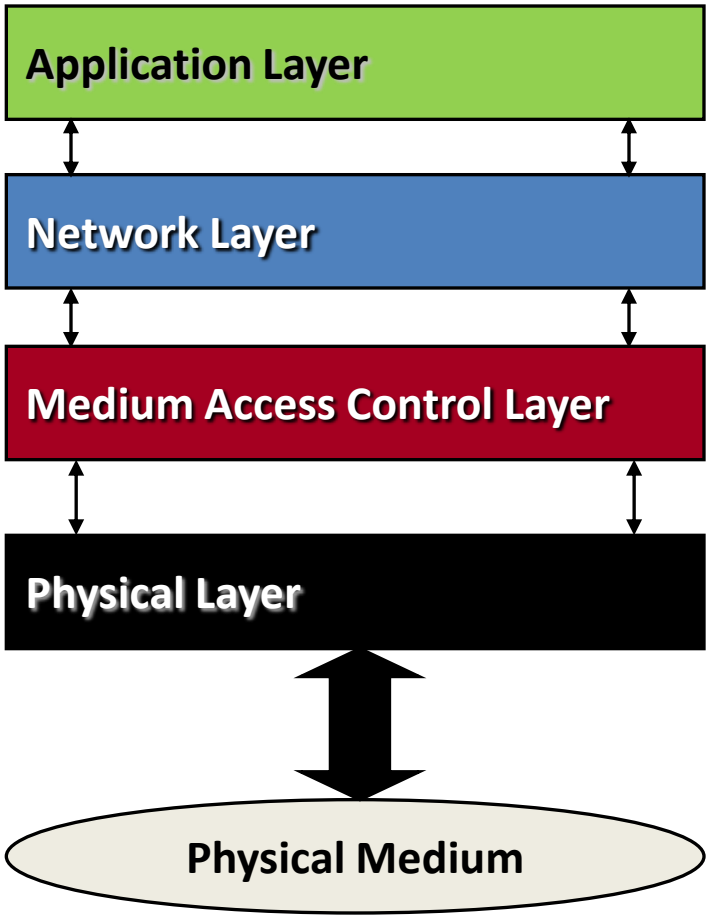
PA/FA requirements

- Requirements to similar variables…
  … but very different values (logarithmic scale)!
- There is no one size fitting all!



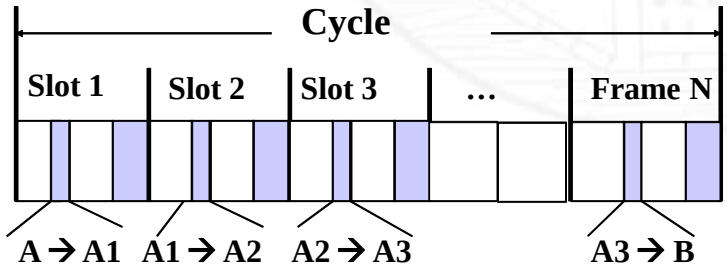
The protocol stack

- How do applications requirements affect the communication protocol stack?

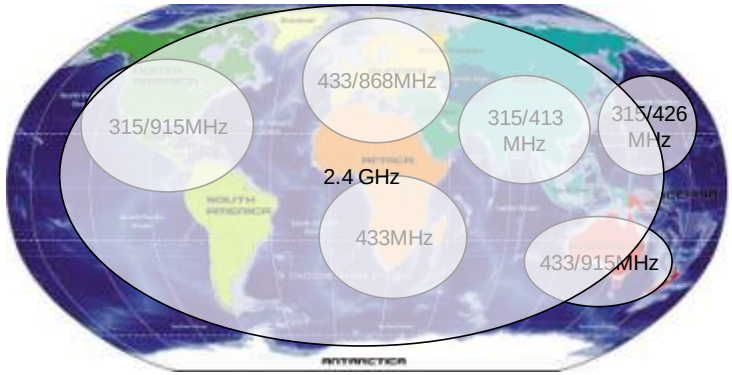


STAR: for factory automation

MESH: for process control



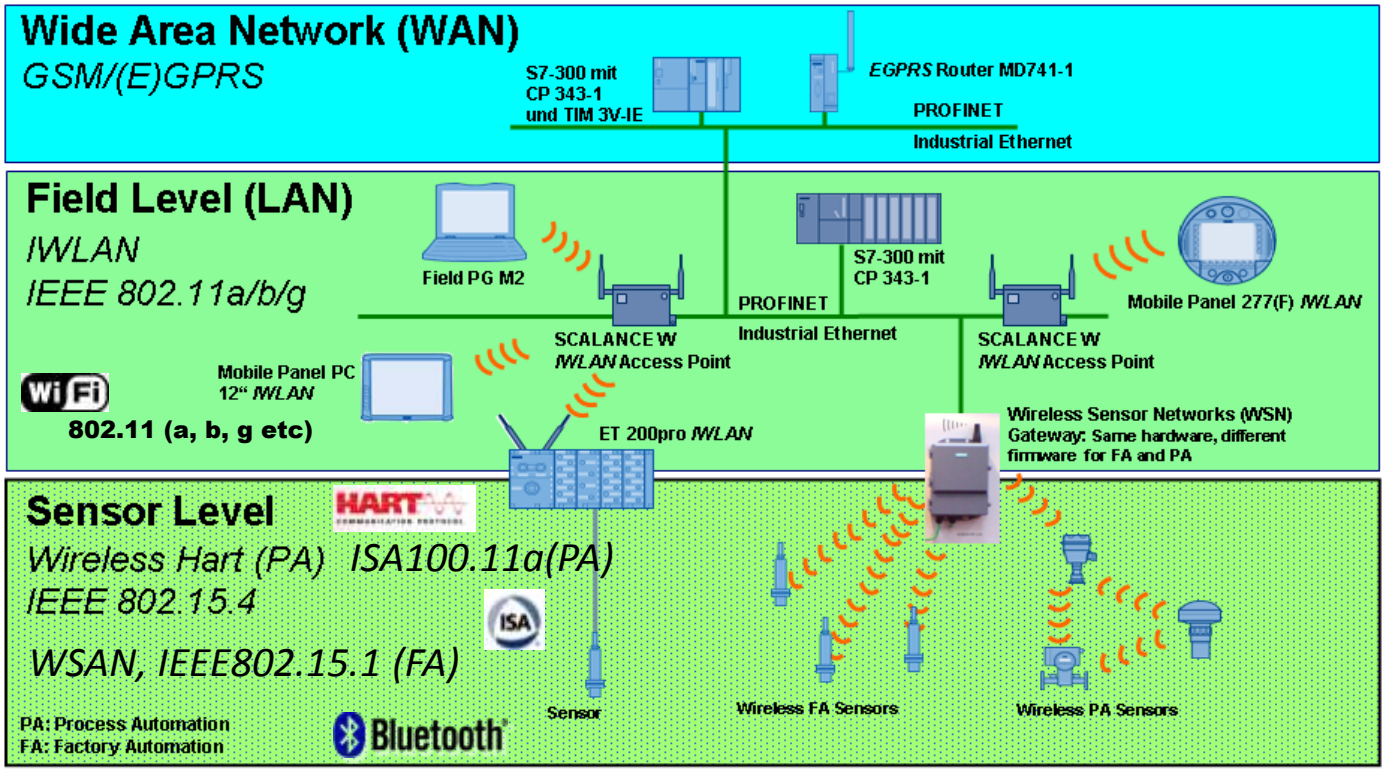
Synchronized TDMA



Worldwide, license free band: ISM @ 2.4GHz!

What about standards?

- Automated interaction among different devices implies some standard mechanism for communication!
- Since there is no one size fits all…industrial wireless is based on a network of networks!



Source:
SIEMENS

The WirelessHART role

- Initiative launched by HCF in November 2004. Standard in September 2007. Now IEC approved (Committee 65C WG 16). Supported by PI for PA wireless applications

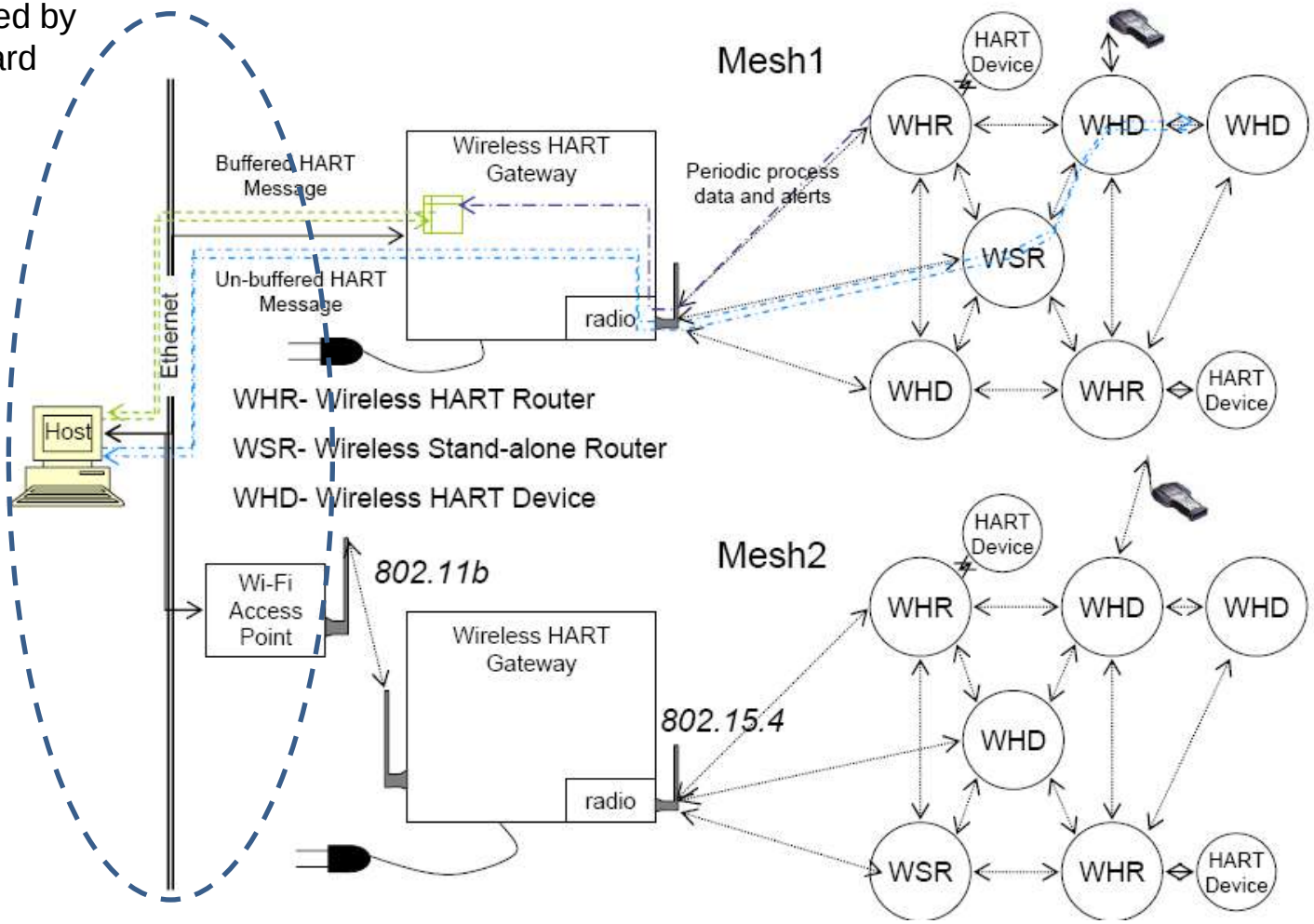
- Objective:

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

- *Wireless***HART:** wireless extension to **HART** protocol
  - Based on IEEE 802.15.4-2006 (250kbps @ 2.4GHz)
  - TDMA using timeslots organized into superframes
  - Full wireless mesh network
  - Highly secure communications using AES-128 block ciphers with individual Join and Session Keys and Data-Link level Network Key
  - Self-organizing capability
  - Cycle time on the order of few s or more

The WirelessHART network

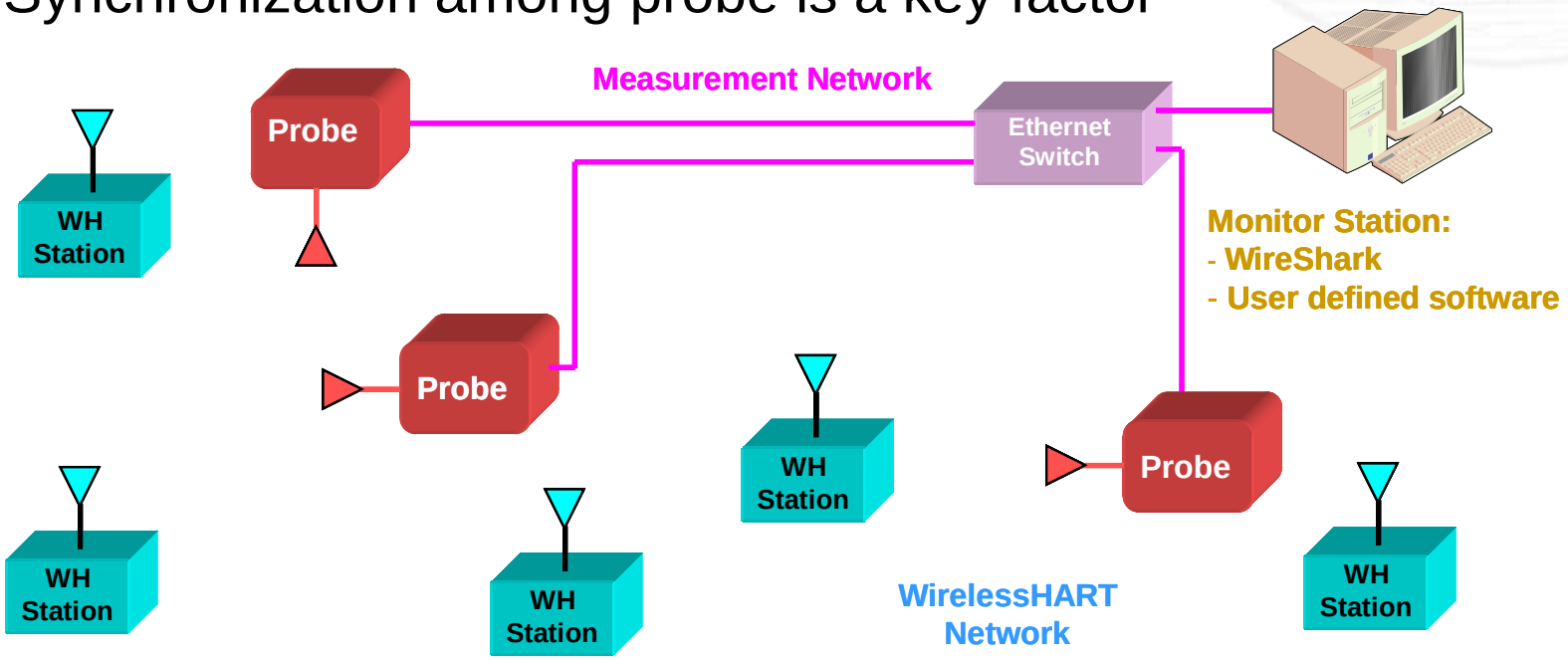
Not covered by the standard



WH traffic analyzer @ UNIBS

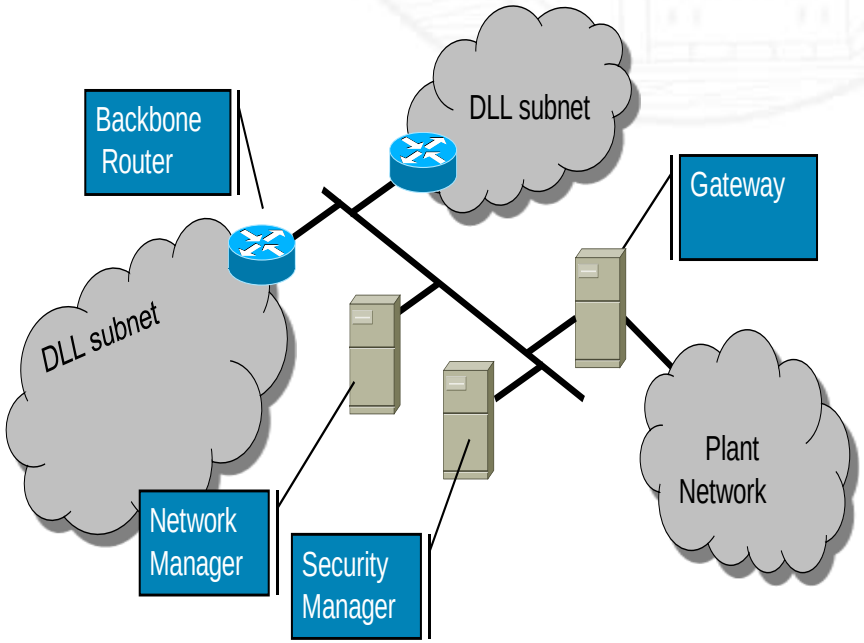
The proposed architecture

- Low-cost probes based on 802.15.4 transceivers and FPGA
- Separate measurement network: non invasive
- Monitor station: standard PC, standard analysis tools (can be connected with the Security Manager)
- Synchronization among probe is a key factor



The ISA100.11a role

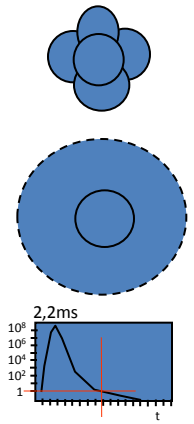
- ISA100.11a was started in 2007 by ISA and “overlaps” WH from the industry target point of view
- It shares many common features in the definition of a wireless node (IEEE802.15.4 @ 2.4GHz, TDMA and channel hopping, mesh networking)
- ISA100.11a also describes backbone routing; the frame format is in accordance with 6LoWPAN specs.
- Different from WH, ISA100.11a defines interfaces towards different application protocols, usually outside the scope of a communication protocol standard



The WSAN role

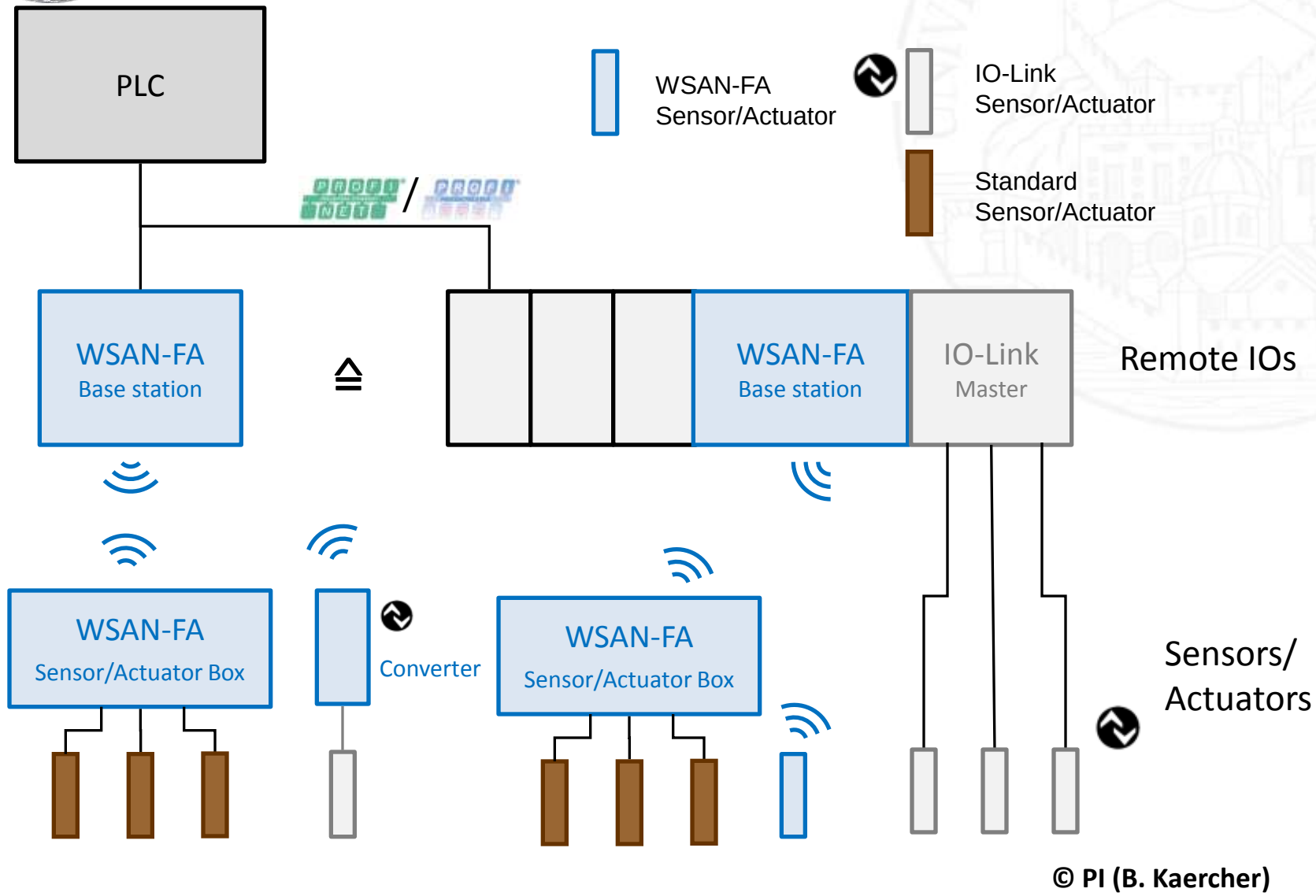
- Profibus International Wireless Standards for Factory Automation at the Sensor/Actuator Level:
  - Based on WISA ABB (derived from IEEE STD 802.15.1, it is based on GFSK)
  - TDMA using timeslots organized into superframes
  - Star topology network
  - Low level data are mapped into IO-link application layer

Requirement	**Max.**
Wireless devices per application per 1 WSAN System	300 (100*)
Overlapping WSAN Systems	5
Range	10 (30) m
Paket loss rate	< 10E-9
Delay max. [ms]	10 ms *



* Scalable: 1-4 Uplinks -> 25 – 100 devices @2ms TDMA cycle time; High speed mode possible with shorter TDMA cycle (-> 50 nodes @1ms TDMA cycle time)

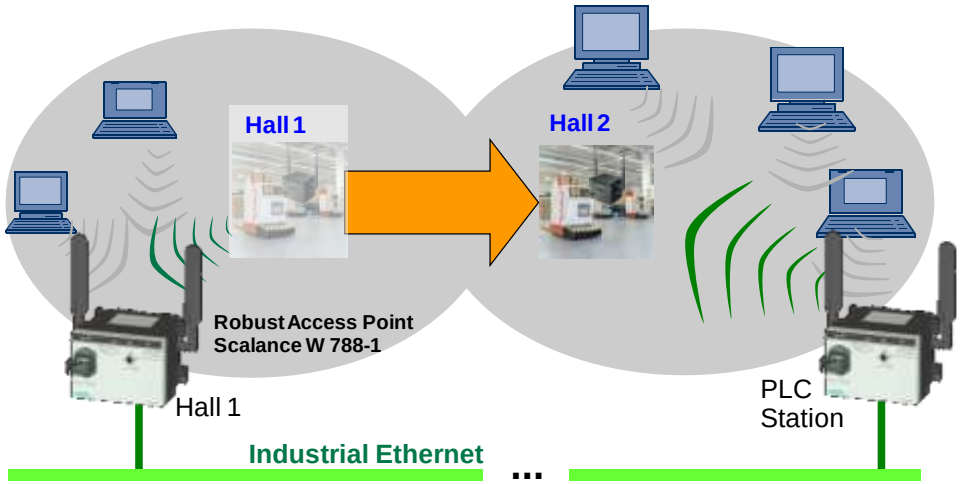
The WSAN network



The iWLAN

- IEEE802.11 adaptation to industrial scenario; proposed by Siemens
- Determinism is ensured thanks to band reservation (TDMA coexists with CSMA/CA; allowed by IEEE802.11-PCF, improved in iPCF: each client has a 2ms timeslot assigned)
- RF channel redundancy; cell redundancy (overlapping)
- Fast roaming among different Access Points (<)
- Easy integration with PROFINET

Source:
SIEMENS



Coexistence (1/2)

- Coexistence is the ability of wireless networks to perform their tasks in an environment where there are other wireless networks that may or may not be based on the same standard
- Coexistence strategy includes:
  - **Autonomous operation**: network provides coexistence without any special setup
  - **Planned configuration**: where operators coordinate the wireless network parameters such as frequency use, transmit powers, directional antennae, etc.
  - **Cooperative operation**; whereby the wireless networks share their intended use of the wireless media and operate in a manner that minimizes mutual interference. Techniques include informing other networks of their frequency usage and duty cycles, and delaying transmissions to allow other networks to send their messages.

Coexistence (2/2)

- ISM band @ 2.4GHz is crowded… what are coexistence strategies adopted by industrial (deterministic) systems?

Technology	Solution	Sharing Resource
IEEE802.15.4, IEEE802.11	DSSS, FHSS	Frequency
	FDMA	Frequency
	TDMA & Short Packet Length	Time
WirelessHART, ISA100.11a	Channel Hopping	Frequency
	Blacklisting	Frequency
iWLAN	--	
IEC WG17	Coexistence management system	Hybrid

- Is it enough? What about the future?
- Cognitive radio, i.e. a wireless system endowed with the capacities to implement choices about its operational aspects in a manner consistent with a purposeful goal!

Conclusions

- Wireless is a hot topic in industrial applications
- Some issues as power supplies/coexistence still exist
- However, thanks to the advent of standard solutions for both Factory and Process Automation, its adoption will be larger and larger
- We will talk about it in the future!

… and what about proprietary solutions?

Proprietary solutions!

- Still needed to solve “unconvetional” requirements!
- E.g. you will later learn about a WSN for Moist Heat Sterilization Processes (T range = -5÷ + 140 °C, P range = 0 ÷ 5 bar, H range = up to RH 100% condensing, Rotating Loads)

THANK YOU FOR YOUR ATTENTION!

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