What do we expect from Wireless in the Factory?

And what are we doing about it?

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What does the Factory, Industrial Control and Automation community want from wireless?

- More data communication to monitor …
  - Equipment condition
  - Secondary processes
  - Environment and emissions
  - Location of assets & tracking
  - Sensors for commissioning
- No new wires
- Reliable communications
- Zero or low maintenance
- Secure
- Low, or at least predictable, latency

Industrial data communication requirements can be categorised

Safety	Class 0: Emergency action *(always critical)*
Control	Class 1: Closed loop regulatory control *(often critical)*
	Class 2: Closed loop supervisory control *(usually non-critical)*
	Class 3: Open loop control *(human in the loop)*
Monitoring	Class 4: Alerting *(short-term operational consequence, e.g. event-based maintenance)*
	Class 5: Logging & downloading/uploading *(no immediate operational consequence, e.g. history collection, SOE, preventive maintenance)*

Source: ISA

- For class 0, even a (single) wired system may not be sufficiently reliable
- The Monitoring classes can be a good fit with wireless communications
- For class 1 and class 2, wireless is generally used only when there's no alternative

In many cases the data rates required are modest

Application area	Likely data volume / frequency
Process temperature sensing	10 bytes / minute
Machinery condition monitoring	1000-50.000 bytes / day
Personal radiation monitor	20 bytes / minute
Portable barcode reader	64 bytes / 10 seconds
Environment alarm	10 bytes / event

Source: ISA

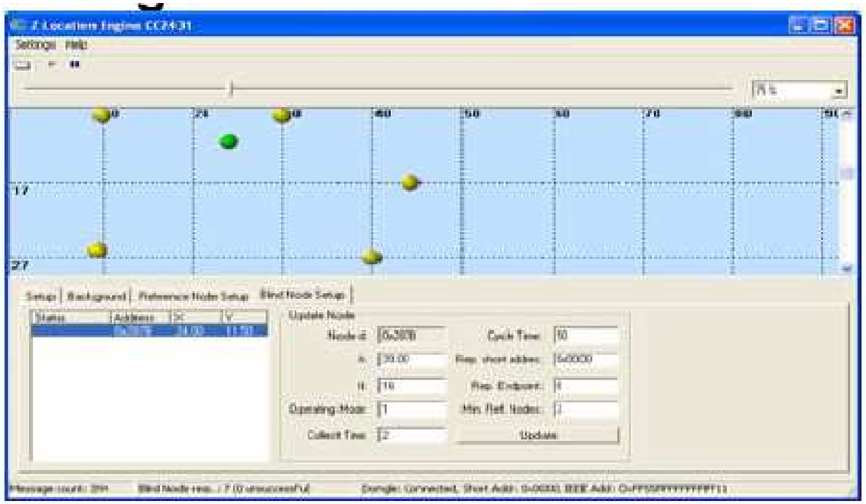
Some of the application areas where wireless provides a good fit include

- Equipment condition monitoring
  - Generally non-critical, replaces a person touring the plant
  - Can monitor vibration, fluid transparency, actuator position, …
  - Aids cost-effective maintenance
- Additional sensors for plant commissioning
  - Temperature, pressure at additional points
  - Environmental monitoring
  - Leak detection in new plant
  - Can be economically removed and re-used after plant is running

What do we want ? – location

As well as communicating with mobile devices, we have the opportunity to locate or track them

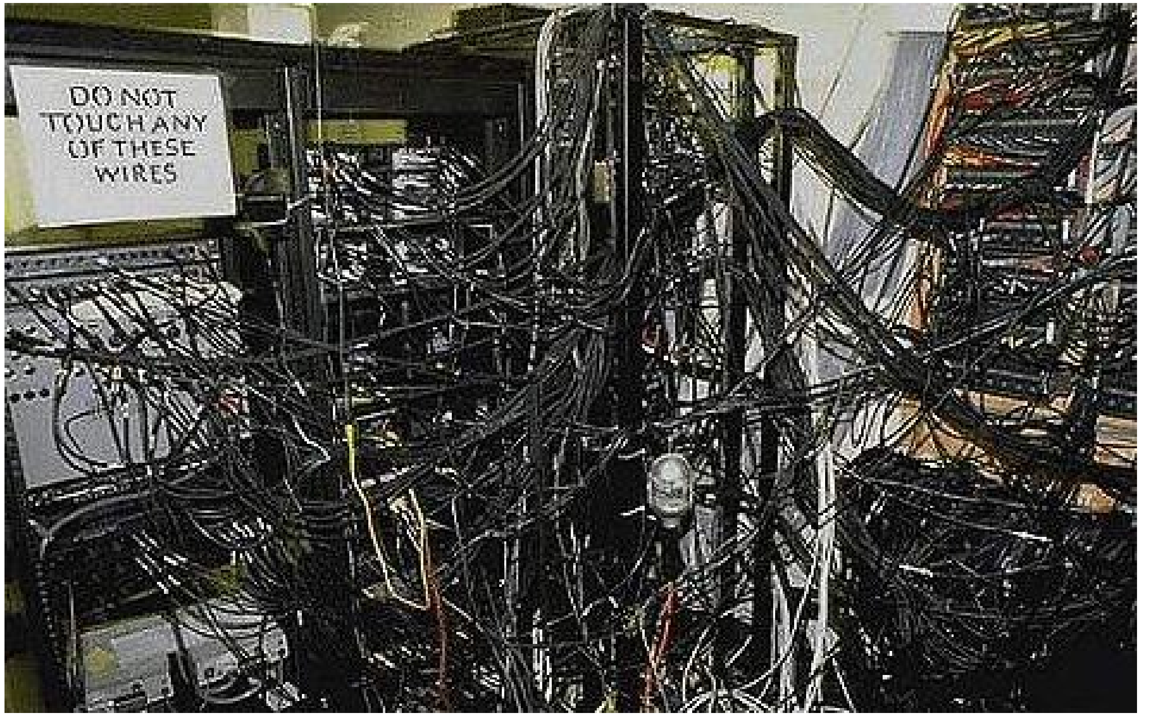
- In all but the smallest facility, the wireless network will have multiple fixed nodes
- A mobile node will hand over communication from one fixed node to the next (cellular operation)
- We can deduce the location of the mobile from
  - The fixed node (base station) serving it
  - Signal strength information from other fixed nodes
  - Time-of-flight information (where the radio system provides sufficient precision)
  - Processing this data with geographical knowledge



Source: Texas Instruments

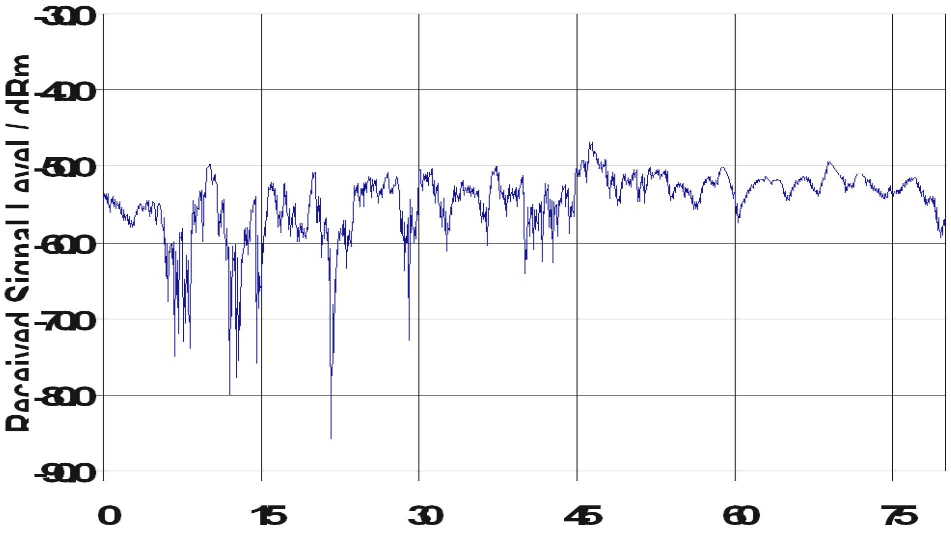
We cannot afford to install any new wires

- Installed industrial wiring can cost between €100 and €10.000 per metre
- This cost can increase substantially where the factory or process cannot be operated during installations
- With wiring, every measurement or control has to justify its installation cost
  - Temporary (commissioning) instrumentation can be hard to justify



Radio is inherently an unreliable medium, so we need various measures to deliver a reliable service

- Signal processing for better immunity to interference, etc.
- Various types of diversity to avoid poor link performance:
  - Space diversity combats reflections and multi-path
  - Path diversity combats shadowing or excessive propagation loss
  - Frequency diversity combats interference
- Send / acknowledge / retry ensures that the end devices know whether the message has got through or not
- Listen before send improves co-existence with other systems
  - Increases chance of first-time success
  - Improves throughput



Radio nodes need a source of power, without significant additional maintenance

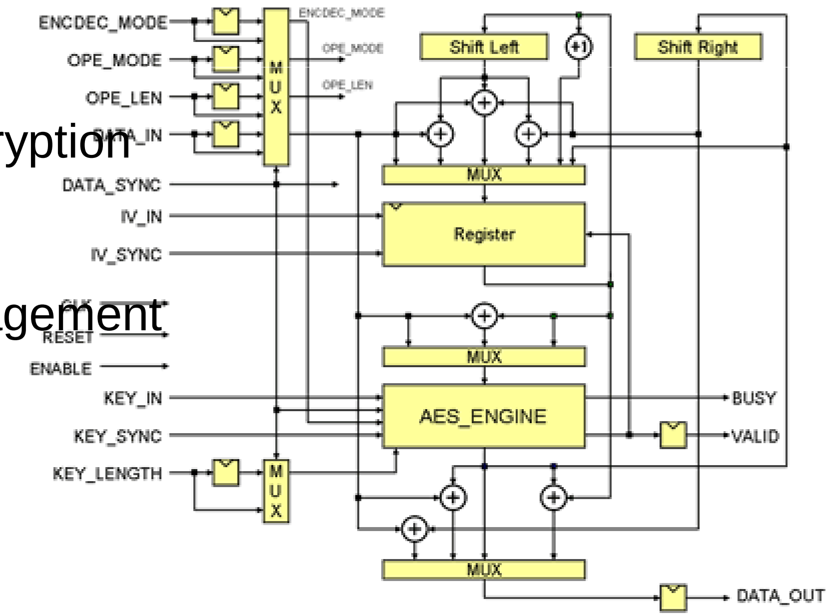
- Batteries will need to be charged or replaced
  - Battery lifetime must be at least a year, and preferably more
  - Places a heavy demand on the system design to achieve this
- Electrical energy can in some cases be harvested from external sources
  - Solar (or other) light
  - Vibration of motors etc.
  - Temperature difference
- Otherwise a power supply needs to be available for the node, which can increase its cost

Source: Perpetuum Ltd.

A radio system must be *at least as secure* as the wired system would have been

- Must ensure that transmitted data is correct – integrity
- Must avoid spoof instrument readings or control actuation – authentication
- May need to keep data secret – confidentiality

- All radio systems achieve these objectives by encryption
  - AES 128 is a popular coding scheme
  - Different methods are specified for key management



What wireless communications standards and products are used now?

(will consider local area systems, as wide area / public services are well understood)

- Wi-Fi has been available for some time in various ‘hardened’ forms
- Bluetooth has been deployed in some industrial systems
- ZigBee was originally targeted at factory automation …
- Wireless HART has recently been released
- ISA 100.11a is in a near-final draft

Source: Cisco Systems

- Specialist standards have been created, e.g. Wireless M-BUS, KNX-RF
- ‘Ex-proprietary’ standards are gaining traction
  - Z-Wave
  - Wavenis
  - …

IEEE 802.15.4 is a very popular PHY/MAC standard for industrial use

- 16 channels, 5 MHz spacing, in the 2.400 – 2.485 GHz licence-free band, peak data rate of 250 kbit/s (also defined for 868 and 902MHz)
- Direct sequence spread spectrum transmission, with a chip rate of 2 MHz, gives a processing gain against interference of 9dB
- 16-bit ‘local’ address allows compact messages
- Operable at very low duty cycles for long battery life
- Encryption engine (invariably hardware) gives 128-bit AES CCM*
- Implemented in silicon in volume now, from many vendors

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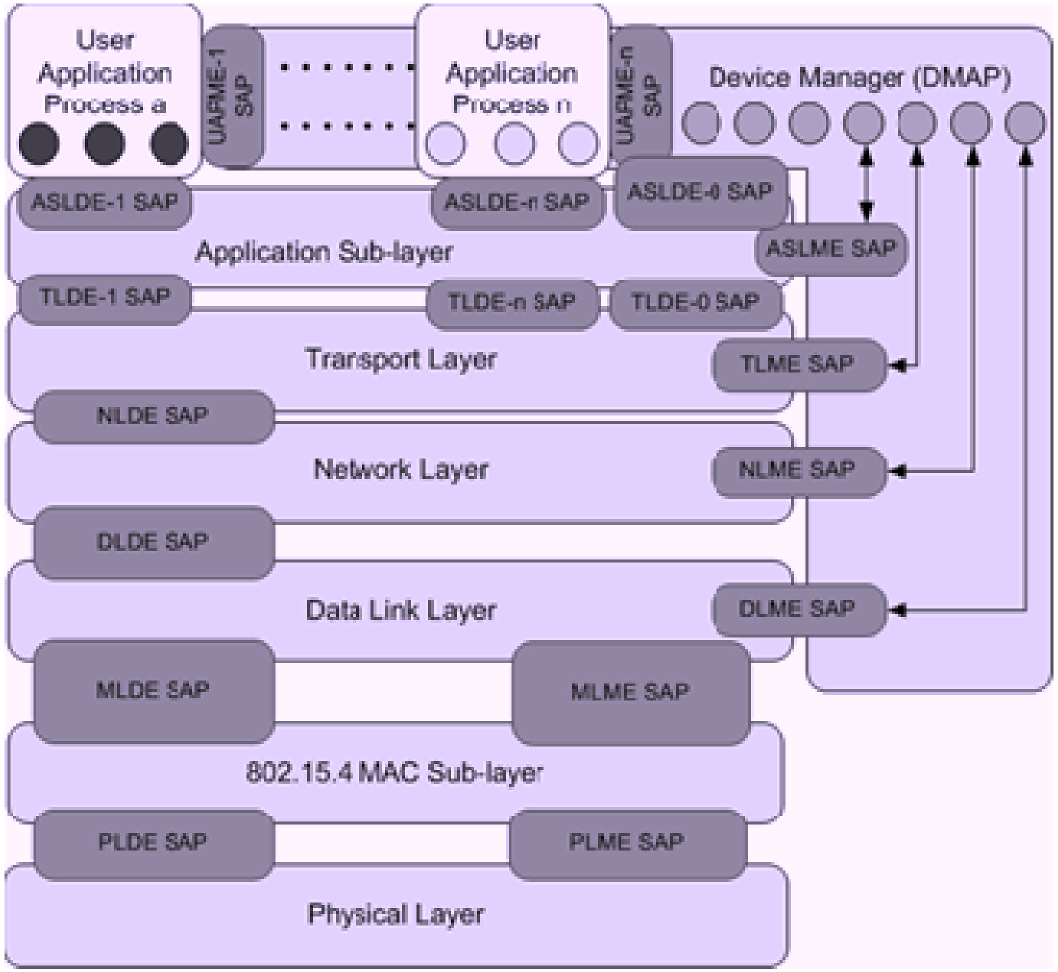
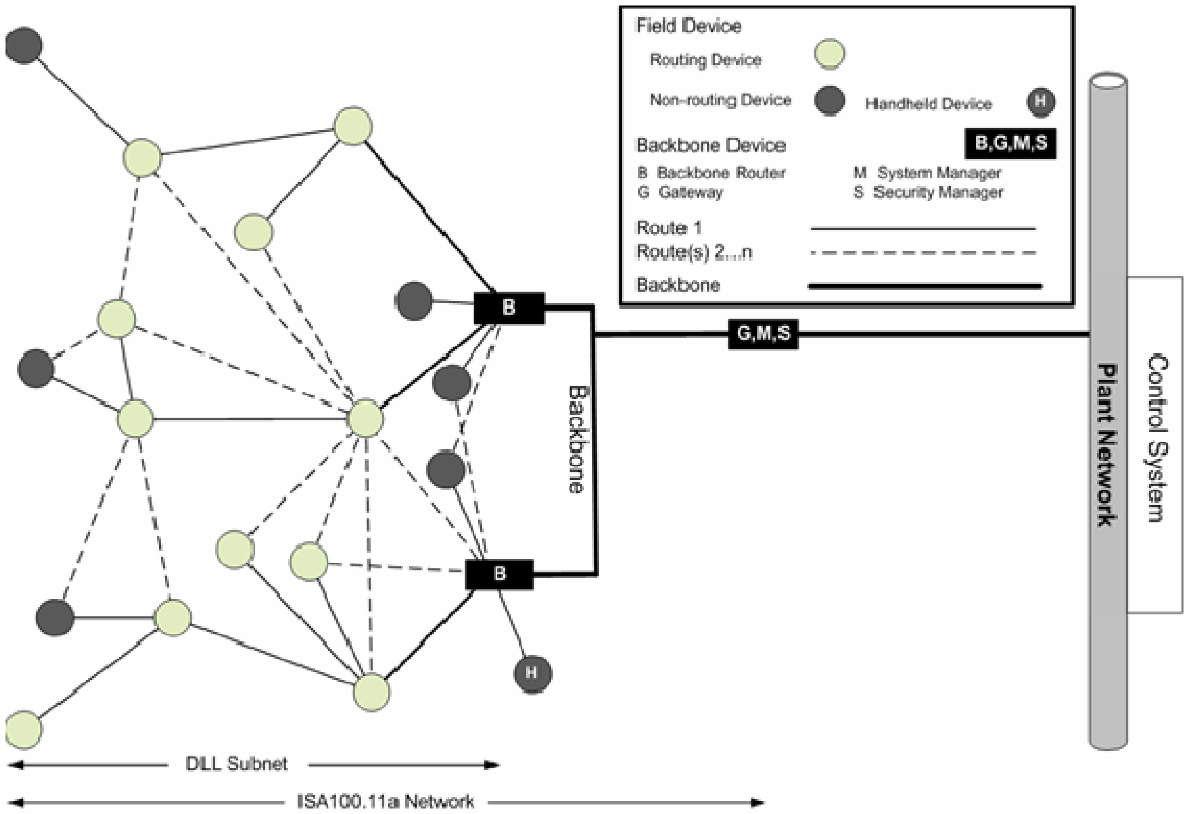
ISA 100 is designed to support native and tunnelled application layers



- User application processes are standardised, with hooks for extension
- Various transport services, including ‘reliable,’ ‘best effort,’ ‘real-time’ are offered
- Network and transport layers are based on TCP or UDP / IPv6
- Separate Data Link layer adds
  - Frequency hopping
  - Mesh routing
- MAC and Physical layer are defined in IEEE 802.15.4

The scope of standard ISA 100.11a includes

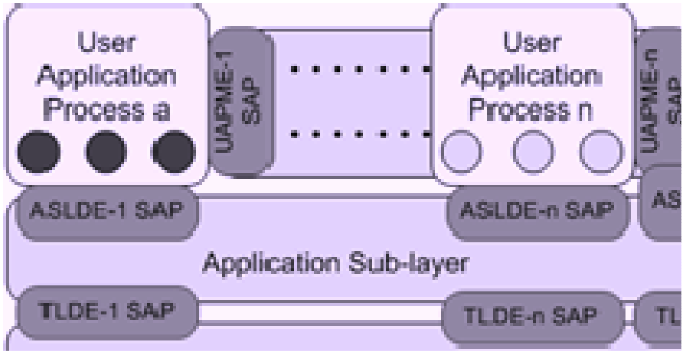
- Permitted networks
  - Radio link
  - ISA 100.11a over Ethernet and field buses
- Topologies
  - Star / tree
  - Mesh
  - Alternative routing
- Security architecture and specification
- Gateways and backbone routers
- System management functions



Example ISA 100.11a network

Application Support Layer delivers communications services to user and management processes

- Data from the transport layer is de-multiplexed and sent to the peer UAP (or MP)
- Can pass objects (methods, attributes) natively within the ISA 100.11a protocol
  - Standard objects defined
  - Standard profiles defined per application
  - Manufacturers also free to define their own
- A tunnelling mode is available to pass legacy data
- Adaption modes supports legacy field protocols:
  - Foundation FieldBus
  - ProfiBus
  - HART …



Industry Independent Objects defined in ISA 100.11a

- UAP management object – 1 per UAP – facilitates common UAP management.
- Device management object.
- Alert reporting management object.
- Alert receiving object(s) – up to four per device, supporting the four alert reporting categories (device related, communication related, security related, and process related).
- UploadDownload object.
- Concentrator object – represents an assembly of data at a publisher.
- Dispersion object – represents an assembly of data at a subscriber.
- Gateway cache object – represents local cache in the gateway.
- Tunnel object – supports encapsulation of non-native ISA100.11a messages.

Security is fully built-in to the standard

- Authentication and confidentiality services are independently available
- A security manager in the network manages and distributes keys
  – Asymmetric keys, or (provisioned) secret master keys for session key distribution
- Each node can secure data at two places
  – Data Link layer encryption, secures each hop
  – Transport layer encryption, secures peer-to-peer comms
- Default device policy sets the minimum security available to an application:

Security requirements for packets transmitted by device		**Outgoing protection of packet requested by device**		
		Unsecured	**Authenticated**	**Authenticated and confidential**
Device's Policy	**Unsecured**	Allowed	Allowed	Allowed
	Authenticated	Not allowed	Allowed	Allowed
	Authenticated and confidential	Not allowed	Not allowed	Allowed

Thank you for your attention

Any questions ?

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