ISA100 Wireless

Network basics and implementation

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ISA100 Wireless : network basics and implementation

Part 1: ISA100 network architecture. [DESIGN]

- Building blocks. End user view of the network.

Part2: Implementation of an ISA100 network. [DEPLOYMENT]

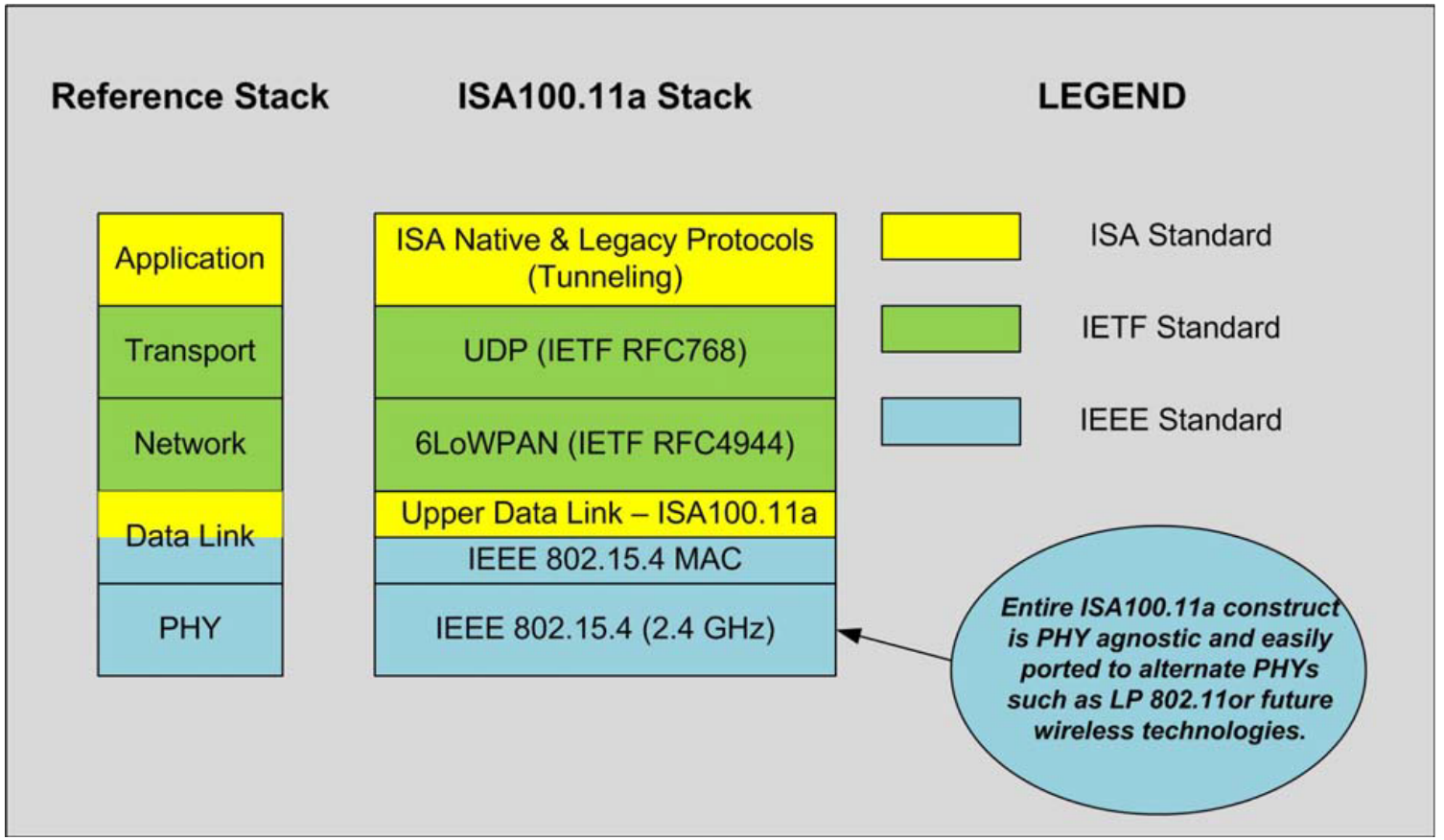
- ISA100 network adoption steps. Installation and operation flow.

ISA100 Wireless architecture challenges

- The ISA100 network was designed to address the **monitoring and control** needs within **industrial environment :**
  - Robustness
  - Reliability
  - Scalability
  - Self-configuring & self-healing wireless network
  - Low-power operation
  - Cost efficient
  - Suitable for harsh environments

ISA100 Wireless Stack overview

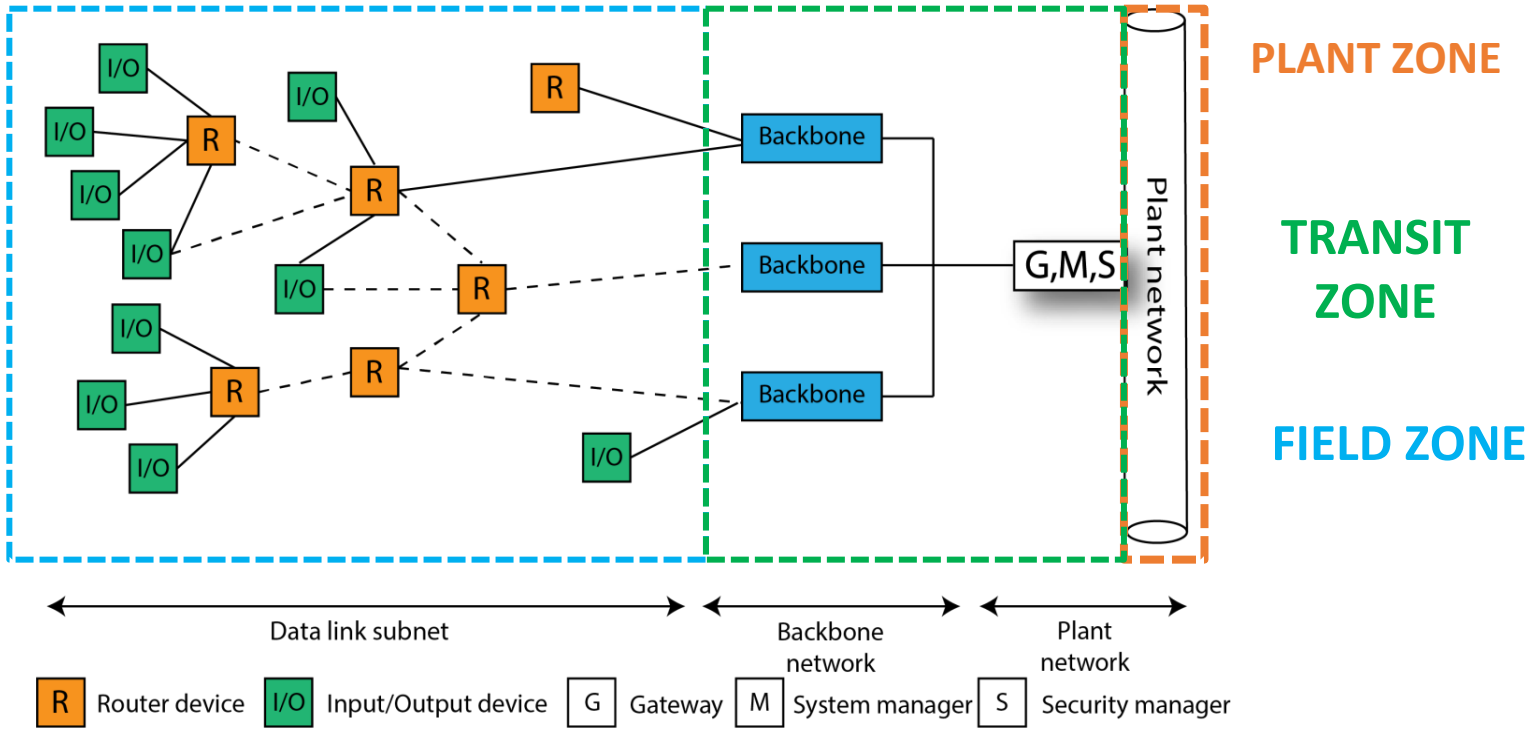
- The entire ISA100.11a stack is constructed employing widely industry accepted and proven standards
- Stack architected in strict adherence to the reference ISO model
- Currently implemented on top of 802.15.4, however new variants are in the works using different PHY layers (802.15.4a – UWB, giving 6Mbps data throughput)



ISA100 Wireless architecture overview

A **complete wireless sensor network architecture** describes three network zones with respect to their functionality:

- the **field network zone** (data link subnet)
- the **transit network zone** (backbone network or Gateway entity)
- the **plant network zone**



PLANT ZONE

TRANSIT ZONE

FIELD ZONE

ISA100 Wireless architecture overview

- **The industrial wireless communication requirements are addressed by the functionalities of each network zone**
- The ISA100 architecture aim is not only to support a *network design* but also a **control and monitoring solution design**
- Transit Zone creates the bridge between the *data acquisition* and *data processing* zones. ISA100 design will be detailed give two perspectives:
    - Field Zone <-> Transit Zone
    - Transit Zone <-> Plant Zone

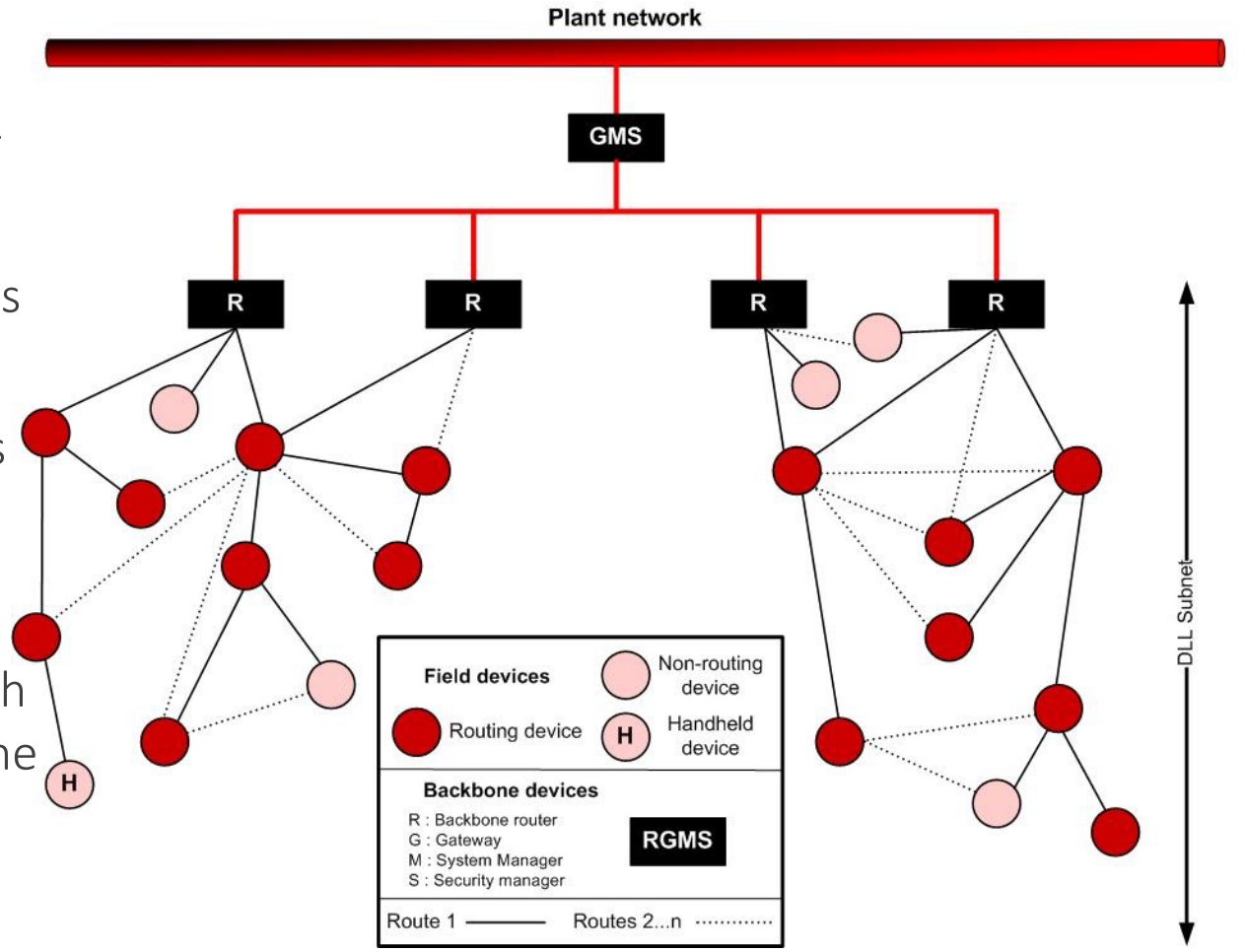
[DESIGN] Field Zone <-> Transit Zone . General aspects

What kind of Wireless Sensor Network is ISA100?

- **Centralized management**: all network related decisions are taken by Transit Zone entities and sent to Field Zone devices.
- **Deterministic:** all devices within the network are time synchronized and the communication is scheduled with a resolution of a time slots (typically 10 ms). The time allocations is the responsibility of the Transit Zone entity (Gateway)
- **Object oriented design:** As oppose to other technologies the ISA100.11a standard does not define a wireless variant of a wired technology, like WirelessHART, but rather it incorporates the current software concepts (like object oriented programming) and it is able to tunnel data in other networks using, for example, IPv6 thus making it a compatible protocol with the Internet of Things (IoT) concept.
- **Industrial focus:** it reflects the requirements of industrial monitoring and control scenarios

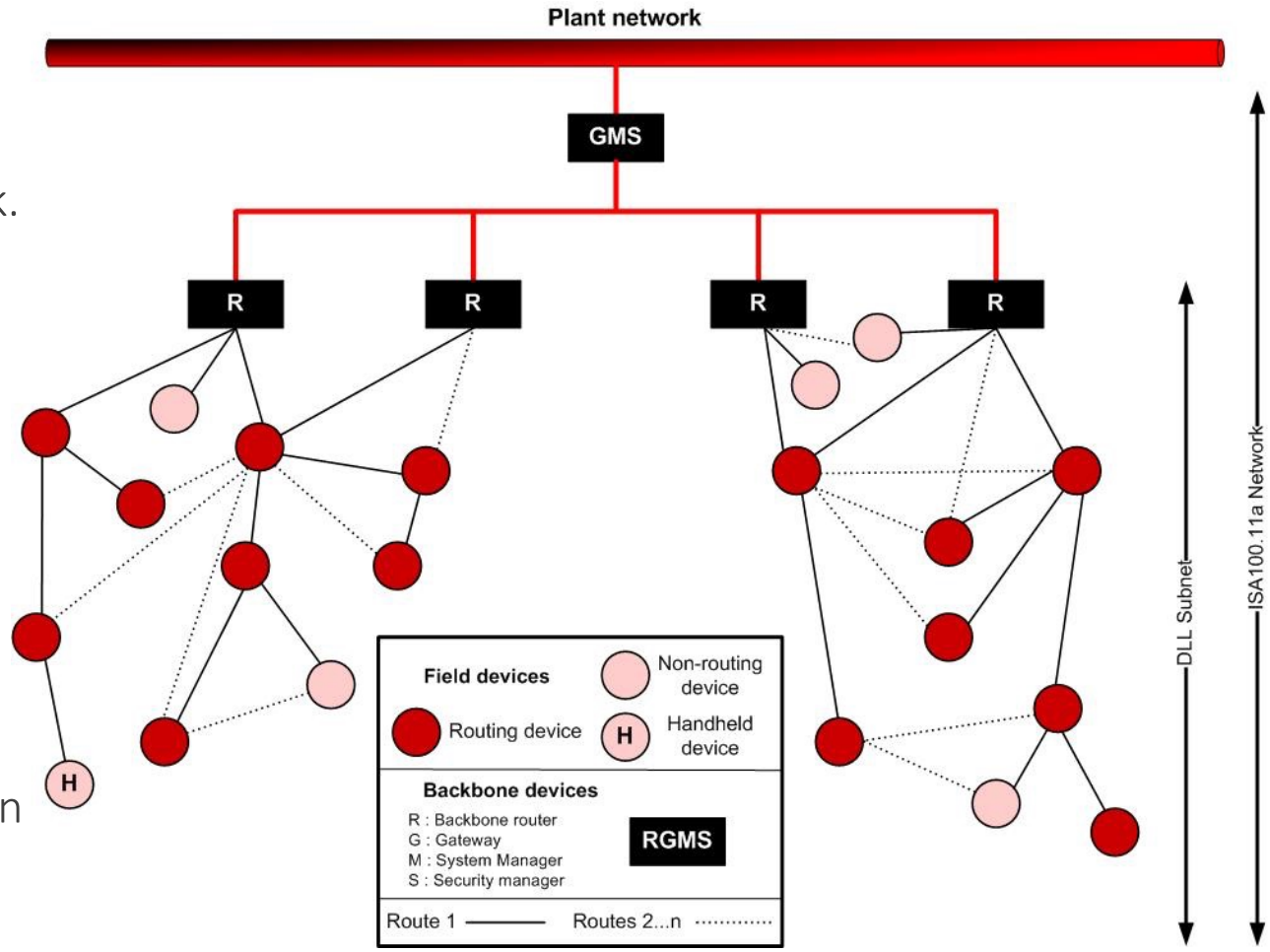
[DESIGN] Field Zone <-> Transit Zone . General aspects

- Field zone: formed by *wireless sensors/field devices* of different roles:
  - [I/O] Input/Output (non-routing device): routes only its own packets/sensing data
  - [R] Routing: routes messages for other devices operating in the wireless subnet
  - [R I/O] Input/Output & Routing
  - [Prov] Handheld device: Provisions devices with configurations required for operation within the network



[DESIGN] Field Zone <-> Transit Zone . General aspects

- Transit zone (ISA100 Gateway) has the following components:
  - [M] System Manager: the “brains” of the network. Manages all network devices through policy controlled configurations based on collection of performance parameters reported
  - [S] Security Manager: Enables, controls and supervises the secure operation of all devices present in the network
  - [G] Gateway: provides an application interface between the wireless network and the plant network
  - [BBR] Backbone Router: routes data via the backbone. Mitigates between devices operating in the wireless subnet and devices operating on the backbone



[DESIGN] Field Zone <-> Transit Zone . Network formation

To form an ISA100 network there are two main steps:

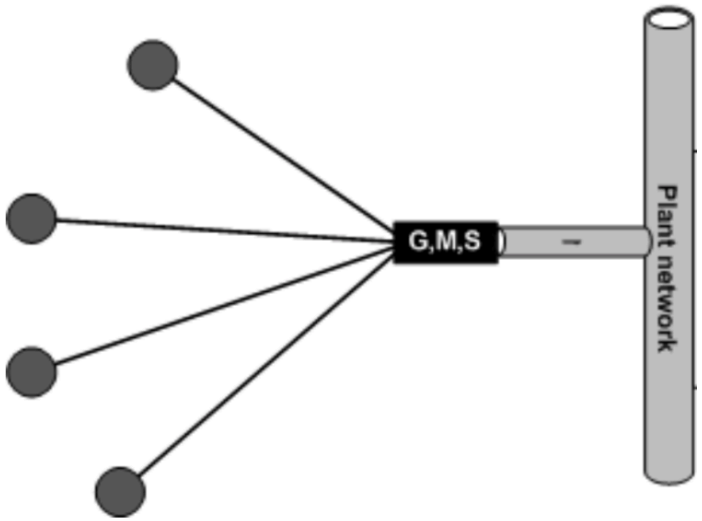
- **Field device provisioning (Step 1):**
  - Each device should target a specific ISA100 network
  - Multiple ISA100 networks can be collocated
  - Provisioning is the process of configuring the device with **network and data acquisition (publish) information**
    - **Network information:** target network, role, energy preferences…
    - **Data acquisition information:** what data to send? at what period? what does it represent?
  - Typically a *handheld* device implements this functionality
  - The communication medium can be: **Out-of-band** (infrared) or **Over-the-air** (in the 2.4 GHz band)

[DESIGN] Field Zone <-> Transit Zone . Network formation

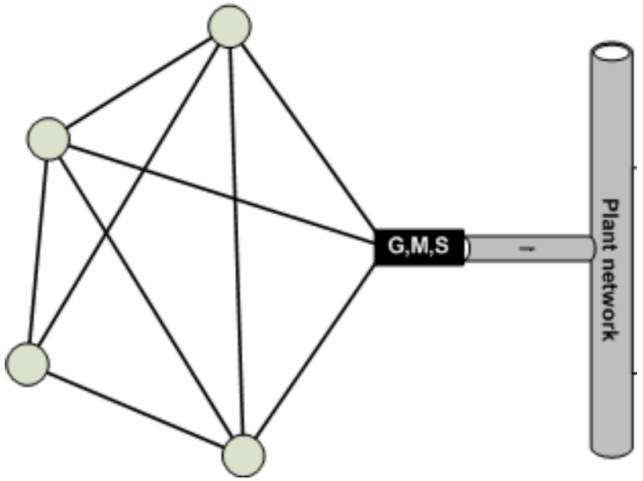
- Field device network join (Step 2)
  - The field device initiates the join process based on the **provisioning information**
  - The Gateway always listen for new join request, it does not have to be set in a particular state
  - The join process is represented by a **series of handshakes messages** in order to **securely** attach a new device to the Gateway
  - The join process is done seamlessly based on the configuration of the field device and Gateway
  - Once a devices a device joins the network the **Gateway will allocate communication resources and paths respecting a time scheduled pattern**

[DESIGN] Field Zone <-> Transit Zone . Network topology. Area coverage

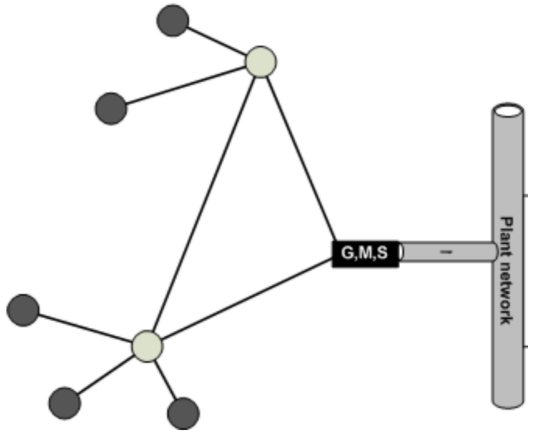
The Field zone can have one of the following network arrangements (topologies):



Star [I/O]



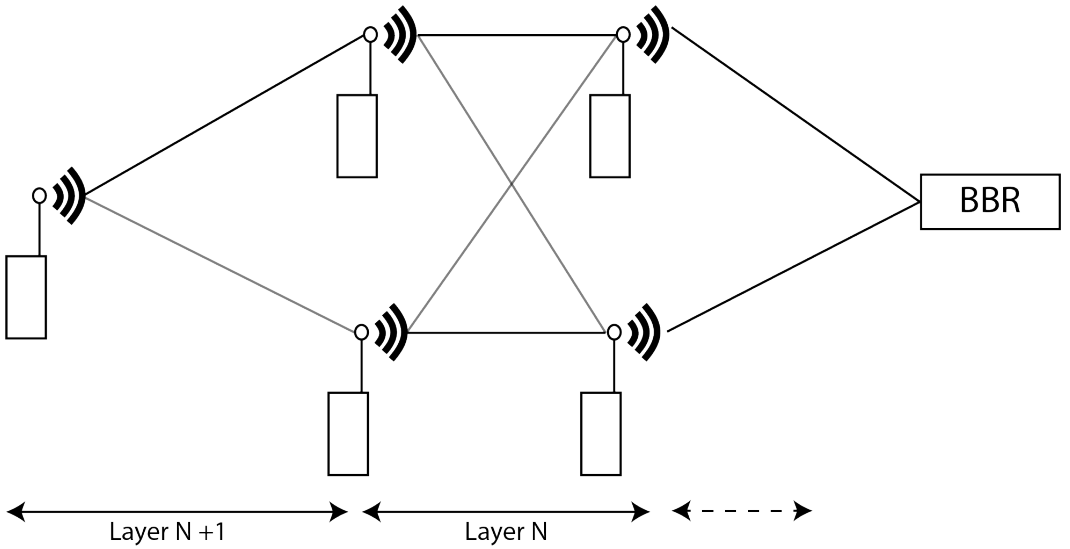
Mesh [R]



Star & Mesh [R I/O]

[DESIGN] Field Zone <-> Transit Zone . Network topology. Area coverage

- In a **Star topology** all devices have direct connectivity to the Gateway/BBR
  - ✚ Simple topology.
  - ✚ Low power consumption
  - ✚ Efficient use of network resources
  - – Small coverage area
  - – Smaller number of field devices
  - – Poor resilience to communication path failure



- In a **Mesh topology** the field devices capable of forwarding the data packets of their neighbors
  - ✚ Large coverage area
  - ✚ Redundant communication paths
  - – Less efficient in terms of energy consumption and network resource allocation

[DESIGN] Field Zone <-> Transit Zone . Data acquisition and publication

- The data acquisition and publication information of a device is configured at the provisioning stage
- After the completion of the join process the Gateway will allocate network resources such that the field device will be able to:
  - Send **sensor data** to the ISA100 Gateway
  - Receive **control data** from ISA100 Gateway
- The resource allocation corresponds to the needs of the field device:
  - How many sensor values? At what period?
  - With what phase?
  - When should the Gateway consider the sensor data not “fresh” anymore?
- The field device expects the response to questions such as:
  - When should I send/receive data?
  - Where should I send data? What time is it? (synchronization)

[DESIGN] Field Zone <-> Transit Zone . Data acquisition and publication

ISA100.11a Standard uses the **Contract and Link concepts** to define the set of elements required to send a message between two devices

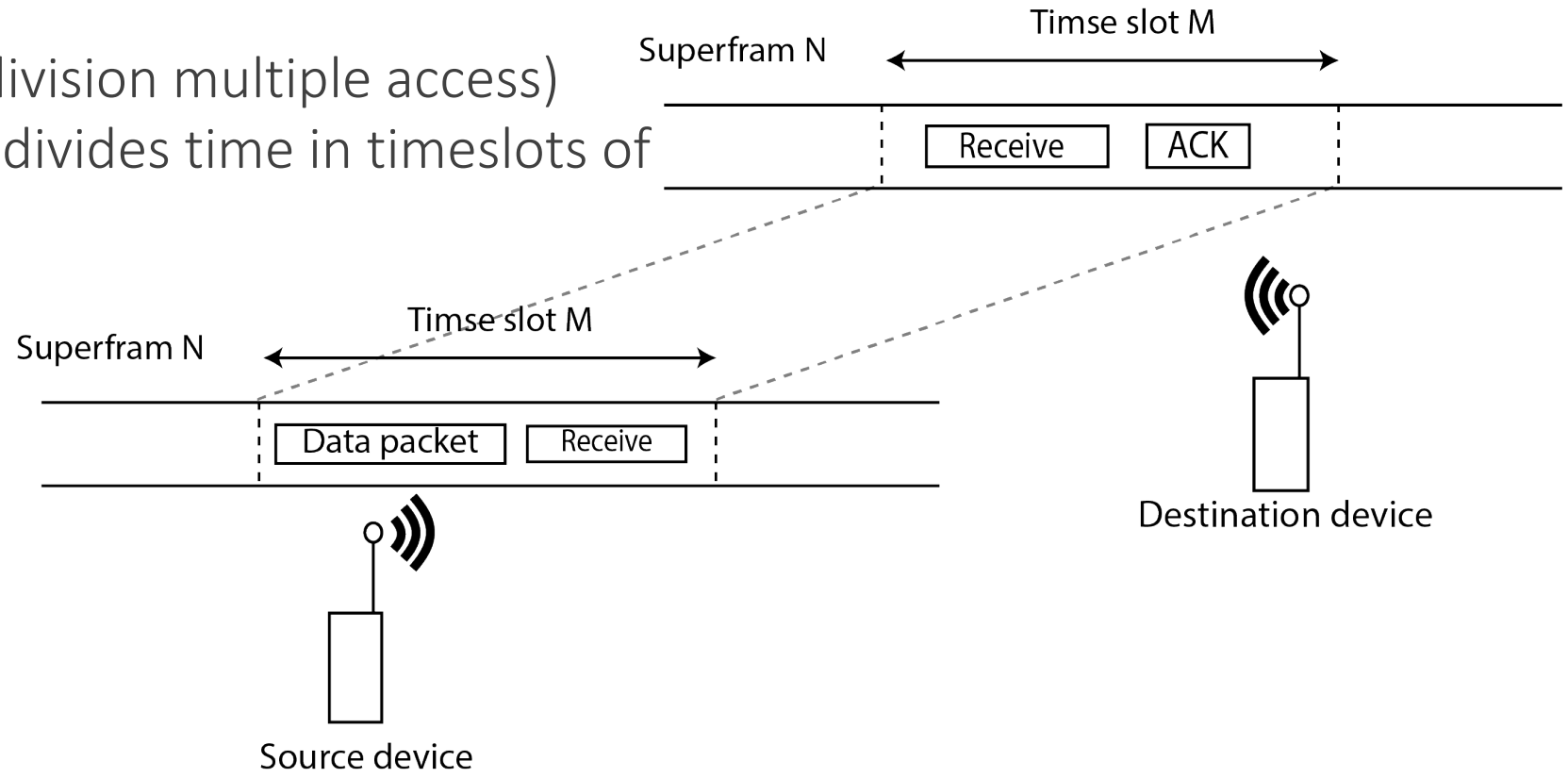
- The System Manager handles all communication contracts requests and their allocated resources
- The System Manager **will allocate link** over the mesh network all the way between the source and the destination device
- **A contracts describes a unidirectional communication path**
- **A link is basically defined by the transmitter, receiver and the time-slot = a communication opportinity**

Contract types:

- **PUBLISH = useful data/sensor data is sent periodically to the Gateway = continuous sensor monitoring**
- **ALERTS** = service for incidental transmissions (ensures low latencies with low bandwidth reservation)
- **CLIENT/SERVER =** service for two way communication
- **TUNNELING** = service to transport any data formats

[DESIGN] Field Zone <-> Transit Zone . Time diversity & determinism

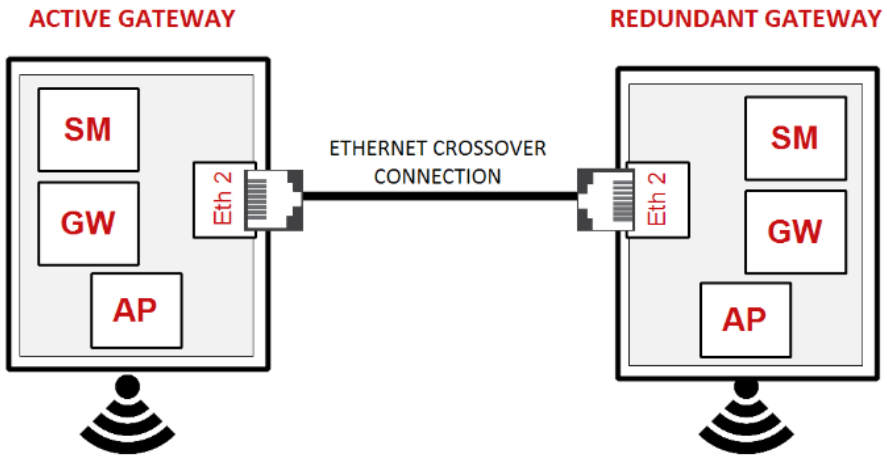
- All devices operating in a wireless subnet communicate at a pre-determined time and pre-allocated frequency channel
- Based on TDMA (time division multiple access) ISA100.11a technology divides time in timeslots of configurable length
- Typical timeslot durations range from10 to 14 ms



[DESIGN] Field Zone <-> Transit Zone . Reliability. Redundancy

System redundancy:

- Duplicated hardware platforms
- The Backup/Redundant platform is continuously synchronized with the Active one
- Seamless take over of the network management in case of a failure

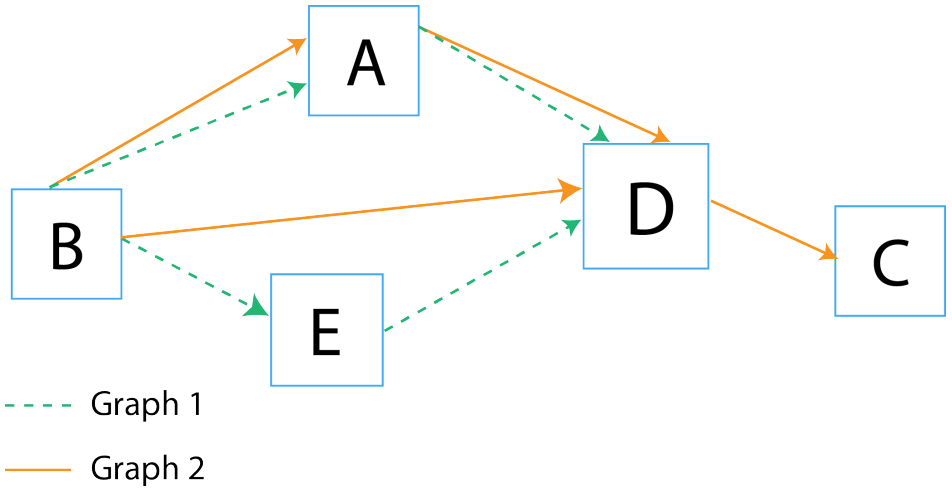


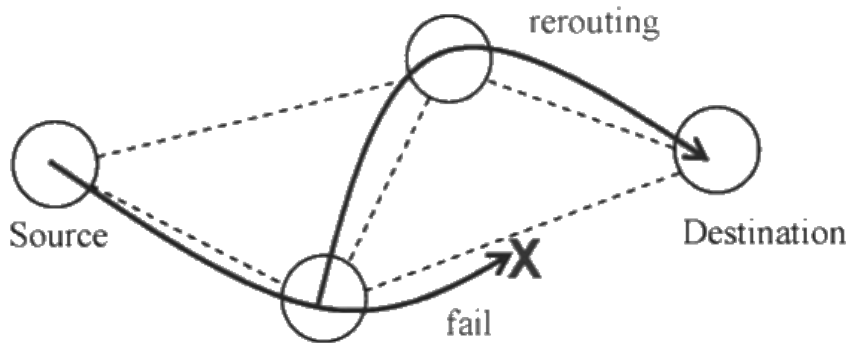
SM - System Manager
GW - Gateway
AP - Access Point
Eth 2 - Ethernet Port 2 (RJ45)

[DESIGN] Field Zone <-> Transit Zone . Reliability. Redundancy

Network redundancy:

- Rerouting:
  - The mechanism that chooses another path from source to destination if the previous transmission failed along the primary path
  - If the primary route fails the backup route will became the primary one and the manager will assign another route and links to recreate a backup route.

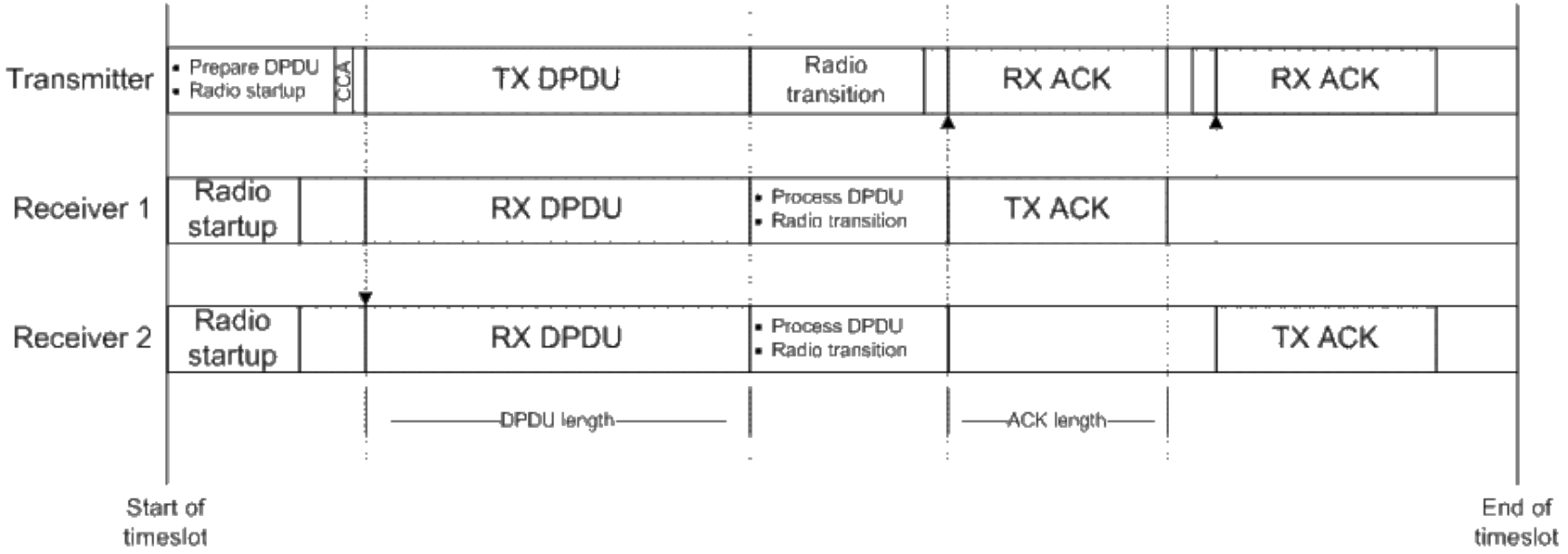




[DESIGN] Field Zone <-> Transit Zone . Reliability. Redundancy

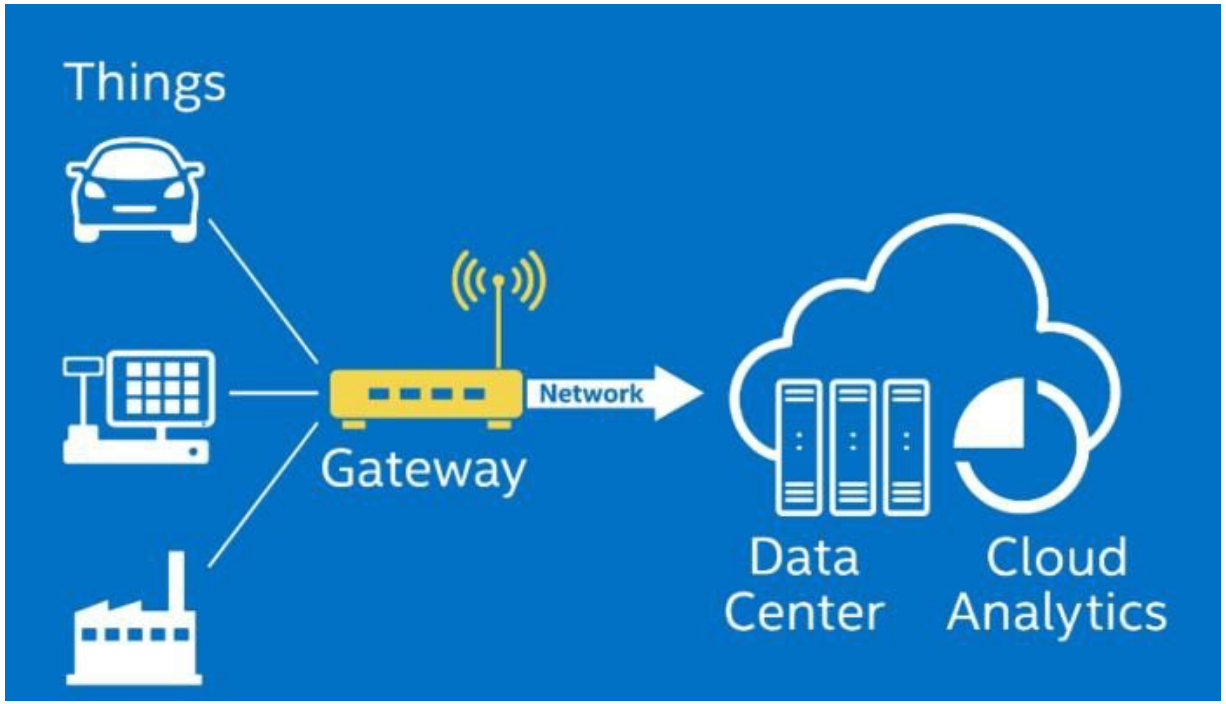
Network redundancy:

- Duocast
  - The duocast mechanism makes use of the spatial diversity given by two infrastructure devices (i.e. BBRs) within an ISA100.11a network
  - Both BBRs are scheduled to receive packets from field devices that are within their range



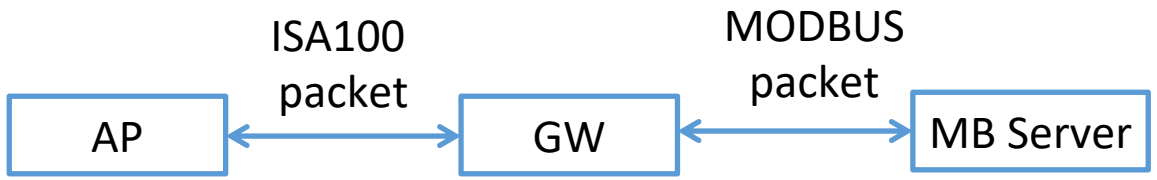
[DESIGN] Transit Zone <-> Plant Zone. General aspects

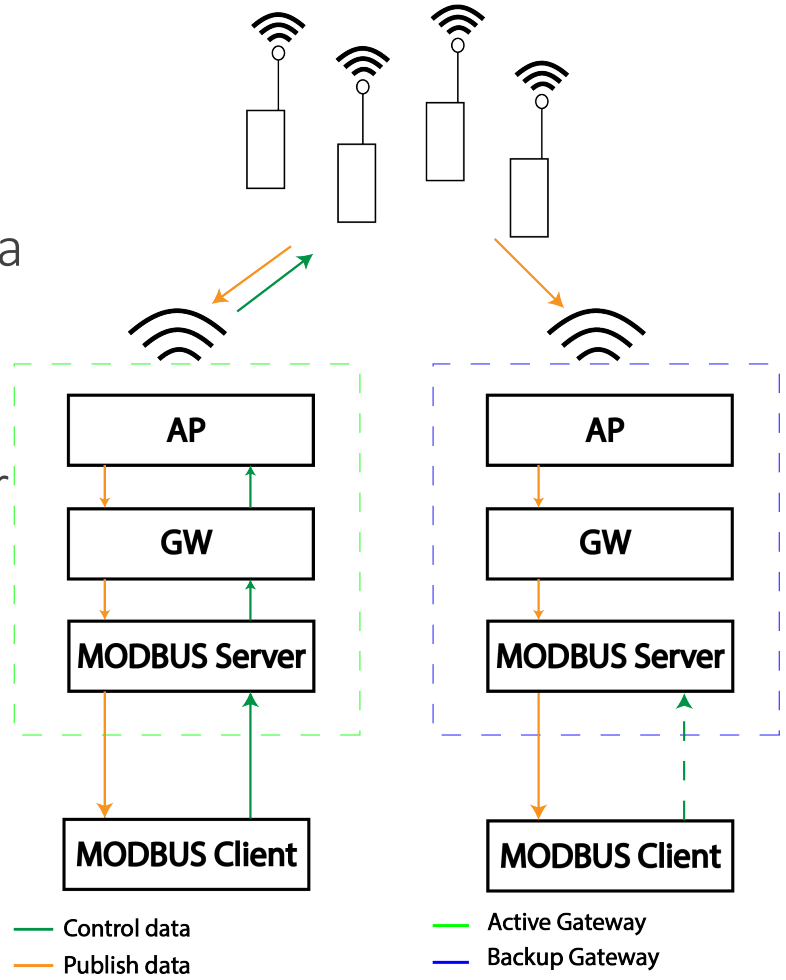
- The Plant Zone characteristics are not specified by the ISA100 standard
- For a complete control and monitoring solution based on the ISA100 network the Gateway has to translate the ISA100 specific data into data type/format that non ISA100 device/servers can understand
- The ISA100 Gateway interfaces:
  - MODBUS TCP/IP
  - GCI (Gateway Common Interface)
  - OPC UA



[DESIGN] Transit Zone <-> Plant Zone. Solution example

- ISA solution employing system redundancy, Active and Backup hardware Gateway
- Field devices are attached to the network (joined) and are given transmission opportunities to send sensor data to the AccessPoint (BBR in ISA100 network)
- The GW module translates the ISA00 packets into MODBUS packets that are exposed using a Client/Server architecture





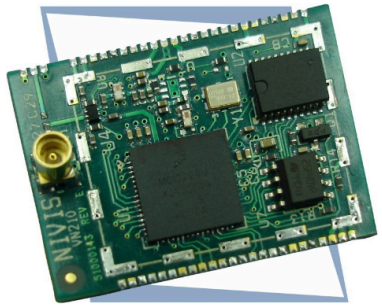
[DEPLOYMENT] Field zone

- The set of ISA100 field devices are usually defined by the control and monitoring needs of a plant
- Field devices are of:
  - **Different types**: temperature, humidity, pressure, vibration
  - **Different vendors**: Yokogawa, Honeywell, Dräger, GE, Spirax Sarco, Bitherm…




[DEPLOYMENT] Field zone

- To address specific needs or use existing sensors one can adopt wired sensors within ISA100 network by :
  - Integrating the sensor with a ISA100 radio module using an API interface



  - Using an wireless adaptor such as Yokogawa FN110

[DEPLOYMENT] Field zone. Device provisioning (configuration)

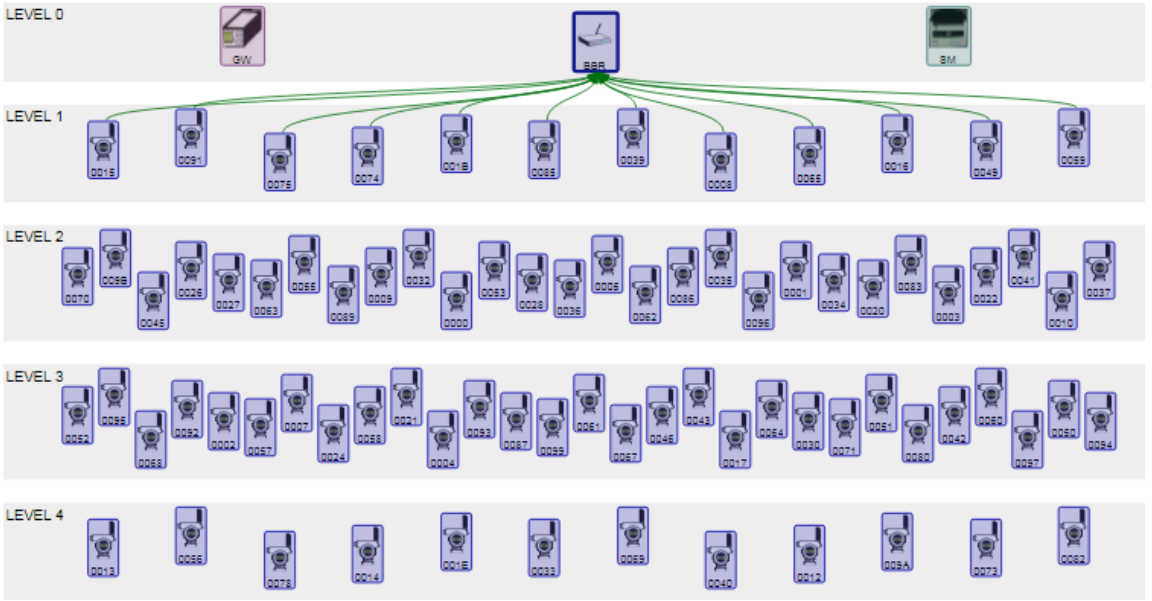
- **Device provisioning**(configuration)
  - The provisioning is done at installation setup phase
  - A handheld device (e.g. FT210) can be used to configure the field devices from multiple vendors
  - Physical transmission medium between Provisioning tool and the devices:
    - Out-of-band. Requires physical access to the device due to short range. Also, the field device should have an infrared port available for communication
    - Over-the-air. Uses the 2.4 GHz band and does not require physical access to the device
  - Example of temperature and humidity configuration on a device

[DEPLOYMENT] Transit zone. ISA100 Gateway

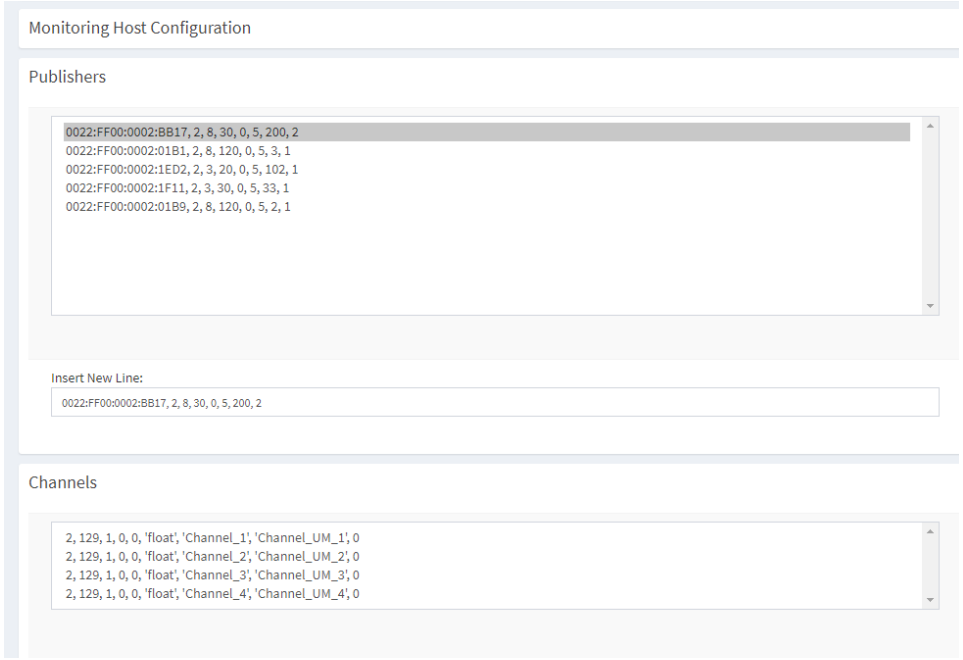
- The network management and data translation is done at Transit zone by a ISA100 Gateway entity
- It can have an **all-in-one** or **distributed** architecture
- Employing a mesh topology and having one point of access (BBR) a Gateway is able to manage around 50 to 100 field devices
- The physical link between the Gateway and Plant servers is done, typically on Ethernet (RJ45 connector)
- Can be deployed in harsh and explosive environments and can be collocated with other communication systems operating in the same 2.4 GHz band (it has EMC and ATEX certifications)

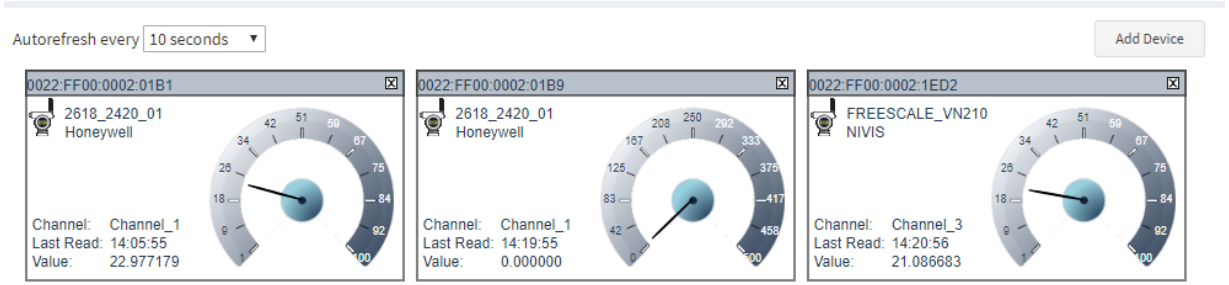
[DEPLOYMENT] ISA100 Gateway. Joined devices. Topology

	EUI-64 Address▲	IPv6 Address	Tag	Revision	Role/Model	Status
	0000:0000:0000:0005	FE80:0000:0000:0000:0000:4E7D:7F00:0001	CDS Backbone	BB__05.01.12	Backbone Router/ FREESCALE_VN210	FULL_JOIN
	0000:0000:0A10:00A0	FE80:0000:0000:0000:0000:4E7B:7F00:0001	CdsSystem_Mngr	3.3.91	System Manager/ SM	FULL_JOIN
	0022:FF00:0002:01B9	FC00:0000:0022:FF00:0002:01B9:0005:00B9	HW_Temp_01B1	OW240.1-15.0	IO Router Device/ 2618_2420_01	FULL_JOIN
	0022:FF00:0002:1ED2	FC00:0000:0022:FF00:0002:1ED2:0005:00D2	Yoko_Temp_1ED2	YK__p4.02.24	IO Router Device/ FREESCALE_VN210	FULL_JOIN
	0022:FF00:0002:1F11	FC00:0000:0022:FF00:0002:1F11:0005:0011	Yoko_Temp_1F11	YK__p4.02.24	IO Router Device/ FREESCALE_VN210	FULL_JOIN



[DEPLOYMENT] ISA100 Gateway. Device discovery. Publish





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