Design and Development of IoT Applications

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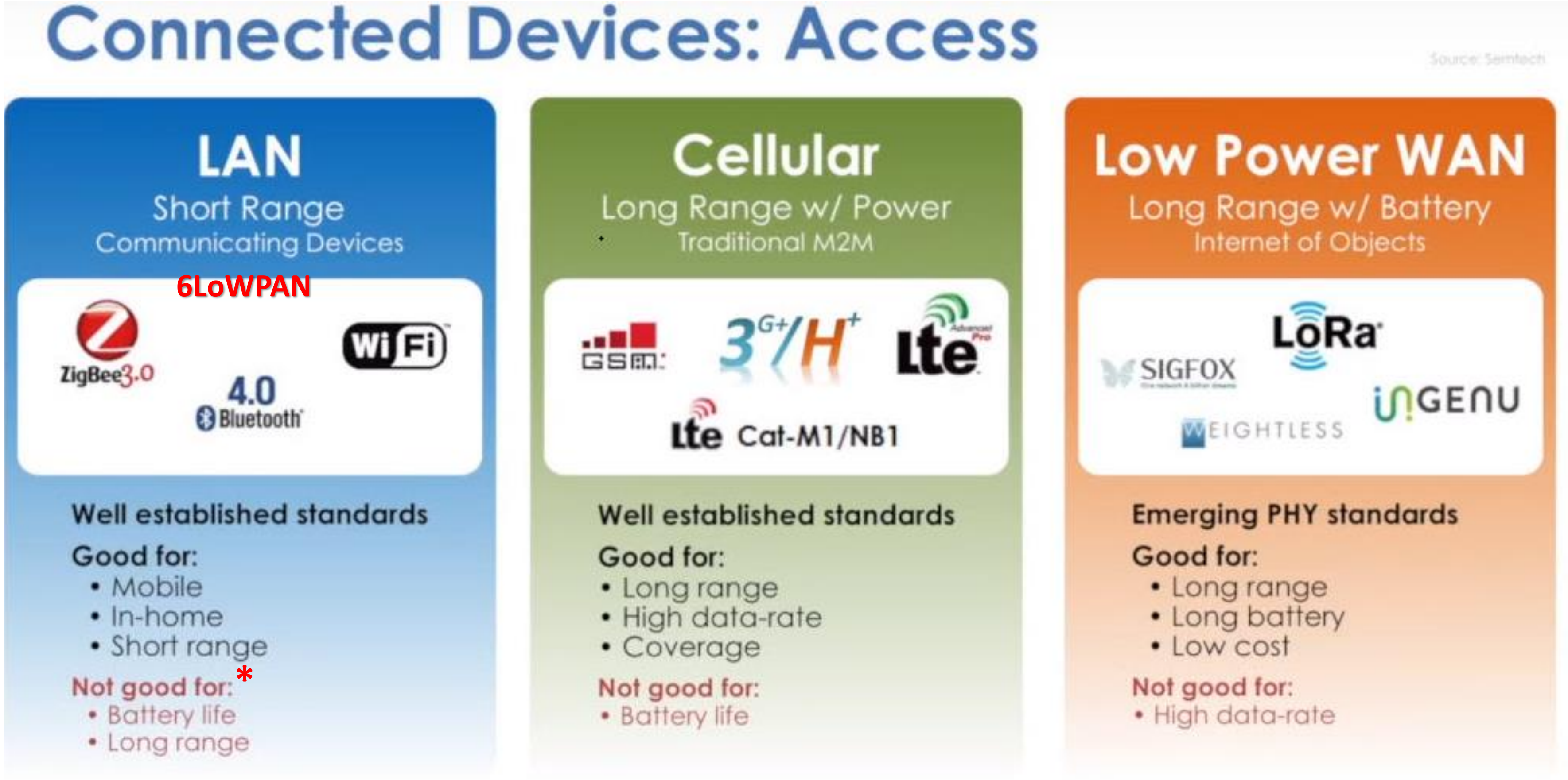
❑ Chapter 7: Industrial IoT standards

- ❖ ZigBee and Z-Wave Technology
- ❖ Dynamic Network protocols
- ❖ Backhaul networks for Home Automation
- ❖ Sub-1GHz technology
- ❖ Thread protocol stack

❑ Chapter 8: Wireless Embedded Internet

- ❖ ICMPv6
- ❖ Auto-configuration & Neighbor Discovery
- ❖ IP routing in WSNs: RPL
- ❖ Embedded web – REST/CoAP
- ❖ MQTT-SN

Technology comparison



Connected Devices: Access

Source: Semtech

LAN

Short Range

Communicating Devices

6LoWPAN

ZigBee3.0
4.0
Bluetooth
WiFi

Well established standards

Good for:

- Mobile
- In-home
- Short range

Not good for: *

- Battery life
- Long range

Cellular

Long Range w/ Power

Traditional M2M

GSM
3G+/H+
Lte Advanced Pro
Lte Cat-M1/NB1

Well established standards

Good for:

- Long range
- High data-rate
- Coverage

Not good for:

- Battery life

Low Power WAN

Long Range w/ Battery

Internet of Objects

Emerging PHY standards

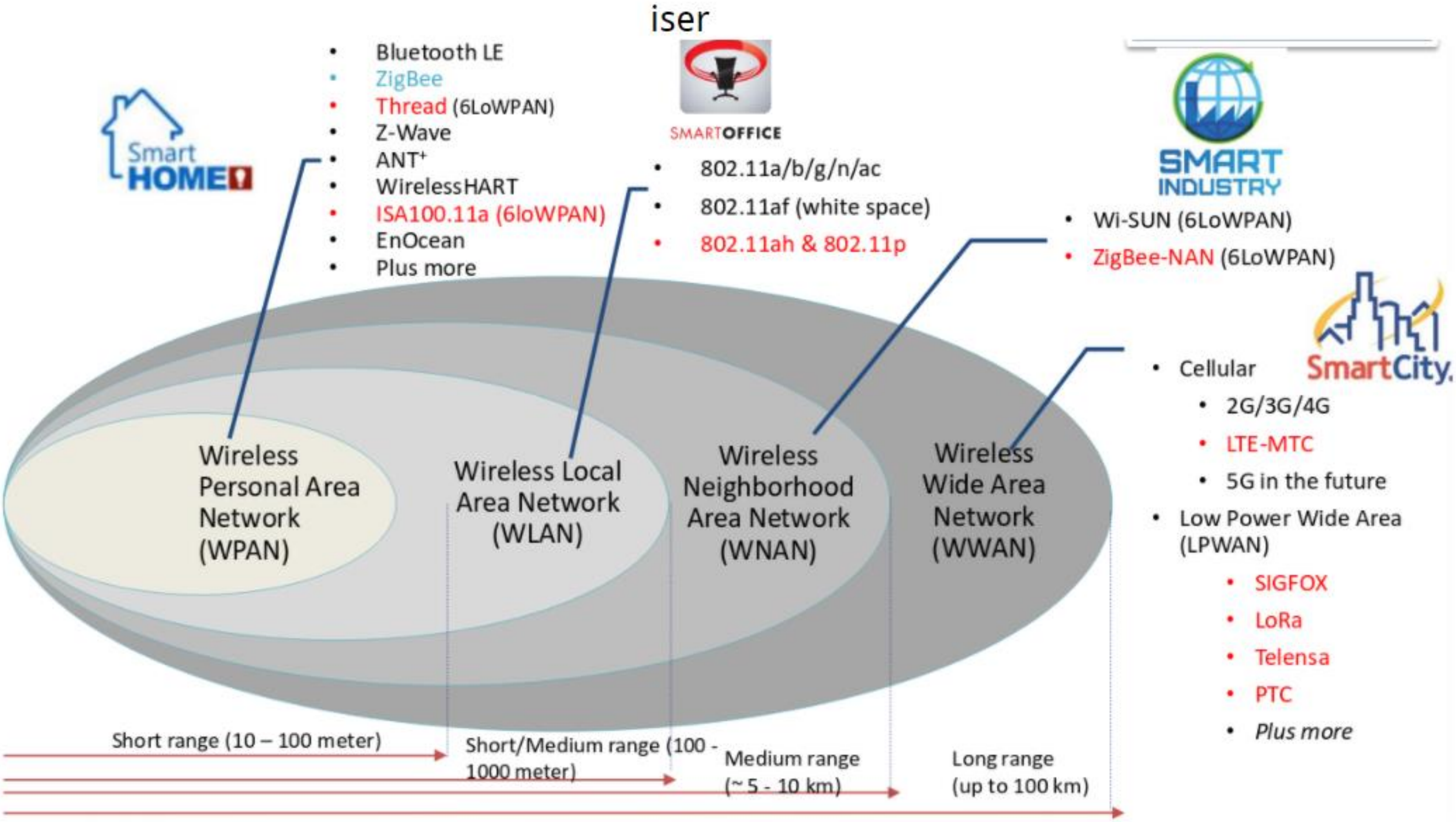
Good for:

- Long range
- Long battery
- Low cost

Not good for:

- High data-rate

Technology comparison



- Bluetooth LE
- ZigBee
- Thread (6LoWPAN)
- Z-Wave
- ANT+
- WirelessHART
- ISA100.11a (6loWPAN)
- EnOcean
- Plus more

- 802.11a/b/g/n/ac
- 802.11af (white space)
- 802.11ah & 802.11p

- Wi-SUN (6LoWPAN)
- ZigBee-NAN (6LoWPAN)

- Cellular
  - 2G/3G/4G
  - LTE-MTC
  - 5G in the future
- Low Power Wide Area (LPWAN)
  - SIGFOX
  - LoRa
  - Telensa
  - PTC
  - *Plus more*

Wireless Personal Area Network (WPAN)

Wireless Local Area Network (WLAN)

Wireless Neighborhood Area Network (WNAN)

Wireless Wide Area Network (WWAN)

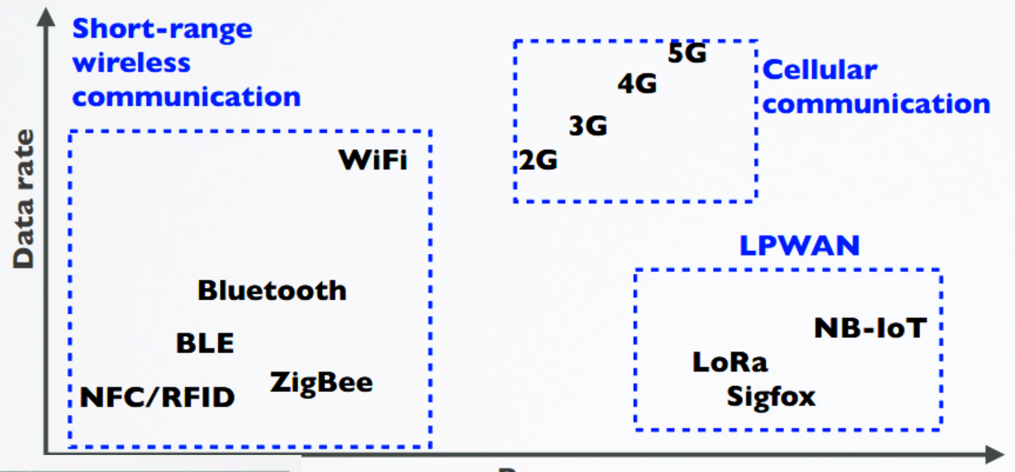
Short range (10 – 100 meter)

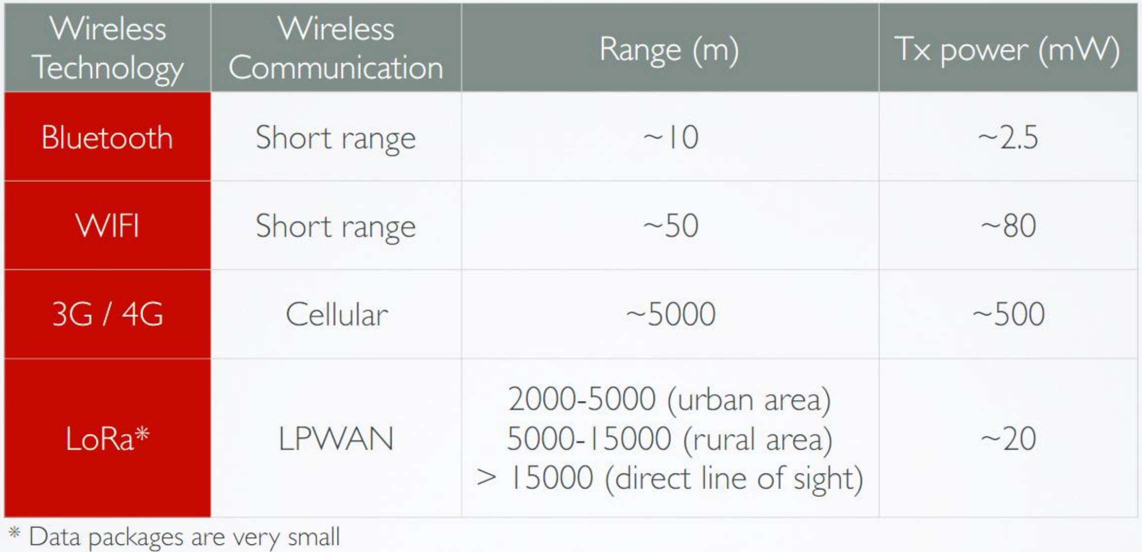
Short/Medium range (100 - 1000 meter)

Medium range (~ 5 - 10 km)

Long range (up to 100 km)

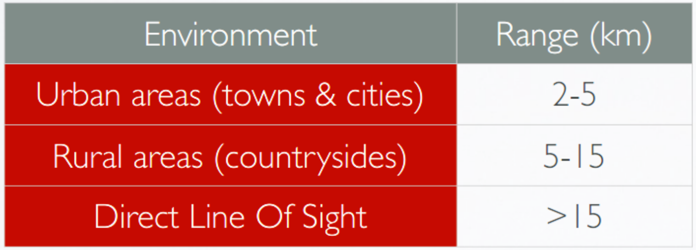
Wireless Communication Comparison





Wireless Technology	Wireless Communication	Range (m)	Tx power (mW)
Bluetooth	Short range	~10	~2.5
WIFI	Short range	~50	~80
3G / 4G	Cellular	~5000	~500
LoRa*	LPWAN	2000-5000 (urban area) 5000-15000 (rural area) > 15000 (direct line of sight)	~20

* Data packages are very small



Environment	Range (km)
Urban areas (towns & cities)	2-5
Rural areas (countrysides)	5-15
Direct Line Of Sight	>15

ZigBee

- ❑ ZigBee is a technological standard designed for control and sensor networks
- ❑ Based on the IEEE 802.15.4 Standard
- ❑ Created by the ZigBee Alliance
- ❑ Operates in Personal Area Networks (PAN's) and device-to-device networks
- ❑ Connectivity between small packet devices
- ❑ Control of lights, switches, thermostats, appliances, etc.

ZigBee Alliance

- □ Organization defining global standards for reliable, cost-effective, low power wireless applications

- □ A consortium of end users and solution providers, primarily responsible for the development of the 802.15.4 standard

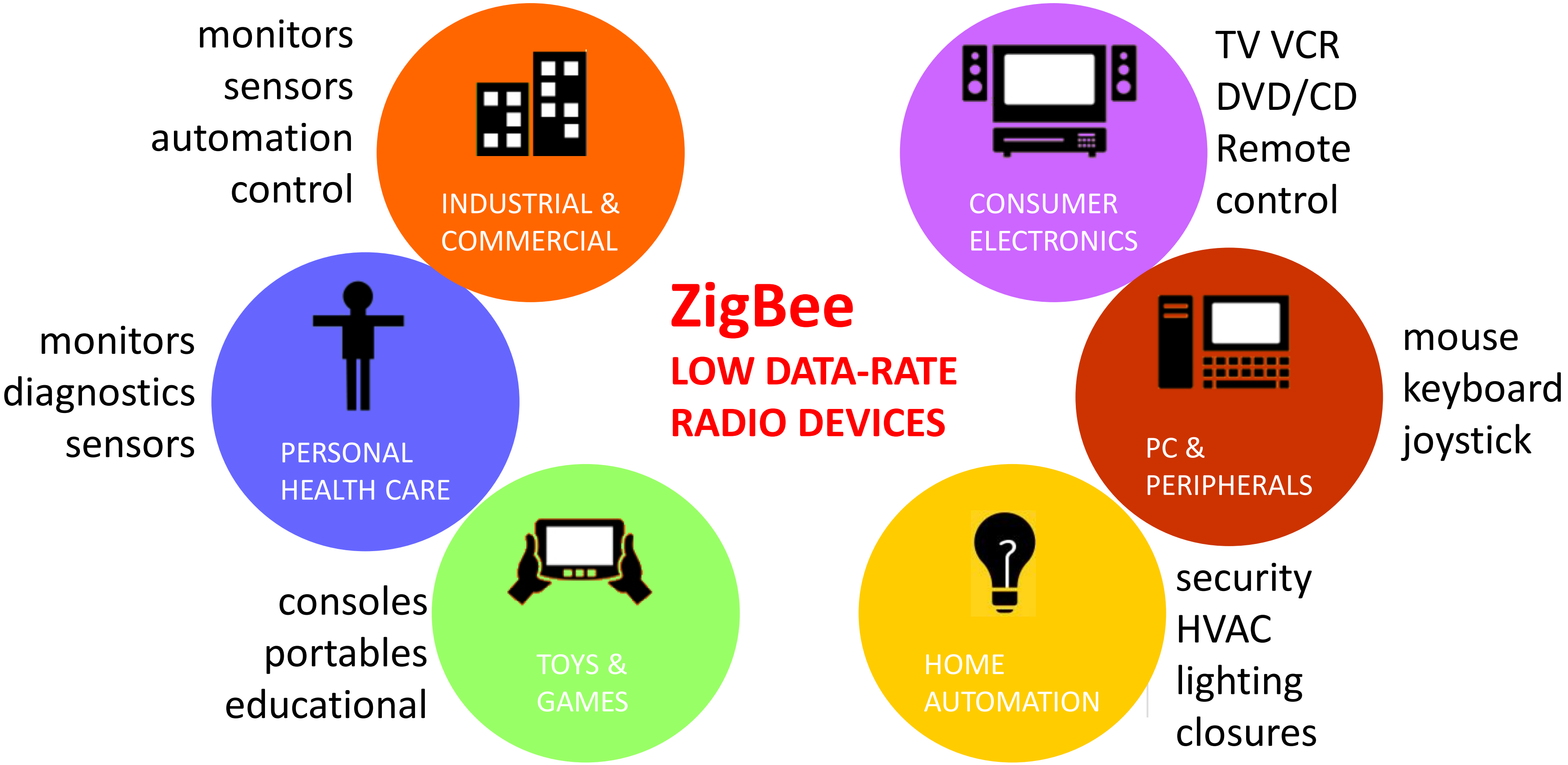
- □ Developing applications and network capability utilizing the 802.15.4 packet delivery mechanism

ZigBee™ Alliance
Wireless Control That Simply Works

Characteristics

- ❑ Low cost
- ❑ Low power consumption
- ❑ Low data rate
- ❑ Relatively short transmission range
- ❑ Scalability
- ❑ Reliability
- ❑ Flexible protocol design suitable for many applications

Applications



monitors
sensors
automation
control

INDUSTRIAL &
COMMERCIAL

CONSUMER
ELECTRONICS

TV VCR
DVD/CD
Remote
control

monitors
diagnostics
sensors

PERSONAL
HEALTH CARE

ZigBee

**LOW DATA-RATE
RADIO DEVICES**

PC &
PERIPHERALS

mouse
keyboard
joystick

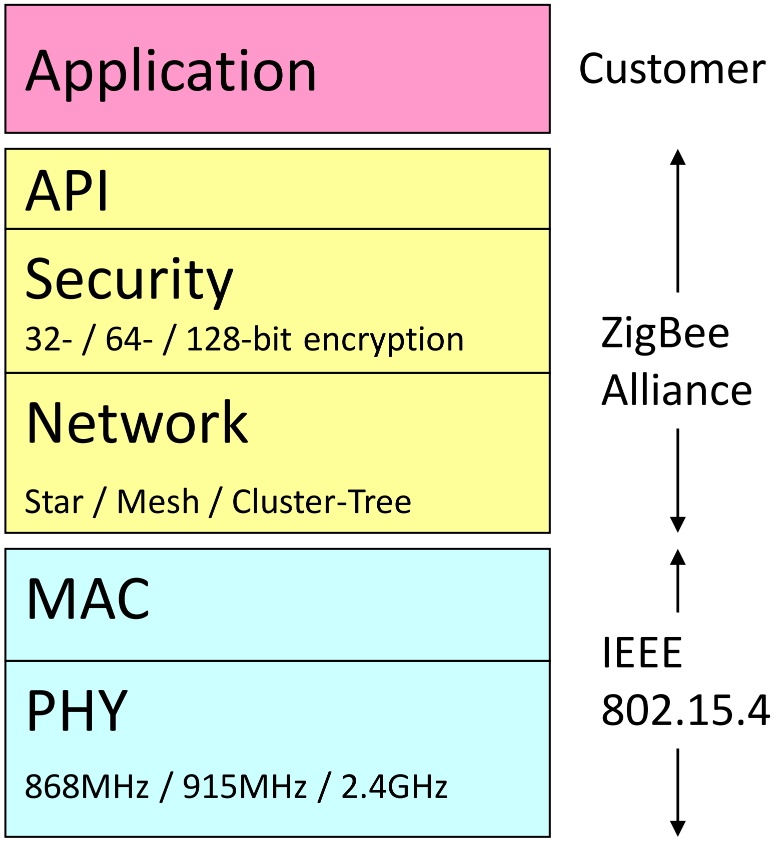
consoles
portables
educational

TOYS &
GAMES

HOME
AUTOMATION

security
HVAC
lighting
closures

ZigBee/IEEE 802.15.4



Application

Customer

API

Security

32- / 64- / 128-bit encryption

Network

Star / Mesh / Cluster-Tree

ZigBee Alliance

MAC

PHY

868MHz / 915MHz / 2.4GHz

IEEE 802.15.4

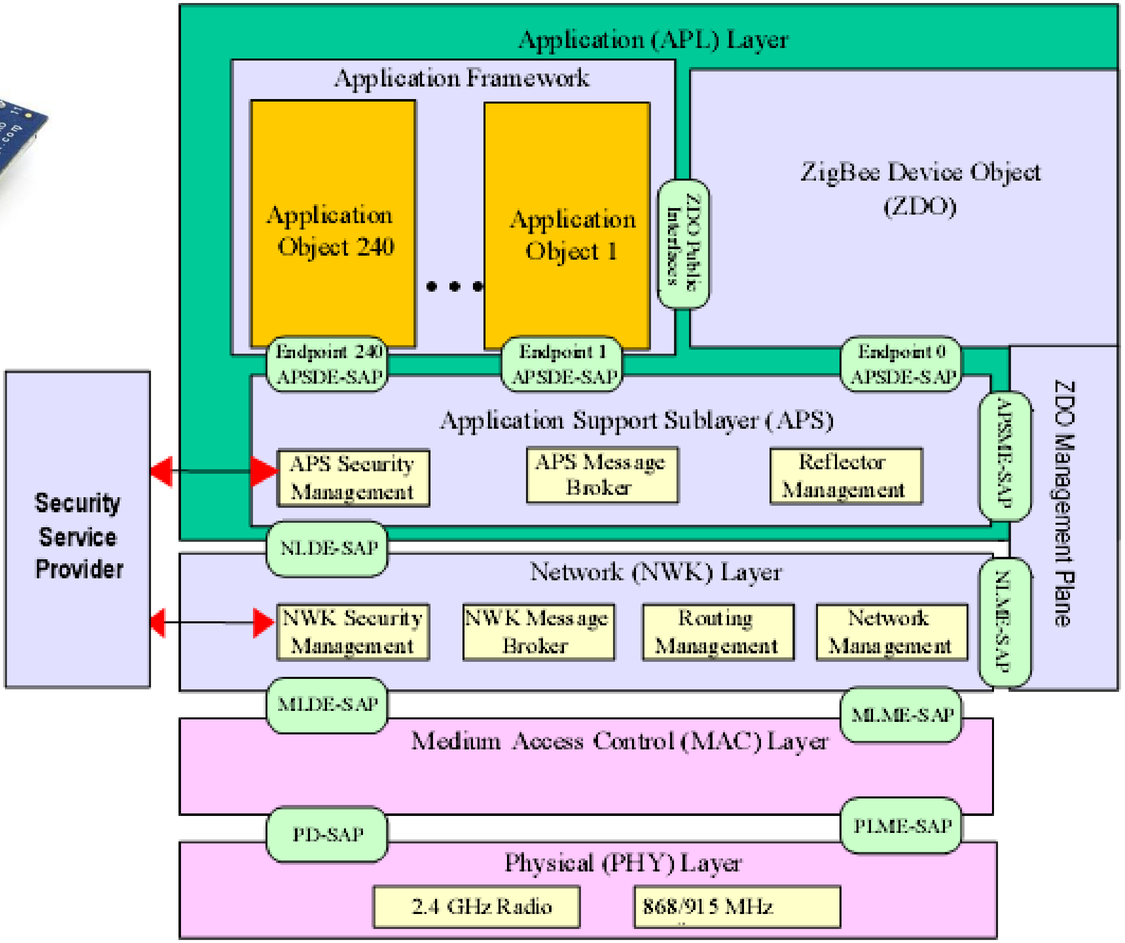
ZigBee Alliance

- "the software"
- Network, Security & Application layers
- Brand management

IEEE 802.15.4

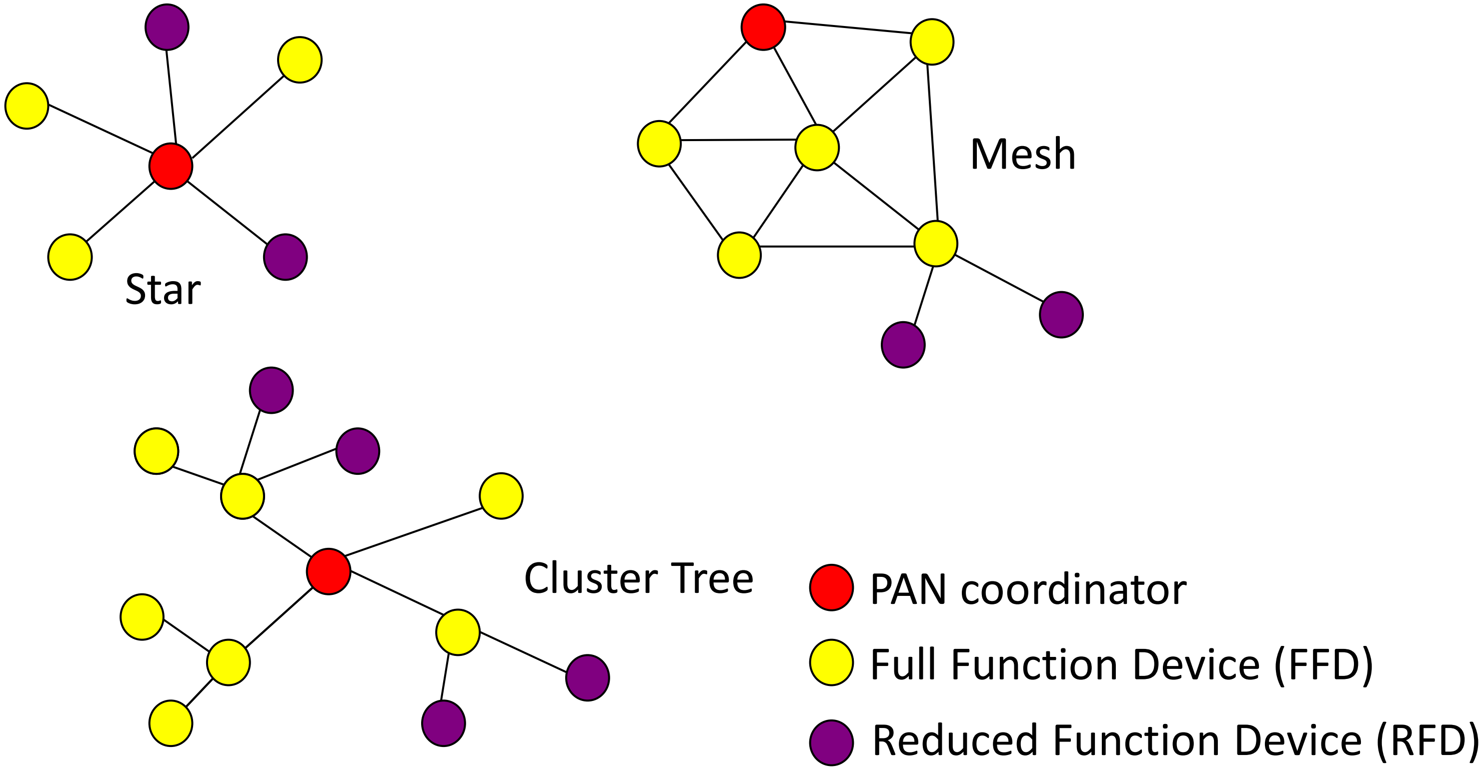
- "the hardware"
- Physical & Media Access Control layers

ZigBee Architecture



🟪	IEEE 802.15.4 defined
⬜	ZigBee™ Alliance defined
🟧	End manufacturer defined
🟨	Layer function
🟩	Layer interface

ZigBee Network Topologies



🔴 PAN coordinator

🟡 Full Function Device (FFD)

🟣 Reduced Function Device (RFD)

ZigBee Network Layer Overview

- Three kinds of devices in the network layer
  - ZigBee coordinator: responsible for initializing, maintaining, and controlling the network
  - ZigBee router: form the network backbone
  - ZigBee end device: must be connected to router/coordinator

- In a tree network, the coordinator and routers can announce beacons.
- In a mesh network, there is no regular beacon.
  - Devices in a mesh network can only communicate with each other in a peer-to-peer manner

Address Assignment

- In ZigBee, network addresses are assigned to devices by a distributed address assignment scheme
- ZigBee coordinator determines three network parameters
  - the maximum number of children (C_m) of a ZigBee router
  - the maximum number of child routers (R_m) of a parent node
  - the depth of the network (L_m)
- A parent device utilizes C_m, R_m, and L_m to compute a parameter called C_{skip}
  - which is used to compute the size of its children’s address pools

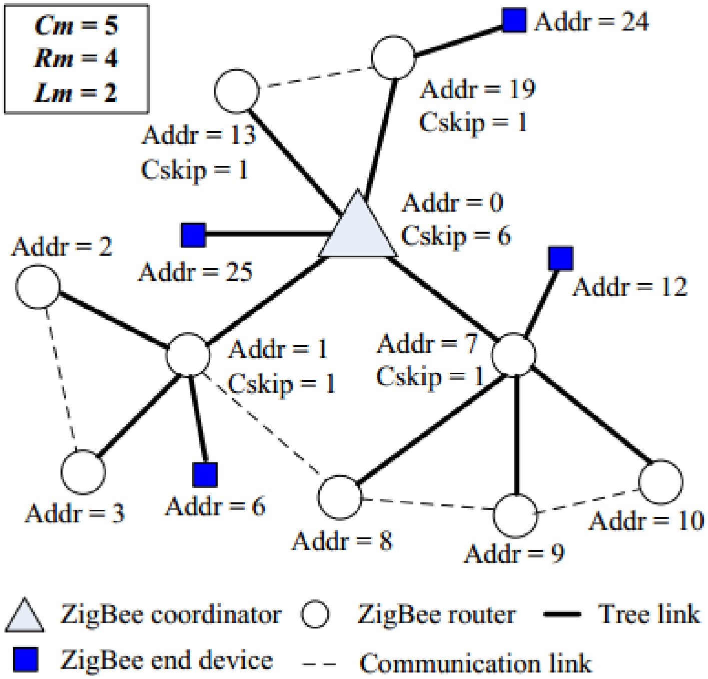
$$Cskip(d) = \begin{cases} 1 + Cm \cdot (Lm - d - 1), & if\ Rm = 1 \quad \cdots\cdots\cdots\cdots(a) \\ \dfrac{1 + Cm - Rm - Cm \cdot Rm^{Lm-d-1}}{1 - Rm}, & Otherwise \quad \cdots\cdots\cdots\cdots(b) \end{cases}$$

Address Assignment

- If a parent node at depth d has an address A_{parent}
  - the n^{th} child router is assigned to address:

    $A_{parent}+(n\text{-}1)\times C_{skip}(d)+1$
  - n^{th} child end device is assigned to address:

    $A_{parent}+R_m\times C_{skip}(d)+n$
  - *Example:*
    - $R_m=4; C_m=5; L_m=2$

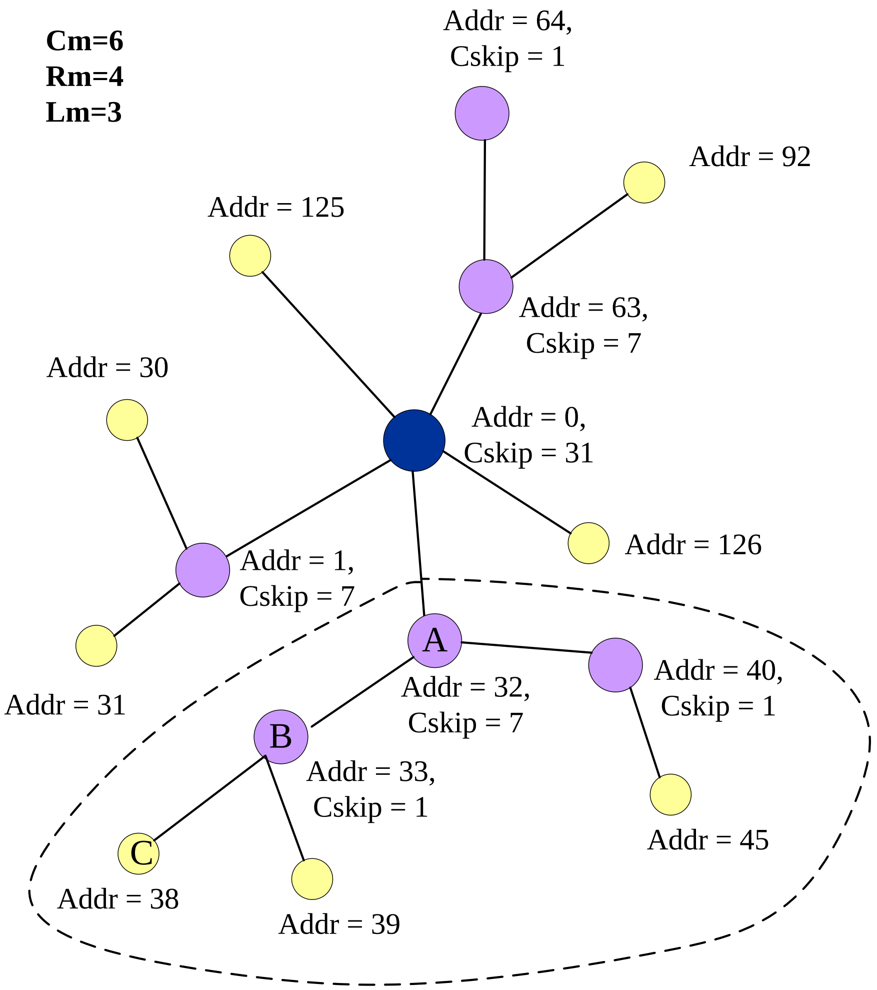


ZigBee Routing Protocols

- In a tree network
  - Utilize the address assignment to obtain the routing paths
- In a mesh network:
  - Routing Capability: ZigBee coordinators and routers are said to have routing capacity if they have routing table capacities and route discovery table capacities
  - There are 2 options:
    - Reactive routing: if having “routing capacity”
    - Tree routing: if having no routing capacity

ZigBee Tree Routing

- ❑ When a device receives a packet, it first checks if it is the destination or one of its child end devices is the destination
- ❑ If so, accept the packet or forward it to a child. Otherwise, relay it along the tree
- ❑ Example:
  - ❖ 38 → 45
  - ❖ 38 → 92

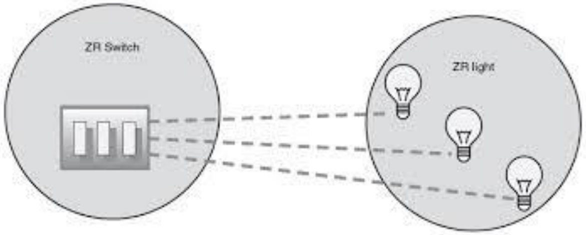


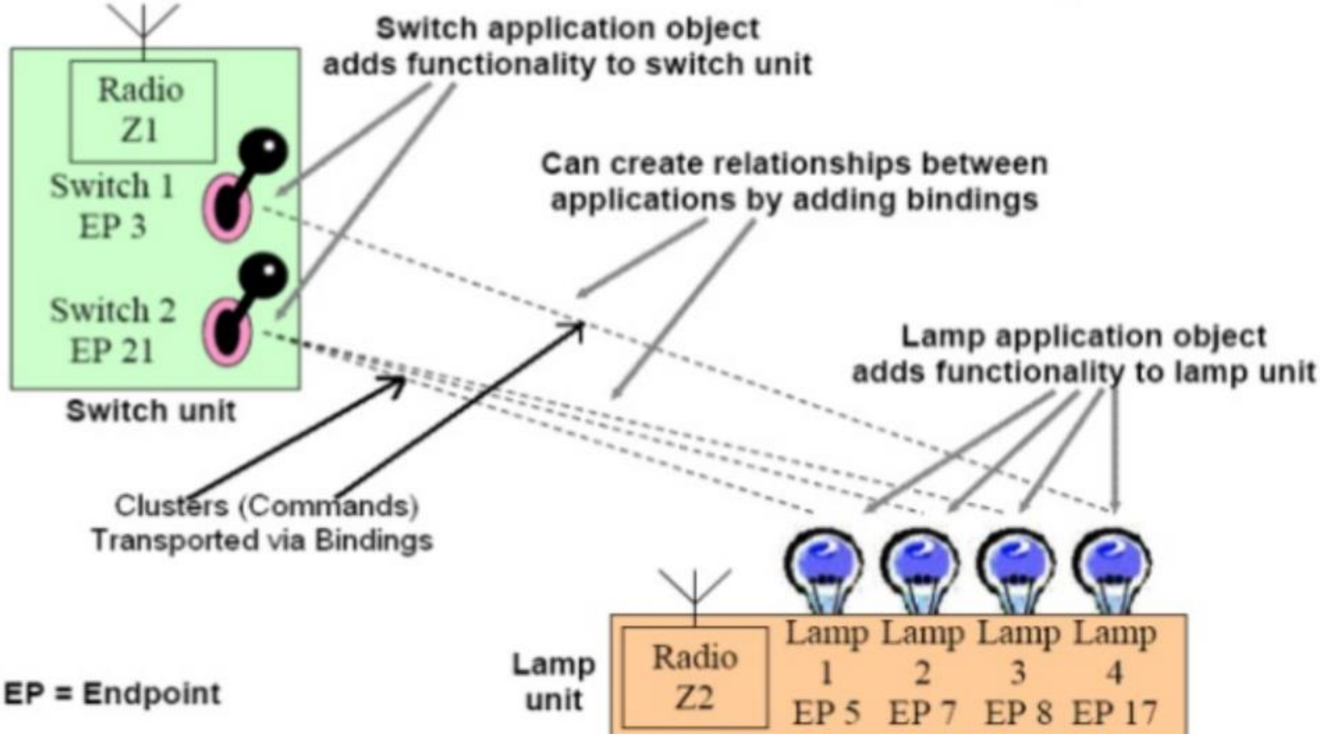
ZigBee Mesh Routing

- ❑Route discovery by AODV-like routing protocol
  - ❖The cost of a link is defined based on the packet delivery probability on that link

- ❑Route discovery procedure
  - ❖The source broadcasts a route request packet
  - ❖Intermediate nodes will rebroadcast route request if
    - They have routing discovery table capacities
    - The cost is lower
  - ❖Otherwise, nodes will relay the request along the tree
  - ❖The destination will choose the routing path with the lowest cost and then send a route reply

ZigBee Device Bindings





Switch application object adds functionality to switch unit

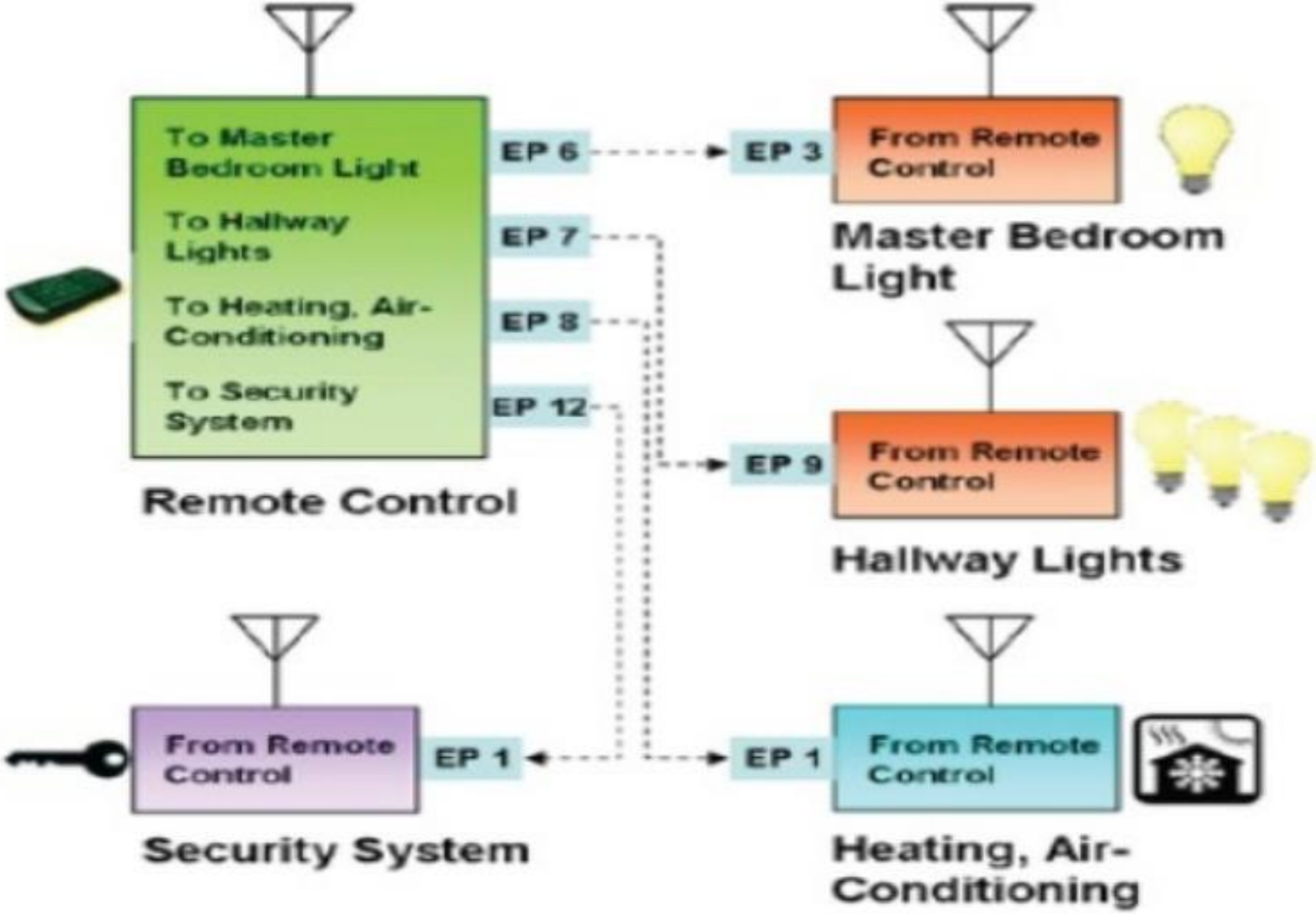
Can create relationships between applications by adding bindings

Lamp application object adds functionality to lamp unit

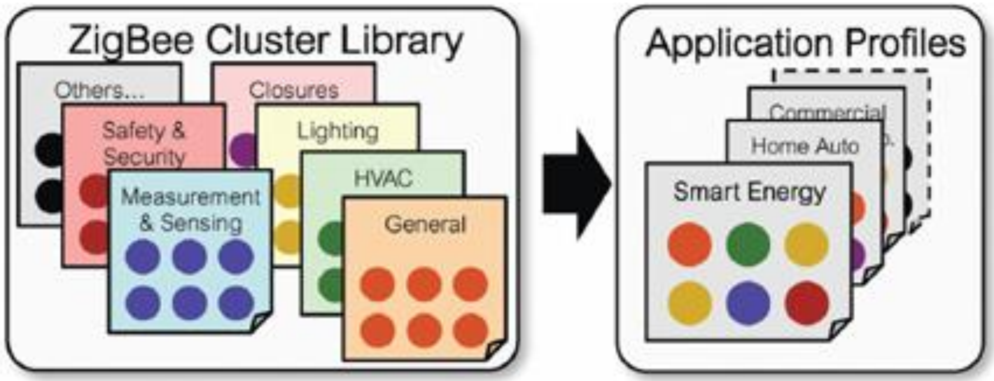
Clusters (Commands) Transported via Bindings

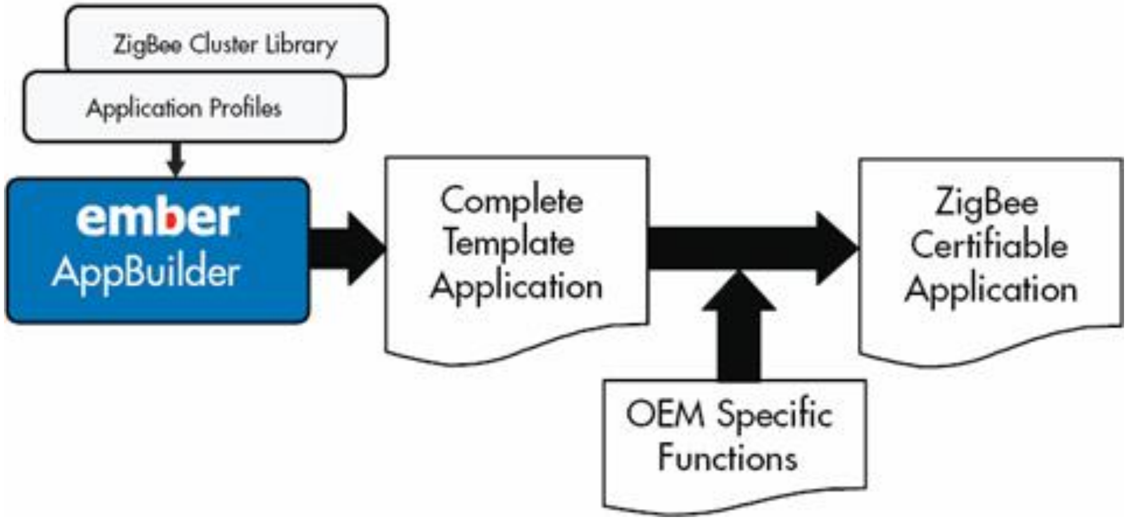
EP = Endpoint

ZigBee Device Bindings



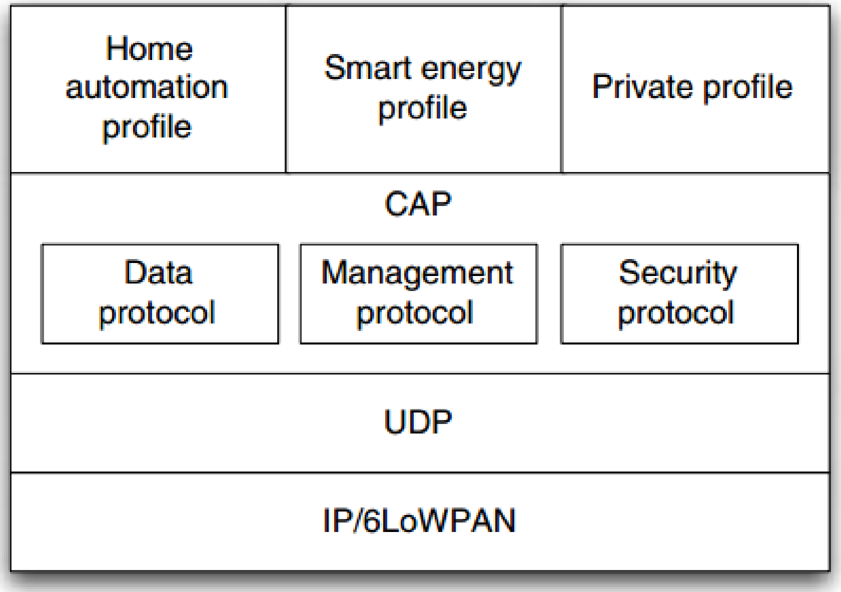
ZigBee Profiles



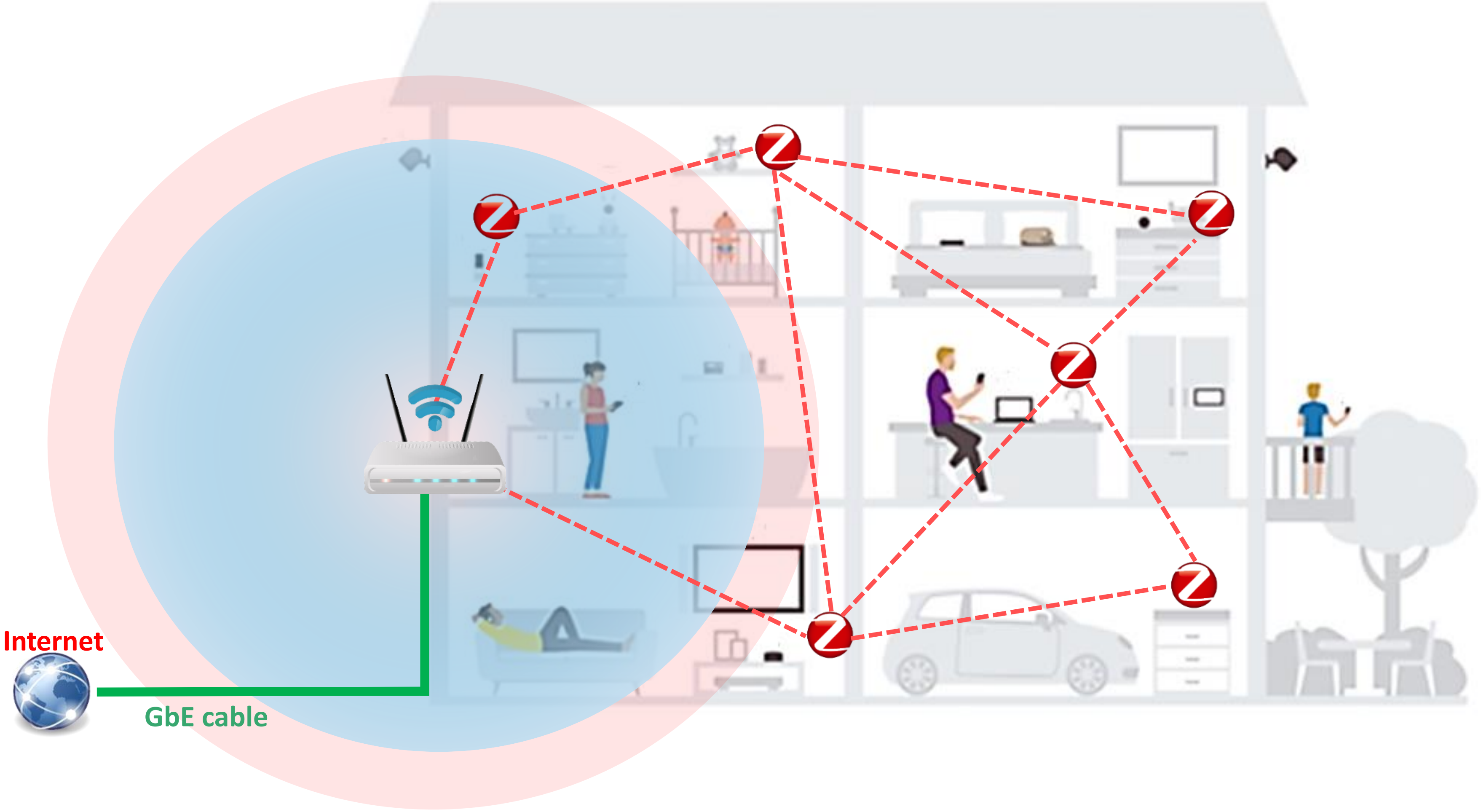


ZigBee over IPv6/6LoWPAN

- ZigBee compact application protocol (CAP)
- The functions of the ZAL and ZCL are implemented by the CAP:
  - The data protocol corresponds to the ZigBee cluster library (ZCL)
  - The management protocol corresponds to the ZigBee device profile handling binding and discovery.
  - Finally the security protocol implements ZigBee application sublayer (APS) security

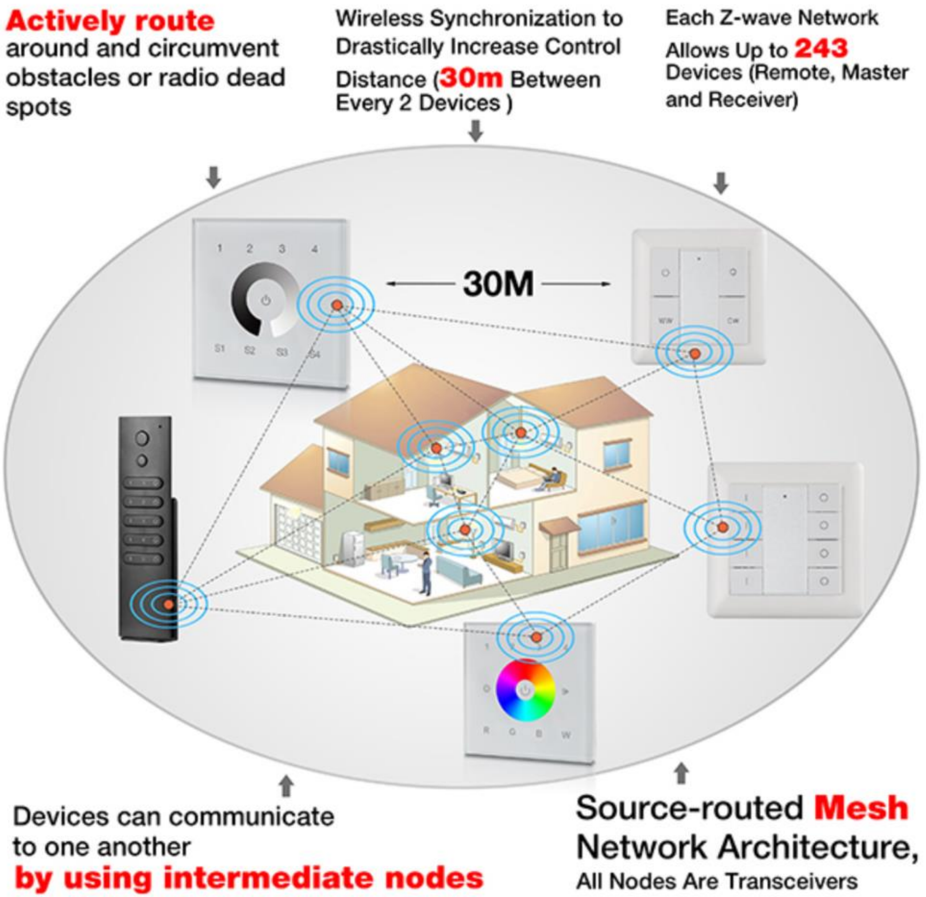


Smart Home Applications



Z-Wave

- **Z-Wave**: wireless standard for connecting IoT devices:
  - Mesh network, maximum 4 hops
  - Low-power support
  - Using sub-1GHz an transmit up to 100 meters
  - Using source routing



Actively route around and circumvent obstacles or radio dead spots

Wireless Synchronization to Drastically Increase Control Distance (**30m** Between Every 2 Devices)

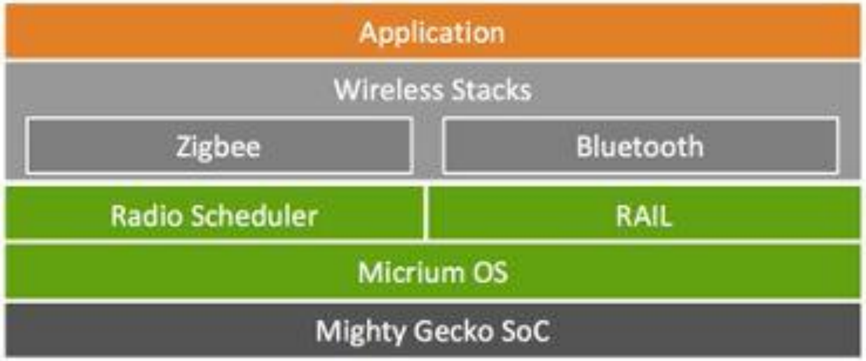
Each Z-wave Network Allows Up to **243** Devices (Remote, Master and Receiver)

Devices can communicate to one another **by using intermediate nodes**

Source-routed **Mesh** Network Architecture, All Nodes Are Transceivers

Dynamic Protocols

- Devices simultaneously run multiple wireless protocols on one SoC, using a *time-slicing* mechanism to share the radio
- First introduced by Silabs for EFR32MG SoC



Application

Wireless Stacks

Zigbee

Bluetooth

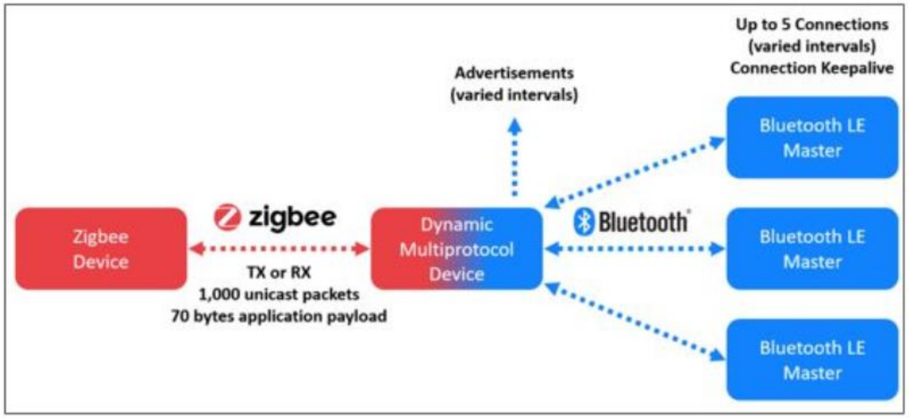
Radio Scheduler

RAIL

Micrium OS

Mighty Gecko SoC

RAIL: Radio Abstraction Interface Layer



Up to 5 Connections (varied intervals) Connection Keepalive

Advertisements (varied intervals)

Zigbee Device

zigbee

TX or RX
1,000 unicast packets
70 bytes application payload

Dynamic Multiprotocol Device

Bluetooth

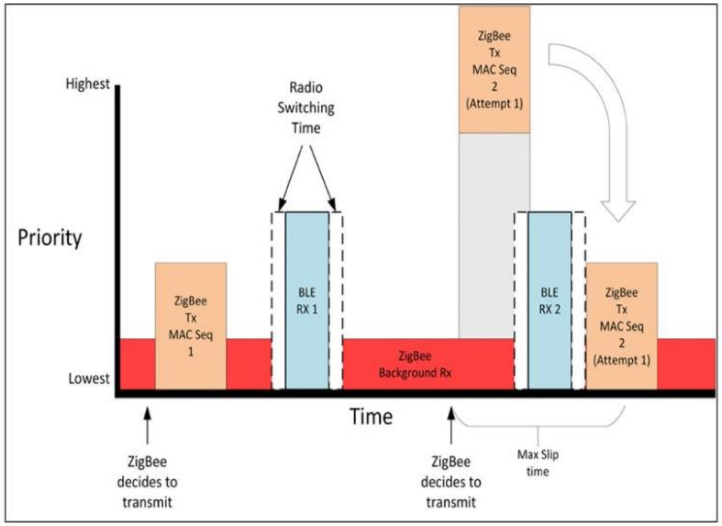
Bluetooth LE Master

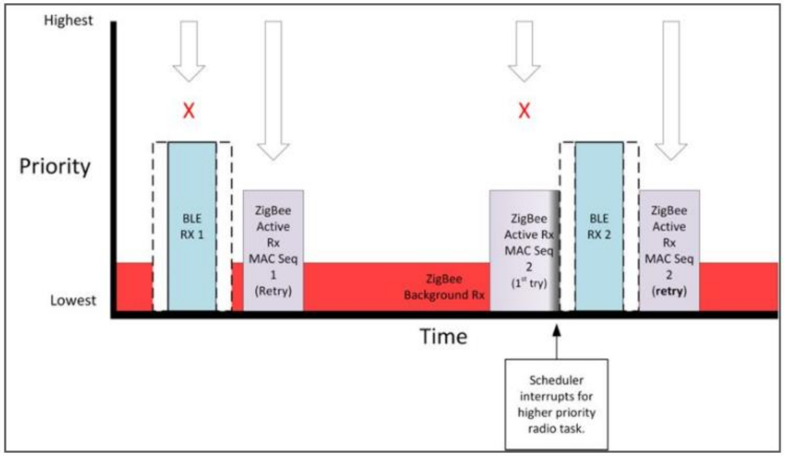
Bluetooth LE Master

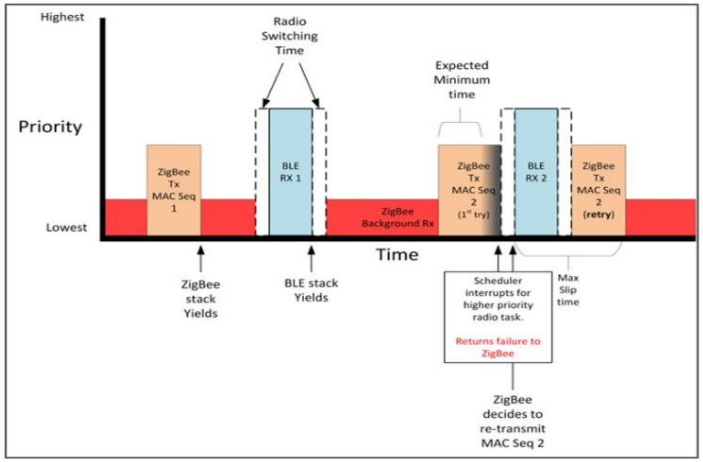
Bluetooth LE Master

Dynamic Protocols

- The low-priority ZigBee receive is the default, but when a ZigBee transmission is required, it interrupts that process. This is normal behavior for a ZigBee device. When a BLE connection is scheduled, this takes precedent, and the scheduler switches out of ZigBee receive mode in time to be available for the Bluetooth connection. If the scheduler has a request for a ZigBee transmission that would exceed the time available on the radio before the next BLE connection or beacon, the scheduler will reschedule the ZigBee transmission to occur after the BLE activity has completed.

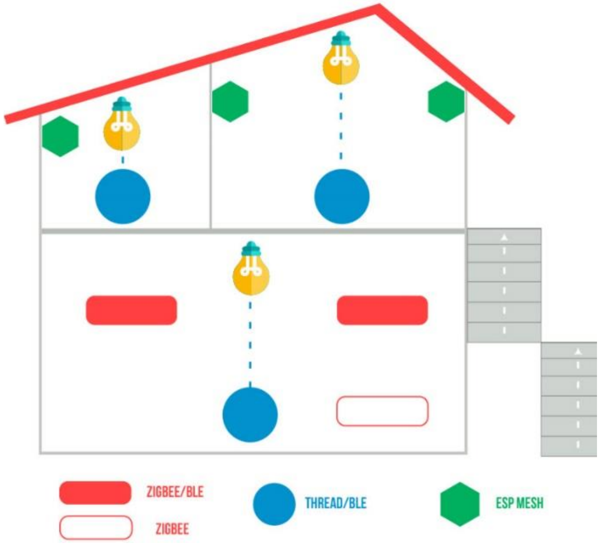

Highest
Priority
Lowest
Radio Switching Time
ZigBee Tx MAC Seq 2 (Attempt 1)
ZigBee Tx MAC Seq 1
BLE RX 1
ZigBee Background Rx
BLE RX 2
ZigBee Tx MAC Seq 2 (Attempt 1)
Time
ZigBee decides to transmit
ZigBee decides to transmit
Max Slip time

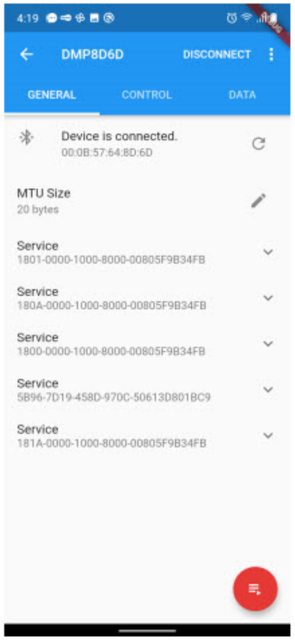

Highest
Priority
Lowest
X
X
BLE RX 1
ZigBee Active Rx MAC Seq 1 (Retry)
ZigBee Background Rx
ZigBee Active Rx MAC Seq 2 (1st try)
BLE RX 2
ZigBee Active Rx MAC Seq 2 (retry)
Time
Scheduler interrupts for higher priority radio task.


Highest
Priority
Lowest
Radio Switching Time
Expected Minimum time
ZigBee Tx MAC Seq 1
BLE RX 1
ZigBee Background Rx
ZigBee Tx MAC Seq 2 (1st try)
BLE RX 2
ZigBee Tx MAC Seq 2 (retry)
Time
ZigBee stack Yields
BLE stack Yields
Scheduler interrupts for higher priority radio task.
Returns failure to ZigBee
Max Slip time
ZigBee decides to re-transmit MAC Seq 2

Dynamic Protocols Demo

Dynamic Protocols Demo





Device is connected.
00:0B:57:64:8D:6D

MTU Size
20 bytes

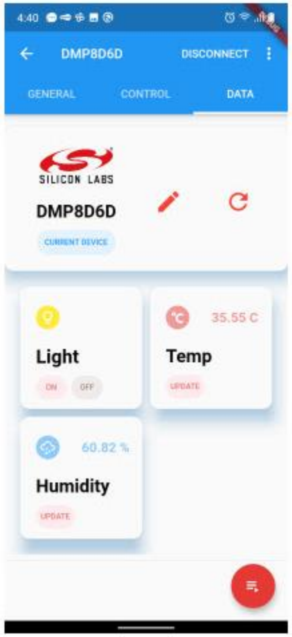
Service
1801-0000-1000-8000-00805F9B34FB

Service
180A-0000-1000-8000-00805F9B34FB

Service
1800-0000-1000-8000-00805F9B34FB

Service
5B96-7D19-458D-970C-50613D801BC9

Service
181A-0000-1000-8000-00805F9B34FB



DMP8D6D
CURRENT DEVICE

Light

Temp 35.55 C

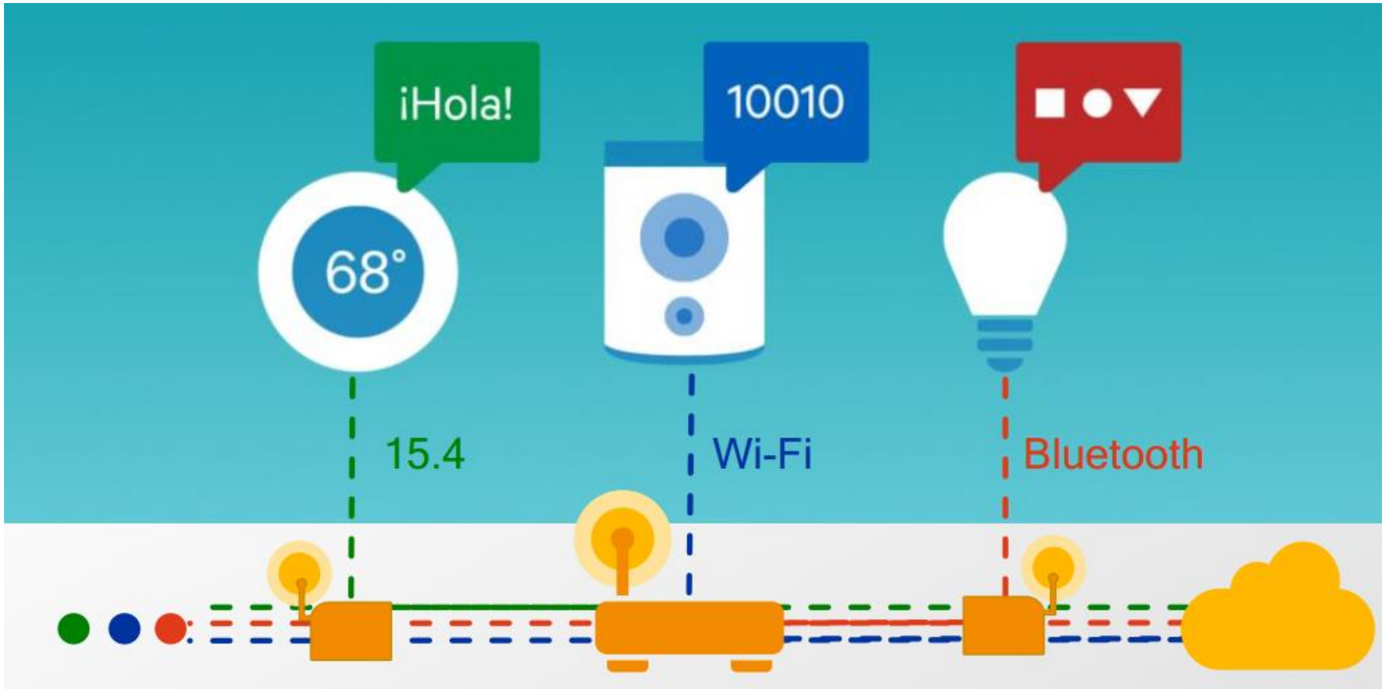
Humidity 60.82 %

A demo of Dynamic Multi-protocol system:

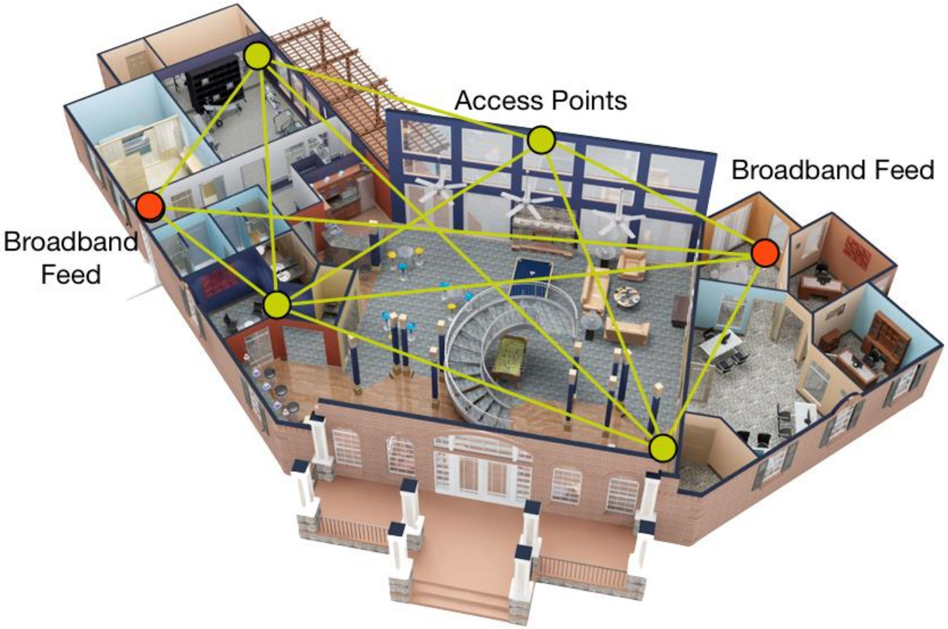
- Dynamic Protocols of BLE and Thread on a SoC Nordic nRF52840
- Dynamic Protocols of ZigBee and BLE on a SoC Silabs EFR32MG12.
- Mesh WiFi using ESP8266
- A Multiple-Protocol Gateway (Thread and Zigbee NCP)
- Control via Unique App

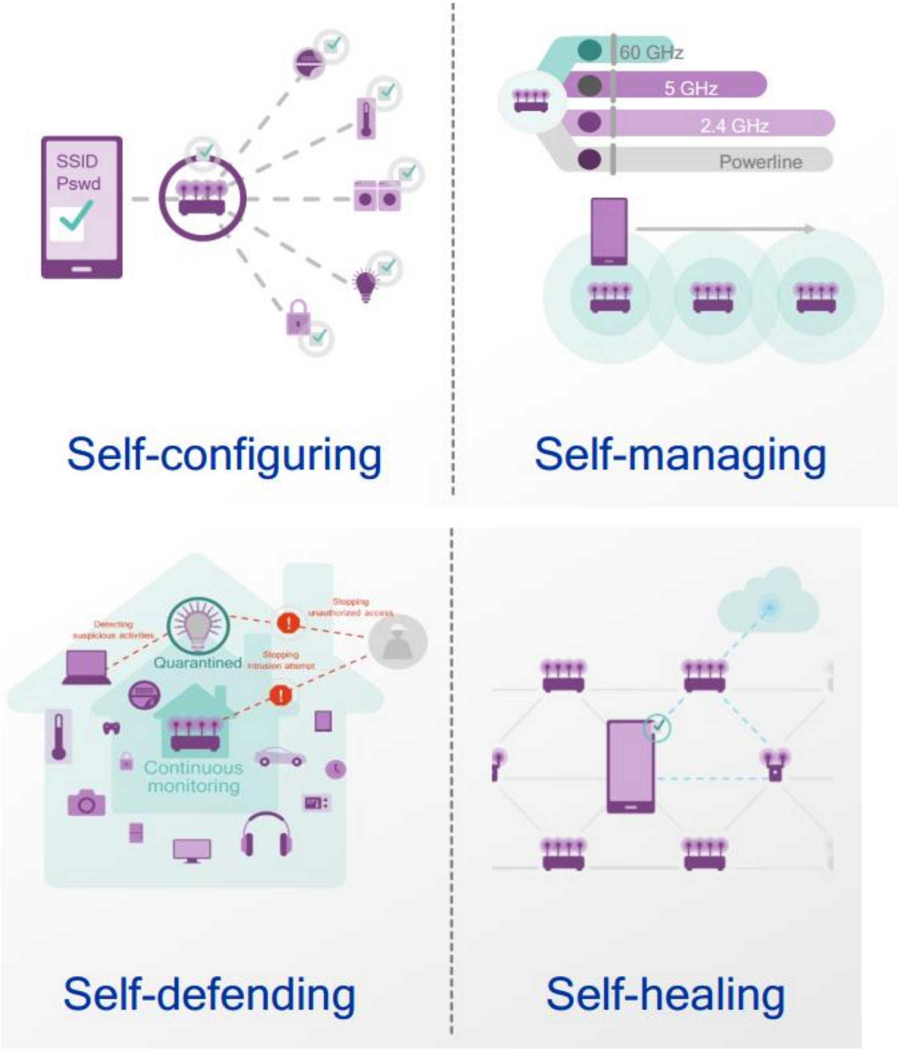
Backhaul Networks for Smart Home

- ❑ Introduced by Qualcomm: WiFi-SON
- ❑ PLC based on HPAV or G.Hn
- ❑ Integrated Voice Service



Features




SSID
Pswd
60 GHz
5 GHz
2.4 GHz
Powerline
Detecting suspicious activities
Stopping unauthorized access
Quarantined
Stopping intrusion attempt
Continuous monitoring

Self-configuring

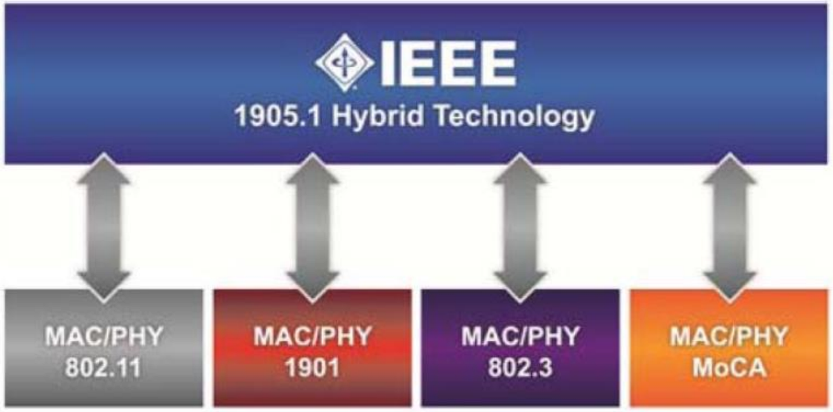
Self-managing

Self-defending

Self-healing

Hybrid Networks

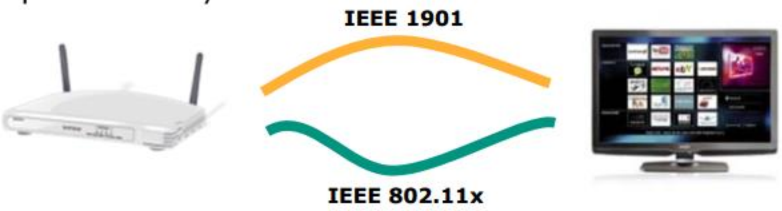
- ❑ The IEEE 1905.1 Draft Standard defines a common fabric that spans established home networking technologies and defines a common data and control Service Access Point.
- ❑ Packets can arrive and be transmitted over any interface, regardless of the upper protocol layers or underlying networking technology.
- ❑ Designed to enhance user experience and enable next generation connected services for consumers.
- ❑ Industry-leading chipmakers, equipment manufacturers, and service providers are collaborating to bring IEEE 1905.1 to fruition.



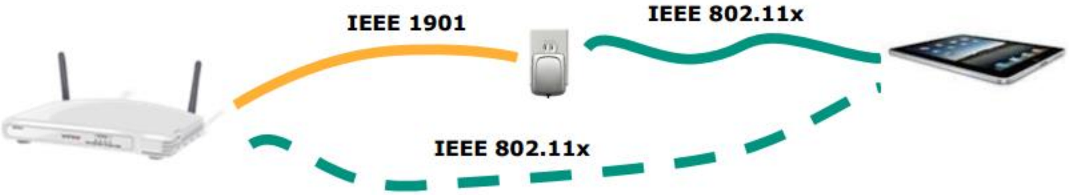
WLAN **PLC** **Ethernet** **Coaxial**

Main uses of HN

- "Multipath" delivery

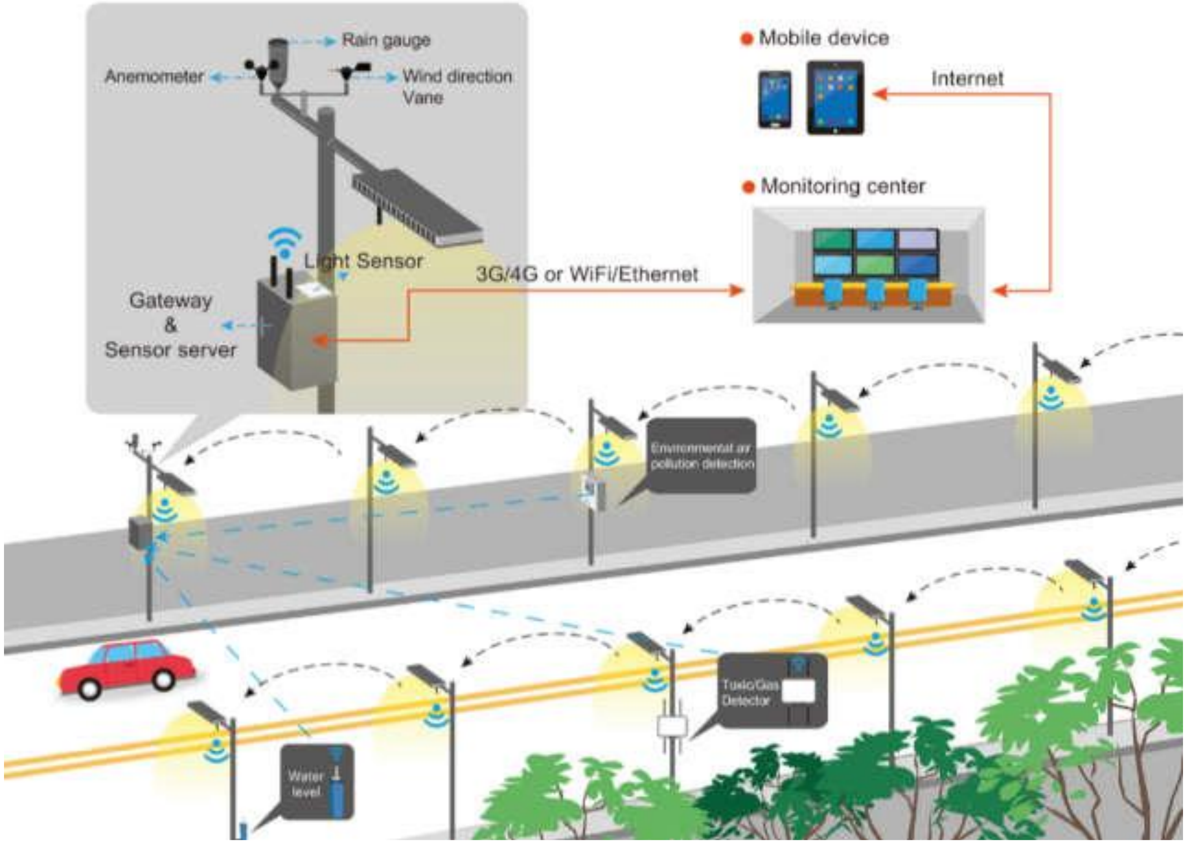


- Range Extension

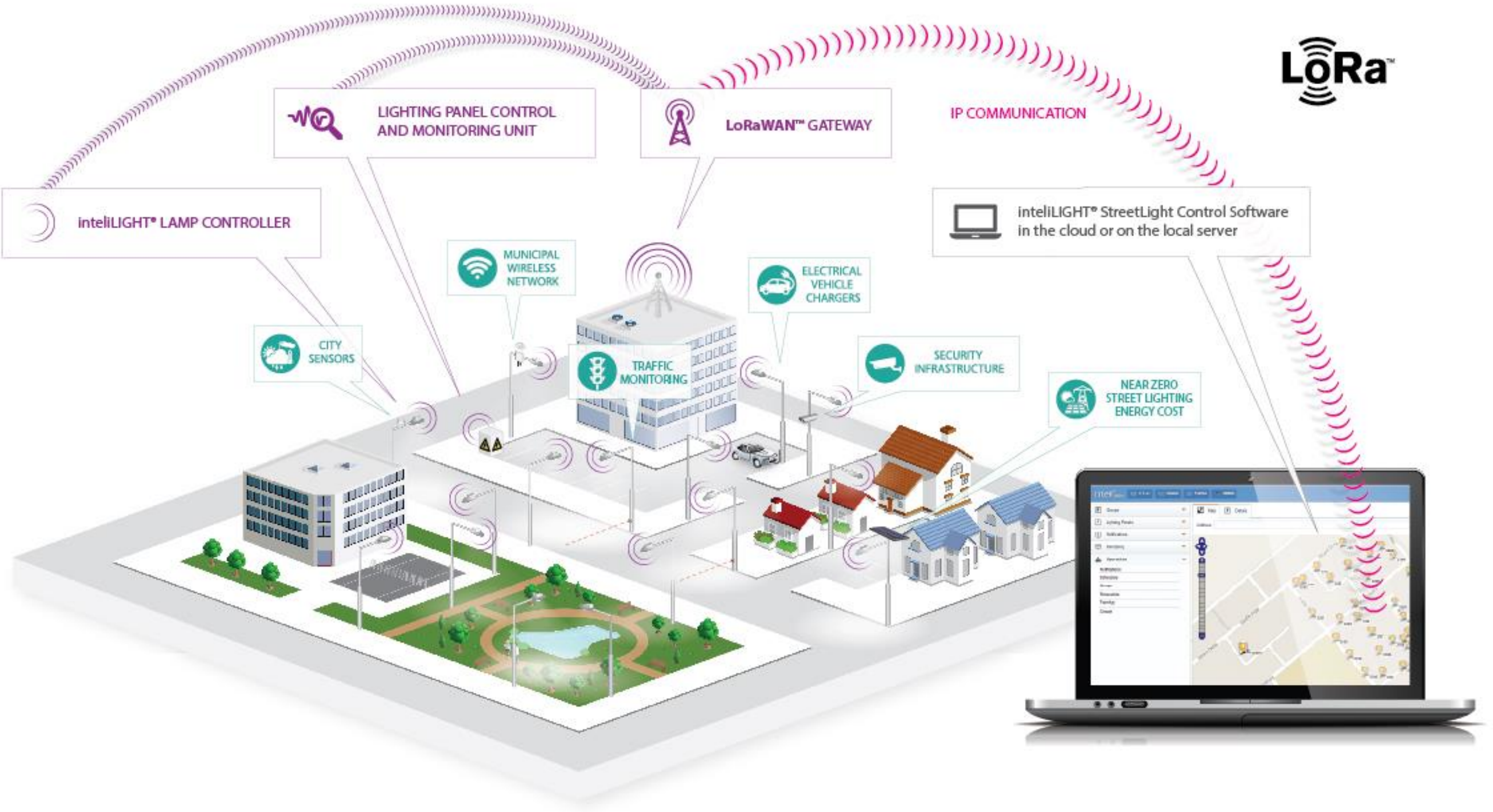


Sub-1GHz Technology

- ❑ 433MHz, 868MHz, 915MHz bands
- ❑ Suitable for outdoor applications

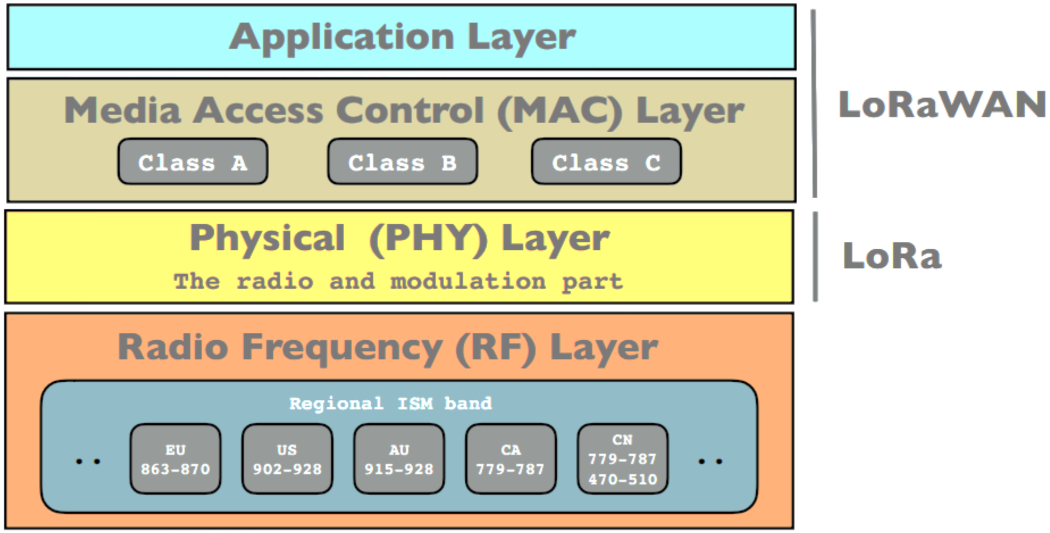


LoRa Networks


LoRa™
LIGHTING PANEL CONTROL AND MONITORING UNIT
LoRaWAN™ GATEWAY
IP COMMUNICATION
inteliLIGHT® LAMP CONTROLLER
inteliLIGHT® StreetLight Control Software in the cloud or on the local server
MUNICIPAL WIRELESS NETWORK
ELECTRICAL VEHICLE CHARGERS
CITY SENSORS
TRAFFIC MONITORING
SECURITY INFRASTRUCTURE
NEAR ZERO STREET LIGHTING ENERGY COST

LoRa Protocol Stack

- ❑ Class A, B, and C



Application Layer

Media Access Control (MAC) Layer

Class A

Class B

Class C

Physical (PHY) Layer

The radio and modulation part

Radio Frequency (RF) Layer

Regional ISM band

..

EU 863-870

US 902-928

AU 915-928

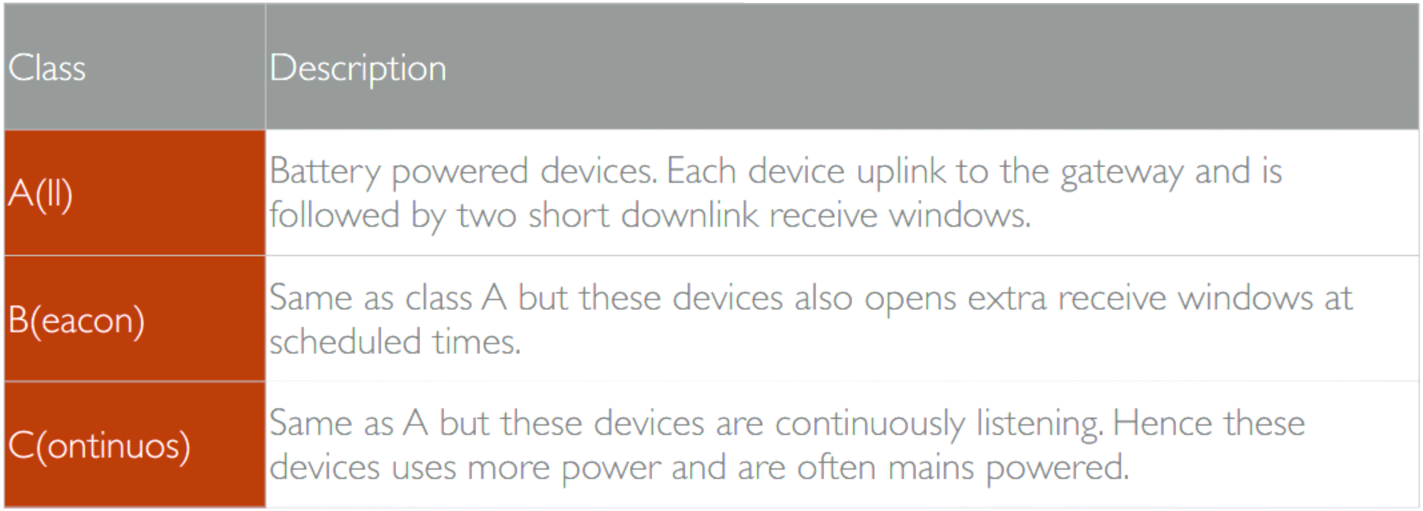
CA 779-787

CN 779-787 470-510

..

LoRaWAN

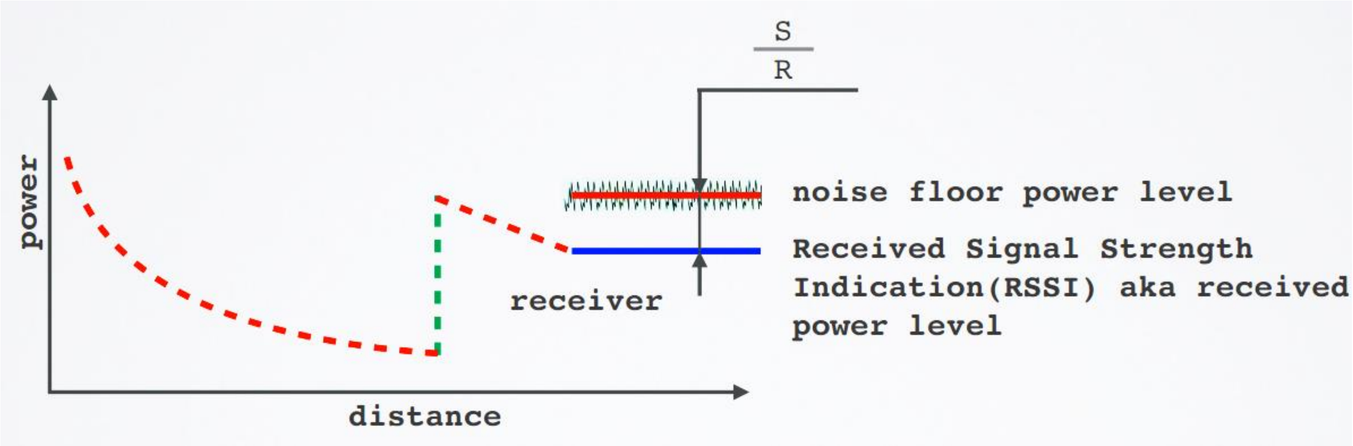
LoRa



Class	Description
A(ll)	Battery powered devices. Each device uplink to the gateway and is followed by two short downlink receive windows.
B(eacon)	Same as class A but these devices also opens extra receive windows at scheduled times.
C(ontinuos)	Same as A but these devices are continuously listening. Hence these devices uses more power and are often mains powered.

SNR in LoRa

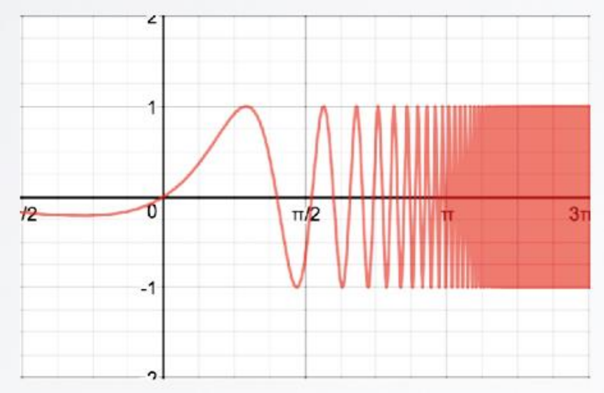
- ❑ Normally the noise floor is the physical limit of sensitivity, however LoRa works below the noise level (SNR<0)
- ❑ Typical LoRa SNR values are between: -20dB and +10dB. A value closer to +10dB means the received signal is less corrupted.
  - ❖ If a device SNR value is negative the device can receive signals below the noise floor.
  - ❖ LoRa can demodulate signals which are -7.5 dB to -20 dB below the noise floor.

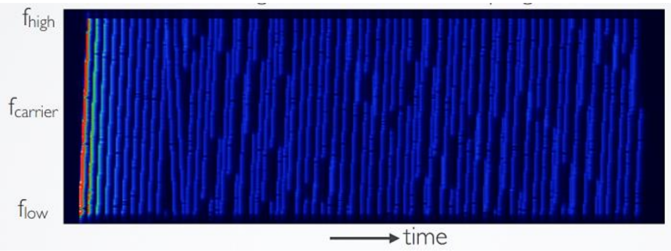


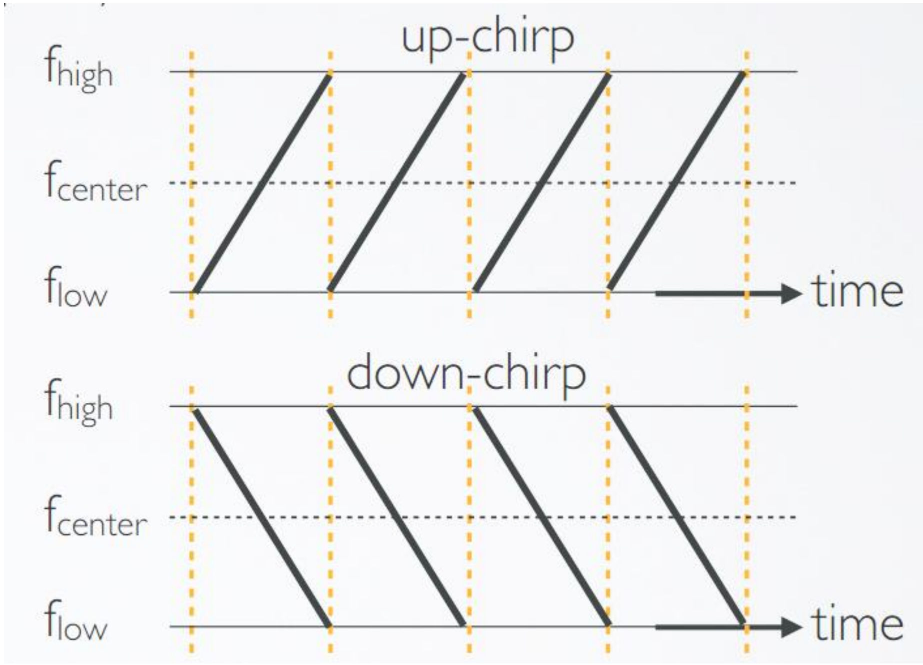
S
R
power
noise floor power level
Received Signal Strength Indication(RSSI) aka received power level
receiver
distance

Modulation in LoRa

- ❑ LoRa is a proprietary spread spectrum modulation scheme that is based on Chirp Spread Spectrum modulation (CSS).
- ❑ Chirp Spread Spectrum is a spread spectrum technique that uses wideband linear frequency modulated chirp pulses to encode information.
- ❑ A chirp, often called a sweep signal, is a tone in which the frequency increases (upchirp) or decreases (down-chirp) with time

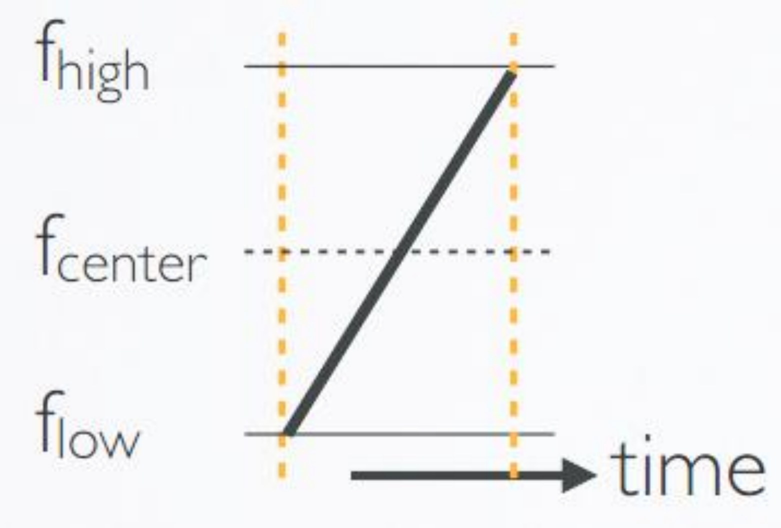






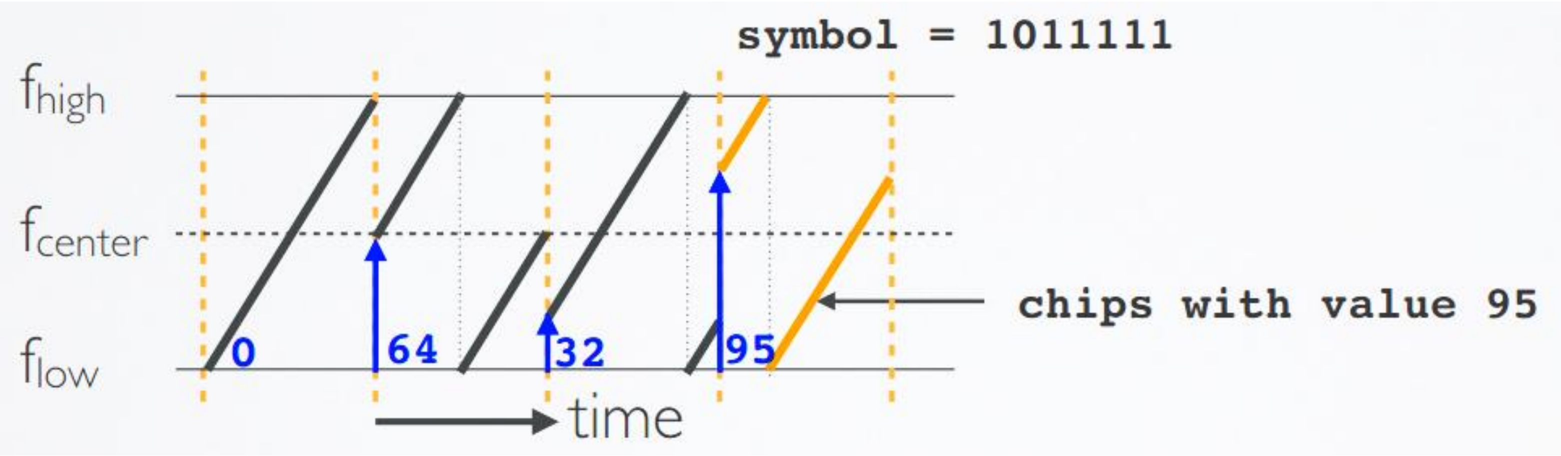
Symbol, Spreading Factor and Chip

- ❑ A symbol represents one, or more bits of data, for example: Symbol = 1011111 (decimal = 95). In the example above the number of raw bits that can be encoded by the symbol is 7. This is the same as saying: Spreading Factor (SF) = 7
- ❑ The symbol has 2^{SF} values. If SF=7, the values ranges from 0 - 127. The symbol value is encoded onto a sweep signal (up-chirp).

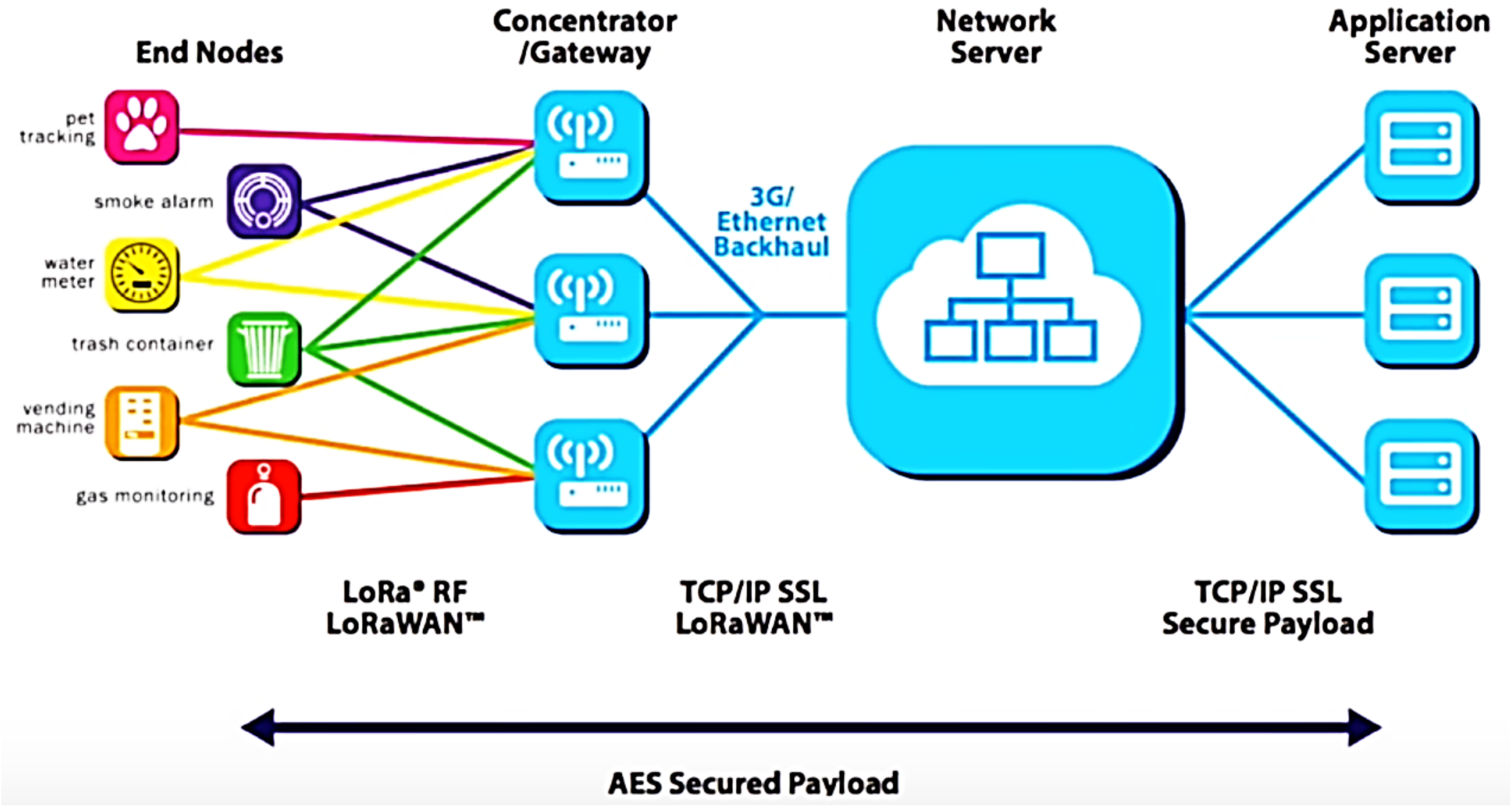


Symbol, Spreading Factor and Chip

- ❑ The sweep signal is divided into 2^{SF} steps or chips. For example the symbol is: 1011111 (decimal value = 95)
- ❑ The number of raw bits that can be encoded by this symbol is 7 (SF=7)
- ❑ The sweep signal is divided in $2^{SF} = 2^7 = 128$ chips



LoRa Network Architecture



LoRa: Characteristics

- P2P communication
- Variable bitrates based on Spread Factor (SF)
- Frequency band: 137 – 525 MHz
- Tx Power: up to 20dBm
- Sensitivity: -148 dBm
- Data rate: 0.18 – 37.5 kbps
- Several km coverage

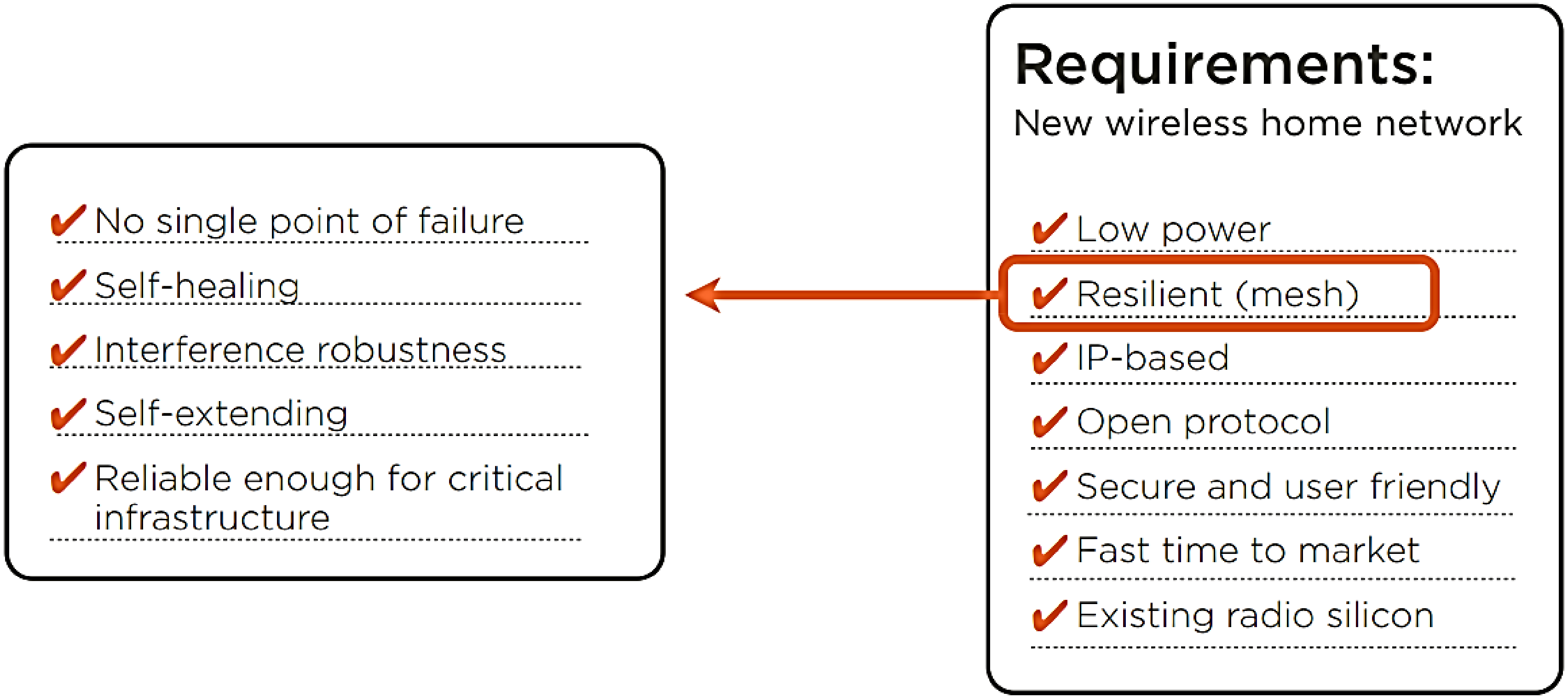
- Frame format

Preamble (6 to 65535 symbols)	Sync Word (2.25 symbols)	Header (Explicit or Implicit)	Payload (Up to 255 bytes)	CRC (2 bytes)

Thread stack

- A secure, wireless mesh networking protocol that:
  - Supports IPv6 addresses and simple IP bridging
  - Is built upon a foundation of existing standards
  - Is optimized for low-power / battery-backed operation
  - Is intended for control and automation (250kbps)
  - Can support networks of 250 nodes or greater
  - Supports low latency (less than 100 milliseconds)
  - Offers simplified security and commissioning
  - Runs on existing 802.15.4 wireless SoCs

The need for a new wireless network



Requirements:

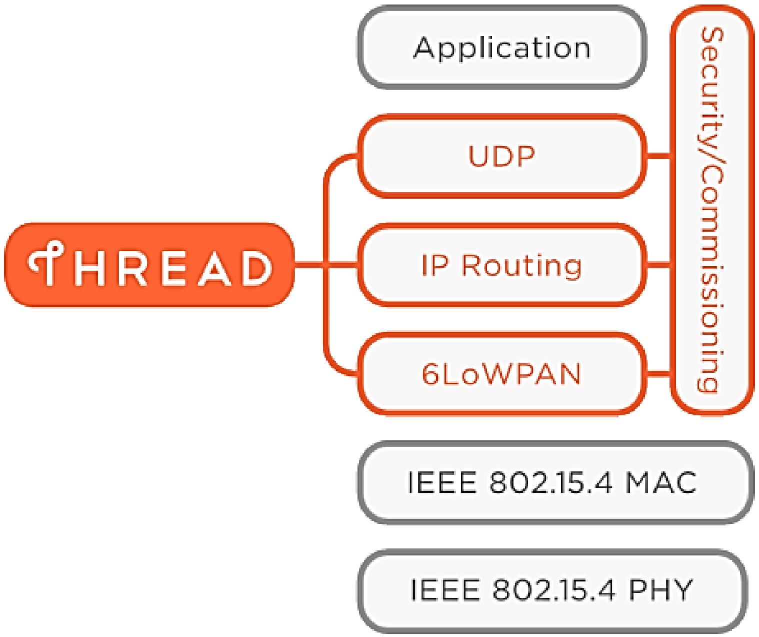
New wireless home network

- ✓ Low power
- ✓ Resilient (mesh)
- ✓ IP-based
- ✓ Open protocol
- ✓ Secure and user friendly
- ✓ Fast time to market
- ✓ Existing radio silicon

- ✓ No single point of failure
- ✓ Self-healing
- ✓ Interference robustness
- ✓ Self-extending
- ✓ Reliable enough for critical infrastructure

Thread stack

Can support many popular application layer protocols and platforms

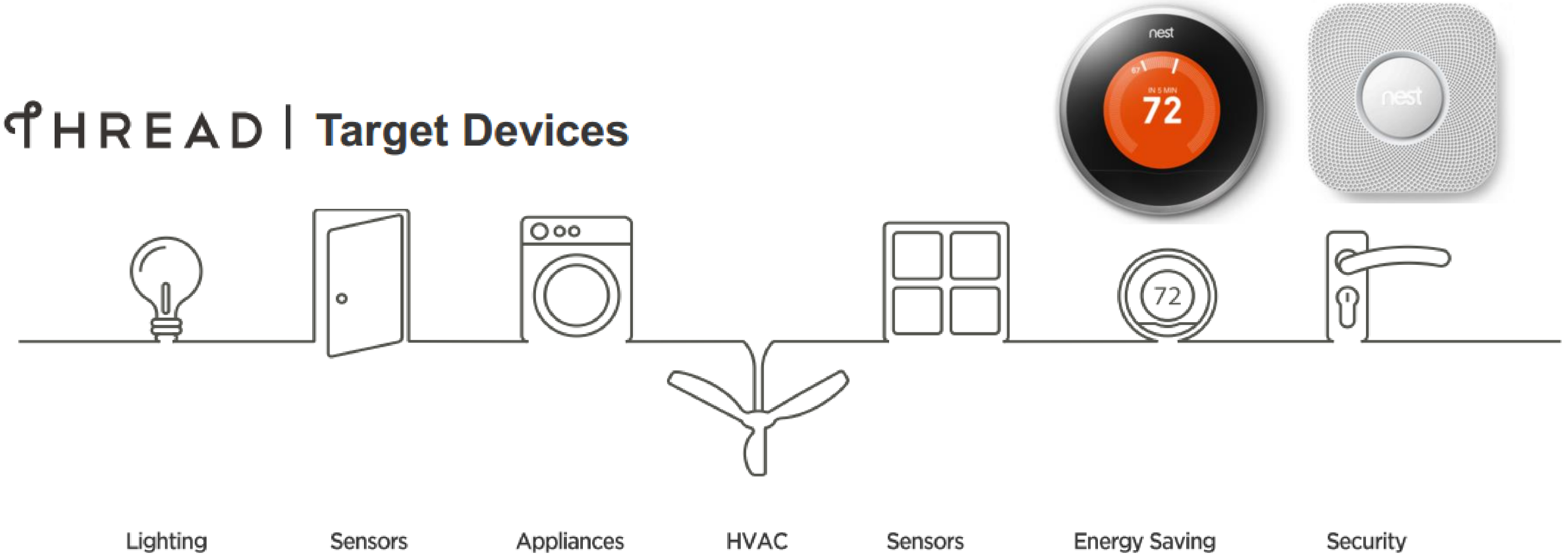


A software upgrade can add Thread to currently shipping 802.15.4 products

THREAD	Standard
UDP + DTLS	RFC 768, RFC 6347, RFC 4279, RFC 4492v RFC 3315, 5007
Distance Vector Routing	RFC 1058, RFC 2080
6LowPAN (IPv6)	RFC 4944, RFC 4862, RFC 6775
IEEE 802.15.4 MAC (including MAC security)	IEEE 802.15.4 (2006)
IEEE 802.15.4 PHY	IEEE 802.15.4 (2006)

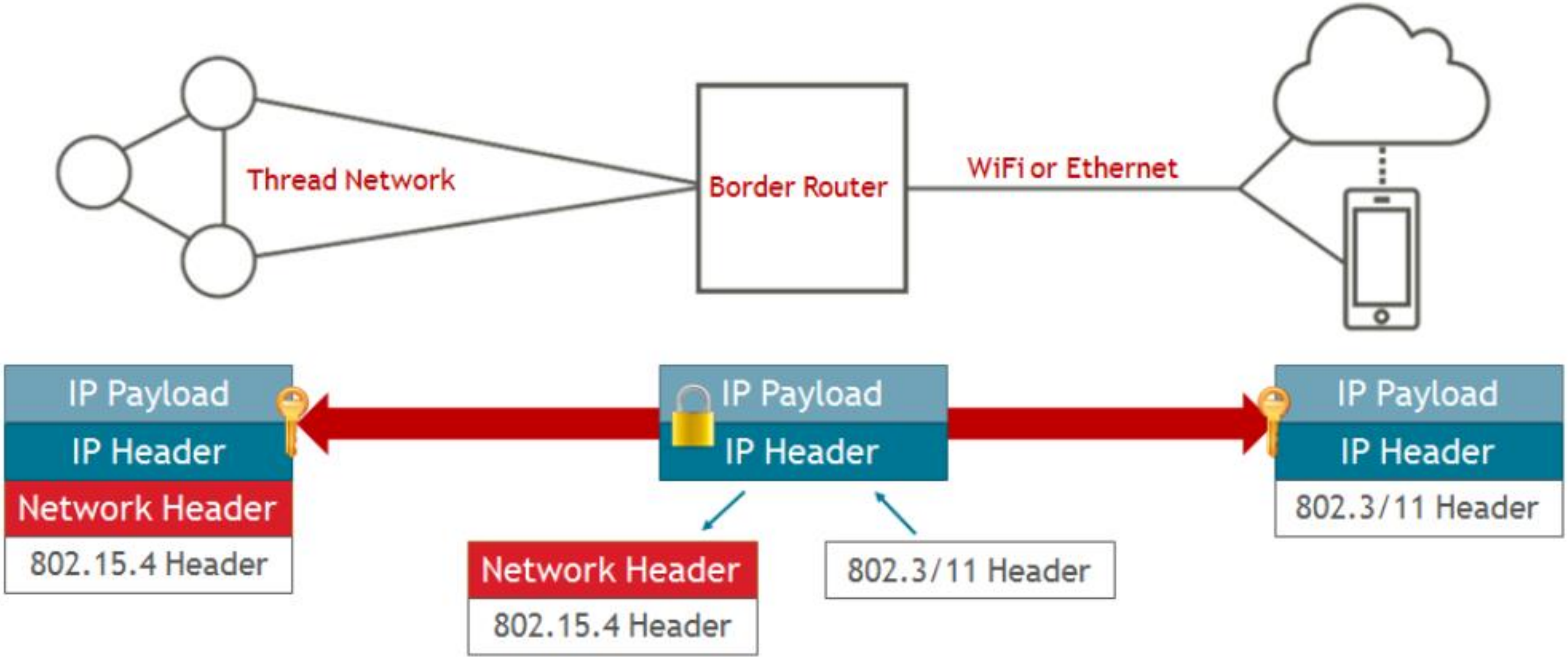
ARM BIGASS FANS No Equal freescale nest SAMSUNG SILICON LABS Yale

Thread Target Devices



- Normally Powered
  - Gateway
  - Lighting
  - Appliances
  - Smart Meter
  - Garage door opener
  - HVAC equipment
  - Smart Plugs
  - Fans
- Powered or Battery
  - Thermostat
  - Light switches
  - Smoke detectors
  - In home display
  - Shades or blinds
  - Door bell
  - Glass break sensors
  - Robots/cleaners
- Normally Battery
  - Door sensors
  - Window sensors
  - Motion sensors
  - Door locks
  - Radiator valves
  - Body sensors

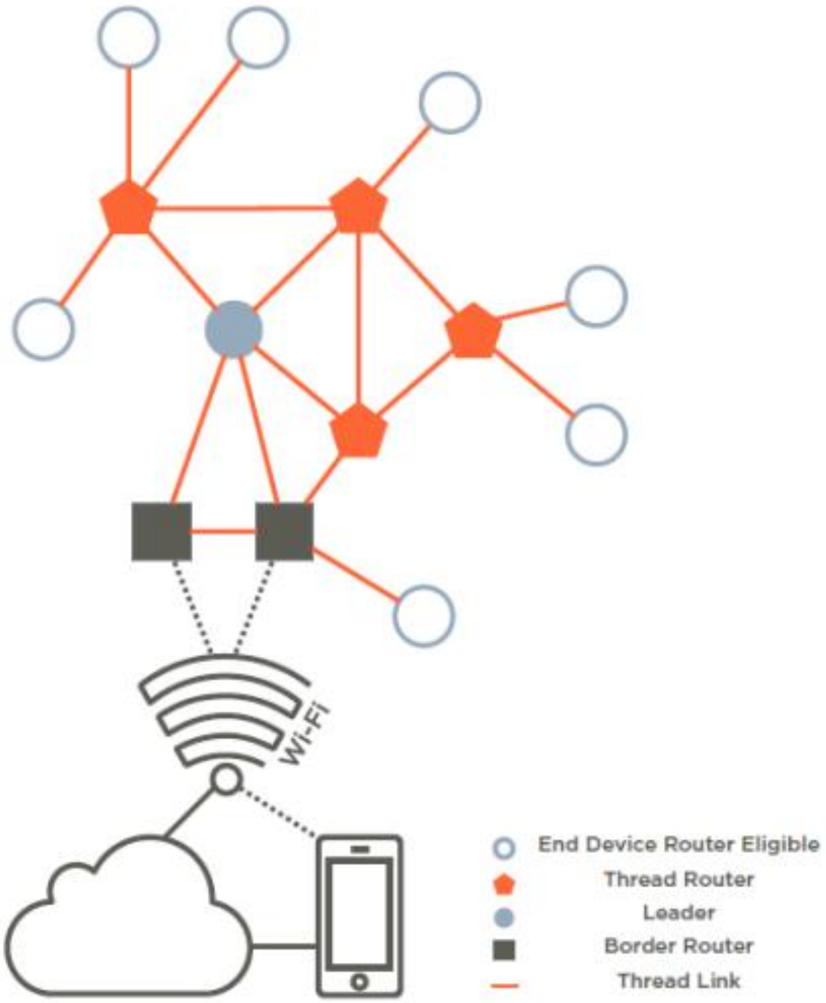
IP-Based: Simplified IP Bridging



1. Simplified bridging between mesh network and Internet
2. Enables end-to-end IP security

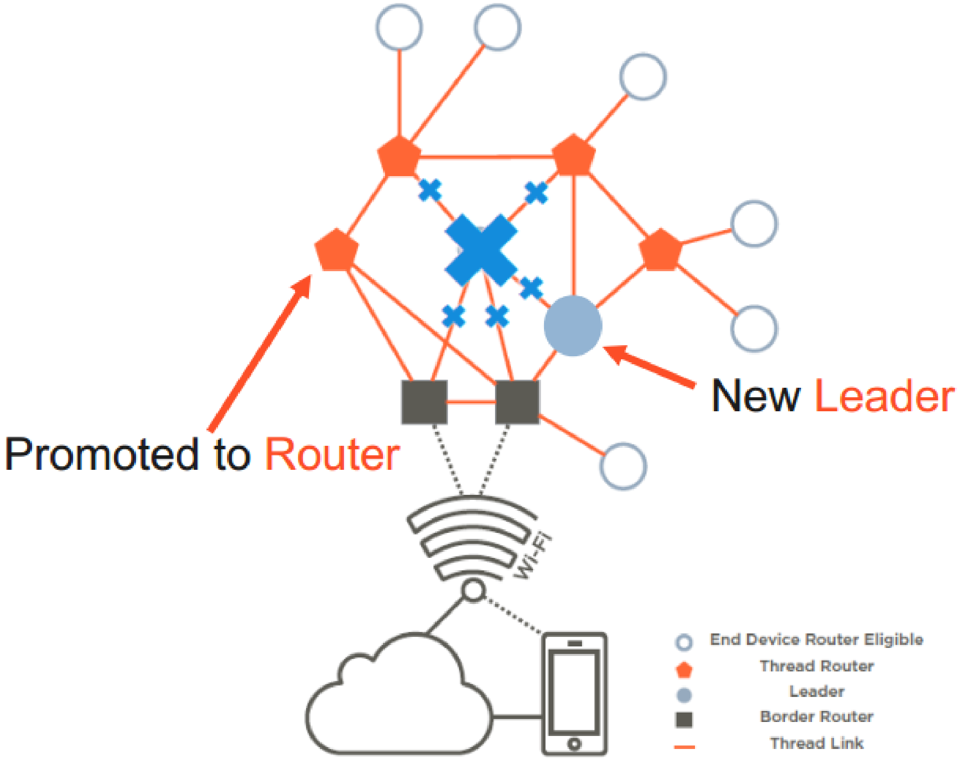
Simplified Device Types

- ❑ Devices join as Router Eligible or End Device
- ❑ Router Eligible: Can become Routers if needed
  - ❖ First router on network becomes Leader
  - ❖ Leader: Makes decisions withi network
- ❑ End Devices: Route through parent
- ❑ Can be "sleepy" to reduce power consumption



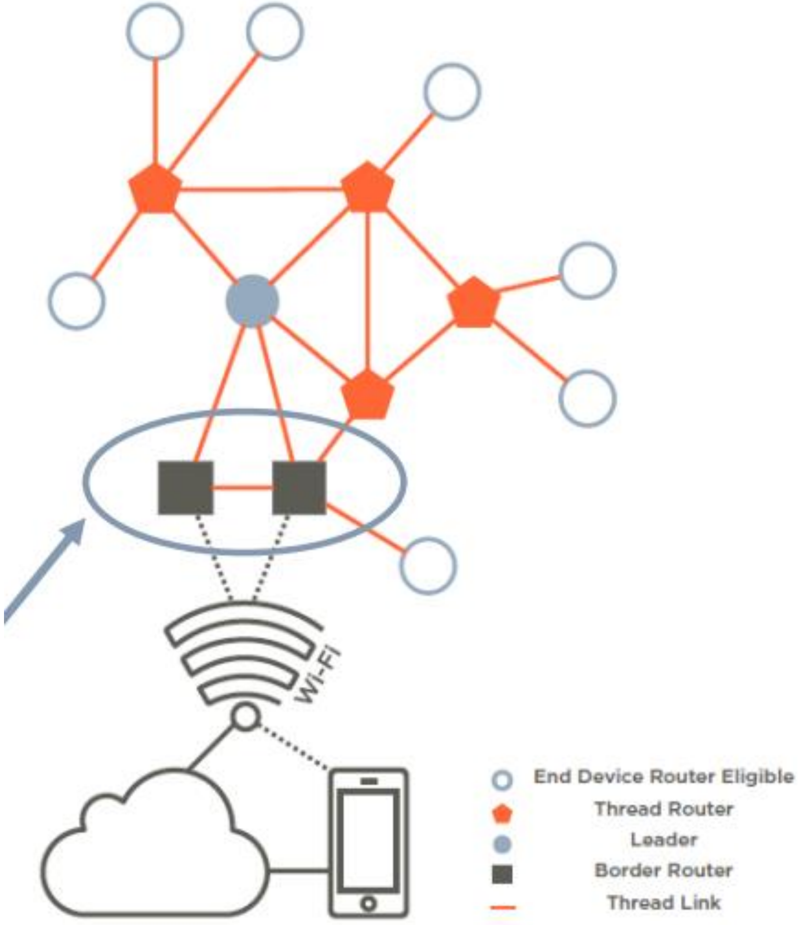
Robust: No Single Point of Failure

- ❑ Dynamic Leaders
  - ❖ If Leader fails, another Router will become Leader‟
- ❑ Router Promotion
  - ❖ Leader can promote Router Eligible devices to Routers tc improve connectivity if required



Robust: No Single Point of Failure

- ❑ Multiple Border Routers can be used for off network access
  - ❖ Devices operate without Border Router
- ❑ What can be a Border Router?
  - ❖ Anything with 15.4 chip and other physical layer
  - ❖ Home Wi-Fi router
  - ❖ Set top box
  - ❖ Smart Thermostat (15.4 and Wi-Fi)



Security and Commissioning

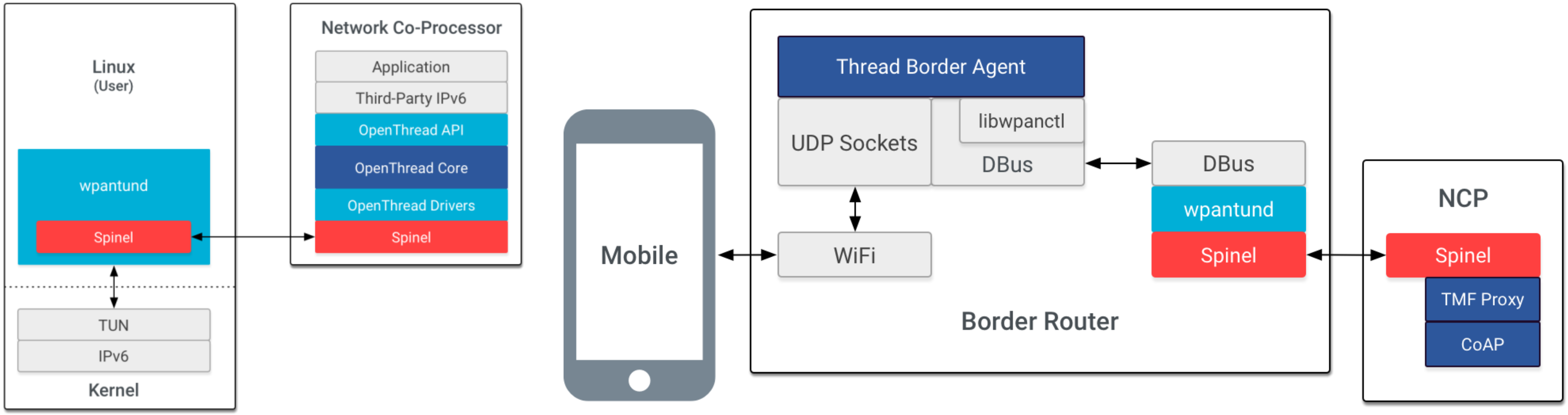
- ❑ Simple Commissioning
  - ❖ User authorizes devices onto the network using smart phone, computer
  - ❖ GUI rich device within network can be used to authorize devices
- ❑ Security session established between new device and commissioning device to authenticate and provide credentials
- ❑ Once commissioning session is done – device attaches to network
- ❑ MAC security used for all messages
- ❑ Application level security used based on device
- ❑ requirement

Low Operation Mode

- ❑Sleeping devices poll parents for messages (or remote device if application configured)
- ❑Sleeping device not required to check in allow lower power operation
- ❑Parents hold messages for sleeping devices
- ❑Sleeping device automatically switches parent if it loses connectivity

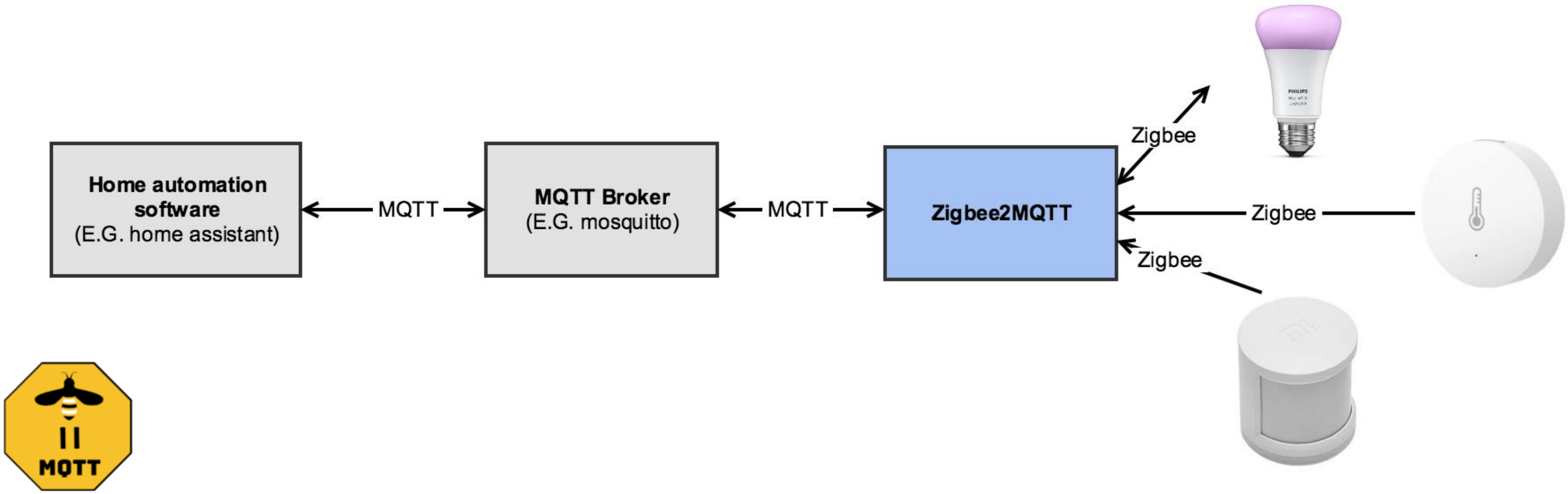
Thread: Implementation

- ❑ OpenThread: https://openthread.io
- ❑ Support simulation
- ❑ Host and NCP
- ❑ Border Router
- ❑ Hardware: CC2538, nRF52840



ZigBee2MQTT: Implementation

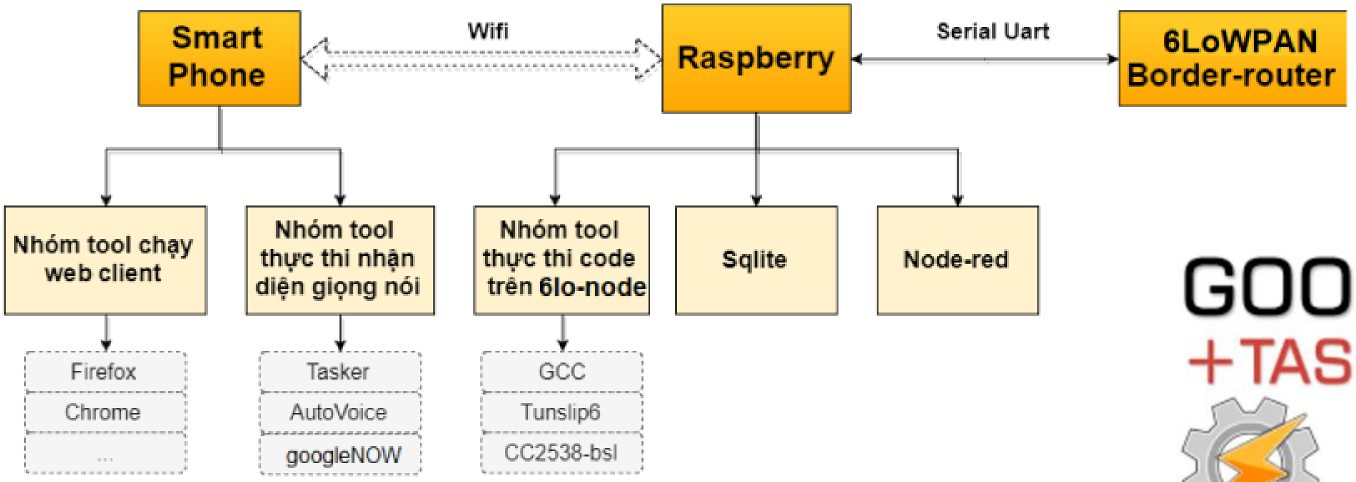
- ❑ Ref: https://www.zigbee2mqtt.io/
- ❑ HW supported: CC2530/ CC2530, CC2538, CC2650/ CC2652
- ❑ supported Homa automation: e.g. Home Assistant

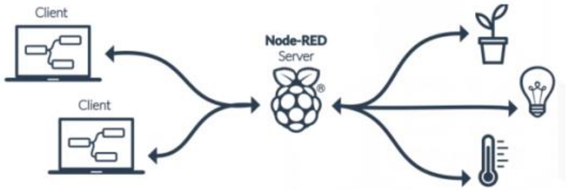


Smart Home protocols

Smart Home Alliances	Z	Z-WAVE PLUS	THREAD GROUP	Wi Fi ALLIANCE	Bluetooth SPECIAL INTEREST GROUP
	Zigbee	Z-Wave	Thread	802.11ah/ax	Bluetooth 5/Mesh
Year of creation	1998	1999	2016	2017	2017
Frequency Band	2.4GHz	908MHz	2.4GHz	900MHz/2.4GHz	2.4GHz
PHY/MAC Radio	IEEE 802.15.14	ITU-TG.9959	IEEE 802.15.4	802.11.ah	LE 1M/2M/Coded
Network/Transport Layer	Zigbee PRO	Proprietary	UDP/ IP - IPv6	IP Compatible	Proprietary
Application Layer	Proprietary (Dotdot)	Proprietary	Agnostic	Proprietary	Proprietary
Architecture	Mesh	Mesh	Mesh	Star/Mesh	Mesh
IP Based	no	no	yes	yes	no
Bandwidth	250Kbps	9.6/40Kbps	250Kbps	>100Mbps	1-5Mbps
Range	10m	30m	30m	30m (indoor)	10m
Target Markets	Smart home	Smart Home	Smart Home	Smart Home/ Factory	Smart Home/Factory
Radio Chipset vendors ecosystem	Silicon Labs, Qorvo, NXP, TI. Combo ZigBee/BLE: Qualcomm, Nordic, redpine	Single Source: Silicon Labs	Silicon Labs, Qorvo, NXP, TI, Qualcomm, Nordic, redpine	Lots of vendors offer a combo chip WiFi/BLE	Lots of vendors offer a combo chip WiFi/BLE

Human-Machine Interface

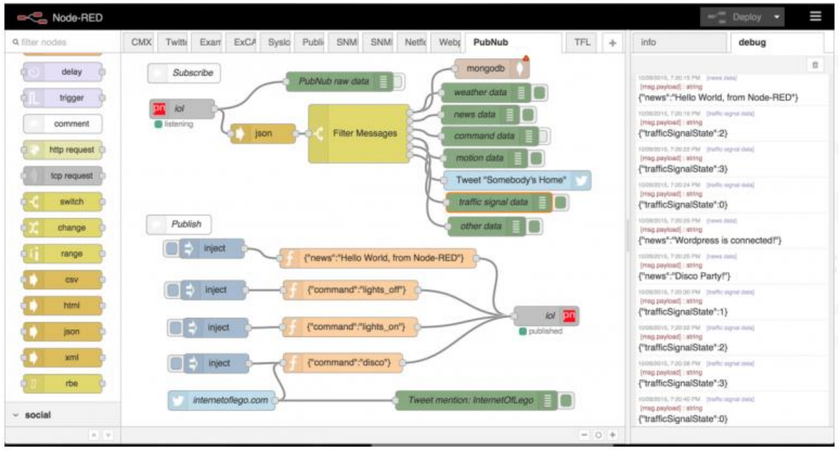




SQL-lite

TASKER

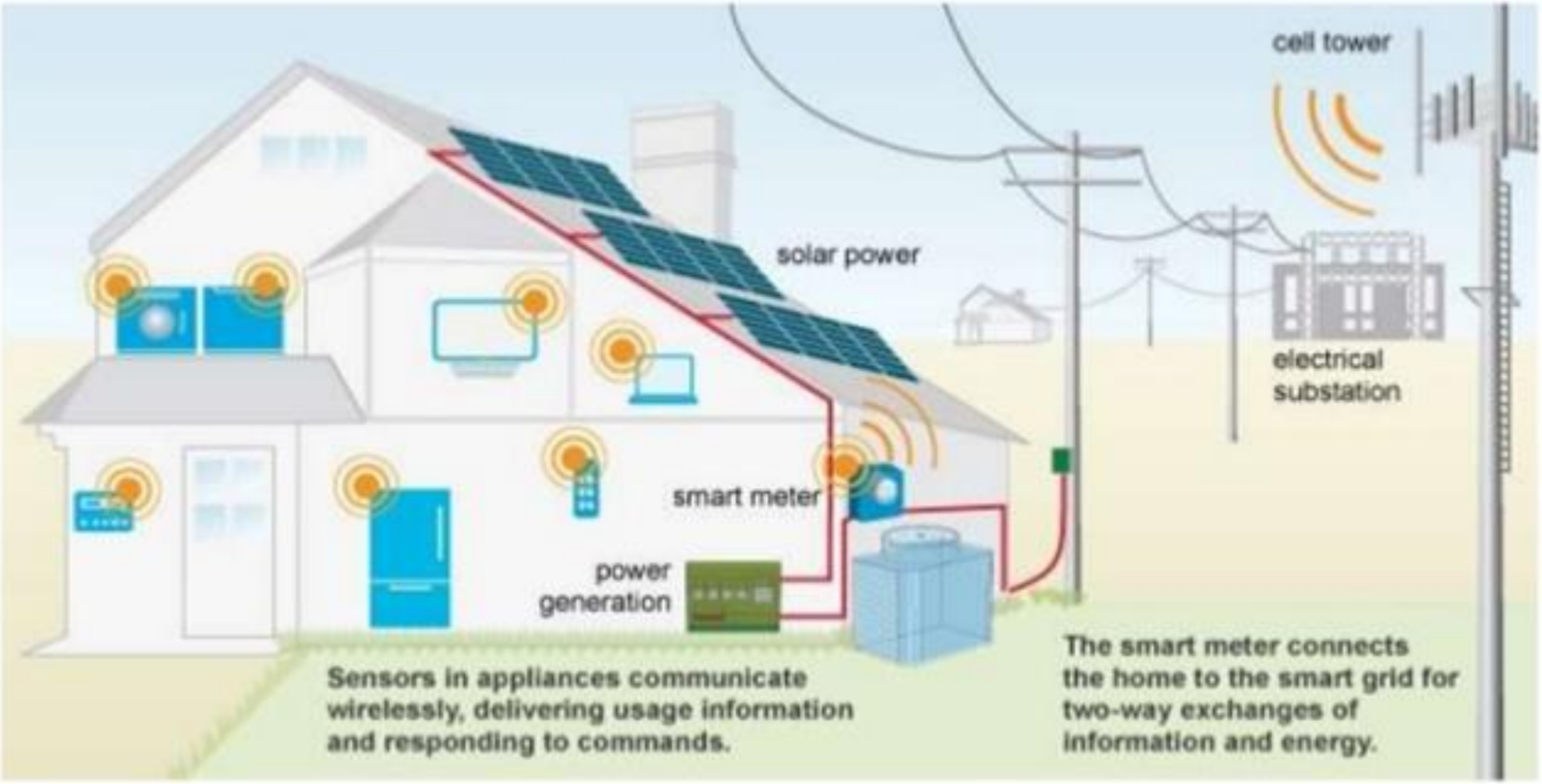
AUTO-VOICE



```
[msg.payload] : string
{"news":"Hello World, from Node-RED"}
[msg.payload] : string
{"trafficSignalState":2}
[msg.payload] : string
{"trafficSignalState":3}
[msg.payload] : string
{"trafficSignalState":0}
[msg.payload] : string
{"news":"Wordpress is connected!"}
[msg.payload] : string
{"news":"Disco Party!"}
[msg.payload] : string
{"trafficSignalState":1}
[msg.payload] : string
{"trafficSignalState":2}
[msg.payload] : string
{"trafficSignalState":3}
[msg.payload] : string
{"trafficSignalState":0}
```

Home Area Network

Home Area Network (HAN) connects thermostats, refrigerators and other electrical devices in a Smart Home to an energy management system.

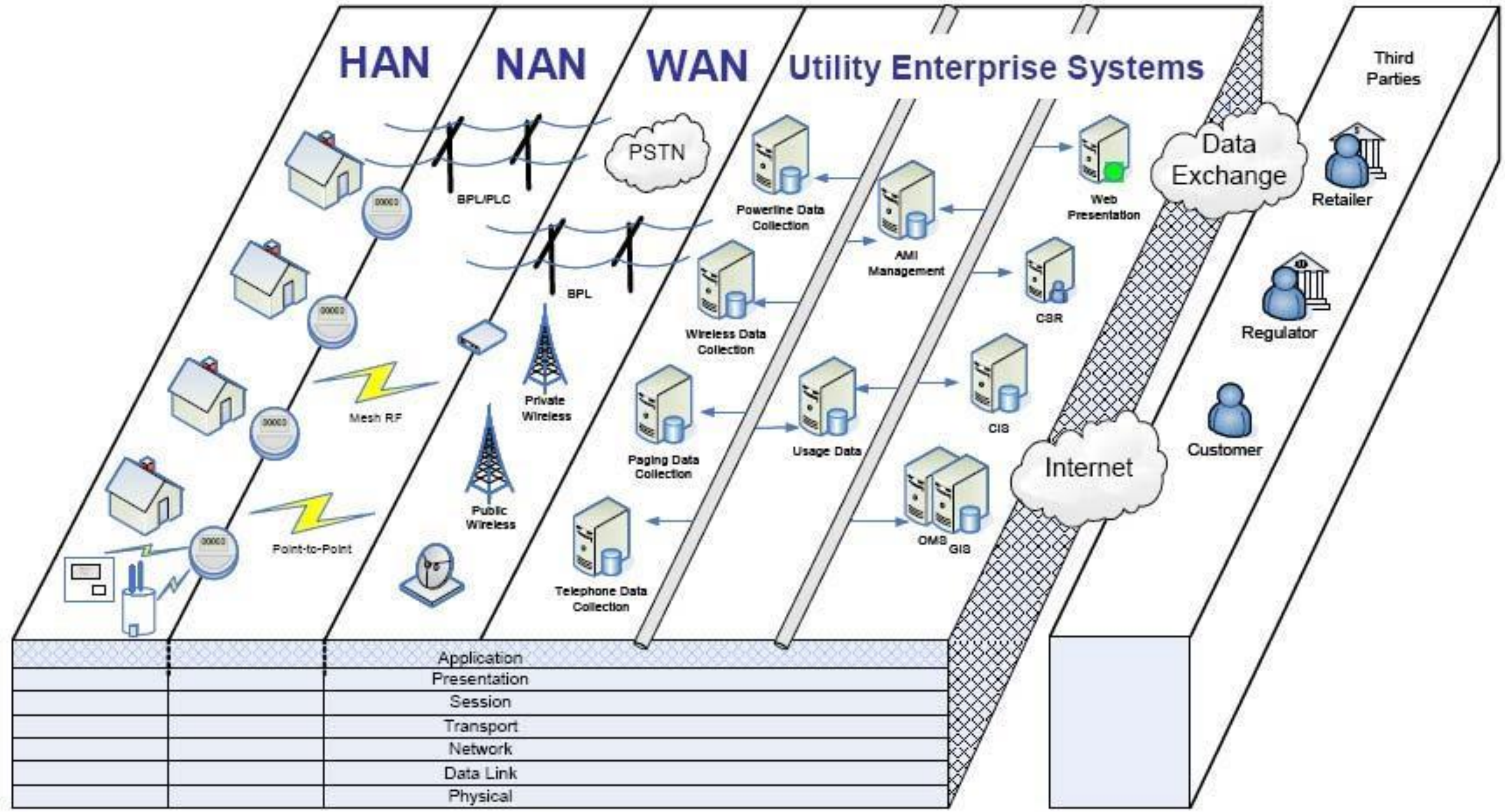


Sensors in appliances communicate wirelessly, delivering usage information and responding to commands.

The smart meter connects the home to the smart grid for two-way exchanges of information and energy.

Source: www.smartgrid portal.org

Network Integration



Neighbor Area Network (NAN)

- ❑ Gathers a **huge volume of various types of data** and distributes **important control signals** from and to **millions of devices** installed at customer premises

- ❑ **The most critical segment** that connects utilities and customers in order to enable primarily important SG applications

Smart Grid Communications Networks: Wireless Technologies, Protocols, Issues and Standards, ECE Dept., McGill University, Montreal, Canada

Characteristics of NAN

- ❑ To support a huge number of devices that distribute over large geographical areas
- ❑ Must be scalable to network size and self-configurable
- ❑ Heterogeneous and location-aware
- ❑ Link condition and thus network connectivity are time-varying due to multipath fading, surrounding environment, harsh weather, electricity power outage, etc.

Characteristics of NAN

- ❑ Deployed outdoor, thus must be robust to node and link failures
- ❑ Carries different types of traffic that require a wide range of QoSs
- ❑ Needs QoS awareness and provisioning
- ❑ Mainly supports Multi-Point-to-Point (MP2P) and Point-to-Multiple-Point (P2MP) traffic
- ❑ Very vulnerable to privacy and security

Other topics

- ❑ 802.15.4 Link Layer Security
- ❑ Secured CoAP (CoAPs)
- ❑ LWM2M with DTLS
- ❑ IPSO Smart Object
- ❑ TSCH and 6TiSCH (IPv6 over TSCH)
- ❑ 6TiSCH Operation Sublayer (6top)
- ❑ IPv6 over BLE
- ❑ IPv6 Multicast
- ❑ Contiki-NG (Next Generation)
- ❑ Mesh-LoRa Networks
- ❑ Wi-SUN