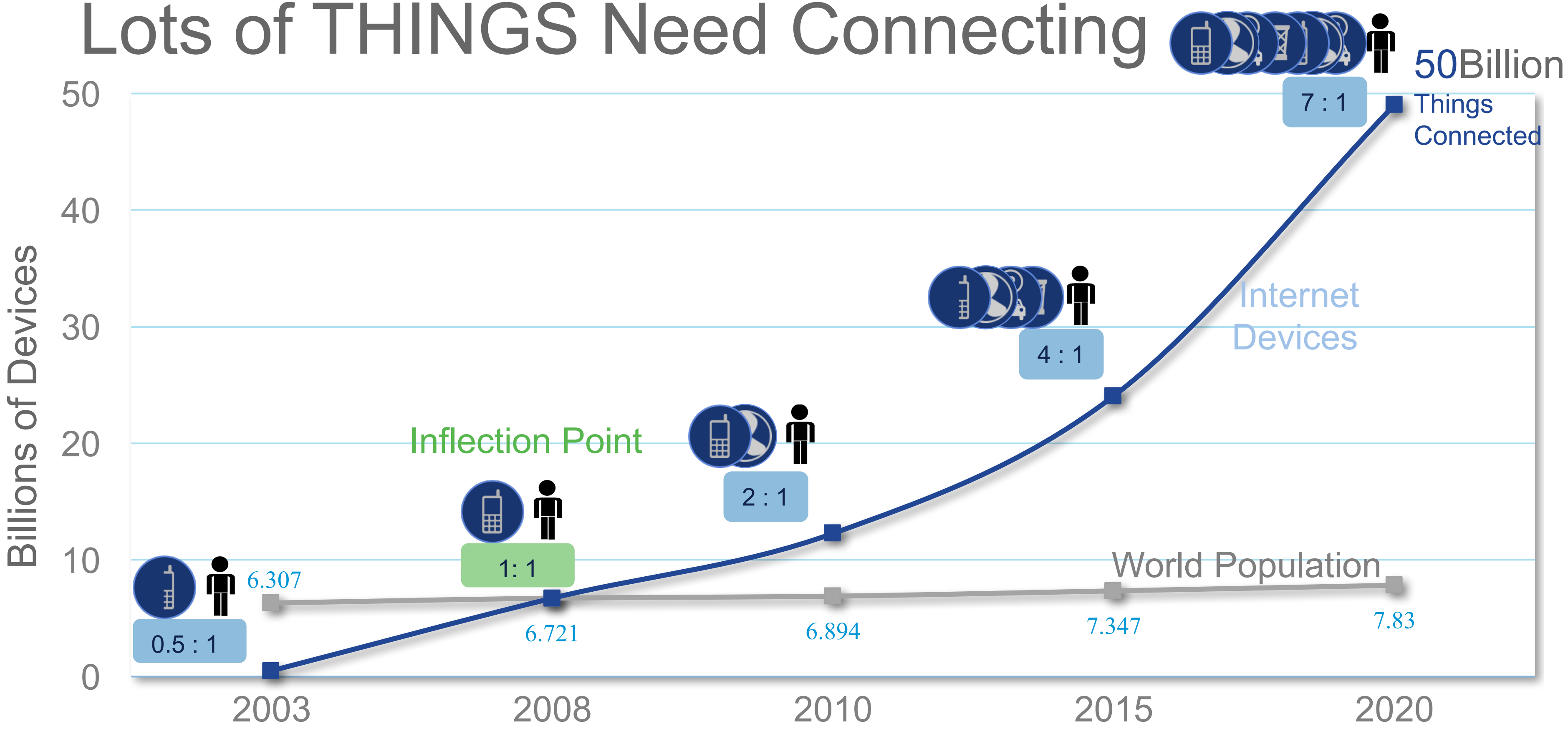
LPWA – Giving a Voice to Things

Jeff Apcar, Distinguished Services Engineer
APRICOT 2017

Lots of THINGS Need Connecting

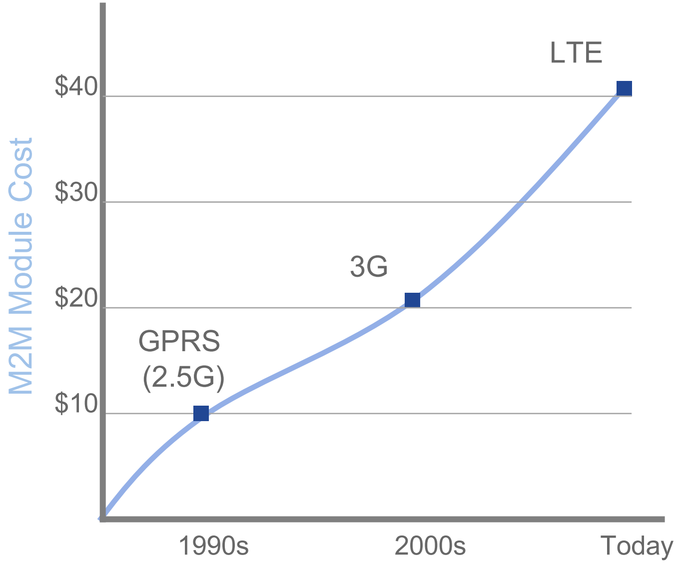


Source: Cisco IBSG projections, UN Economic & Social Affairs http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf

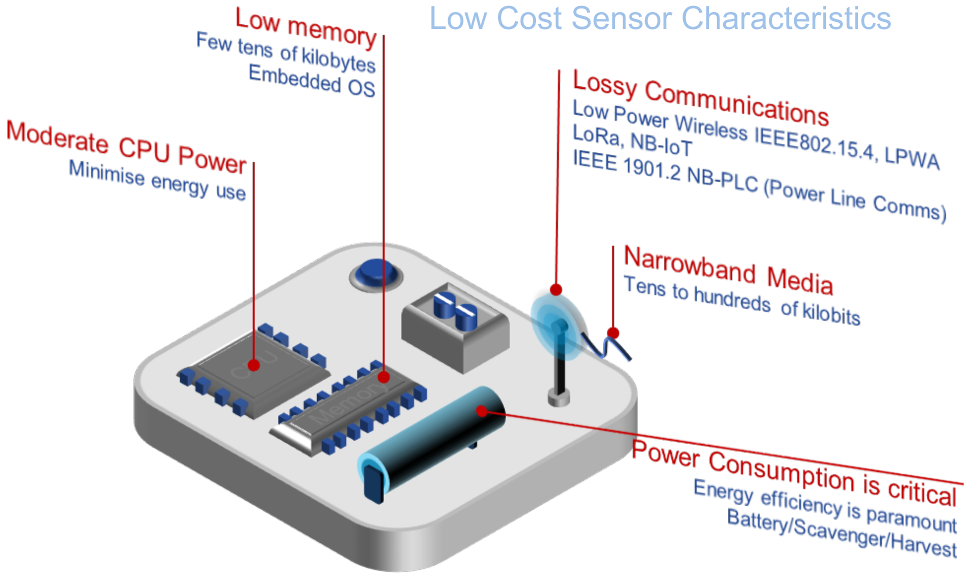
3G/4G, WiFi Not Suitable For “Cheap” Things

Cellular networks generally connect expensive things

- In terms of energy available and data usage e.g., cars
- Bulk of existing cellular M2M use embedded GPRS modules



Low Cost Sensor Characteristics



Examples Constrained "Cheap" Things

Fire Detection
CO_2 Temp, Humidity, Infrared

Smart Parking
Magnetic Field Sensor

Snow Depth
UltraSound Sensor

River Levels
Level sensor, Ultrasound

Street Lighting
Light Sensors, Relays

Urban Air Pollution
NO_2CO_2 Gas Sensors

Chemical Leakage
PH Monitor, Oxygen levels

Earthquake Warning
Accelerometer

LPWA

A new category of low cost network for low powered devices across a wide area

“The IoT contains devices that allow us to sense and control the physical world by making objects smarter and connecting them through an intelligent network”

Connecting a new generation smart objects/devices poses challenges: Pervasive connectivity, Power Availability and Low Cost

This requires a new generation of network to connect the low-powered things: Low Power Wide Area Networks

Low Power Wide Area Networks (LPWA)

6

What Is An LPWA?

Low Data Throughput

~200 Bytes per day, higher instantaneous

Small packets (12 to 255 Bytes), mostly uplink traffic

Low Power

Devices last several years on battery

Long Range

0-5kms (dense urban), 10-65kms open area

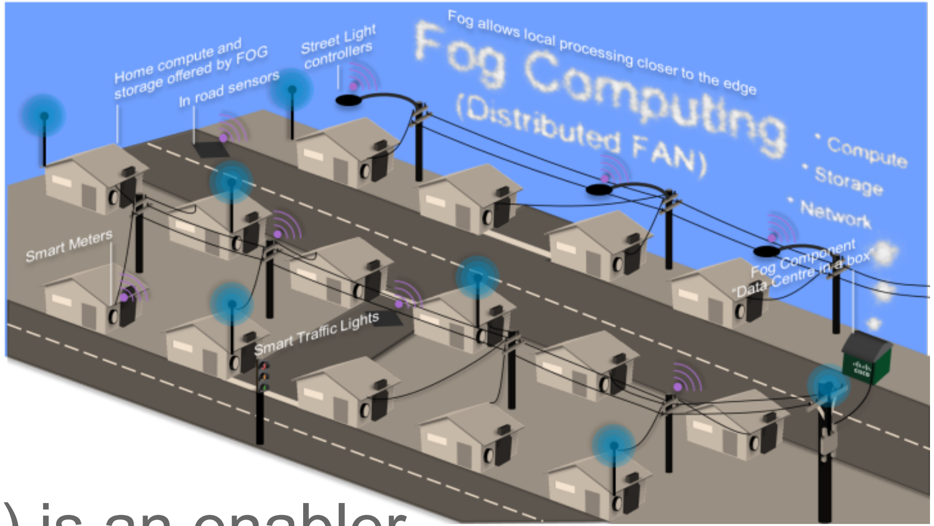
Several LPWA technologies (Licensed vs Unlicensed Spectrum)

LoRa, SIGFOX, Weightless, On-Ramp, NB-IoT, EC-GPRS, eMTC

Trend: Many SP Are Investigating LPWA

Innovative IoT Business Models require different networks

- How to connect millions of devices across a cityscape
- Connect wireless sensors
- Highly constrained devices

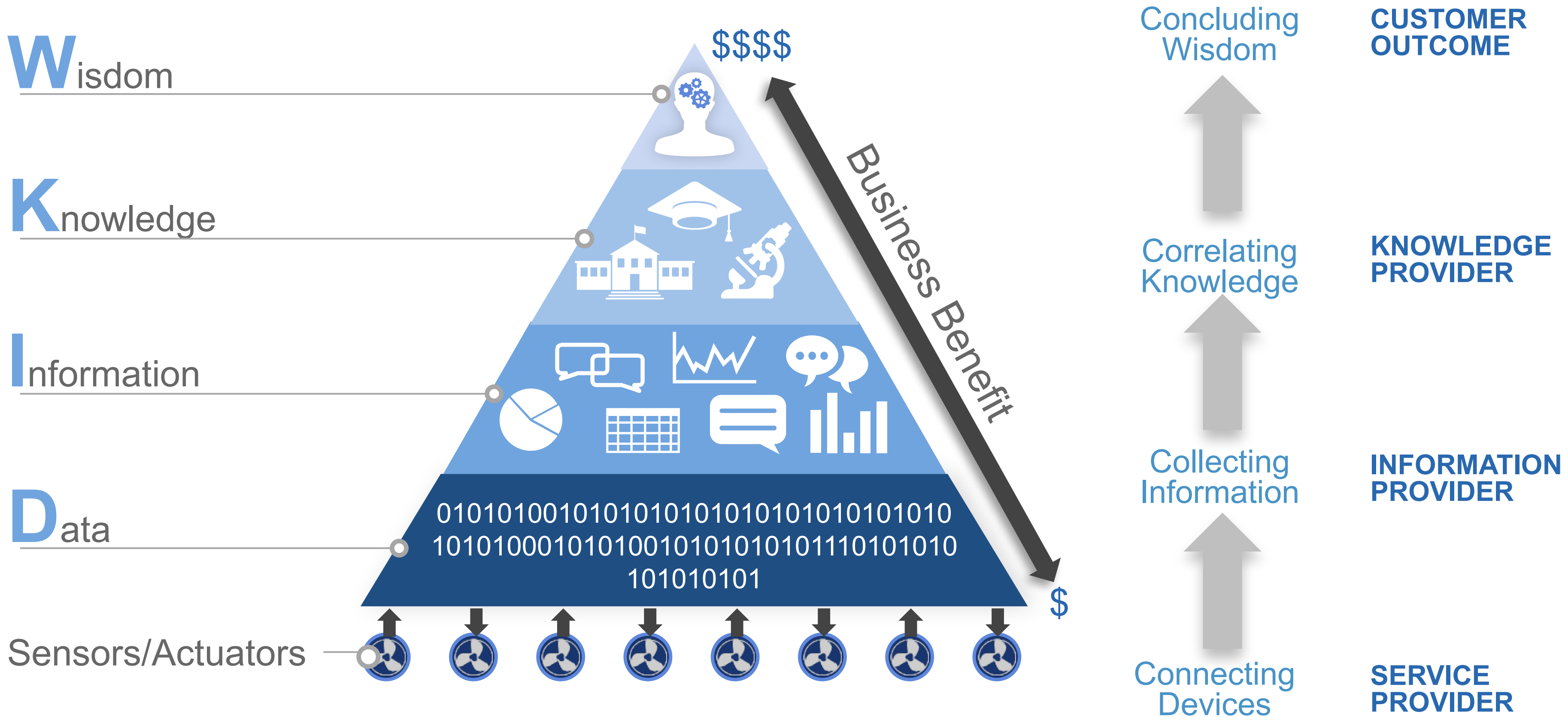


Become Knowledge Provider

- Revenue Models?
- Use Cases?
- Data Collection?

Low Power Wide Area (LPWA) is an enabler

LPWA – Enables Innovation & Knowledge Providers



LPWA Device Characteristics & Typical Values

Spectrum
Unlicensed/Licensed, < 1GHz

Data Rate
Low, <100kb/s

Range
10s Km, No Relay

Latency
Low-High, Up to minutes

Objects
Many, 1000+

Battery Life
Long Life, Up to 10 years

Data Volume
Small, tens kB per day

Module Cost
Low, < $5

Service Cost
Low, < $1-3 pm

Installation Cost
Low, < $5-$10

Current IoT Wireless vs LPWA

Long Range

2G | 3G | 4G | 5G

WiFi .p | WiFi .a | WiFi .ac | WiFi .ah

Medium Range

802.15.4 g/e | 6LowPan | W-HART | Mesh

6Tisch | Mesh | ZigBee | ISA 100.11a

Short Range

B-LE

High — Low

Cost
Licensed vs unlicensed
Frequency bands, power requirements,
Provisioning, i.e. SIM card

TX Power
Standby Power
Module Cost

Signal penetration
GHz vs sub-GHz
Frequency bands
Bandwidth capacity

Use cases applicability
Indoor vs Outdoor
Mobile v Fixed

Low — High

Long Range

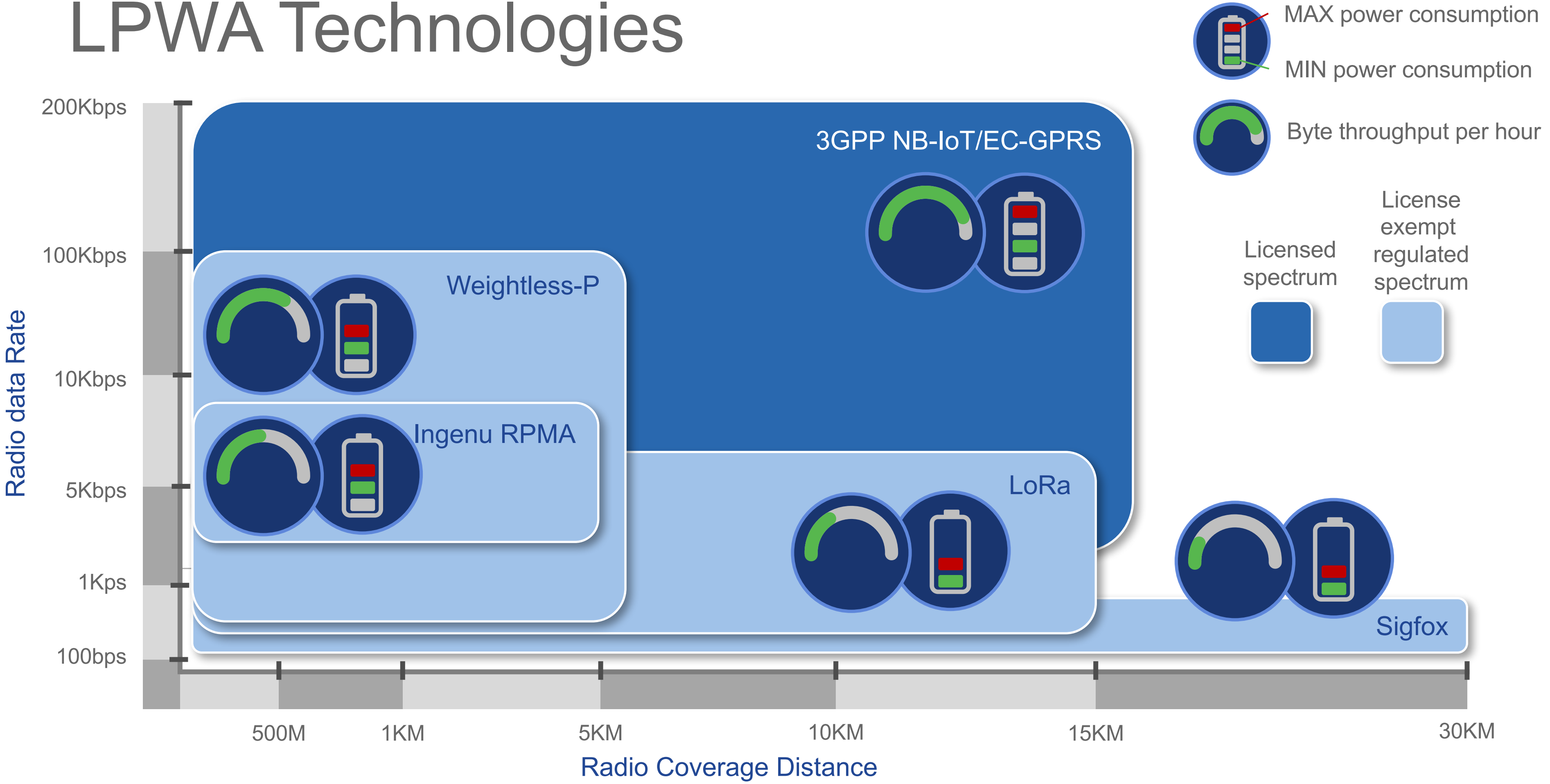
LoRa | SigFox | Weight-less | 3GPP EC-GPRS | 3GPP CAT-NB1

Broad Use Cases support

Utilities, Industrial (process and discrete manufacturing), Smart Cities (parking, environment,…), Agriculture and rural, Transportations, horizontal/consumers, Assets management

- Power consumption
- Massively scattered deployment
- Low data rate applications
- Open technology
- Eco-system for solution

LPWA Technologies



3GPP IoT Standards Licensed Spectrum

LTE MTC (3GPP R12)
Creation of CAT-0

3GPP LPWA Standards

Standard	UE Category	Description
LTE-M/eMTC (3GPP R13)	UE CAT-M1 (1.4Mhz)	Same LTE air interface Compatible with existing infrastructure Connected cars, telematics…
NB-IOT (3GPP R13)	UE CAT-NB1 (200Khz)	New air interface, Clean slate technology Uses LTE infrastructure (SGW/PGW) Power & parking meters, sensors…
EC-GSM-IOT		Based on eGPRS Software upgrade Smart metering, agricultural sensors…

CIoT
Cellular IoT Study
Coexistence with GSM, UMTS, LTE

Bandwidth & Power Consumption
Higher
Lower

LPWA Use Cases

Some Approaches to Address LP Wireless

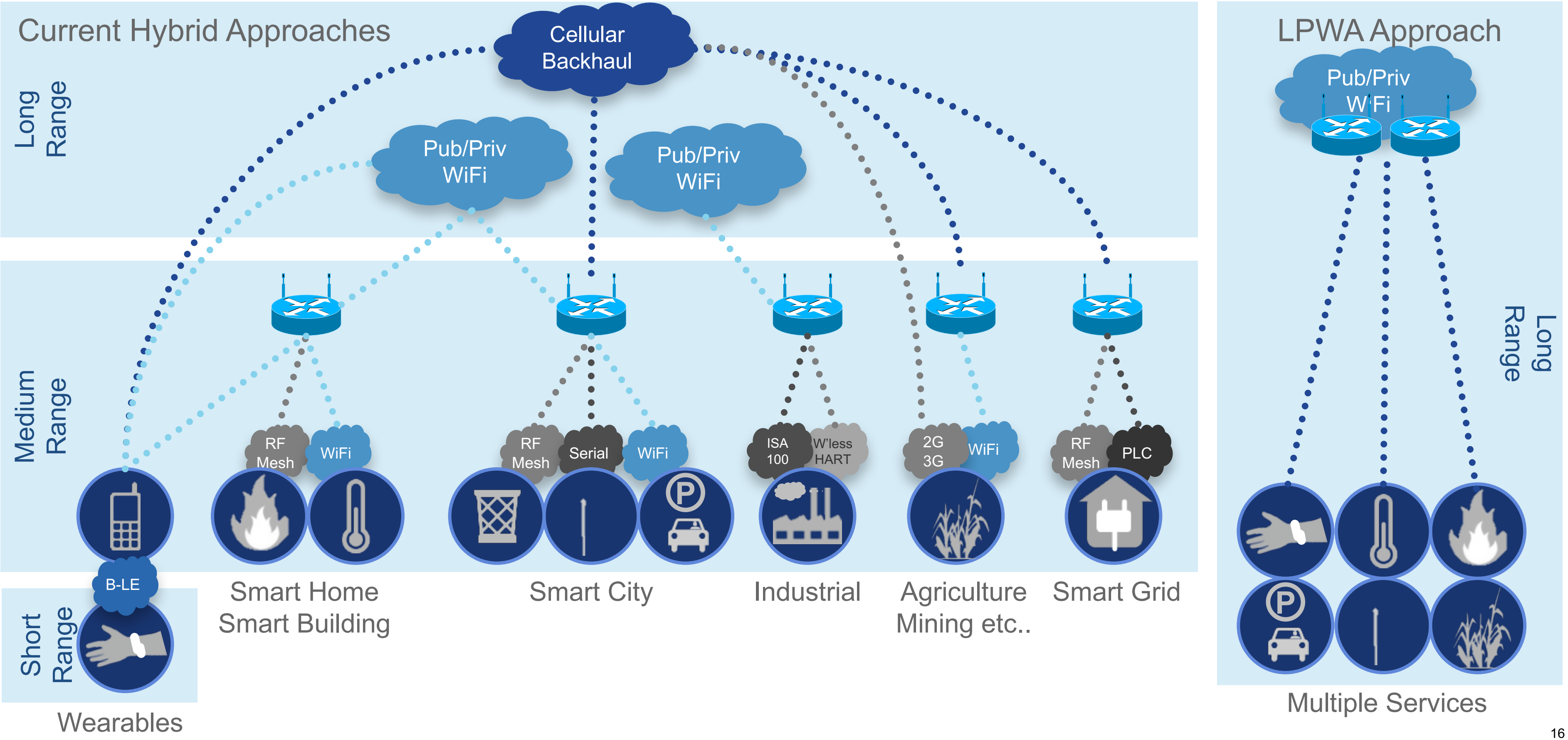
Technology	Topology	Outdoor	Use Case	Range
802.15.4g/6lowpan	Mesh	Yes	Smartgrid, Metering, Oil&Gas	Medium
WirelessHart	Mesh	No	Industrial	Short
Zigbee/ZigbeePro	Mesh	No	Smart Home/Building	Short
ISA100	Mesh	No	Industrial	Short
Proprietary 802.15.4	Point-to-Multipoint	Yes	Smart Parking, Traffic	Short
Enocean	Mesh	No	Building	Short
StarSense RF	Mesh	Yes	Smart Lighting	Short
Z-Wave	Mesh	No	Smart Home	Short

In most cases the technology is tailored to a narrow area/use case and indoor, with some attempts to support other use cases.

To cover a wide area a hybrid approach is required.

Hybrid LPWA: low power wireless short range and cellular/wire backhaul

Hybrid LPWA Approach



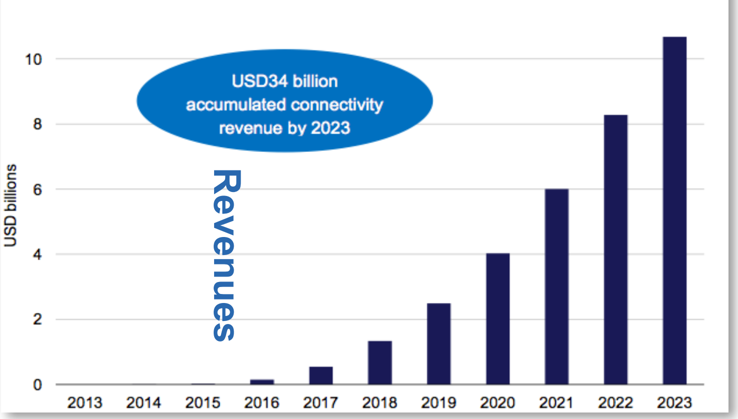
LPWA Market Research

TAM - 2023	Complementary Technology	Impacts Many Vertical Markets	Sustainable Business Models
• Will reach 3 Billion Connections • $10B Connectivity Revenues • $10B in Device and Apps sales • ??B in Knowledge Sales	• Complements Cellular – only 4% overlap • LPWA will create new market opportunities that can't be addressed with Cellular, LAN	• Suitable for any vertical with low power, low-bandwidth requirements • Immediate use cases in Smart Cities, Utilities, Agriculture • Many use cases to be discovered	• Low/Predictable lifetime costs help reduce barriers to adoption, drive market growth • Bundling infrastructure to services to enable sustainable business

Source: analysys mason

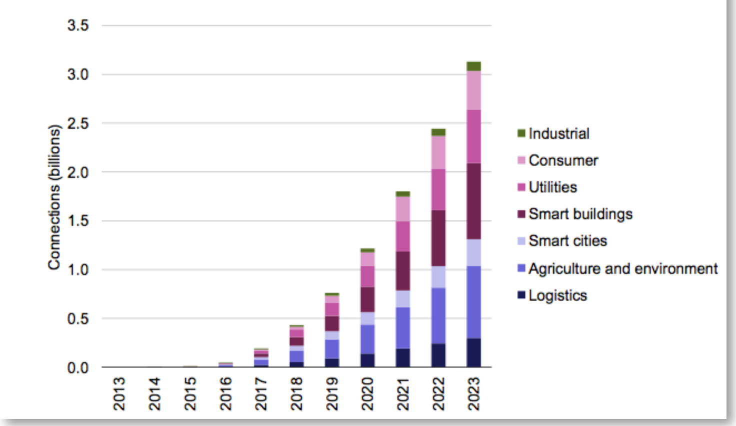
LPWA Connection TAM By 2023

3: Forecast of connectivity revenues from LPWA services [Source: Analysys Mason, 2014]



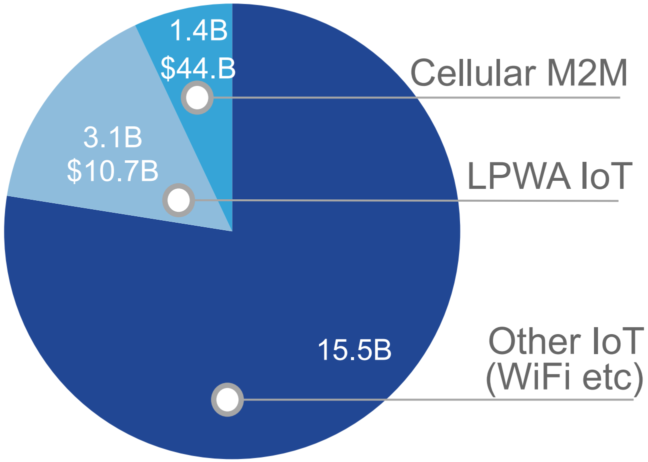
Revenues

Figure 2: Forecast for LPWA connections [Source: Analysys Mason, 2014]



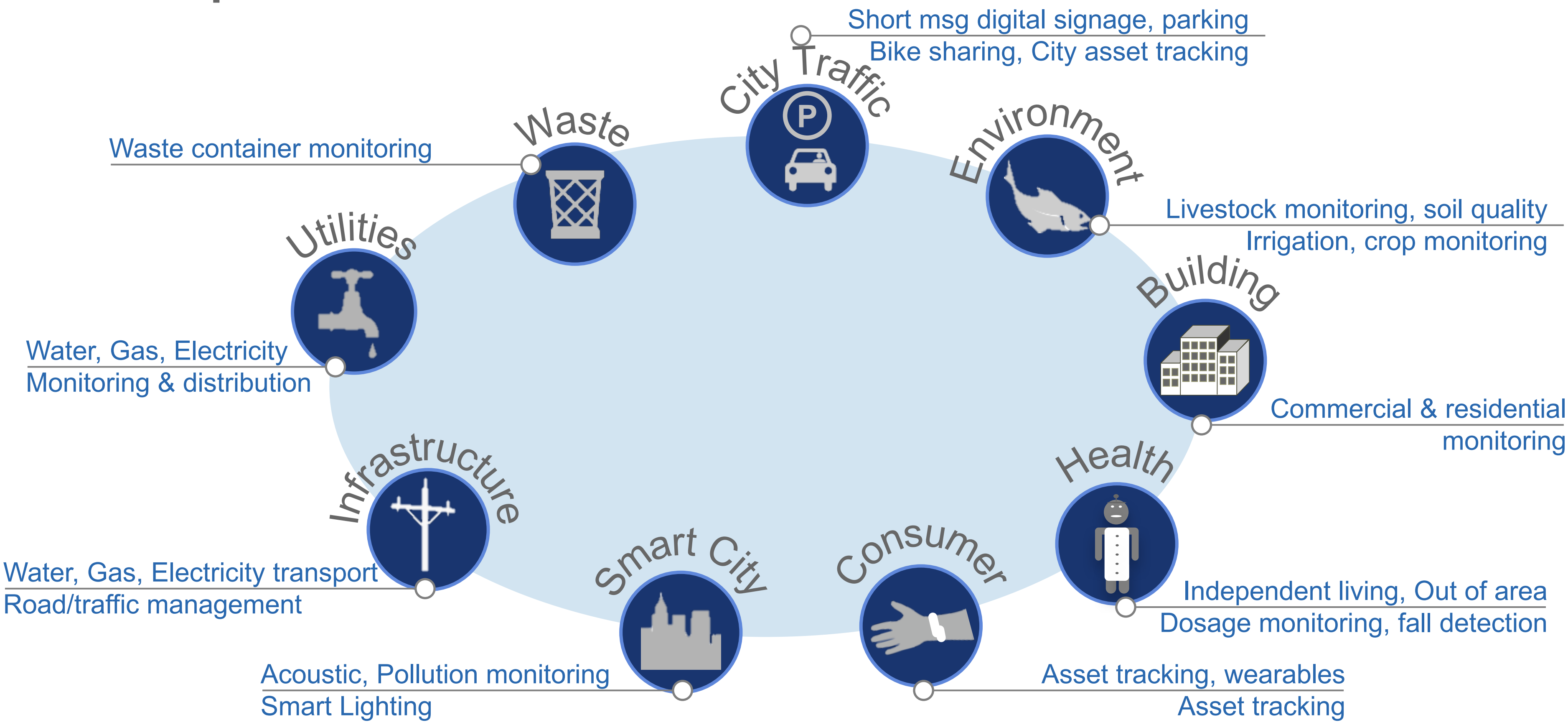
Connections

Connections
Revenue



Source: analysys mason

Sample Use Cases



LPWA Use Cases (Part 1)

Domain	Sub-domain	Use case
Utilities	Water & Gas distribution	Collect 3-4 times daily water and gas usage data
	Water Network monitoring	Collect 3-4 times daily water flow, pressure data
	Electricity distribution	Collect daily or hourly electricity usage data
Infrastructure Networks	Water & Gas transportation	Water and Gas infrastructure network surveillance (alarm, metering parameters)
	Electricity transportation	Electricity transport status monitoring and command/control
	Road / traffic management	Traffic light control, traffic level monitoring, emergency gate status control, digital signage status and updates
Environment (City)	Acoustic Noise Monitoring	Collect data on Levels, location
	Humidity, Temperature	Collect data on humidity, temperature, rain, luminosity
	Air pollution monitoring and alerting	Collect data on different gas CO2, CO, NO, SO

LPWA Use Cases (Part 2)

Domain	Sub-domain	Use case
City Traffic/Mobility	Parking	Collect data on parking sensors
	Traffic	Collect Data on traffic sensors
	Bike Sharing/Bike	Bike & rack availability, status monitoring, location
	City Asset tracking	Collect data on asset: e.g. manhole
	Digital Signage	Display short message on Digital Signage
Waste Management	Waste Container monitoring	Collect data on waste containers: level, temperature
Consumer Services	Pet tracking	Monitor location of pets
	Personal asset tracking	Monitor location/usage of personal items
	Wearables	Collect data from wearables

LPWA Use Cases (3/3)

Domain	Sub-domain	Use case
 Environment (Country side)	Soil quality monitoring	Acidity, humidity, nitrogen , landslide prevention,
	Livestock surveillance	Geolocation, health status, wolf prevention (accelerometer), geofencing, teleguidance
	Cattle & pet monitoring	Geolocation
	Climate	Rain, wind, temperature, humidity, (pressure)
	Irrigation	Leakage
 Building Management	Residential	Fire detection, smoke, CO, flood, leakage, intrusion, temperature, home automation (blinds etc.)
	Commercial	Fire detection, smoke, CO, flood, leakage, intrusion, temperature, building automation (blinds, heating, air conditioning etc), telesurveillance,
 Healthcare	Patient monitoring	Fall down detection, out of area detection, ECG monitoring, activity monitoring, Alert
	Home Medical Equipment status and usage	Control of correct usage of medical equipment and status

LPWA Architecture

LPWA Architecture Value Proposition

Low Power Wide Area IoT as a Service

Managed IoT using for example, LoRaWAN technology

Shift from CAPEX to OPEX

Low CAPEX deployment, Subscription based revenue model

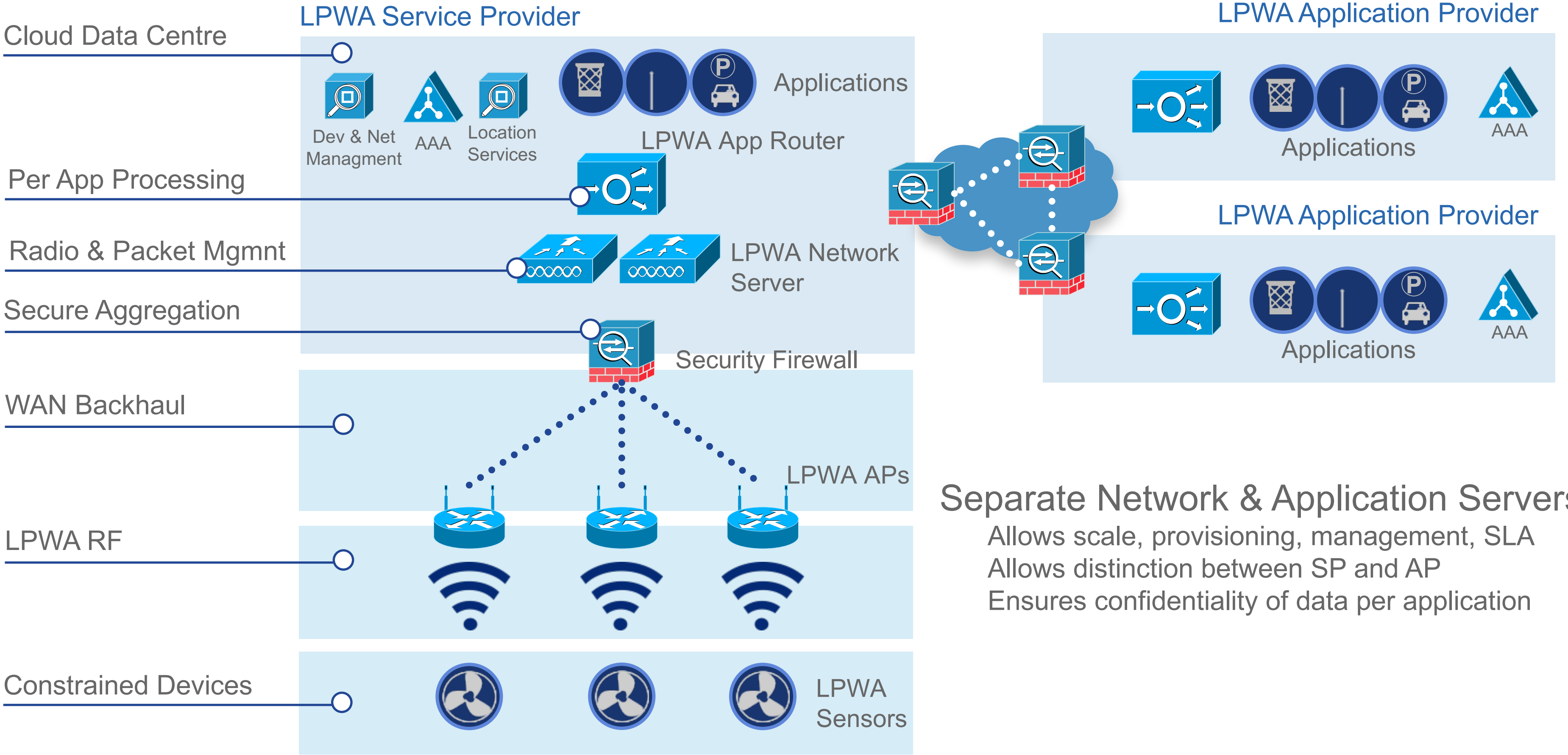
Shift from HW to SW

All intelligence is in the Cloud implemented in software

Application Centric

Application/Data based routing/forwarding and services

Low Power Wide Area Architecture



Separate Network & Application Servers

- Allows scale, provisioning, management, SLA
- Allows distinction between SP and AP
- Ensures confidentiality of data per application

LPWA Architectural Component Summary

Component	Description	Function
LPWA Device	Smart devices (sensor, actuator) with LPWA RF	Support a given use cases/applications: (e.g. metering). Send or receive data to/from LPWA
LPWA AP	LPWA Access Point	LPWA RF interface to devices Packet Relay WAN backhaul: 3G, wifi, fiber, Security
LPWA NS	LPWA Network Server	Terminate MAC layer, Relay Packet to Application server Collect data from multiple AP Security: MAC layer, communication to AP and App Server Application based routing to AP server Collect data for network management, billing, optimization, Location Services
LPWA App Server (optional)	LPWA Application Server or Router (can be collocated with NS)	One per application Relay Packet network server and application Interface with end-to-end application Mapping from IPv6 to NS
WAN Aggregation	WAN aggregation	Secure Tunnel termination Firewall, IDS/IPS, Load-Balancing
AAA and Security	Authorization, Authentication, Accounting	Authenticate users, device, accounting, etc.
Network/Device Management	Network/Device Management	Device provisioning, activation End-to-end Network management

LoRa Physical Layer (PHY)

An LPWA technology

Semtech Long Range (LoRa) PHY

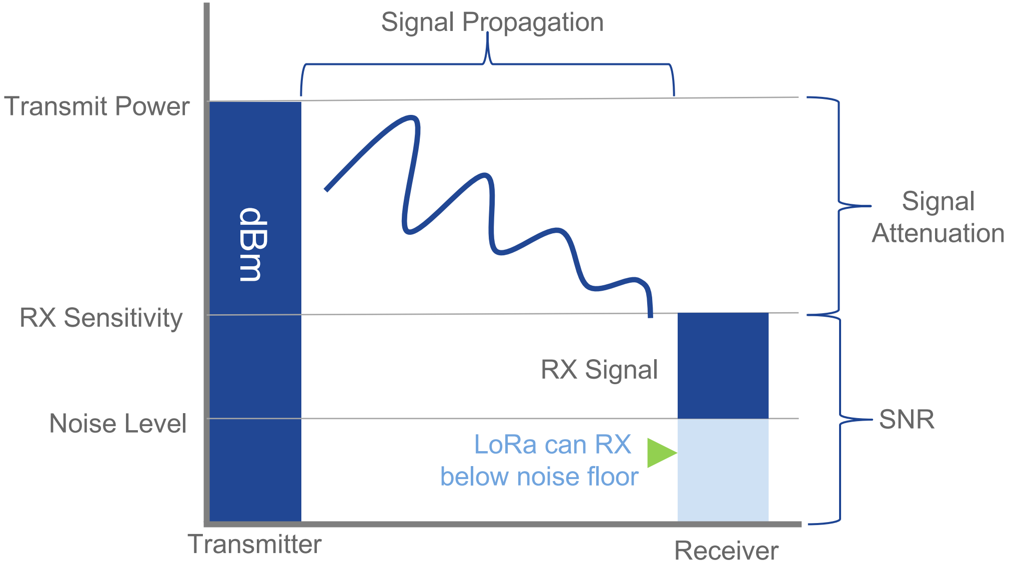
- Secure Sub-Ghz (ISM bands) bi-directional point-to-point wireless link
- Proprietary digital and chirp spread-spectrum modulation with FEC
- Data rates 300bps and 10kbps, 50 kbps via FSK, Packet size up to 250 Bytes
- Can trade data rate against range, up to +20dBm TX power, 168dB link budget
- 10 mA RX current, < 200 nA sleep current
- Allow localization of end devices via a combination of time-of-flight and RSSI
- Capacity can be incrementally increased by reducing cell size
- Physical layer supports ISM bands (915/868/433/169)
  - Upper layer protocols (LoRaWAN) may not necessarily supports all the bands the PHY does

RF Signal Primer

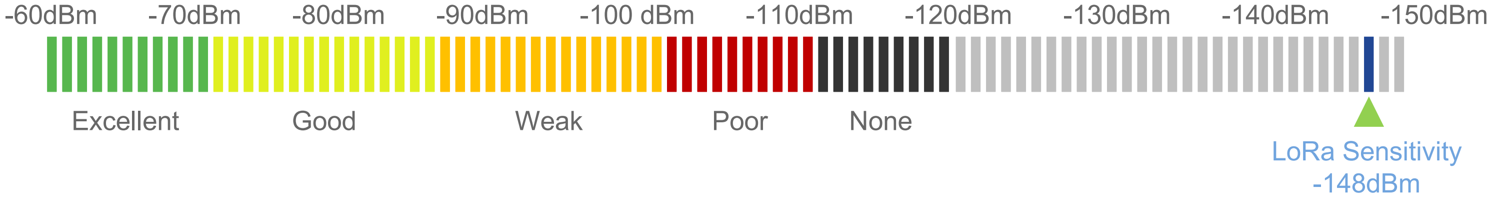
dBm – Decibel-milliwatts

dBm	Power	
0	1 Milliwatt	Bluetooth at 1m
30	1 Watt	GSM Mobile Phone
-127	0.178 FemtoWatt	GPS Satellite Signal

SNR – Signal to Noise ratio

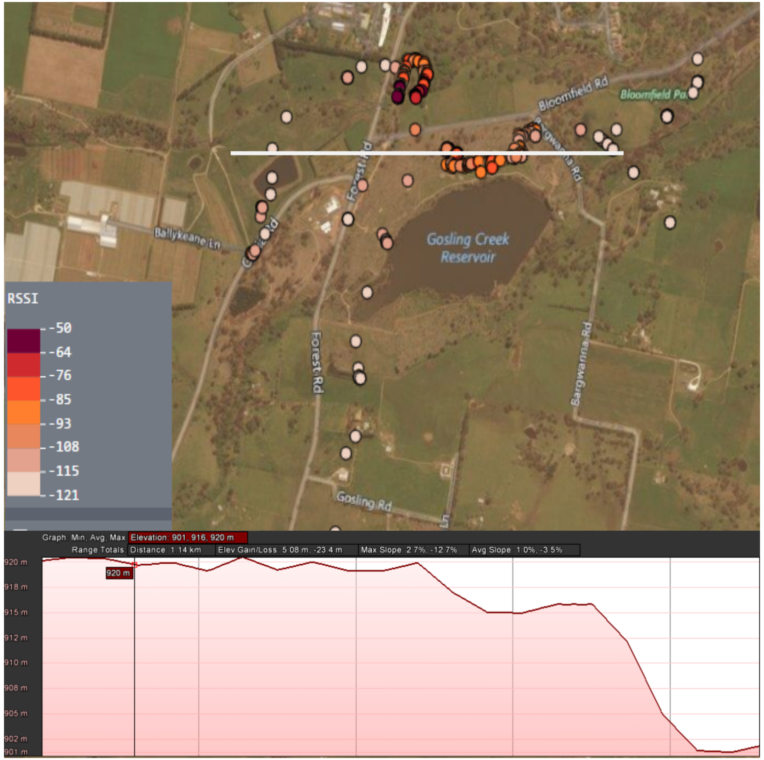


RSSI – Received Strength Signal Indicator

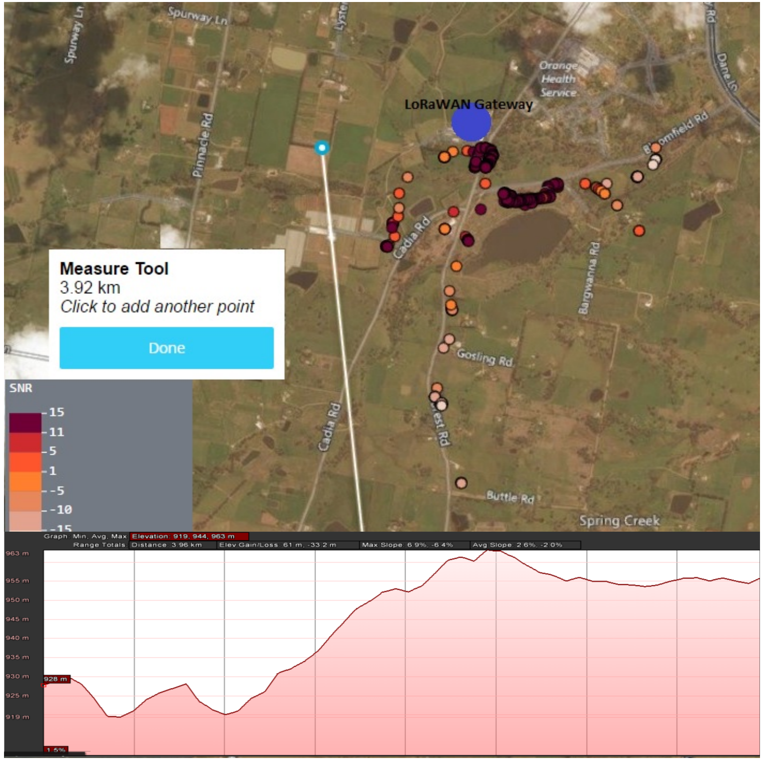


Rural Drive Test (Australian Countryside)

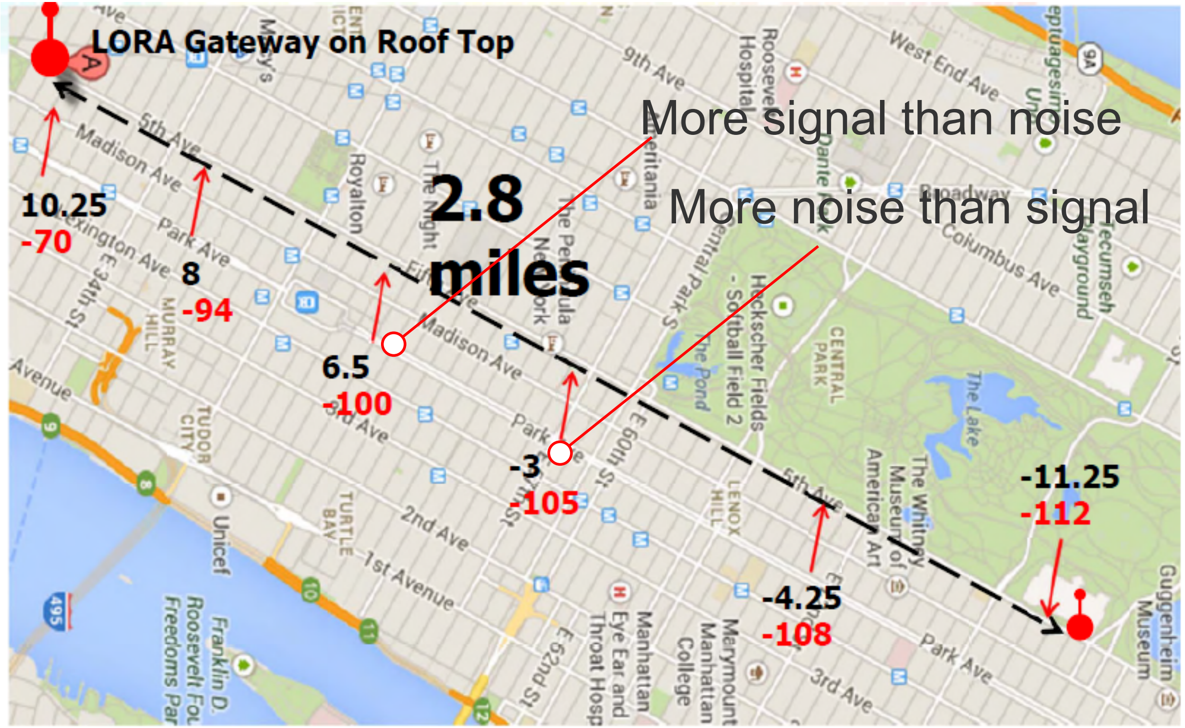
RSSI (5cm TX Antenna, +6dB gain RX antenna)



SNR



CBD Walk Test (5th Ave New York 4.5km)

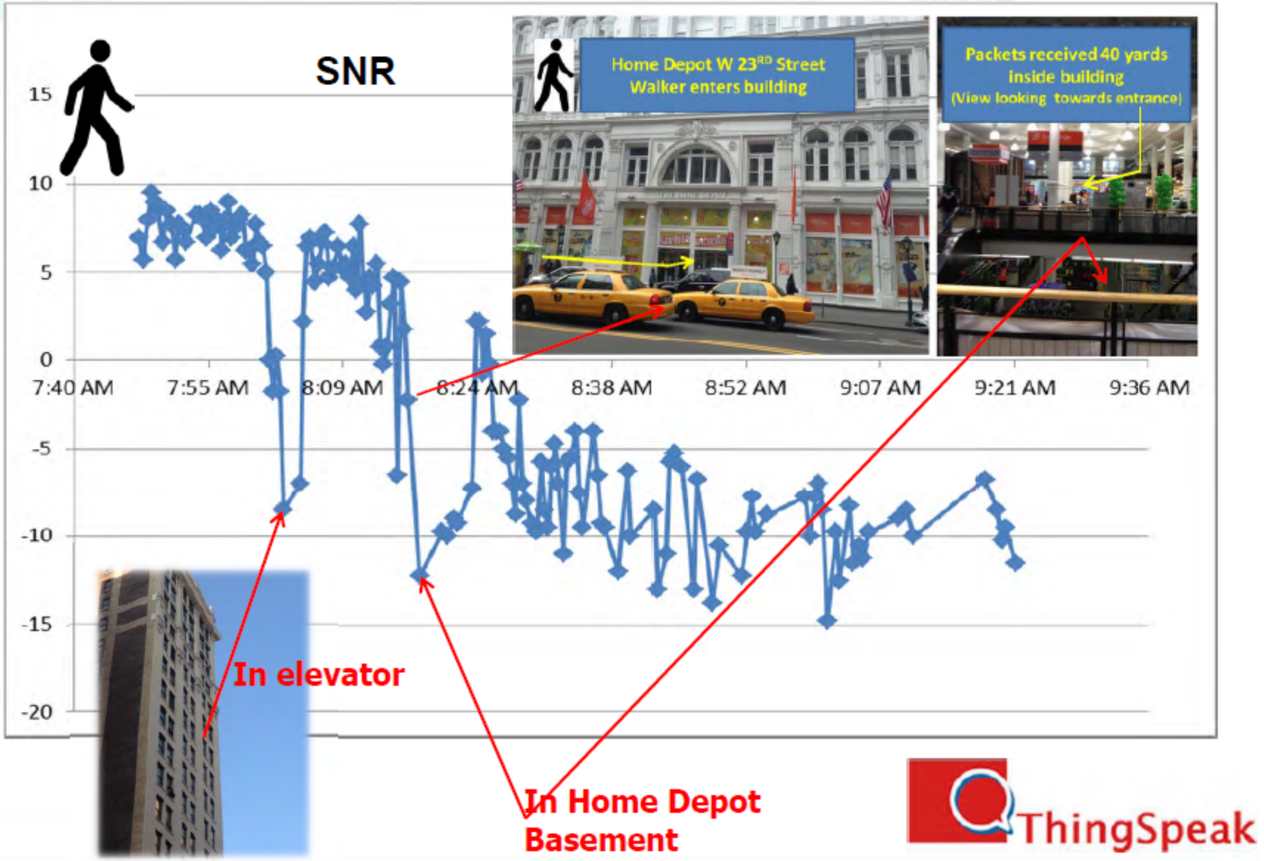


LORA Radio on street

Walker reported real-time location via text messages
SNR and RSSI were measured on valid packets received by roof-top gateway.

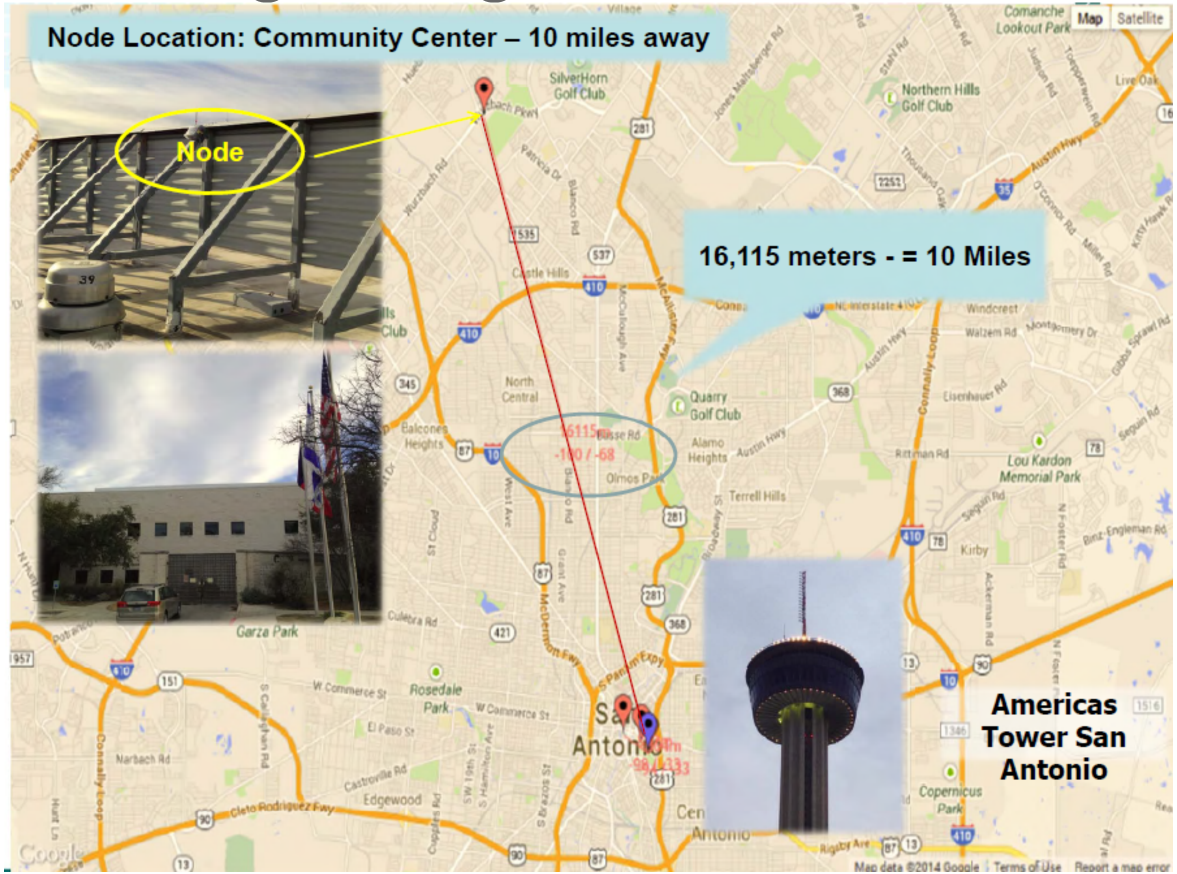
Source: Semtech

Semtech Indoor Penetration test

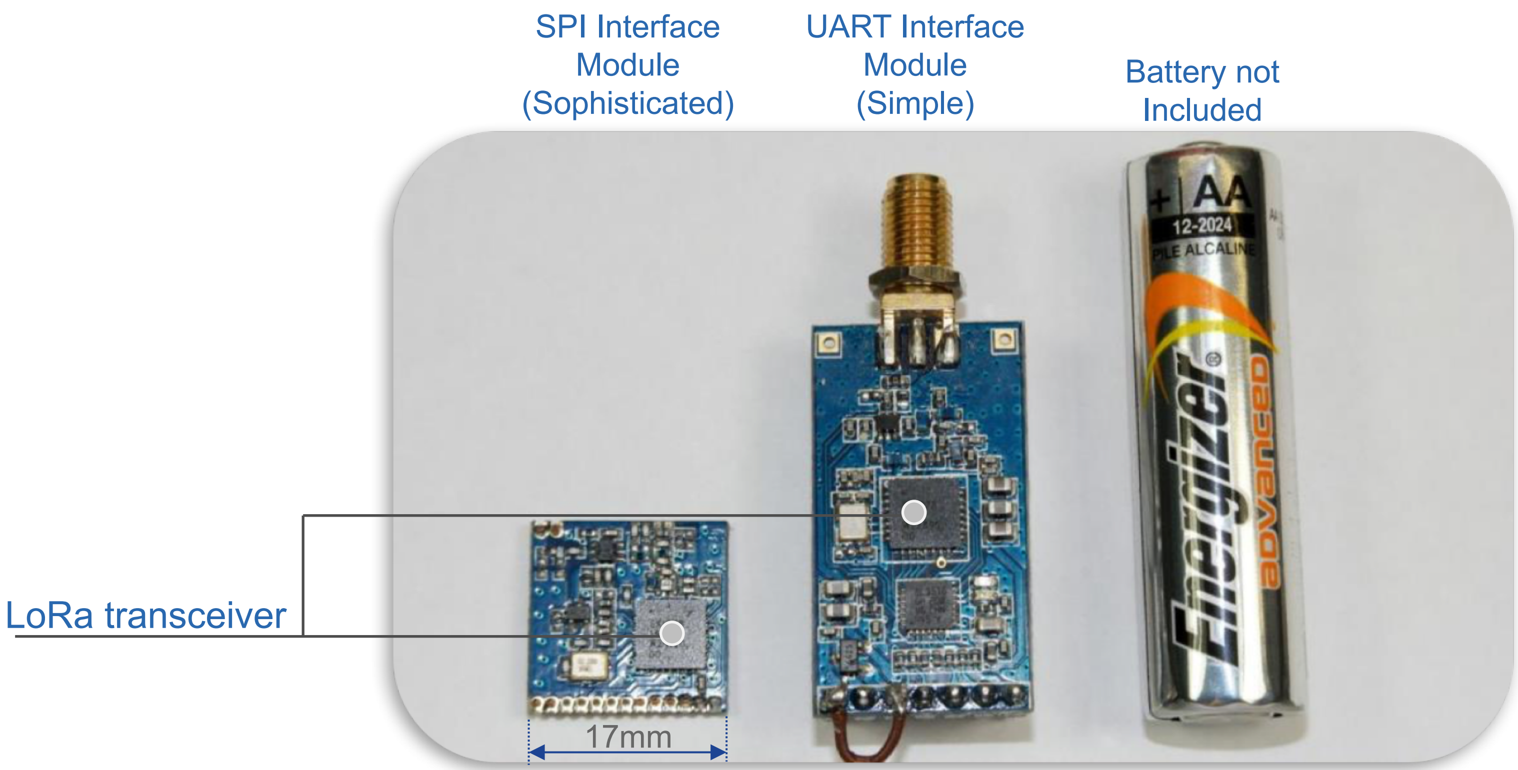


Source: Semtech

Semtech Long Range Test



Source: Semtech



Semtech LoRa Chips (modules by Dorji)

LoRaWAN™ (MAC)

LoRa Alliance (What is above the PHY?)

Non-profit association that believes the IoT era is now

Mission: Standardize LPWA Networks with a first focus on LoRaWAN

Initial Members: IoT solution providers: Actility, Cisco, Eolane, IBM, Kerlink, IMST, MultiTech, Sagemcom, Semtech, and Microchip Technology. SP: Bouygues Telecom, KPN, SingTel, Proximus, Swisscom, and FastNet (part of Telkom South Africa)

LoRaWAN specification 1.0.2 is available from LoRA alliance

(http://lora-alliance.org)

LoRaWAN™ Layered Architecture

Applications

CoAP	MQTT	IPv6/6LoWPAN (IETF 6LPWA WG)	Raw	others

LoRaWAN™ MAC

Class A (Baseline)	Class B (Beacon)	Class C (Continuous)

LoRa Modulation

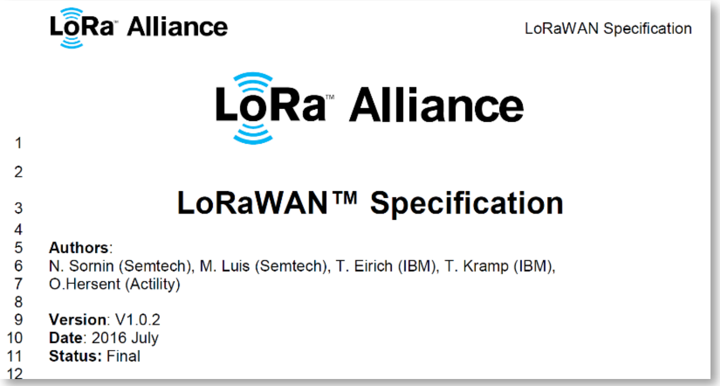
EU868	EU433	US915	CN779	AU915	Others

LoRaWAN 1.0.2 Released Specification

Authored by Semtech, Actility, IBM

LoRaWAN Specification Document

- Identifiers definition, Security procedures
- Data and Control messages
- Class A, B & C procedures



LoRa Alliance LoRaWAN Specification

LoRa Alliance

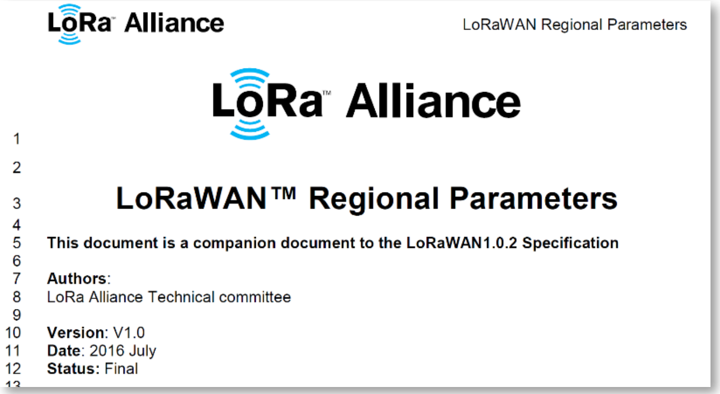
LoRaWAN™ Specification

Authors:
N. Sornin (Semtech), M. Luis (Semtech), T. Eirich (IBM), T. Kramp (IBM),
O.Hersent (Actility)

Version: V1.0.2
Date: 2016 July
Status: Final

Regional Parameters Document (Join Freq, Duty Cycles Dwell times…)

- 900Mhz, 800Mhz, 700Mhz and 433Mhz bands
- Europe, US, China, Australia, South Korea defined
- Australia: 915Mhz – 928Mhz (13MHz available)
- Special AS923Mhz plan (intersection of ISM frequencies)
  - Brunei, Cambodia, Hong Kong, Indonesia, Japan, Laos, NZ, Singapore, Taiwan, Thailand, Vietnam



LoRa Alliance LoRaWAN Regional Parameters

LoRa Alliance

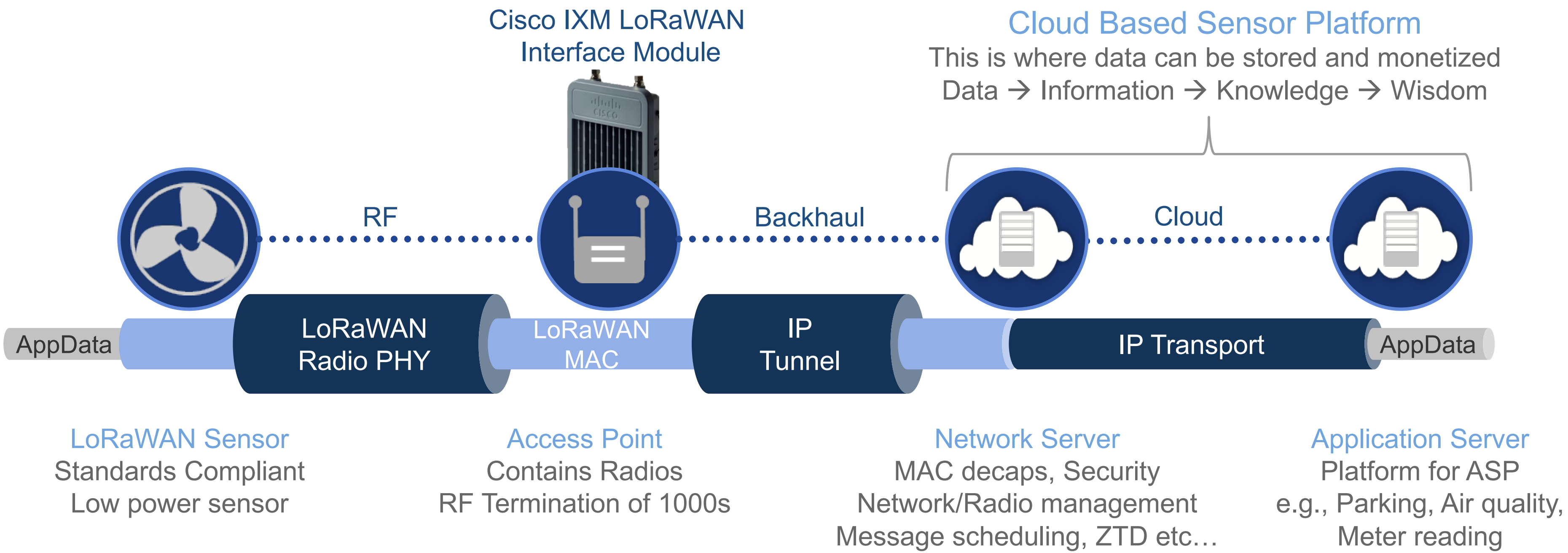
LoRaWAN™ Regional Parameters

This document is a companion document to the LoRaWAN1.0.2 Specification

Authors:
LoRa Alliance Technical committee

Version: V1.0
Date: 2016 July
Status: Final

LoRaWAN End-to-End Architecture



LoRaWAN Description

Star-of-stars topology

Gateways (AP) act as transparent bridge relaying messages between end-devices and a cloud based network server (NS)

Sensors use single-hop wireless communication

To one or many gateways

Communication between sensors and Gateway is spread

Different frequency channels and data rates

NS manages the data rate and RF output for each sensor

Using adaptive data rate (ADR) scheme

LoRaWAN is a Simple Network

Any device can transmit to any channel at any time

No synchronization between devices required

- Easy to implement devices

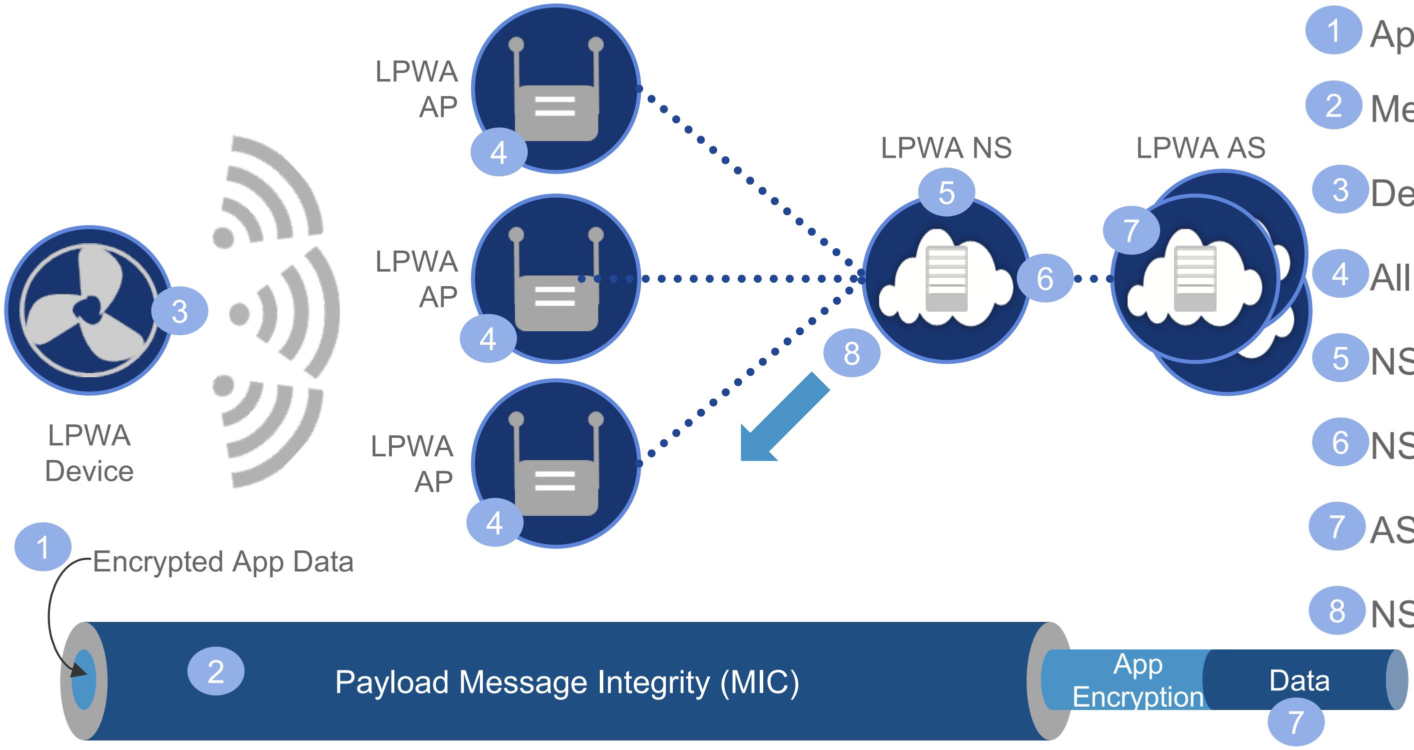
Mote changes channel randomly for each transmission

- Robust to interferers and collisions

Piggy-backing for gateway to node/mote communication

- Acknowledgement may be sent in the next data packet
- Predictable battery-life

Simple & Secure Cloud-Based Radio Access



1. Application data encrypted
2. Message integrity calculated
3. Device transmits a packet
4. All APs in range RX packet
5. NS receives & checks MIC
6. NS forwards packet to AS
7. AS decrypts using app key
8. NS selects best AP for return TX

Three Important LoRa Parameters

Modulation Bandwidth
7.8, 10.4, 156.6, 20.8, 31.25, 41.7, 62.5, 125, 500 kHz

Spreading Factor
6, 7, 8, 9, 10, 11, 12

4/5
00001

Coding Rate
4+1, 4+2, 4+3, 4+4 bits

Design trade off

- Link Budget
- Spectral Occupancy
- Interference Immunity
- Nominal data rate

Configuring these parameters — Influences these properties

Spreading Factor Example

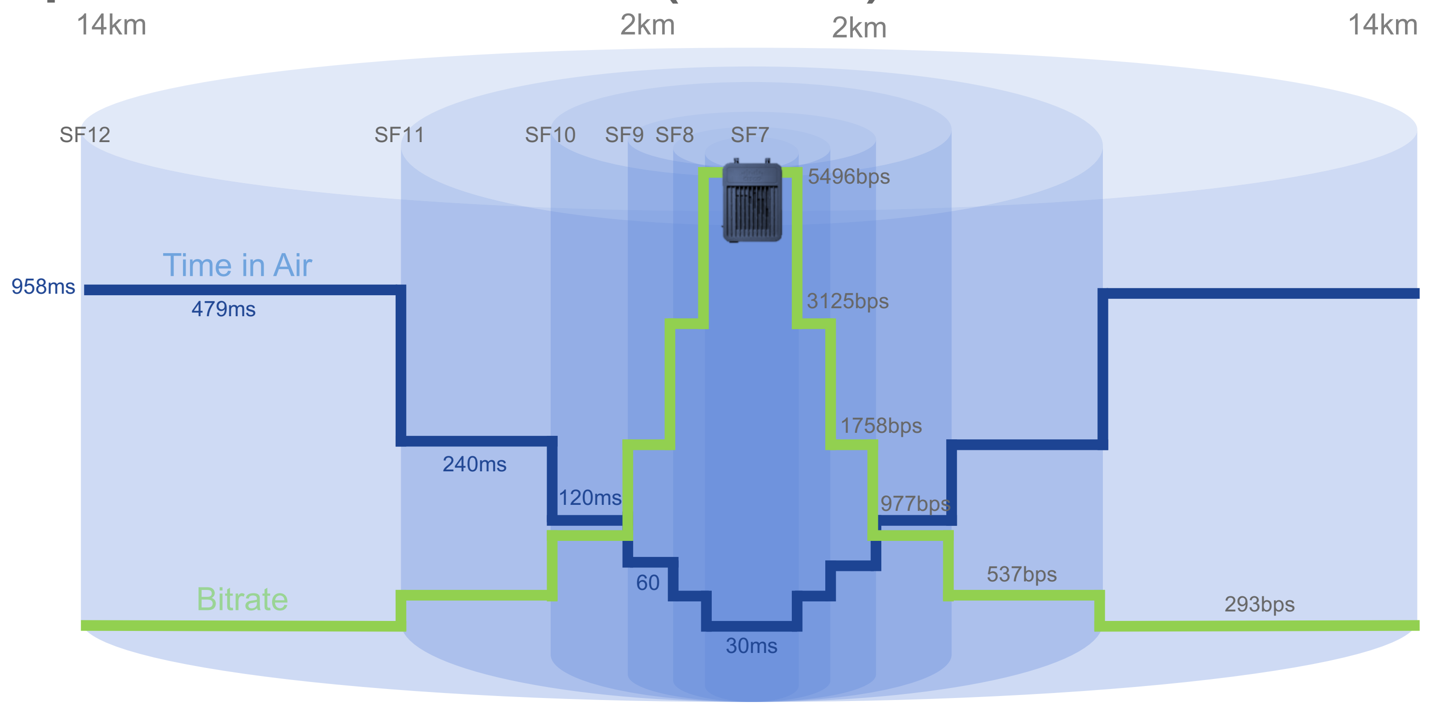
Bandwidth: 125Khz, Coding Rate: 4/5, Payload: 4 bytes, Preamble: 12 symbols

Spreading Factor	Chips/Symbol	Bit rate (bps)	Sensitivity (dBm)	Time on Air
6	64	9375 bps	-118 dBm	17 ms
7	128	5469 bps	-123 dBm	30 ms
8	256	3125 bps	-126 dBm	60 ms
9	512	1758 bps	-129 dBm	120 ms
10	1024	977 bps	-132 dBm	240 ms
11	2048	537 bps	-134 dBm	479 ms
12	4096	293 bps	-137 dBm	958 ms

Immunity to Interference: Less ↔ More

Each spreading factor is orthogonal on the same transmission channel

Adaptive Data Rate (ADR)

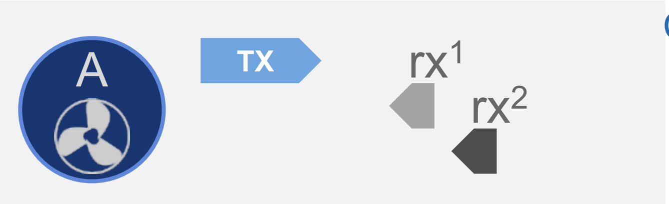


ADR maximises battery life overall & network capacity

ADR manages the data rate and RF output for each device

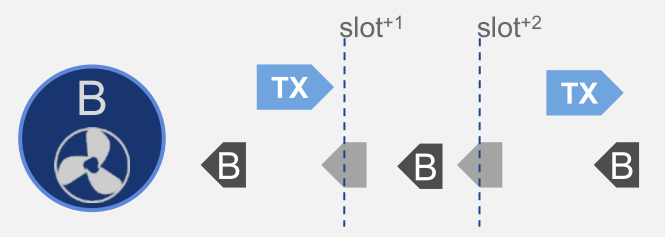
Acknowledgement: Actility for diagrammatic representation

LoRaWAN Device Classes



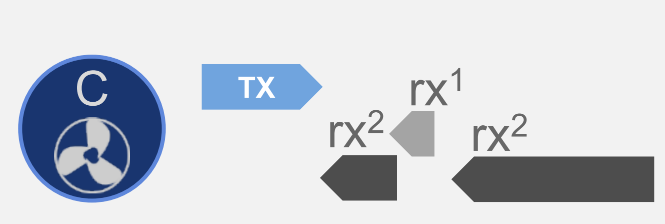
Class A Bi-directional (Baseline)

- Generally battery powered
- Device UL TX followed by 2 short DL RX windows (TX from NS)
- Class A must initiate a TX before listening on RX windows
- Very suitable for lowest powered devices



Class B Bi-directional with scheduled receive slots (Beacons)

- Generally battery powered
- Implements Class A plus…
- Open extra receive windows at scheduled times
- Scheduled time synchronised with Beacon frames from gateway



Class C Bi-directional with maximum receive slots (Continuous RX)

- Mains powered
- Implements Class A RX^1 window plus…
- Continually listens on RX^2 channel, only closed when TX
- Uses most power, provides low latency

LoRaWAN Device Channel Access

End device may use listen-before-talk

TX on any channel available, anytime

Adhere to max transmit dwell time

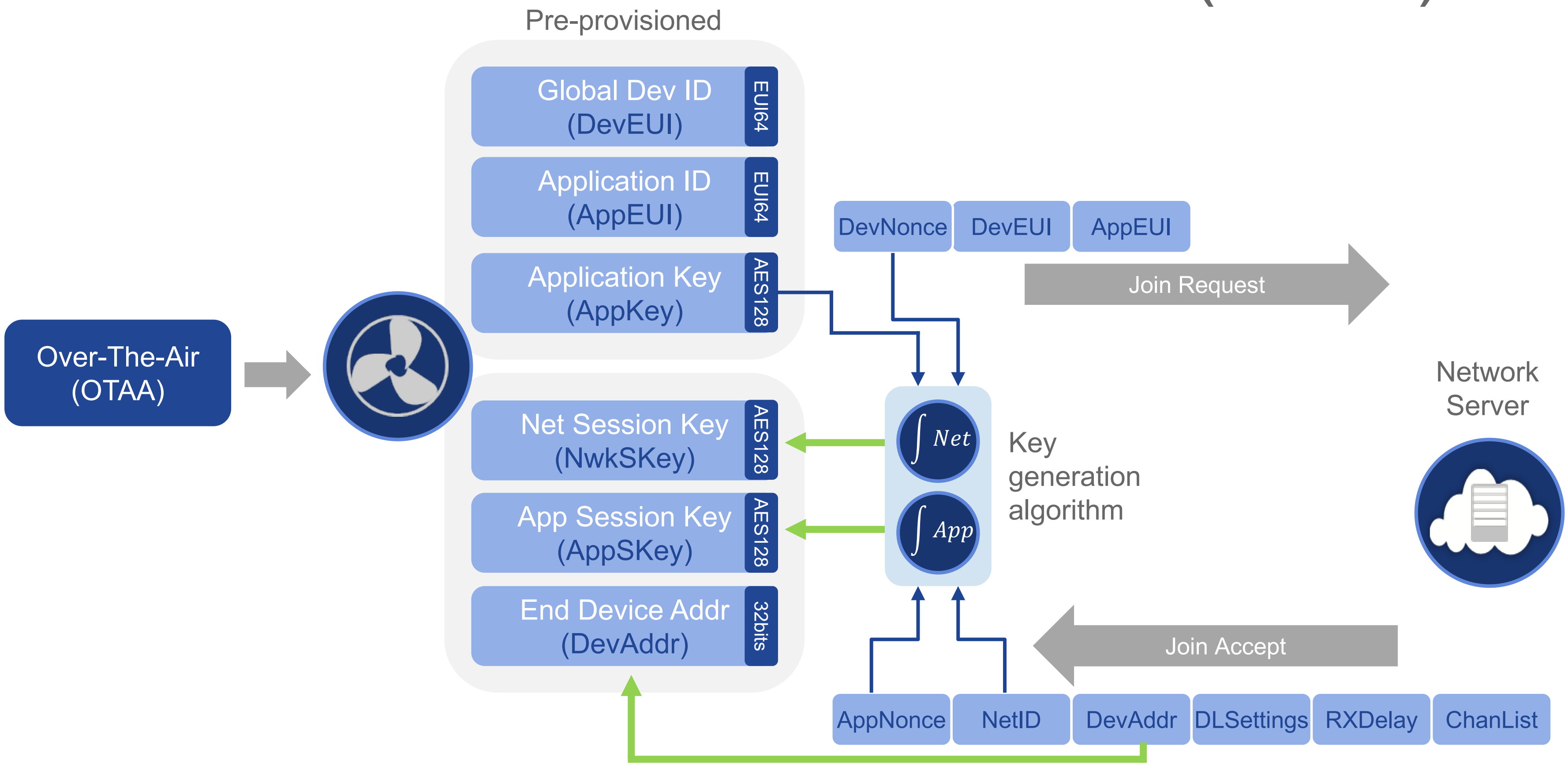
Changes channel in pseudo random fashion

Adhere to max transmit Duty Cycle

Requirements are subject to local regulation

Not all are necessarily required in a local region

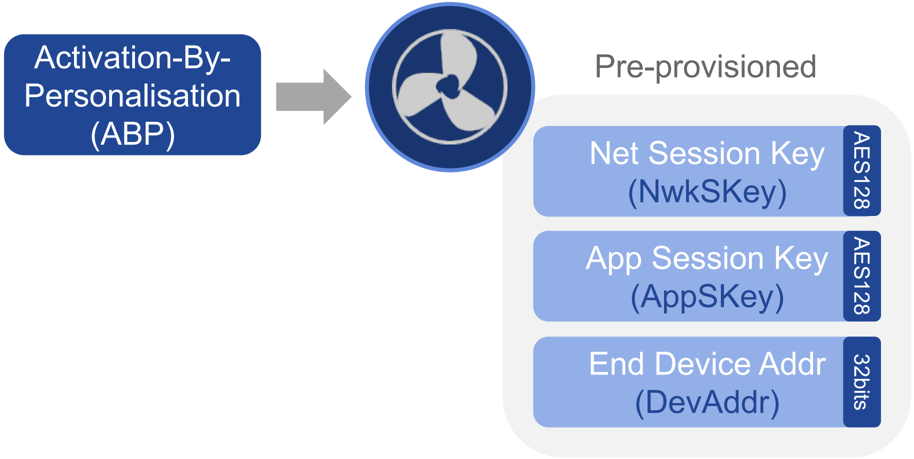
LoRaWAN Over-The-Air Activation (OTAA)



LoRaWAN Activation-By-Personalisation (ABP)

ABP pre-provisions keys and device address

Join procedure is bypassed



LoRaWAN Key Information Element (IE)

IE	Description
DevUI	A globally unique device ID in EUI64 format
DevAddr	A device ID of 32 bits that uniquely identifies the end device. Dev is composed of NetworkID (7 bits) and NetworkAddr (25 bits)
AppEUI	A globally unique application ID in EUI64 format that uniquely identifies the application provider (i.e., owner) of the end device
NwkSKey	A device-specific network session key used by both the network server and the end device to calculate and verify the Message Integrity Check (MIC) of all data messages to ensure data integrity. It is further used to encrypt and decrypt the payload field of MAC-only data messages.
AppSKey	A device-specific application session key used by both the network/app server and the end device to encrypt and decrypt the payload field of application- specific data messages. It may also be used to calculate and verify an application- level MIC to be optionally included in the payload of application-specific
AppKey	The AppKey is an AES-128 root key specific to the end-device. Whenever an end-device joins a network via over-the-air activation, the AppKey is used to derive the session keys NwkSKey and AppSKey specific for that end-device to encrypt and verify network communication and application data.

LoRaWAN™ Band Plan

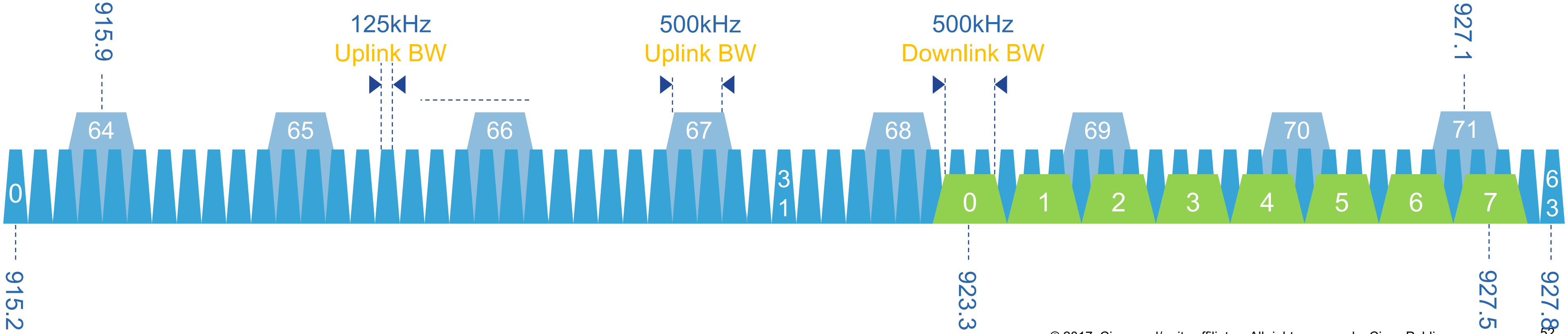
AU915MHz - 928MHz Band Example

Parameter	Condition
TX Power 125kHz TX Power 500kHz	+30dBm (20dBm +10dBm gain) +26dBm (20dBm + 6dBm gain)
Transmit	Any available channel DR0-DR4
Frequency Hop	Min 20 channels on 125kHz
Dwell Time	400ms
Duty Cycle	<1% per hour (~32 packets)

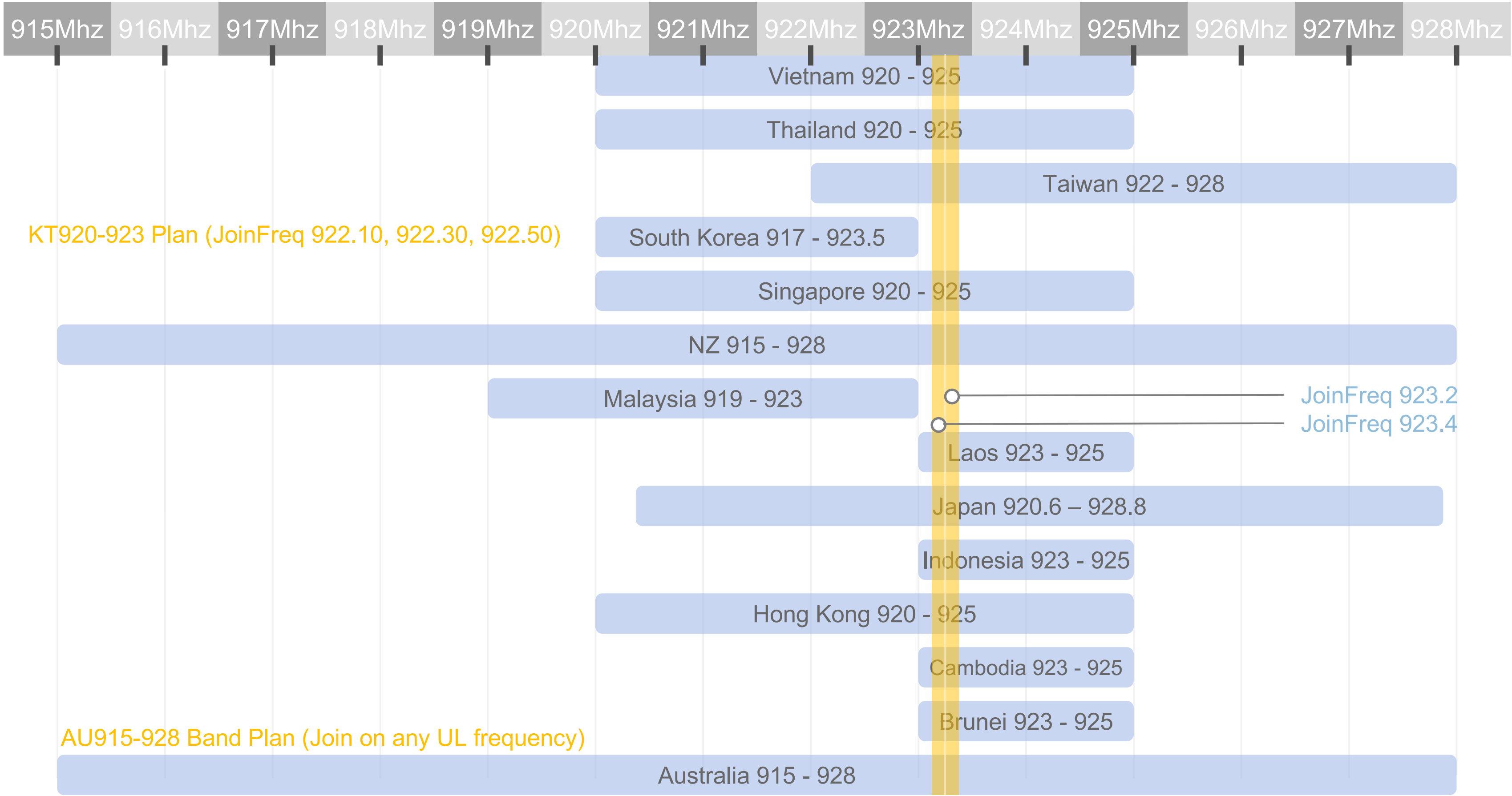
125kHz UL Data Rates		
DR0	SF10	980bps
DR1	SF9	1760bps
DR2	SF8	3125bps
DR3	SF7	5470bps

500kHz UL Data Rates		
DR4	SF8	12500bps

500kHz DL Data Rates		
DR8	SF12	980bps
DR9	SF11	1760bps
DR10	SF10	3900bps
DR11	SF9	7000bps
DR12	SF8	12500bps
DR13	SF7	21900bps



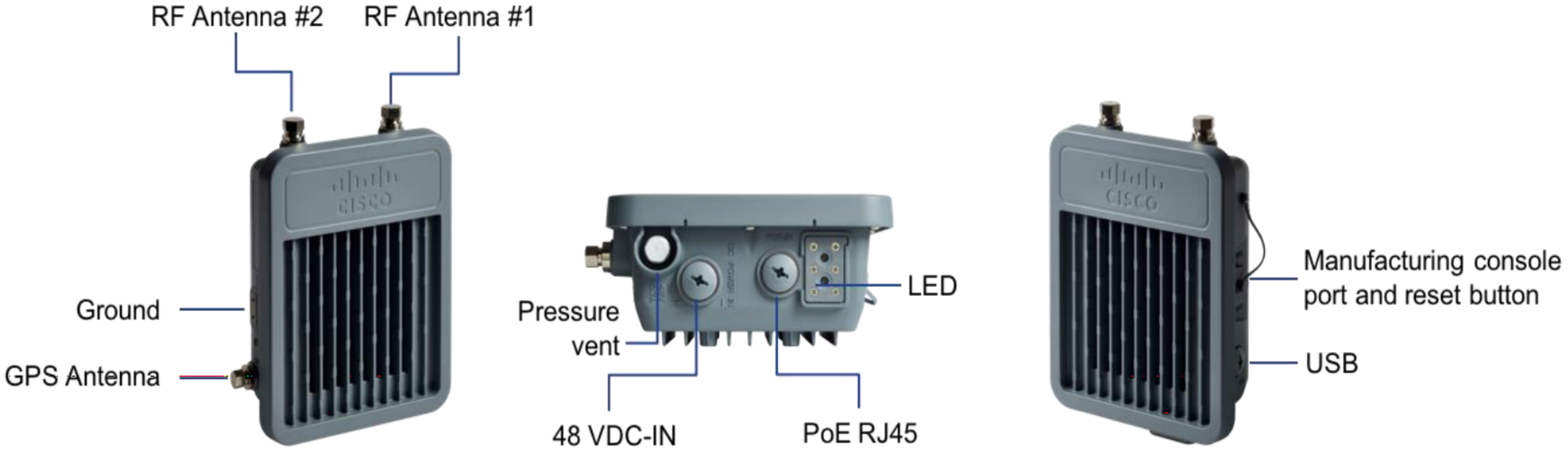
AS923 Band Plan (Covers many Asian countries)



Cisco LoRaWAN Gateway

Cisco LoRaWAN Interface Module

Part of IoT eXtension Module Series (IXM)



LoRaWAN Gateway Deployment

Connect to IR809/829 LAN via PoE cable

Carrier-grade LoRa gateway function

Semtech v2 reference design

Integrate with Actility (LoRa Network Server)

Support ZTD via Field Network Director

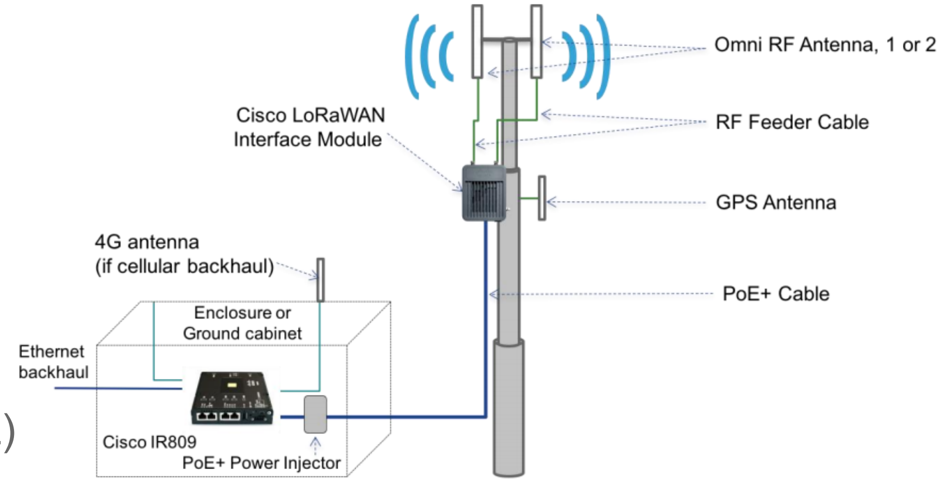
FCS - 16-chan for EU (868MHz), US (915Mhz)

Post FCS – Australia, Singapore

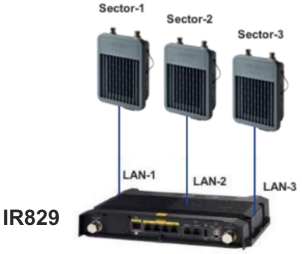
Omni LoRa Gateway – IR809 with single LoRa modem

3-sectors LoRa Gateway – IR829 with 3 LoRa modems

Multiple backhaul options – Ethernet, 4G and Wi-Fi



Omni LoRaWAN Gateway



3-sector LoRaWAN Gateway

LoRaWAN Applications

Multi-Purpose Tester: IMST LoRa Mote

LoRaMote is perfect for testing, demo, prototyping

LoRa transceiver and Cortex-M3 controller

GPS

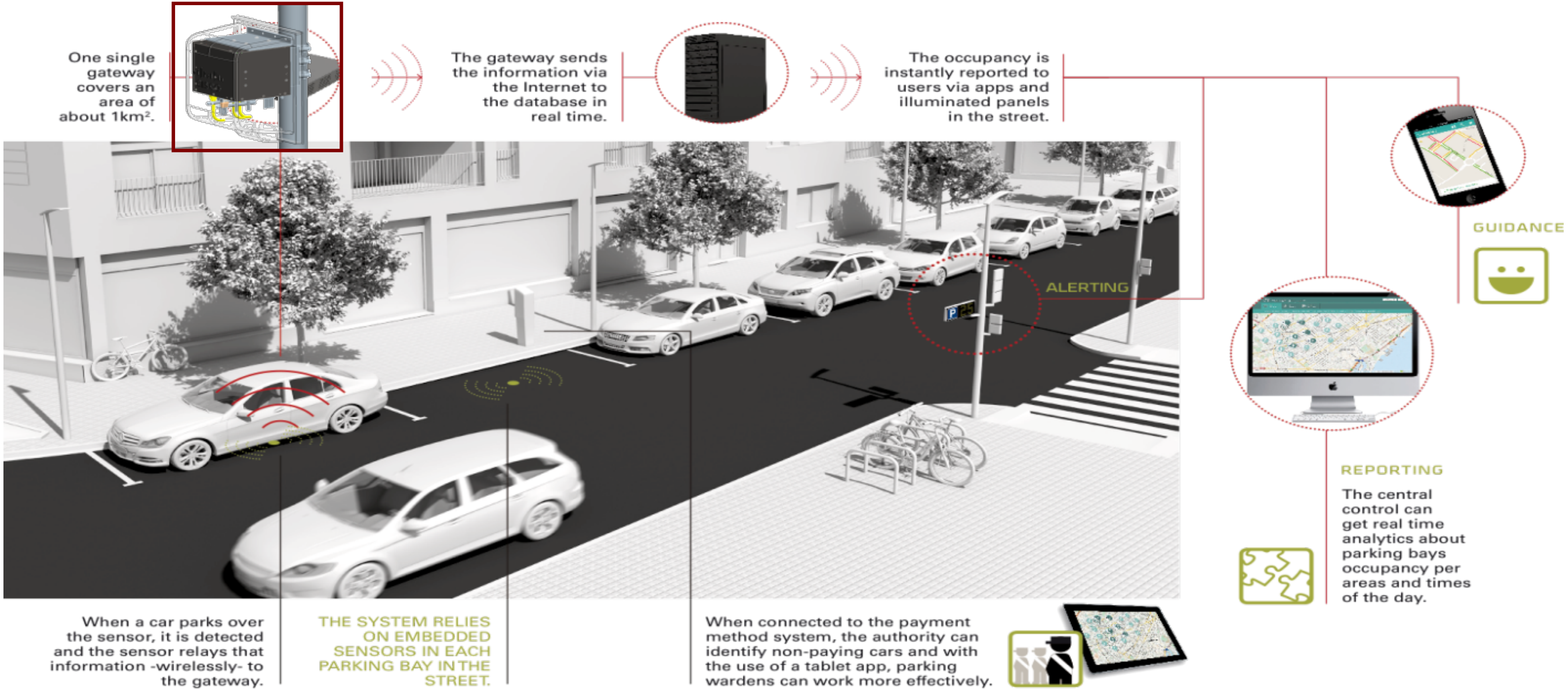
Various sensors

- proximity, magnetic, three axis accelerometer, pressure and temperature sensors

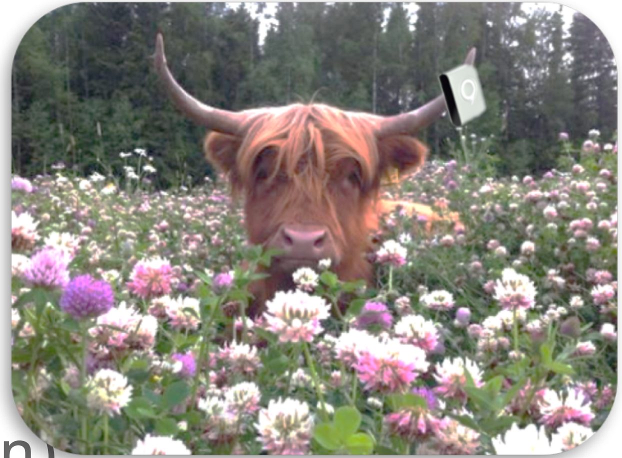
Schematics and source code are available on https://github.com/Lora-net

Smart Parking – Worldsensing Fastpark with LoRa

Cisco IR900 with Semtech LoRa Card



Asset Tracking : Abeeway



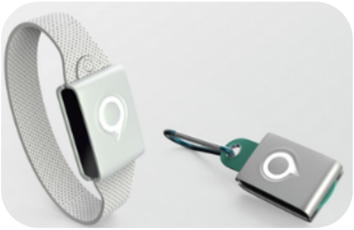
Tracker for people, pet, assets, cows…

Up to 1 year of battery autonomy

Small and handy size (starts at 6cm / 2,4in)

Leverage GPS for location and LoRa to communicate

Application: any asset, amusement park, ski resort, farm, children tracking, pet tracking, etc.



Waste Management

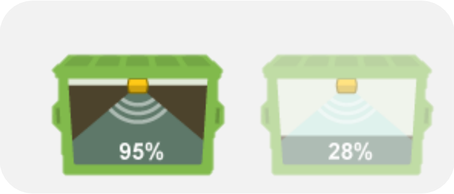
Sensor measuring the level of large containers

- Key to optimising waste collection

Long term (years) battery life, Long range transmission

Several vendors with waste collection sensors

- Enevo, BH Technologies and Homerider



Water Metering: Home Rider Systems

- HOMERIDER has developed integrated end points
  - In partnership with manufacturers : Actaris/Itron, Sappel, Elster, Sensus
- Comprehensive data collection
  - Up to 96 indexes per day
  - Maximum & minimum debit by 6 hour slot
  - Back flow: Number, Volume
  - 28 day consumption histogram
  - Continuous flow by debit period
  - Alarms: leaks, back flow, battery, fraud.

Summary

LPWA is a hot topic amongst network vendors/startups globally

Provides a “low cost network for low cost devices”

- Looks like a cellular network, operates like a WiFi network
- Simple access architecture, intelligence in the cloud

Many applicable use cases

Revenue models formulating

- Subscription; Data Volume, Number of devices, Storage, Analytics?

Enables the Knowledge Provider

References

LoRa MAC Specification (Semtech, Actility, IBM)

http://lora-alliance.org

LoRa net Github:

https://github.com/Lora-net