Keysight Measurement Forum 2016

Chang Seung-Taek

# Connectivity Technologies and Interference Signal Analysis for IoT Service.

KEYSIGHT TECHNOLOGIES

HARDWARE+SOFTWARE+PEOPLE=INSIGHTS

# What is Internet of Things (IoT)?

**Privacy traded……** | **Convenience gained**




**Connecting billions of devices to the internet**



**Cost Efficiency** | **Market Efficiency**

# IoT Market Predictions

50B devices will be connected by 2020
- Cisco

>30B Connected devices by 2020
- ABI Research

95.5B connected devices by 2025
- HIS Technology

# Vertical and Horizontal

Consumer

Connected homes

Wear-ables

Connected cars

Connected cities

Industrial

Healthcare

Manufacturing

Energy

Transportation

Agriculture

**$262B** **Apps & Analytics**

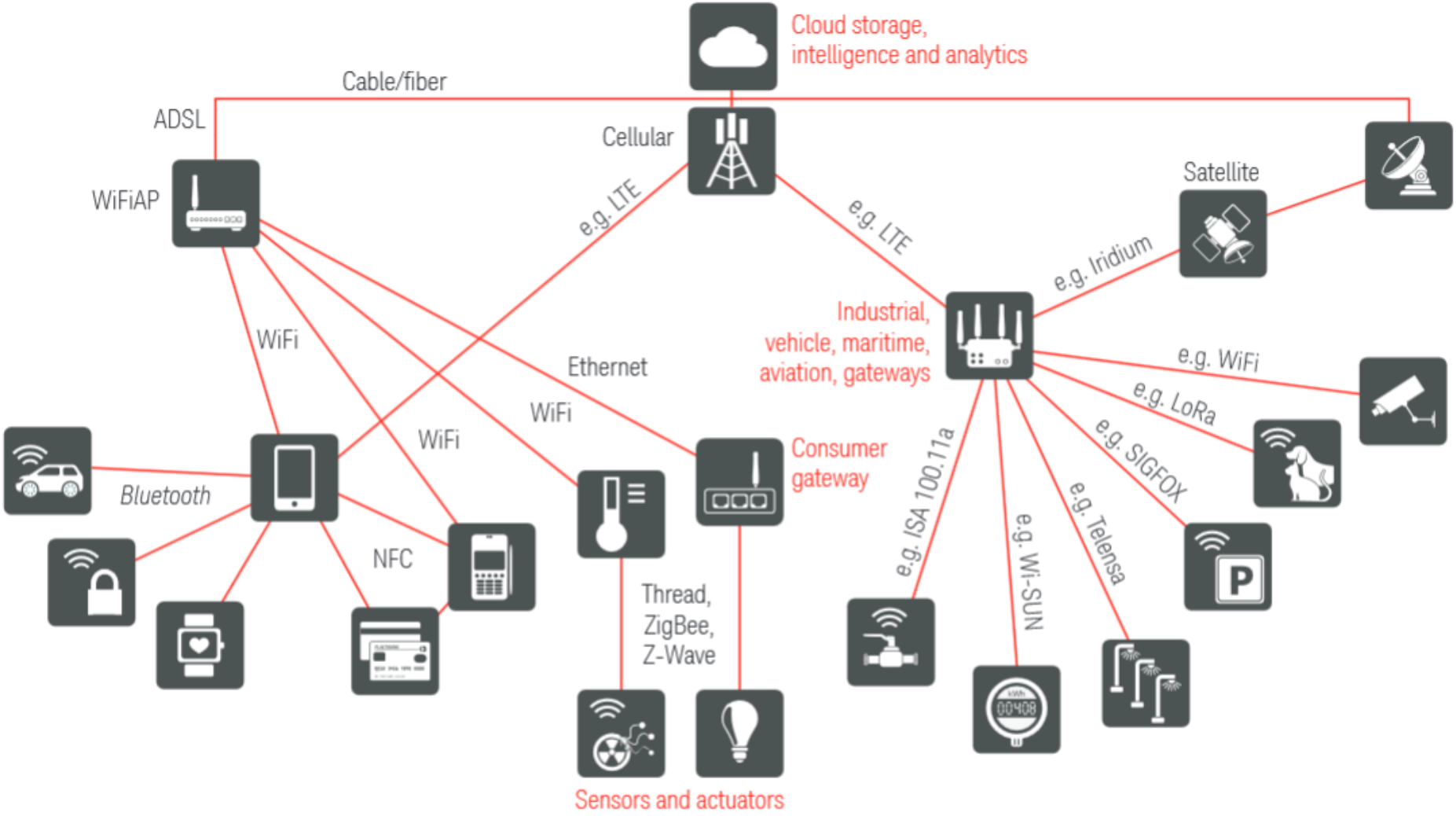
**$18B** **Compute & storage**

**$17B** **Communication**

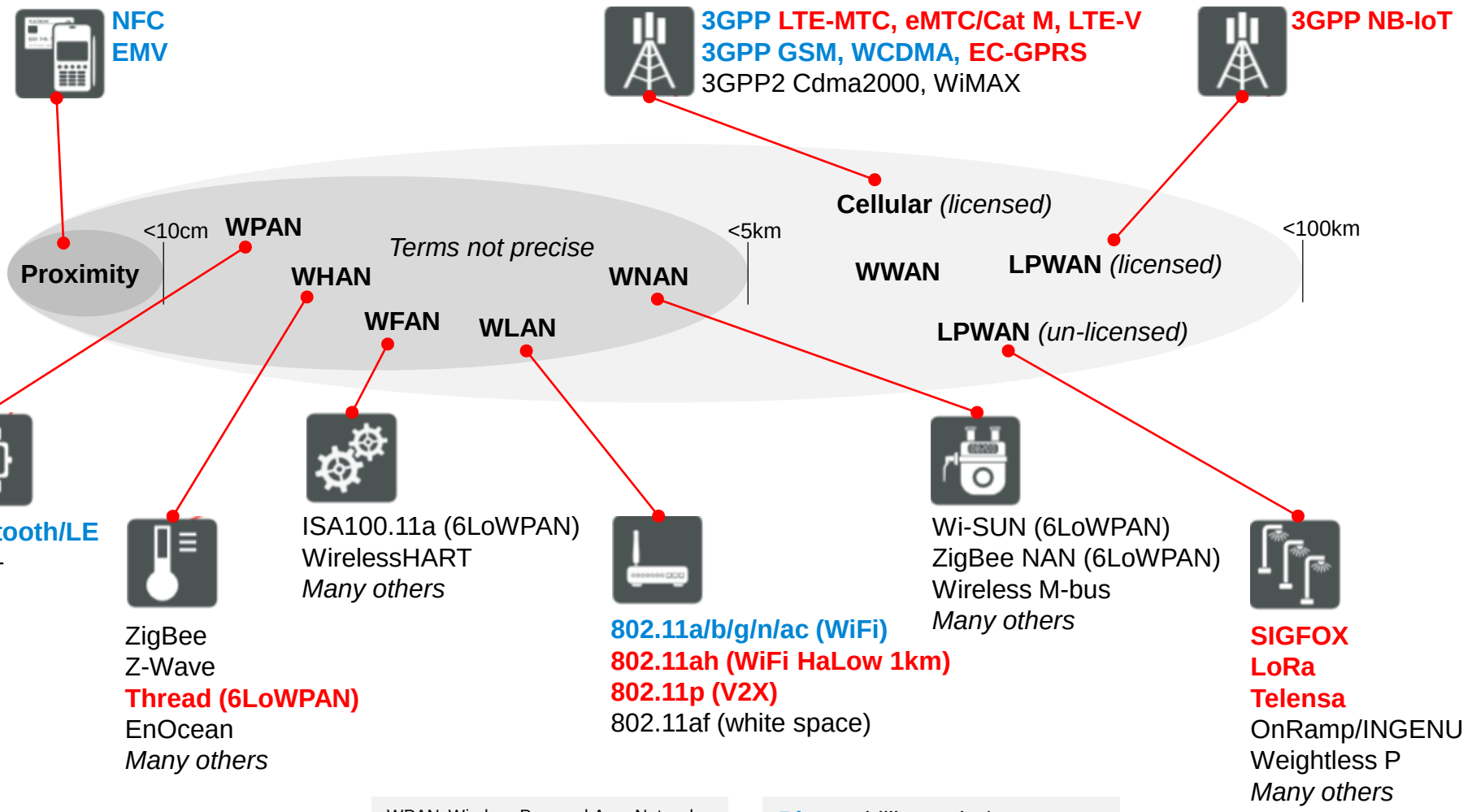
**$31B** **Things**

Gartner's estimated 2020 IoT revenue

# Connecting Things to the Cloud



# IoT Radios




WPAN: Wireless Personal Area Network
WHAN: Wireless Home Area
WFAN: Wireless Field (or Factory) Area
WLAN: Wireless Local Area
WNAN: Wireless Neighbourhood Area
WWAN: Wireless Wide Area
LPWAN: Low Power Wide Area Network

**Blue:** > billion units/year now
**Red:** emerging

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# Primary Market for the Internet of Things

## Smart Home

- Security & alarm
- Light control
- HVAC control
- Remote control
- Door control
- Energy efficiency
- Entertainment
- Appliances

## Wearables

- Health monitor
- Fitness trackers
- Smart watch
- Smart glasses
- Smart bands
- E-textiles
- Hearing-aid

## Smart City

- Traffic management
- Water distribution
- Waste management
- Security
- Lighting
- Environmental monitoring
- Infrastructure
- Parking sensor

## Industry Automation

- Smart machine
- Surveillance camera
- Factory automation
- Asset tracking
- Logistics and optimization of supply chain

## Smart Energy

- Generation & trading
- Transmission
- Distribution & metering
- Storage
- Services

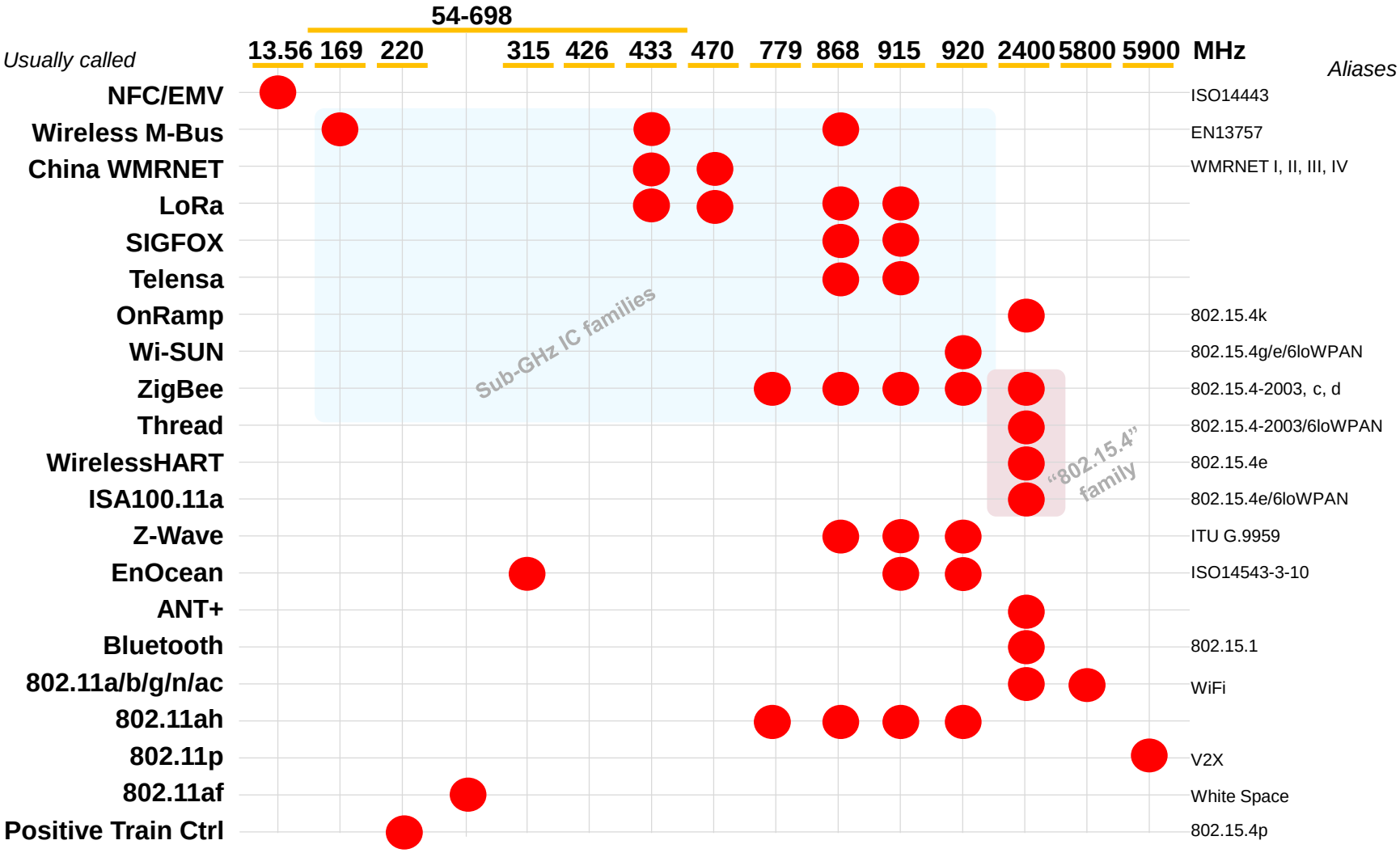
## Connected Car

- V2V / V2X /V2I communications
- eCall
- Infotainment
- Traffic control
- Navigation
- Autonomous vehicles
- Maintenance

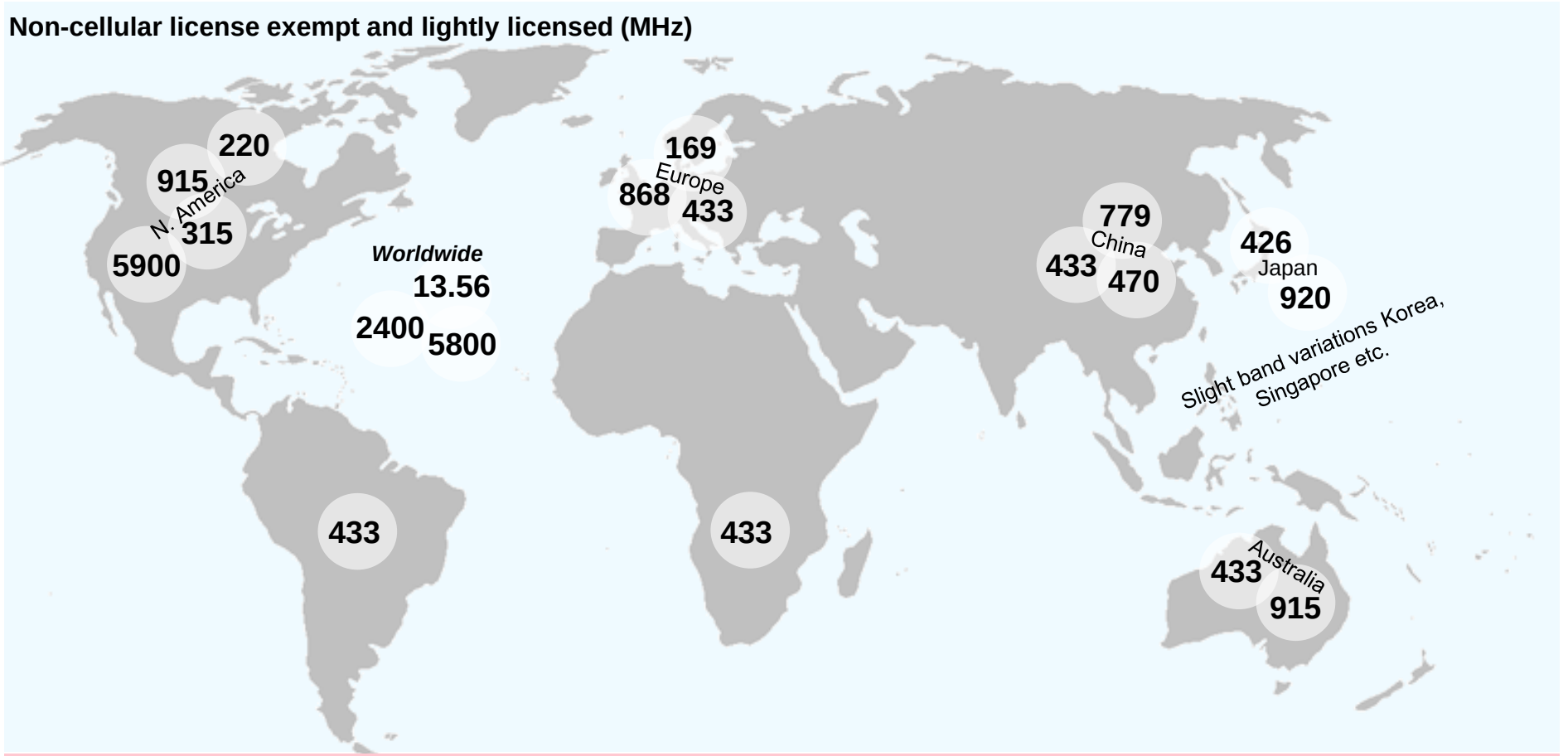
Wireless Connectivity

A single wireless technology can not accommodate the diverse need of IoT markets

# Popular Frequency Use



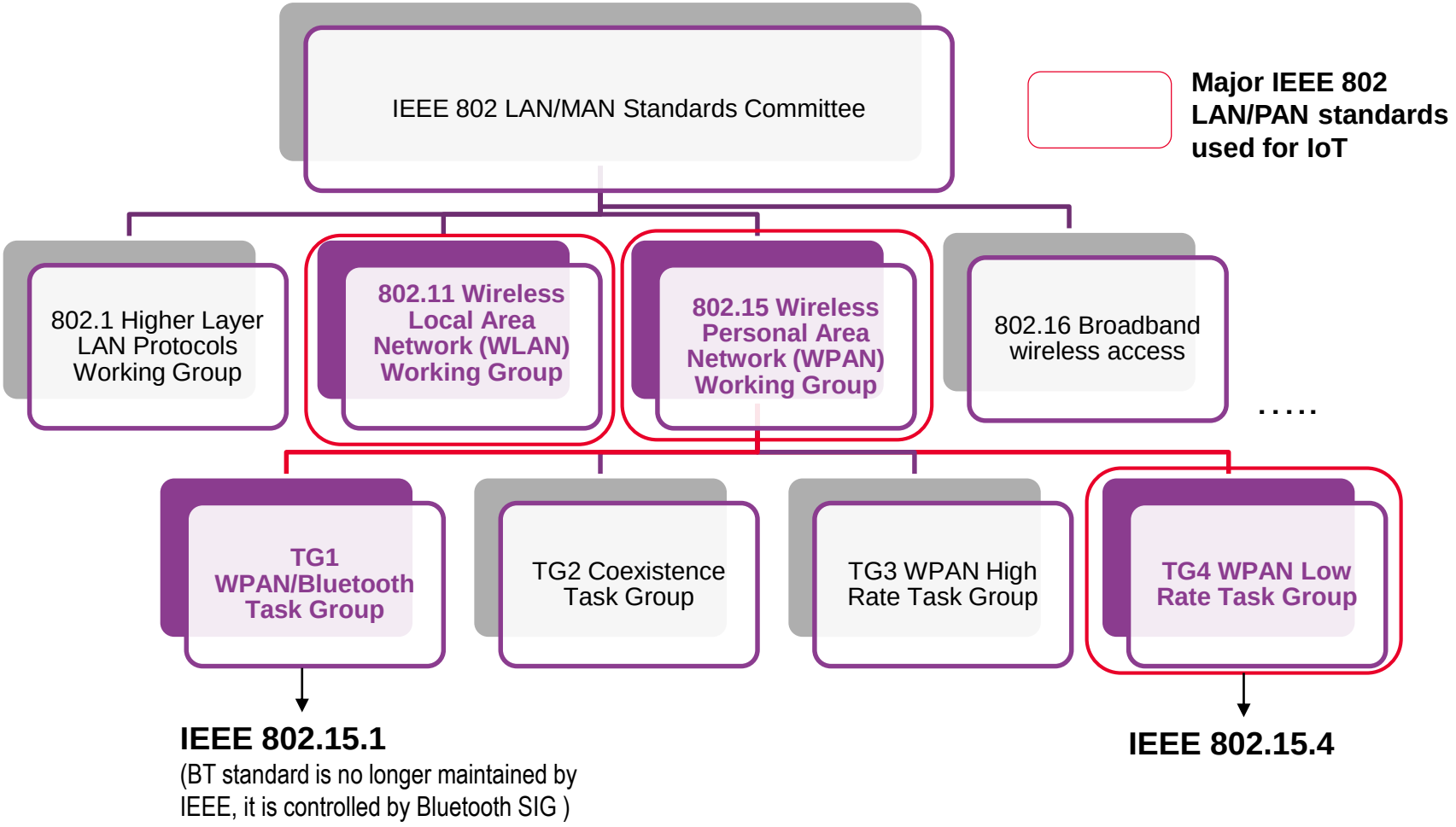
# Frequently Cited IoT Bands



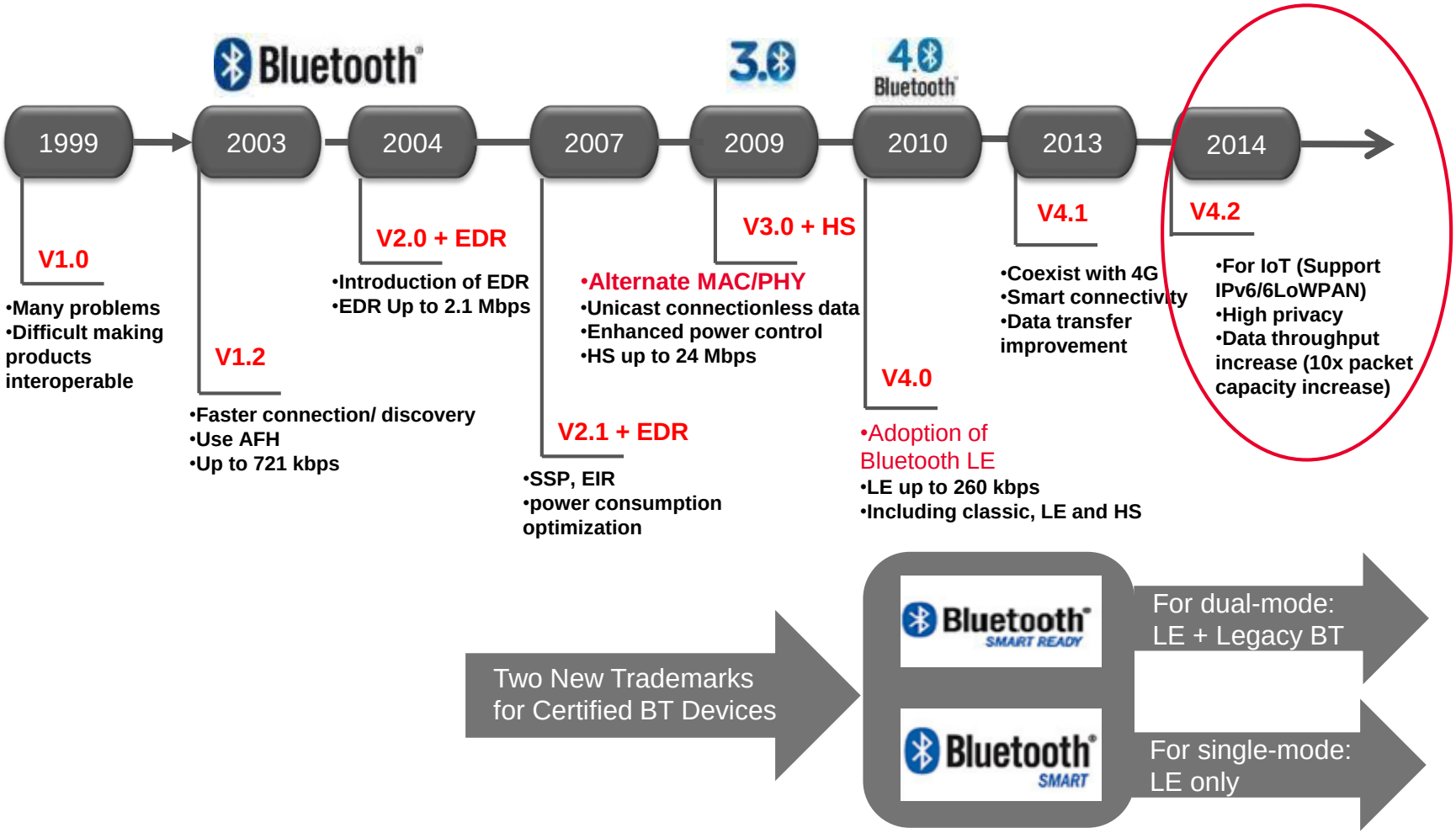
# Agenda

- **IoT/M2M Introduction and Market Situation**
- **IoT/M2M Key Enabling Wireless Technologies**
  - IEEE 802 LAN/MAN Working Group
  - Wide area networks (LPWAN) and NB-IoT
- **IoT Optimization and test challenges**
  - Optimization
  - Interference & operating environment replication
- **Summary**

# IEEE 802 LAN/MAN Working Group



# Bluetooth® Standard Evolution



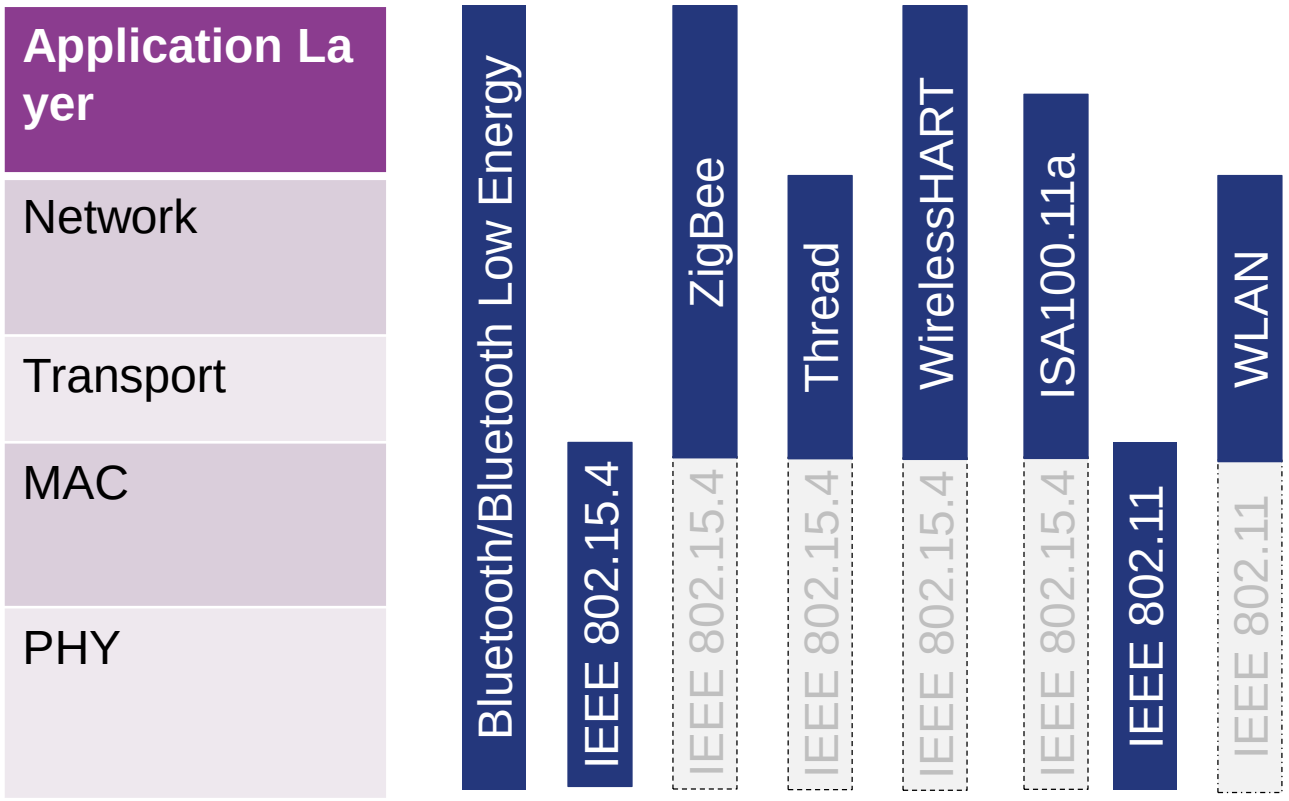
# IoT Key Enabling Technologies

## Bluetooth Smart – Powering IoT

**Bluetooth Core 4.0/4.1/4.2 enables a world of sensors**

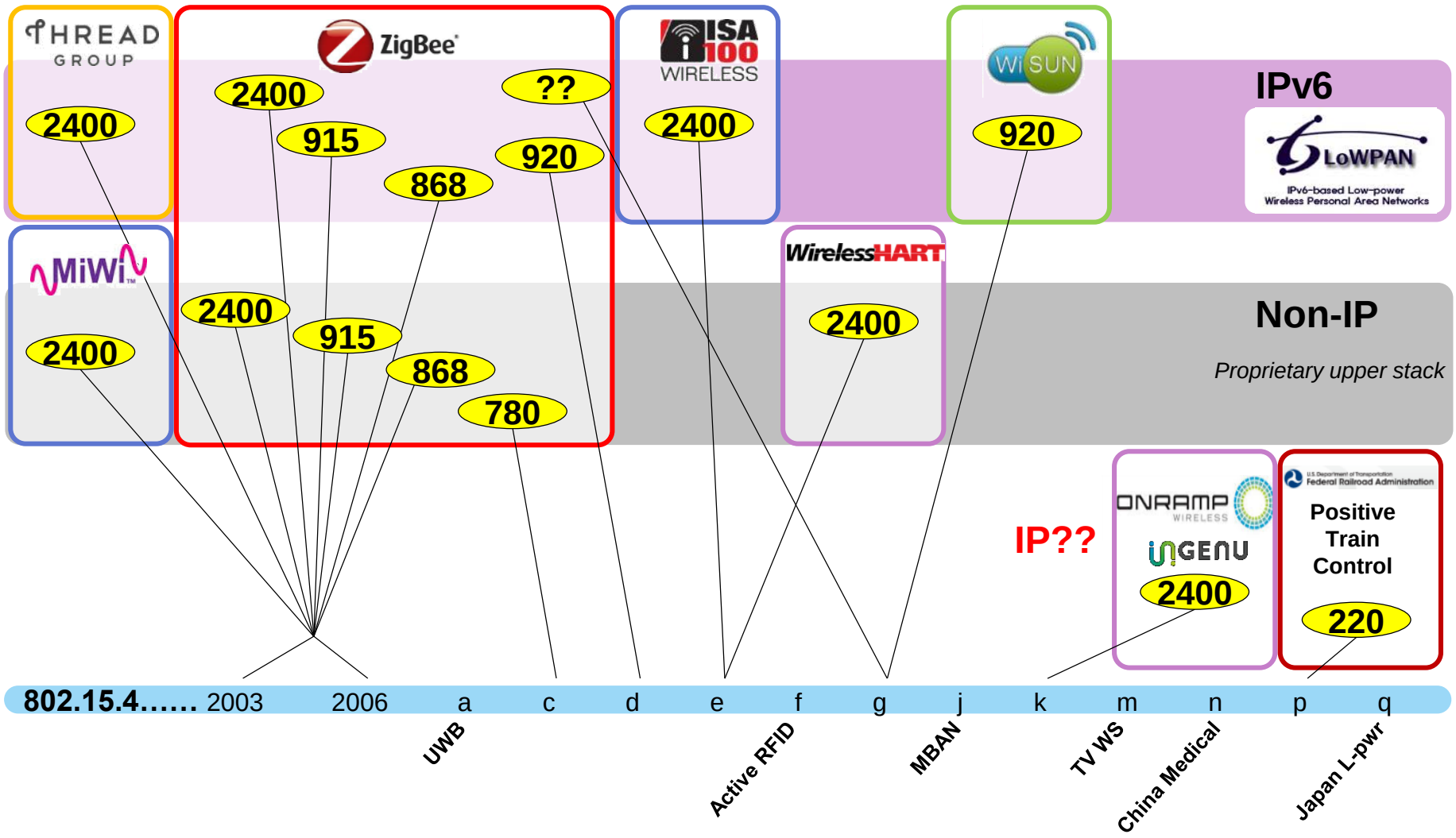
- Bluetooth Low Energy (BLE) enables low cost sensors to send their data over the internet
  - Version 4.2 enables IPv6 to a BT device
- Very low duty cycle = low power consumption
- Ability to run for years (up to 5 years) on standard coin-cell batteries
- Target applications:
  - Health monitors such as heart rate monitor
  - Fitness devices, smart watches
  - Environmental sensing
  - Proximity applications and many others

# Wireless Standards




IEEE 802 defines standards, does not define a certification process or test plans, that is done by the individual standards/working groups

# 802.15.4…. Something for Everyone



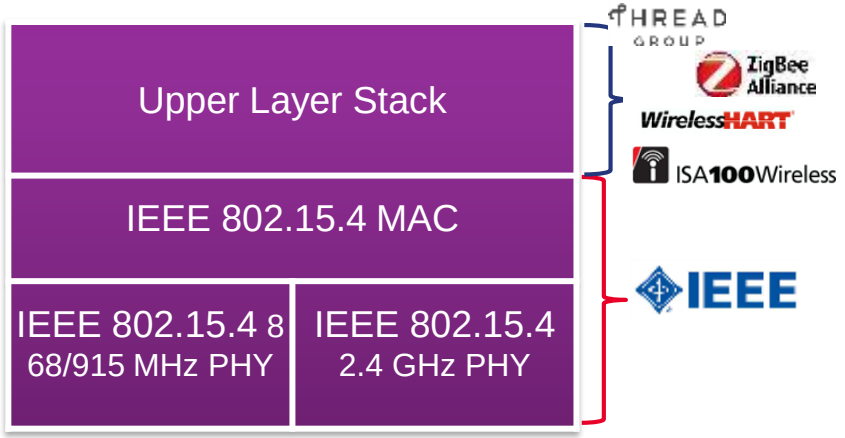

**MHz** = A popular non-interoperable format

802.15.4 includes >60 non-interoperable PHY combinations

# IEEE 802.15.4

## Low Rate Wireless Personal Area Network (LoWPAN)

- Important standard for home networking, industrial control and building automation
- Deals with low data rate, long battery life (months or even years) and very low complexity
  - Data rates of 250 kbps, 40 kbps, and 20 kbps
- Specifies PHY and MAC layers for LoWPAN networks
  - Ex. ZigBee, THREAD, WirelessHART, ISA100.11a
- Upper layers for WPAN are not developed by IEEE 802.15 working group
  - Standards or working groups, such as ZigBee Alliance, implement upper layers to enable multi-vendor interoperable solutions

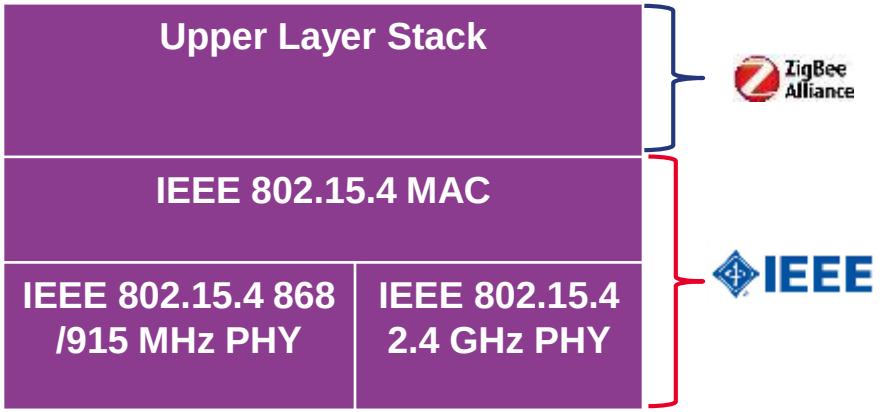


# IoT Key Enabling Technologies

## ZigBee

Low power, low data rate, mesh network

- Conceived in 1998, first standardized in 2003 and revised multiple times, latest in 2012 (ZigBee PRO)
- Based on IEEE 802.15.4 physical and MAC layers operating in sub-GHz and 2.4GHz frequency bands
- Transmission distances range from 10 to 100 meters - depending on power output and environmental characteristics




Target Applications: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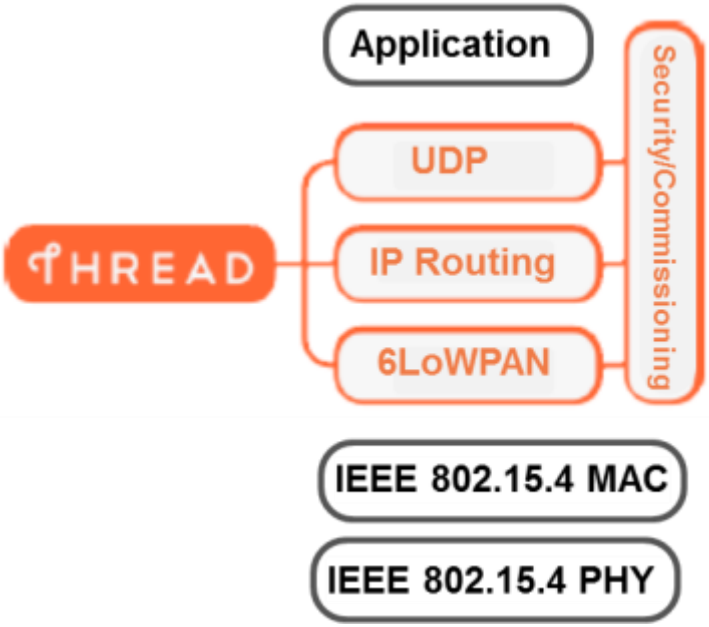
# IoT Key Enabling Technologies
## THREAD

– Thread Group launched in July 2014

– Main competitor to ZigBee for home automation
  - Appliances, access control, climate control, lighting, energy management etc..

– Collection of existing IEEE and IETF standards:
  - IEEE 802.15.4-2006 PHY/MAC operating in 2.4 GHz
  - 6LoWPAN (IPv6) based protocol

– Requires only software update to run on existing IEEE 802.15.4 based silicon such as 2.4 GHz version of ZigBee




Thread Protocol Stack

Ref:www.threadgroup.org

# IoT for Home Automation

## Technology Tradeoffs for Home Automation Application

### Bluetooth SMART

**Pros:**

- Low energy
- Available on mobile devices *(Already supported on IOS and Android)*
- IPv6 based

**Cons:**

- Star network
- Short range
- New technology – not well established compared to ZigBee

### Wi-Fi

**Pros:**

- Well established standards
- Available on mobile devices
- Good range
- IPv6 based

**Cons:**

- Star network
- Not low energy – new standard coming in 2016 (802.11ah)

### ZigBee

**Pros:**

- Low energy
- Well established standards
- Mesh network
- Good range

**Cons:**

- Not IP based for home automation *(ZigBee IP for Smart Energy 2.0 is IP based)*
- Not available on mobile phones/ tablets

### THREAD

**Pros:**

- Low energy
- Mesh network
- Good range
- IPv6 based

**Cons:**

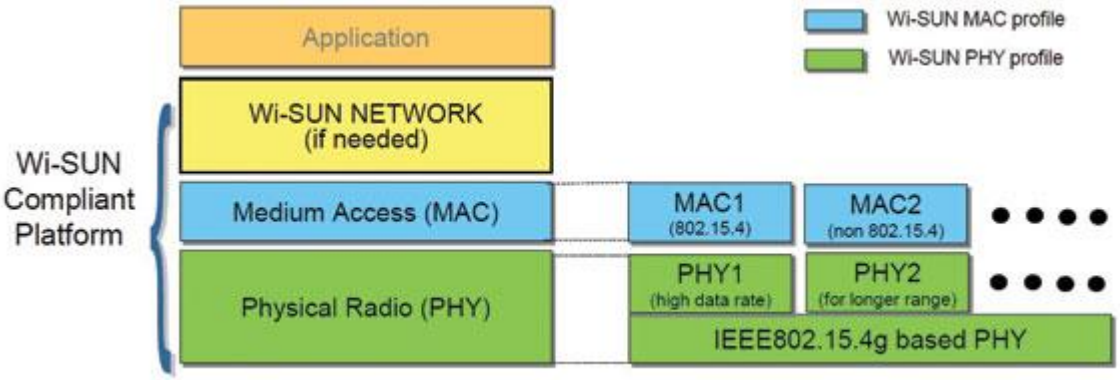
- Not well established compared to ZigBee
- Not available on mobile phones/ tablets

# IoT Key Enabling Technologies

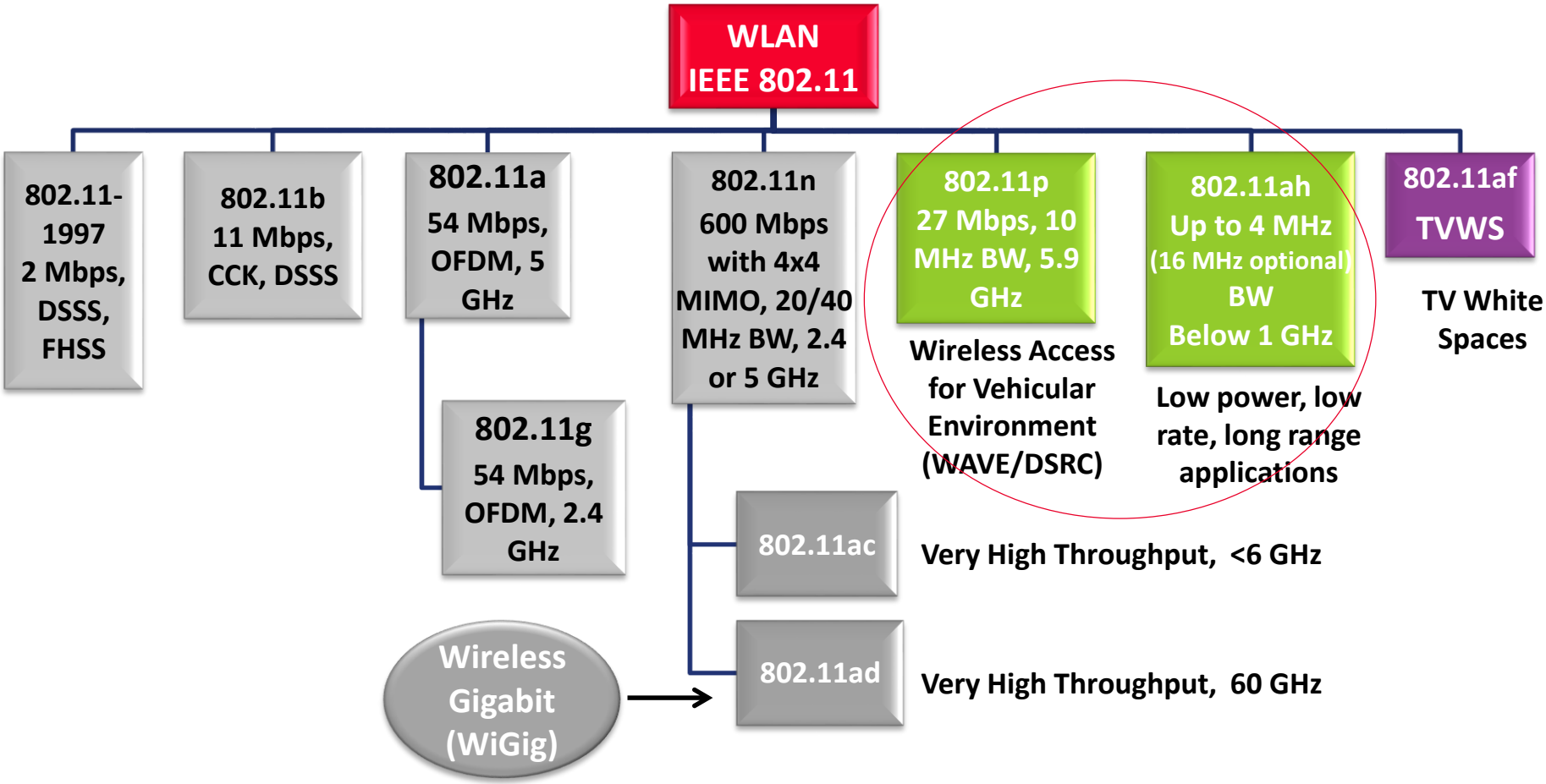
## Wi-SUN

- IPv6 based Wireless Smart Utility Network (Wi-SUN) based on IEEE 802.15.4g
  - IEEE 802.15.4g, also known as the Smart Utility Networks (SUN), was approved by IEEE in March, 2012
- Initially Japan focused, now expanding globally (US, South East Asia, India, Europe)
- Target smart utility use cases:
  - Gas metering; demand/response; distribution automation
- PHY layer based on IEEE 802.15.4g but the specification will be categorized based on use cases
  - Frequency: 868 MHz (EU), 915 MHz (USA), 2.4 GHz ISM bands (worldwide)
- MAC may be based on or not based on 802.15.4. Application dependent.

3 PHY formats supported:
- MR-FSK: 2FSK and 4FSK
- MR-OFDM: available but not popular
- MR-O-QPSK: DSSS and multiplexed DSSS



# IEEE 802.11 Standards Evolution

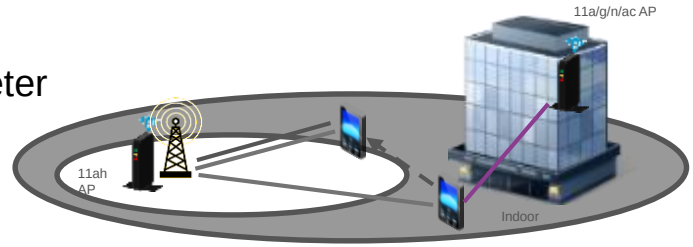



DSRC = Dedicated Short-Range Communications

# IoT Enabling Technologies

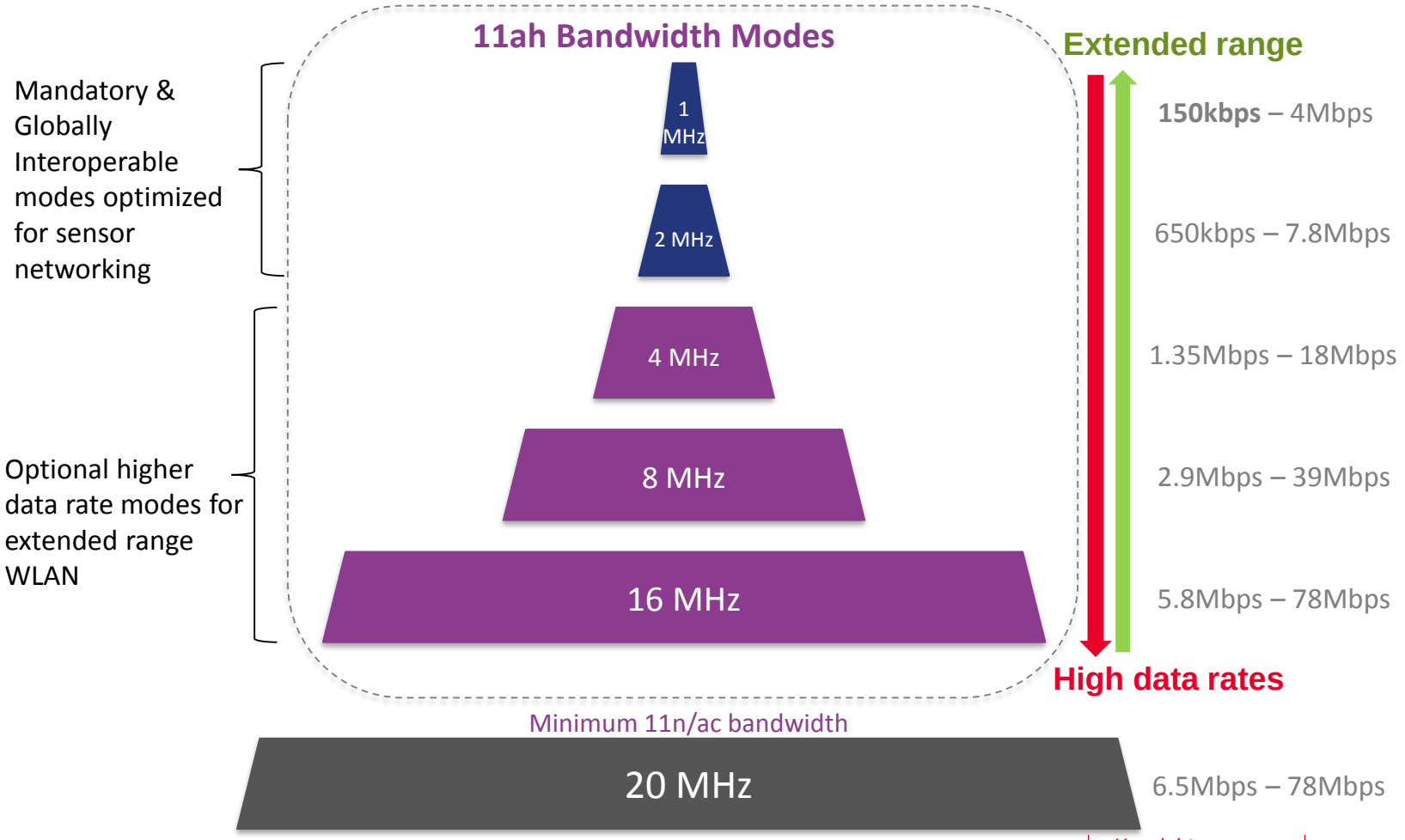
## IEEE 802.11ah – Middle 2016

- Optimized for IoT applications
- PHY/MAC – *trade-off of power, range, rate*
  - PHY based on 802.11ac with data rates > 100 kbps
  - Optimizations for highly robust links and low power consumption required for battery operated devices
  - Sub-1 GHz unlicensed bands
  - Range up to 1 km – beyond 2.4 and 5 GHz range due to improved propagation characteristics of sub-GHz radio waves
- Target use cases
  - Large scale low power sensor networks and smart meter
  - Video surveillance, wearable consumer electronics
  - Backhaul for aggregated sensor and meter data
  - Outdoor Wi-Fi for cellular traffic offloading



# IoT Enabling Technologies

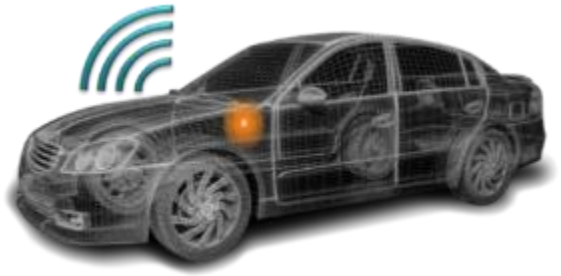
## IEEE 802.11ah Bandwidth and Data Rates



# IoT Key Enabling Technologies

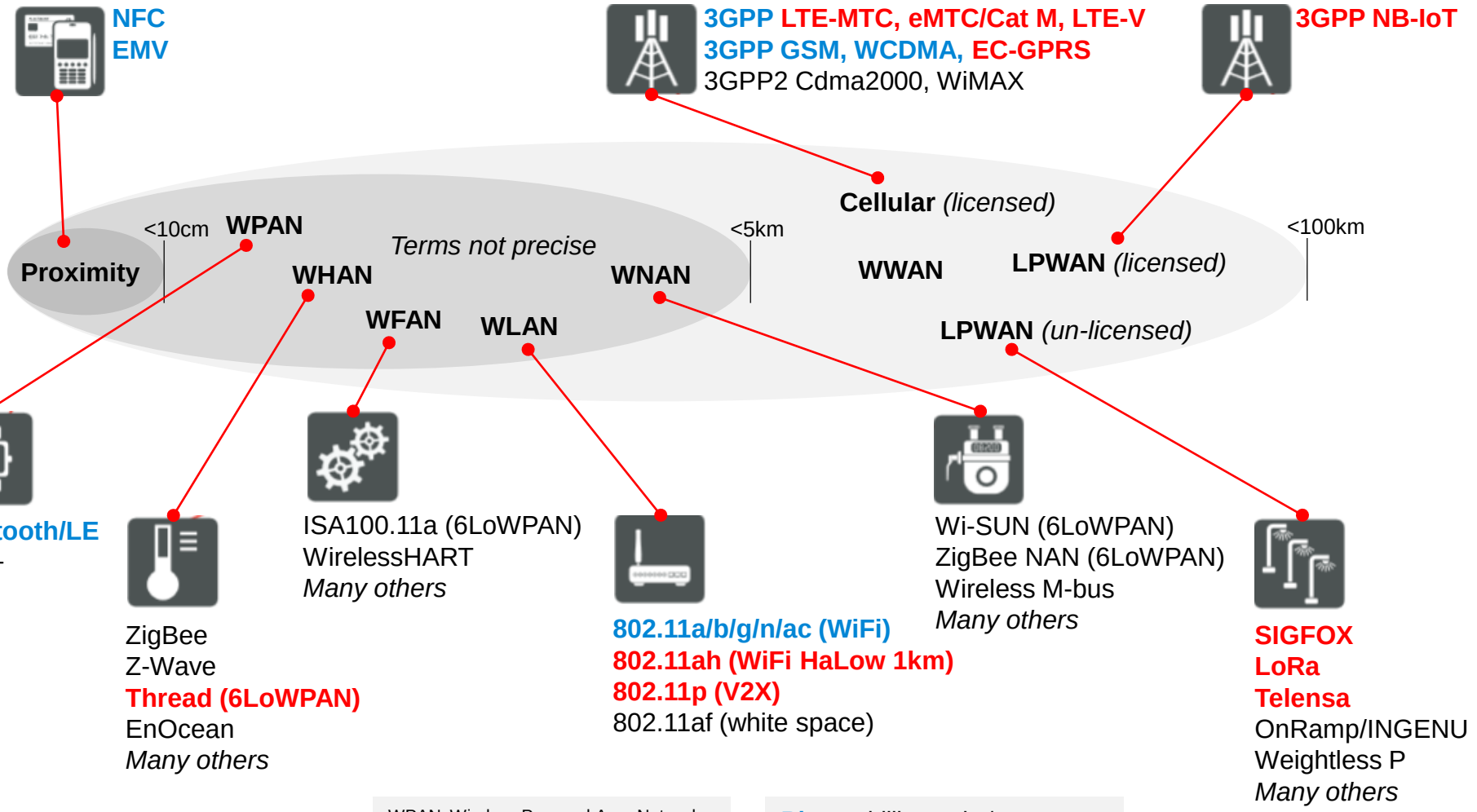
## IEEE 802.11p

- Adds a vehicular communication system to IEEE 802.11 WLAN standard -> Wireless Access in Vehicular Environment (WAVE)
- Supports low latency, Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2X) communication
  - Vehicle broadcasts its position and velocity and receives broadcasts of neighboring road users
  - Uses channels of 10MHz bandwidth in the 5.9GHz band (5.850-5.925 GHz)
  - Developed based on 802.11a but targets for reliable connection
- Main uses:
  - Vehicle safety services
  - Commerce transactions via cars
  - Toll collection
  - Traffic management



- USA, Europe, China, Japan, Korean and Singapore are working towards hard /soft mandate or MOU for dedicated short range communication (DSRC) installation.

# IoT Radios

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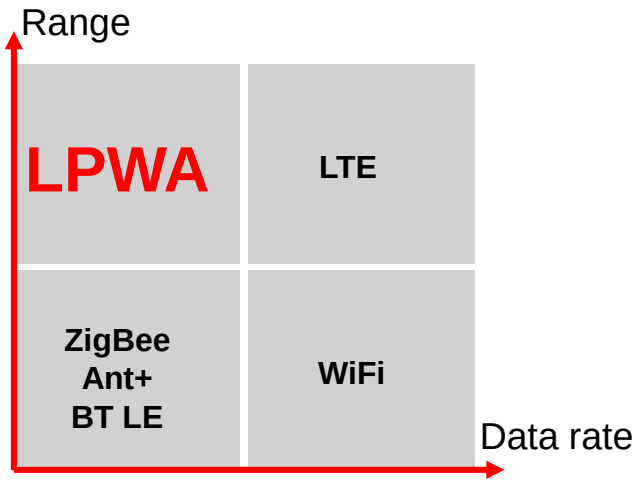
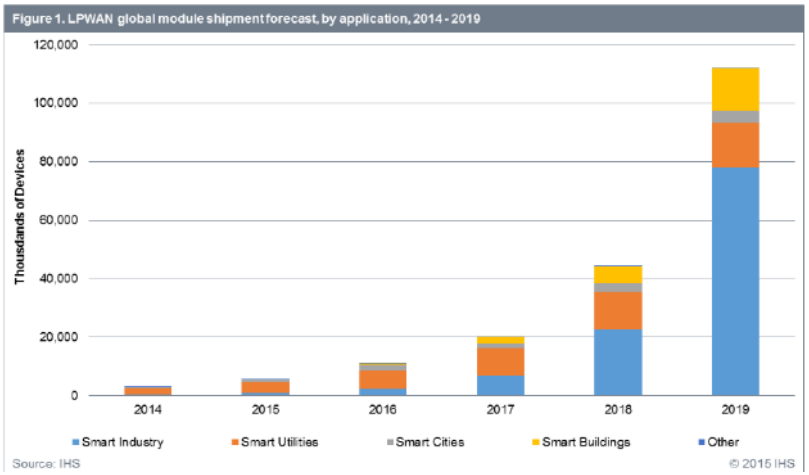
WWAN: Wireless Wide Area
LPWAN: Low Power Wide Area Network

**Blue:** > billion units/year now
**Red:** emerging

# Low Power Wide Area (LPWA)

**Narrow band + Robust modulation =**
- 20dB better link budget than cellular
- 10 year battery life, Very low data rates




**Coverage pools** → **Region coverage** → **Global coverage**

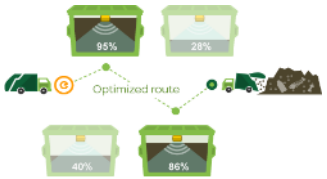
*Street lighting*

*Fire detection*

*Social housing monitoring*

*Parking sensor*

*Trash collection*




*Soil moisture*

*Pet tracker*

*Bag tracker*

*Bike tracker*

*Embedded asset status*

*Capital asset inventory*

*Usage statistics*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# Low Power Wide Area (LPWA)

## Unlicensed niche rollouts

*Funded multi-country multi-application rollouts*

SIGFOX

LoRa Alliance
Wide Area Networks for IoT


*Significant US, UK and Asia streetlight rollouts*

Telensa

*US potential TBC*

ONRAMP WIRELESS
ingenu

*Died, reincarnated, may not make it?*

WEIGHTLESS
nwave

## Licensed Global

*Preparing for 2017 LTE/GSM BS rollouts*


vodafone

Sprint

3GPP
A GLOBAL INITIATIVE

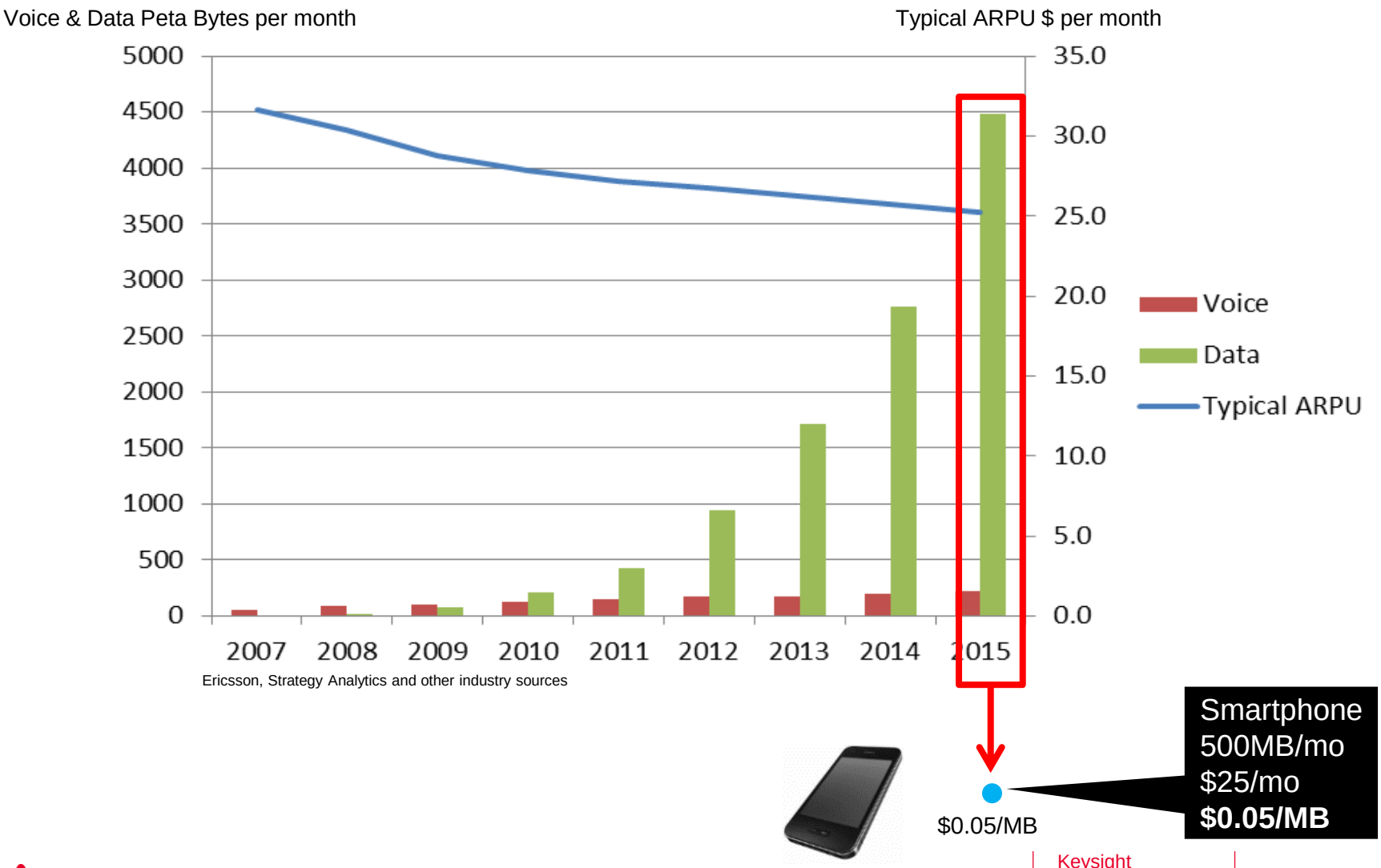
### 3GPP Release 13:

**Clean sheet:**
- **NB-IoT** 180kHz BW
- Huawei (HiSilicon/Nuel), Qualcomm, Intel, MTK all working on silicon for 2016 release
- LTE and GSM base station software upgrade
- Deploy in re-farmed GSM spectrum, dedicated fragmented spectrum and LTE guard bands

**LTE derivative**
- **LTE Cat 0 (or 00?)** 1.4MHz BW
- Altair, Sequans, probably others working on silicon
- LTE base station software upgrade

**GSM derivative**
- **EC-GSM** 200kHz BW
- Ericsson promoting
- GSM base station software upgrade

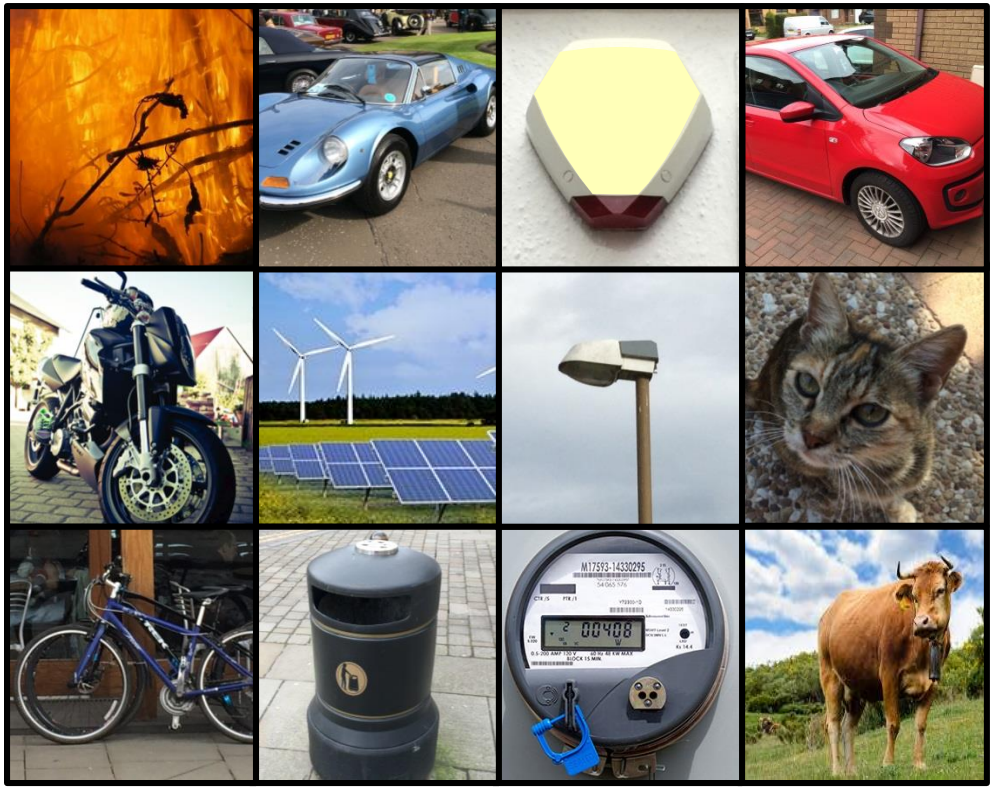
# Why is LPWAN attracting so much excitement?

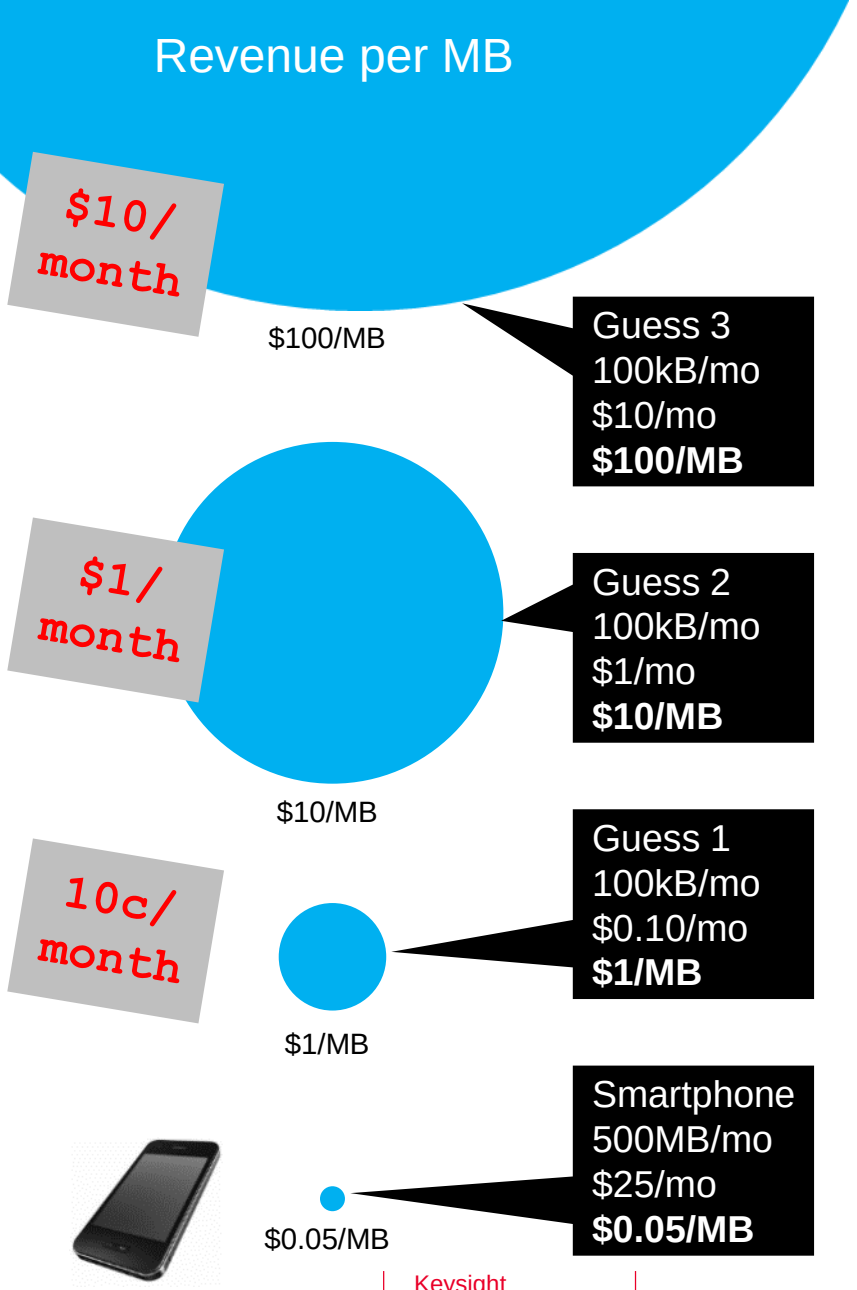


# It's a money maker!

## How much would you pay a month?

*Car, cat, bike, livestock, capital equipment tracker?*
*Building, fire, trash-can alarm?*
*Meter reader, lighting control?*





# IoT Key Enabling Technologies

## LoRa™(Long Range)

LoRa Alliance
Wide Area Networks for IoT

- LoRa is a Semtech technology for IoT
- Provides long range and low power wireless technology to connect low-cost, battery-operated sensors over long distances (10 miles range and > 10 years battery life)
- The LoRa Alliance was formed in February 2015. Release 1.0 of LoRaWAN specification was released to public on June 16, 2015
- **Applications:** smart city, sensor networks, industrial automation application

| Frequency (MHz) ISM Band | Bandwidth | Modulation Schemes | Range |
|---|---|---|---|
| 433 (Europe) | 125 kHz & 250 kHz | **LoRa*** (Chirp Spread Spectrum or CSS) **GFSK** | >15 km (9 miles) in a suburban environment and up to 5 km (3 miles) in a dense urban environment |
| 853-870 (Europe) | 125 kHz & 250 kHz | **LoRa*** (Chirp Spread Spectrum or CSS) **GFSK** | |
| 779-787 (China) | 125 kHz & 250 kHz | **LoRa*** (Chirp Spread Spectrum or CSS) **GFSK** | |
| 902-928 (North America) | 125 kHz & 500 kHz | **LoRa*** (Chirp Spread Spectrum or CSS) | |

* LoRa, Semtech's proprietary modulation, is a spread spectrum modulation scheme that is derivative of Chirp Spread Spectrum modulation (CSS) and which trades data rate for sensitivity within a fixed channel bandwidth.

LoRa Alliance
Wide Area Networks for IoT

# LoRaWAN™
## Products & Services

For Carrier Grade Low Power
Wide Area Solutions

LoRa Alliance
Wide Area Networks for IoT

KEYSIGHT TECHNOLOGIES

# Keysight

*Radio Test equipment*

Keysight vector signal analyzers and generator enable designers and manufacturers to verify the receiver and transmitter performance of wireless devices

Arbitrary waveforms based on model or capture data can be loaded and replayed at low signal levels to test receiver sensitivity

Transmitter spectrum occupancy can be verified. Vector Signal Analyzers can verify modulation metrics for GMSK. The 89601B FMCW Radar option can visualize and provide metrics for chirp modulated signals

Keysight Battery Drain Analysis tools enable developers to optimize software and hardware designs to extend battery lifetime

### LoRaWAN™ Ready
Yes

### Radio Regions
Europe 868 MHz
USA 915 MHz
Asia 470 MHz
433 MHz

### Focus Markets
- Signal generation and analysis
- Battery drain analysis
- Tools for R&D and manufacturing test

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Company: **Keysight**
Country: USA
Type: Test and Measurement tool provider
Commercial Contact: ian_reading@keysight.com
Technical Contact: ian_reading@keysight.com

# Wide area networks

## Technology Trade-offs

SIGFOX

### Pros:

- Long range
- Long battery life (up to 20 years)
- Low cost

### Cons:

- New standard
- Unlicensed band - interference
- Can't run on existing cellular network – needs a dedicated SIGFOX network
- Very low data rate - can only be used for IoT

LoRa Alliance
Wide Area Networks for IoT

### Pros:

- Long range
- Long battery life (>10 years)
- Low cost
- Uses cellular network as backhaul

### Cons:

- New standard
- Unlicensed band - interference
- Very low data rate – can only be used for IoT

3GPP

### Pros:

- Well established standards
- Long rage
- High data rate
- Very wide coverage
- Licensed band (except LTE-U)

### Cons:

- Not optimized for IoT
  - Battery life
  - Cost

# Key 3GPP Release 13 updates

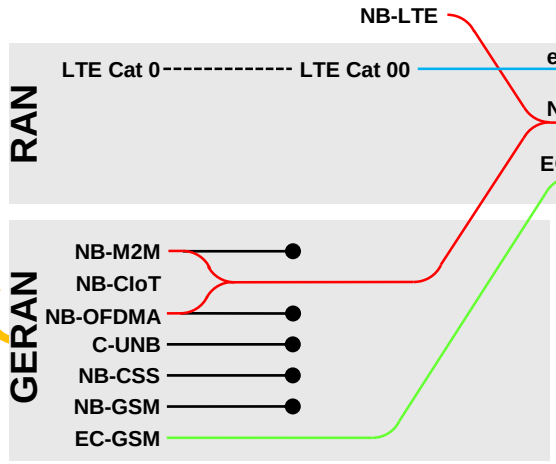
**Clean sheet:**
- **NB-IoT** 180kHz BW
- LTE and GSM base station software upgrade
- Trial service 2016, commercial service 2017

**LTE derivative**
- **LTE Cat M** 1.4MHz BW
- LTE base station software upgrade
- Commercial service 2017

**GSM derivative**
- **EC-GSM (EC-GPRS)** 200kHz BW
- GSM base station software upgrade
- Commercial service TBC

# 3GPP Release 13 Cellular IoT timelines

**GERAN Objectives**
- 164dB link budget (GPRS +20dB)
- 40 devices per home (~50k/cell)
- >160bps at range limit
- 10 second latency
- 10 year life with 5Wh ~AA battery




3GPP Rel 13

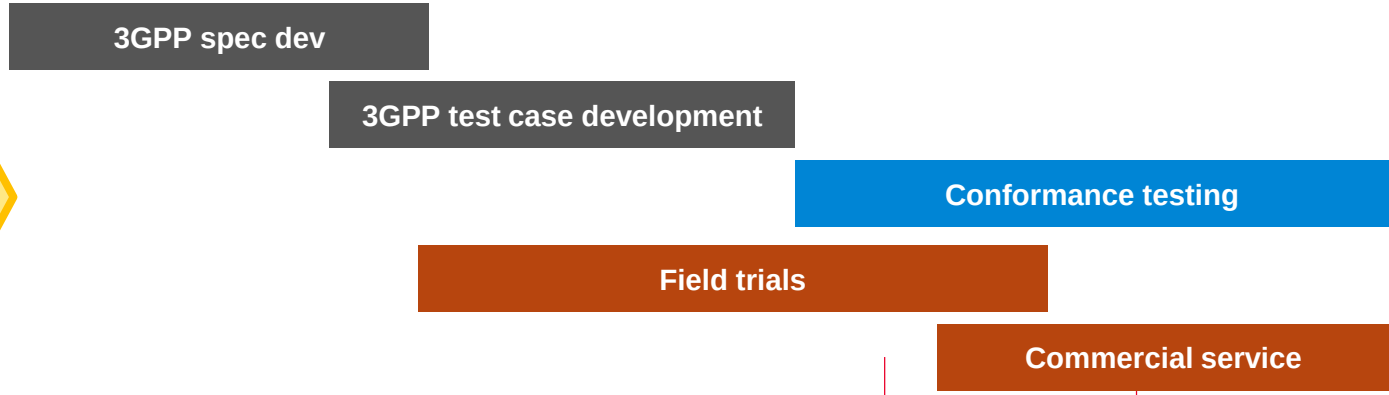
March-June 2016

**eMTC Cat M:**
- Machine Type Communication
- 1.4MHz Bandwidth LTE derivative
- Software update to LTE infrastructure
- 1Mbps, full mobility, 156dB link, 10 year batt

**NB-IoT:**
- Narrowband IoT
- 200 (180kHz) Clean sheet format
- Software update to LTE or GSM infrastructure
- <~250kbps, nomadic, 164dB, 10 year batt

**EC-GPRS**
- Extended coverage GPRS
- 200kHz GSM/EDGE
- Repetitions to get to 164dB link budget
- EC-PDTCH and EC-PACCH, ~52 min DRX
- Software update to GSM infrastructure


**GSMA Mobile IoT initiative backed by 21 MNOs:**
AT&T, Bell Mobility, Bermuda Digital Comm, China Telecom, China Unicom, China Mobile, Deutsche Telekom, Etisalat, KDDI, KT, Mobistar, NTT DoCoMo, Orange, Singtel, Softbank, Taiwan Mobile, Telecom Italia, Telefonica, Telenor, Telstra, Verizon, Vodafone

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# 3GPP Cellular IoT summary

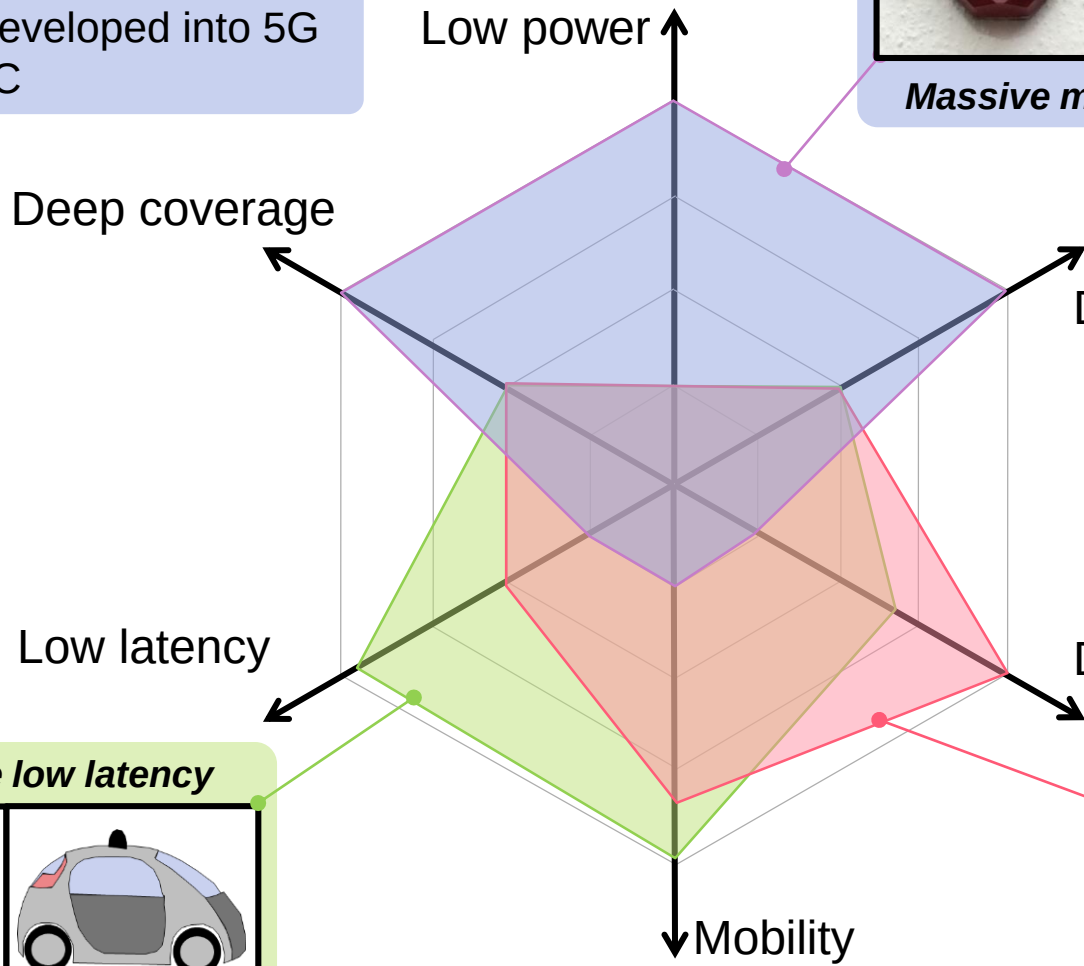
| | 3GPP Rel 12 | 3GPP Rel 13 | | |
|---|---|---|---|---|
| | MTC Cat 0 | eMTC Cat M* | EC-GPRS | NB-IoT* |
| **Heritage** | LTE | LTE | GSM | Clean-slate |
| **Bandwidth (downlink)** | 20 MHz | 1.4 MHz | 200 kHz | 180kHz (12 by 15kHz) |
| **Bandwidth (uplink)** | 20 MHz | 1.4 MHz | 200 kHz | Single-tone (180kHz by 3.75kHz or 15kHz) or multi-tone (180kHz by 15kHz) |
| **Multiple access (downlink)** | OFDMA | OFDMA | TDMA | OFDMA |
| **Multiple access (uplink)** | SC-FDMA | SC-FDMA | TDMA | Single-tone FDMA or multi-tone SC-FDMA |
| **Modulation (downlink)** | QPSK, 16QAM, 6 4QAM | QPSK, 16QAM, 64 QAM | GMSK, optional 8PSK | BPSK, QPSK, optional 16QAM |
| **Modulation (uplink)** | QPSK, 16QAM | QPSK, 16QAM | GMSK, optional 8PSK | TBC π/4-QPSK, rotated π/2-BPSK, 8PSK optional 16QAM |
| **Peak data rate** | 1 Mbps | 1 Mbps | 10 kbps to 240kbps TBC | DL up to 250kbps TBC, UL single tone up to 20 to 64kbps TBC, UL multi-tone up to 250kbps TBC |
| **Coverage (link budget)** | ~141dB | ~156dB | ~164dB | ~164dB |
| **Mobility** | Full | Full | Full | Nomadic |

Note * Cat M also currently referred to as Cat M1, NB-IoT also referred to as Cat M2. Details for NB-IoT are subject to change as 3GPP drafting continues

# NB-IoT 5G context

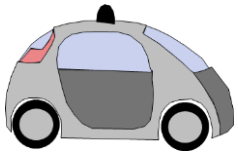
NB-IoT is a pre-5G technology likely to be developed into 5G massive MTC

***Massive machine type communications***



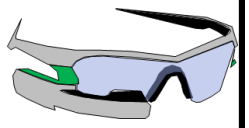

***Ultra reliable low latency***

*Drones*



*Vehicles*

***Enhanced mobile broadband***



*VR & AR*

*Smartphones*

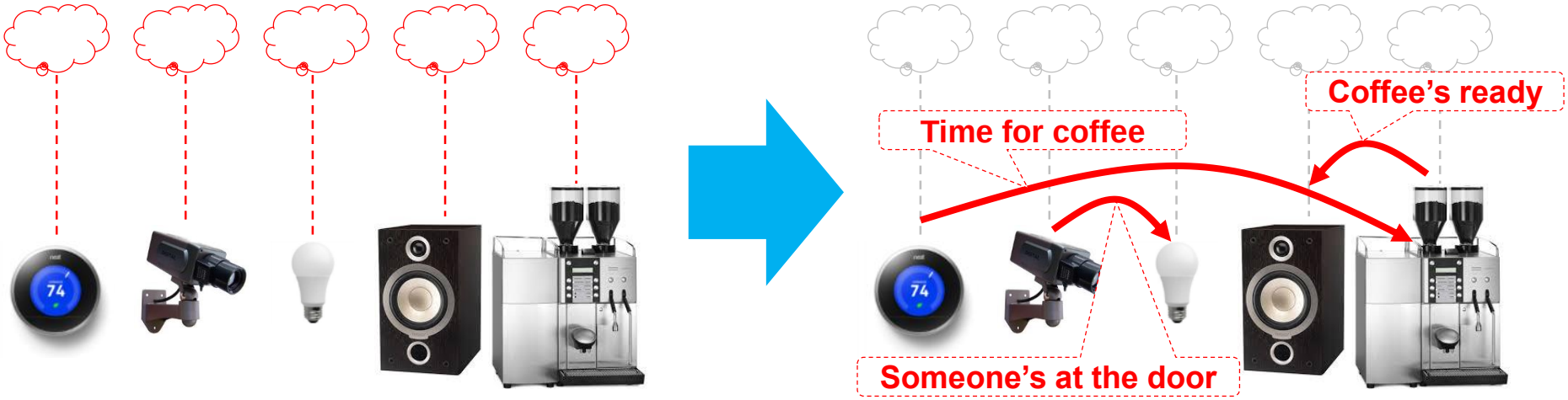
KEYSIGHT TECHNOLOGIES

# Local Interworking

## Device discovery, publish, subscribe

***Competing consortia***

| AllSeen Alliance (Qualcomm) | Open Interconnect Consortium (Intel) | Apple HomeKit | Google Weave |
|---|---|---|---|
| ALLSEEN ALLIANCE AllJoyn<br>Open source<br>Qualcomm, Sharp, Sony, Cisco, Microsoft, LG……. | OPEN INTERCONNECT CONSORTIUM IoTivity<br>Open source<br>Intel, Samsung. GE, Cisco, Broadcom, IBM…. | HomeKit | Google WEAVE |

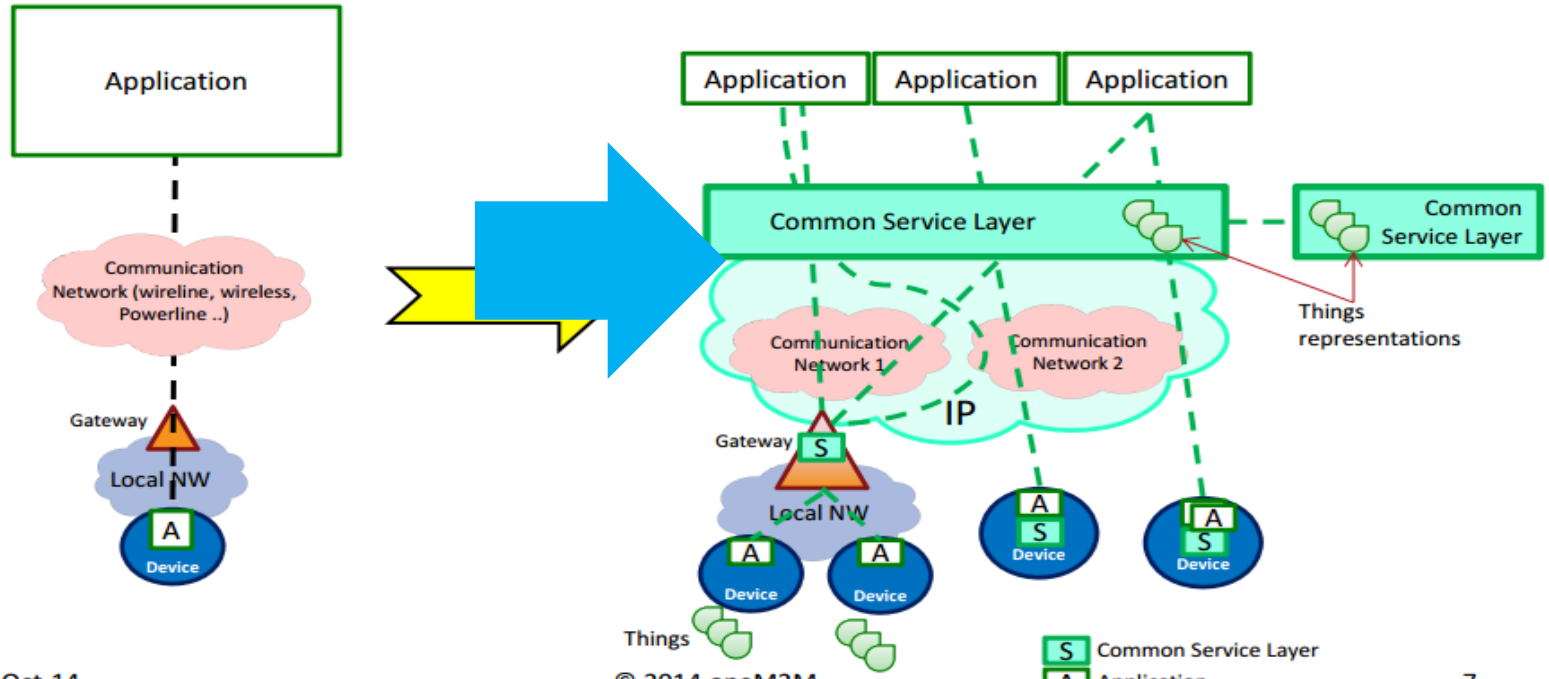


# Global Interworking

*"If Company A runs a fleet of trucks and Company B runs a fleet of container ships then their mutual customer, Company C, can use one application to track the cargo, regardless of the handler"*

## OneM2M

- Formed July 24th 2012, Founding partners: **ARIB, ATIS, CCSA, ETSI, TIA, TTA, TTC**
- Reference architecture and conformance test regime for a common service layer for global interworking
- Focus is edge to cloud so good synergy with Allseen & OIC. Also looking at HomeKit interworking
- CoAP, MQTT, DTLS, OMA LWM2M

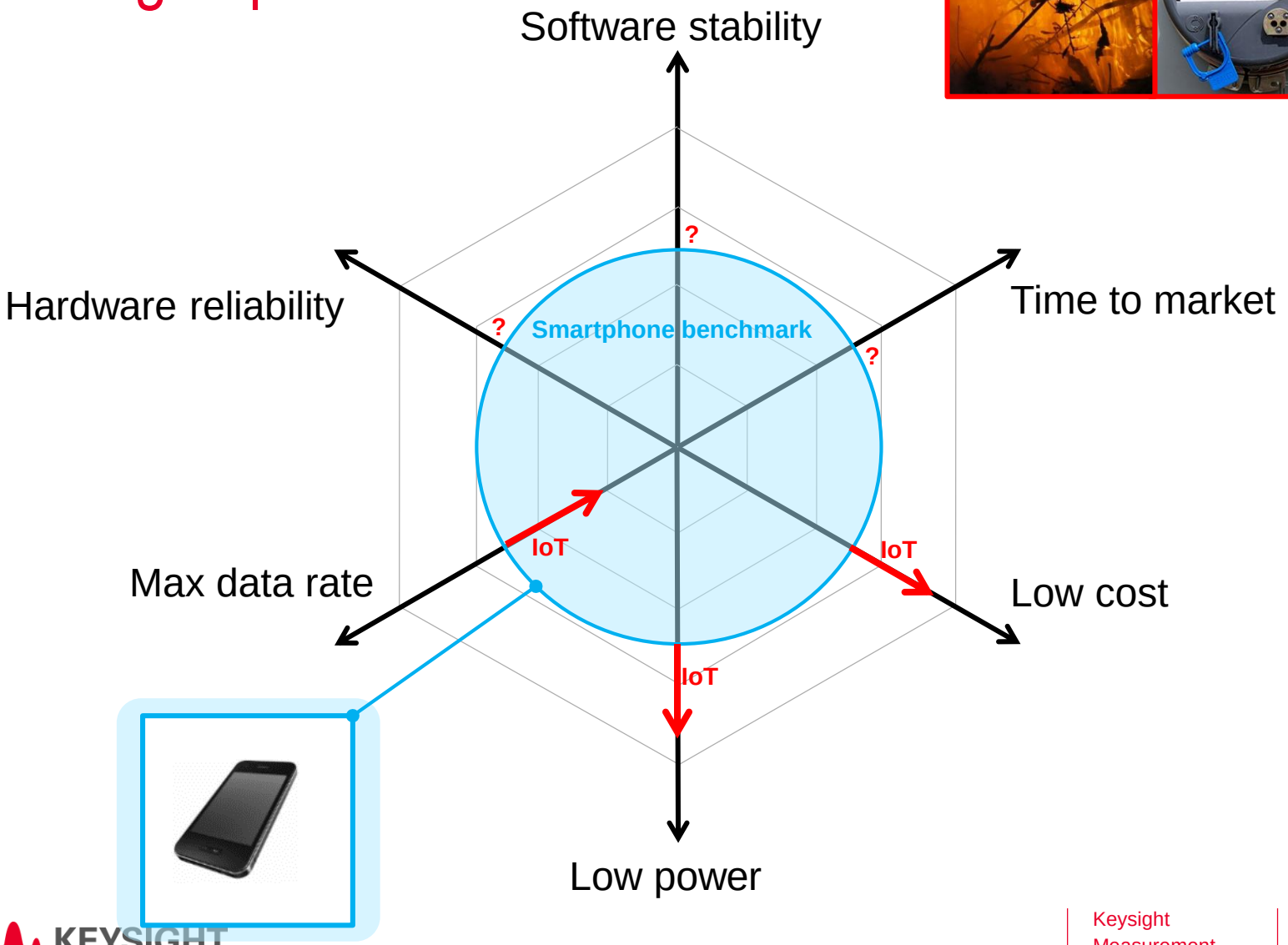


# Agenda

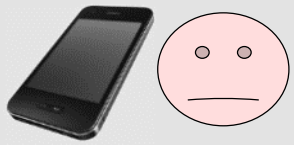
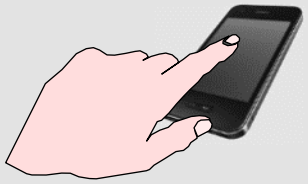


- **IoT/M2M Introduction and Market Situation**
- **IoT/M2M Key Enabling Wireless Technologies**
  - IEEE 802 LAN/MAN Working Group
  - Wide area networks (LPWAN) and NB-IoT
- **IoT Optimization and test challenges**
  - Optimization
  - Interference & operating environment replication
- **Summary**

# Design optimization

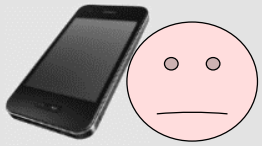
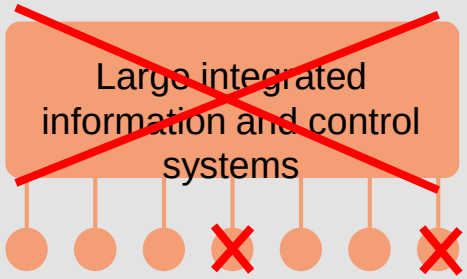
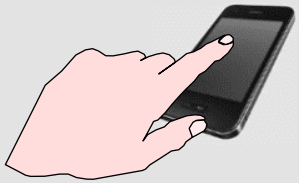


# Design optimization

| | Smartphone | Critical IoT |
|---|---|---|
| Failure impact |  | Large integrated information and control systems<br>Distributed sensors/actuators |
| Repair |  <br>User powers off/on<br>User recharges<br>Unlimited software updates |  <br>Onsite repair to reset and/or replace prematurely drained battery<br>Battery constrains software updates |

- How often do you need to power cycle your smartphone?
- Have you ever experienced an app or network problem that drained the battery?
- What was the cost to repair… power off/on or recharge the battery until software fixed?
- Large systems may only be as good as the weakest (IoT) element
- Repair can involve expensive onsite visit

# Design optimization

| | Smartphone | Critical IoT |
|---|---|---|
| Failure impact |  |  |
| Repair |  <br>User powers off/on<br>User recharges<br>Unlimited software updates |  <br>Onsite repair to reset and/or replace prematurely drained battery<br>Battery constrains software updates |

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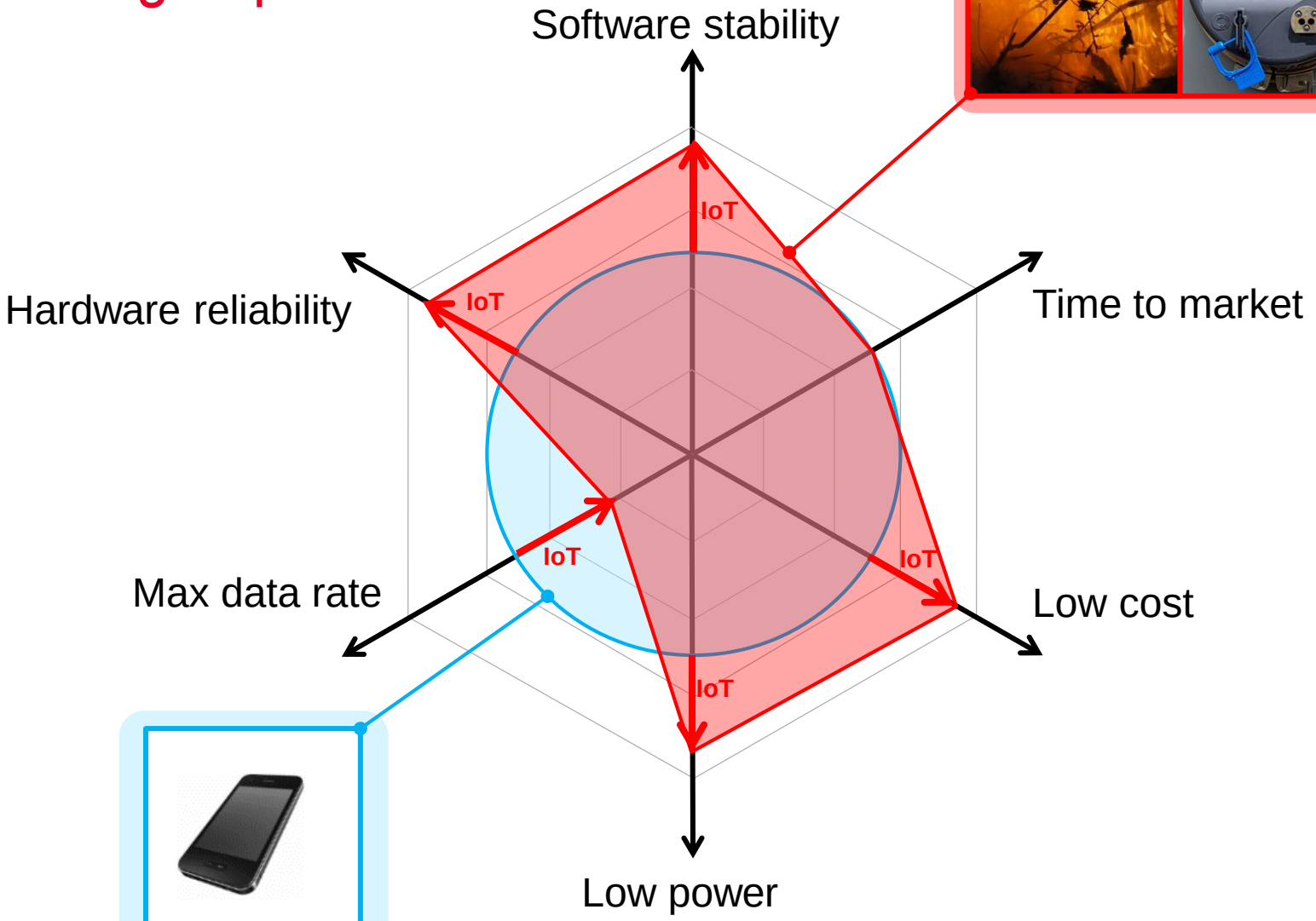
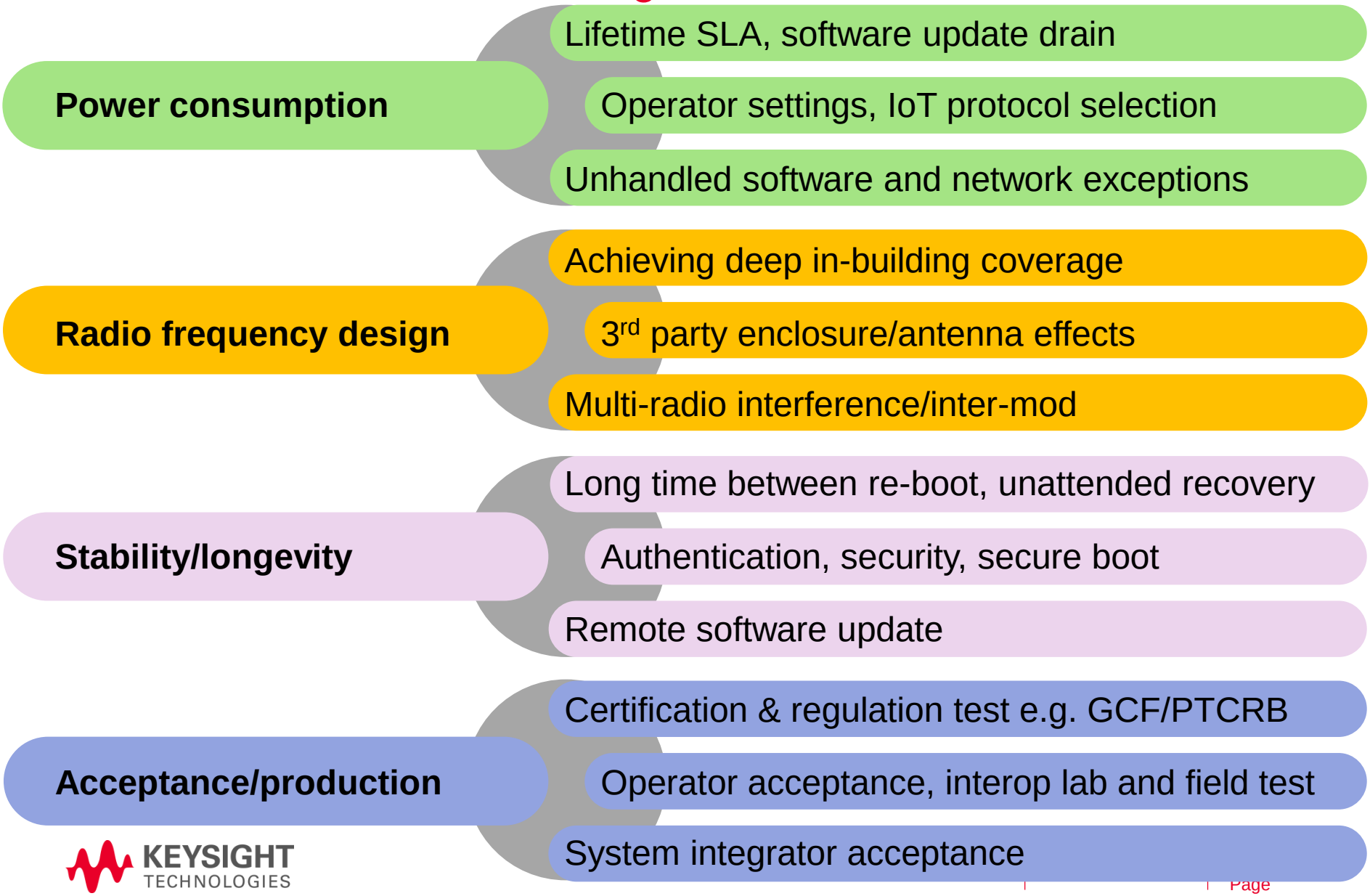
# Design optimization




# IoT Verification Challenges




KEYSIGHT TECHNOLOGIES

# Example applications

**Power consumption**

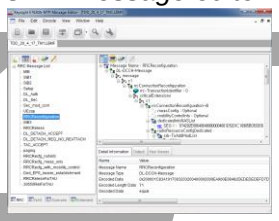
**Radio frequency design**

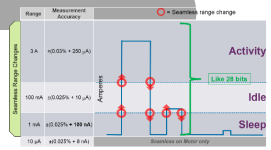
**Stability/longevity**

**Acceptance/production**

UXM

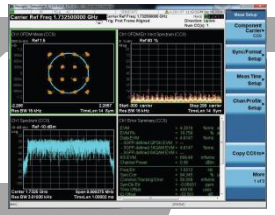
UXM message editor






Source Measurement Unit

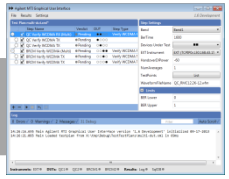
UXM RF Meas'



GP RF test tools

Antenna test systems

UXM built-in app server



Test Automation Platform (TAP)

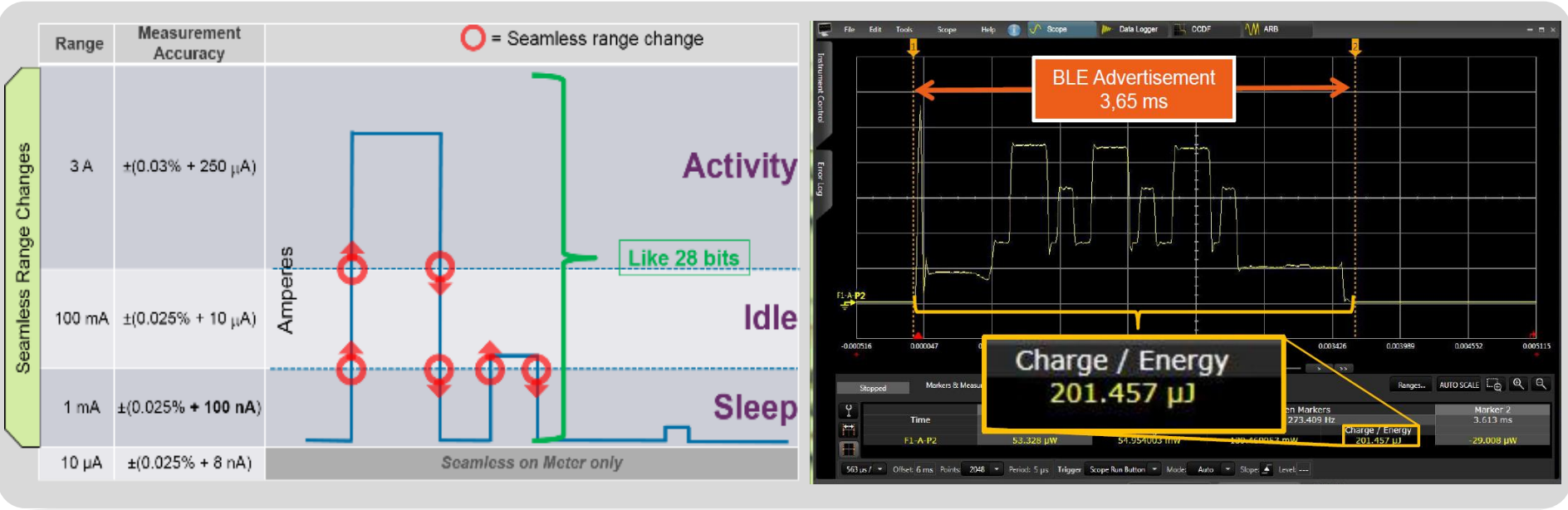
T4000S RCT/RRM operator RF

EXM high volume mfg

Anite protocol and operator test

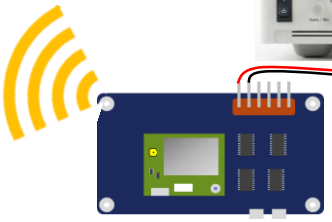
KEYSIGHT TECHNOLOGIES

# Power consumption analysis



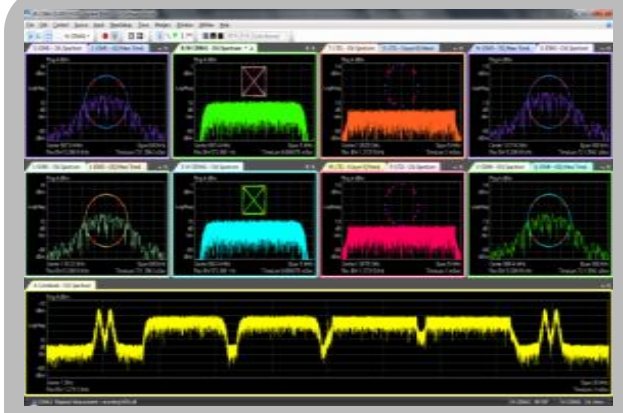

*Golden device*

*N6705B with Source Measurement Unit*



*Device under test*

# Probing for insight

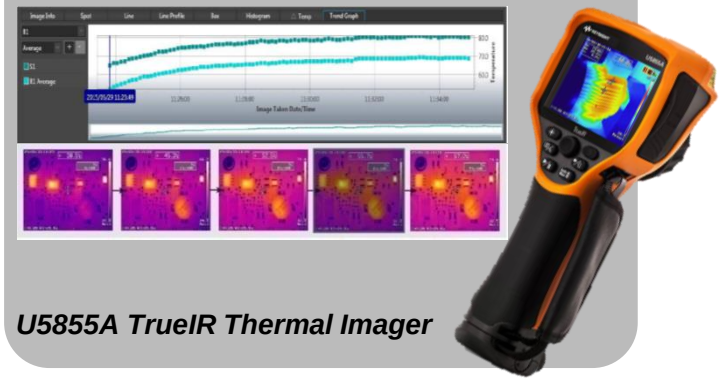


*89601B VSA Software*

*Infiniium S-Series oscilloscopes*

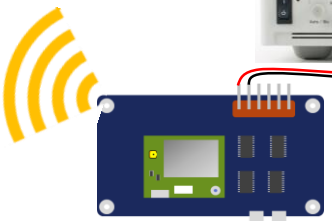
*N2820A 3 MHz/50uA High Sensitivity AC/DC Current Probe*

*N9010B EXA Signal Analyzer, Multi-touch, 10 Hz to 44 GHz*



*U5855A TrueIR Thermal Imager*

*N6705B with Source Measurement Unit*

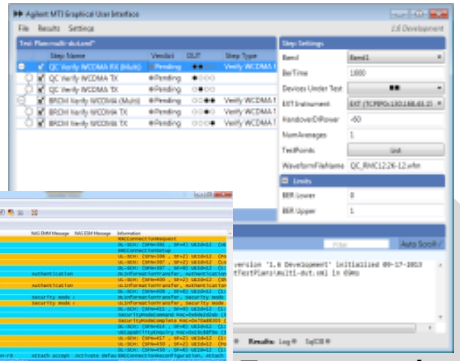


*Device under test*

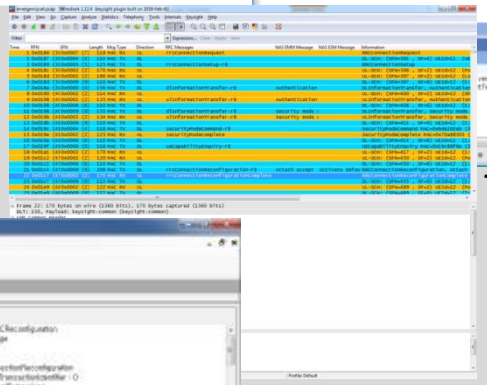
# Base station and network emulation

## Keysight UXM Wireless Test Set

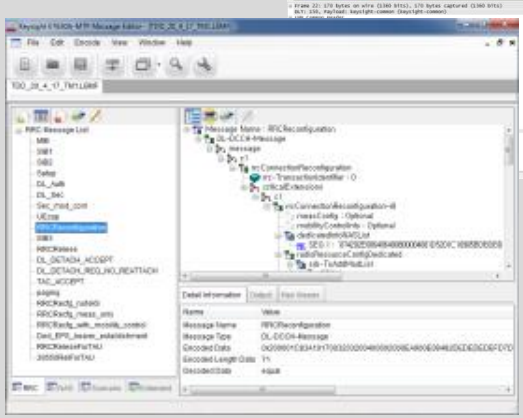
- 300MHz to 6GHz Multi-format base station emulation
- Built-in server PC to host cloud & remote end-point apps
- End to end IP connection to internet
- IMS support
- Tx and Rx measurements
- Built-in channel emulator (fader)



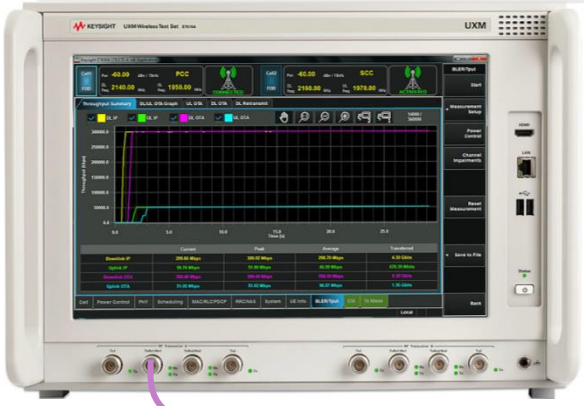
*Test automation*



*Wireshark logging*

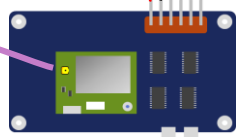


*Protocol message editor*



*UXM Wireless Test Set*

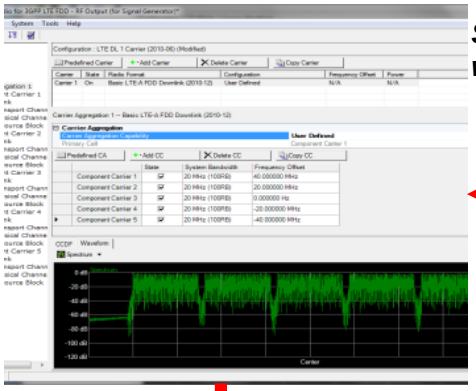
*N6705B with Source Measurement Unit*



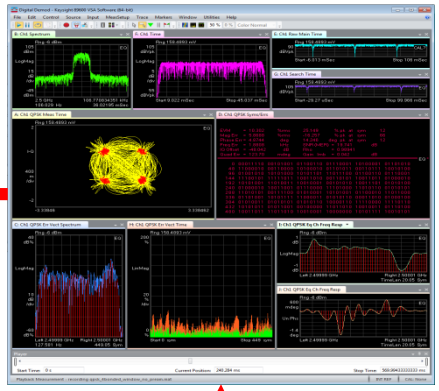
*Device under test*

KEYSIGHT TECHNOLOGIES

# RF Design verification



*Signal Studio & waveform creator*



*89601B Flexible VSA*

*Replay and edit captured waveforms*

*X-series measurement applications*

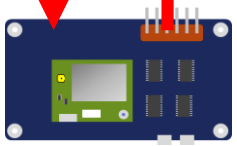
*arb*

*Matlab*

*Rx test*

*Tx test*

*M9420A VXT PXIe Vector Transceiver*



*Device under test*

**M9420A VXT PXIe Vector Transceiver**

- 60MHz to 6GHz
- 160MHz channel bandwidth

**Complement with:**

- Vector Network analysers
- Microwave sources and analyzers
- Power supplies
- Software, fixtures, systems, services

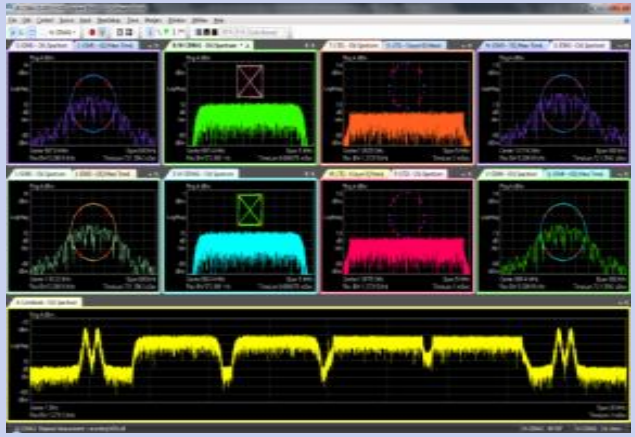
**Broadest format coverage**

- LTE-A, GSM, WCDMA, cdma2000
- eMTC Cat M and NB-IoT TBC
- GNSS
- 802.11a/b/g/n/ac/p/j/ah/af
- 802.15.4 (Zigbee, Thread/ 6LoWPAN)
- Bluetooth/BLE, Z-Wave, ANT+
- Wireless M-Bus, LoRa, SIGFOX & many others

# Vector Signal Analysis and Generation

## Signal Analysis

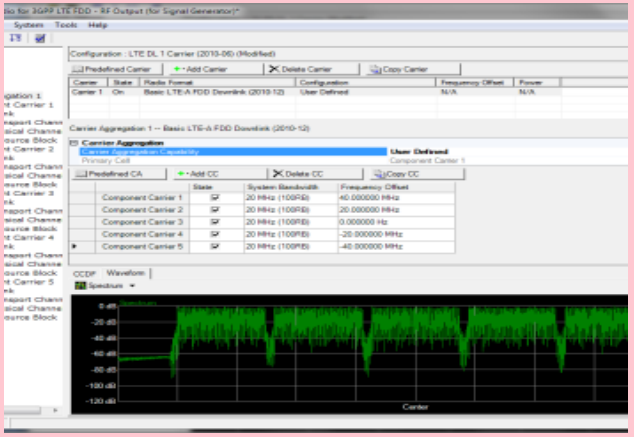
### 89600 VSA Software

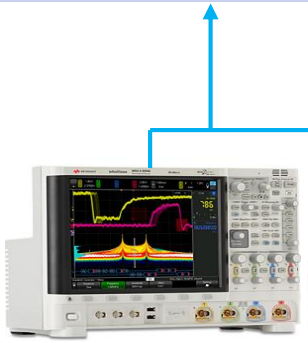


### X-Series Application


## Signal Generation

### Signal Studio & Waveform Creator





InfiniiVision
Oscilloscopes

X-Series Analysers
e.g. MXA

Modular
e.g. VXT

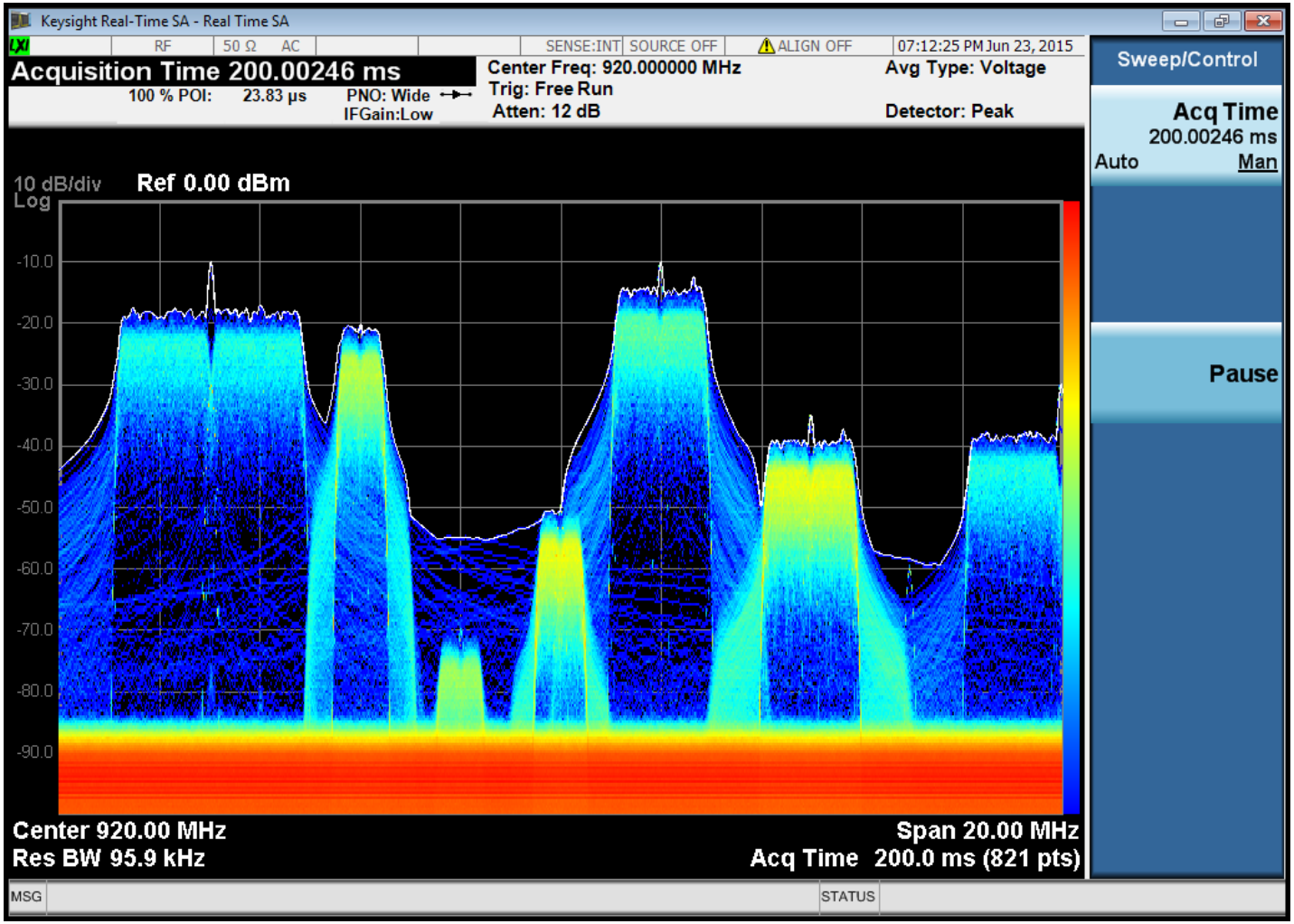
Integrated Test sets
e.g. EXM & EXF

X-Series Generators
e.g. MXG

KEYSIGHT TECHNOLOGIES

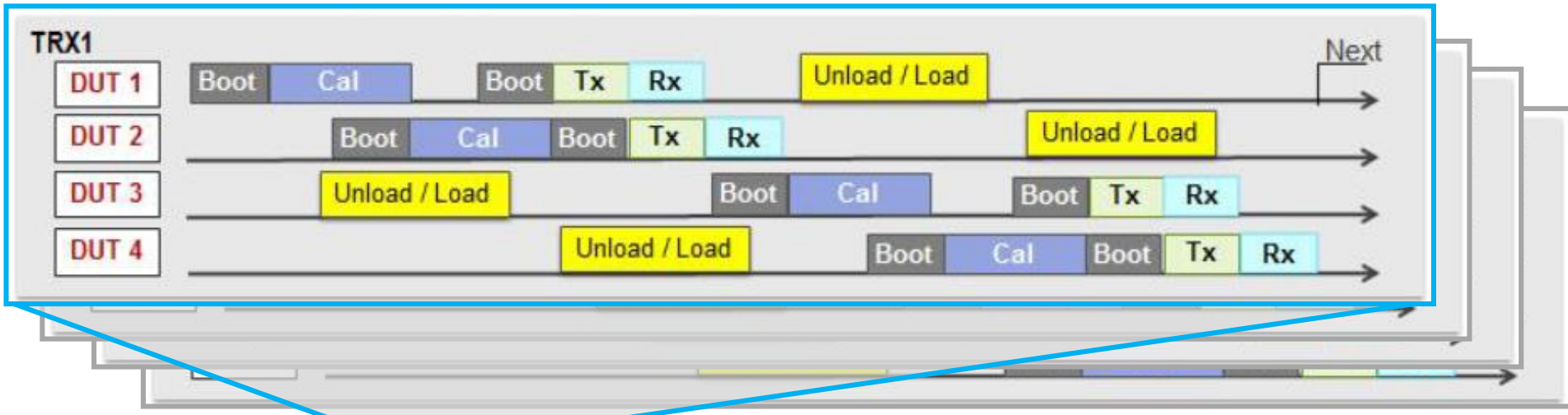
# Test Challenges (Interference)

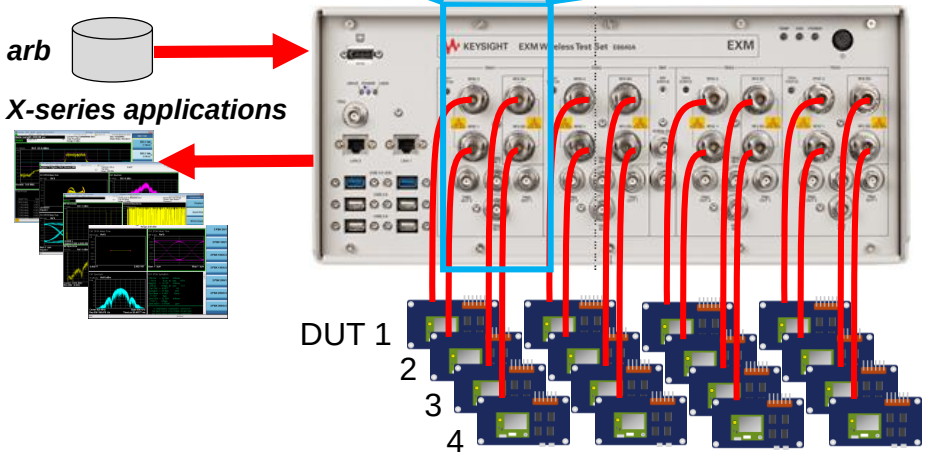
## Some Common Test Challenges for IoT




Sensor Networks – Up to 8,000 devices (sensors) may connect to a single AP

# Production ramp




**E6640A EXM Wireless Test Set**

- High speed sequencer
- Overlap/parallel Ping-Pong and pipelined testing
- Scalable and upgradeable from 1 to 4 TRX
- Port switching, robust N-connectors
- Broadest format coverage with arb files and X-Apps
- Systems, software, consulting and services

# Keysight Technologies


*Modelling tools*

*Network Analyzers*

*Anite*

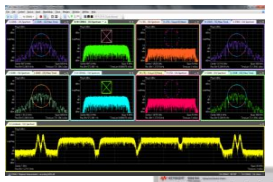
*Propsim channel emulator*

*A9000 protocol conformance test*


*i3070 test systems*

*FieldFox*

| R&D | Design validation | Compliance | Manufacturing | Deployment |
|---|---|---|---|---|
| Modelling | RF performance | OTA | IC | Spectrum clearance |
| PHY/RF | Throughput | Lab IOT | Module | Installation |
| L2/L3 | Battery Drain | Operator | Product | Optimization |
| Apps | Stress | GCF/PTCRB | Sample | Repair |
| Integration | Regression | Regulations | Debug | Operations |



*VSA/VSG*

*Thermal test*

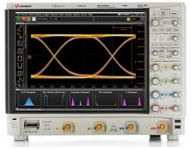
*UXM Wireless Test Set*

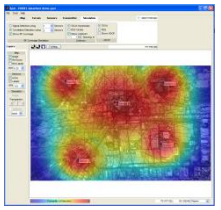
*Source measurement units*

*RF & RRM conformance*

*EXM Wireless Test Set*

*Oscilloscopes*





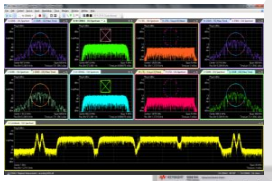
*Spectrum regulation and network optimization tools*

# Keysight Technologies

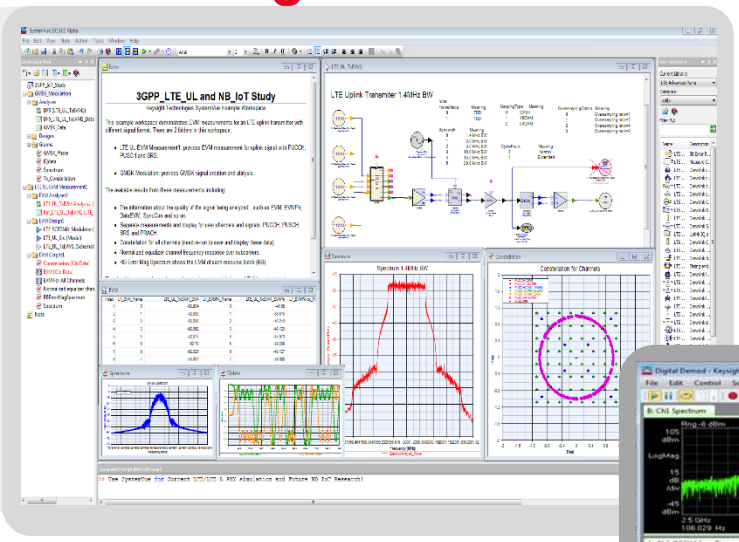

*Modelling tools*

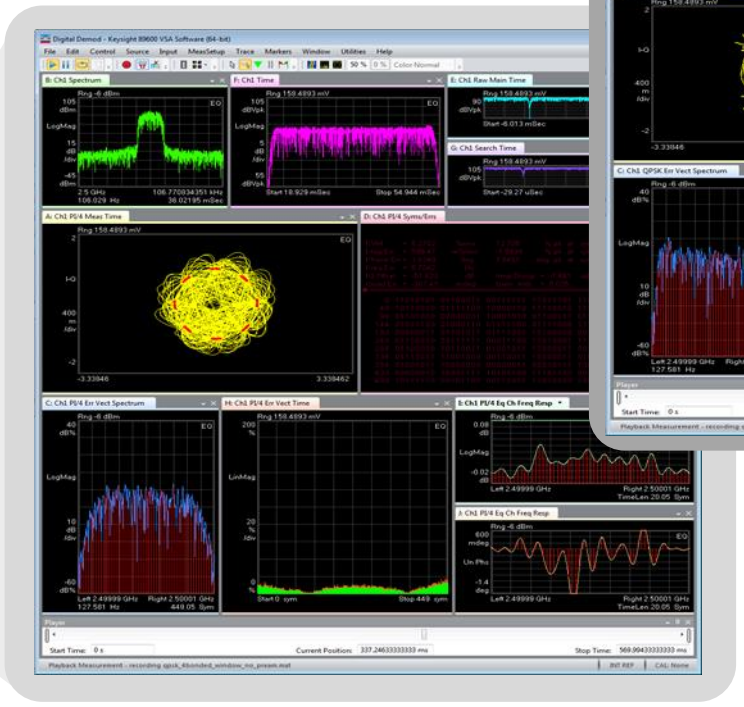
**R&D**

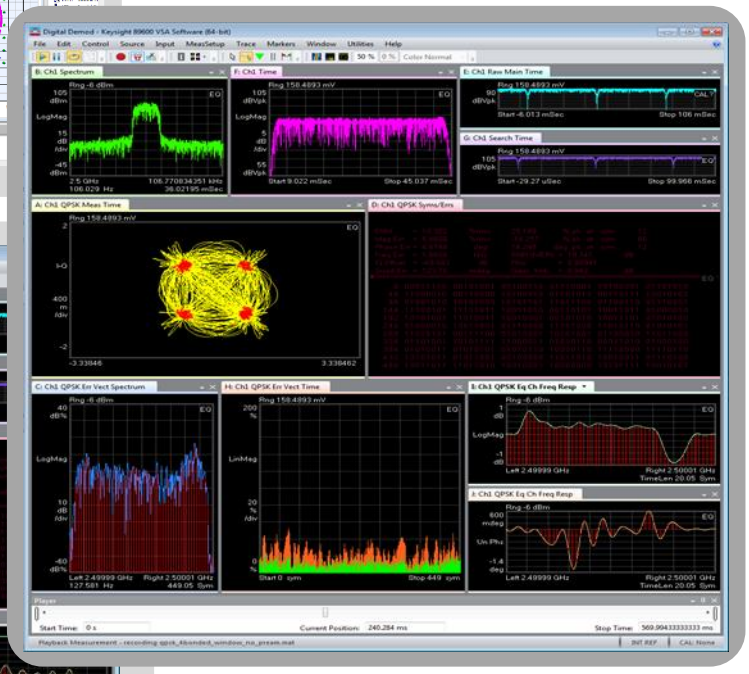
- Modelling
- PHY/RF
- L2/L3
- Apps
- Integration



*VSA/VSG*





*Pre-standard NB-IoT simulation and signal analysis*

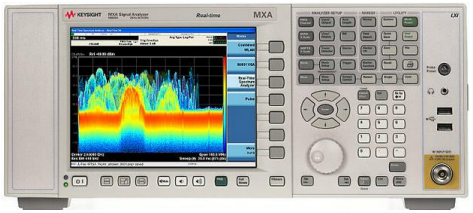
# Test Instrument Used for Drone Testing

Power Meter

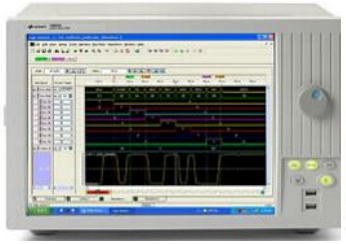
Power Analyzer

Scope

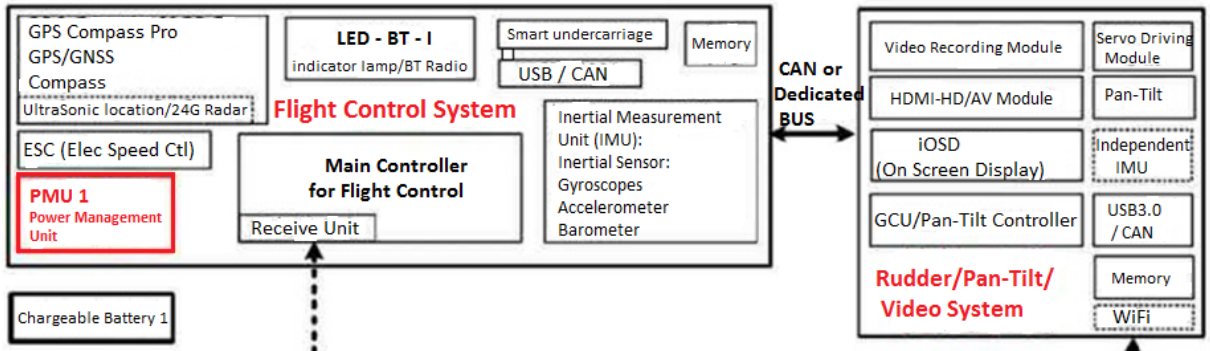
Network Analyzer



Signal Analyzer



Logic Analyzer




DMM

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Signal Generator

HH Meter

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# Q and A Session