Wireless network evolution
&
Internet of Things

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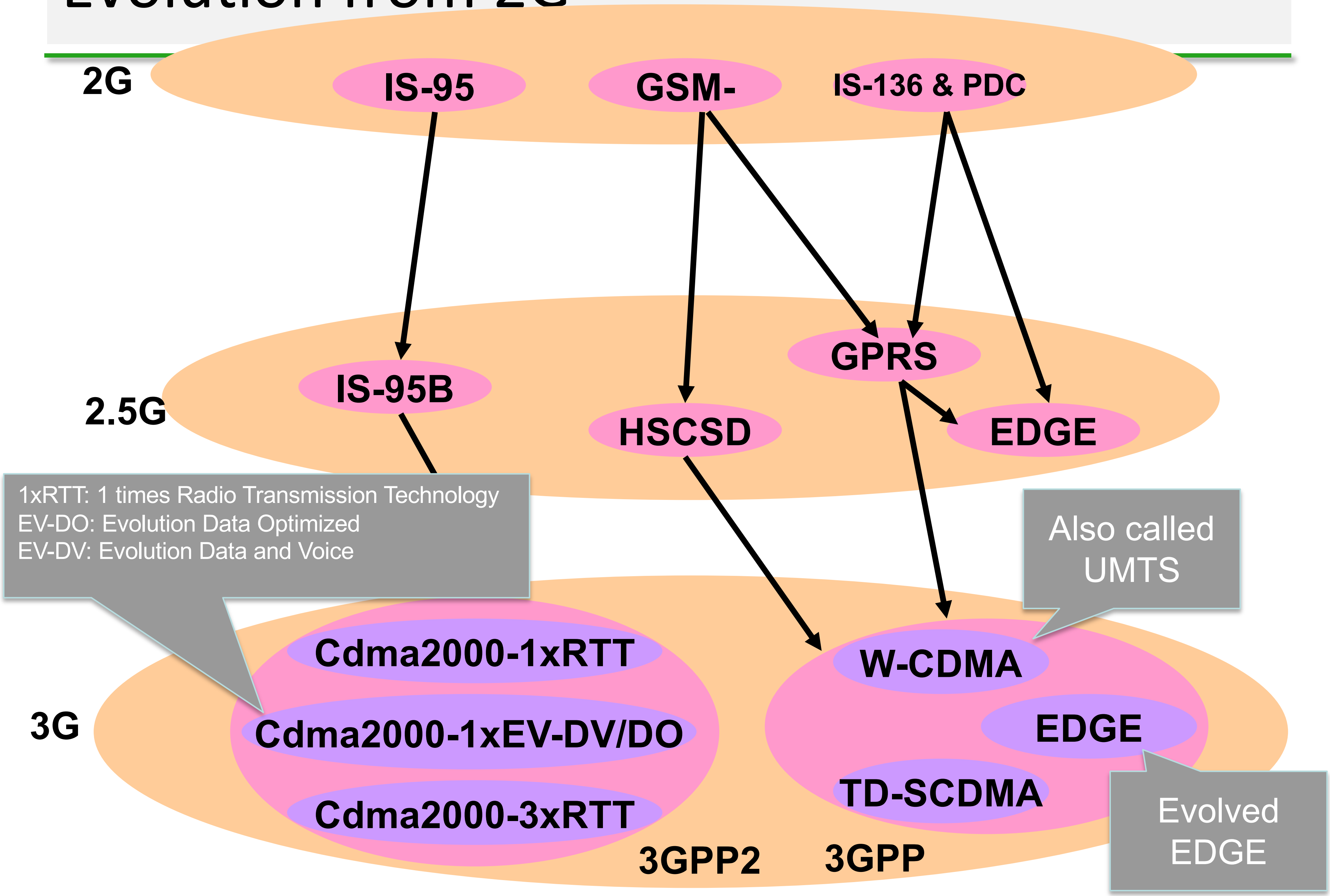
Cellular Network Generations

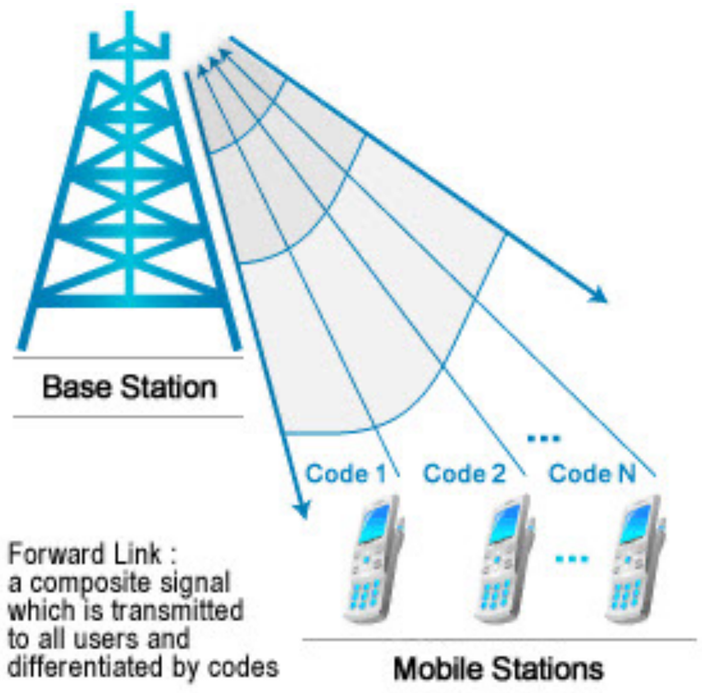
- It is useful to think of cellular Network/telephony in terms of *generations*:
  - 0G: Briefcase-size mobile radio telephones
  - 1G: *Analog* cellular telephony
  - 2G: *Digital* cellular telephony
  - 3G: *High-speed* digital cellular telephony (including *video telephony*)
  - 4G: IP-based “anytime, anywhere” voice, data, and multimedia telephony at *faster* data rates than 3G
  - 5G: more throughput, smaller latency, M2M, IoT,…

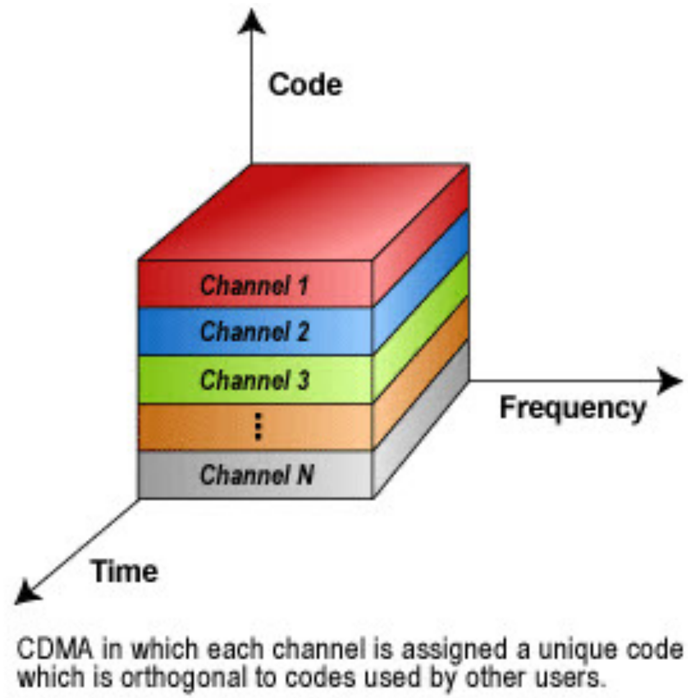
Evolution from 2G



CDMA

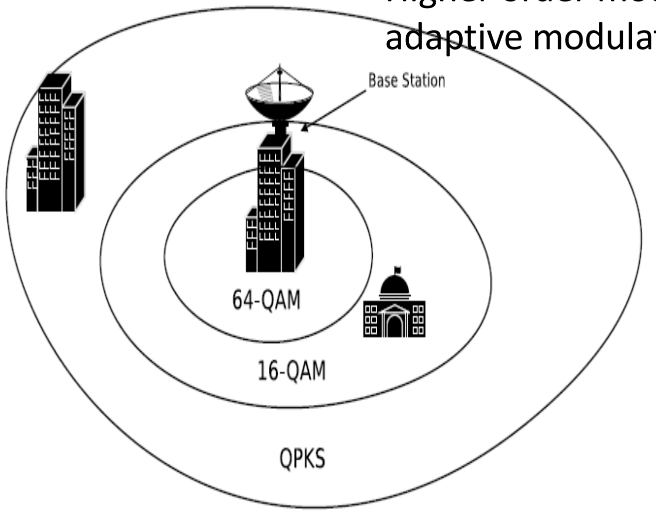
- Allow usage of the whole bandwith for each end-user
- Orthogonal spread spectrum code

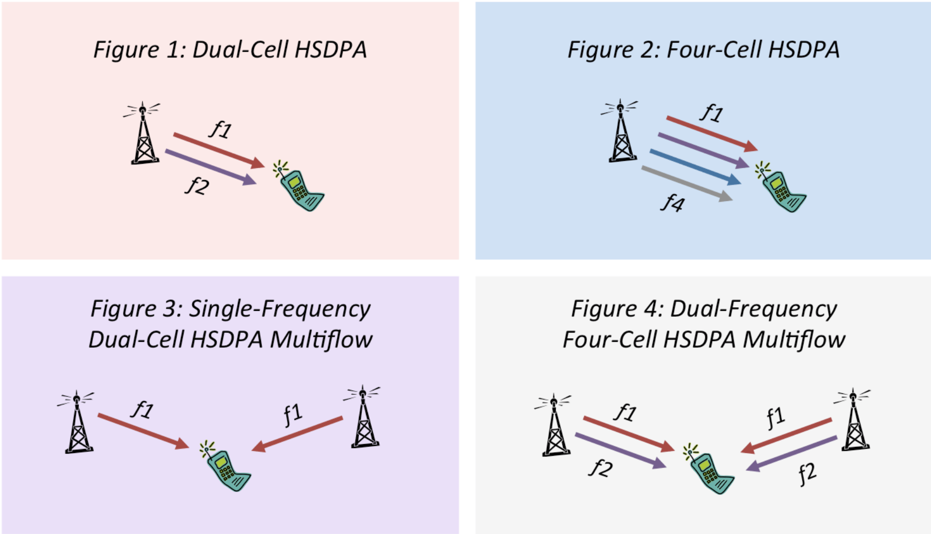




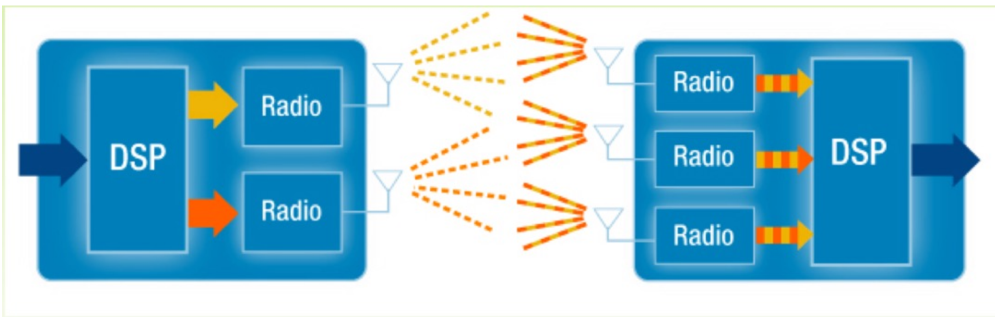
(some) key technologies

Higher order modulation and adaptive modulation

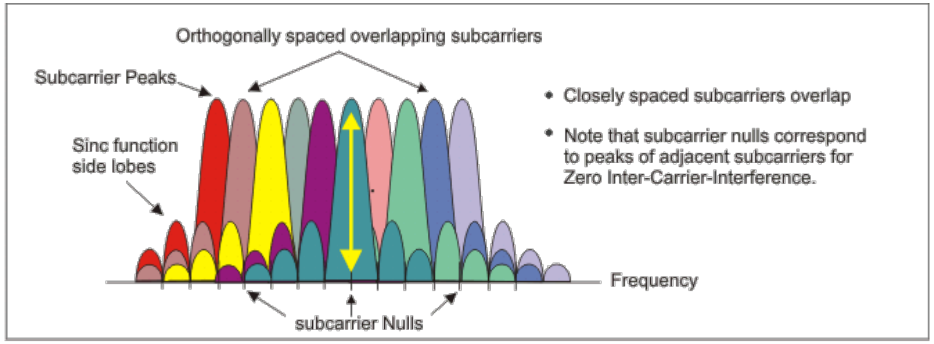




Multiple antenna systems, MIMO

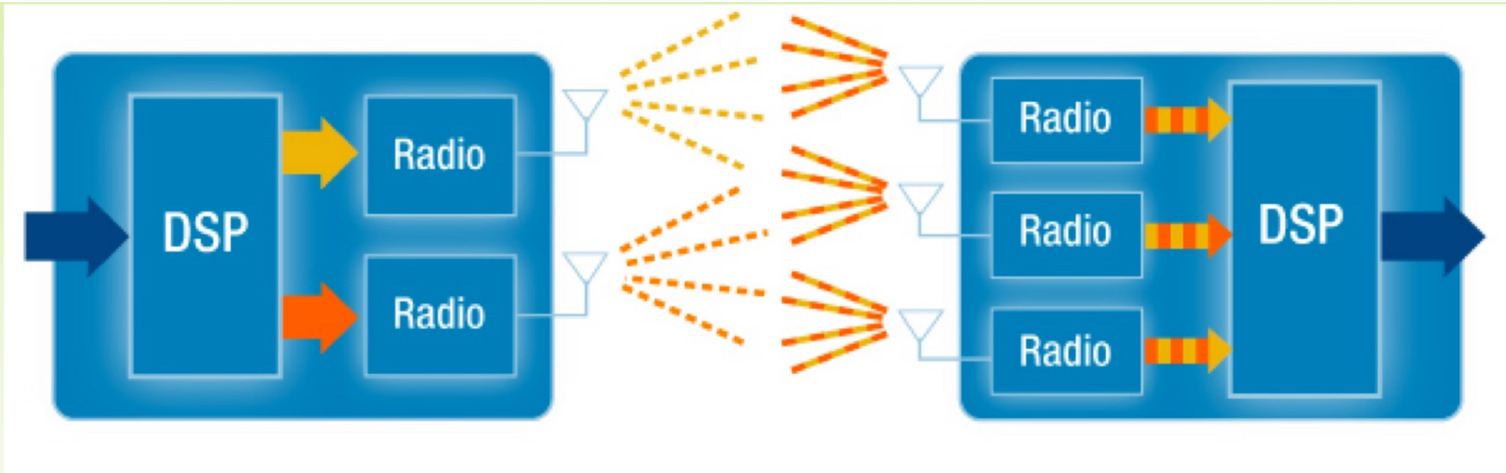


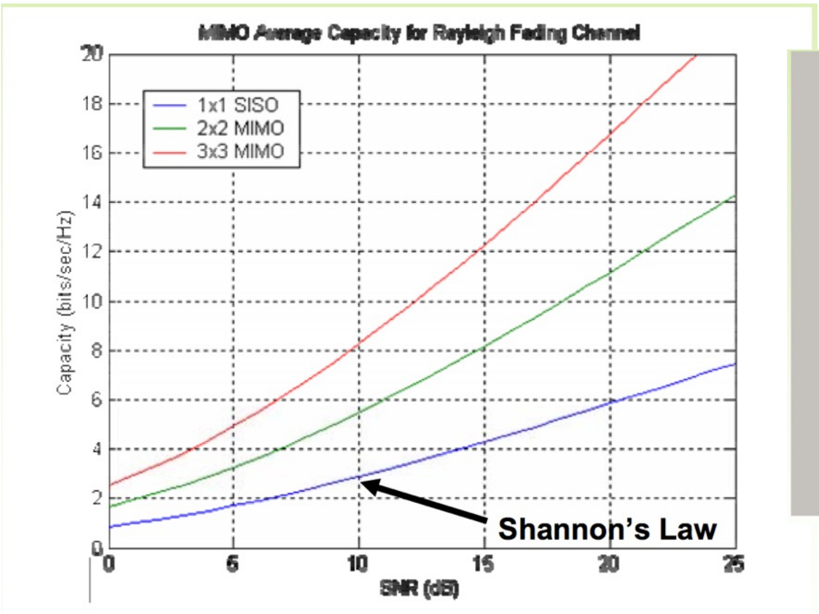
Orthogonal Frequency Division Multiplexing (OFDM)



OFDM Signal Frequency Spectra

MIMO - Multiple Input Multiple Output

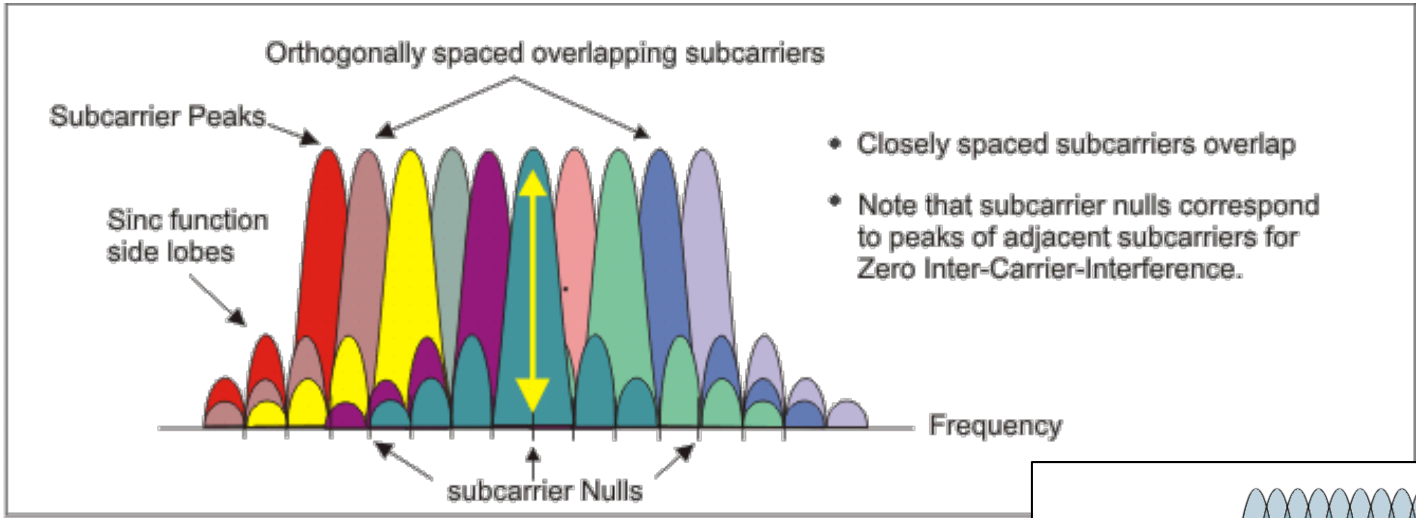




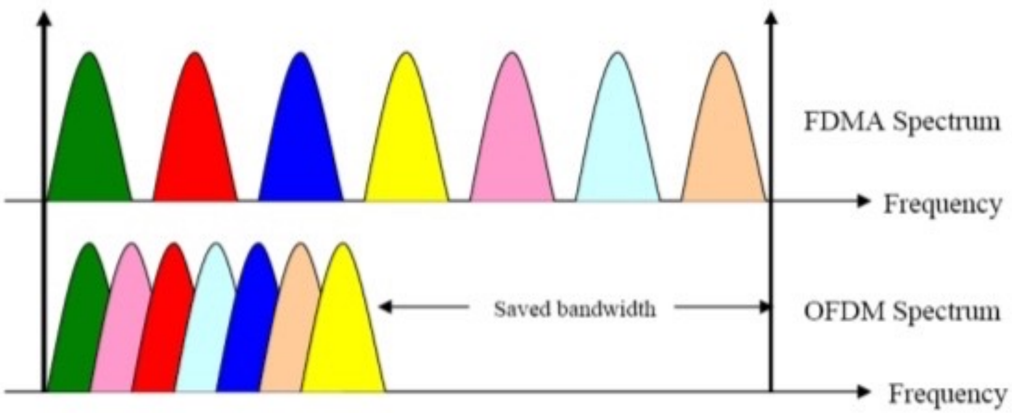
Each multipath route is treated as a separate channel, creating many "virtual wires" over which to transmit signals

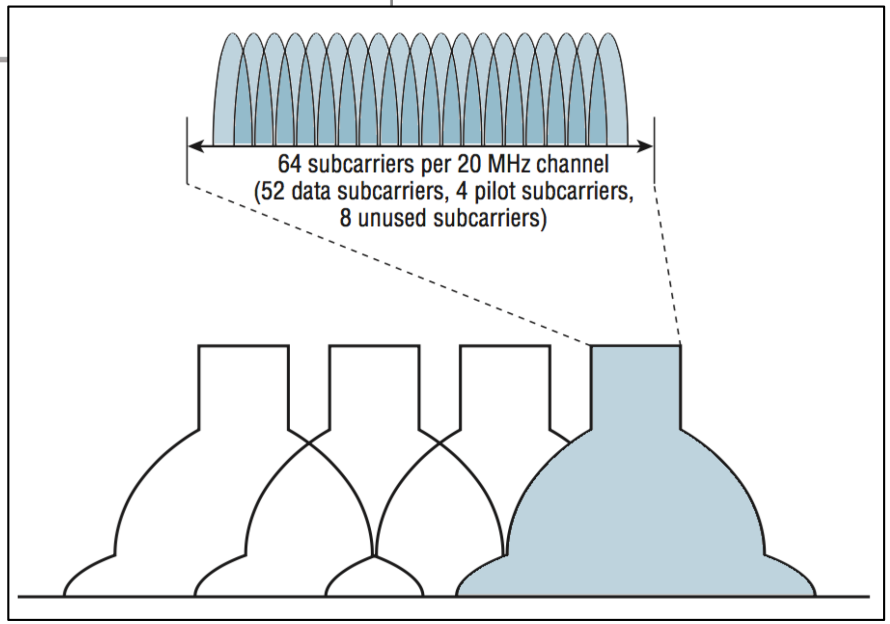
Traditional radios are confused by this multipath, while MIMO takes advantage of these "echoes" to increase range and throughput

OFDM

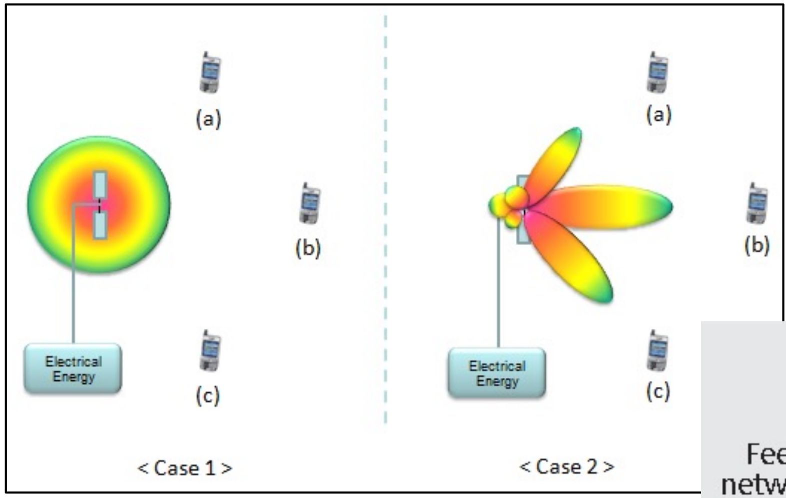


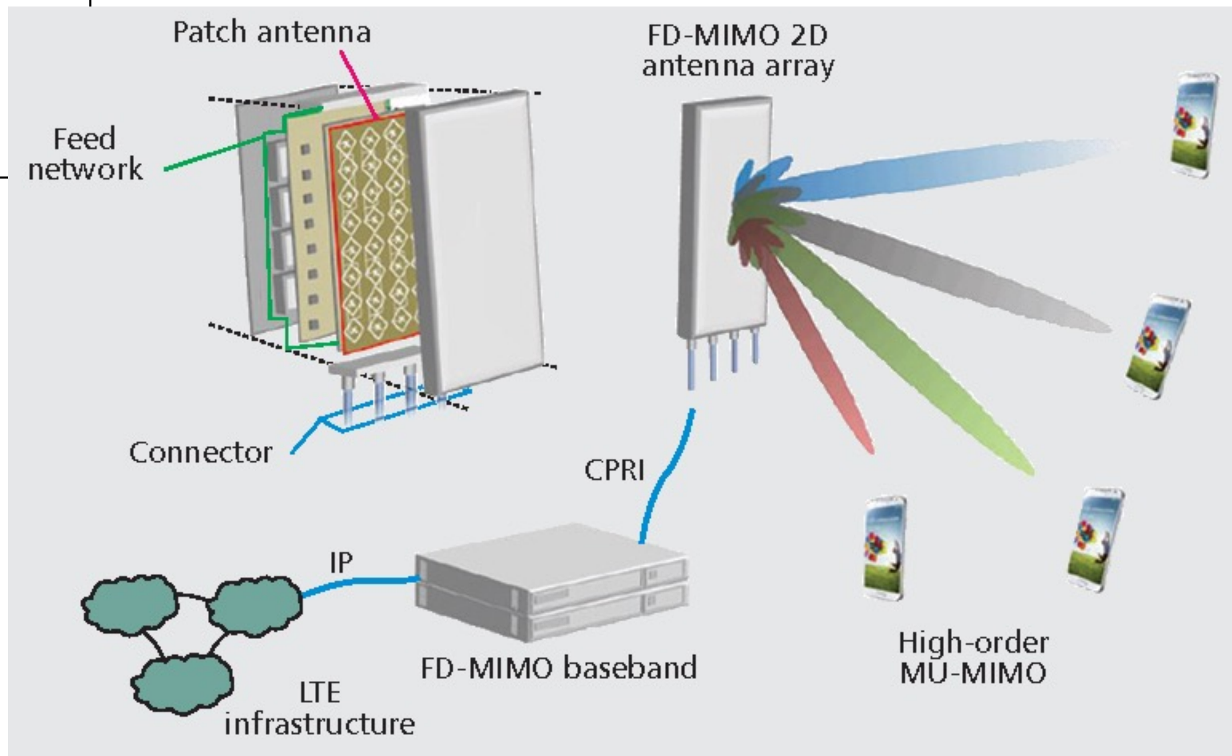
OFDM Signal Frequency Spectra





beam forming on Massive MIMO





3.5G (HSPA)

INFO

High Speed Packet Access (HSPA) is an amalgamation of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), that extends and improves the performance of existing WCDMA protocols.

14 Mbit/s in the downlink and 5.76 Mbit/s in the uplink

3.5G introduces many new features that will enhance the UMTS technology in future. 1xEV-DV already supports most of the features that will be provided in 3.5G. These include:

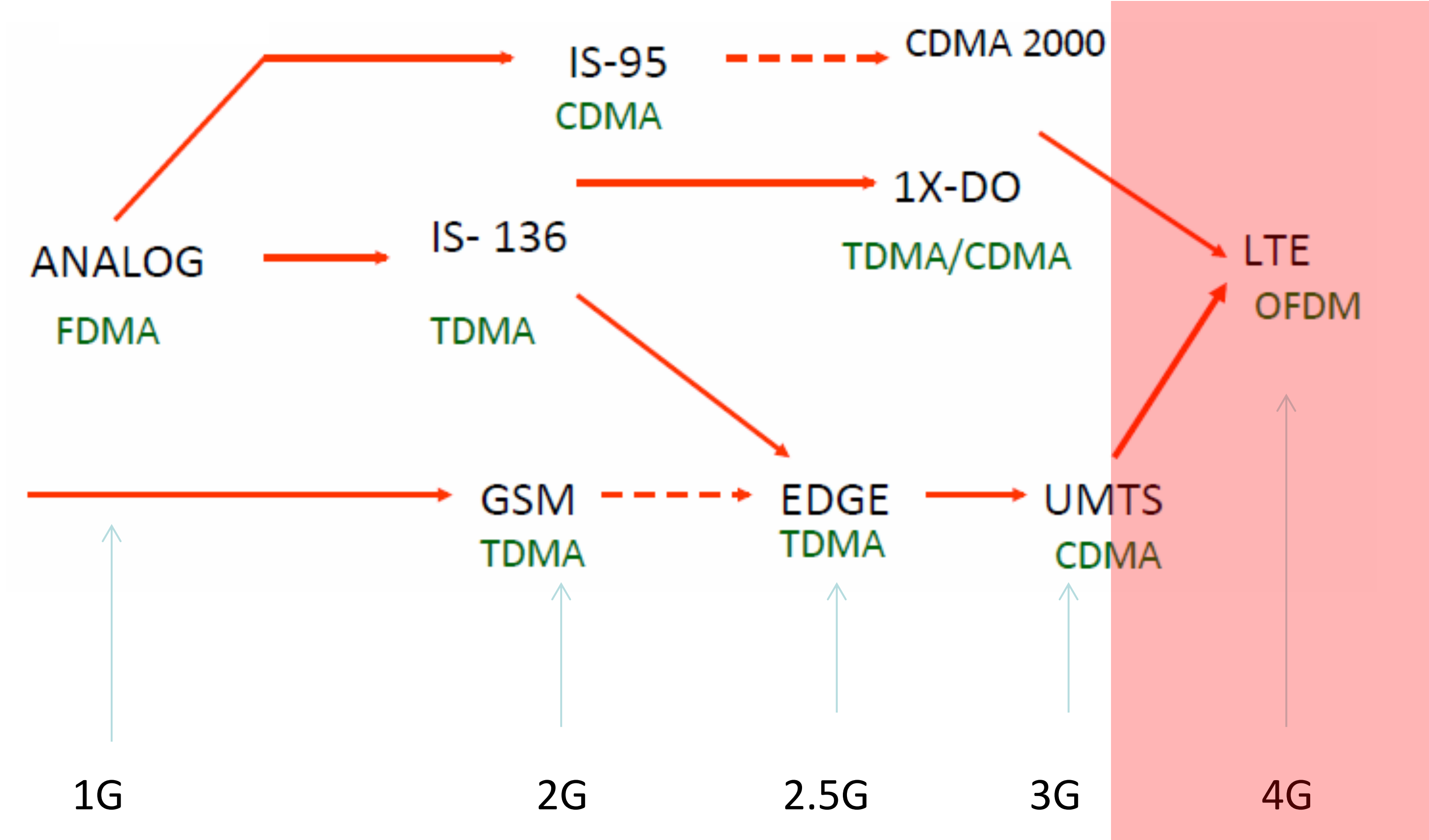
- Adaptive Modulation and Coding (16-QAM & 64-QAM)
- Fast Scheduling (prioritizes users with the most favorable channel conditions)
- MIMO

HSPA+

INFO

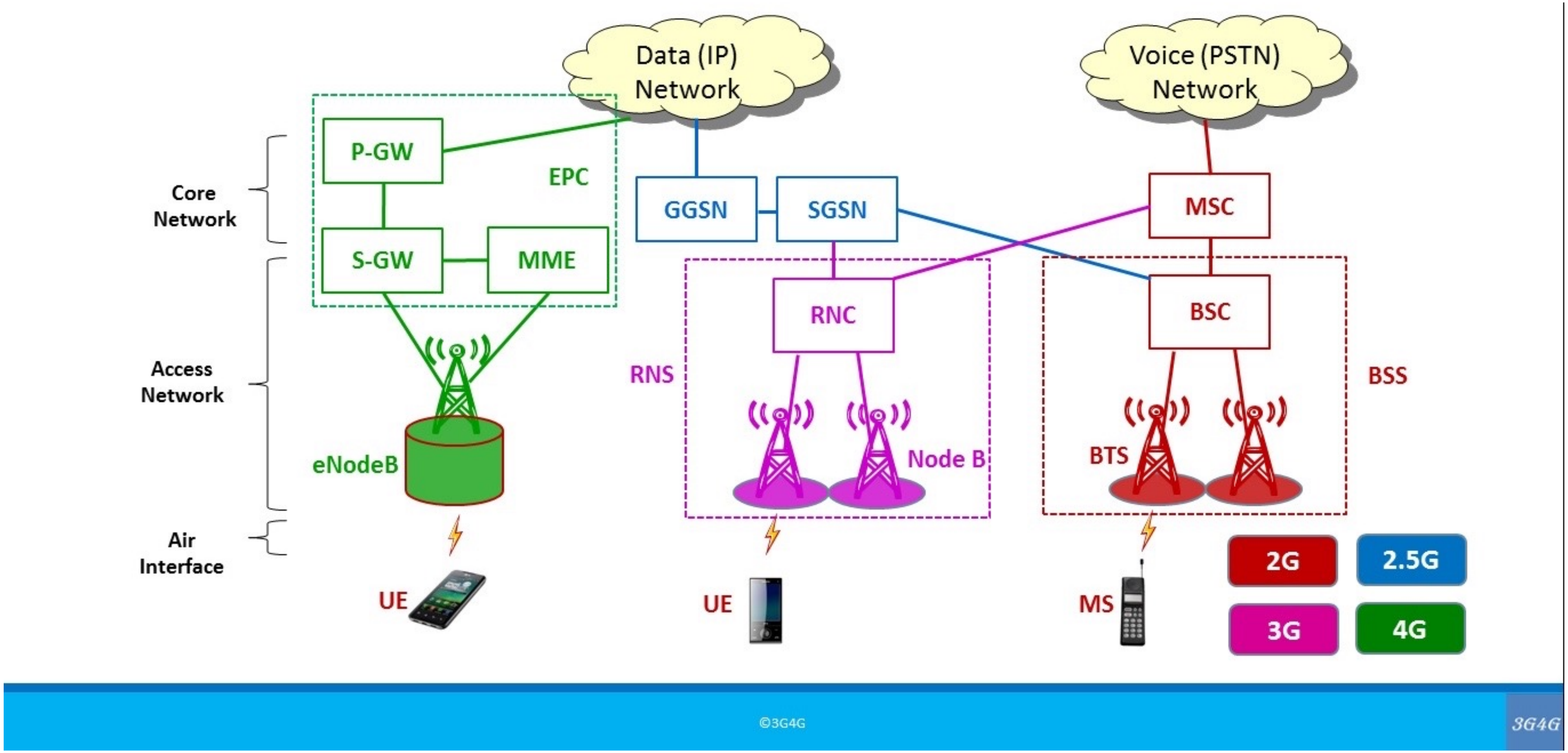
- Evolved HSPA (also known as: HSPA Evolution, HSPA+) is a wireless broadband standard defined in 3GPP release 7 and 8 of the WCDMA specification.
- Provides extensions to the existing HSPA definitions and is therefore backwards compatible all the way to the original Release 99 WCDMA network releases.
- Data rates up to 84 Mbit/s in the downlink and 10.8 Mbit/s in the uplink (per 5 MHz carrier) with multiple input, multiple output (2x2 MIMO) technologies and higher order modulation (64 QAM). With Dual Cell technology, these can be doubled.

4G

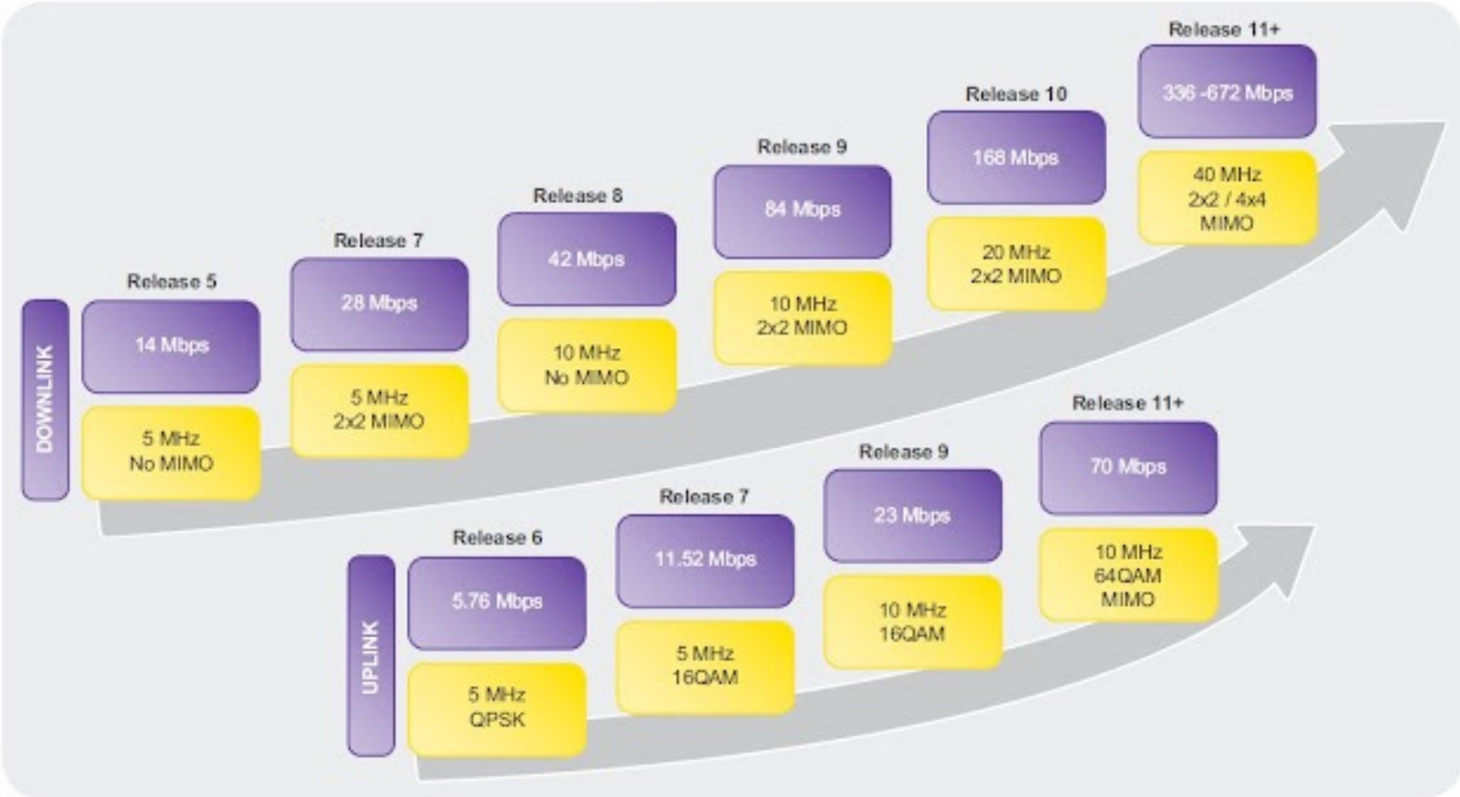


CDMAone->CDMA2000
EGDE: Enhanced Data Rates for GSM Evolution
UMTS:Universal Mobile Telecommunications System (W-CDMA)

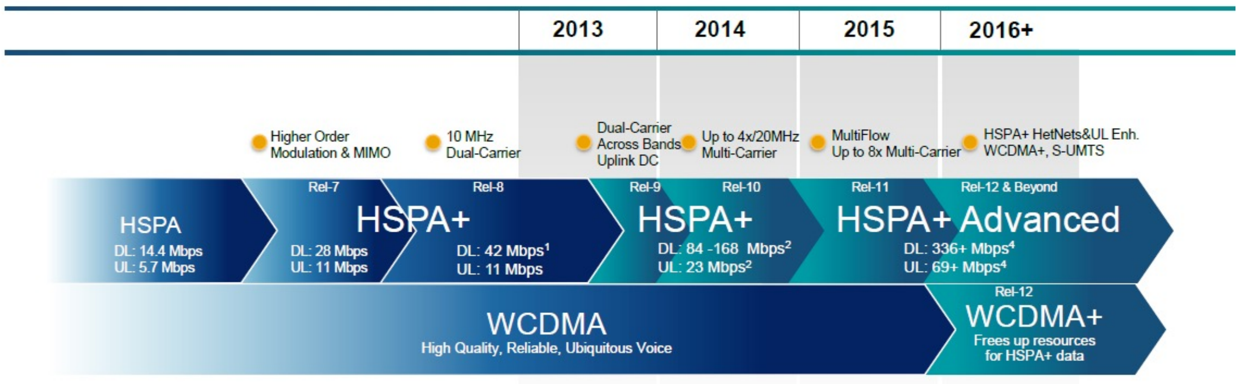
2G, 3G & 4G network architecture



More throughput in near future!



From NSN white paper on HSPA evolution



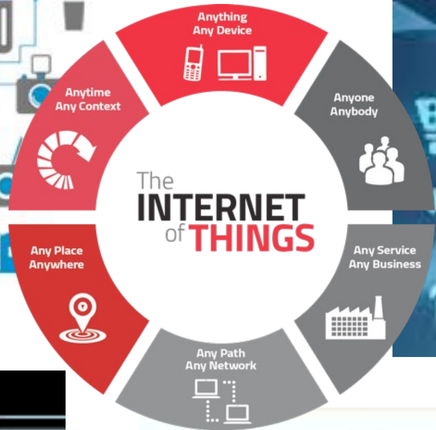
From QualComm

Cellular network standards

INFO

V · T · E		Cellular network standards [hide]
0G (radio telephones)		MTS · MTA * MTB * MTC · IMTS · MTD · AMTS · OLT · Autoradiopuhelin
1G	AMPS family	AMPS (TIA/EIA/IS-3, ANSI/TIA/EIA-553) · N-AMPS (TIA/EIA/IS-91) · TACS · ETACS
	Other	NMT · C-450 · Hicap · Mobitex · DataTAC
2G	GSM/3GPP family	GSM · CSD
	3GPP2 family	cdmaOne (TIA/EIA/IS-95 and ANSI-J-STD 008)
	AMPS family	D-AMPS (IS-54 and IS-136)
	Other	CDPD · iDEN · PDC · PHS
2G transitional (2.5G, 2.75G)	GSM/3GPP family	HSCSD · GPRS · EDGE/EGPRS (UWC-136)
	3GPP2 family	CDMA2000 1X (TIA/EIA/IS-2000) · 1X Advanced
	Other	WiDEN
3G (IMT-2000)	3GPP family	UMTS (UTRAN) · WCDMA-FDD · WCDMA-TDD · UTRA-TDD LCR (TD-SCDMA)
	3GPP2 family	CDMA2000 1xEV-DO Release 0 (TIA/IS-856)
3G transitional (3.5G, 3.75G, 3.9G)	3GPP family	HSPA · HSPA+ · LTE (E-UTRA)
	3GPP2 family	CDMA2000 1xEV-DO Revision A (TIA/EIA/IS-856-A) EV-DO Revision B (TIA/EIA/IS-856-B) · DO Advanced
	IEEE family	Mobile WiMAX (IEEE 802.16e) · Flash-OFDM · IEEE 802.20
4G (IMT-Advanced)	3GPP family	LTE Advanced (E-UTRA)
	IEEE family	WiMAX-Advanced (IEEE 802.16m)
5G		Research concept, not under formal development
Links	Related articles	Cellular networks · Mobile telephony · History · List of standards · Comparison of standards · Channel access methods · Spectral efficiency comparison table · Cellular frequencies · GSM frequency bands · UMTS frequency bands · Mobile broadband · NGMN Alliance · MIMO
	External links	3rd Generation Partnership Project (3GPP) · Third Generation Partnership Project 2 (3GPP2) · IMT-2000/IMT-Advanced Portal · Institute of Electrical and Electronics Engineers Inc. (IEEE) · International Telecommunication Union (ITU) · Telecommunications Industry Association (TIA)

Communicating Objects



LTE-M (Cat M1, LTE-MTC)

- 3GPP Extension of LTE (4G) for Machine Type Communication (MTC) to propose lower throughput (up to 1Mbps) and low-power operation
- No need to change much hardware
- Can handle voice and video
- Can handle mobility (roaming inherited from 4G)

3GPP Narrowband Cellular Standards [edit]

V·T·E [7][8]	LTE Cat 1	LTE-M	
		LC-LTE/MTCe	
		LTE Cat 0	LTE Cat M1
3GPP Release	Release 8	Release 12	Release 13
Downlink Peak Rate	10 Mbit/s	1 Mbit/s	1 Mbit/s
Uplink Peak Rate	5 Mbit/s	1 Mbit/s	1 Mbit/s
Latency	50–100ms	not deployed	10ms–15ms
Number of Antennas	2	1	1
Duplex Mode	Full Duplex	Full or Half Duplex	Full or Half Duplex
Device Receive Bandwidth	1.4 – 20 MHz	1.4 – 20 MHz	1.4 MHz
Receiver Chains	2 (MIMO)	1 (SISO)	1 (SISO)
Device Transmit Power	23 dBm	23 dBm	20 / 23 dBm

LTE-M by Orange

Orange developing end-to-end IoT ecosystem from device to platform

In France :

- LTE-M POC in Lille in July 2018
- 8th November Commercial Launch
- Nov-Dec 2018 : Developer Challenge with SNCF

98% population covered

- **800 MHz**
- **Cat M1**
- **PSM**
- **SMS**

Coverage map online :

https://www.orange-business.com/fr/reseau-LTE-M

LTE-M

5G?

- A set of objectives, various technologies

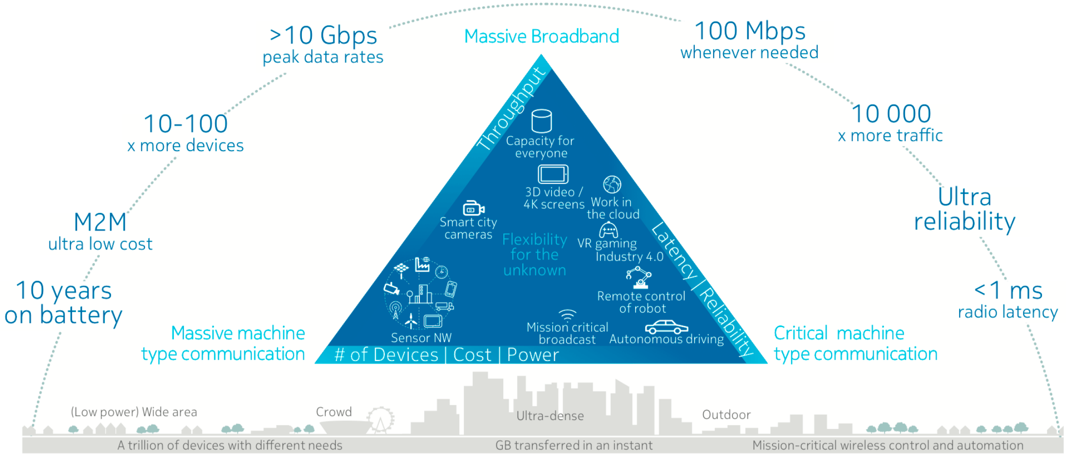
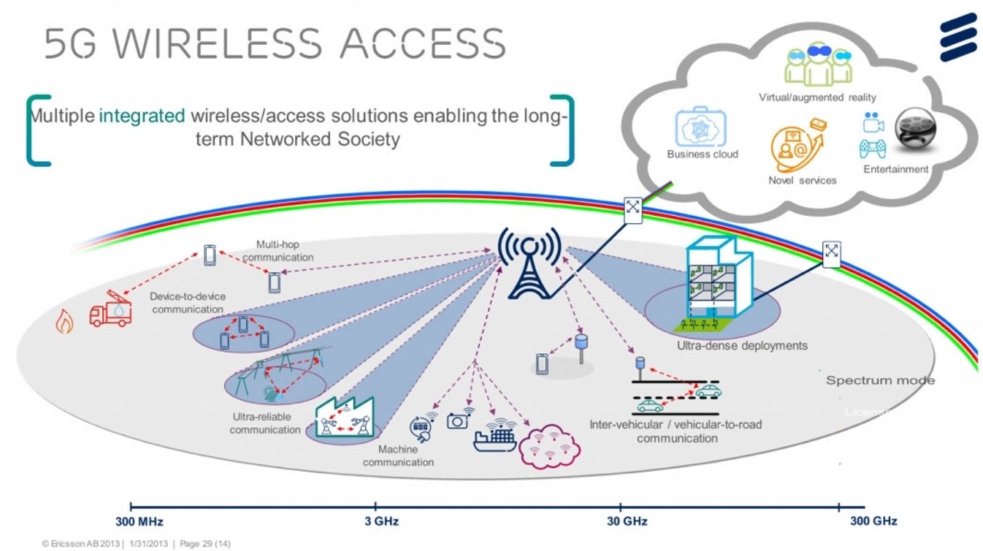
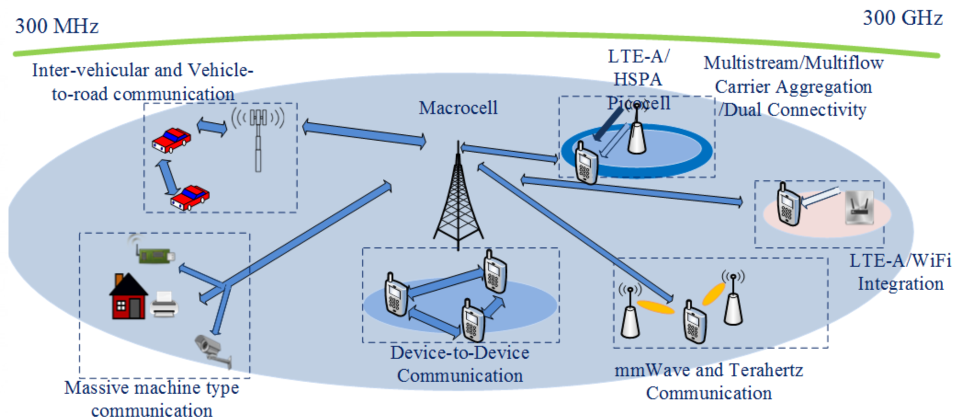
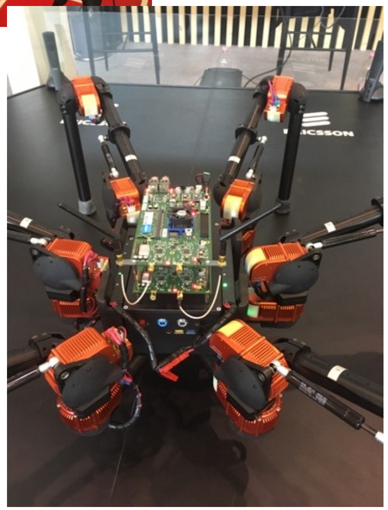


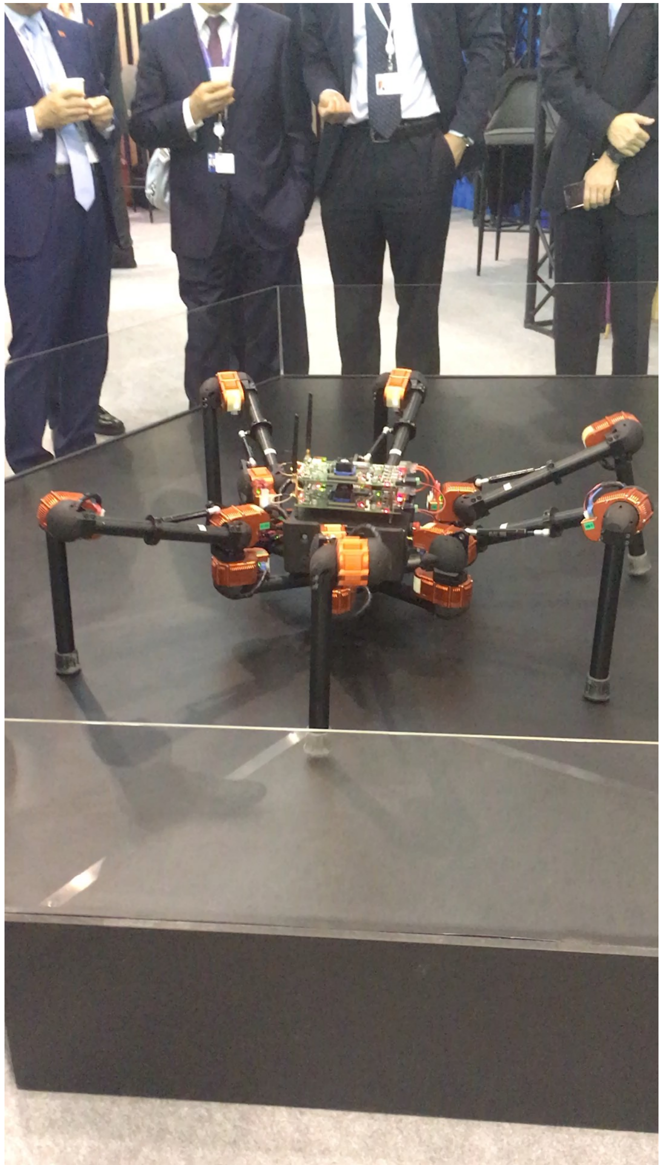
Figure 1. 5G will enable very diverse use cases with extreme range of requirements





5G demo at ITU Telecom World'19





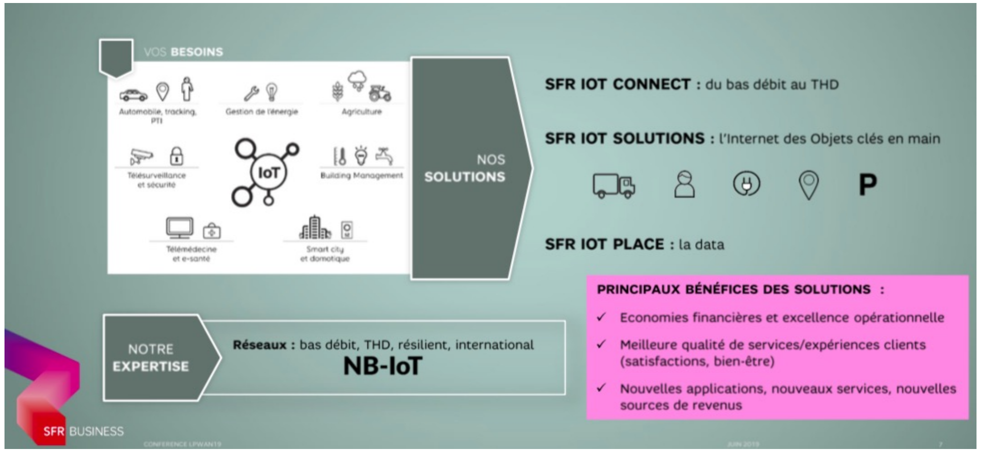
NB-IoT (LTE Cat NB1)

- Narrow-Band IoT uses much smaller bandwitdh than LTE-M to offer very low-power operation mode to small devices
- Throughput up to 250kbps

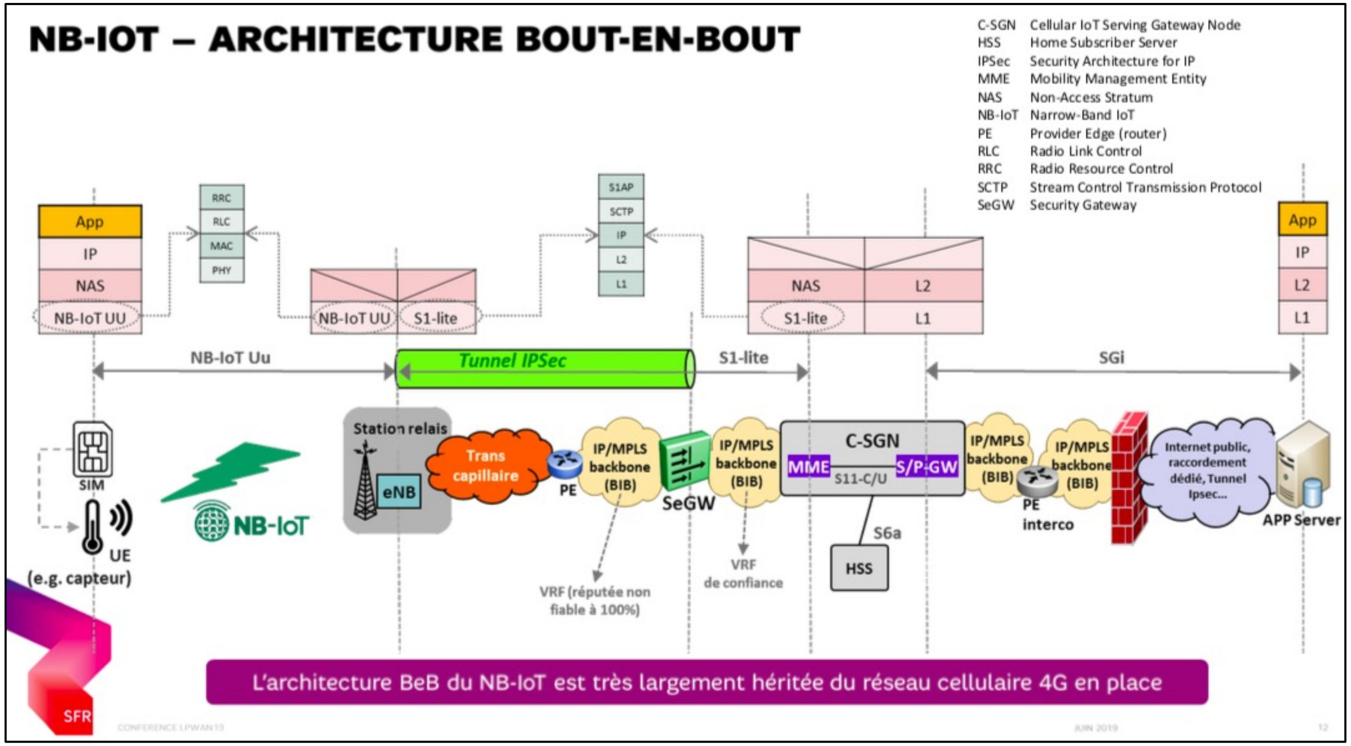
3GPP Narrowband Cellular Standards [edit]

V·T·E [7][8]	LTE Cat 1	LTE-M				NB-IoT
		LC-LTE/MTCe	eMTC			
		LTE Cat 0	LTE Cat M1	LTE Cat M2	non-BL	LTE Cat NB1
3GPP Release	Release 8	Release 12	Release 13	Release 14	Release 14	Release 13
Downlink Peak Rate	10 Mbit/s	1 Mbit/s	1 Mbit/s			250 kbit/s
Uplink Peak Rate	5 Mbit/s	1 Mbit/s	1 Mbit/s			250 kbit/s (multi-tone) 20 kbit/s (single-tone)
Latency	50–100ms	not deployed	10ms–15ms			1.6s–10s
Number of Antennas	2	1	1			1
Duplex Mode	Full Duplex	Full or Half Duplex	Full or Half Duplex			Half Duplex
Device Receive Bandwidth	1.4 – 20 MHz	1.4 – 20 MHz	1.4 MHz			180 kHz
Receiver Chains	2 (MIMO)	1 (SISO)	1 (SISO)			1 (SISO)
Device Transmit Power	23 dBm	23 dBm	20 / 23 dBm			20 / 23 dBm

NB-IoT by SFR

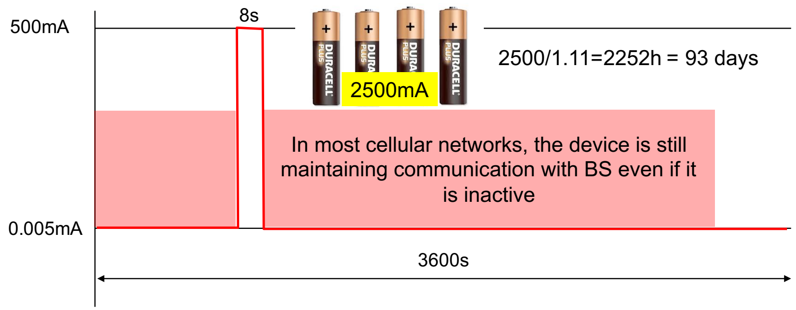


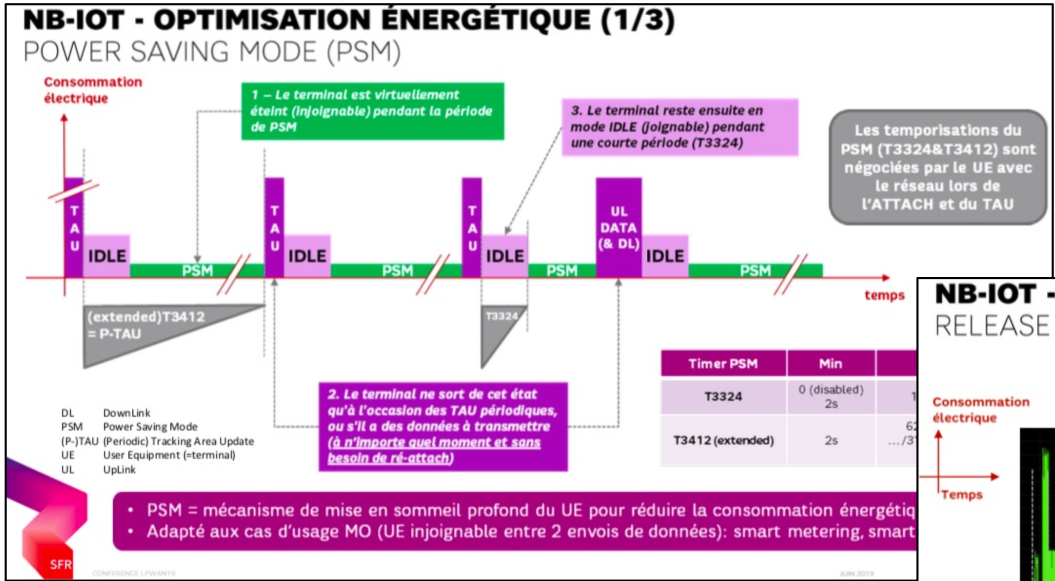
VOS BESOINS
Automobile, tracking, PTI
Gestion de l'énergie
Agriculture
IoT
Télésurveillance et sécurité
Building Management
Télémédecine et e-santé
Smart city et domotique
NOS SOLUTIONS
SFR IOT CONNECT : du bas débit au THD
SFR IOT SOLUTIONS : l'Internet des Objets clés en main
P
SFR IOT PLACE : la data
NOTRE EXPERTISE
Réseaux : bas débit, THD, résilient, international
NB-IoT
PRINCIPAUX BÉNÉFICES DES SOLUTIONS :
✓ Economies financières et excellence opérationnelle
✓ Meilleure qualité de services/expériences clients (satisfactions, bien-être)
✓ Nouvelles applications, nouveaux services, nouvelles sources de revenus
SFR BUSINESS

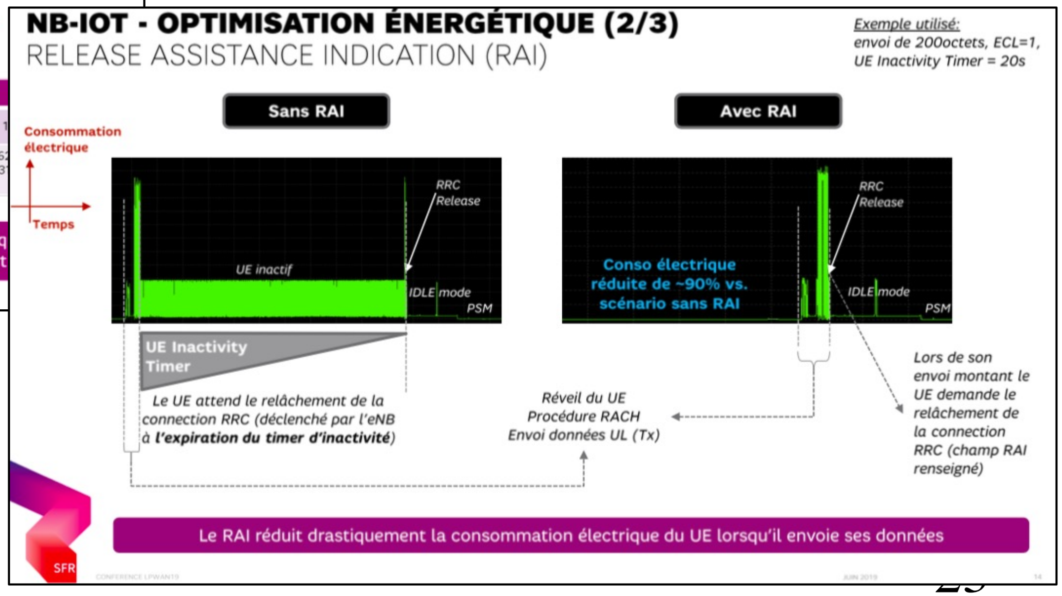


NB-IOT – ARCHITECTURE BOUT-EN-BOUT
C-SGN Cellular IoT Serving Gateway Node
HSS Home Subscriber Server
IPSec Security Architecture for IP
MME Mobility Management Entity
NAS Non-Access Stratum
NB-IoT Narrow-Band IoT
PE Provider Edge (router)
RLC Radio Link Control
RRC Radio Resource Control
SCTP Stream Control Transmission Protocol
SeGW Security Gateway
App
IP
NAS
NB-IoT UU
RRC
RLC
MAC
PHY
NB-IoT UU
S1-lite
S1AP
SCTP
IP
L2
L1
NAS
L2
S1-lite
L1
App
IP
L2
L1
NB-IoT Uu
Tunnel IPSec
S1-lite
SGi
SIM
UE
(e.g. capteur)
NB-IoT
Station relais
eNB
Trans capillaire
PE
IP/MPLS backbone (BIB)
SeGW
IP/MPLS backbone (BIB)
C-SGN
MME
S/P-GW
S11-C/U
S6a
HSS
IP/MPLS backbone (BIB)
PE interco
IP/MPLS backbone (BIB)
Internet public, raccordement dédié, Tunnel Ipsec...
APP Server
VRF (réputée non fiable à 100%)
VRF de confiance
L'architecture BeB du NB-IoT est très largement héritée du réseau cellulaire 4G en place
SFR

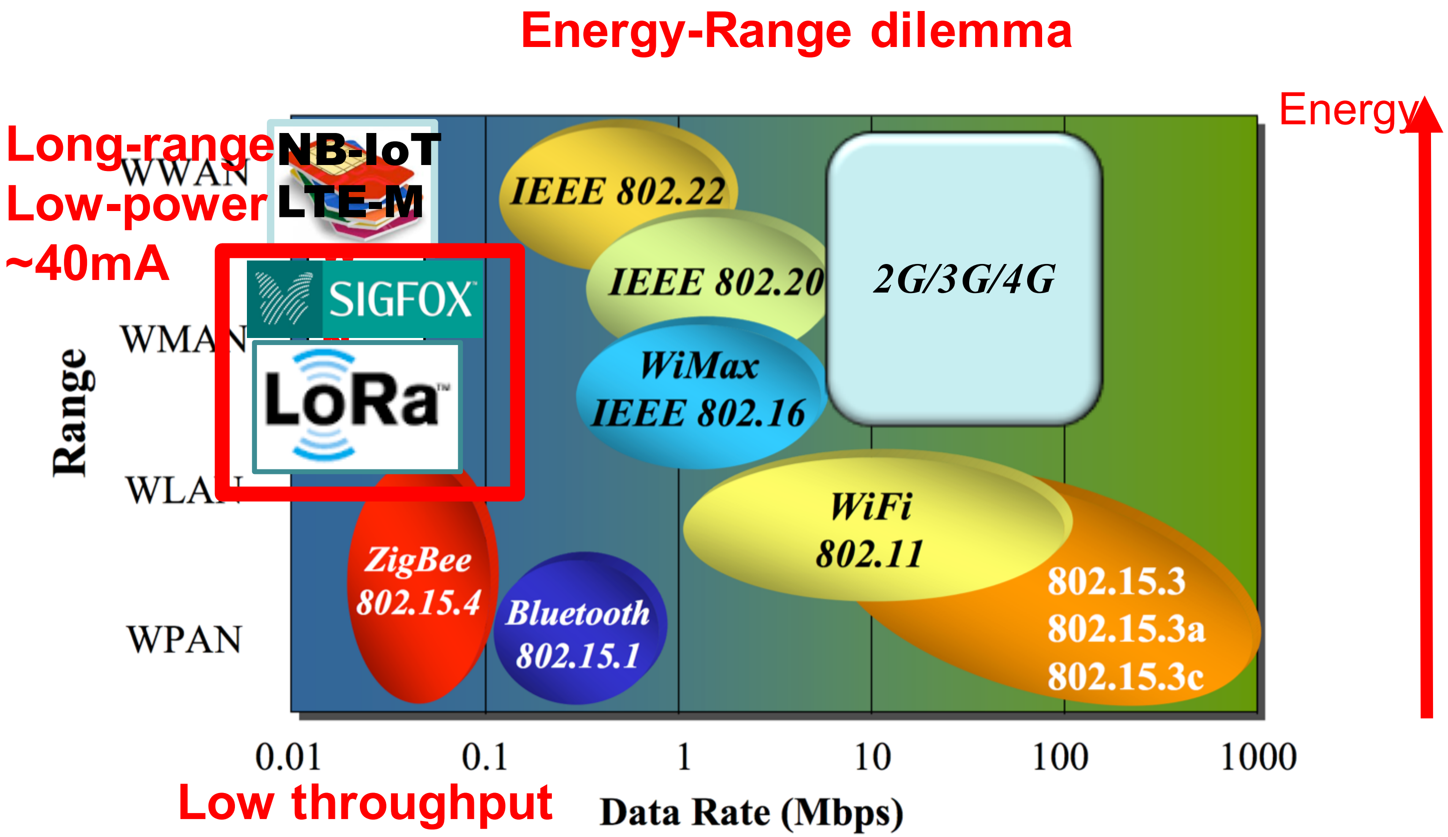
Optimizing for IoT





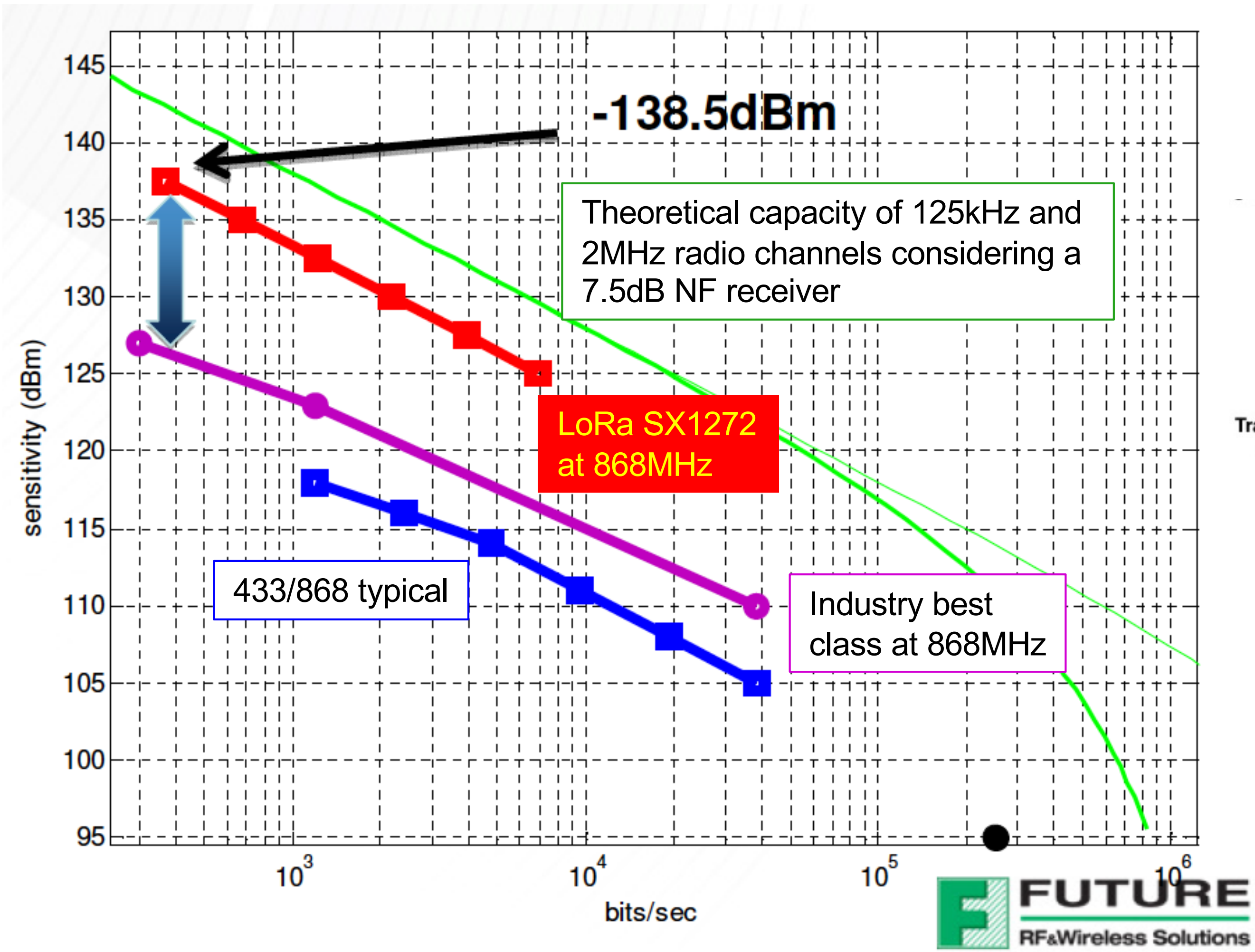


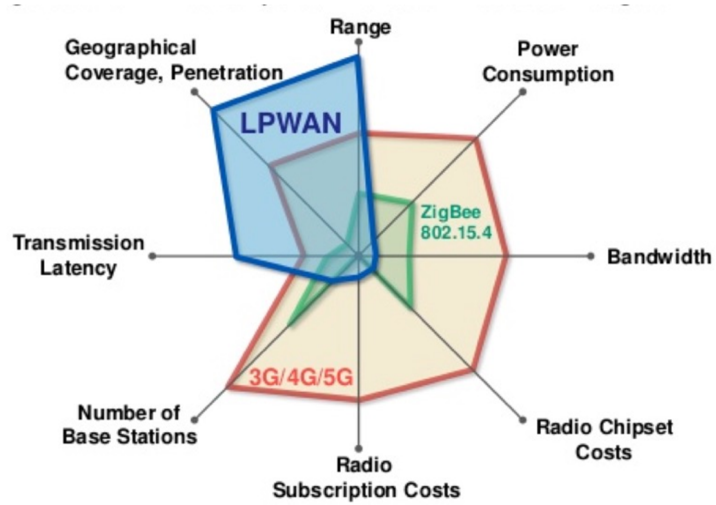
Wireless space – long range



Transmitting: `TC/22.5/HUM/67.7` ; about 20 bytes with packet header
Time on air can be 1.44s with LoRa

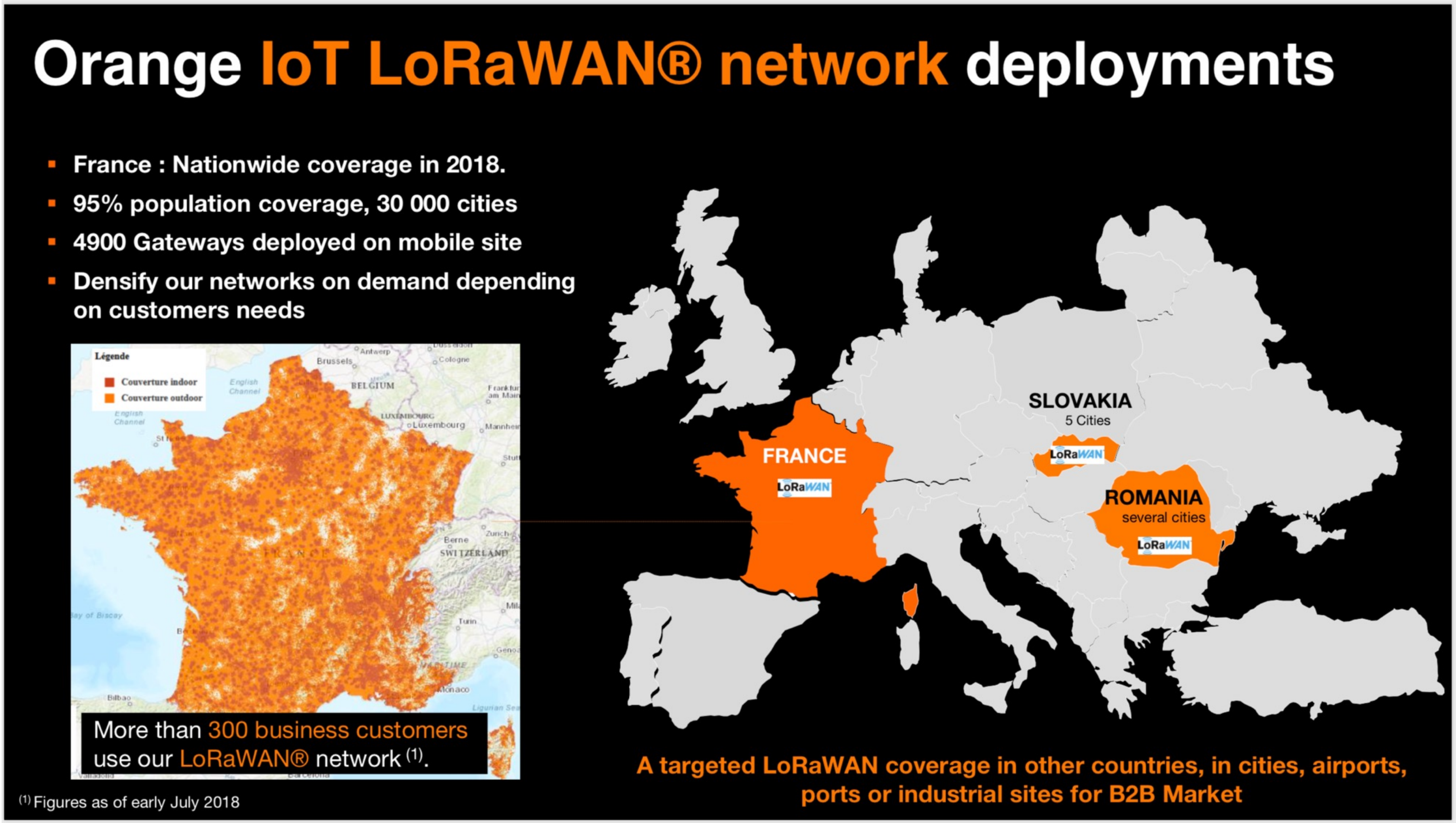
THE TRUE LPWAN REVOLUTION!





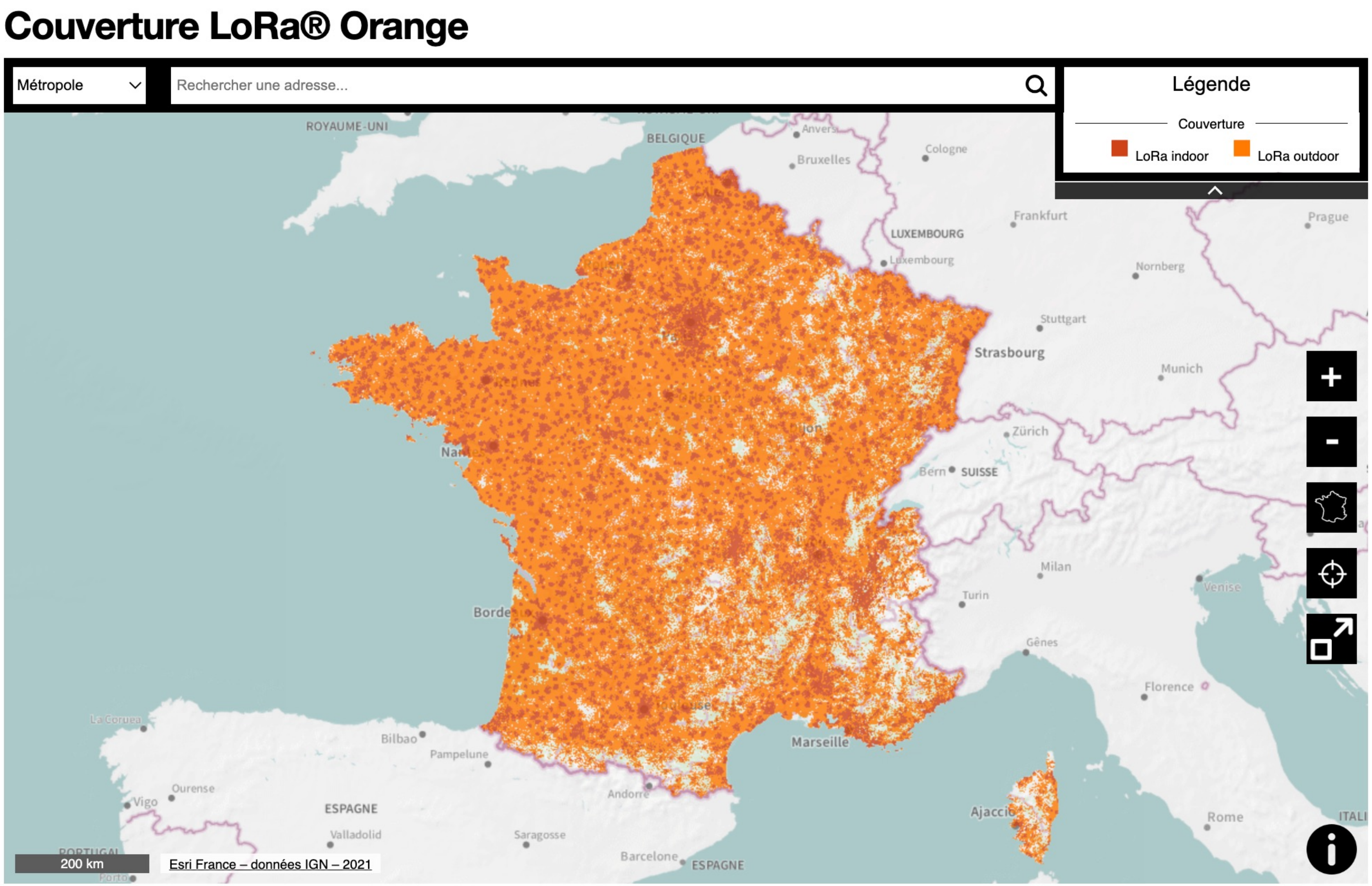
From Peter R. Egli, INDIGOO.COM

Orange LoRa



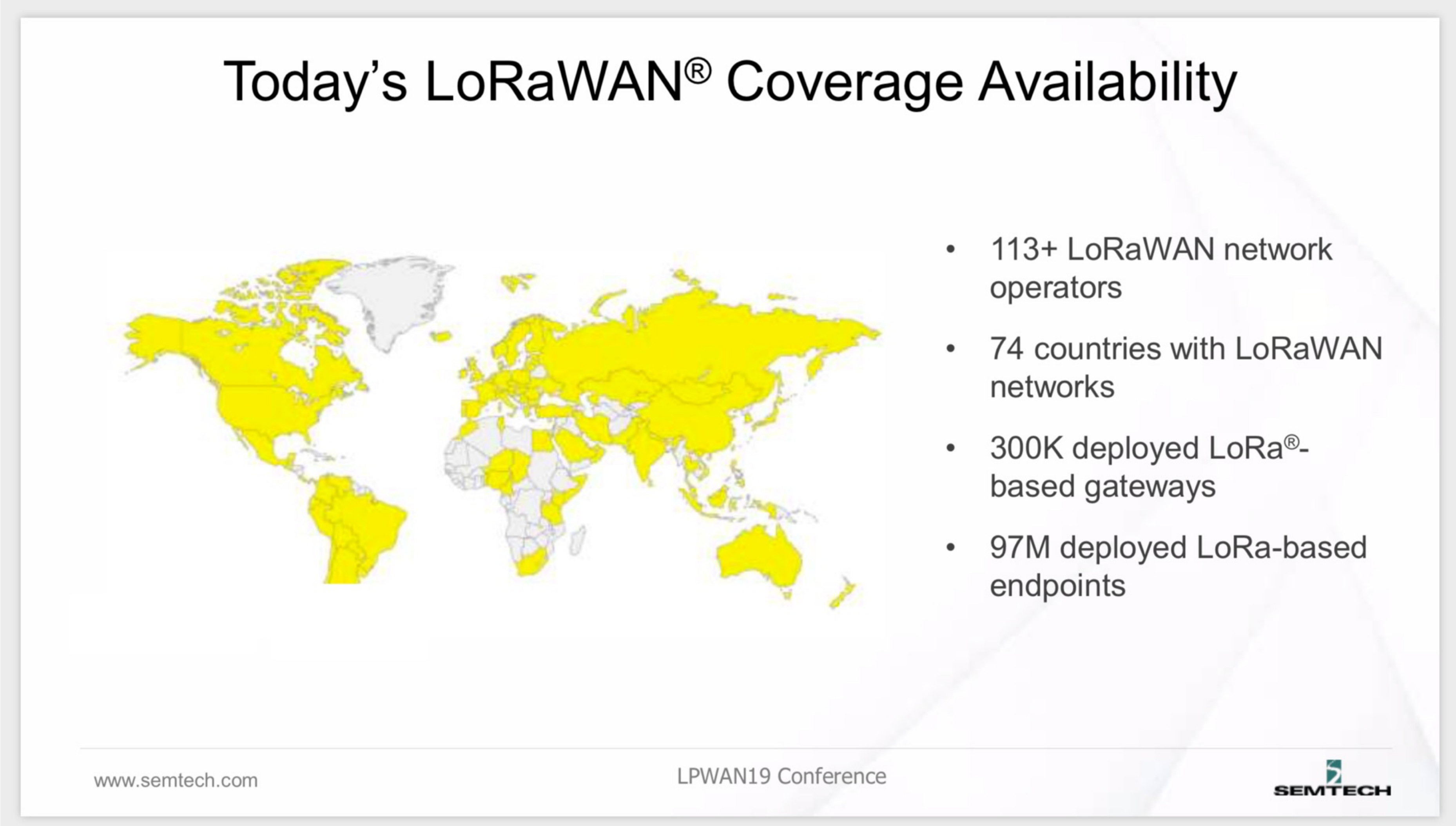
Orange IoT LoRaWAN® network deployments
France : Nationwide coverage in 2018.
95% population coverage, 30 000 cities
4900 Gateways deployed on mobile site
Densify our networks on demand depending on customers needs
Légende
Couverture indoor
Couverture outdoor
More than 300 business customers use our LoRaWAN® network (1).
FRANCE
LoRaWAN
SLOVAKIA
5 Cities
LoRaWAN
ROMANIA
several cities
LoRaWAN
A targeted LoRaWAN coverage in other countries, in cities, airports, ports or industrial sites for B2B Market
(1) Figures as of early July 2018

For France

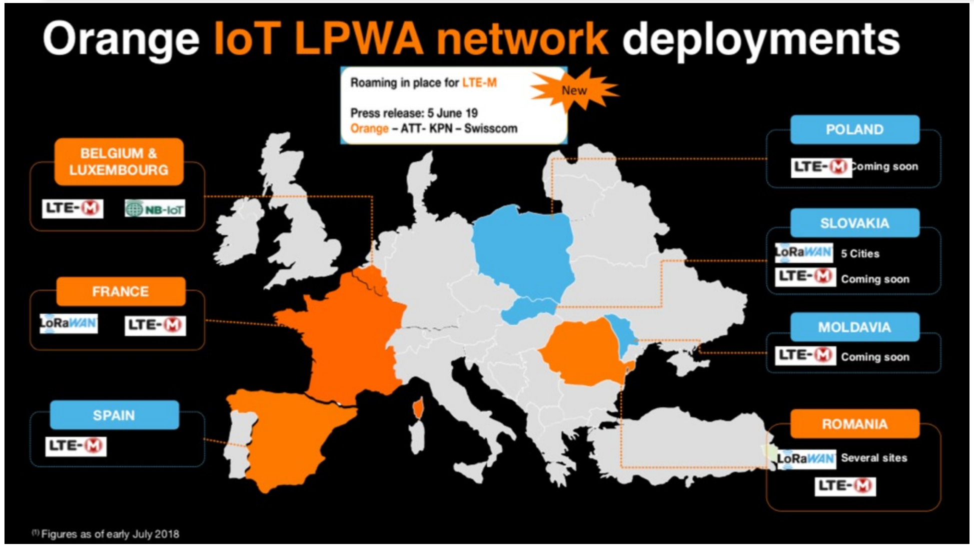


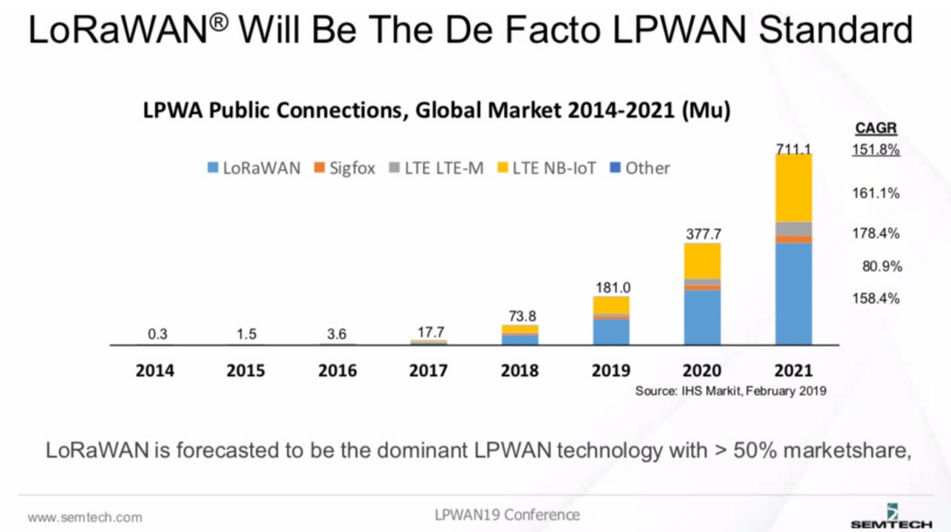
https://www.orange-business.com/fr/reseau-iot

LoRaWAN coverage from Semtech



LTE-M vs NB-IoT vs LoRa vs SigFox?





LPWAN=star topology, gateway centric

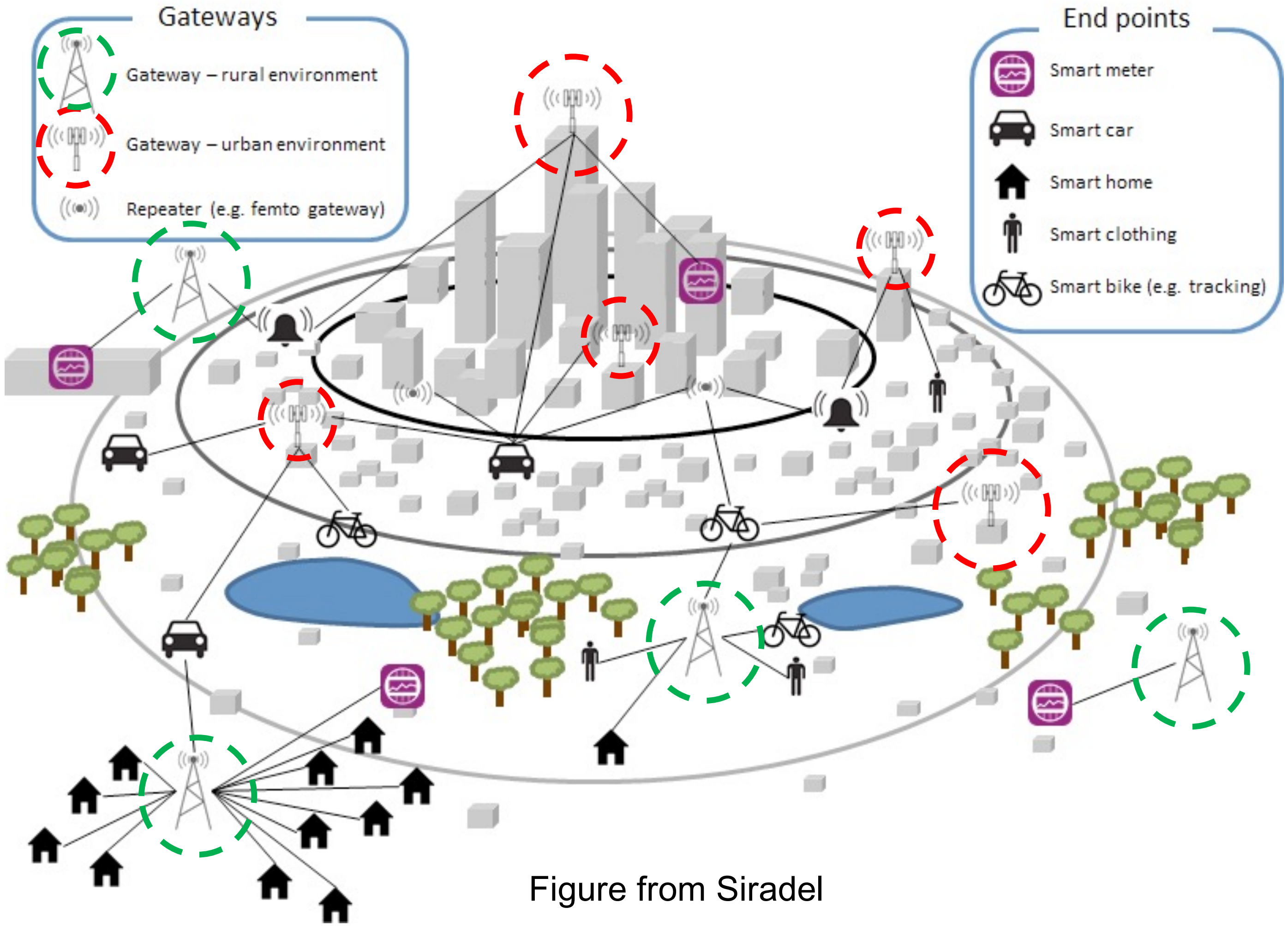
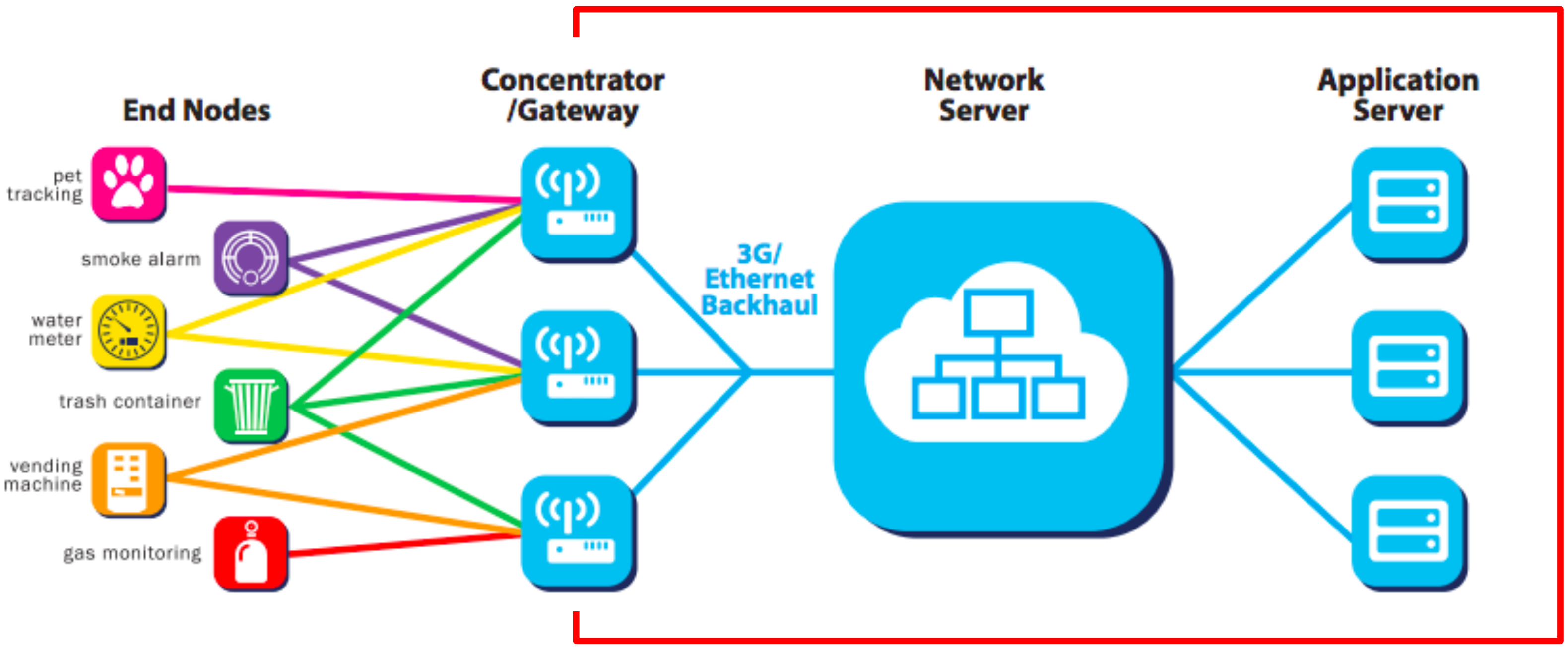
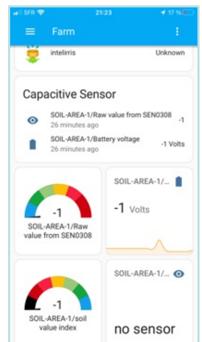


Figure from Siradel

LoRaWAN IoT networks

- LoRaWAN specifications/protocols run on top of LoRa physical networks. It is defined and managed by the LoRa Alliance
- Make possible to run large-scale, public LoRa networks



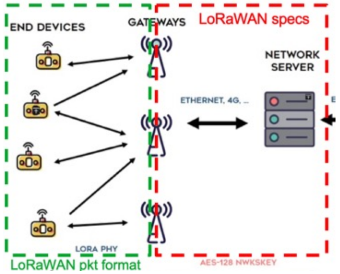


ThingsBoard

Undestanding LoRa vs LoRaWAN

- The physical layer, thus the long-range radio technology, is called LoRa
- A so-called 1-byte sync word is used to add a "filtering" level
- You can decide to transmit using only the LoRa physical layer and then define our own packet format
- With pure LoRa you can transmit from any device to any other device with same LoRa datarate, frequency and sync word
- LoRaWAN uses LoRa physical layer but defines its own packet format and uses sync word of 0x34 (public LoRaWAN)
- "In LoRaWAN, a gateway applies I/Q inversion on TX, and nodes do the same on RX. This ensures that gateways can talk to nodes and vice-versa, but gateways will not hear other gateways and nodes will not hear other nodes" [LMIC Arduino]

LoRaWAN gateway



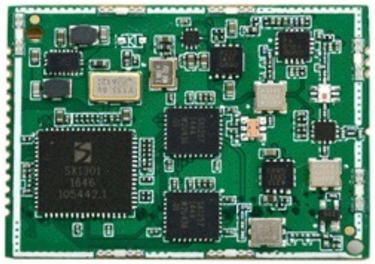
- A full LoRaWAN gateway should be able to listen on multiple channels and spreading factors

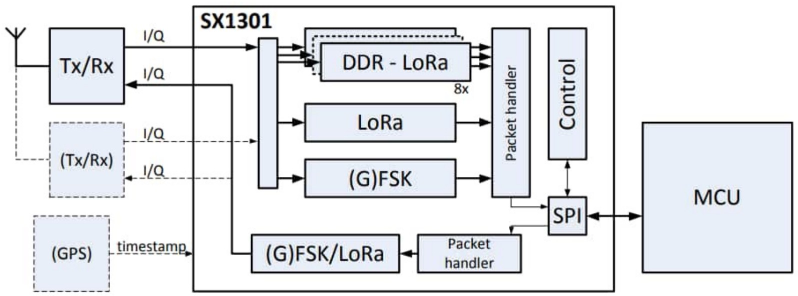
EU863-870

Uplink:

1. 868.1 - SF7BW125 to SF12BW125
2. 868.3 - SF7BW125 to SF12BW125
3. 868.5 - SF7BW125 to SF12BW125
4. 867.1 - SF7BW125 to SF12BW125
5. 867.3 - SF7BW125 to SF12BW125
6. 867.5 - SF7BW125 to SF12BW125
7. 867.7 - SF7BW125 to SF12BW125
8. 867.9 - SF7BW125 to SF12BW125
9. 868.8 - FSK

- They are mostly based on the Semtech SX1301 radio concentrator

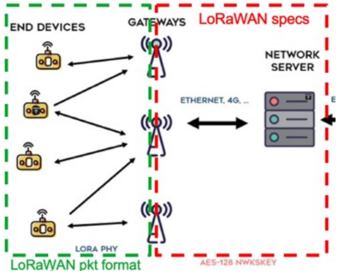




LoRaWAN gateway software

- Most of LoRaWAN gateways run the following software
  - the Semtech's concentrator gateway at the lowest level (https://github.com/Lora-net/lora_gateway)
  - The Semtech's LoRa packet forwarder on top of the low-level concentrator gateway (https://github.com/Lora-net/packet_forwarder)
- "*A LoRa packet forwarder is a program running on the host of a LoRa gateway that forwards RF packets receive by the concentrator to a server through a IP/UDP link, and emits RF packets that are sent by the server*."
- The server is the so-called LoRaWAN Network Server (LNS) as described in the next slides
- The Network Server is usually linked to the Application Server which can be seen as a LoRaWAN cloud

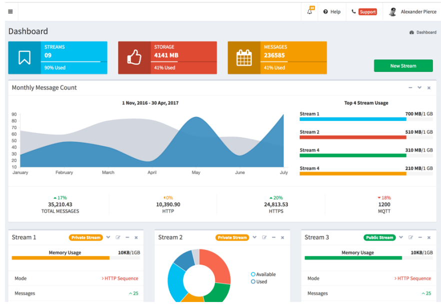
LoRaWAN Network Server (LNS)

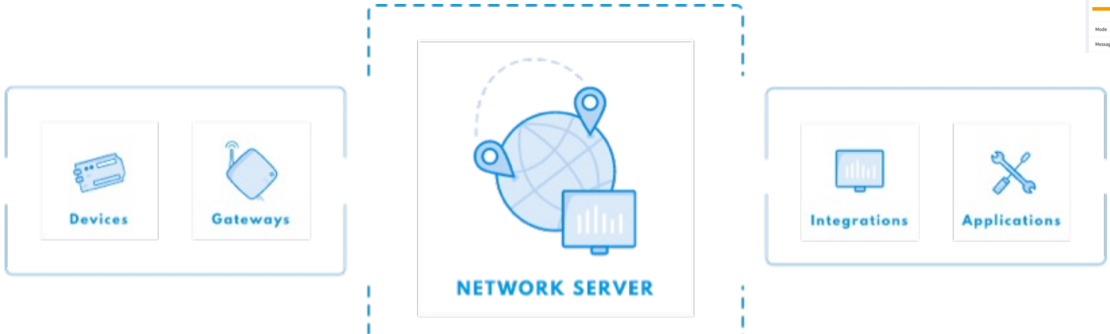


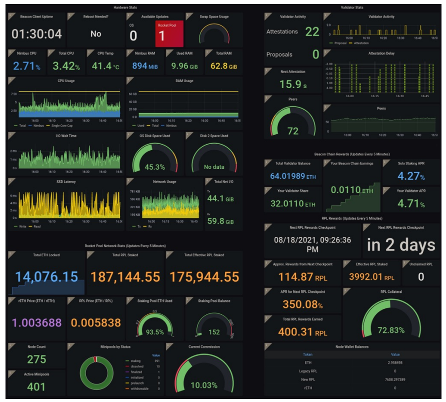
- LNS manages the state of the network, has knowledge of devices active on the network and is able to handle over-the-air-activation procedure (OTAA)
- When data is received by multiple gateways, the LNS can also de-duplicate this data
- When a message needs to be sent back to a device, the LNS forwards it to one of the gateways
- Currently, each LoRaWAN network provider will have their own LNS
  - The Packet Forwarder run on deployed gateways needs to identify an LNS
  - Therefore users need to be "bounded" to a particular LoRa network provider because end-devices need to be registered

TheThingNetwork (TTN)

- Popular LoRa Network Provider
- Provides the TTN Network Server

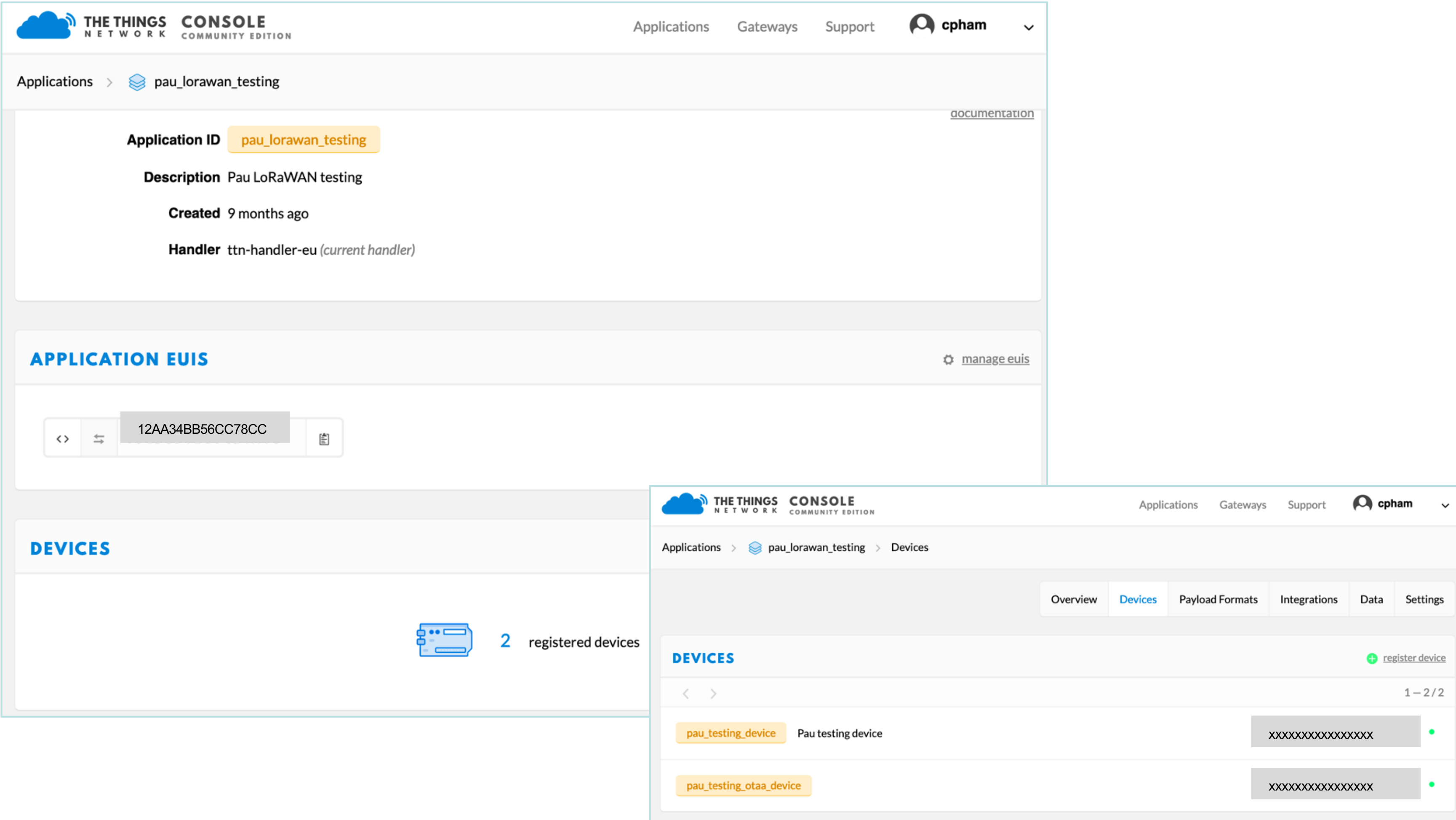




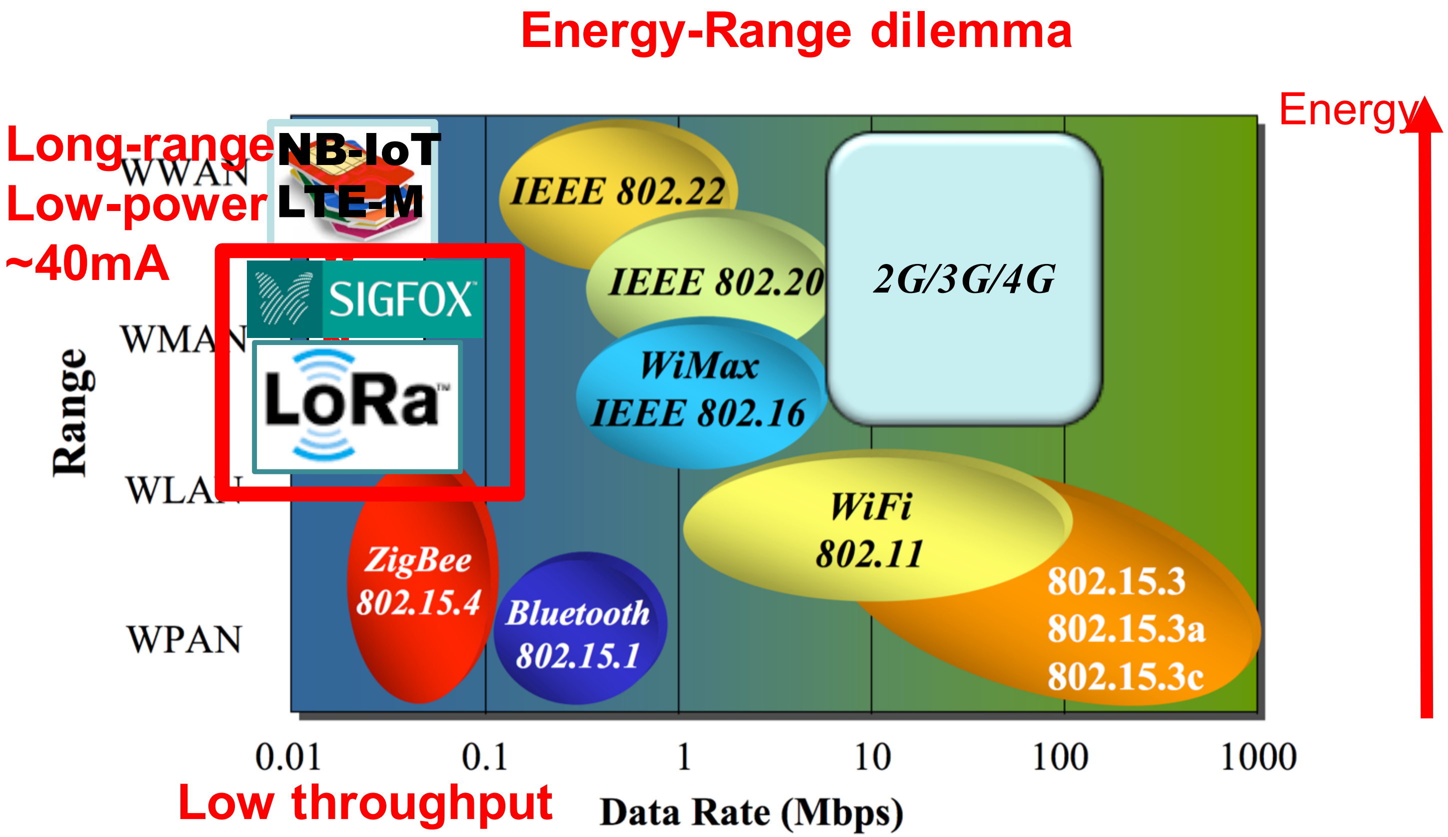


- Community-based deployment of LoRa gateways
  - User A can buy a LoRa gateway, register it and deploy it
  - User B then creates an account on TTN to register its devices
  - Messages from registered devices received by a TTN gateway will be made available for users on the TTN console

TTN user console



Wireless space – short range



Transmitting: `TC/22.5/HUM/67.7` ; about 20 bytes with packet header
Time on air can be 1.44s with LoRa

Bluetooth 802.15.1

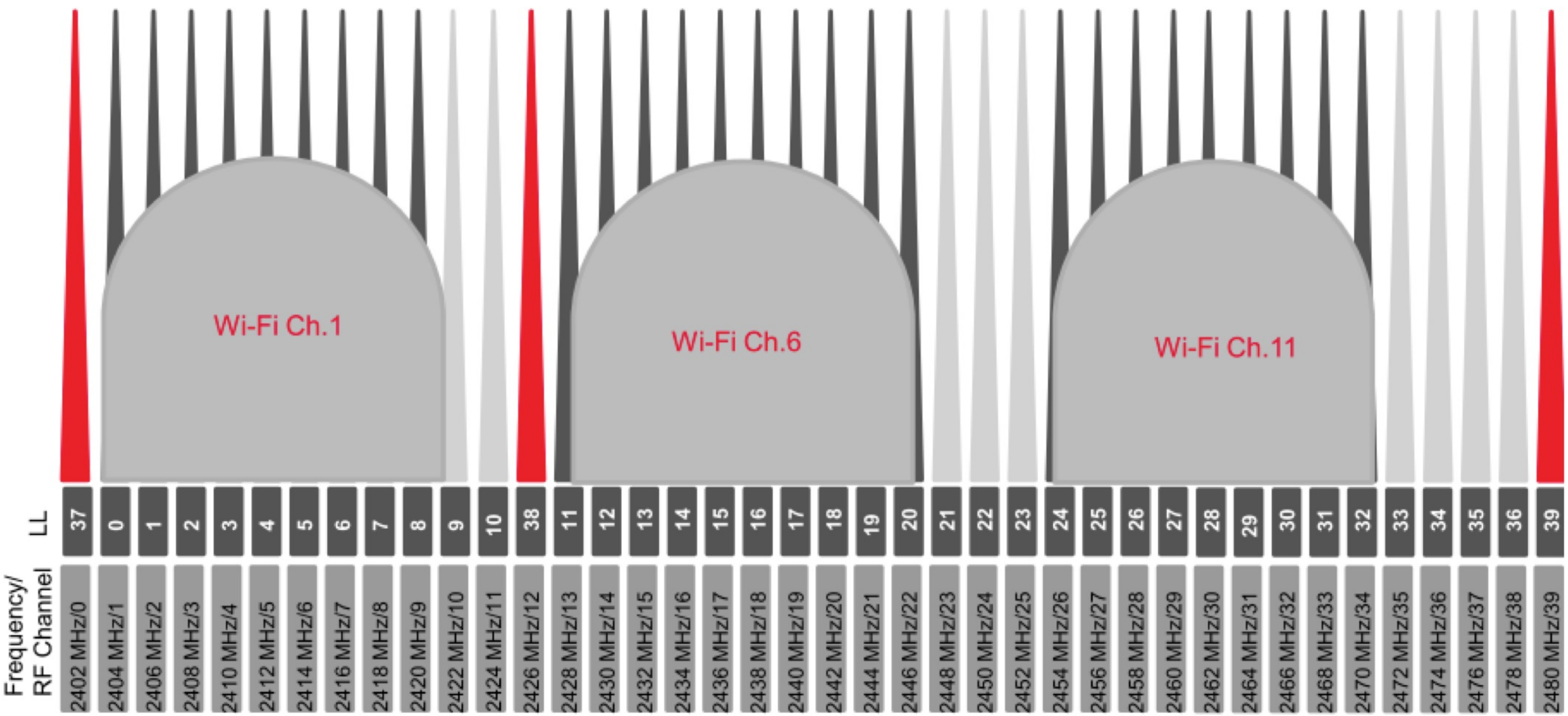
Bluetooth Spec. Evolution

Specifications	1.1	1.2	2.0 + EDR	2.1 + EDR	3.0 +HS	4.0
Adopted	2002	2005	2004	2007	2009	2010
Transmission Rate	723.1 kbps	723.1 kbps	2.1 Mbps	3 Mbps	24 Mbps	25 Mbps
Standard PAN Range	10 m	10 m	10 m	10 m	10 m	50 m
Improved Pairing (without a PIN)				Yes	Yes	Yes
Improved Security		Yes	Yes	Yes	Yes	Yes
NFC Support			Yes	Yes	Yes	Yes

IoT Key Enabling Wireless Technologies Summary

Standards	Freq(s)	Max BW	Data rate	Mod	Range	Network	Applications
LTE-M Category 0/1 (LTE Rel12/13)	LTE band	1.4 MHz	200 kbps ~ 1 Mbps	OFDM	1000m	WMAN	lower speed and power versions of the LTE standard defined in Rel12/13
802.11ah	Sub GHz	1 to 16 MHz	150kbps to 78 Mbps	OFDM	1000m	WLAN	Target for Internet of Things, wearable devices or extend range
802.11p	Sub GHz	5/10/20 MHz	1.5Mbps to 54Mbps	OFDM	1000m	WLAN	Wireless access in vehicle environment (WAVE)
Bluetooth Low Energy	2.4GHz	2 MHz	1Mbps	GFSK	50m	WPAN	automotive, healthcare, security, home entertainment
Z-Wave (ITU G.9959)	868.42 MHz 908.42 MHz	200 kHz	9.6 kbps ~100 kbps	BFSK GFSK	100cm	WPAN	Remote controls, smoke alarm, security sensors Owned by Denmark Zensys
Zigbee (802.15.4)	ISM <2.4GHz	5 MHz	40kbits/s, 250kbis/s	BPSK OQPSK	10m	WPAN	Home automation, smart grid, remote control
Thread (802.15.4)	ISM <2.4GHz	5 MHz	40kbits/s, 250kbis/s	BPSK, FSK OQPSK	10m	WPAN	Mesh network for home and support 6LoWPAN
Wi-Sun (802.15.4g)	ISM <2.4GHz	200kHz to 1.2 MHz	50 kbps to 1Mbps	FSK ,OFDM, OQPSK	1000m	WPAN	FAN and HAN Smart Utility Networks, Smart Grid, Smart Metering
NFC	13.56 MHz	1MHz	848Kbps	FSK, ASK	20cm	P2P	Contactless payment, easy other connection (Wi-Fi, BT), identity and access

Bluetooth Low Energy Channel Allocations



Bluetooth Low Energy:

- 3 advertising channels (37, 38, 39)
- 37 data channels
- 0.6-1.2 ms for scanning

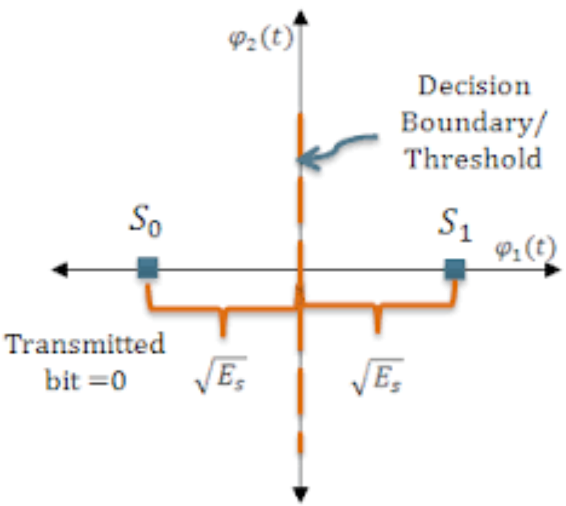
< 10 – 20 times less power

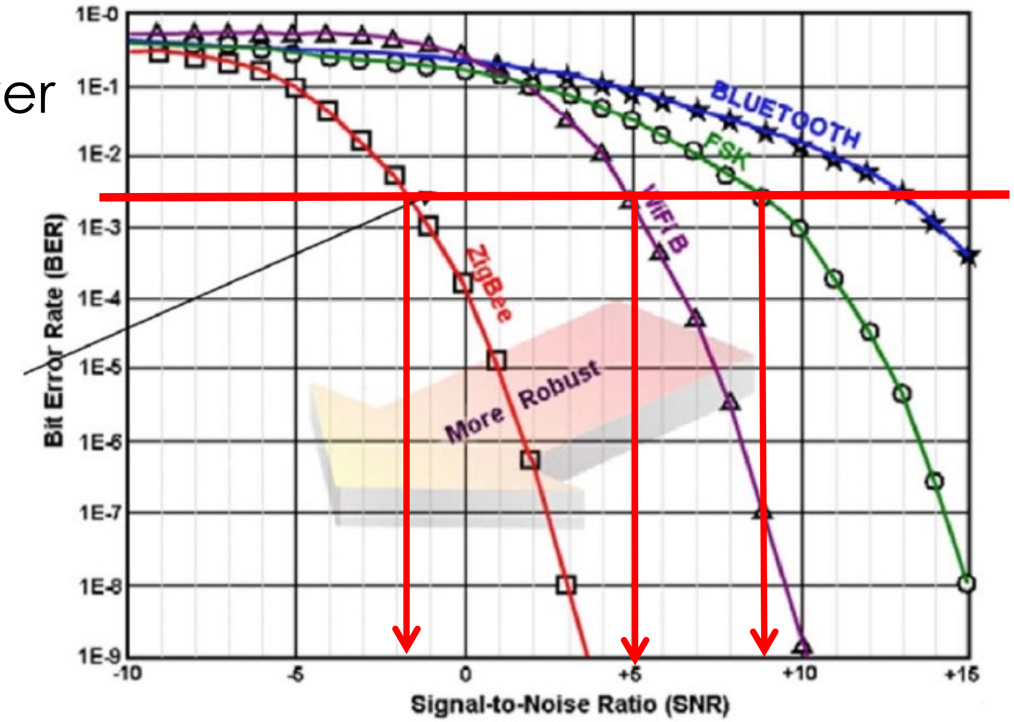
Classic Bluetooth:

- 32 hop frequencies for same task
- 22.5 ms

IEEE 802.15.4 in ISM 2.4GHz

- Low-power radio in the 2.4GHz band offering 250kbps throughput at physical layer
- Power transmission from 1mW to 100mW for range from 100m to about 1km is LOS
- CSMA/CA
- BPSK, used as physical layer in ZigBee



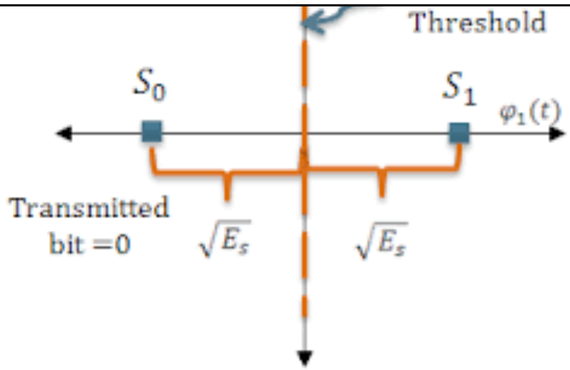


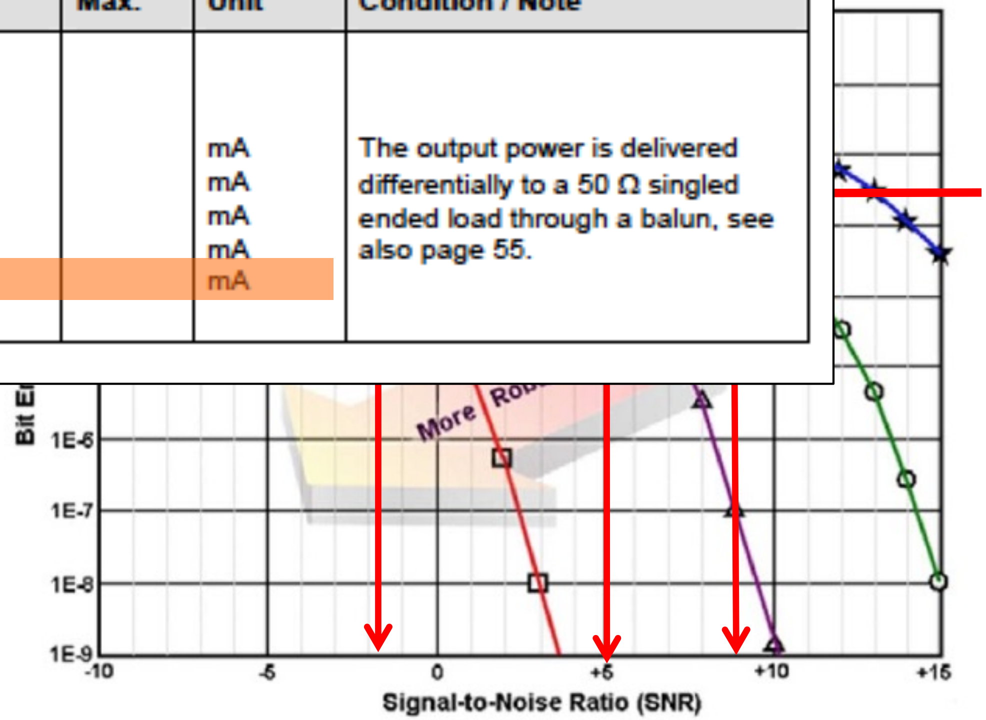
IEEE 802.15.4 in ISM 2.4GHz

- Low-power radio in the 2.4GHz band offering 250kbps throughput at physical layer

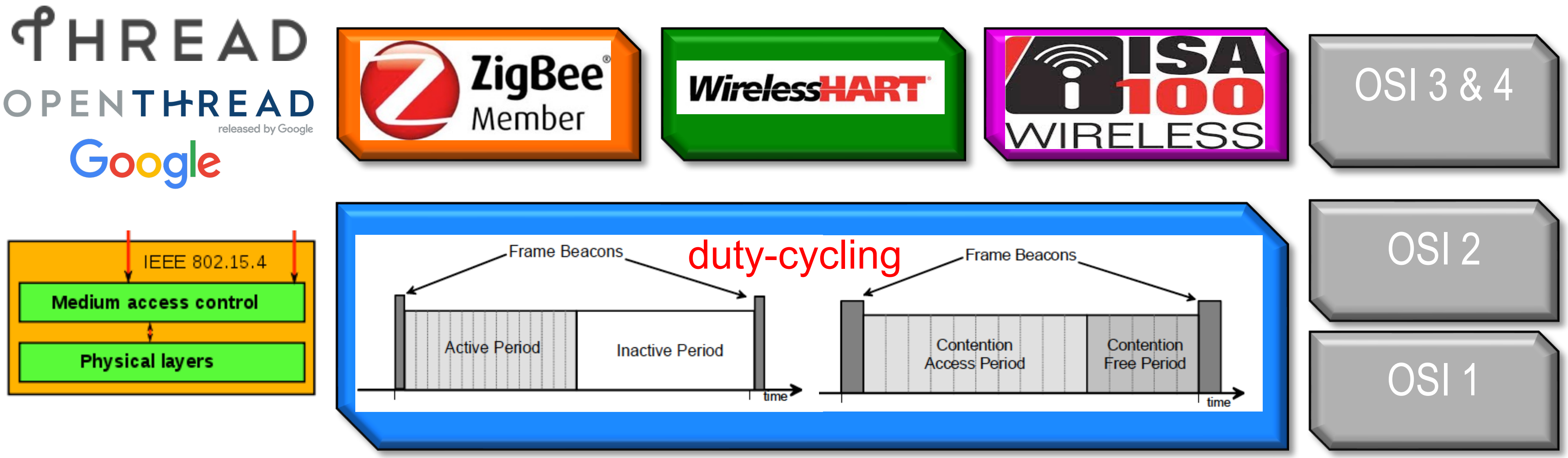
Chipcon Products from Texas Instruments — **CC2420**

Parameter	Min.	Typ.	Max.	Unit	Condition / Note
Current Consumption, transmit mode:					
P = -25 dBm		8.5		mA	The output power is delivered differentially to a 50 Ω singled ended load through a balun, see also page 55.
P = -15 dBm		9.9		mA	
P = -10 dBm		11		mA	
P = −5 dBm		14		mA	
P = 0 dBm		17.4		mA	





IEEE 802.15.4 in industry



CC2420 (TI)

Xbee (Digi)

MRF24J40MA (Microchip)

ZigBit AT86RF230 (ATMEL)

IoT Key Enabling Wireless Technologies Summary

Standards	Freq(s)	Max BW	Data rate	Mod	Range	Network	Applications
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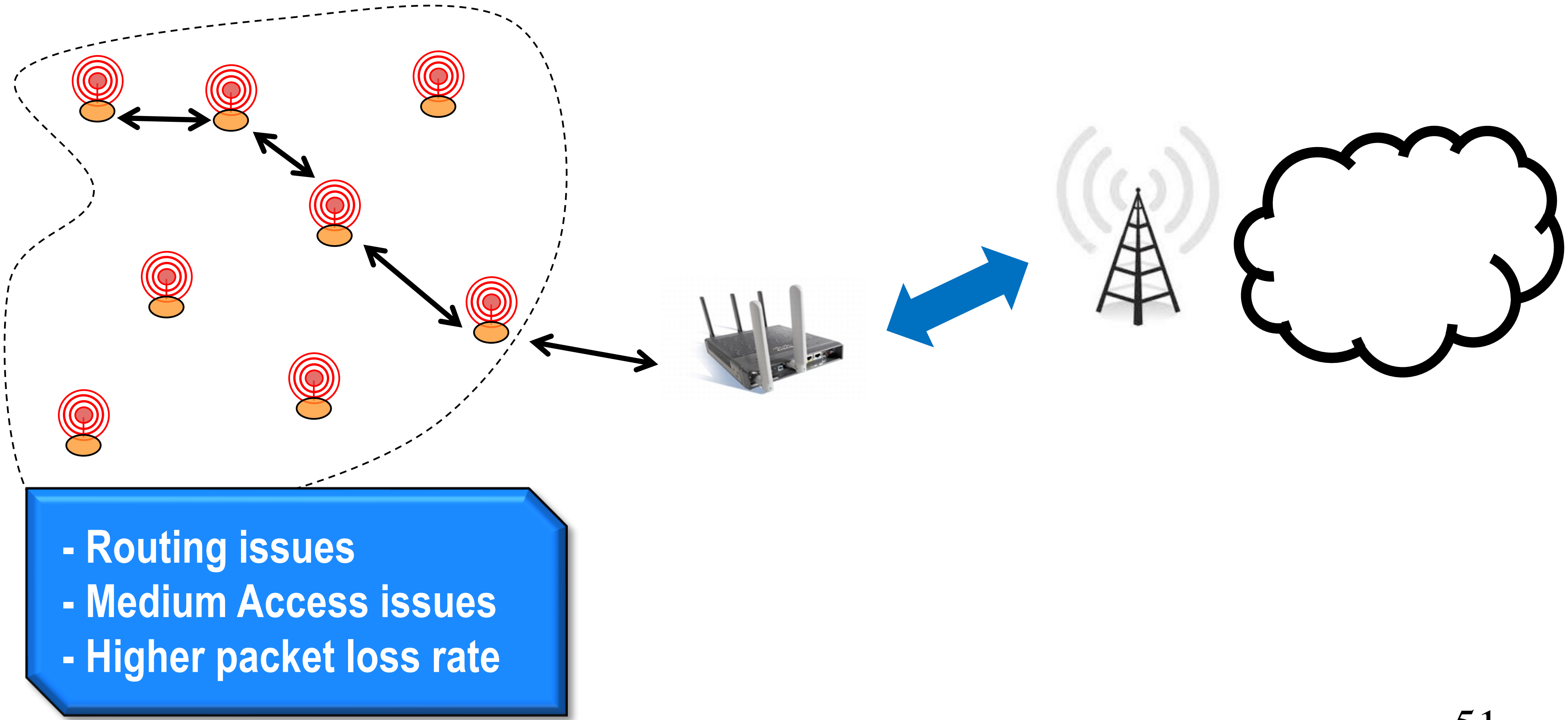
PHY Differences between 802.11ac and 802.11ah

Feature	802.11ac	802.11ah
Channel bandwidth	20/40/80/160 MHz	1/2/4/8/16 MHz
FFT size	64/128/256/512	32/64/128/256/512
Data subcarriers /	52/108/234/468	24/52/108/234/468
Pilot Sub-carriers	4/6/8/16	2/4/6/8/16
Pilot Type	Fixed pilot	Fixed pilot or traveling pilot
Subcarrier spacing	312.5 kHz	31.25 kHz
OFDM symbol duration	4.0/3.6 us	40/36 us
Guard interval (short/normal/long)	0.4/0.8/1.6 us	4/8/16 us
Preamble duration	16 us	320 us(1M BW)/160 us
Modulation types	BPSK/QPSK/16QAM/64QAM/256QAM	BPSK/QPSK/16QAM/64QAM/256QAM
Coding rates	1/2, 2/3, 3/4, 5/6	1/2 rep2, 1/2, 2/3, 3/4, 5/6
MCS	0-9	MCS0-9, 10
Transmission Mode	VHT mode, non-HT duplicate mode	Normal mode S1G, 1 MHz duplicate mode, 2 MHz duplicate mode
Duplicated PPDU	Non-HT PPDU	S1G_DUP_1M, S1G_DUP_2M
MIMO	Up to 8	Up to 4
Multi-user	Up to 4	Up to 4, only available in S1G_LONG PPDU
Beamforming	Support	Support

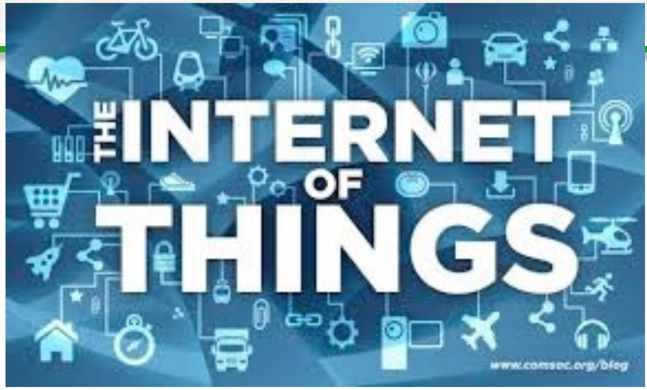
Source: Draft Amendment Proposed by 802.11 TGah Working Group

Lower energy means shorter range!

- Shorter range means multi-hop to gateways
- Usually implemented with mesh networks



The benefit of IP

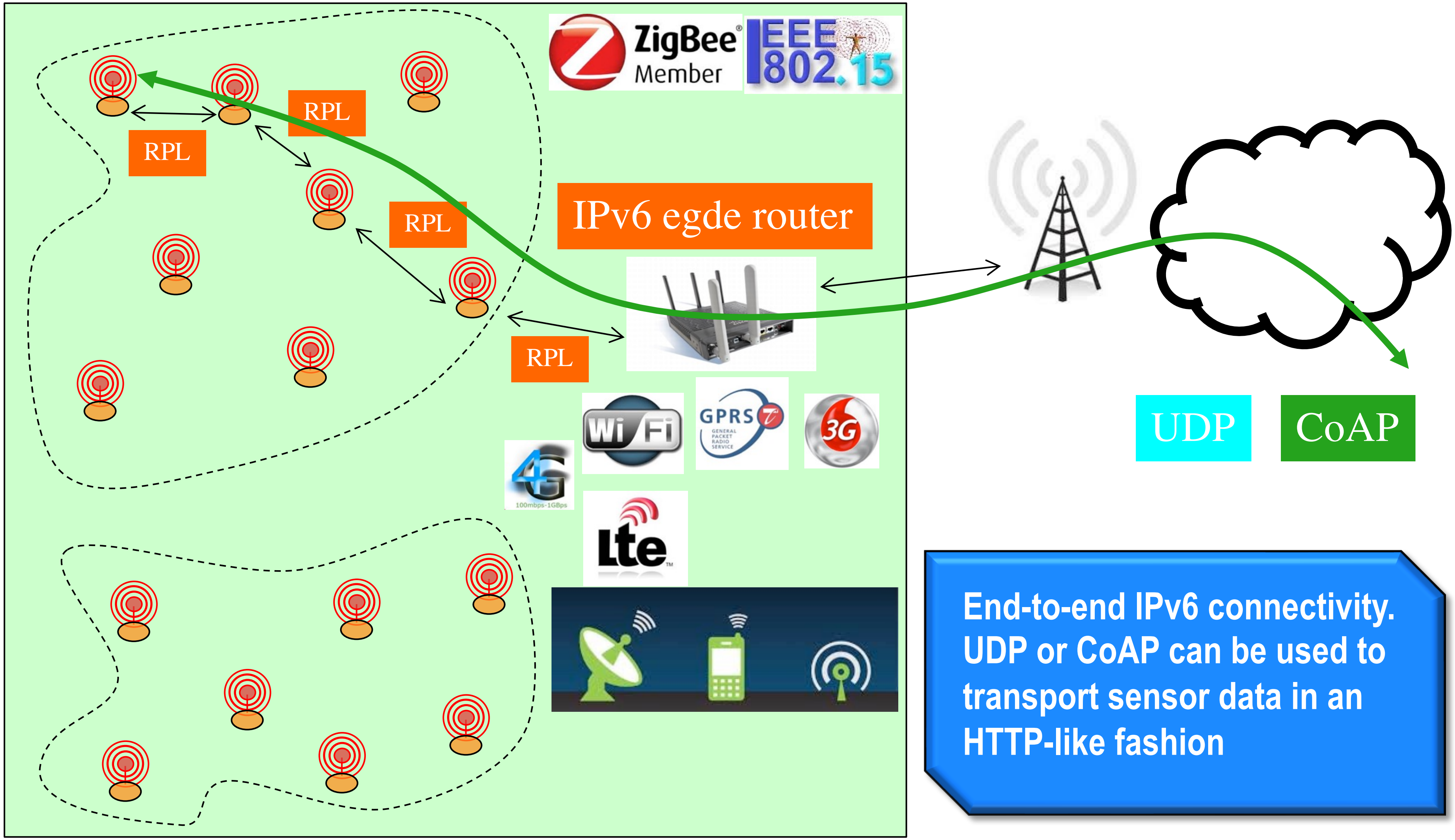


Don't reinvent the wheel!

RFC 768	UDP - User Datagram Protocol	[1980]
RFC 791	IPv4 – Internet Protocol	[1981]
RFC 792	ICMPv4 – Internet Control Message Protocol	[1981]
RFC 793	TCP – Transmission Control Protocol	[1981]
RFC 862	Echo Protocol	[1983]
RFC 1101	DNS Encoding of Network Names and Other Types	[1989]
RFC 1191	IPv4 Path MTU Discovery	[1990]
RFC 1981	IPv6 Path MTU Discovery	[1996]
RFC 2131	DHCPv4 - Dynamic Host Configuration Protocol	[1997]
RFC 2375	IPv6 Multicast Address Assignments	[1998]
RFC 2460	IPv6	[1998]
RFC 2765	Stateless IP/ICMP Translation Algorithm (SIIT)	[2000]
RFC 3068	An Anycast Prefix for 6to4 Relay Routers	[2001]
RFC 3307	Allocation Guidelines for IPv6 Multicast Addresses	[2002]
RFC 3315	DHCPv6 - Dynamic Host Configuration Protocol for IPv6	[2003]
RFC 3484	Default Address Selection for IPv6	[2003]
RFC 3587	IPv6 Global Unicast Address Format	[2003]
RFC 3819	Advice for Internet Subnetwork Designers	[2004]
RFC 4007	IPv6 Scoped Address Architecture	[2005]
RFC 4193	Unique Local IPv6 Unicast Addresses	[2005]
RFC 4291	IPv6 Addressing Architecture	[2006]
RFC 4443	ICMPv6 - Internet Control Message Protocol for IPv6	[2006]
RFC 4861	Neighbor Discovery for IP version 6	[2007]
RFC 4944	**Transmission of IPv6 Packets over IEEE 802.15.4 Networks**	**[2007]**

From ArchRock "6LowPan tutorial"

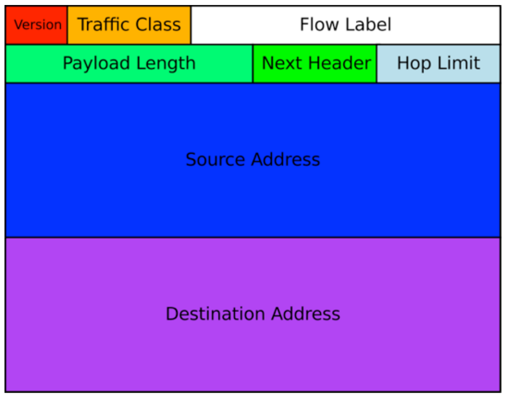
Using IP protocols



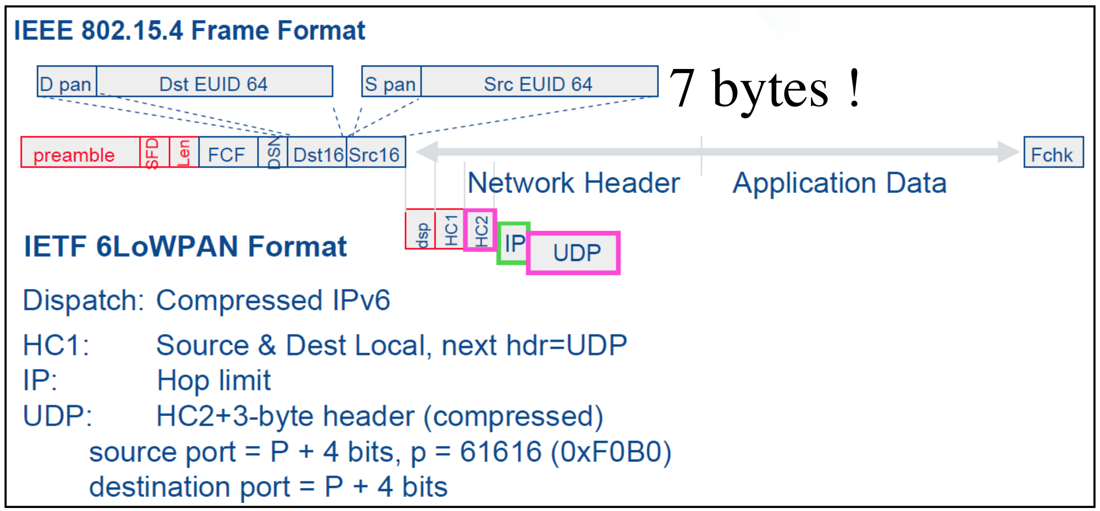
End-to-end IPv6 connectivity. UDP or CoAP can be used to transport sensor data in an HTTP-like fashion

IP need IP addresses!

- IPv4 has no more addresses!
- IPv6 gives plenty of addresses
  - 128bit address=16bytes!
- 6LowPan adapts IPv6 to resource-constrained devices
  - Compressed IPv6 header

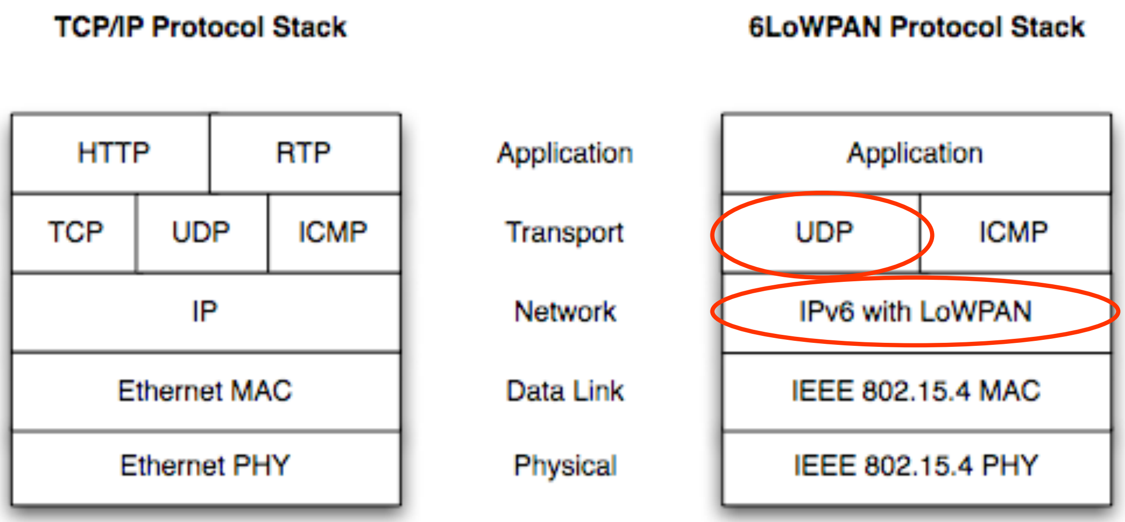


40 bytes

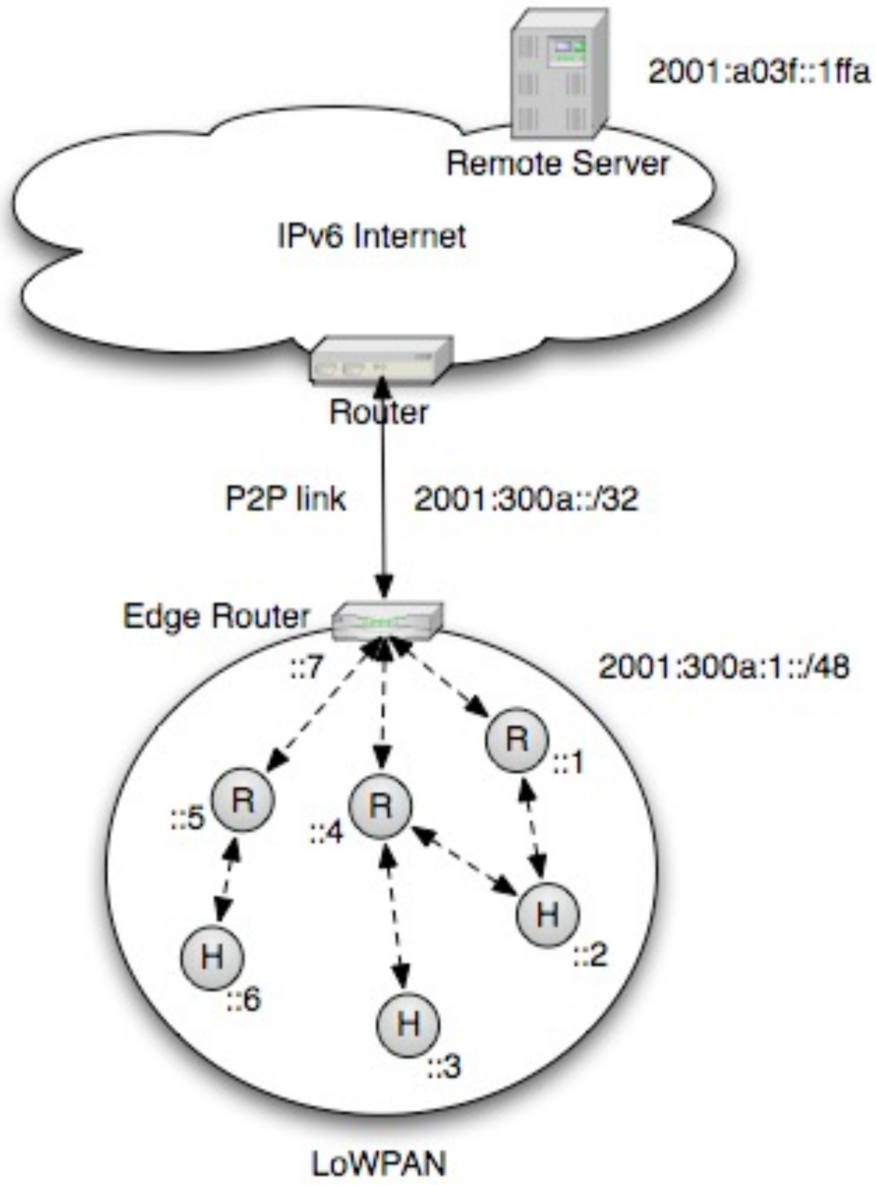


The 6LoWPAN Format

- 6LoWPAN is an adaptation header format
  - Enables the use of IPv6 over low-power wireless links
  - IPv6 header compression
  - UDP header compression



Addressing Example



Internet for things

UDP

RPL
Routing Protocol for Low power & Lossy Networks

6LowPan
802.15.4

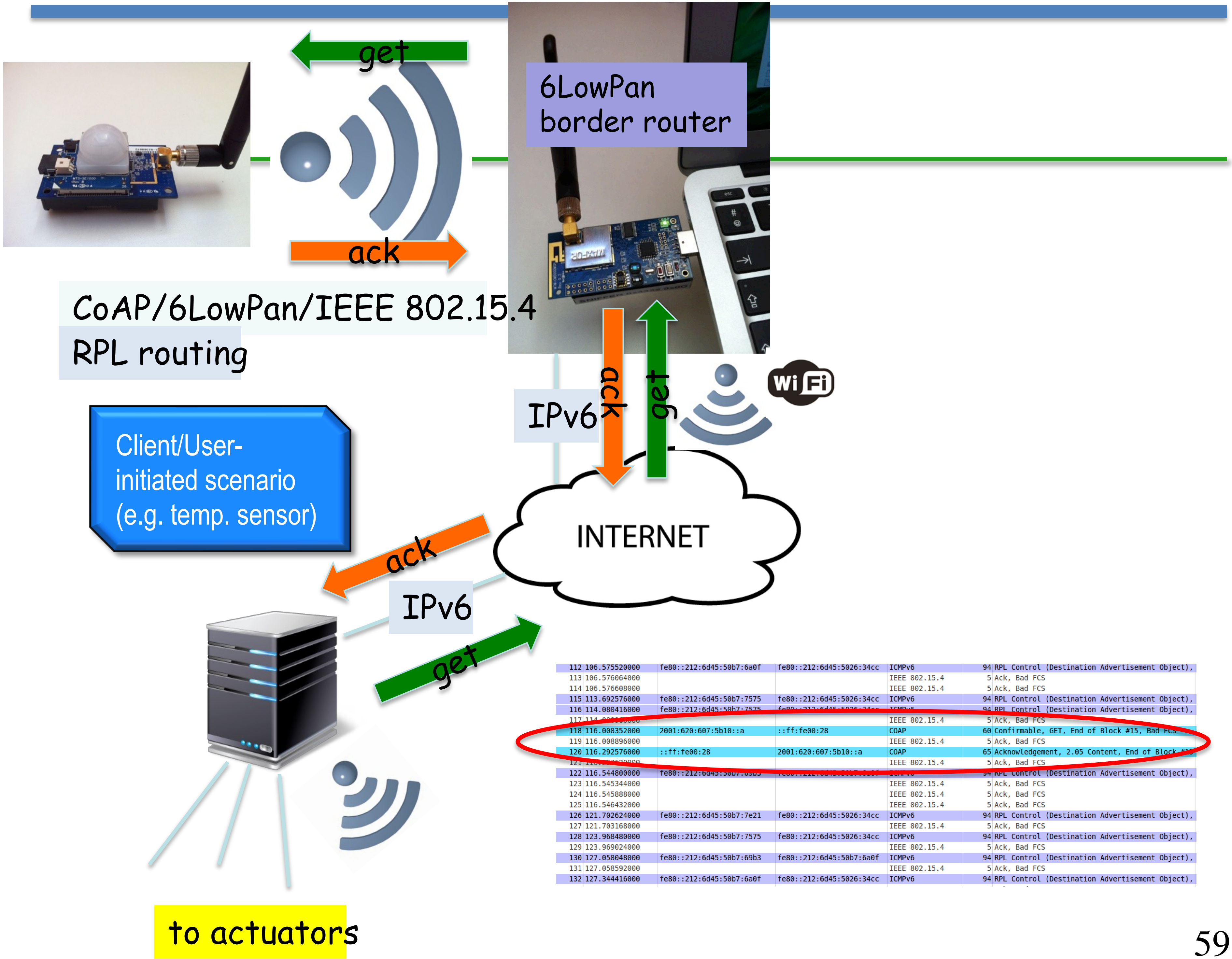
TCP, UDP

Internet Routing Protocols: RIP, OSPF, BGP,…

IPv4, IPv6

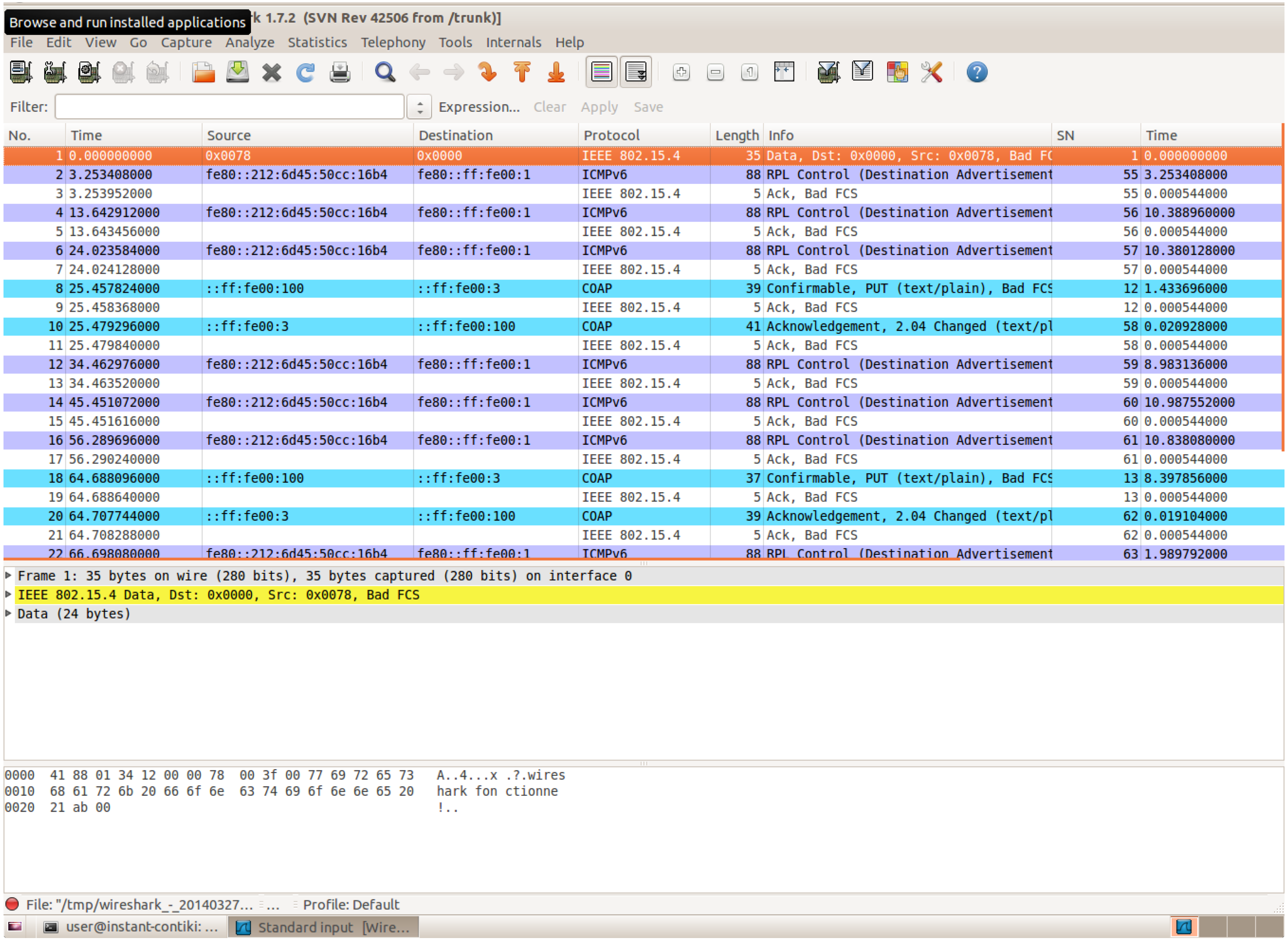
Internet for things

CoAP: Constrained Application Protocol	HTTP
UDP	TCP, UDP
RPL Routing Protocol for Low power & Lossy Networks	Internet Routing Protocols: RIP, OSPF, BGP,...
6LowPan 802.15.4	IPv4, IPv6



112	106.575520000	fe80::212:6d45:50b7:6a0f	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
113	106.576064000			IEEE 802.15.4	5	Ack, Bad FCS
114	106.576608000			IEEE 802.15.4	5	Ack, Bad FCS
115	113.692576000	fe80::212:6d45:50b7:7575	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
116	114.080416000	fe80::212:6d45:50b7:7575	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
117	[illegible]			IEEE 802.15.4	5	Ack, Bad FCS
118	116.008352000	2001:620:607:5b10::a	::ff:fe00:28	COAP	60	Confirmable, GET, End of Block #15, Bad FCS
119	116.008896000			IEEE 802.15.4	5	Ack, Bad FCS
120	116.292576000	::ff:fe00:28	2001:620:607:5b10::a	COAP	65	Acknowledgement, 2.05 Content, End of Block #15
121	[illegible]			IEEE 802.15.4	5	Ack, Bad FCS
122	116.544800000	fe80::212:6d45:50b7:69b3	[illegible]	[illegible]	94	RPL Control (Destination Advertisement Object),
123	116.545344000			IEEE 802.15.4	5	Ack, Bad FCS
124	116.545888000			IEEE 802.15.4	5	Ack, Bad FCS
125	116.546432000			IEEE 802.15.4	5	Ack, Bad FCS
126	121.702624000	fe80::212:6d45:50b7:7e21	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
127	121.703168000			IEEE 802.15.4	5	Ack, Bad FCS
128	123.968480000	fe80::212:6d45:50b7:7575	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),
129	123.969024000			IEEE 802.15.4	5	Ack, Bad FCS
130	127.058048000	fe80::212:6d45:50b7:69b3	fe80::212:6d45:50b7:6a0f	ICMPv6	94	RPL Control (Destination Advertisement Object),
131	127.058592000			IEEE 802.15.4	5	Ack, Bad FCS
132	127.344416000	fe80::212:6d45:50b7:6a0f	fe80::212:6d45:5026:34cc	ICMPv6	94	RPL Control (Destination Advertisement Object),

RPL and CoAP exchanges



Copper for web browser

- CoAP pluggin to query CoAP nodes in an http-like fashion