Wireless network evolution, Digital eco-system
&
Internet of Things

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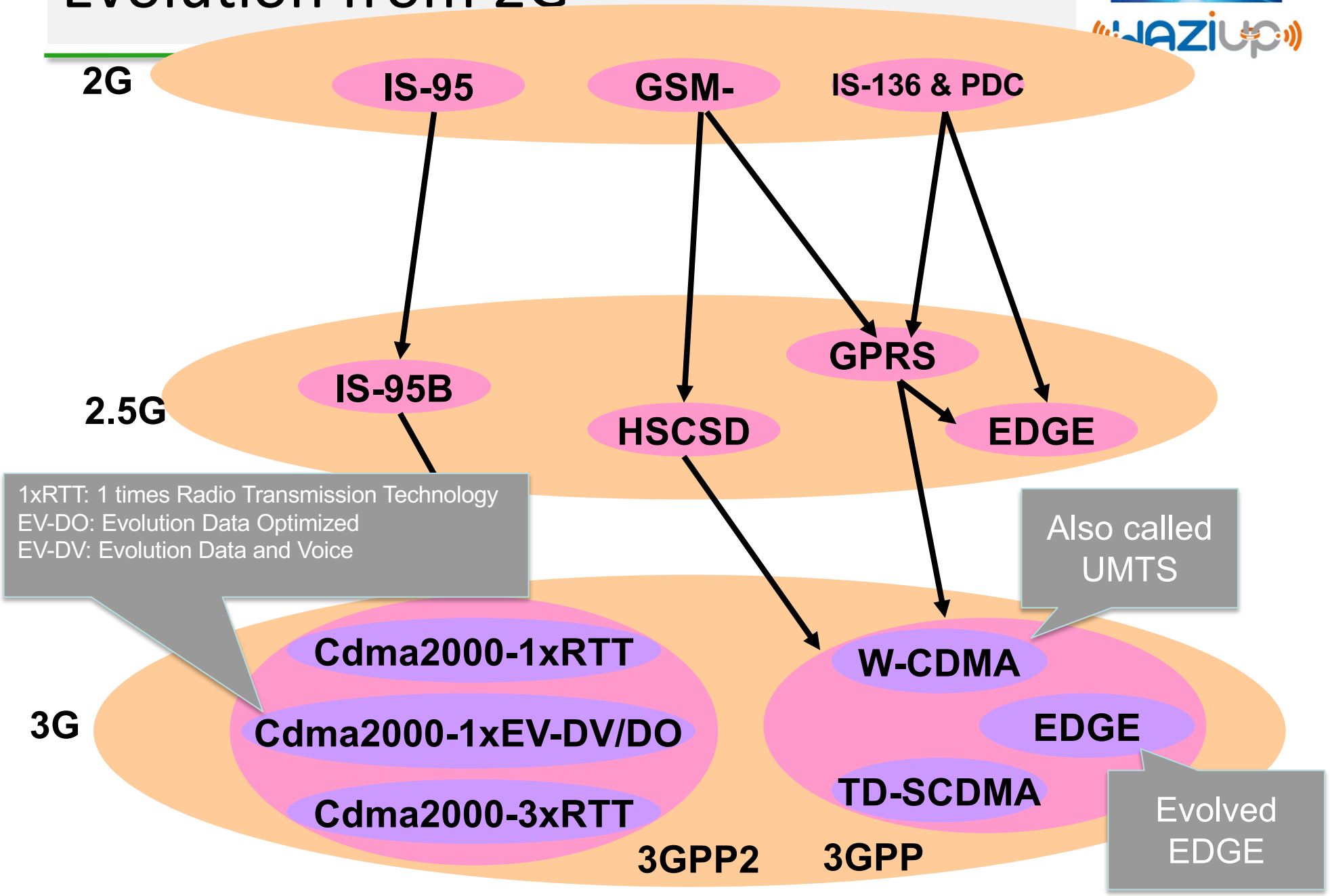
Cellular Network Generations

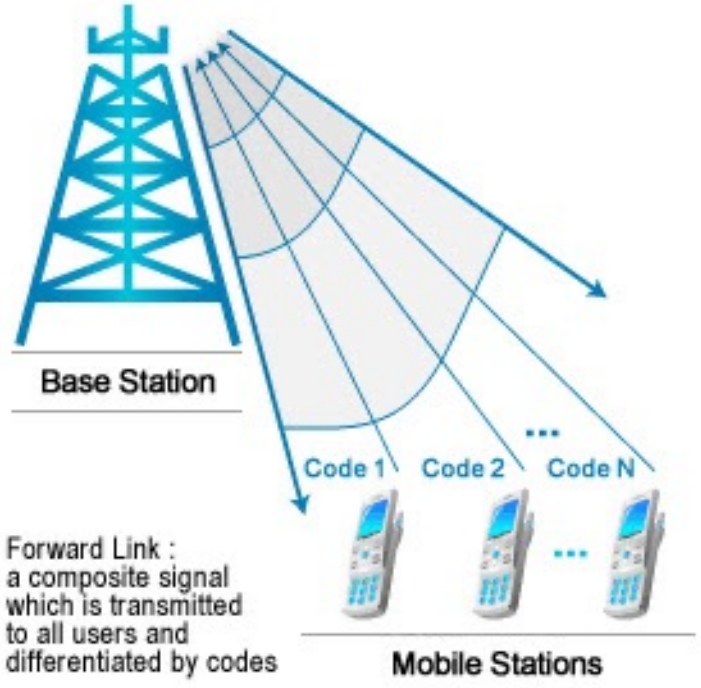
- It is useful to think of cellular Network/telephony in terms of *generations*:
  - 0G: Briefcase-size mobile radio telephones
  - 1G: *Analog* cellular telephony
  - 2G: *Digital* cellular telephony
  - 3G: *High-speed* digital cellular telephony (including *video telephony*)
  - 4G: IP-based “anytime,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

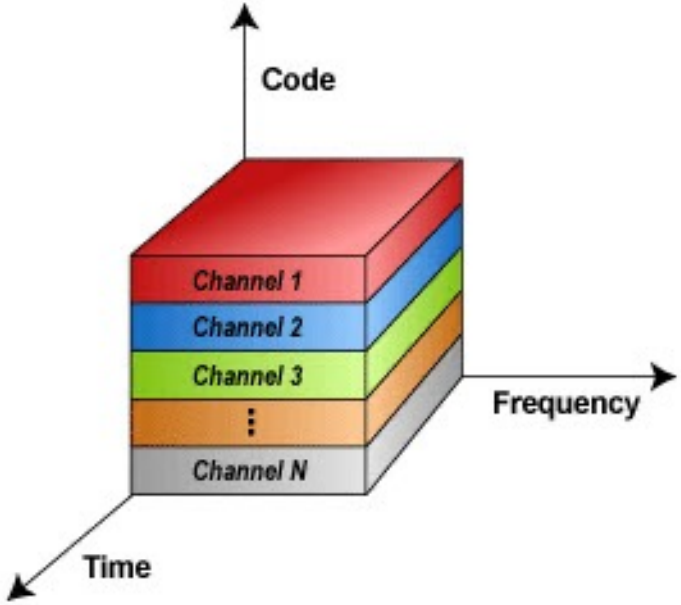
Evolution from 2G



CDMA

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

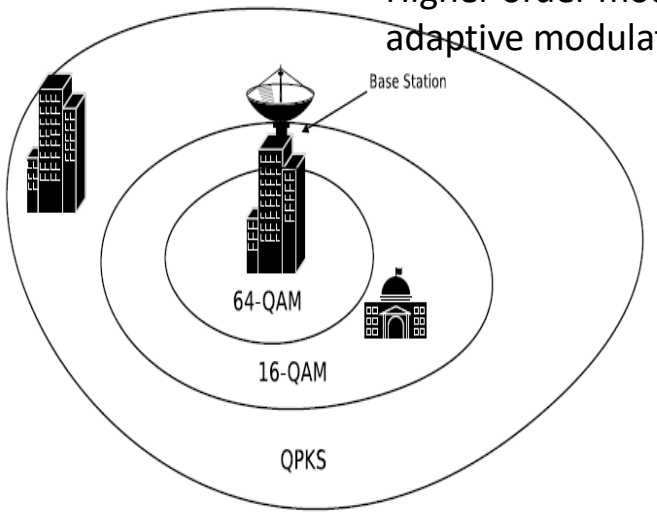


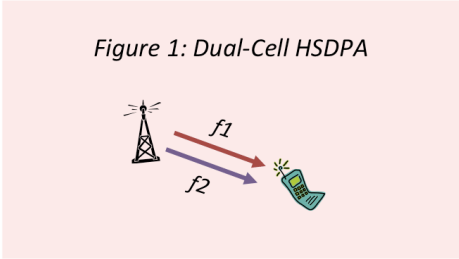


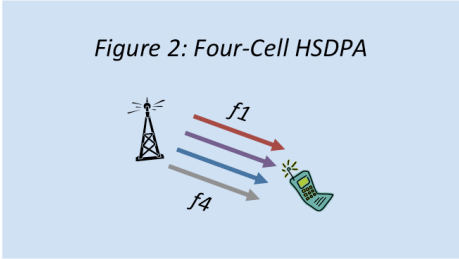
CDMA in which each channel is assigned a unique code which is orthogonal to codes used by other users.

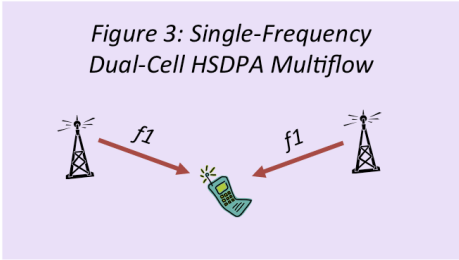
(some) key technologies

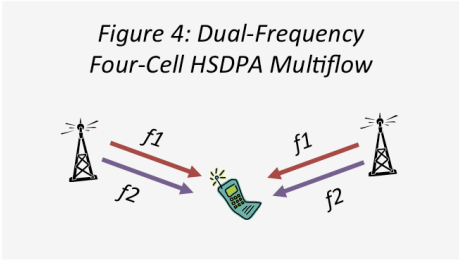
Higher order modulation and adaptive modulation



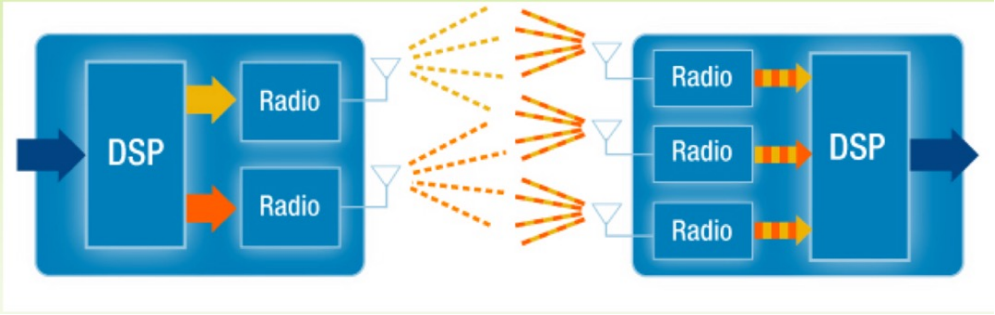




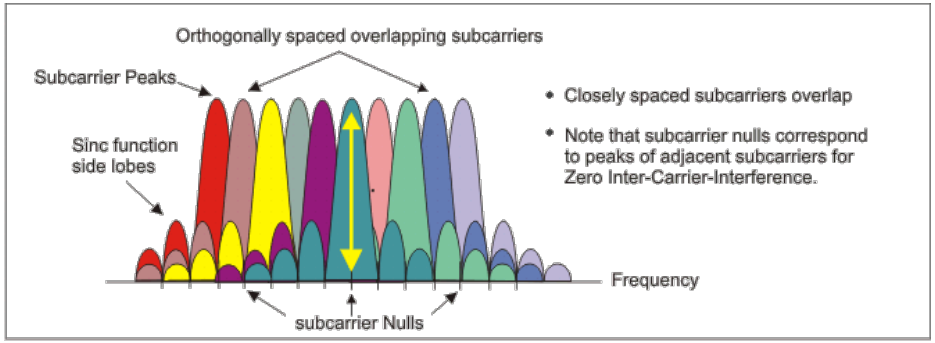




Multiple antenna systems, MIMO

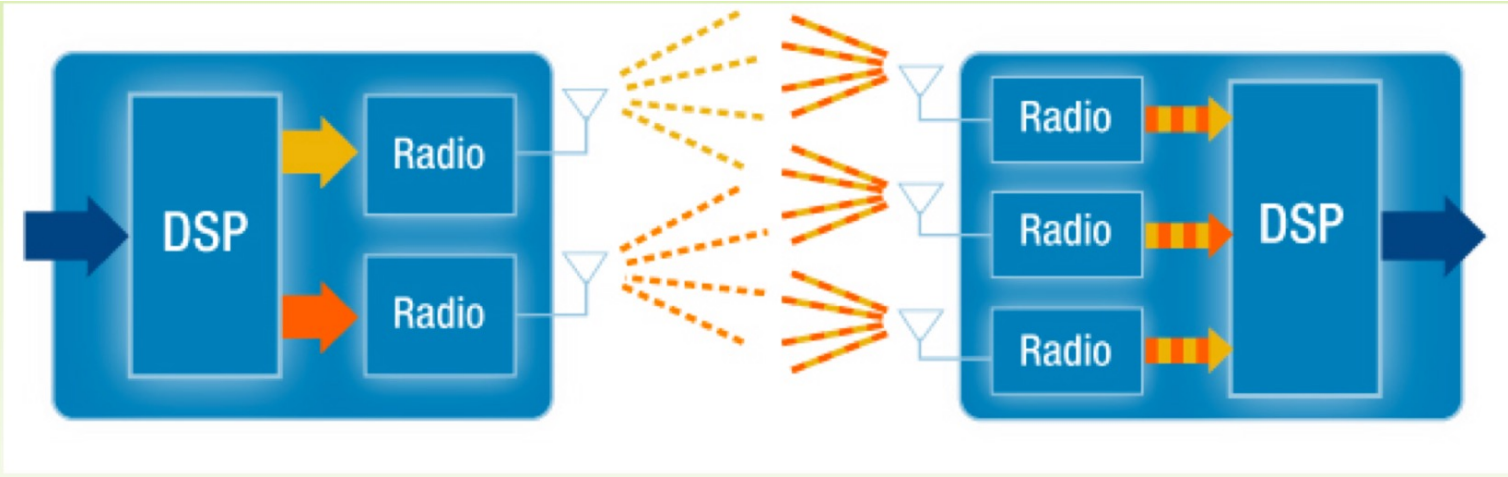


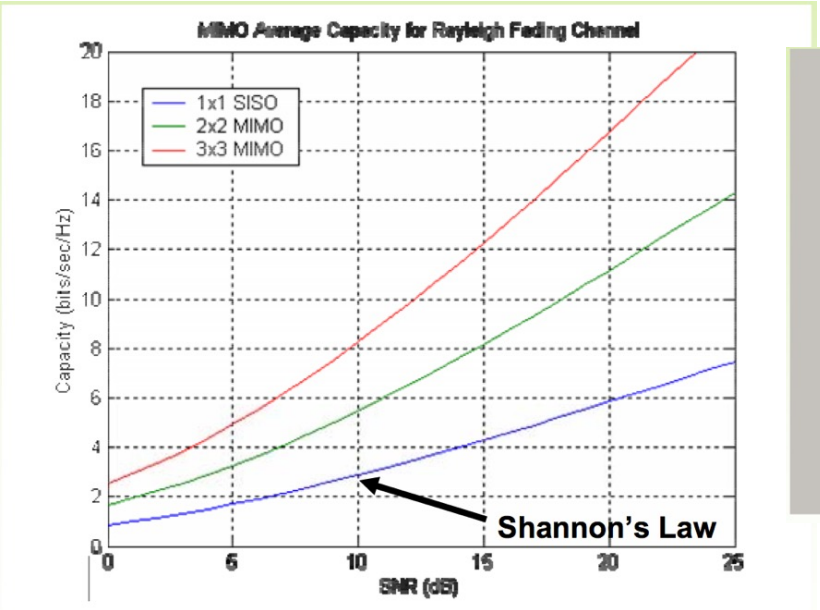
Orthogonal Frequency Division Multiplexing (OFDM)



OFDM Signal Frequency Spectra

MIMO - Multiple Input Multiple Output

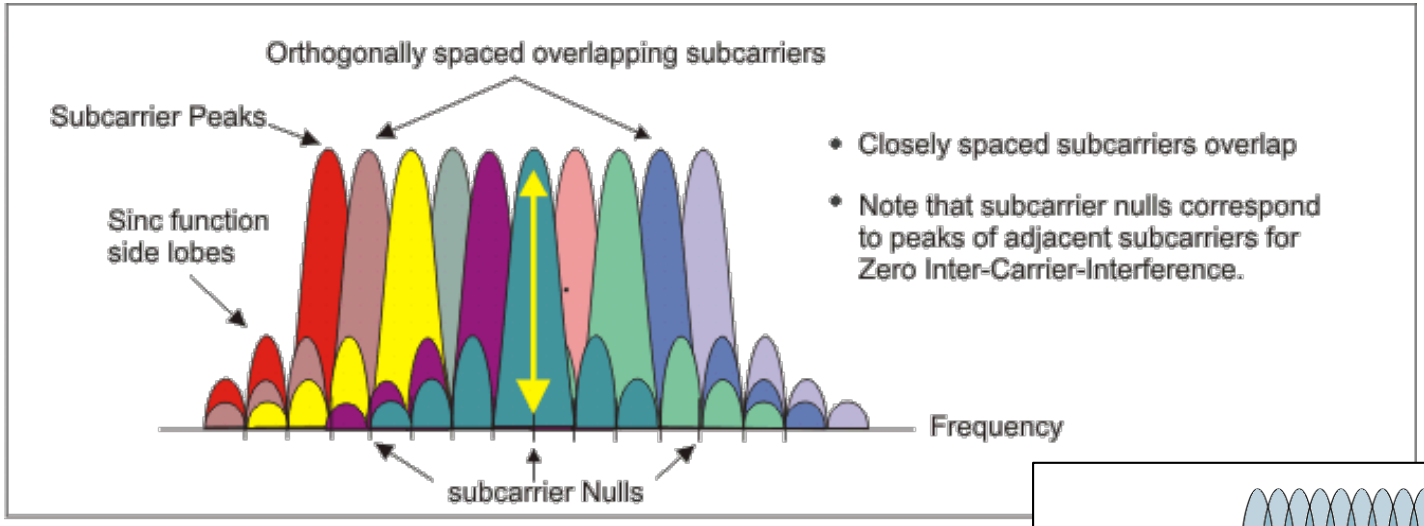




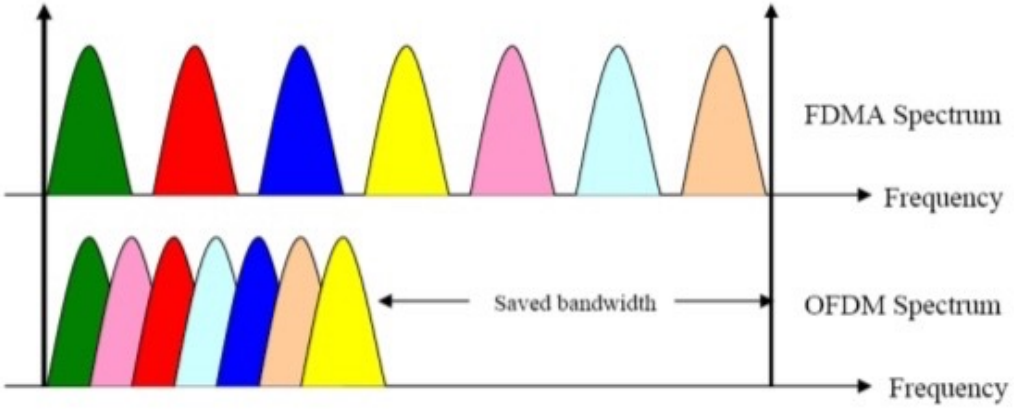
Each multipath route is treated as a separate channel, creating many "virtual wires" over which to transmit signals

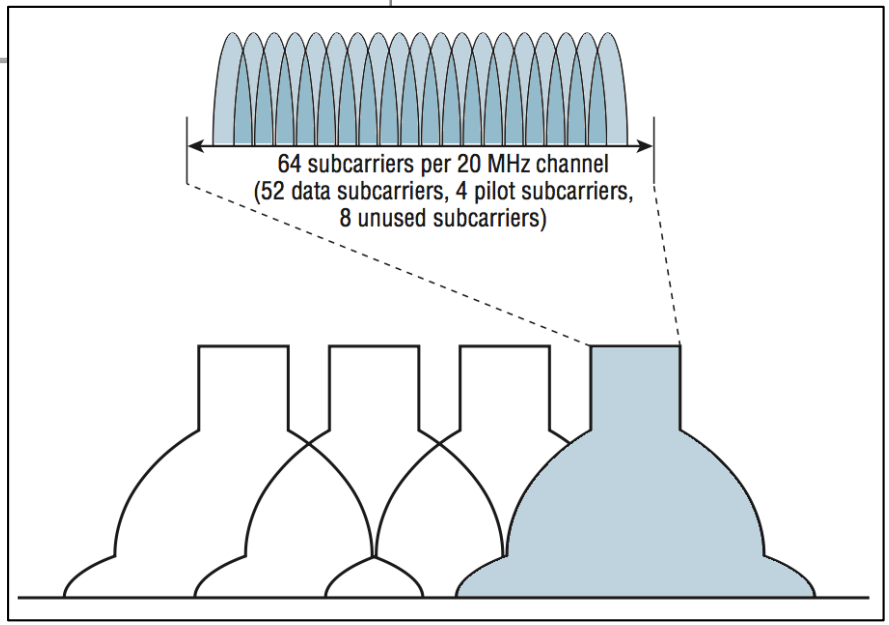
Traditional radios are confused by this multipath, while MIMO takes advantage of these "echoes" to increase range and throughput

OFDM

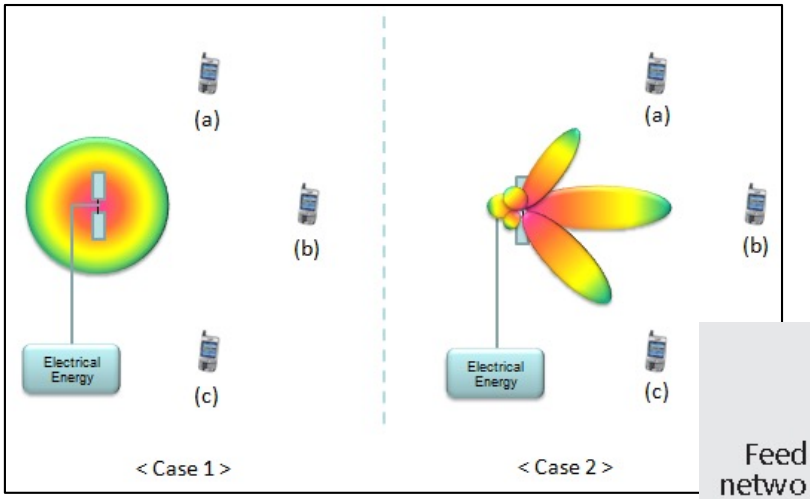


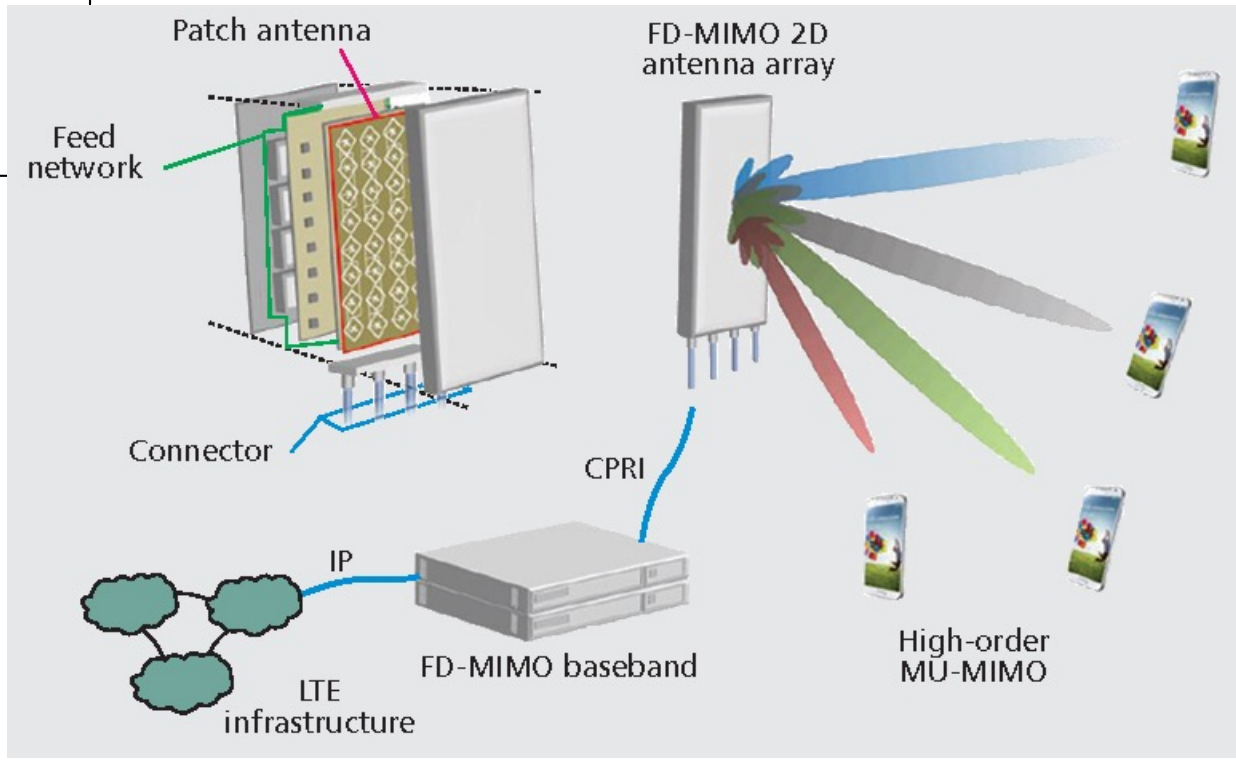
OFDM Signal Frequency Spectra





beam forming on Massive MIMO





3.5G (HSPA)

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

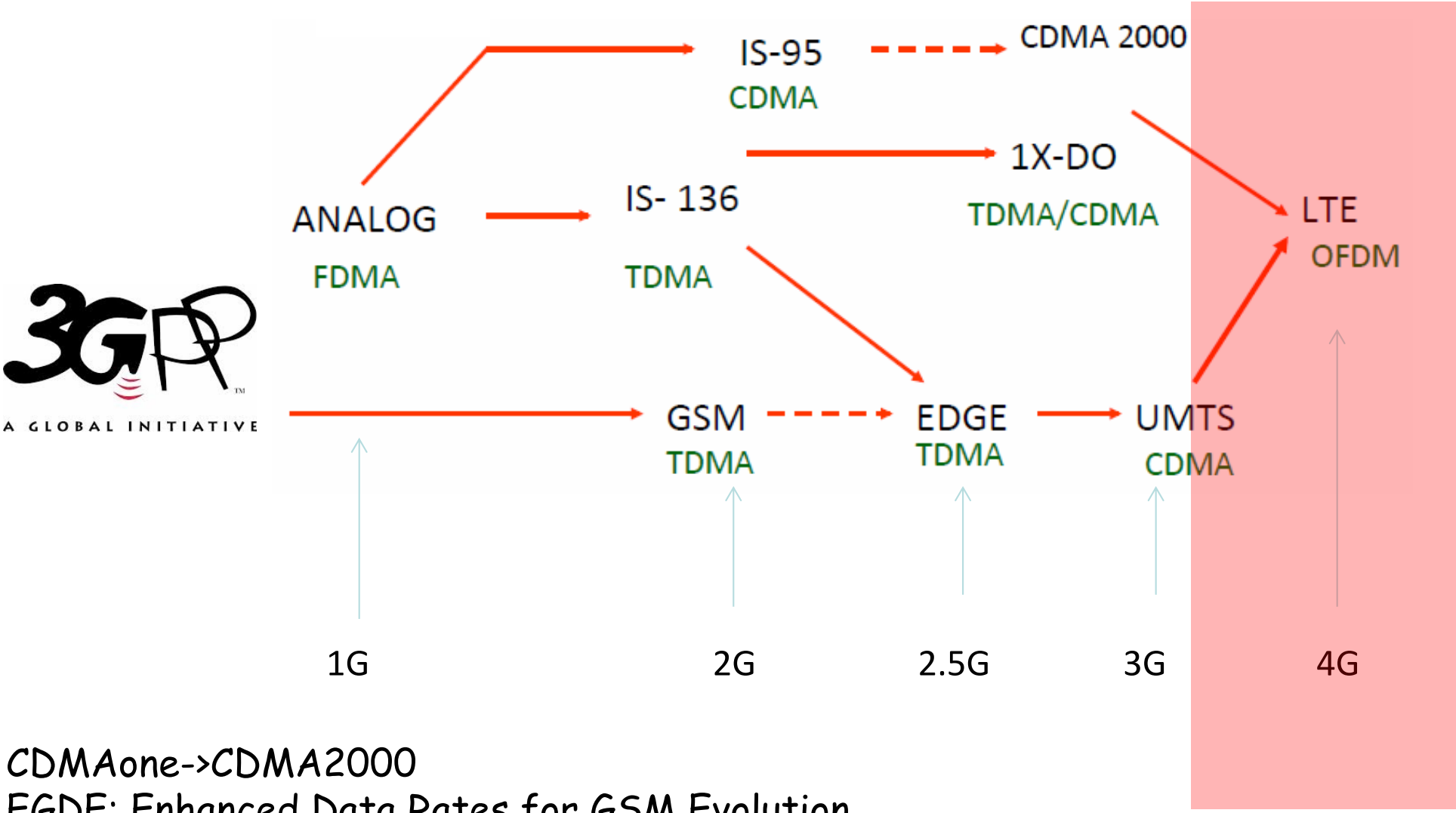
3.5G introduces many new features that will enhance the UMTS technology in future. 1xEV-DV already supports most of the features that will be provided in 3.5G. These include:

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

HSPA+

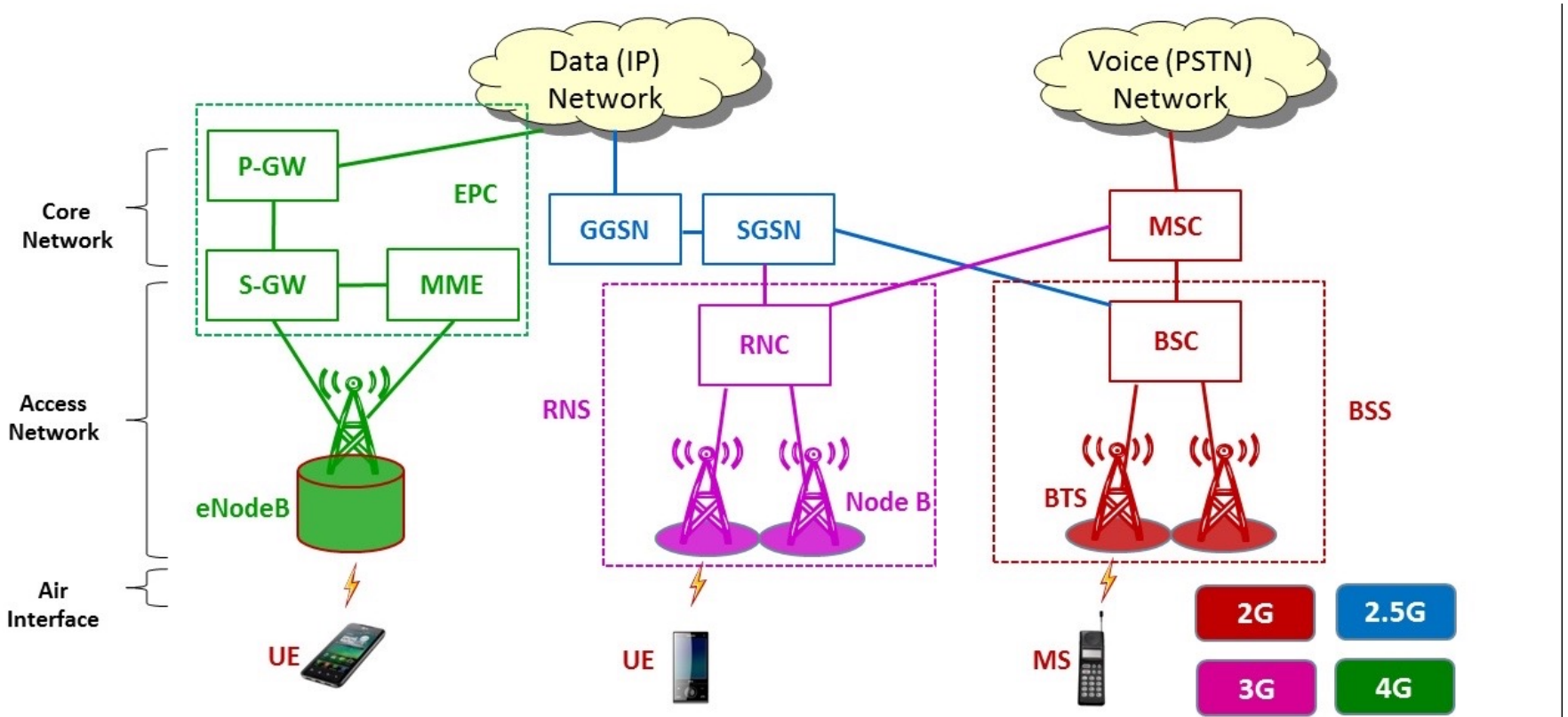
- Evolved HSPA (also known as: HSPA Evolution, HSPA+) is a wireless broadband standard defined in 3GPP release 7 and 8 of the WCDMA specification.
- Provides extensions to the existing HSPA definitions and is therefore backwards compatible all the way to the original Release 99 WCDMA network releases.
- 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

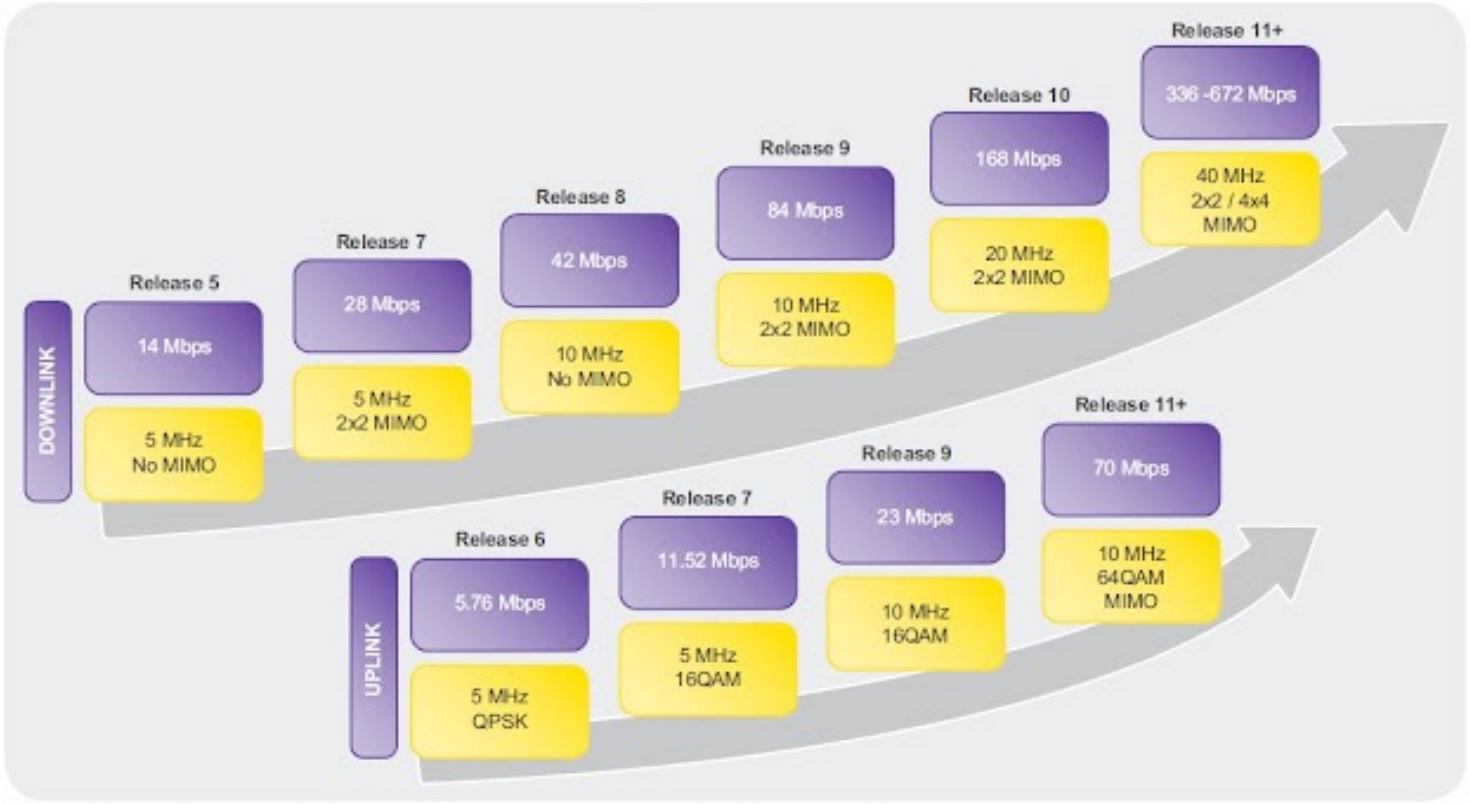


CDMAone->CDMA2000
EGDE: Enhanced Data Rates for GSM Evolution
UMTS:Universal Mobile Telecommunications System (W-CDMA)

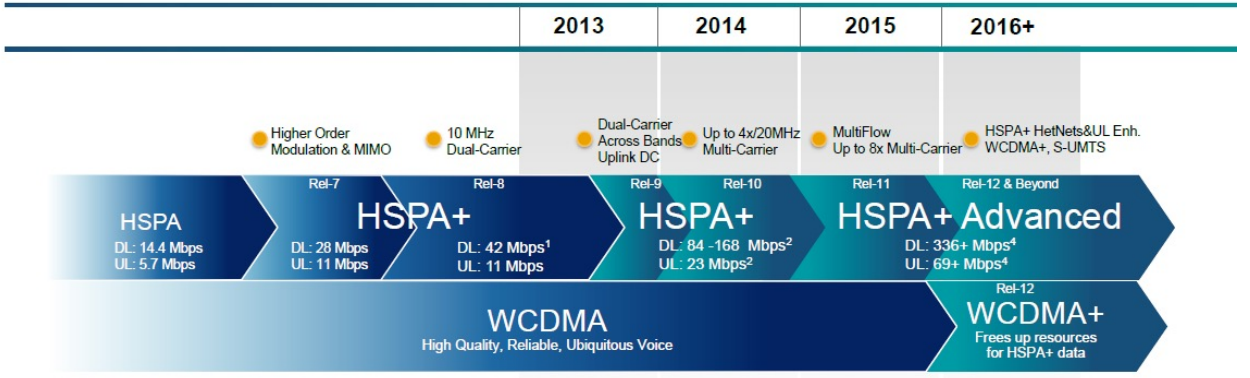
2G, 3G & 4G network architecture



More throughput in near future!



From NSN white paper on HSPA evolution



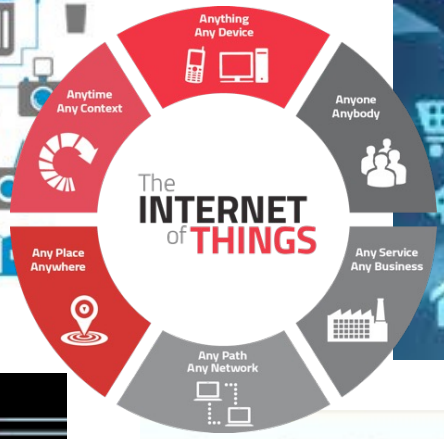
From QualComm

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

5G?

- A set of objectives, various technologies

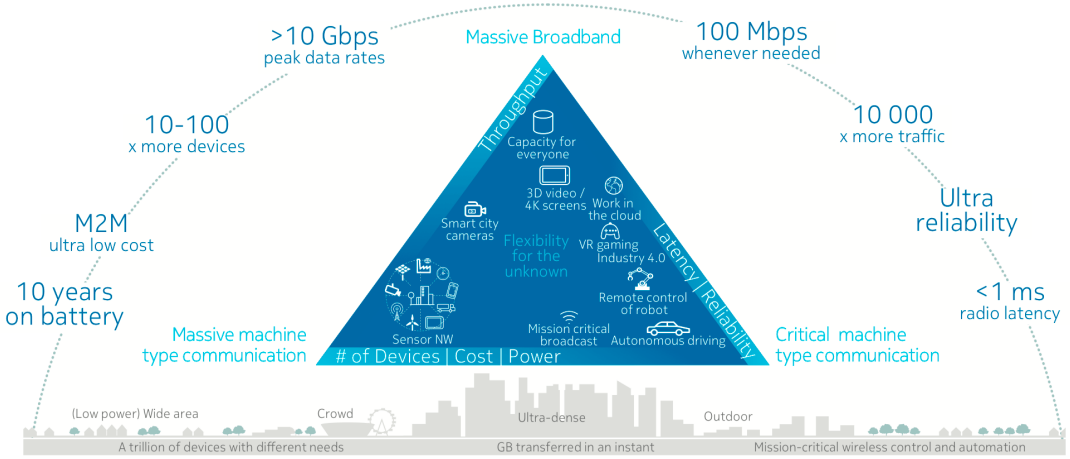
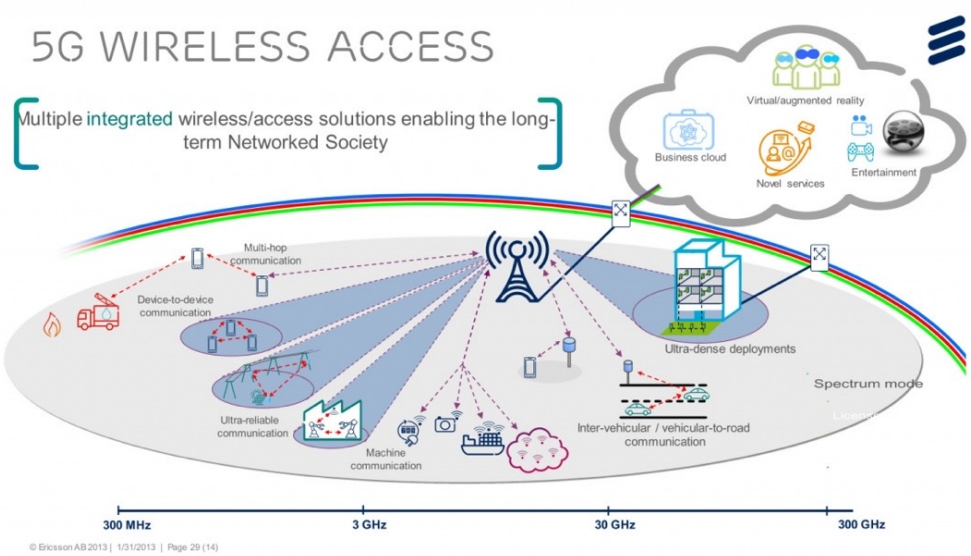
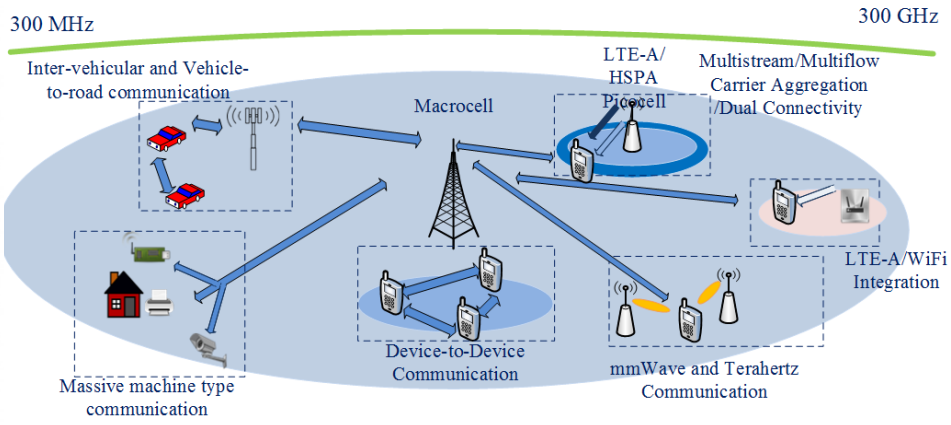
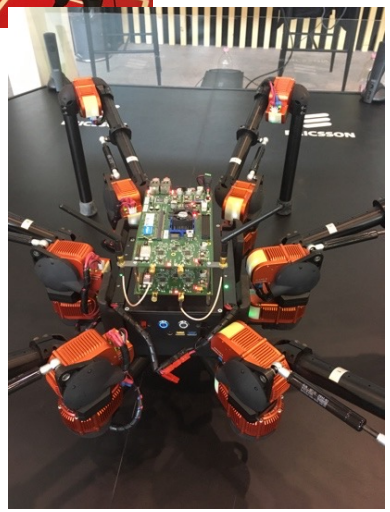


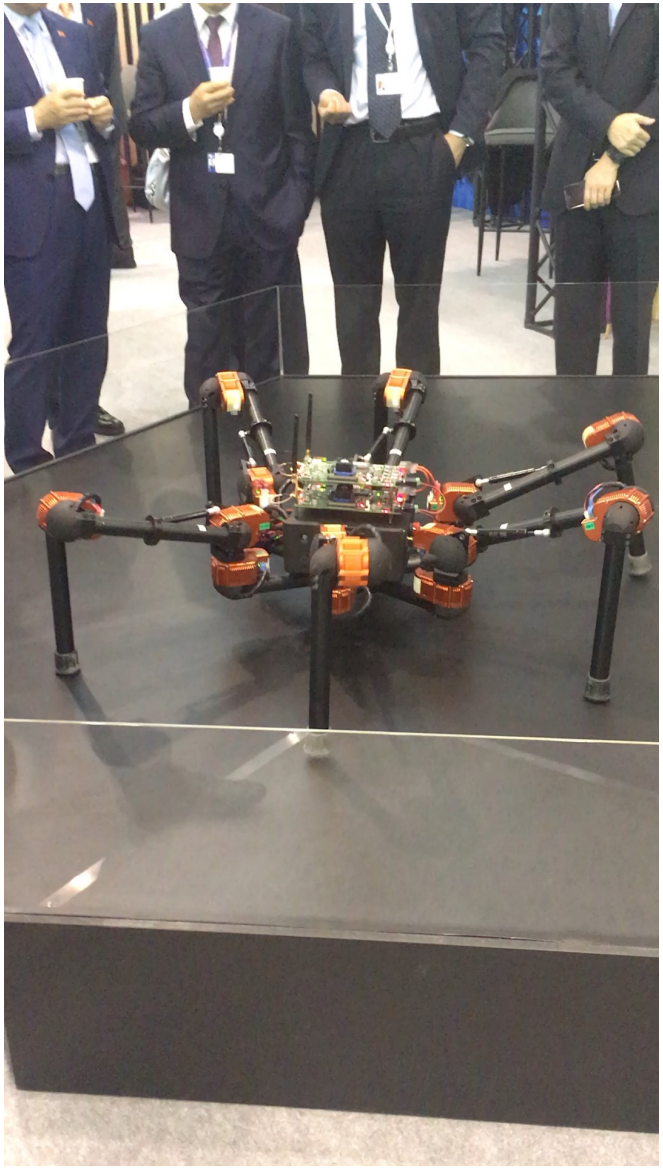
Figure 1. 5G will enable very diverse use cases with extreme range of requirements





5G demo at ITU Telecom World'19





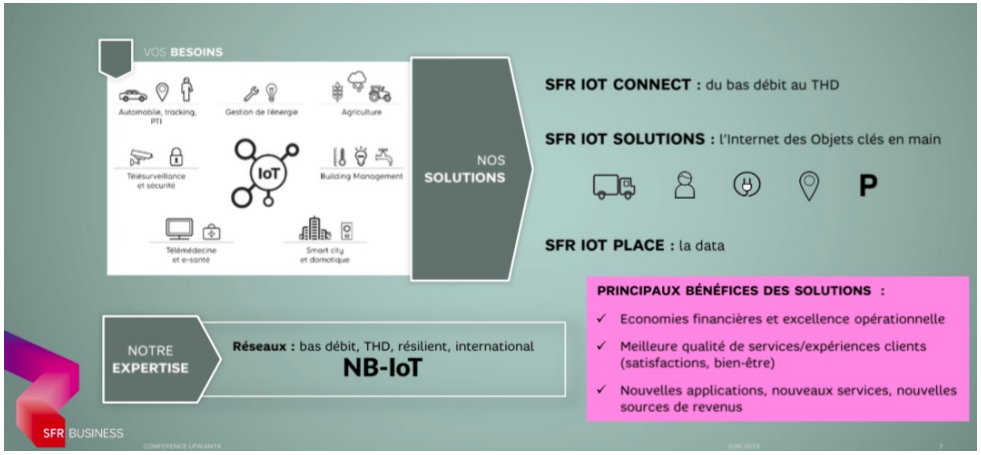
NB-IoT (LTE Cat NB1)

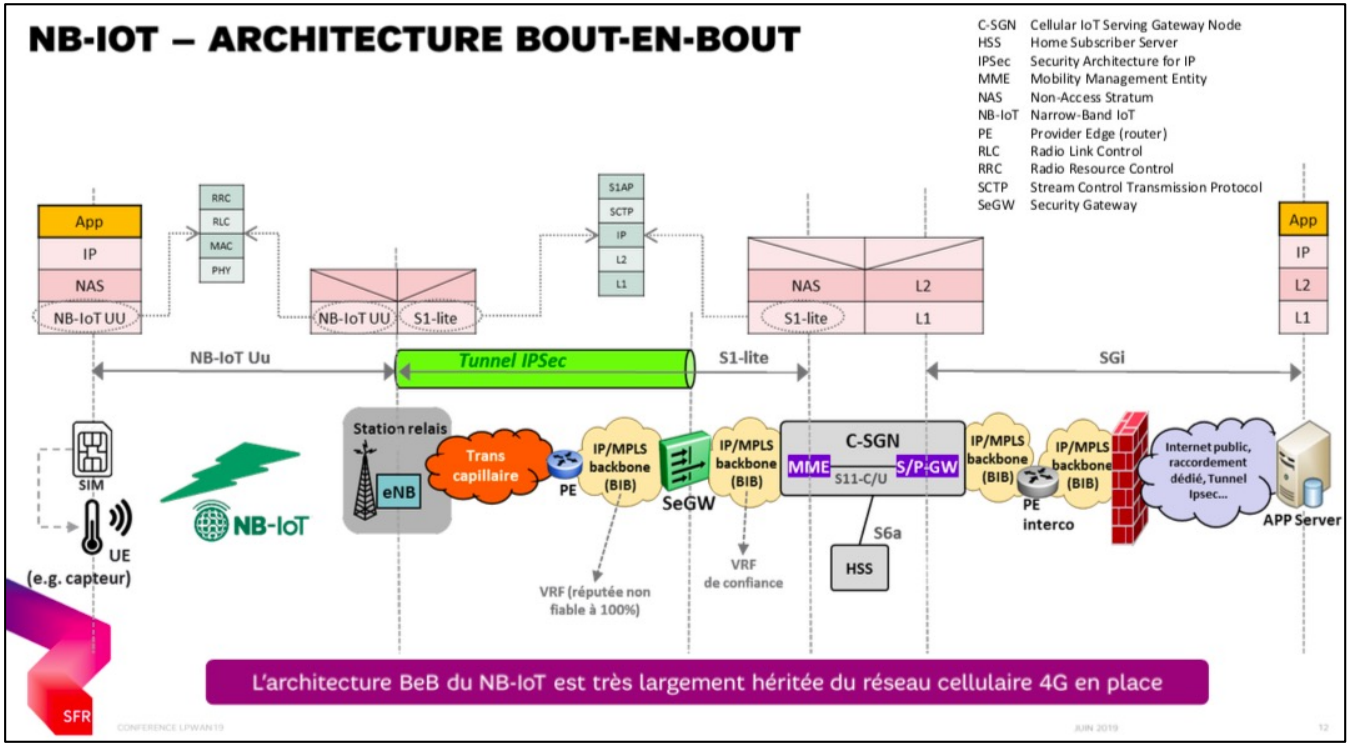
- Narrow-Band IoT uses much smaller bandwitdh than LTE-M to offer very low-power operation mode to small devices
- Throughput up to 250kbps

3GPP Narrowband Cellular Standards [edit]

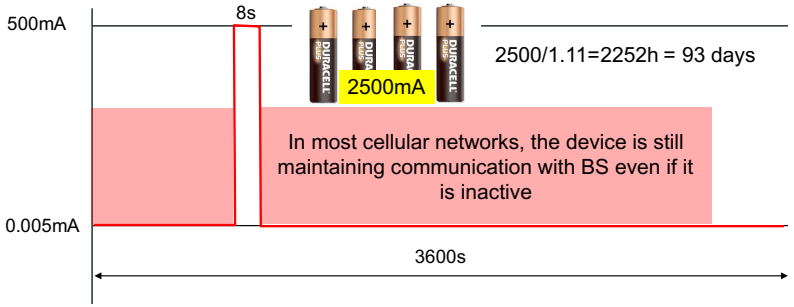
V·T·E [7][8]	LTE Cat 1	LTE-M				NB-IoT
		LC-LTE/MTCe	eMTC			
		LTE Cat 0	LTE Cat M1	LTE Cat M2	non-BL	LTE Cat NB1
3GPP Release	Release 8	Release 12	Release 13	Release 14	Release 14	Release 13
Downlink Peak Rate	10 Mbit/s	1 Mbit/s	1 Mbit/s			250 kbit/s
Uplink Peak Rate	5 Mbit/s	1 Mbit/s	1 Mbit/s			250 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

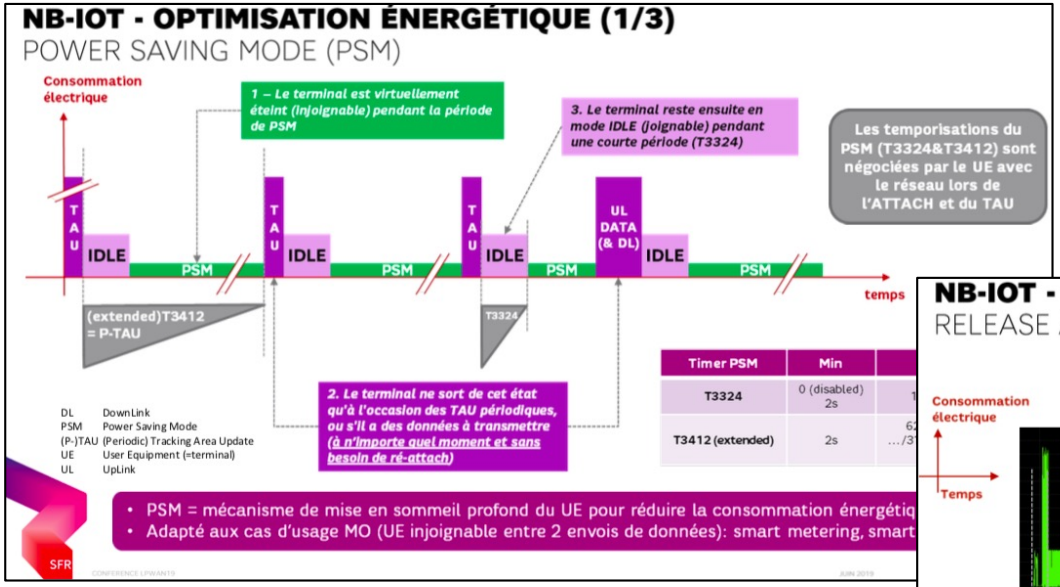
NB-IoT by SFR

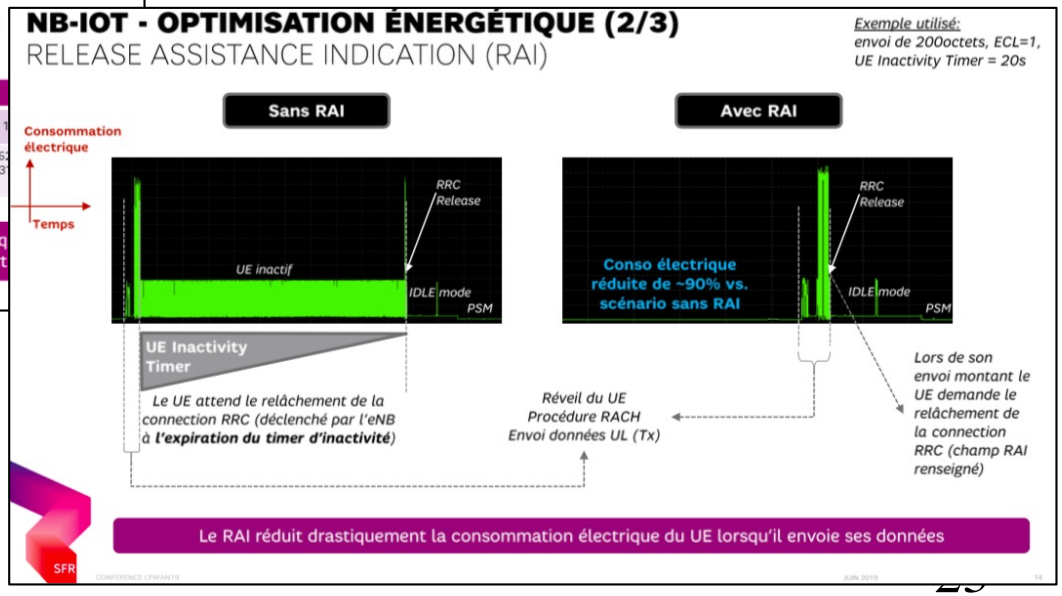

VOS BESOINS
Automobile, tracking, PTI
Gestion de l'énergie
Agriculture
Télésurveillance et sécurité
IoT
Building Management
Télémédecine et e-santé
Smart city et domotique
NOS SOLUTIONS
SFR IOT CONNECT : du bas débit au THD
SFR IOT SOLUTIONS : l'Internet des Objets clés en main
P
SFR IOT PLACE : la data
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
NOTRE EXPERTISE
Réseaux : bas débit, THD, résilient, international
NB-IoT
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
S1AP
SCTP
IP
L2
L1
S1-lite
NB-IoT Uu
Tunnel IPSec
SGi
SIM
UE
(e.g. capteur)
NB-IoT
Station relais
eNB
Trans capillaire
PE
IP/MPLS backbone (BIB)
SeGW
VRF (réputée non fiable à 100%)
VRF de confiance
C-SGN
MME
S11-C/U
S/P-GW
S6a
HSS
PE interco
Internet public, raccordement dédié, Tunnel Ipsec...
APP Server
L'architecture BeB du NB-IoT est très largement héritée du réseau cellulaire 4G en place
SFR

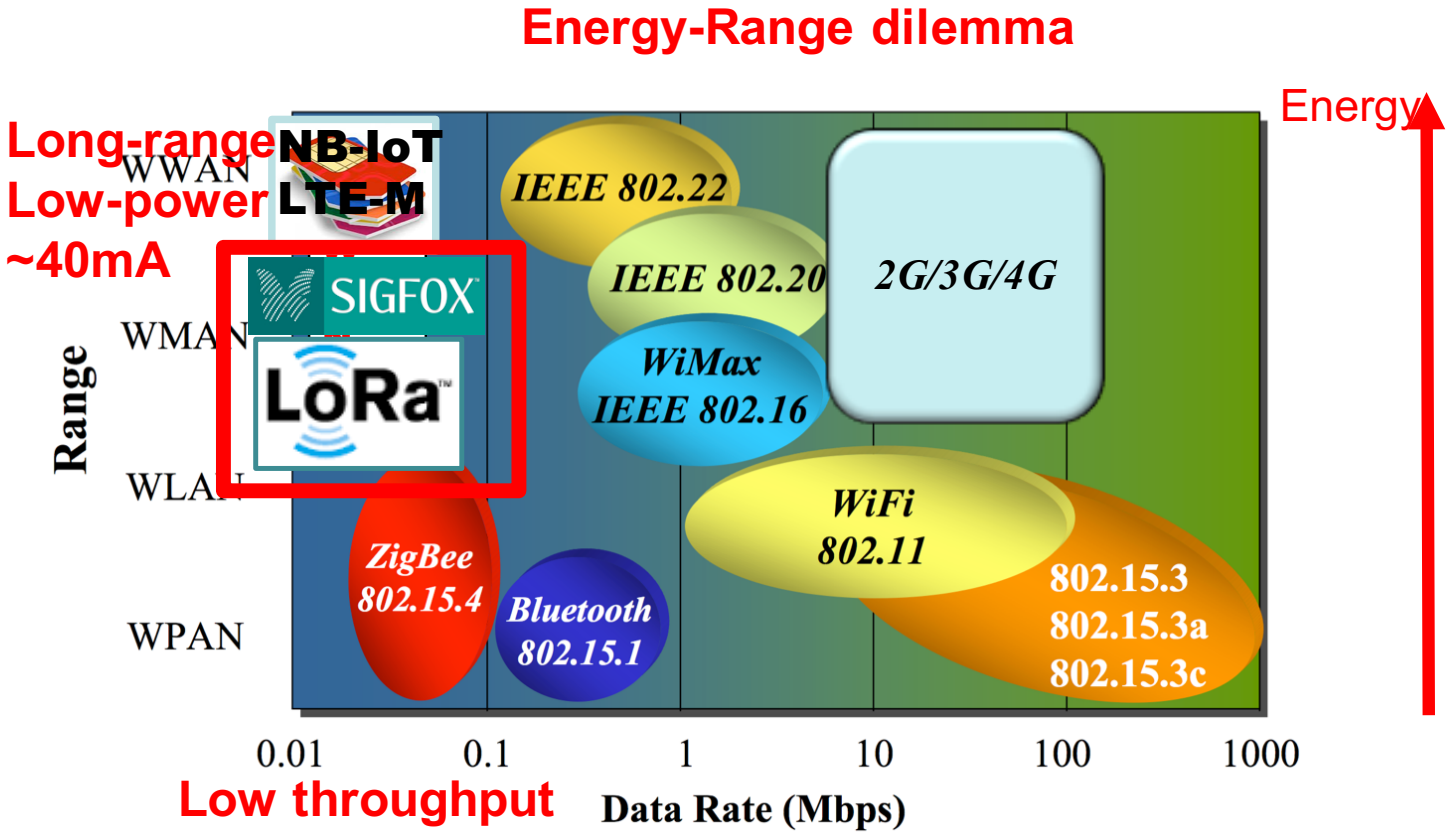
Optimizing for IoT







Wireless space – long range

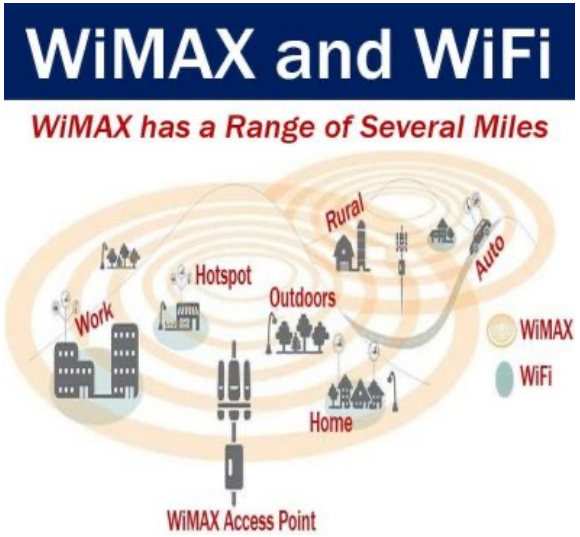


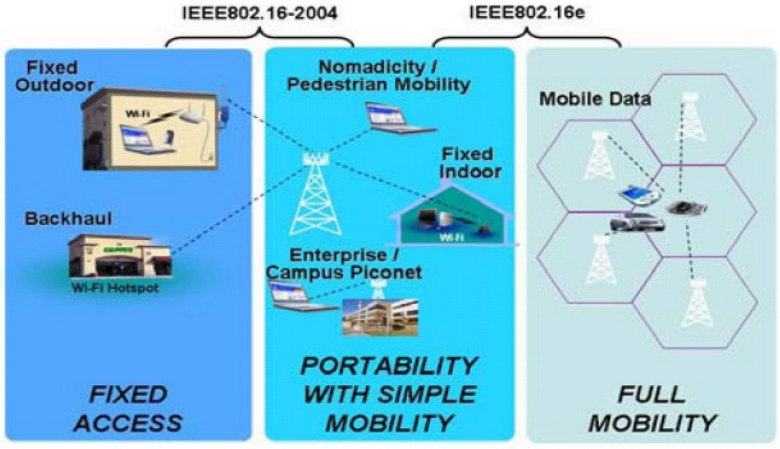
Transmitting: `TC/22.5/HUM/67.7` ; about 20 bytes with packet header
Time on air can be 1.44s with LoRa

802.16: WiMAX

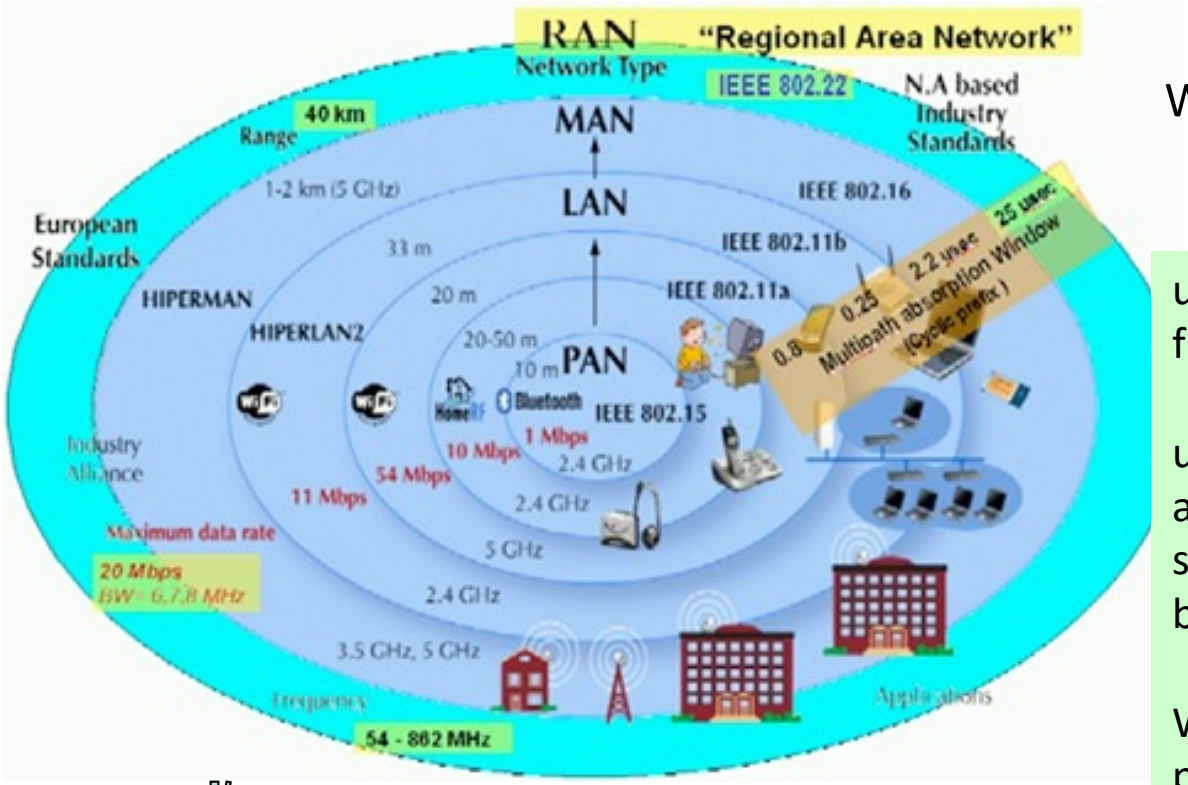
Worldwide Interoperability for Microwave Access

- 802.16e (10-66 GHz and 2-11 GHz) uses Scalable OFDMA to carry data, supporting channel bandwidths of between 1.25 MHz and 20 MHz, with up to 2048 sub-carriers. Users have allocated slots
- Adaptive modulation and coding: in conditions of good signal, a highly efficient 64 QAM coding scheme is used, whereas when the signal is poorer, a more robust BPSK coding mechanism is used. In intermediate conditions, 16 QAM and QPSK can also be employed.
- Support for Multiple-in Multiple-out (MIMO) antennas to provide good non-line-of-sight propagation (NLOS) characteristics or higher bandwidth
- It is still popular in some countries but 4G has been replacing it





802.22 WRAN

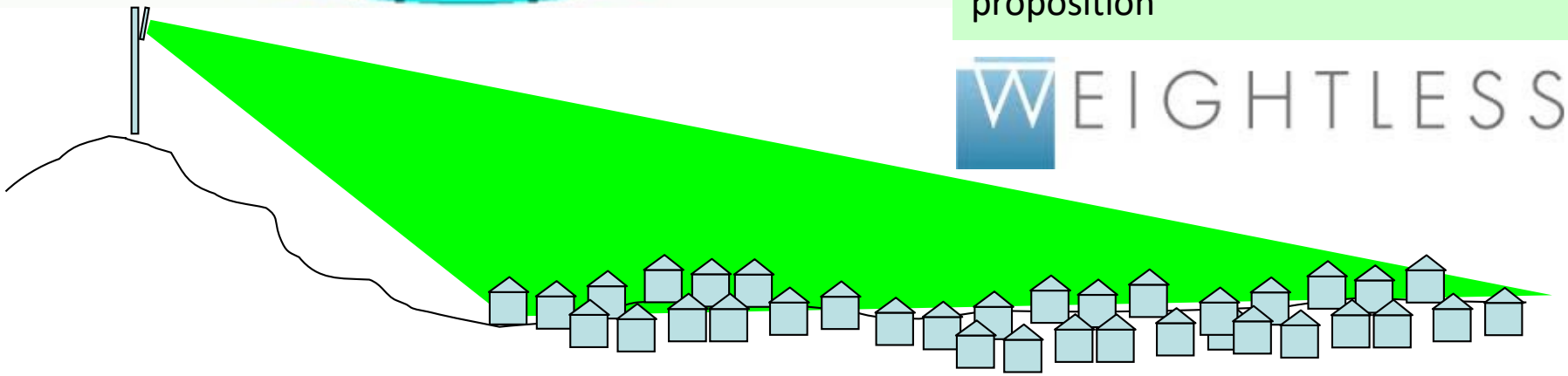


Wireless Regional Area Networks

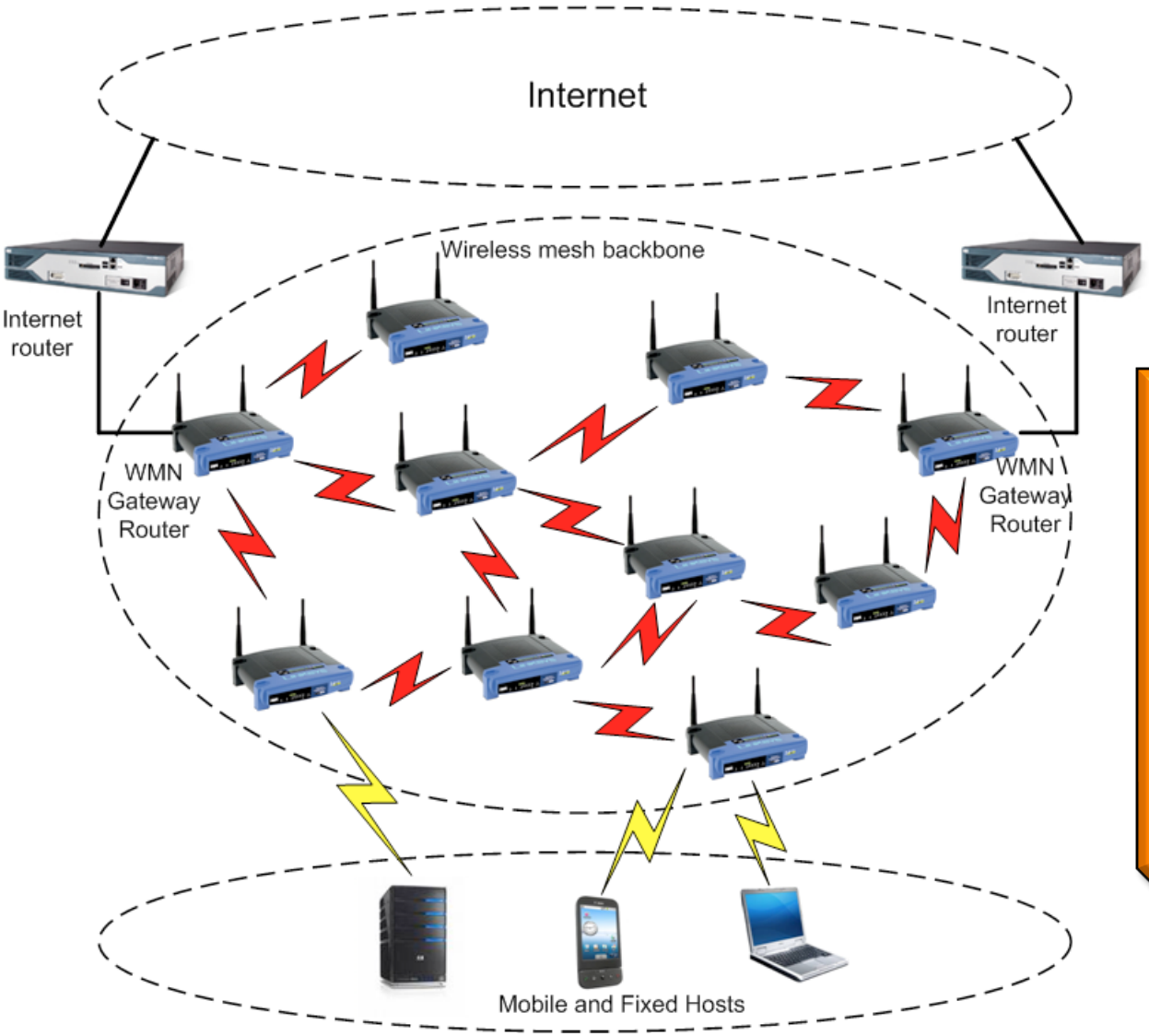
uses white spaces in the television (TV) frequency spectrum.

using cognitive radio (CR) techniques to allow sharing of geographically unused spectrum allocated to the television broadcast service.

Weightless-W was one of the first proposition

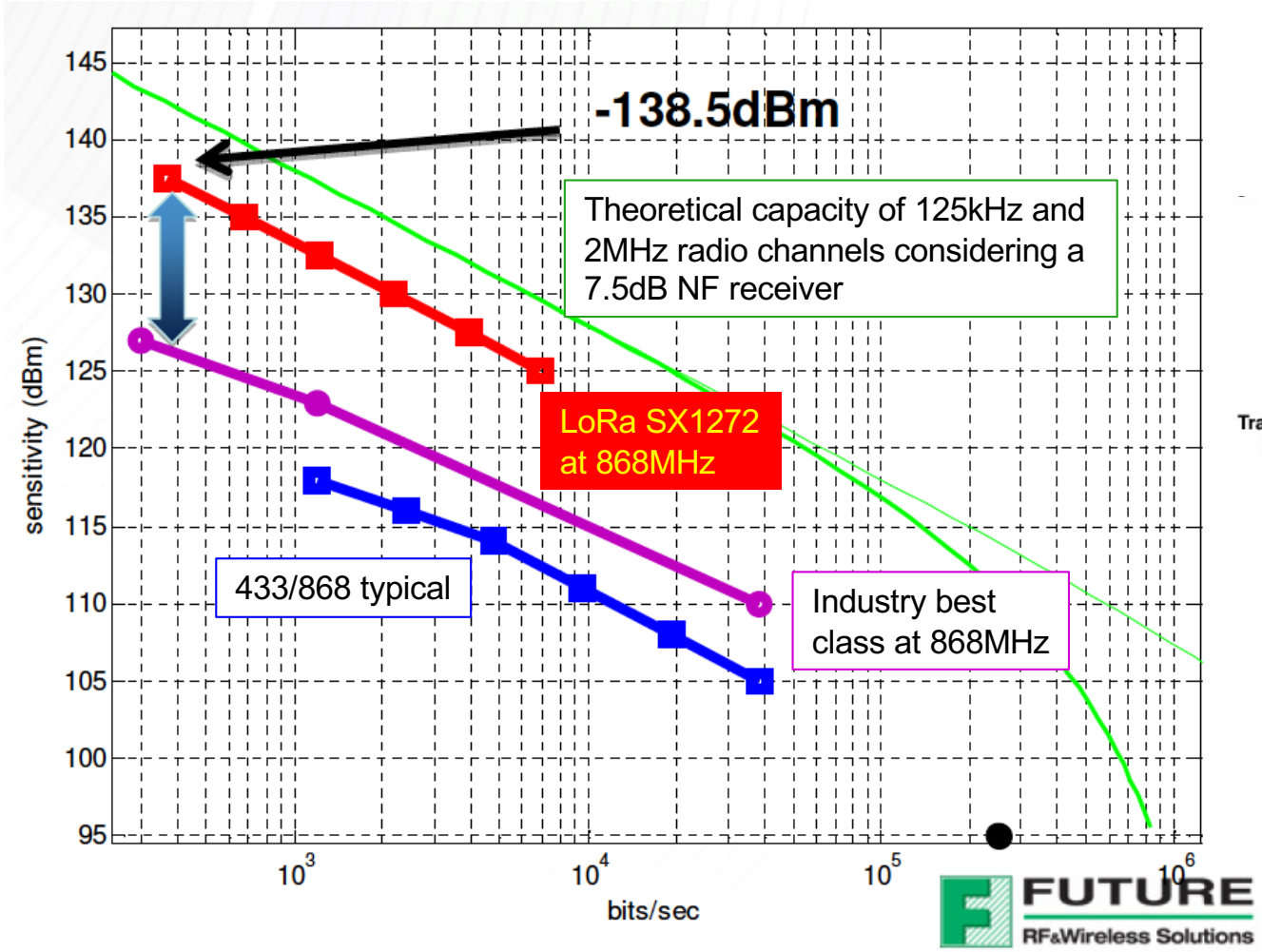


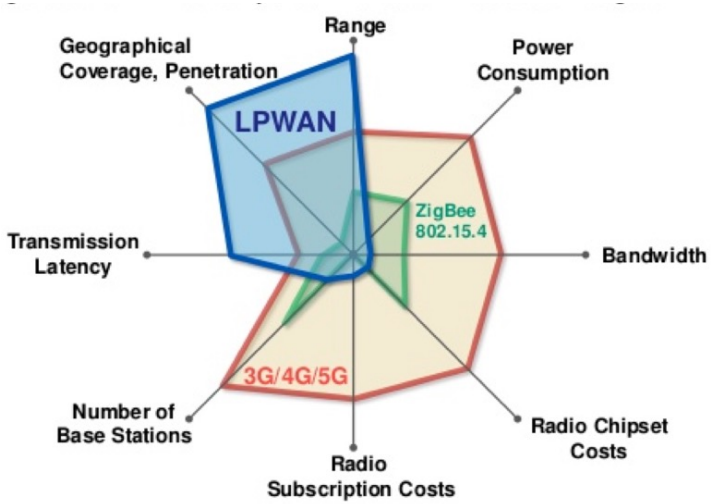
Cognitive radio wireless mesh networks



Cognitive, opportunistic, multi-channel radio for large-scale wireless infrastructures

THE TRUE LPWAN REVOLUTION!





From Peter R. Egli, INDIGOO.COM

Orange LoRa

Orange IoT LoRaWAN® network deployments

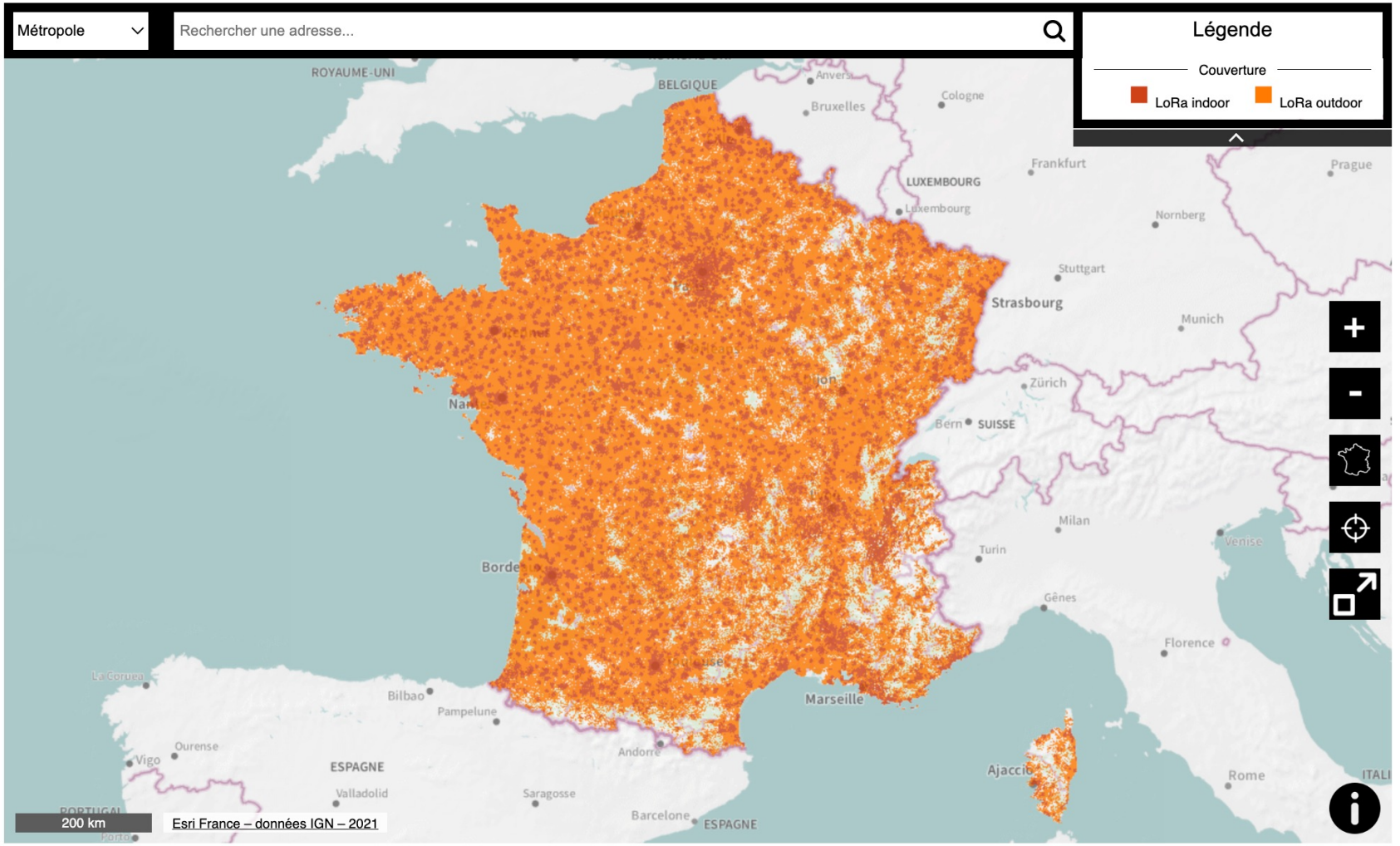
- France : Nationwide coverage in 2018.
- 95% population coverage, 30 000 cities
- 4900 Gateways deployed on mobile site
- Densify our networks on demand depending on customers needs

(1) Figures as of early July 2018

A targeted LoRaWAN coverage in other countries, in cities, airports, ports or industrial sites for B2B Market

For France

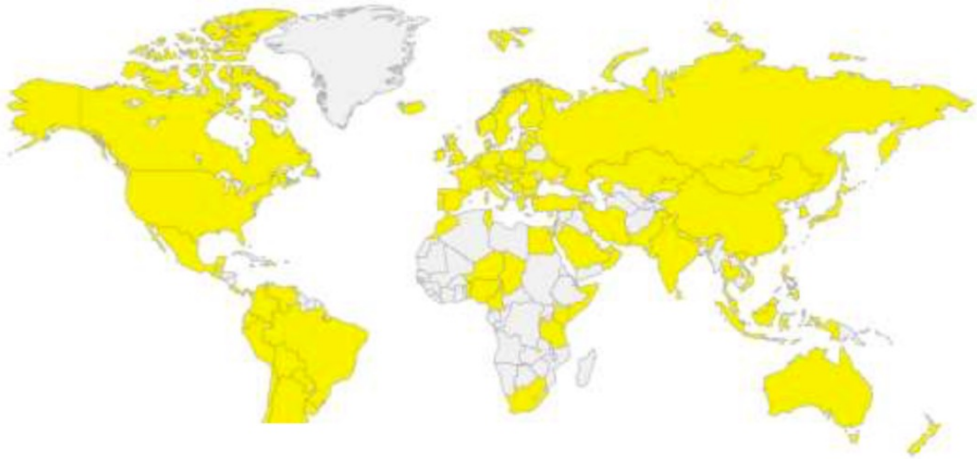
Couverture LoRa® Orange



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

LoRaWAN coverage from Semtech

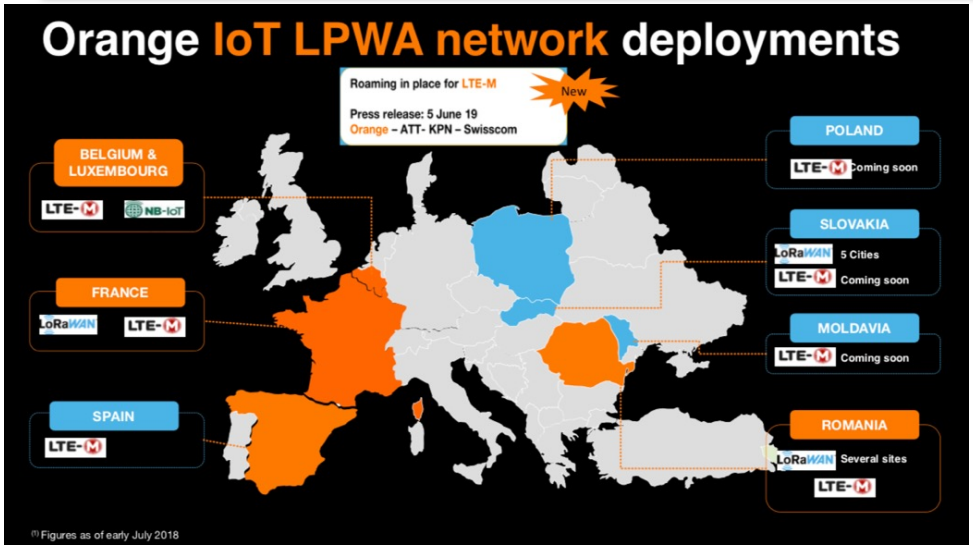
Today's LoRaWAN® Coverage Availability

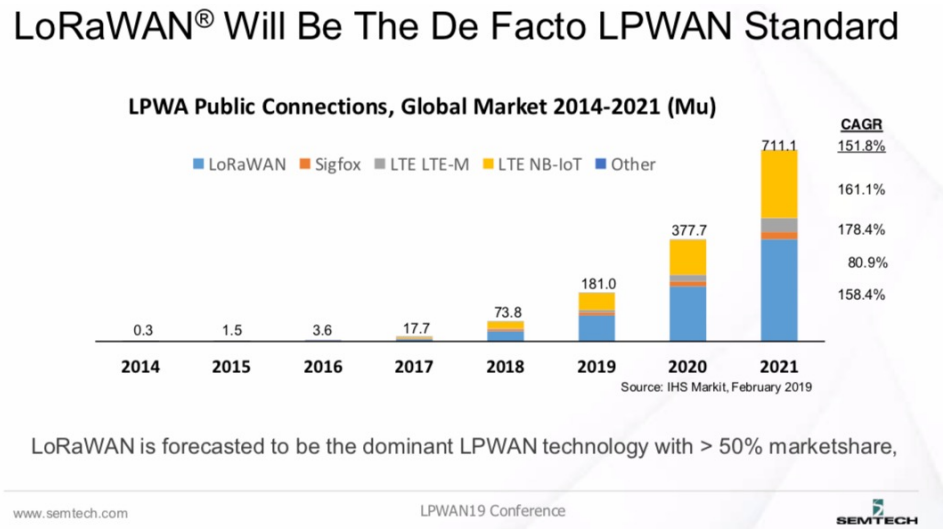


- 113+ LoRaWAN network operators
- 74 countries with LoRaWAN networks
- 300K deployed LoRa®-based gateways
- 97M deployed LoRa-based endpoints

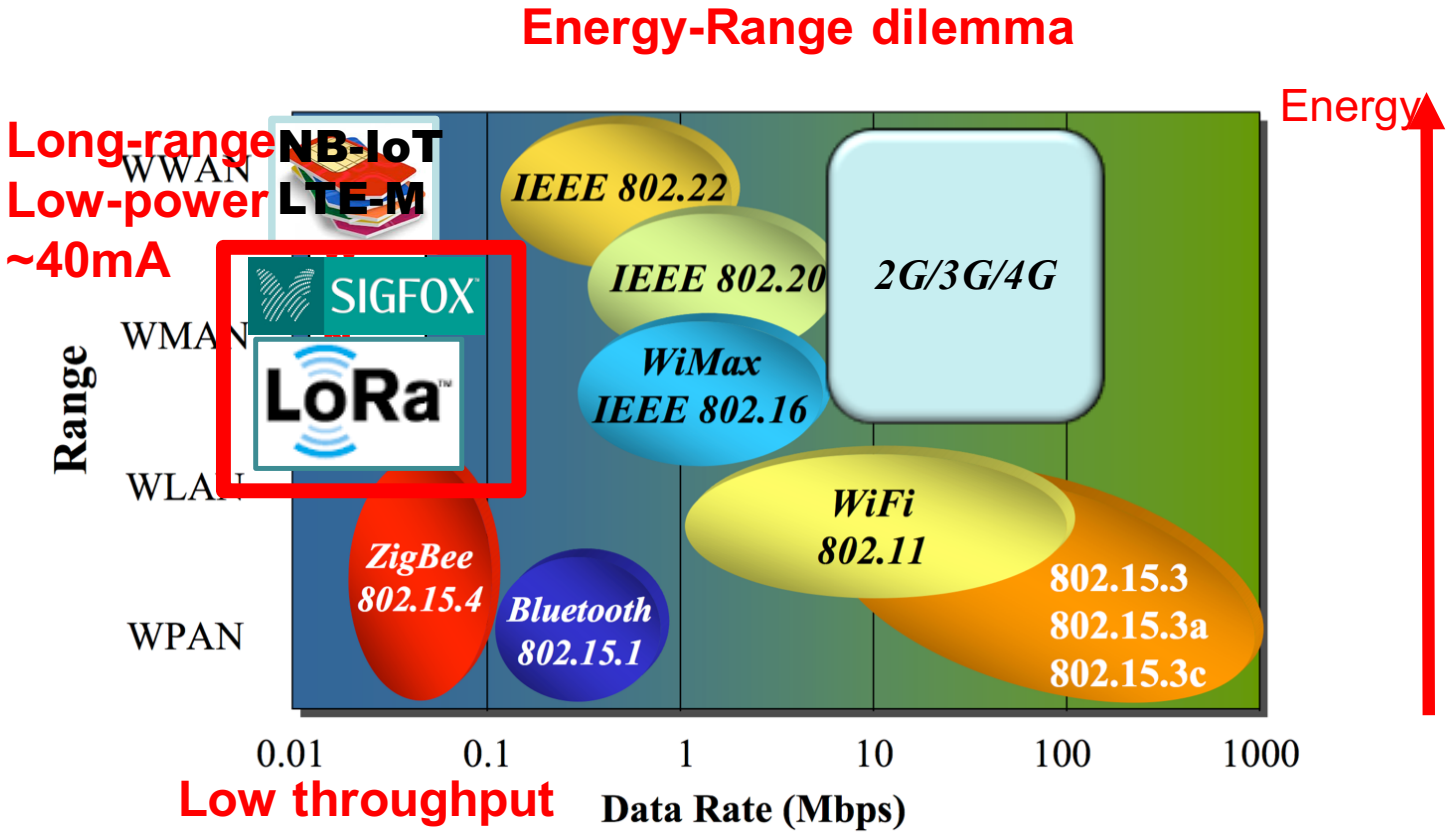
www.semtech.com LPWAN19 Conference SEMTECH

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





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
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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
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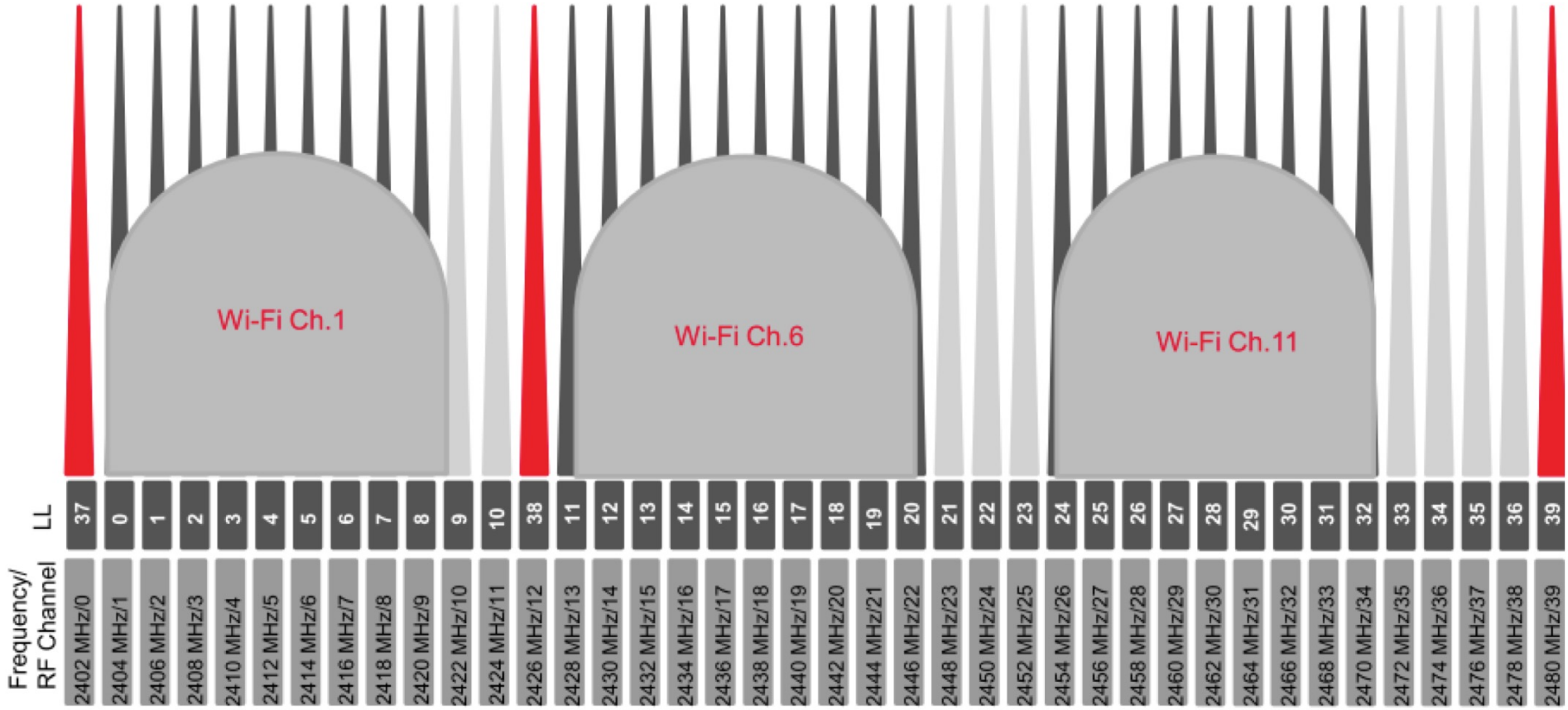
NFC	13.56 MHz	1MHz	848Kbps	FSK, ASK	20cm	P2P	Contactless payment, easy other connection (Wi-Fi, BT), identity and access

Bluetooth Low Energy Channel Allocations



Bluetooth Low Energy:

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

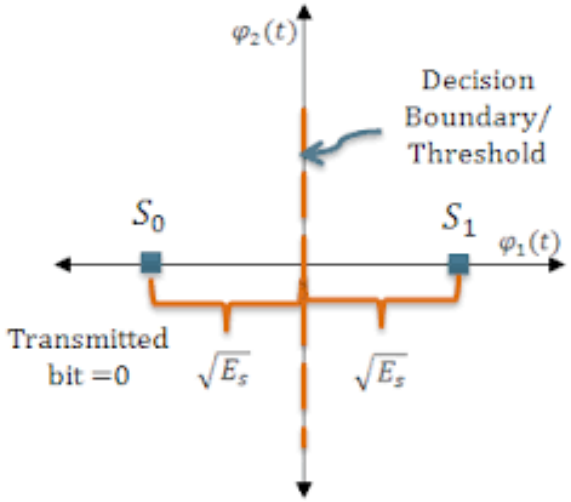
< 10 – 20 times less power

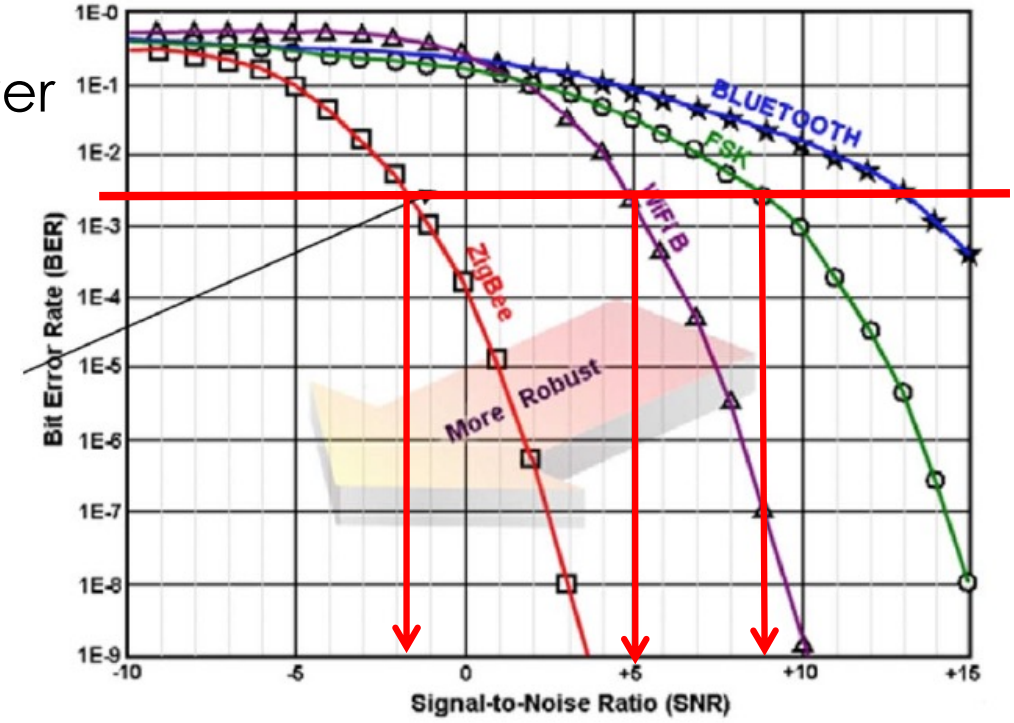
Classic Bluetooth:

- 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



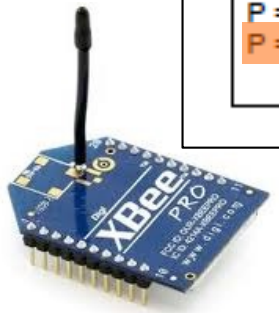


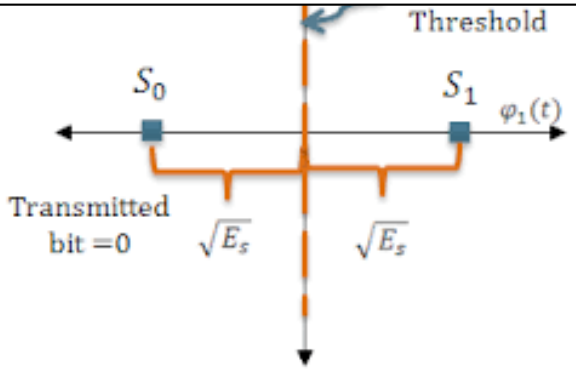
IEEE 802.15.4 in ISM 2.4GHz

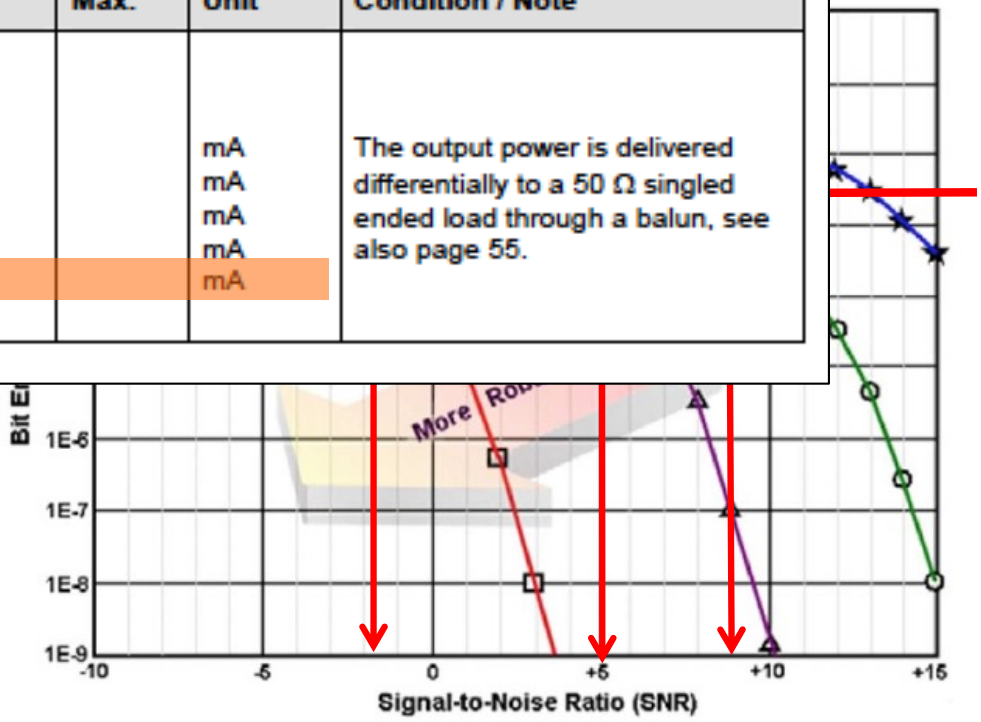
- Low-power radio in the 2.4GHz band offering 250kbps throughput at physical layer
-
-
-

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	







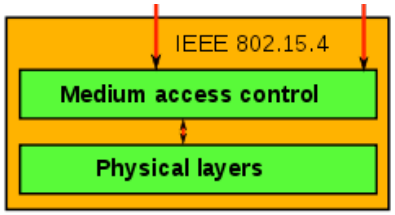
IEEE 802.15.4 in industry

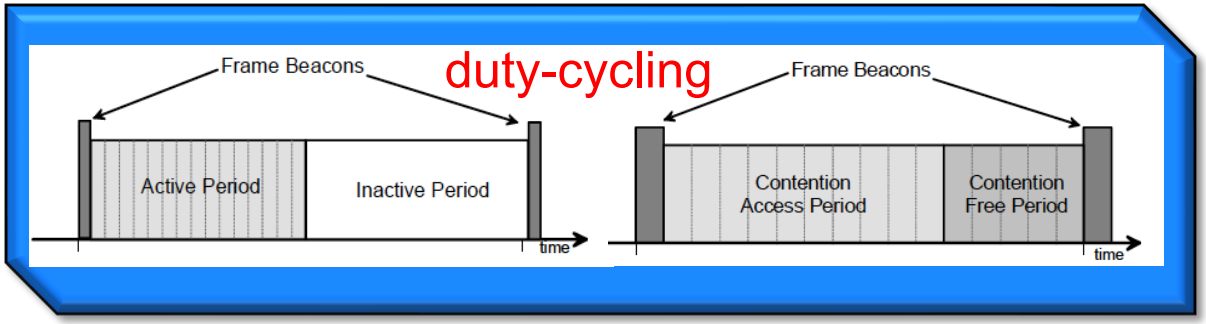
ZigBee Member

WirelessHART

ISA 100 WIRELESS

OSI 3 & 4





OSI 2

OSI 1

CC2420 (TI)

Xbee (Digi)

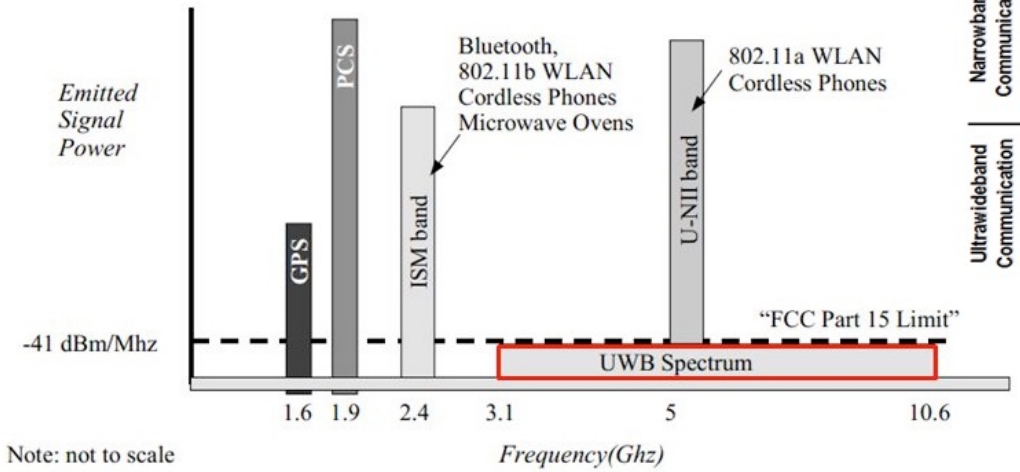
MRF24J40MA (Microchip)

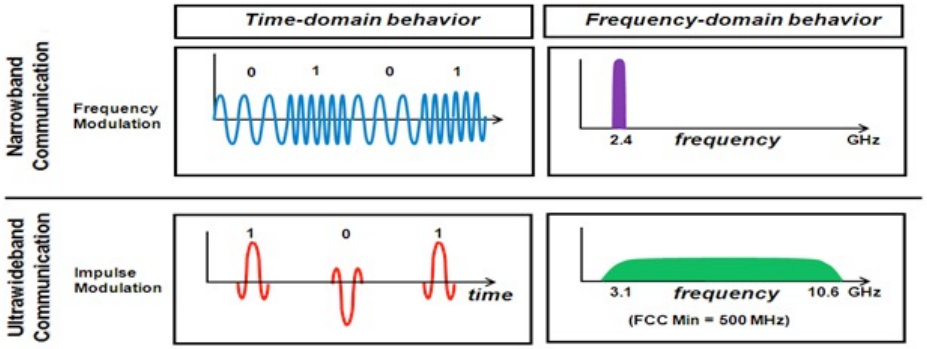
ZigBit AT86RF230 (ATMEL)

Ultra Wide Band (former 802.15.3) – pulse radio

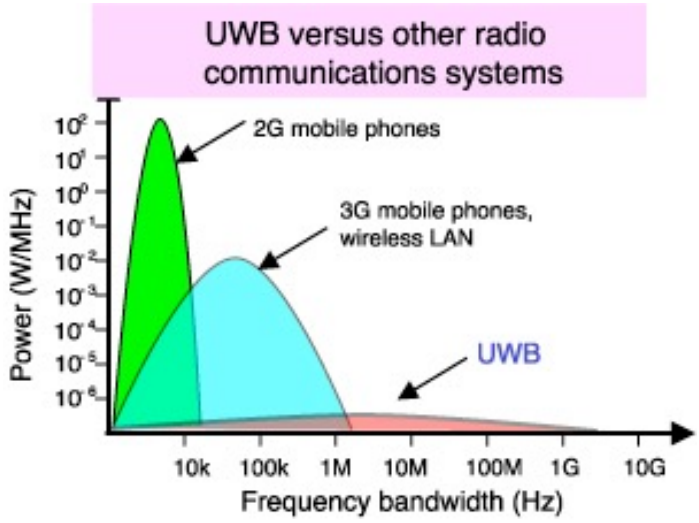
INFO

- Short-range high-speed wireless communication
- Bandwidth is over 110 Mbps (up to 480 Mbps) which can satisfy most of the multimedia applications





- UWB is a form of extremely wide spread spectrum where RF energy is spread over gigahertz of spectrum
  - Wider than any narrowband system by orders of magnitude
  - Power seen by a narrowband system is a fraction of the total UWB power
  - UWB signals can be designed to look like imperceptible random noise to conventional radios



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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