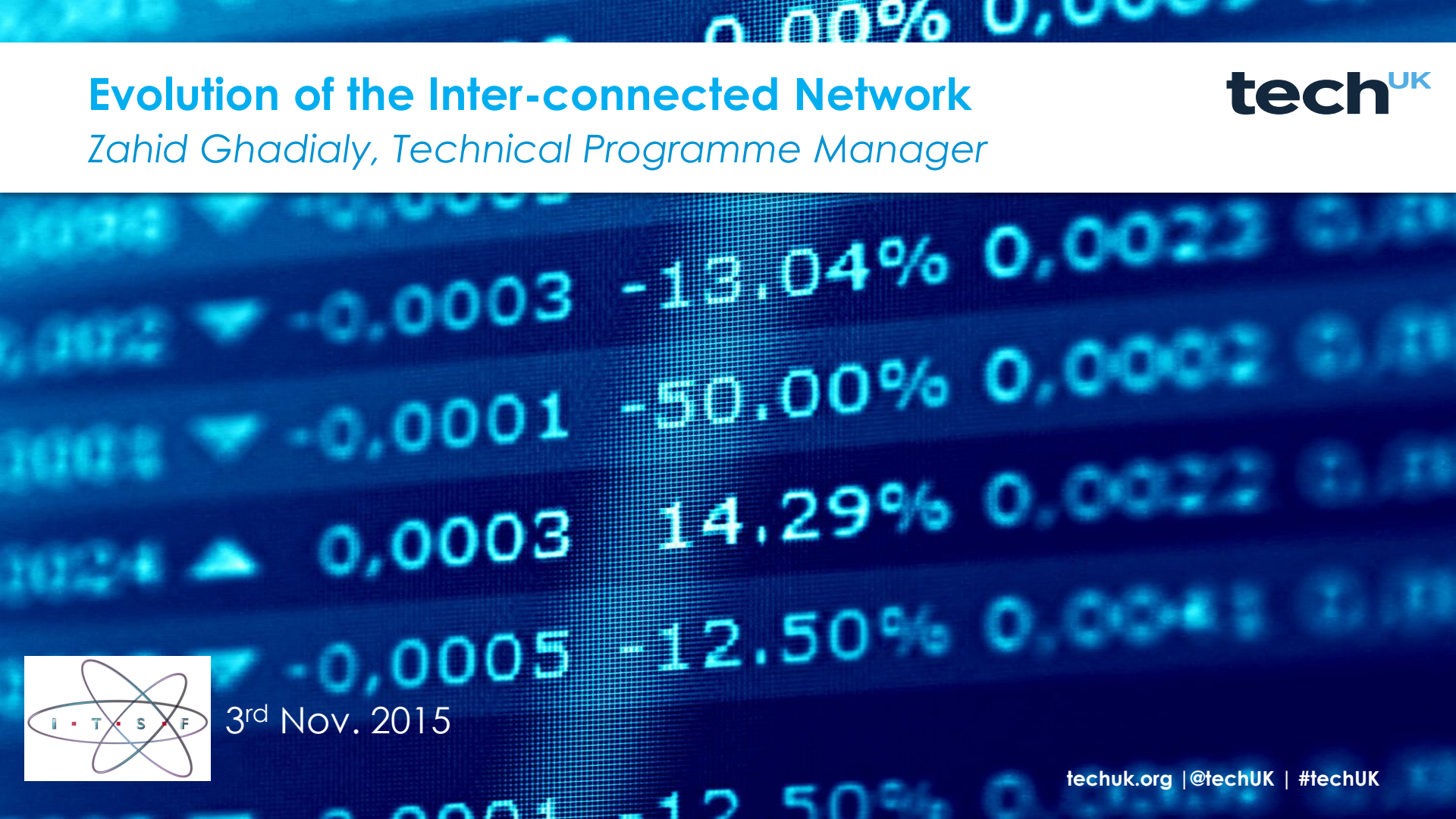
# Evolution of the Inter-connected Network

*Zahid Ghadialy, Technical Programme Manager*

techUK




3rd Nov. 2015

# About techUK

**techUK represents the companies and technologies that are defining today the world that we will live in tomorrow.**

More than 850 companies are members of techUK. Collectively they employ more than 700,000 people, about half of all tech sector jobs in the UK. These companies range from leading FTSE 100 companies to new innovative start-ups.

techUK supports a diverse base of innovative and fast growing tech companies operating across the economy. The majority of our members are small and medium sized businesses.

It is hard to think of any aspect of modern life that is not touched by digital technology. Our role as techUK is to ensure that we seize the potential on behalf of our members and address the disruptive new challenges that change and innovation will continue to present.

# What does techUK do?

## techUK has a clear, simple mission:

- To ensure the UK is a great place for tech companies to locate & grow

- To ensure that technology is good for the whole of the UK economy

- To ensure that technology is good for UK citizens and society.

# techUK value proposition

## We deliver tangible value to members in four key areas:

- Developing relationships and networks
- Developing markets
- Reducing business costs
- Reducing business risks.

# techUK programmes - 2015

**techUK programmes are designed around vertical and cross market areas of work which we are pursuing on behalf of the tech sector.**

Our programme grid demonstrates where organisations can get involved with techUK.

The grid acts as a map where techUK members can derive value, from building networks and developing markets, to reducing business costs and risks.

| | | Vertical-market programmes | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Tech for Business & Consumer | | | | | Tech for Government | | | | | |
| | | Communications Infrastructure | Data Centres | Digital Devices & Services | Financial Services & Payments | Smart Energy | Central Government | Defence | Health & Social Care | Justice & Emergency Services | Local Government | National Security |
| Cross Market programmes | Big Data & Analytics | • | • | • | • | • | • | • | • | • | • | • |
| | Cloud & Mobile Services | • | • | • | • | • | • | • | • | • | • | • |
| | Cyber Security | • | • | • | • | • | • | • | • | • | • | • |
| | Future Technologies & Electronics | • | • | • | • | • | • | • | • | • | • | • |
| | Environment & Compliance | • | • | • | • | • | • | • | • | • | • | • |
| | Internet of Things | • | • | • | • | • | • | • | • | • | • | • |
| | Policy | • | • | • | • | • | • | • | • | • | • | • |
| | Privacy & Identity | • | • | • | • | • | • | • | • | • | • | • |
| | Satellite Applications & Services | • | • | • | • | • | • | • | • | • | • | • |
| | Skills, Innovation & IP | • | • | • | • | • | • | • | • | • | • | • |
| | International: Collaboration, Trade & Investment | • | • | • | • | • | • | • | • | • | • | • |

# My contact details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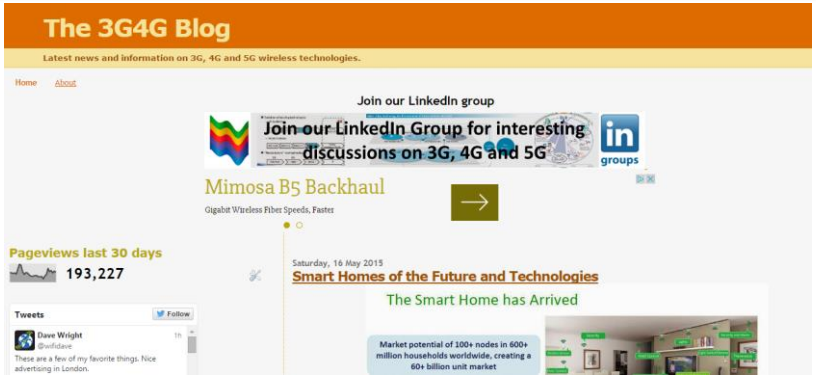
# About Me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# Disclaimer!

This presentation is intended to stimulate discussion on some of the exciting current and future developments in digital communications technology and networks.

It also contains some forward looking statements, research and speculation that may never become part of standards.

It would not be prudent to make any financial or investment decisions based on this presentation.

# Important parameters for the next generation networks

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- Speed
- Latency
- Availability
- QoS / QoE
- Jitter


"With 4G, an 800 megabyte movie takes around 40 seconds to download; with 5G that would be cut to one second," – David Cameron, Prime Minister of UK

# G.Fast – Next generation DSL standard

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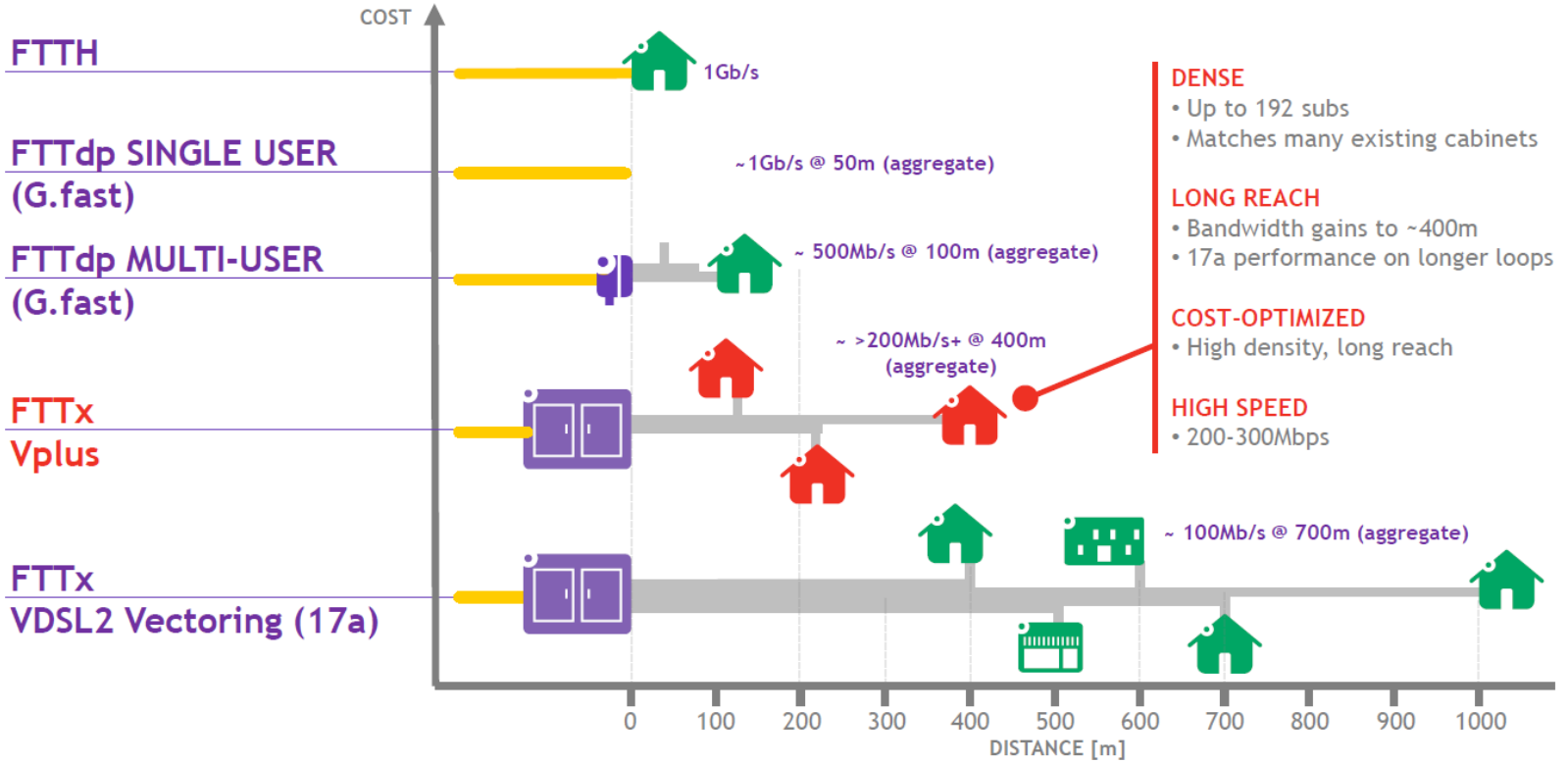


Alcatel·Lucent

# DOCSIS 3.1 – Next-generation cable broadband

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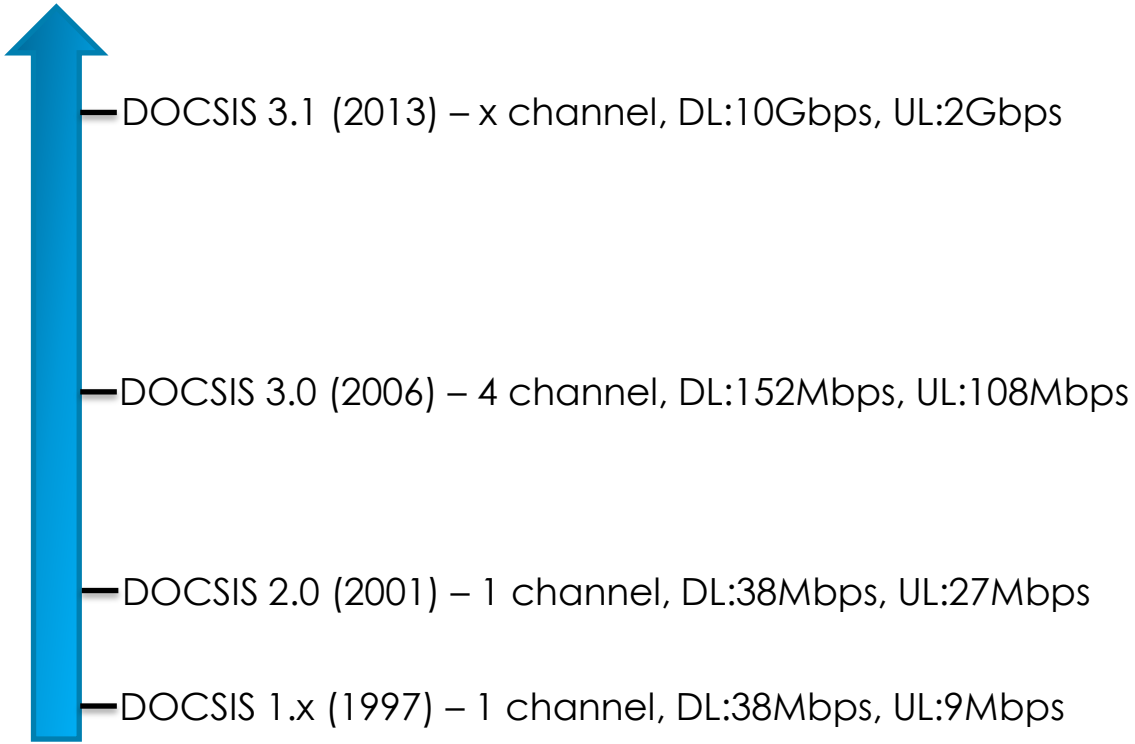
## DOCSIS 3.1

- Backward compatible to DOCSIS1.1
- OFDM with 25KHz QAM channels (instead of 6MHz)
- Upto 4096-QAM support
- New LDPC FEC

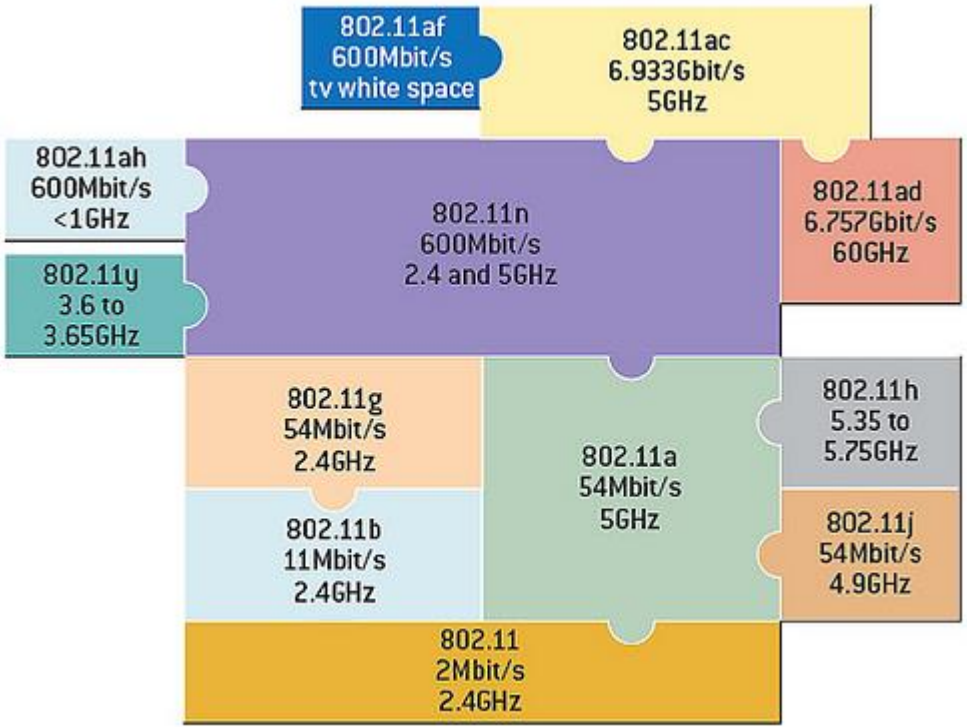


# Pure fibre optic broadband


Single fibre can do 3 Tbps theoretically but 1-3 Gbps practically

Four blown fibres in the sleeve / duct typically – 1 in use, remaining backups

# Evolution of Wi-Fi / 802.11 technologies



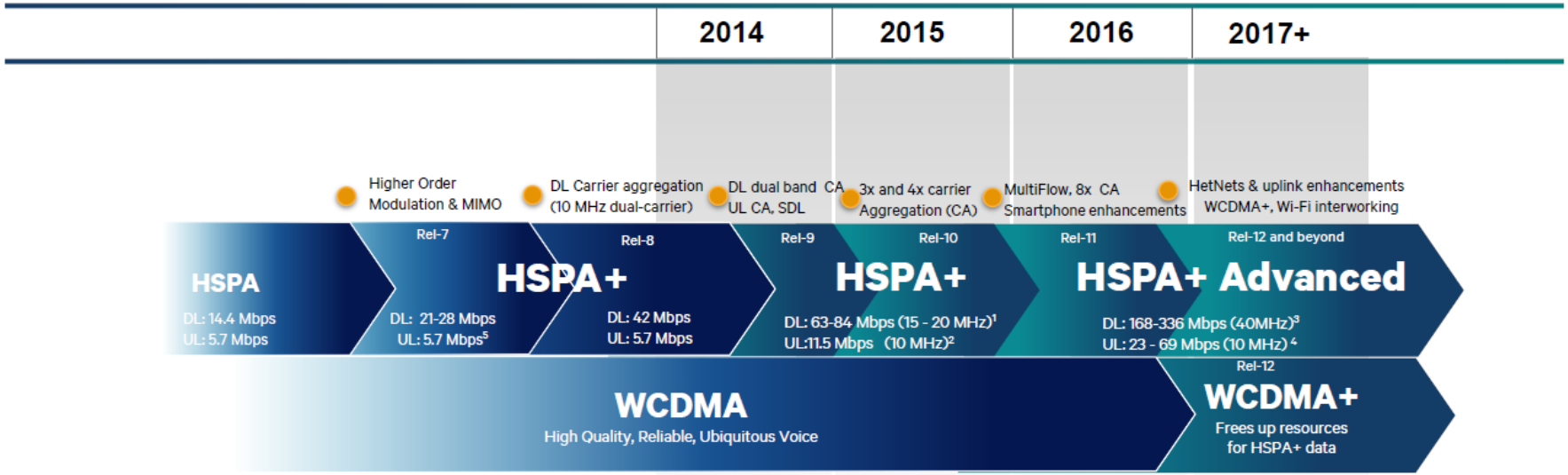

5GHz

- 802.11n – 600Mbps
- 802.11a c – ~7Gbps
- **802.11ax – 14Gbps**

60GHz

- 802.11ad – ~ 7Gbps

# 3G / HSPA+ evolution continues…




[1]Peak rate of 63 Mbps by aggregating 3 carriers, (15 MHz) and 84Mbps by 4 carriers (20 MHz). Rel. 10 standard supports up to 168 Mbps (see note 3 below), but not expected to be commercial in initial launches

[2]Uplink carrier aggregation (10 MHz) doubles uplink peak data rate to 11.5 Mbps without 16 QAM, and 23 Mbps with 16 QAM

[3]Rel 10 supports up to 186 Mbps with 20 MHz and 2x2 MIMO, Rel 11 supports 336 Mbps with 40 (4 carriers) and 2x2 MIMO,

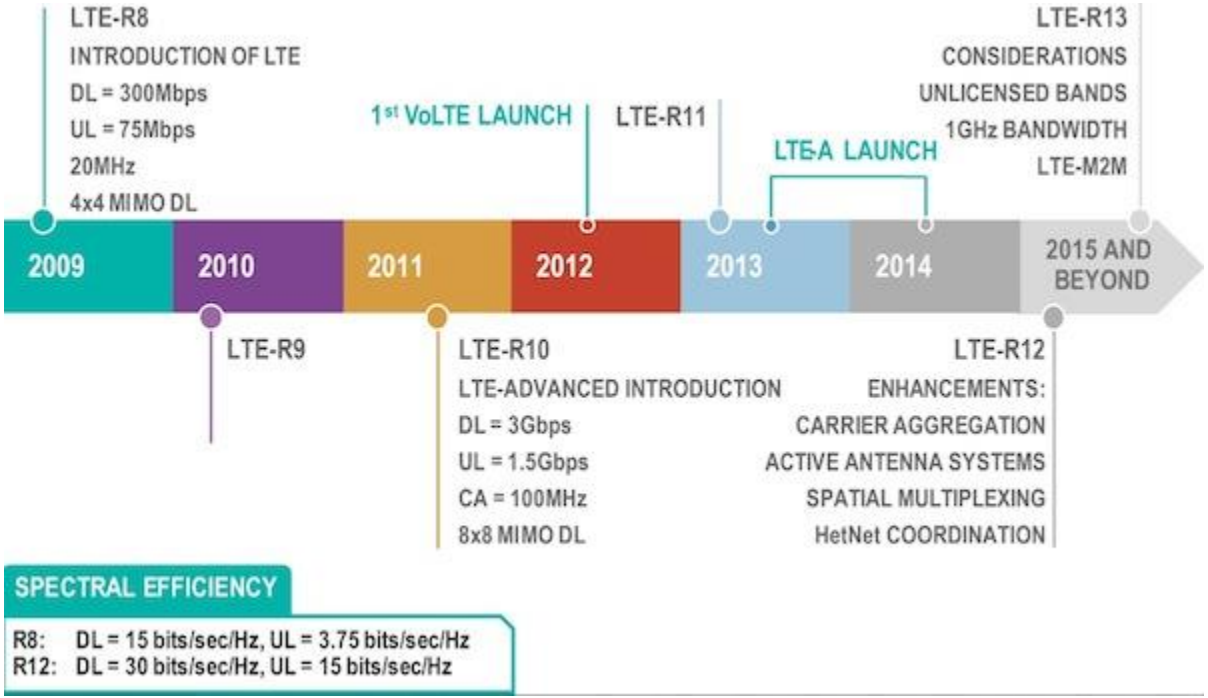
[4] 69 Mbps Uplink rate achieved by 2x2 MIMO and 64QAM

[5] Rel. 7 supports peak rate of 11.5 Mbps, but only 5.7 Mbps commercialized

Commercial

Note: Estimated commercial dates.

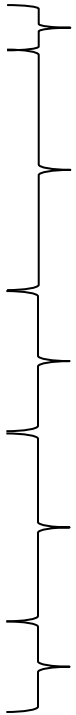
# 4G / LTE evolution continues…




Picture Source: EDN

# 4G / LTE – Release-12 (Dec. 2014)

| (E-UTRA) LTE Categories – Ref. 3GPP TS 36.306(2015-03) | | |
|---|---|---|
| Category | Max Download (Mbps) | Max Upload (Mbps) |
| Category 0 | 1 | 1 |
| Category 1 | 10 | 5 |
| Category 2 | 50 | 25 |
| Category 3 | 100 | 50 |
| Category 4 | 150 | 50 |
| Category 5 | 300 | 75 |
| Category 6 | 300 | 50 |
| Category 7 | 300 | 100 |
| Category 8 | 3000 | 1500 |
| Category 9 | 450 | 50 |
| Category 10 | 450 | 100 |
| Category 11 | 600 | 50 |
| Category 12 | 600 | 100 |
| Category 13 | 390 | 150 |
| Category 14 | 3900 | 1500 |



**3GPP Release-12**

3GPP Release-8/9

3GPP Release-10

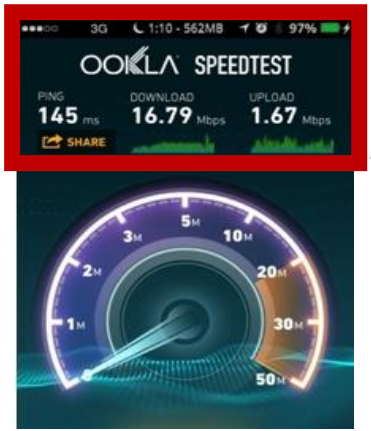
3GPP Release-11

**3GPP Release-12**

# 3G vs 4G real life comparison

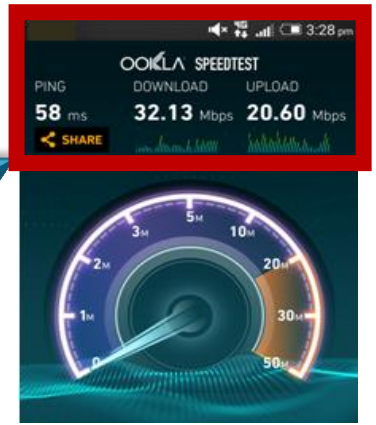
## 3G

Download: 17 Mbps
Upload: 1.7 Mbps

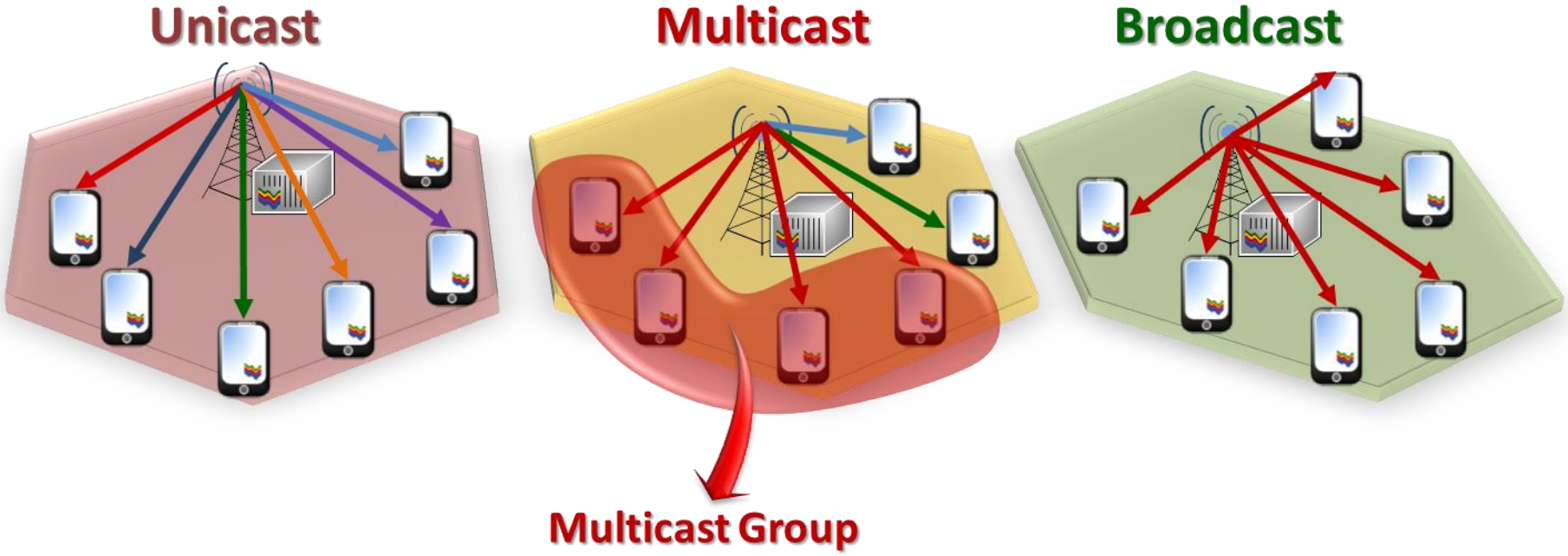



## LTE

Download: 32 Mbps
Upload: 20 Mbps

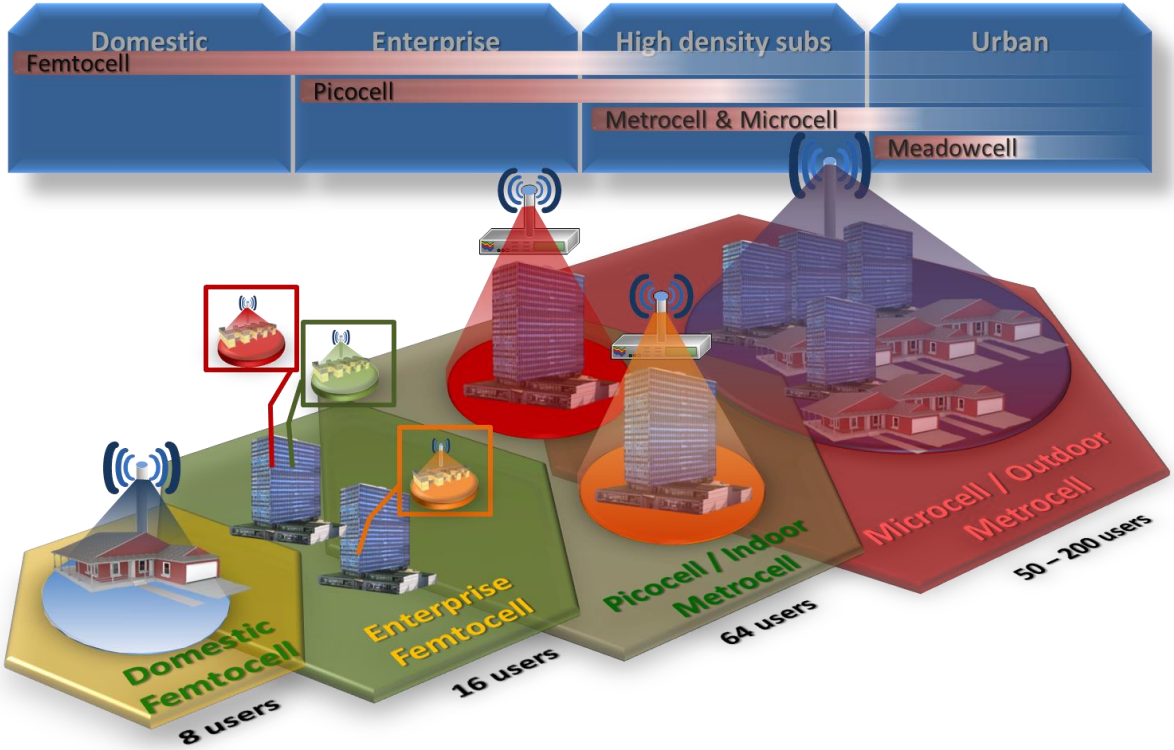


# LTE-Broadcast (eMBMS) – 3GPP Rel-9+



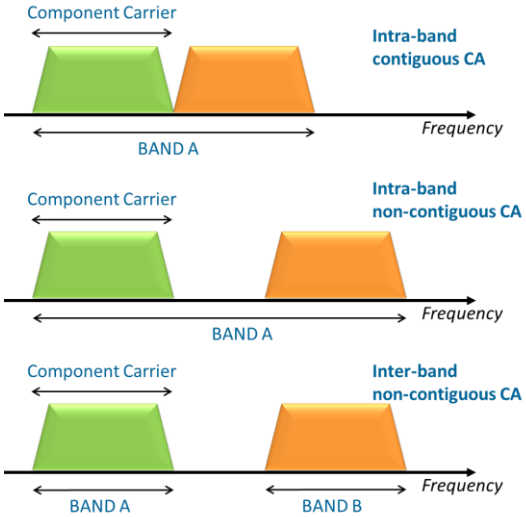

Source: eXplanoTech

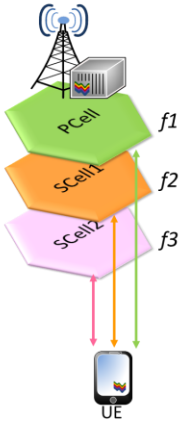
# Small Cells or Home eNodeB (HeNB) – 3GPP Rel-9+

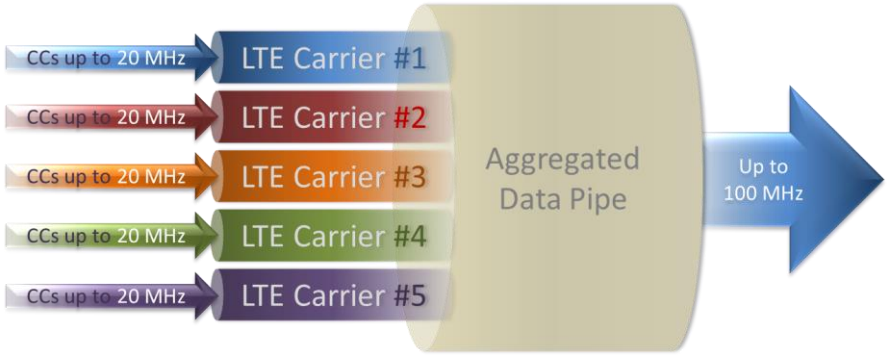



Source: eXplanoTech

# Carrier Aggregation – 3GPP Release-10 onwards




Source: eXplanoTech

# The Real '4G'

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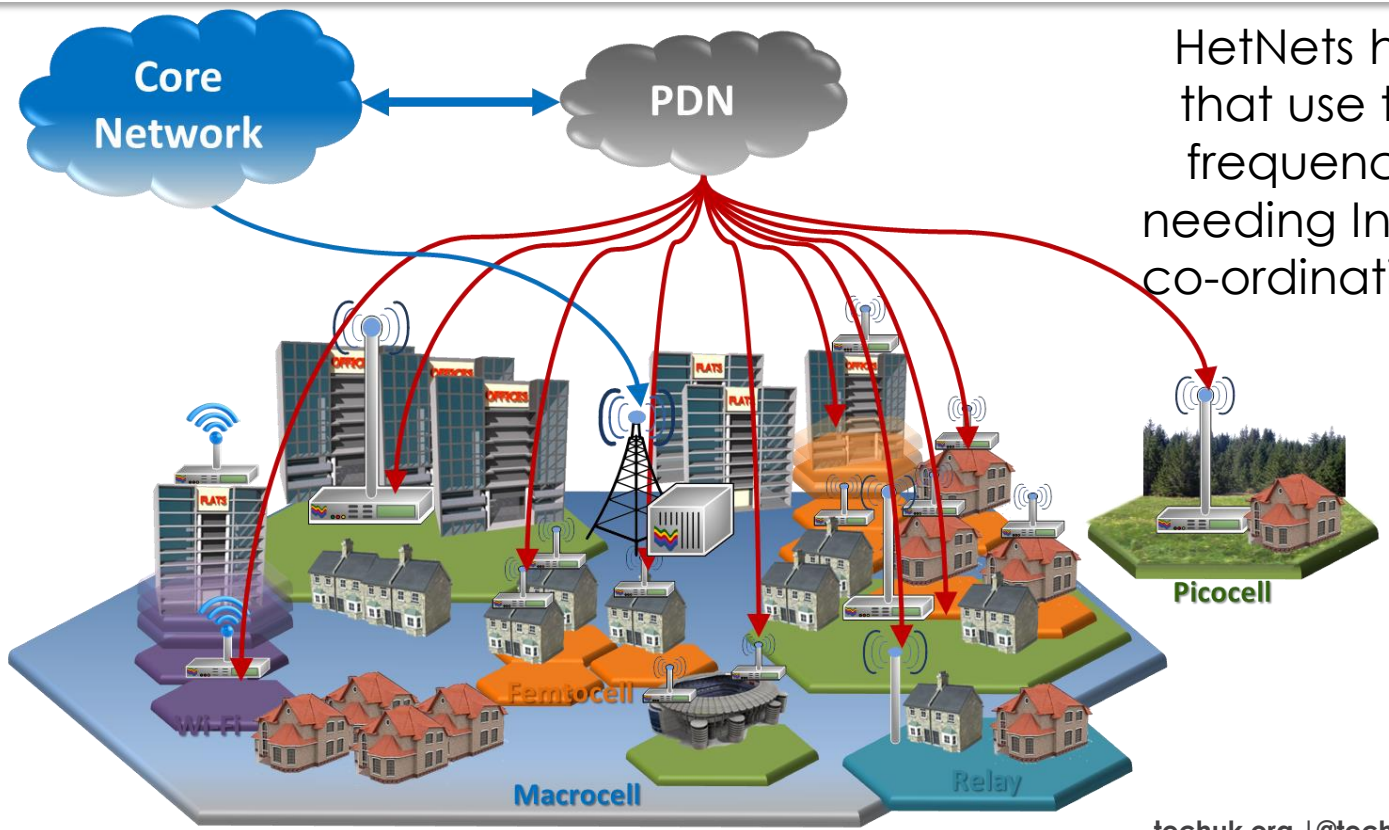
| | | IMT-A | LTE (Rel.8) | LTE-A (Rel.10) | LTE-A THEORETICAL |
|---|---|---|---|---|---|
| Bandwidth | | **Scalable** At least 40 MHz | **Scalable** 1.4 MHz – 20 MHz | Max 2x20 (40 MHz) | **Scalable** Up to 5x20 (100 MHz) |
| Peak Data Rates | | DL = 1 Gbps UL = 1 Gbps | DL = 150 Mbps (2x2) UL = 50 Mbps | DL = 300 Mbps (2x2) UL = 100 Mbps (2x2) | DL = 3 Gbps (8x8) UL = 1.5 Gbps (4x4) |
| Latency | User Plane (UP) | 10 ms max | 4.9 ms | 4.9 ms | 4.9 ms |
| | Control Plane (CP) | 100 ms max | 50 ms | 50 ms | 50 ms |
| Max peak spectral efficiency | Downlink (DL) | 15 bps / Hz | 16.3 bps / Hz | 16.8 bps / Hz | 30 bps / Hz |
| | Uplink (UL) | 6.75 bps / Hz | 4.32 bps / Hz | 8.4 bps / Hz | 15 bps / Hz |

**The criteria for real 4G as defined by IMT-A is not satisfied by Rel-10.**

Source: eXplanoTech

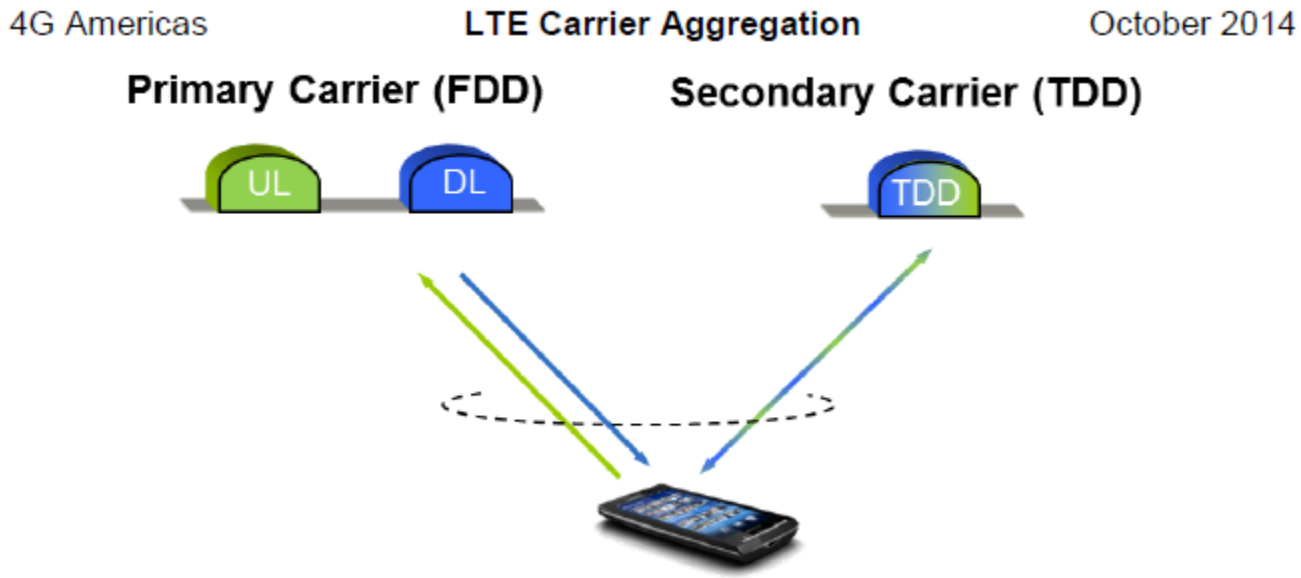
# Heterogeneous Networks (HetNets) – 3GPP Rel-10+




HetNets have cells that use the same frequency hence needing Interference co-ordination (eICIC)

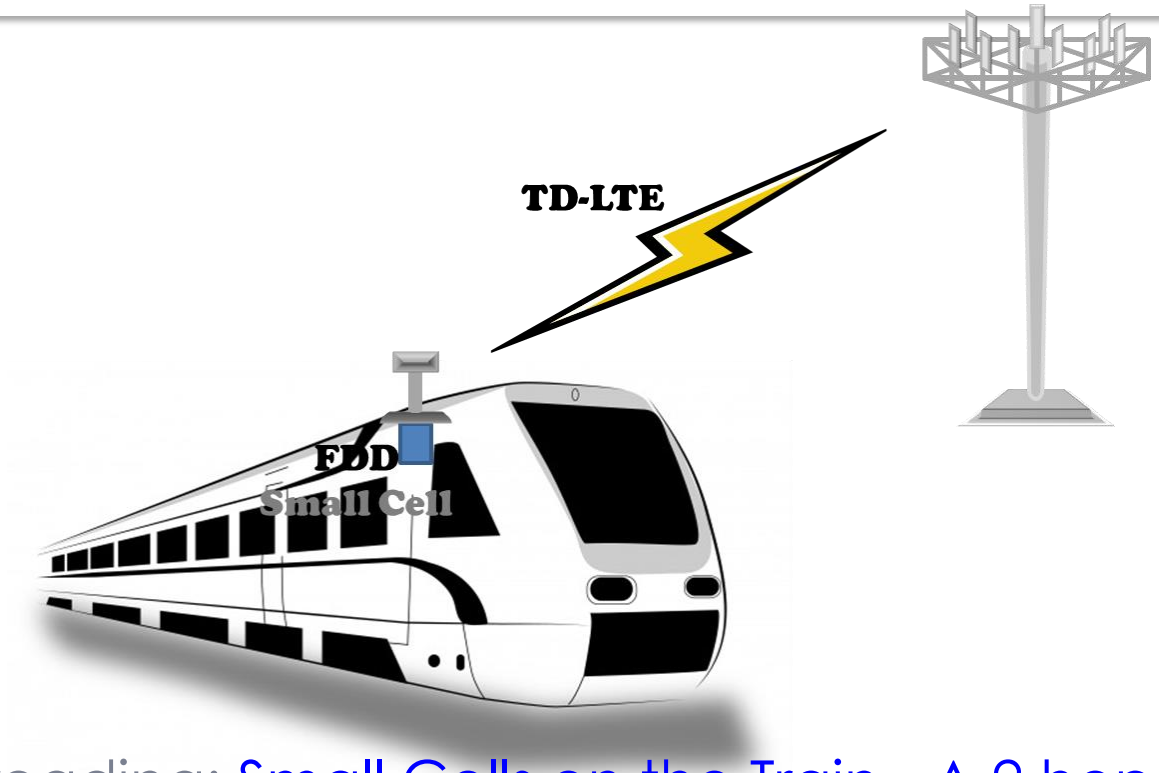
Source: eXplanoTech

# FDD-TDD CA – 3GPP Rel-12+



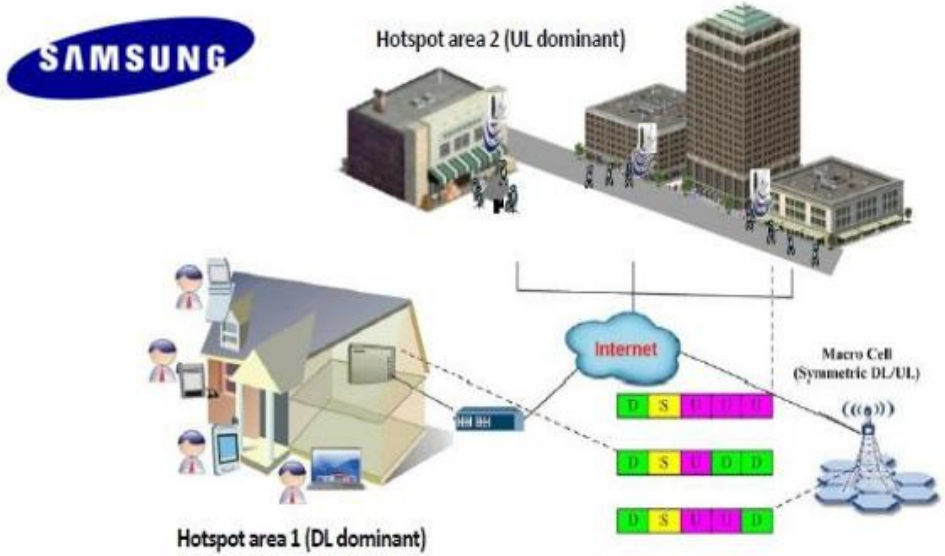

TDD is going to play an increasingly important role in future 4G & 5G networks

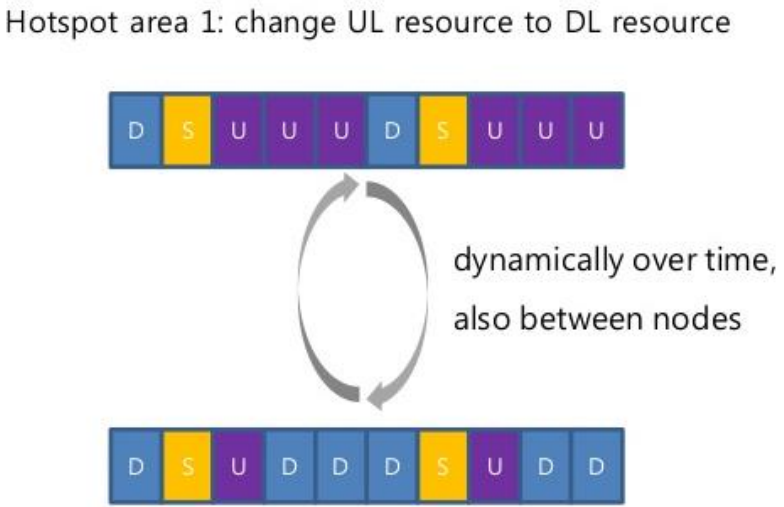
# TDD / TD-LTE will increasing be used for backhaul




Further reading: [Small Cells on the Train - A 2 hop solution]

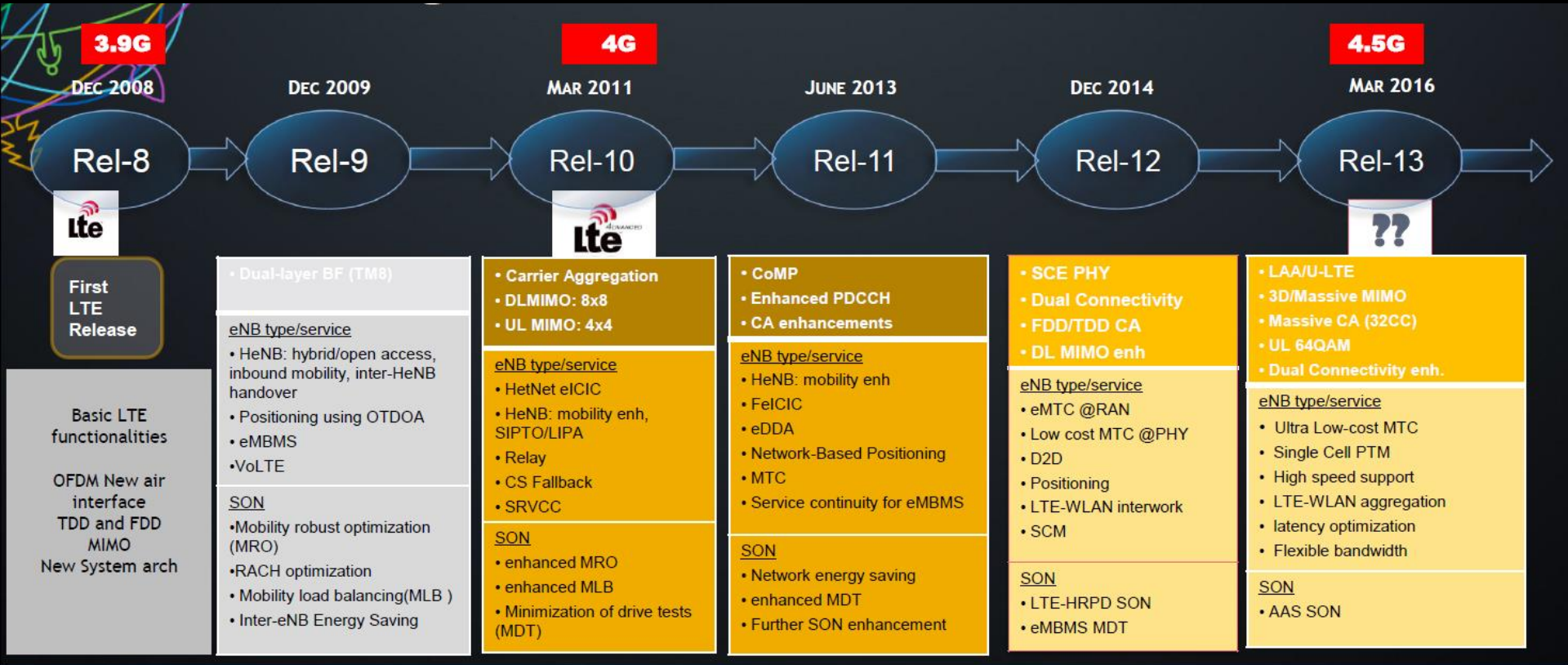
# eIMTA (Enhanced Interference Mitigation & Traffic Adaptation) – 3GPP Rel-12+



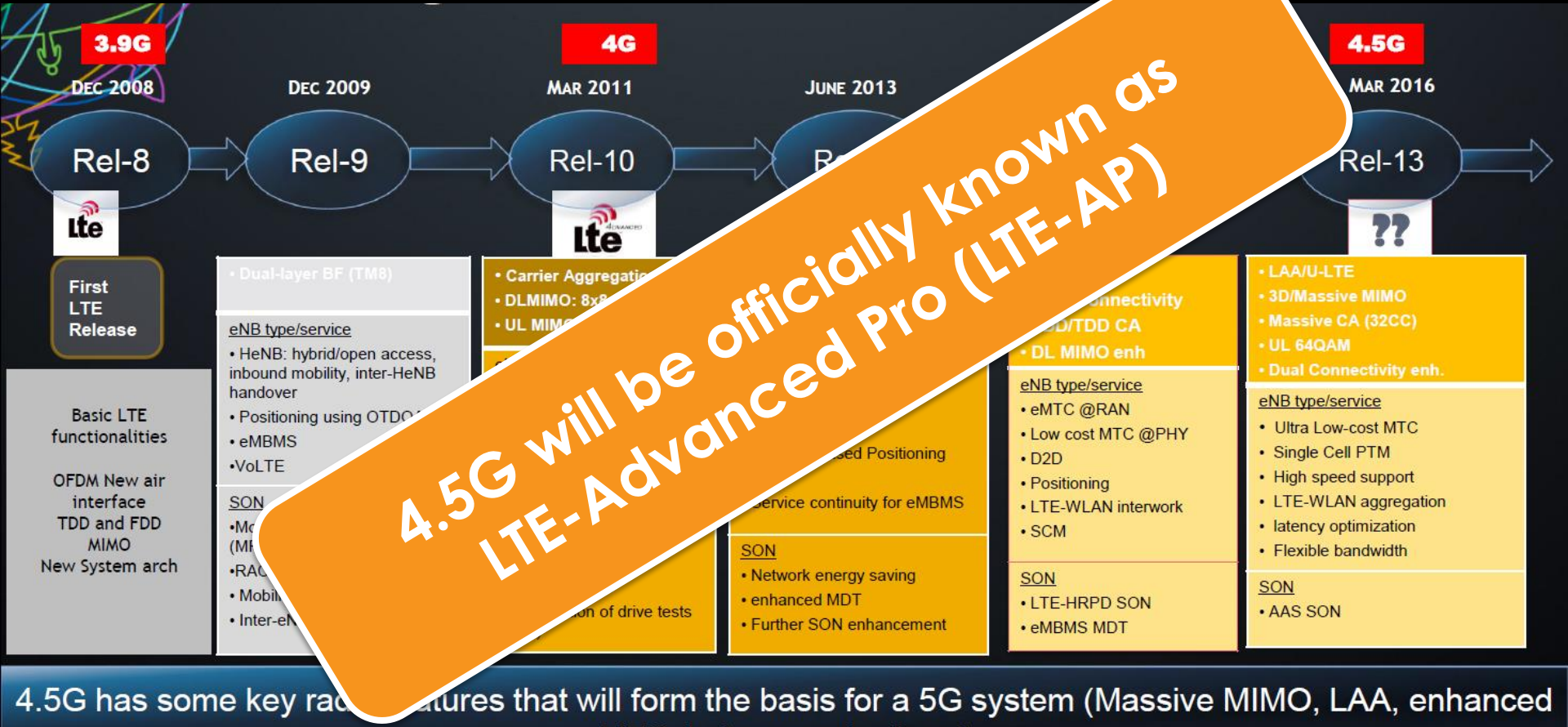

Dynamic switching between uplink and downlink TDD resources

# 3.9G → 4G → 4.5G




4.5G has some key radio features that will form the basis for a 5G system (Massive MIMO, LAA, enhanced MTC, Latency reduction..)

# 3.9G → 4G → 4.5G




4.5G will be officially known as LTE-Advanced Pro (LTE-AP)

4.5G has some key rad atures that will form the basis for a 5G system (Massive MIMO, LAA, enhanced MTC, Latency reduction..)





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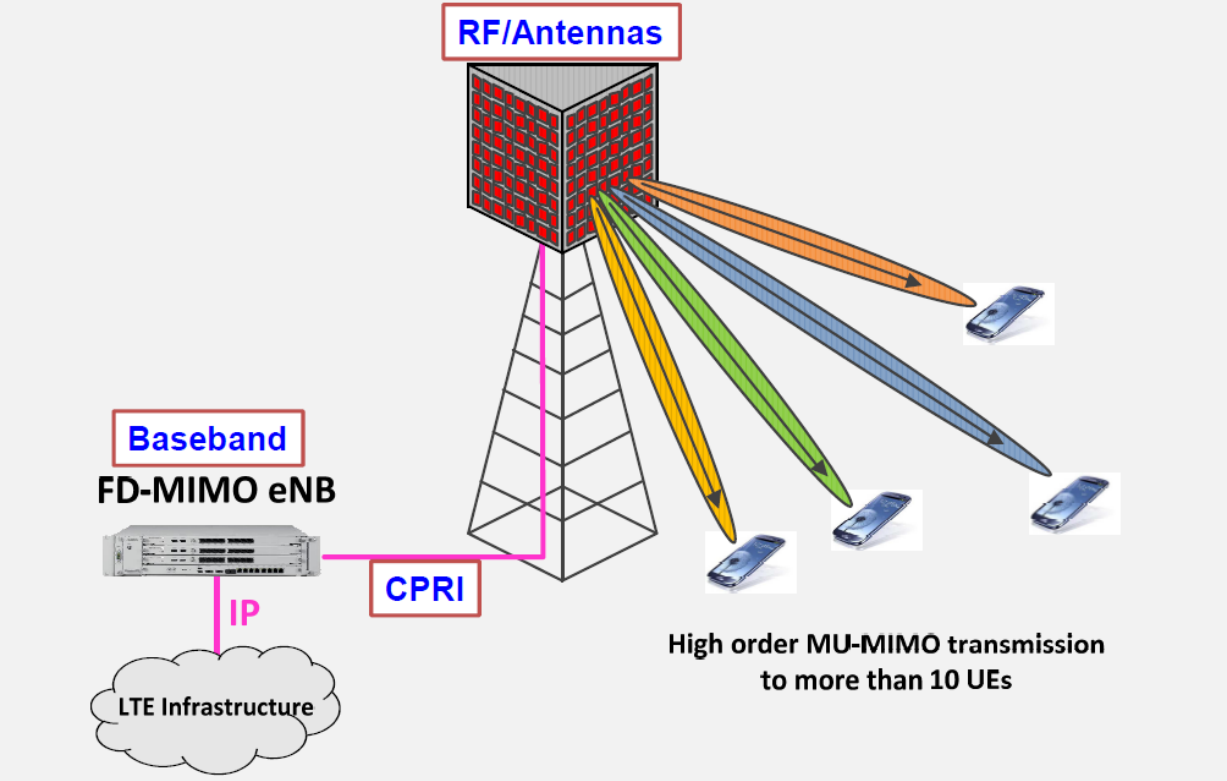
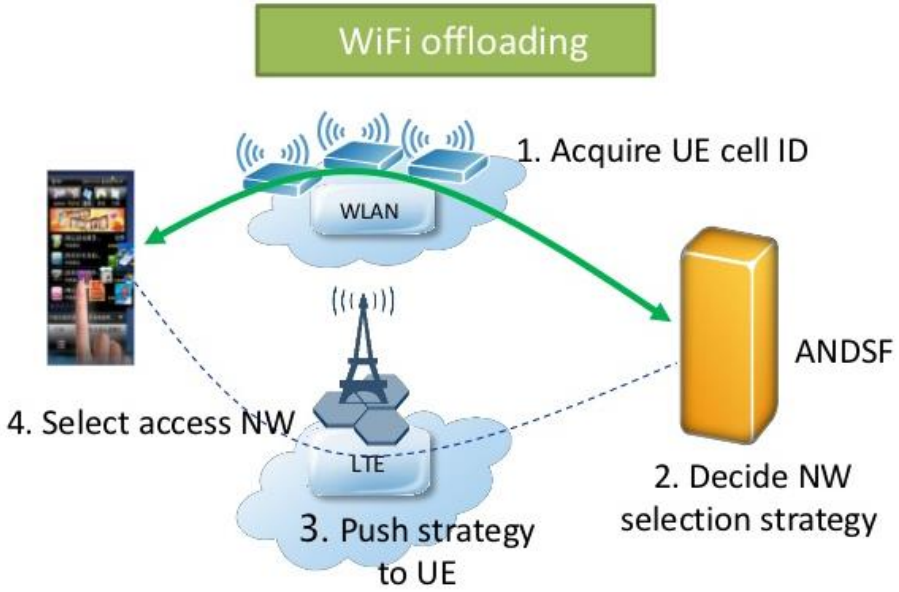
# 3D / Elevation Beamforming – 3GPP Rel-13+



# Wi-Fi offloading – 3GPP Rel-8+

中国移动 China Mobile




- Offload cellular data traffic to Wireless LAN when appropriate
- Mainly based on static strategies without much known about radio conditions and load on WLAN access point (AP)

# The battle for License-exempt spectrum

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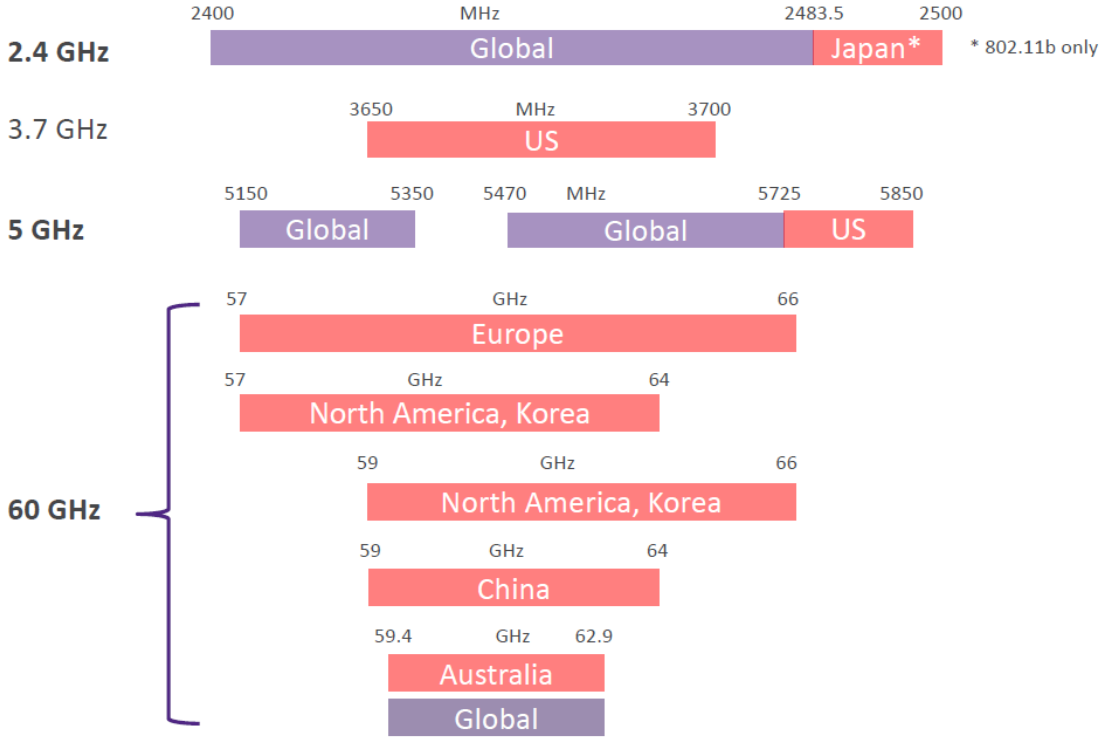

# LAA & LWA – 3GPP Rel-13+

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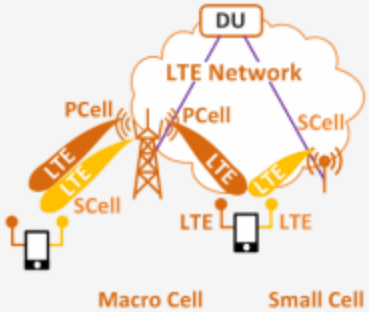
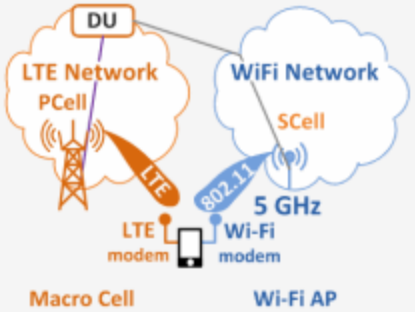
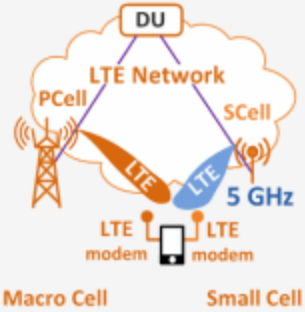
## Three different approaches at the radio level

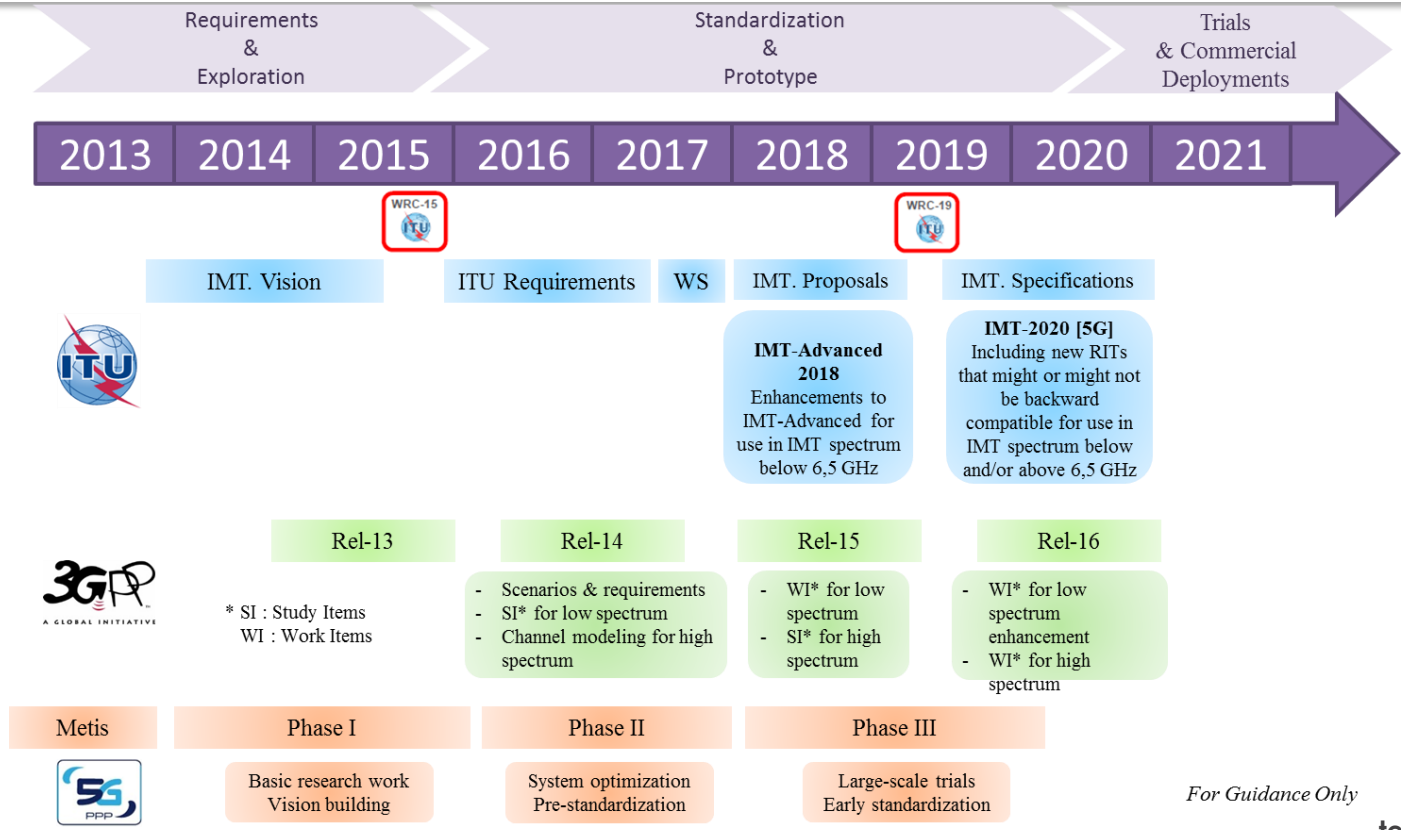
- LTE-U / U-LTE (U = Unlicensed)
  - Supplemental downlink (SDL) using Wi-Fi spectrum. No fair share mechanism with Wi-Fi. Not supported by standards.
- LAA (License Assisted Access)
  - Same as LTE-U but with sharing mechanism (LBT) with Wi-Fi. Supported by 3GPP standards (Rel-13)
- LWA (LTE – Wi-Fi Link Aggregation a.k.a. LTE-Hetnet)
  - Study Item in 3GPP standards (Rel-13)

# LTE-A CA, LTE-H & LTE-U comparison

| Category | | LTE-A CA | LTE-H | LTE-U |
|---|---|---|---|---|
| Licensed band<br>LTE Band 3 (1.8 GHz)<br>LTE Band 5 (850 MHz)<br>Unlicensed band<br>WiFi band (5 GHz) | |  |  <br>LTE-WiFi Link Aggregation |  |
| **CA Type** | | CA using licensed LTE bands | CA using licensed LTE and unlicensed WiFi | CA using licensed LTE and unlicensed LTE |
| **RAT** | | Single RAT (LTE only) | Multi-RAT (LTE and WiFi) | Single RAT (LTE only) |
| **CA band** | **PCell** | Licensed | Licensed | Licensed |
| | **SCell** | Licensed | Unlicensed (5GHz) | Unlicensed (5GHz) |
| **CA level** | | Link level (MAC layer) | Link level (PDCP layer) | Link level (MAC layer) |

Source: Netmanias

# 5G: 2020 or maybe earlier




3GPP and industry have agreed recently to the following timetable

- 5G Phase 1: H2 2018
- 5G Phase 2: Dec. 2019

*For Guidance Only*

Source: Future Networks – Bernard Celli, ANFR, Digiworld 2014

# 5G: An end-to-end ecosystem

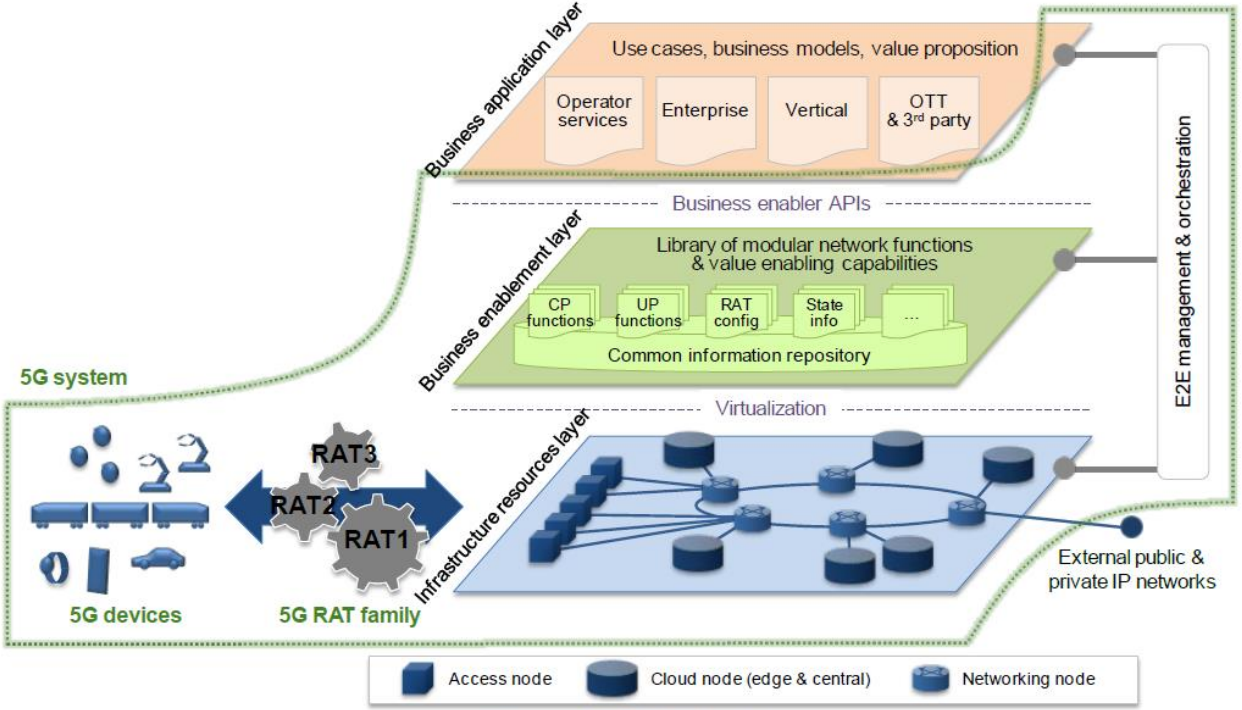
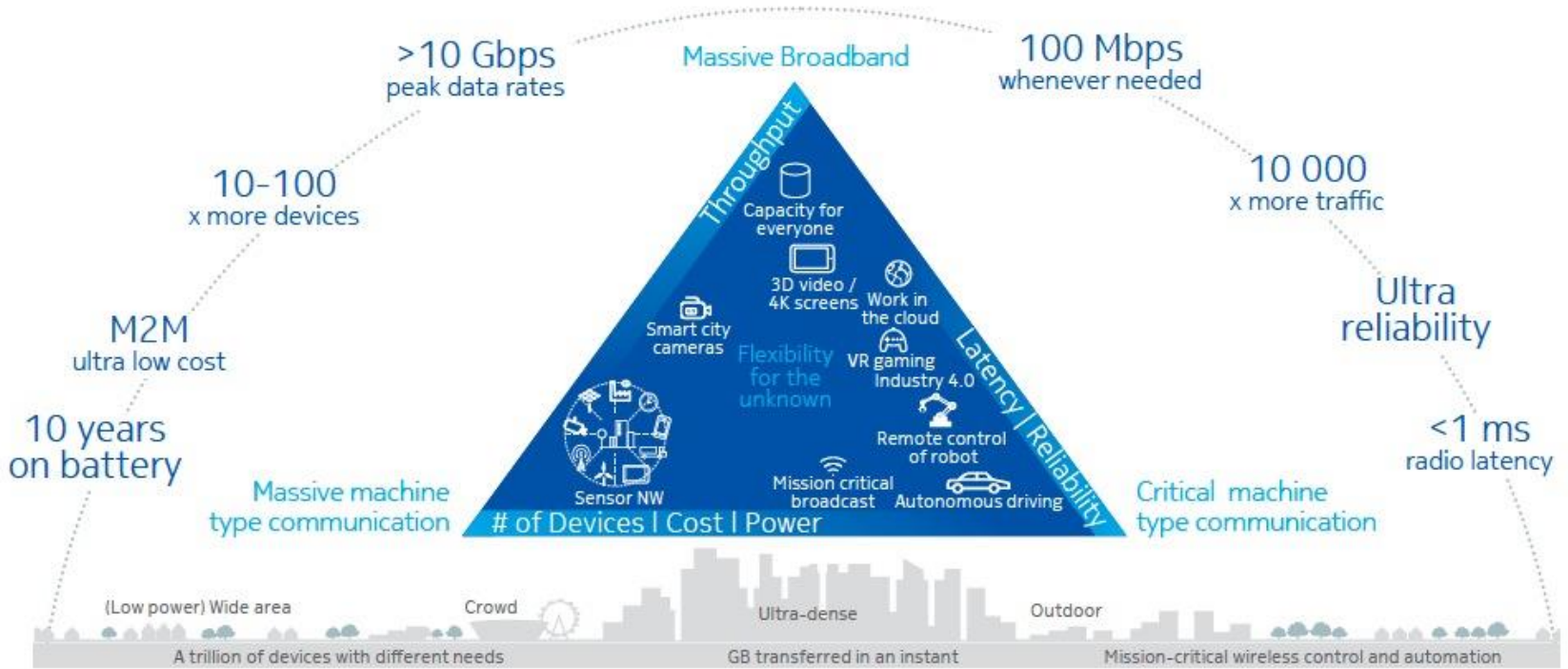



**Figure 8: 5G Architecture**

"5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models."

Source: NGMN

# 5G (IMT-2020): Technology Requirements




Source: Nokia

# 5G: Multifaceted and conflicting requirements

Optimize for data rate

Optimize for connection numbers

Optimize for delay

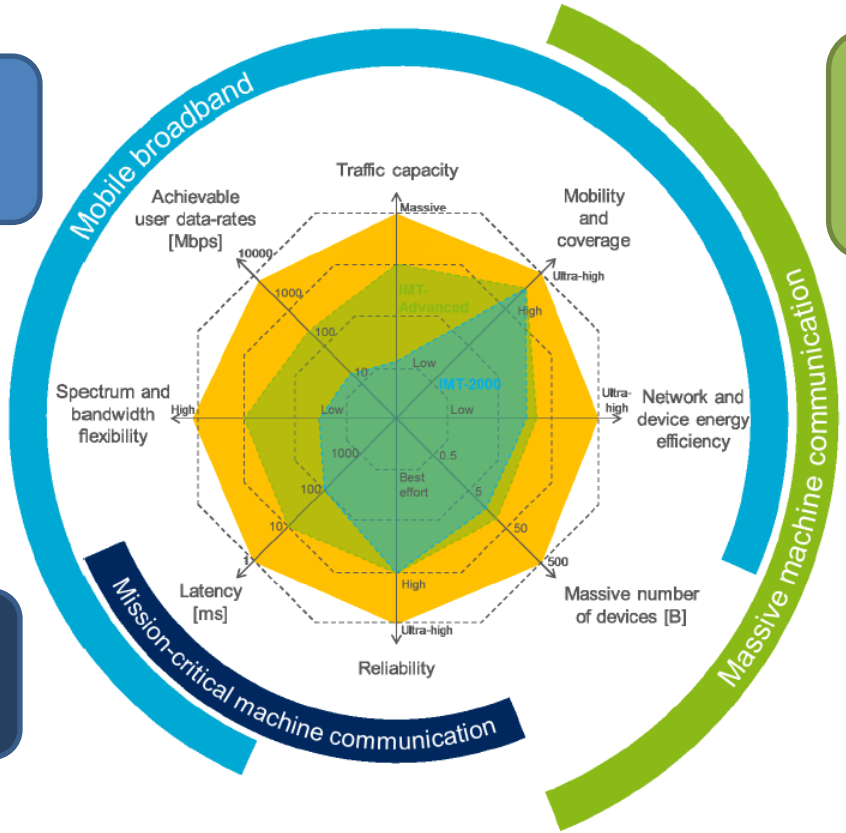
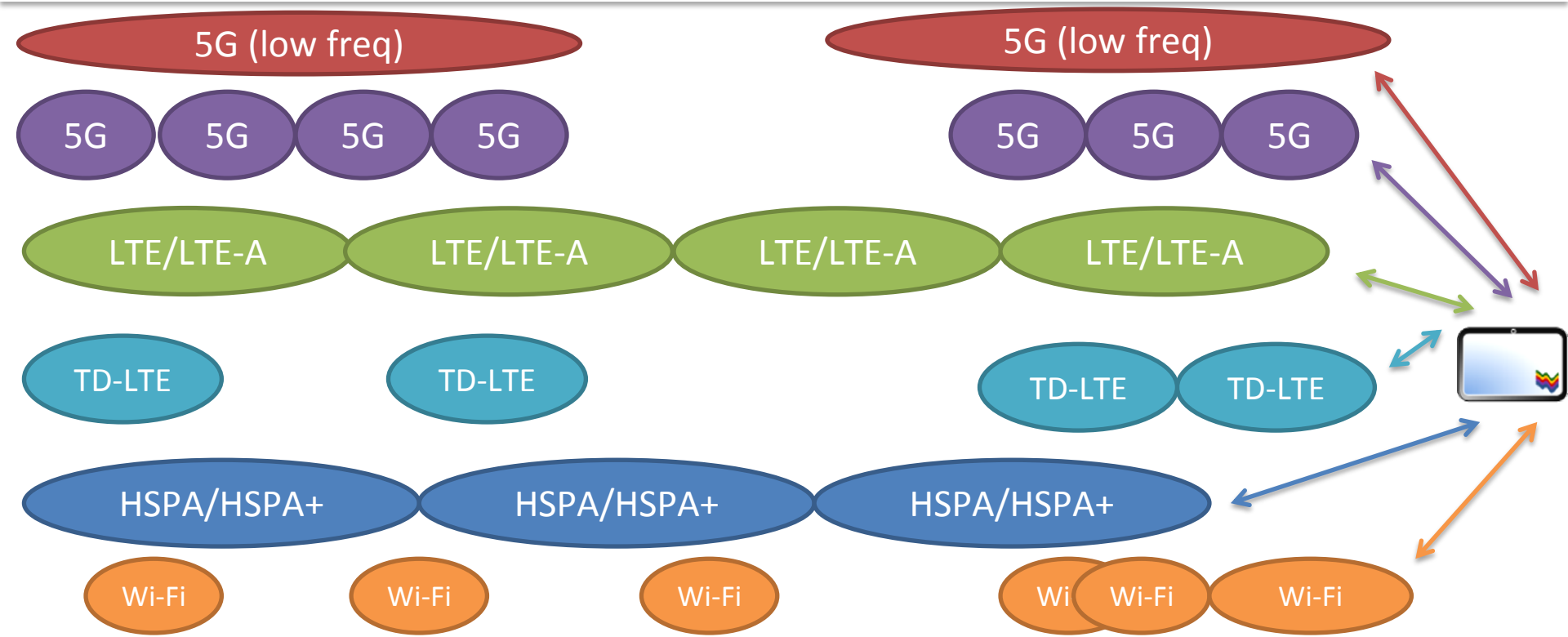




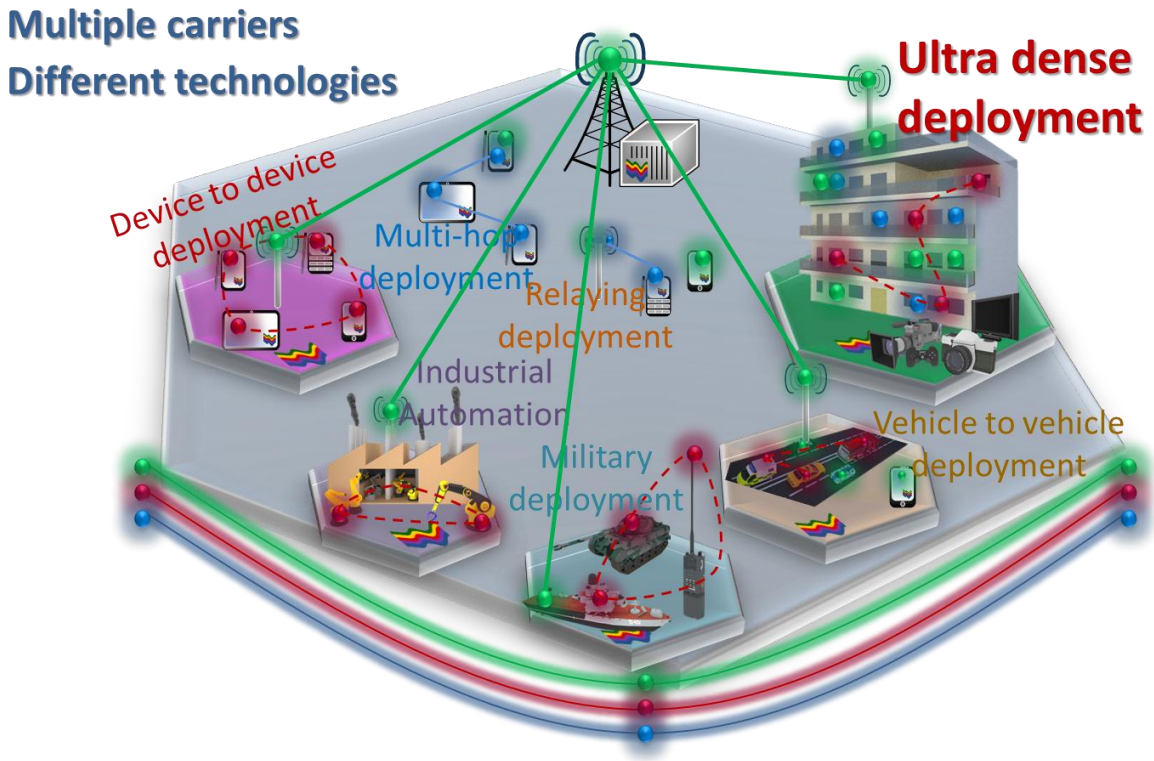

Image Source: 5G-From Research to Standardisation - Bernard Barani European Commission, Globecom2014

# Multi-Stream Aggregation (MSA) / Multi-connectivity (a.k.a. Opportunistic Aggregation)



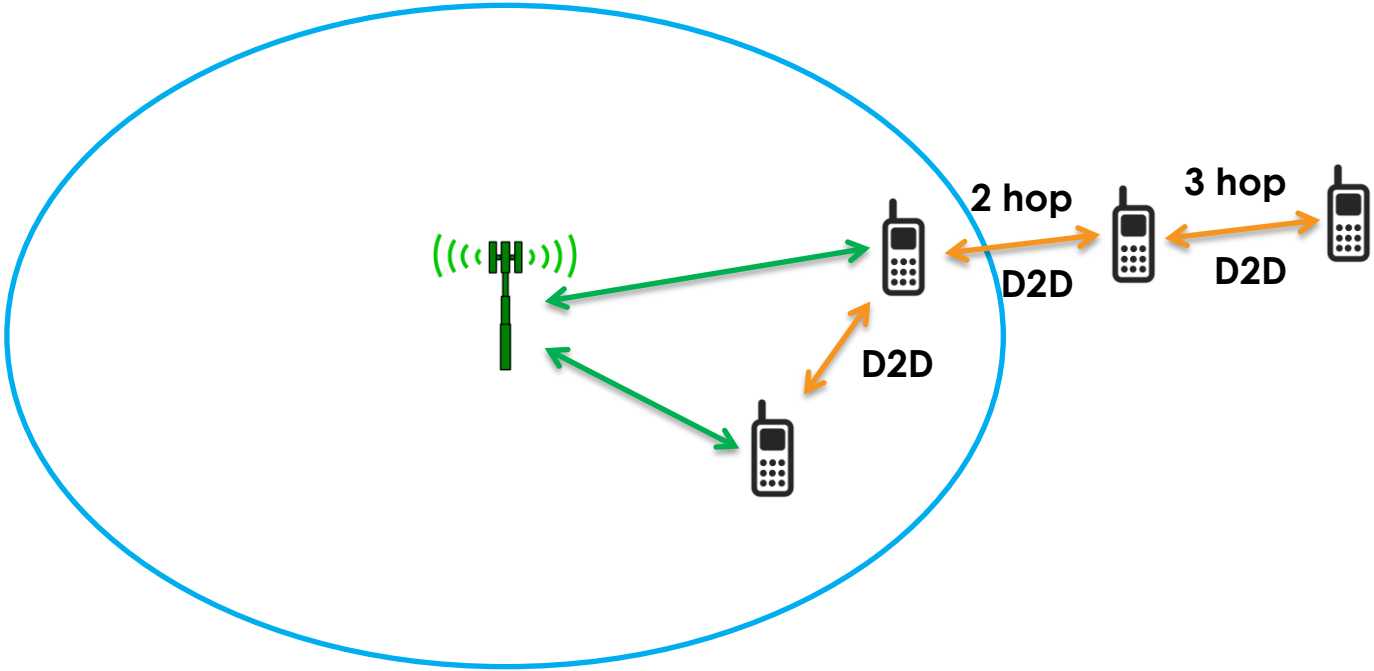

Source: eXplanoTech

# Ultra-Dense Networks (UDN)



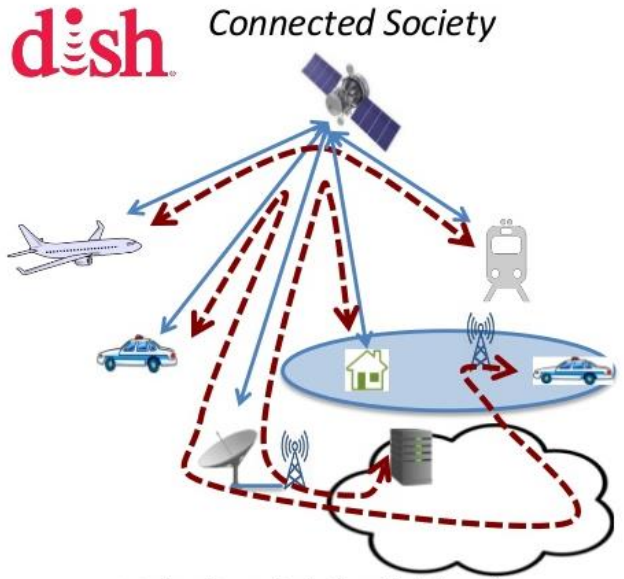

Source: eXplanoTech

# Device-to-device (D2D) & Multi-hop networks



# Should satellites be an integral part of 5G?

- Overlay satellite based systems are well suited for cost effectively implementing many 5G use cases:
  - Ubiquitous connectivity through hybrid satellite and terrestrial networks (e.g. coverage on a lake, mountain, etc)
  - Massive MTC
  - Software updates for all connected devices nationwide (e.g. mobiles, vehicles, MTC)
  - Mobile connectivity in vehicles (cars, trains)
  - Airplane connectivity
  - Broadcast like services (e.g. linear TV, emergency broadcast)
  - Emergency/disaster communications for first responders & subscribers provides ultra reliability
- Common "5G" standard and specifications for satellite & terrestrial networks ensure interoperability and seamless user experience



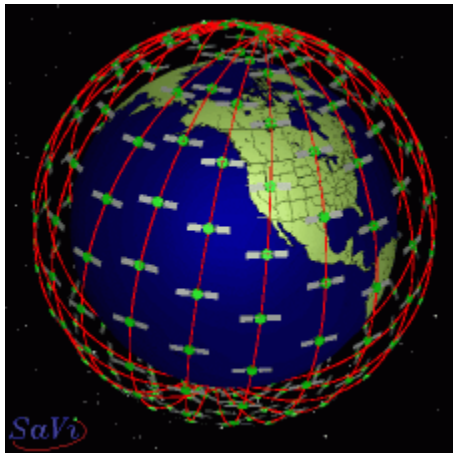

*A single radio standard, allows flexibility to the devices to choose the best access link for connectivity based on required service.*

***Satellite based 5G access could drive early deployment of ubiquitous 5G systems and should an integral part of the Connected Society***

Source: 3GPP RAN 5G Workshop

# Megaconstellations

- OneWeb
  - 648 LEO satelites delivering 3G/4G/WiFi
- LEOSAT
  - 78-108 smallsats to deliver LEO-HTS services
- SSII
  - 300 satellites constellation in LEO announced
- Samsung
  - imagines Earth-wide internet through 4,600 satellites



# Facebook Drones

- Solar powered
- Fly without landing, 3 months at a time
- Operate between 60 and 90 thousand feet
- Laser communication, 10Gbps, up to 10 miles away.

# Google Loon

- Operate at 20km (65,000 ft) high
- Iridium satellite comms. for sending commands to the Loon
- Wi-Fi and LTE transmission
- Covers 25 miles (40 km) area
- Data speeds on LTE, 15Mbps to phones, 40Mbps to MiFi devices

# Google Drone

- Drones, easier to place in a target area.
- Same functionality as the Loon
- Transmission of LTE and Wi-Fi

# Next-Generation Inter-Connected Network