CREATING THE LIVING NETWORK™

5G Wireless and the Future of Telecoms

Barclays Conference Call
28 November 2017

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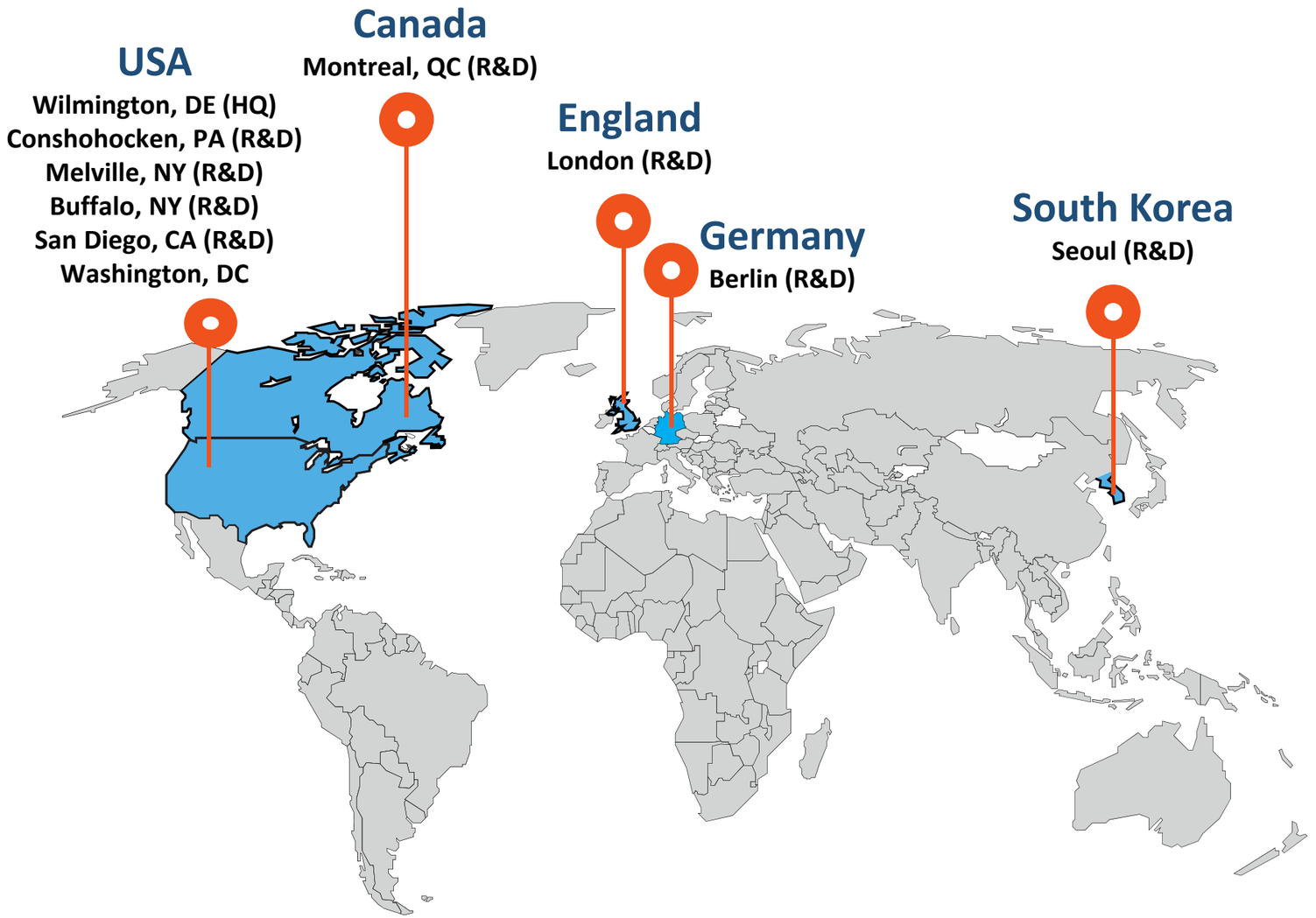
Forward-Looking Statements

- This presentation contains forward-looking statements within the meaning of Section 27A of the Securities Act of 1933, as amended, and Section 21E of the Securities Exchange Act of 1934, as amended, regarding InterDigital, Inc.'s current beliefs, plans and expectations regarding 5G technology and use cases and future connected device shipments. Such statements are subject to the safe harbor created by those sections.
- Forward-looking statements are subject to risks and uncertainties. Actual outcomes could differ materially from those expressed in or anticipated by such forward-looking statements due to a variety of factors, including changes in the 5G timeline, changes or inaccuracies in market projections and those factors detailed in our Annual Report on Form 10-K for the year ended December 31, 2016 and from time to time in our other Securities and Exchange Commission filings.
- We undertake no duty to update publicly any forward-looking statement, whether as a result of new information, future events or otherwise, except as may be required by applicable law, regulation or other competent legal authority.

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InterDigital – A Pioneer in Wireless Technologies

- Over four decades of discovery and innovation in wireless technology
  - Founded in 1972
- Key contributions to global wireless standards
- Inventing solutions for more efficient broadband networks
- ~ 180 engineers
  - ~80% hold advanced degrees
- NASDAQ:IDCC

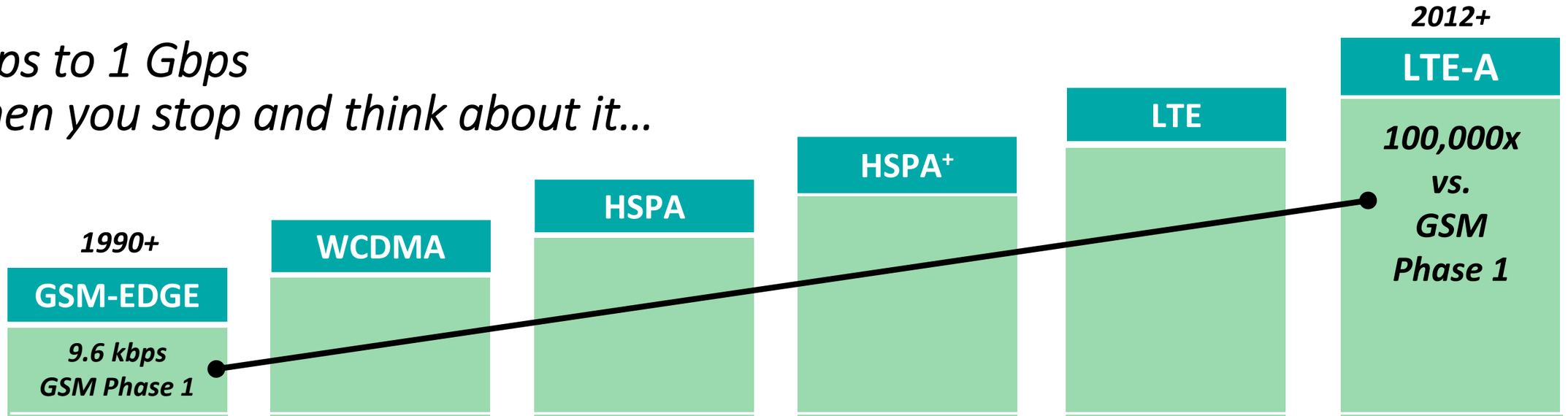


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Oh, So Many G's

2G Narrowband Era | **3G** Broadband Era (for the few) | **4G** …and for the masses

From 9.6 kbps to 1 Gbps
Amazing when you stop and think about it…



	GSM-EDGE	WCDMA	HSPA	HSPA+	LTE	LTE-A
Downlink Peak Data Rate	**240 kbps**	**2 Mbps**	**14 Mbps**	**42 Mbps**	**150 Mbps**	**1 Gbps**
Spectral Efficiency	0.17-0.33 bps/Hz	0.51 bps/Hz	2.9 bps/Hz	12.5 bps/Hz	16.3 bps/Hz	30 bps/Hz
Carrier Bandwidth	200 kHz	5 MHz	5 MHz	5 MHz	Up to 20 MHz	Up to 100 MHz
Round Trip Latency	300 ms	250 ms	~70 ms	~40 ms	~30 ms	~20 ms

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5G - Why do we need this? Or do we just want it?

Well, lots of good reasons and many new business opportunities

Me and You	Incumbent Wireless Service Providers & Equipment Manufacturers	Entrepreneurs & Visionaries
Reliable coverage everywhere	***Protect the business***	***Use wireless connectivity to grow businesses and create new businesses***
High data rates	***Reduce operating expenses***	***Access to customers!***
More cool apps	***Reduce capital expenses***	
Low prices	***Grow the business***	

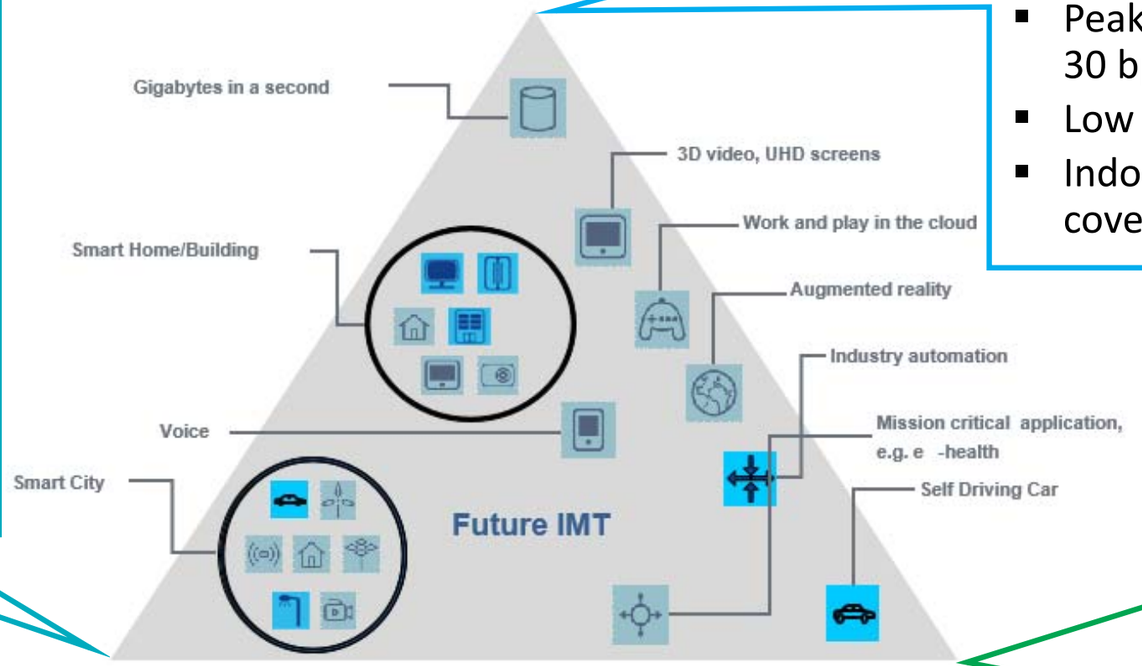
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5G Use Cases and Key Requirements

Key challenge for 5G design: support for different services having diverging requirements

Massive Machine Type Communications (mMTC)

- Low data rates (1 to 100 kbps)
- High device density (up to 1,000,000/km^2)
- Latency: seconds to hours
- Low power: up to 15 years battery life



Source: ITU-R SG5 WP-5D

Enhanced Mobile Broadband (eMBB)

- Peak data rates: 20 Gbps (downlink) and 10 Gbps (uplink)
- Peak spectral efficiency: 30 bps/Hz (downlink) and 15 bps/Hz (uplink)
- Low latency: 4 ms user plane latency
- Indoor/hotspot and enhanced wide-area coverage

Ultra-Reliable and Low Latency Communications (URLLC)

- Low to medium data rates (50 kbps to 10 Mbps)
- 0.5 ms user plane latency
- 99.999% reliability and availability within 1 ms
- High mobility

More on Use Cases Later…

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5G Timeline: 3GPP Standardization & Deployment

Phased approach enables early deployments starting in 2018



Pre-Standards Trials & Demos

- Technology demos & trial deployments
- Announcements of roll-out “5G services” using R14-15 LTE and NB-IoT
- Upgrades to existing 4G networks
- 2018 Pyeongchang Winter Olympics, South Korea

Early Commercial Deployment

- Early deployment of Non-Standalone New Radio on top of LTE for Enhanced Mobile Broadband (eMBB) services
- 2018 FIFA World Cup, Moscow
- 2020 Tokyo Summer Olympics, Japan

Full Scale Deployment

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Background: Simplified Wireless Network



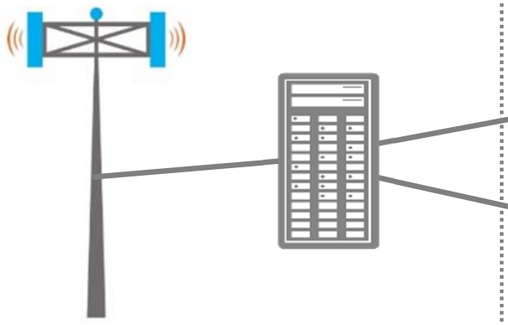
Terminal Devices

- 4G: Primarily Smartphones & Tablets
- 5G: Any device requiring wireless connectivity (sensors, cars, …)



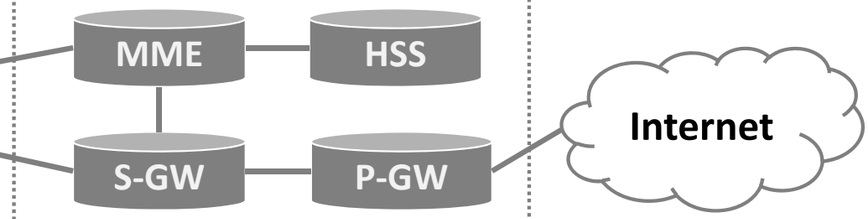
Spectrum

- Frequency bands that are used for transmitting wireless signals between terminal devices and Radio Access Network
- Spectrum can be licensed, shared or unlicensed



Radio Access Network

- Provides wireless connectivity to terminal devices
- Includes antennas, remote radio heads, base stations, radio network controllers



Core Network

- Responsible for establishing and managing connections to terminal devices (authentication, security, billing, …)
- Provides connection to external networks

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5G Spectrum Outlook – Exploring Higher Frequencies



3GPP Design Assumptions

- Reference frequency ranges for 5G design: 30 GHz and 70 GHz
- Maximum carrier bandwidth of 80 MHz
- Maximum contiguous aggregated bandwidth of 200 MHz and up to 1 GHz aggregated bandwidth overall

- Reference frequency ranges for 5G design: 700 MHz, 2 GHz and 4 GHz
- Maximum Aggregated Bandwidths:
  - Up to 100 MHz at 700-800 MHz
  - Up to 160 MHz at 2 GHz
  - Up to 200 MHz at 4 GHz

USA Spectrum Outlook

FCC Notice of Proposed Rulemaking (NPR) in 07/16:

- 3.85 GHz for licensed and flexible use in 28 GHz, 37 GHz and 39 GHz bands
- 7 GHz for unlicensed use in 64-71 GHz band
  - 14 GHz in total when combined with existing spectrum
- Shared access in the 37-37.6 GHz band
  - Provides 600 MHz of spectrum with dynamic access

- 600, 700, 800 MHz highly attractive for 5G IoT applications
- Between 1 GHz and 5 GHz, spectrum is fragmented
  - Use of carrier aggregation and/or dual connectivity
  - 3.5 GHz range seen as good target for new 5G radio
- In 5 GHz range, unlicensed band could be used to provide LTE (LAA) and/or 5G service

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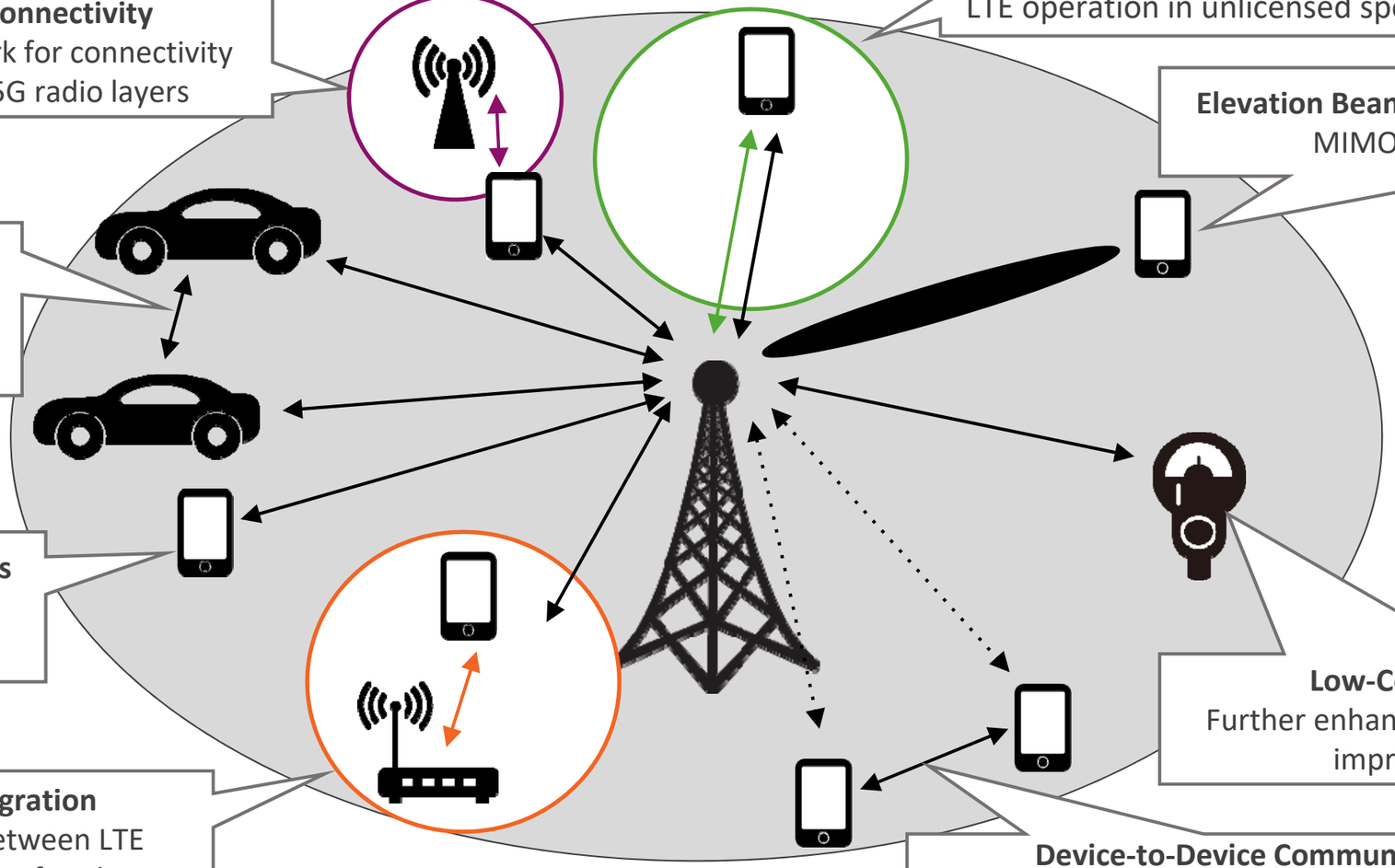
LTE-Advanced Pro – 5G Opportunities in LTE Evolution

Multi-Layer Connectivity
Providing framework for connectivity across multiple 5G radio layers

LTE in unlicensed spectrum
LTE operation in unlicensed spectrum to exploit available spectrum

Elevation Beamforming/Full-Dimension (FD) MIMO
MIMO with up to 64 antenna ports

LTE-based V2X Services
Providing V2V, V2I and V2P connectivity for safety, traffic management, …



Macro Layer LTE

New 5G Radio Layers

5GHz LTE

Wi-Fi

LTE Protocol Improvements
Control and data plane latency enhancements

Low-Cost LTE for MTC (or LTE-M)
Further enhancements to reduce complexity and improve battery consumption

LTE / Wi-Fi Integration
Tight integration between LTE and Wi-Fi at radio interface layer

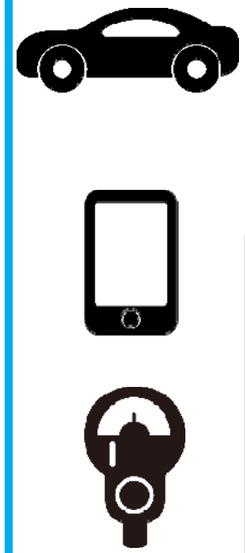
Device-to-Device Communication
Enabling wider range of proximity services for Public Safety and commercial applications

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5G New Radio (NR) – Whole New System Design

3GPP designing new non-backwards compatible air interface and radio network architecture for 5G

NR Terminal Devices



NR Air Interface

New L2/L3 User and Control Plan Architecture and Protocols

- More efficient initial access protocols (e.g. on-demand system information)
- New mobility management approaches (e.g. terminal-centric mobility)
- New protocol function split across network nodes

New Physical Layer Design

- New non-backwards compatible physical layer: waveform, multiple access scheme, ….
- Massive number of antennas (i.e. massive MIMO)
- Exploiting new spectrum: mmWave, unlicensed/shared spectrum, ...

NR Radio Access Network



TRP*

New Radio Access Network Architecture

- Centralized/Cloud RAN architecture
- Fronthaul protocol split and design
- Tight interworking with LTE

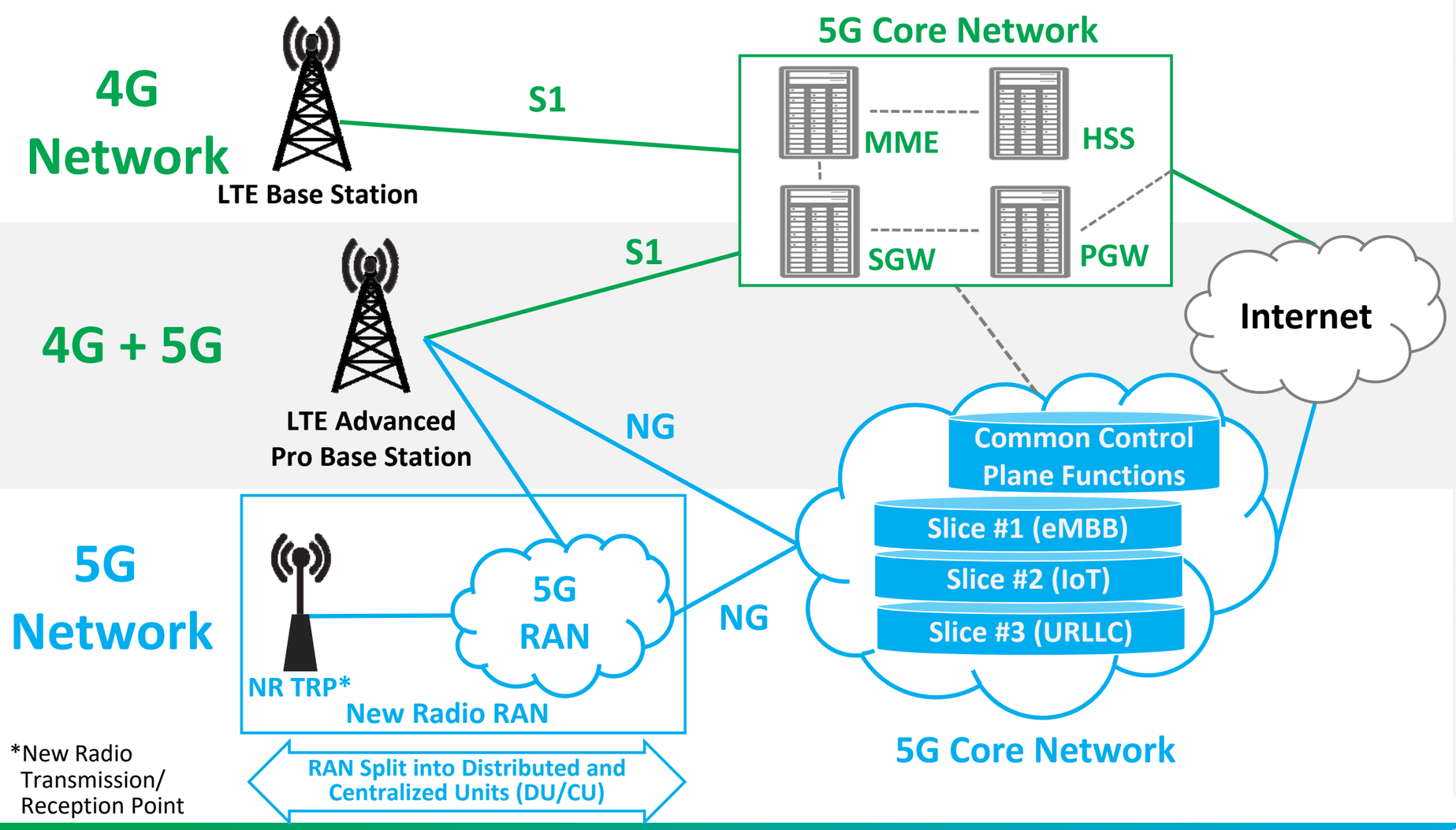
*Transmission/Reception Point

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5G Core Network – Gluing 4G, 4G Evolution & 5G

Independent evolution and flexible deployment of RAN and Core Network



*New Radio Transmission/ Reception Point

New core network technologies target lower cost infrastructure and customized services

Network Function Virtualization

- Centralized CN – Software configurable with commodity servers similar to IT data centers

Network Slicing

- Segmentation of resources to form different logical CNs per service (IoT, eMBB, …)
- Allows dynamic scaling of resources based on service type needs

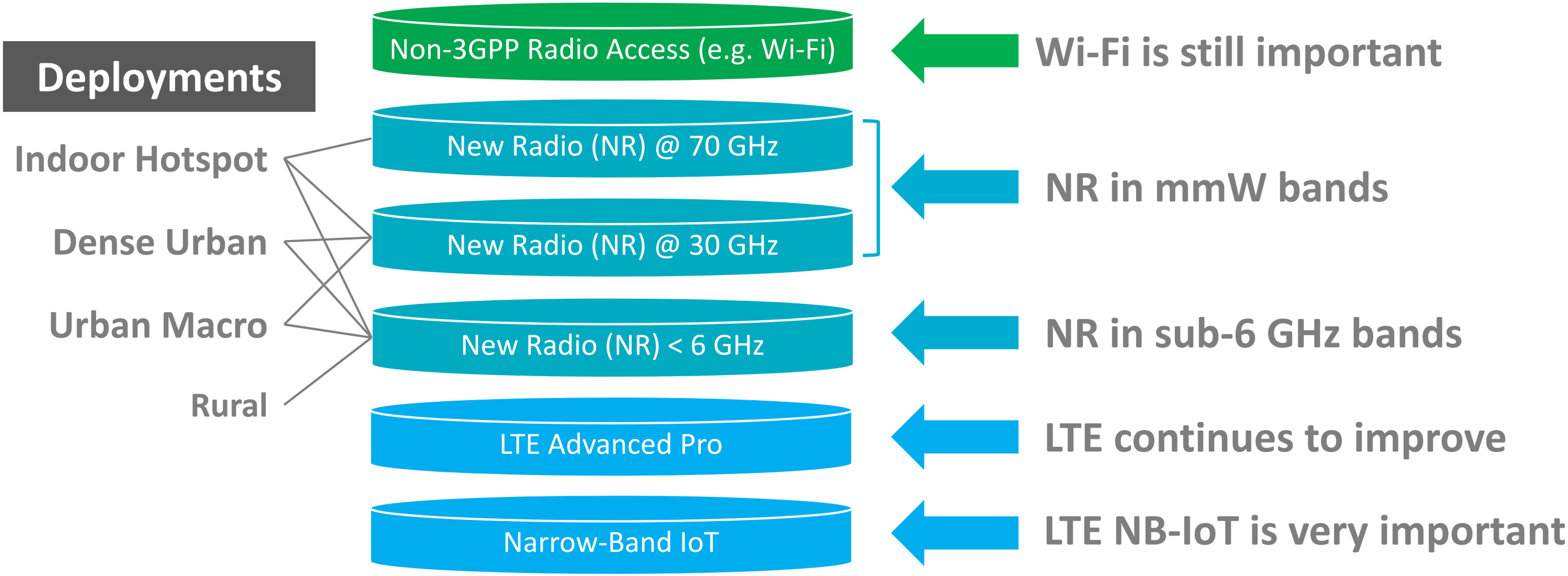
Service Capability Exposure

- 3rd party service/application providers gain access to information and service customization

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5G: Connectivity Across A Multi-Layer Radio Network

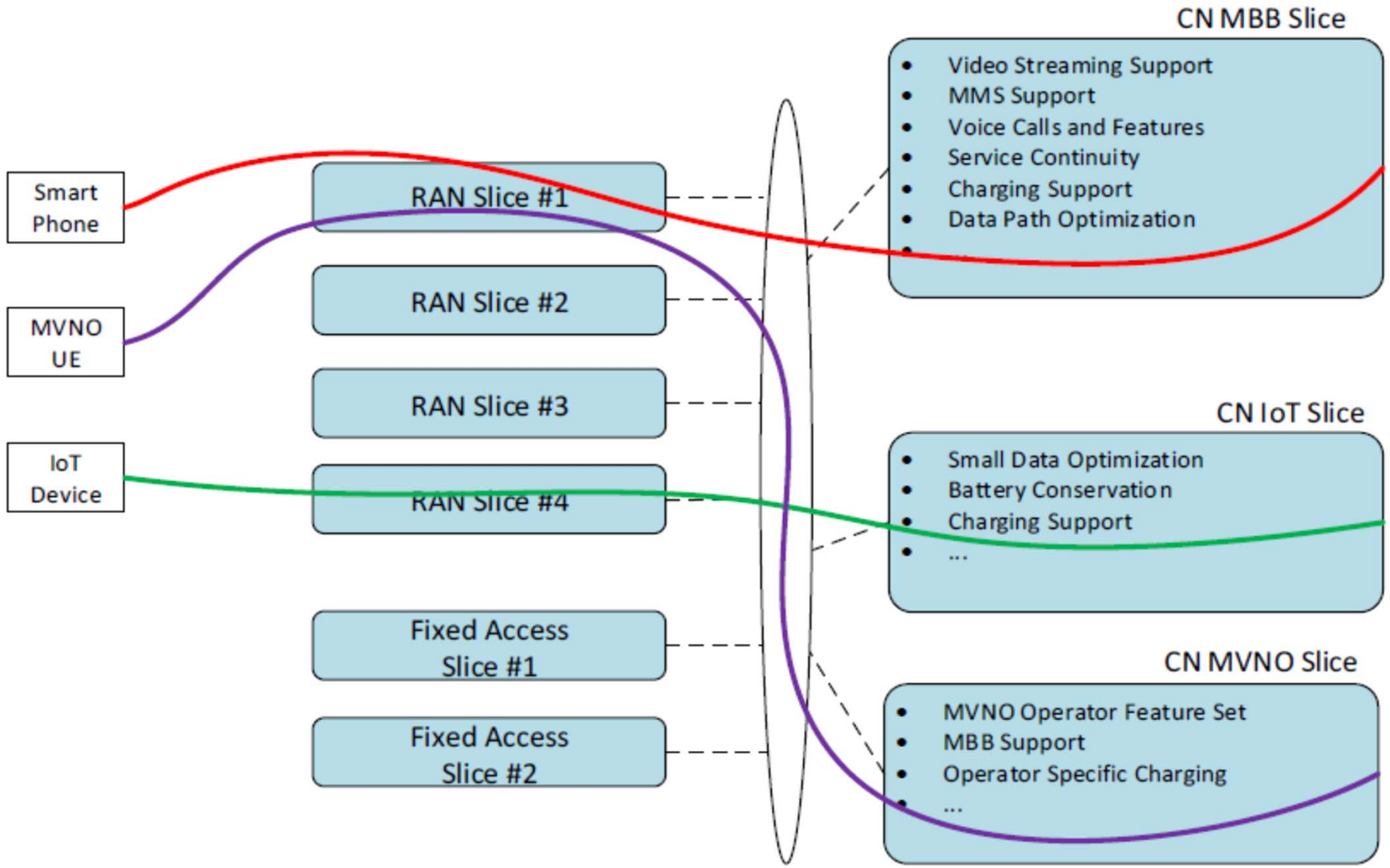
Includes a New Radio (NR) in sub 6 GHz frequencies and millimeter wave (mmW) bands



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Network Slicing – Reconfigurable RAN & Core Network

OTTs and new entrants leverage network slices to manage services & features through slices of shared equipment

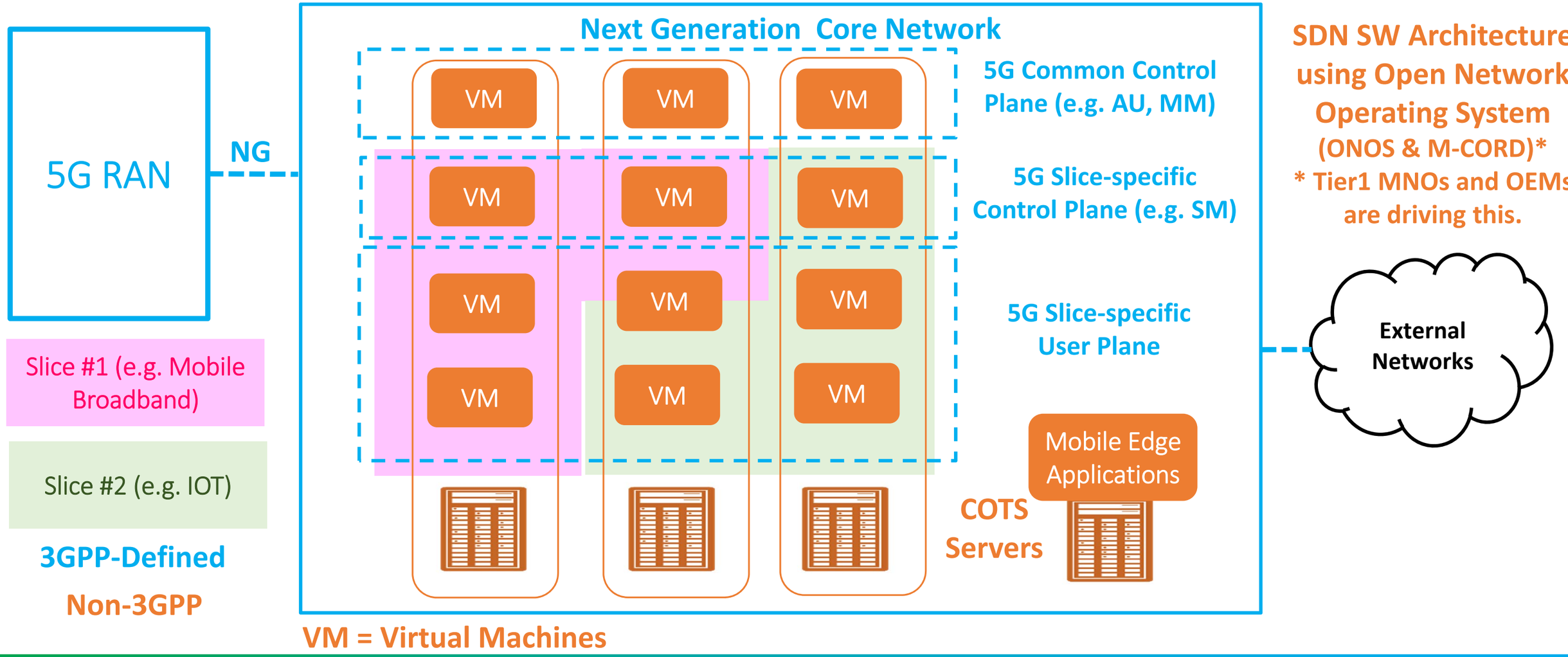


Source: "Network Slicing for 5G Networks and Services," 5G Americas, November 2016

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5G Core Network Components – 3GPP & Non-3GPP

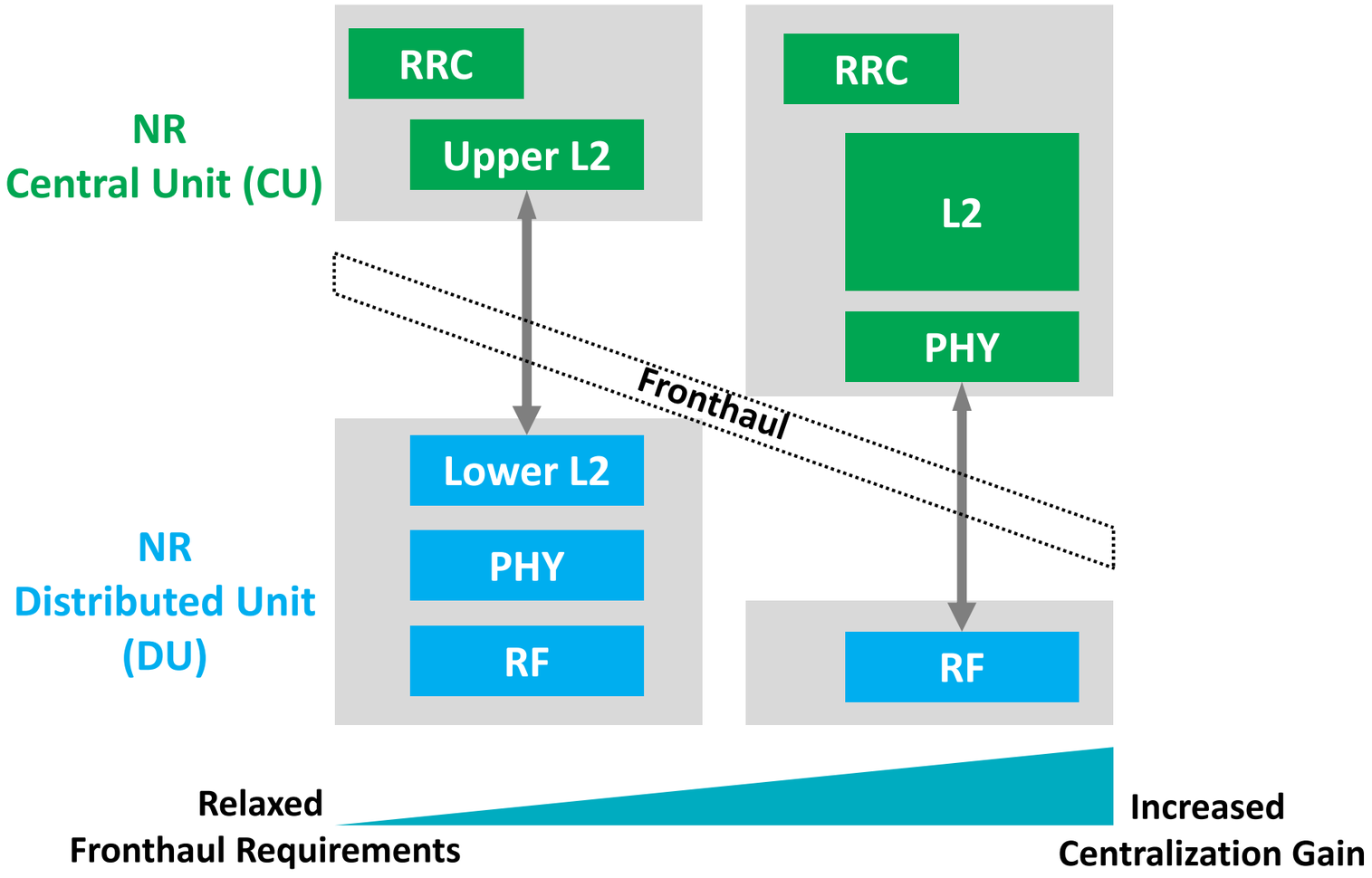
Segmentation of network resources to form different logical 5G Core Networks per service



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RAN Functional Split → Virtualized RAN / Cloud RAN (CRAN)

Distributed and flexible architecture to meet diverging requirements and allow operator flexibility



- Re-architecting protocol design to support centralized cloud processing and flexible distribution of functions
- Layer 2/3 design has to consider tradeoff between fronthaul requirements (e.g. throughput, latency) and centralization gains (e.g. mobility, interference coordination, overhead)
- Distributed architecture allows for flexible functional split to accommodate for different operator deployments
- User plane and control plane separation should be ensured and designed such that they be split across layers, nodes, and units

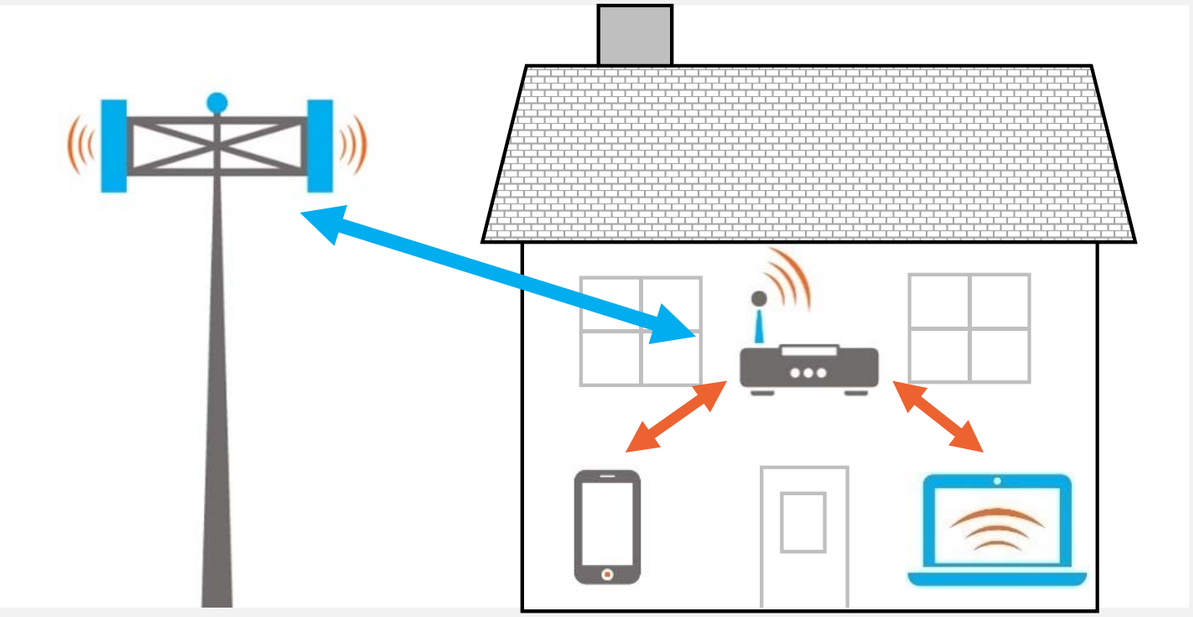
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5G Use Case Spotlight:
Fixed Wireless Access (FWA) & 5G Indoor Connectivity

5G design requirements for eMBB could enable connectivity to and inside the home

Scenario 1: 5G Connectivity to the home

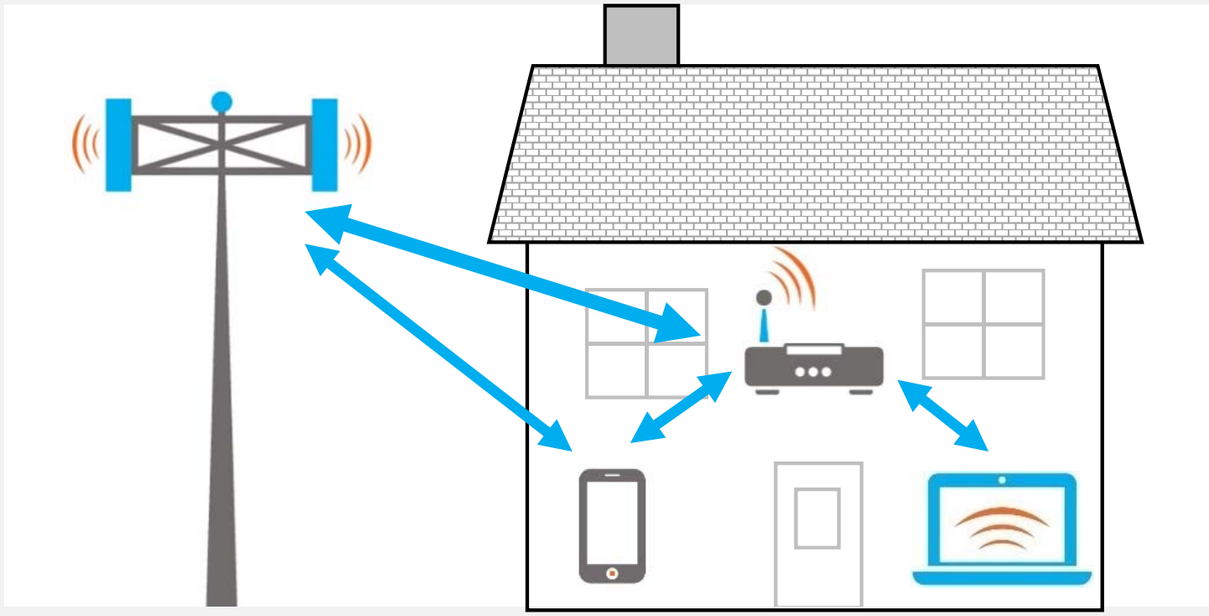
- Large bandwidth in mmWave spectrum could provide connectivity to access point within the home
- Other technology (e.g. WiFi) used for connectivity inside home



WiFi Connectivity

Scenario 2: 5G Connectivity inside the home

- 5G connectivity to access point within the home
- Devices inside home connected using 5G NR (licensed, unlicensed, or shared spectrum) through access point and 3GPP radio network

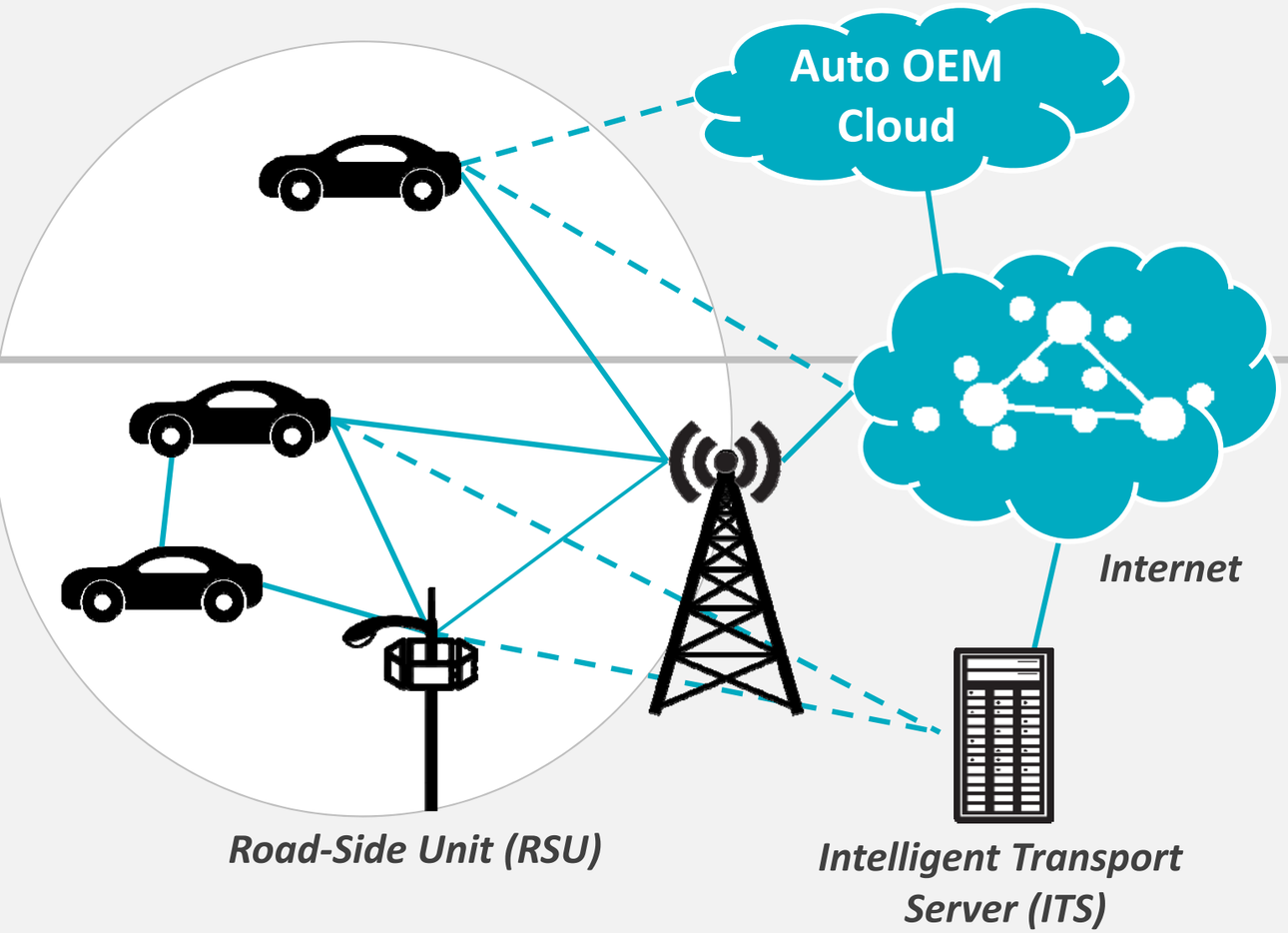


3GPP 5G Connectivity

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5G Use Case Spotlight: Connected Vehicles

The Connected Car



V2X for Safety and Traffic Management

	Near-Term	Long-Term
The Connected Car	Already happening today many cars connected to internet and automotive OEM clouds ➔ Mix of 3G and 4G modems	Cars expected to evolve as mobile multimedia hubs ➔ Need for 5G eMBB higher data rates and capacity
V2X for Safety and Traffic Management	First phase of V2X to <u>enhance</u> safety and traffic management ➔ Combination of DSRC (available today) and LTE V2X (available soon) expected to be deployed	Second phase of V2X <u>necessary</u> for safety and traffic management of <u>autonomous</u> vehicles ➔ Need for 5G URLLC low latency and high reliability

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5G Use Case Spotlight: Internet of Things

Low Power Wide Area Access (LPWA) – A Fast Growing Use Case with Lots of Competition

Worldwide Connected Devices (billions)

	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	15.5	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	

Source: Ericsson Mobility Report, June 2017

- LPWA connects a broad range of IoT devices
  - Low cost: <$5 per module
  - Low power & long battery life: > 10 years
  - Small data transfers and delay tolerant
  - Large coverage area, including indoor
  - Large number of devices
- Competing technologies
  - Most deployed devices are 2G: **GSM/GPRS**
  - A number of recent competing technologies operate in unlicensed frequency bands:
    Sigfox, LoRa, Ingenu
  - Cellular
    Early answers - **Cat 1/ Cat 0 / Cat M1**
    5G answer, at least for now, is **NB-IoT**

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Cellular-Based LPWA Technologies

Alternatives offer various combinations of data rates, power requirements, and coverage

Cellular technologies offer the QoS advantages of licensed spectrum, proven network & device security, a deployed infrastructure footprint, and a one-stop shop for wireless connectivity services

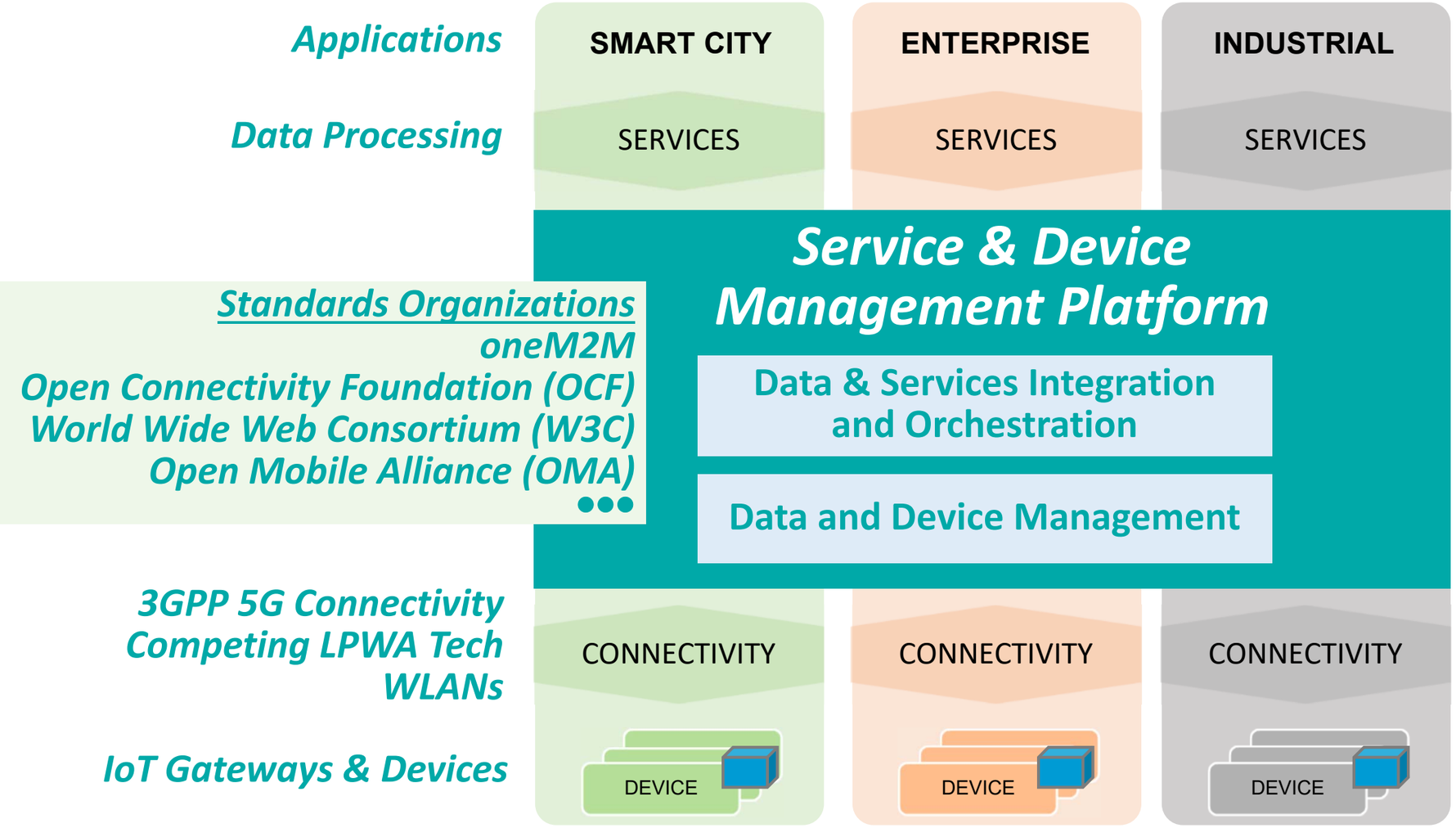
	LTE Cat 1	LTE Cat 0/Cat M1 (LTE-M)	EC-GSM	NB-IoT
3GPP	Release 8	Releases 12-13	Release 13	Release 13 & Beyond
Data Rates	Up to 10 Mbps DL & 5 Mbps UL	~ 1 Mbps	~ 100 kbps	~ 200 kbps
Highlights	Early market lead for IoT services on 4G networks	Wide-range of IoT services that co-exists with LTE mobile broadband	Deploys in existing 2G spectrum and networks with 20 dB coverage improvement	Best low power wide area coverage technology with 10+ years battery life

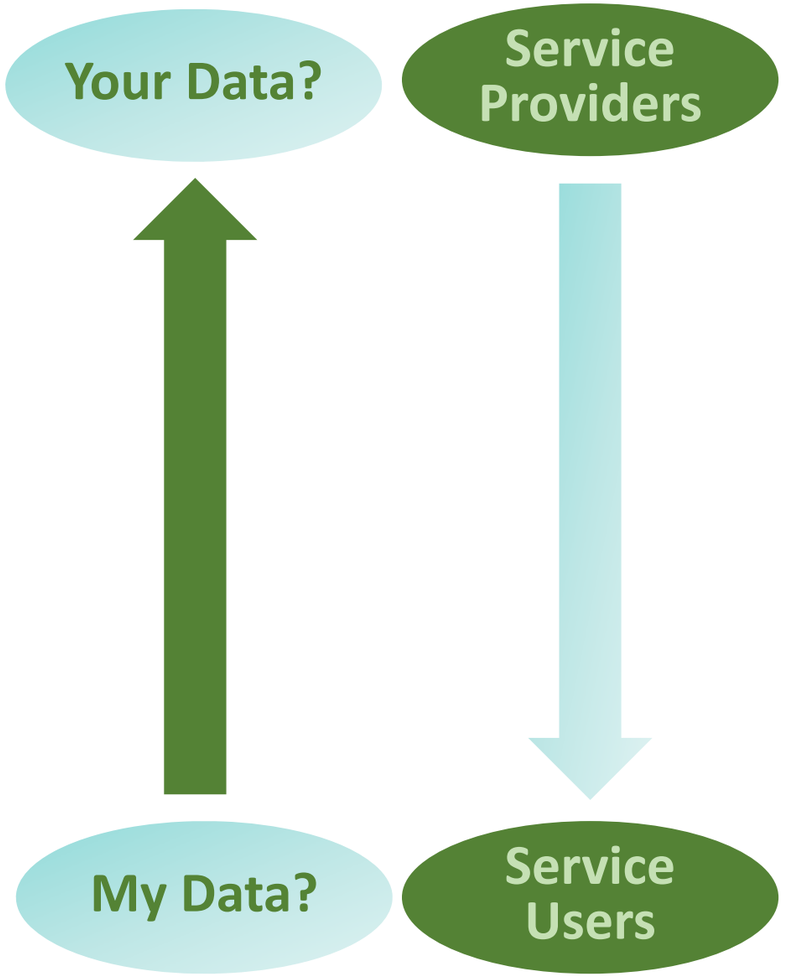
Increasing coverage and battery life & newer technology

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5G Will Enable Massive Dataflow Through IoT Stacks

… but who owns the data, who pays, and who will thrive?

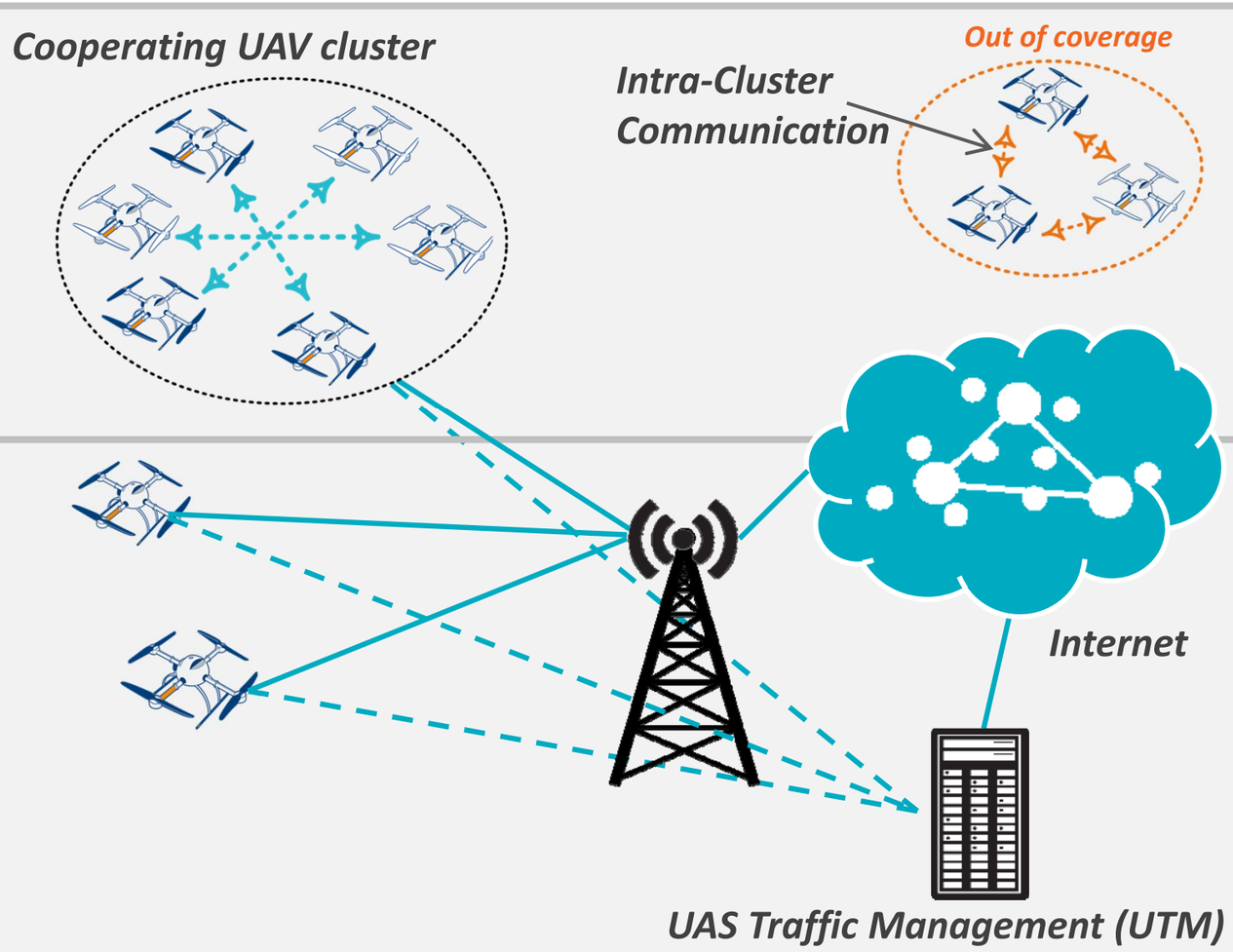




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5G Use Case Spotlight: Unmanned Autonomous Vehicles – UAVs/Drones



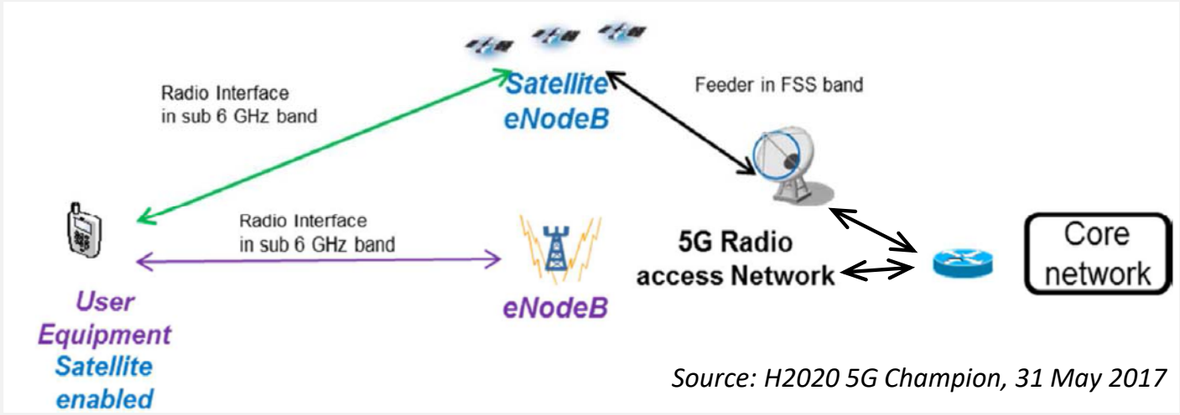
UAV Communications for BV-LOS operations and Traffic Management

Near-Term	Long-Term
Today: Only Visual LOS operations are allowed by regulators (ex. FAA, CAA, etc.) ➔ Mix of Wi-Fi & Bluetooth connectivity	Beyond Visual LOS (BV-LOS) and autonomous UAV operations ➔Multitude of drone use-cases need enhanced connectivity
First phase of UAV Comm. enhancements to <u>enable</u> control, safety and traffic management ➔ LTE-Pro enhancements for UAV to base-station communication are expected to be deployed first	Second phase of UAV Comm. enhancements <u>necessary</u> for safety and traffic management of <u>autonomous</u> UAVs ➔ Need for 5G URLLC low latency and high reliability along with UAV-to-UAV communication support

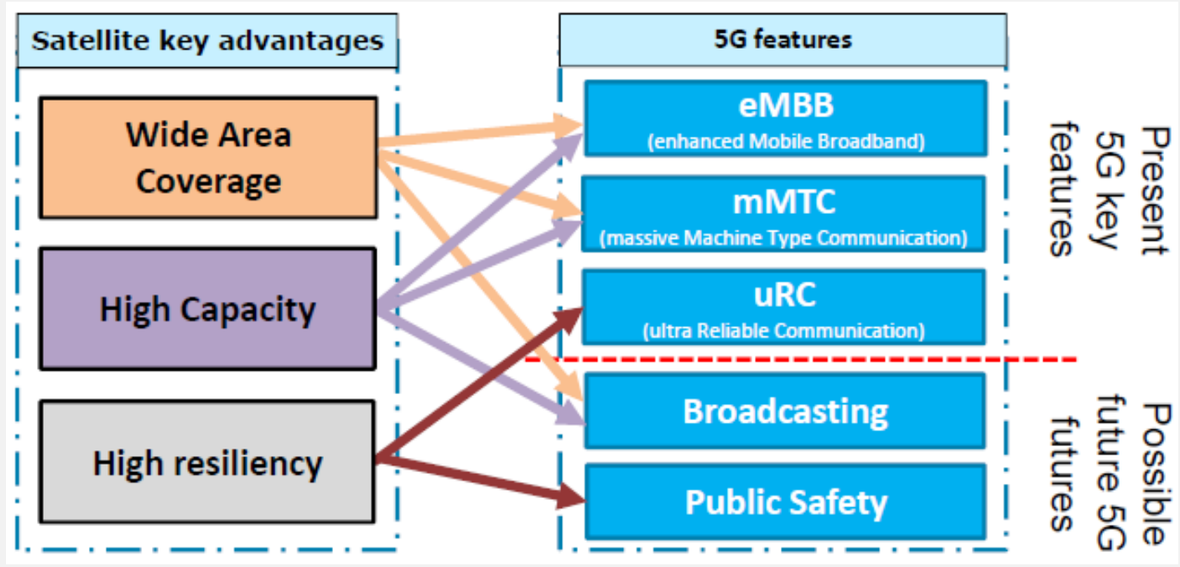
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5G Use Case Spotlight: Non-Terrestrial Networks (NTN) - Satellites

Satellite key advantages can benefit 5G



Source: H2020 5G Champion, 31 May 2017



Wide array of NTN use cases in 5G, including:

- MTC/IoT services - Fleet management, asset tracking, metering, control
- Broadband access - Rural, underserved, remote areas
- High speed mobility - Airplanes, high speed trains
- Broadcast services - Multi-media or SW updates
- Ultra-reliable communications - First responders

Status and Roadmap of NTN in 3GPP

- NTN Study Item (SI) for 3GPP RAN: Approved 03/17
- Satellite Access in 5G SI for 3GPP SA: Approved 09/17
- Objectives of the Study Items include:
  - Identify use cases for NTN integrated w/ 5G
  - Requirements of new services
  - Channel model: Feasibility of adapting 3GPP models for NTN
  - Identify key impact areas on 5G standardization

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Summary

Wireless industry off and running on 5G standardization and trials

Preliminary deployments likely to be announced in 2018

Serious commercialization expected in ~2019-2020 timeframe

Full scale deployments expected in ~2022+

Diverse use cases present new challenges and opportunities to technology companies and mobile operators

5G has potential to unlock new revenue models for incumbents and a rich set of opportunities for new entrants

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Thank You!



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