



# Proliferation of IoT & Advent of 5G: Impact on QoS & QoE for virtualized networks

ITU Workshop on Telecommunications Service Quality hosted by Turk Telekom in Istanbul

Rob Roy, EVP & GM TEOCO

# Outline



The IoT Revolution



Emerging 5G Technology



New Disruptive Applications



QoS & QoE Requirements in 5G

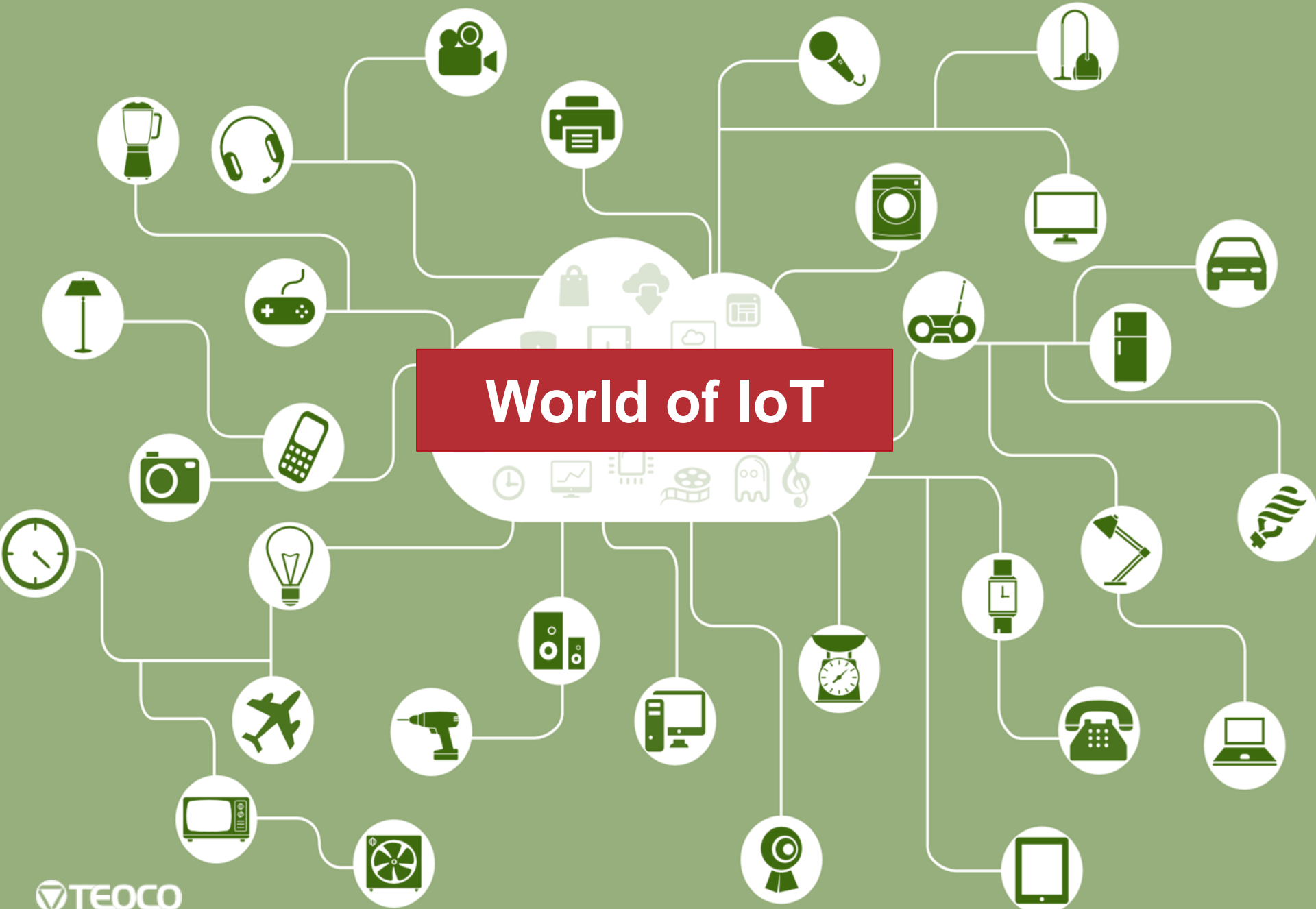


IoT: QoS & QoE Angle



Summary

# World of IoT

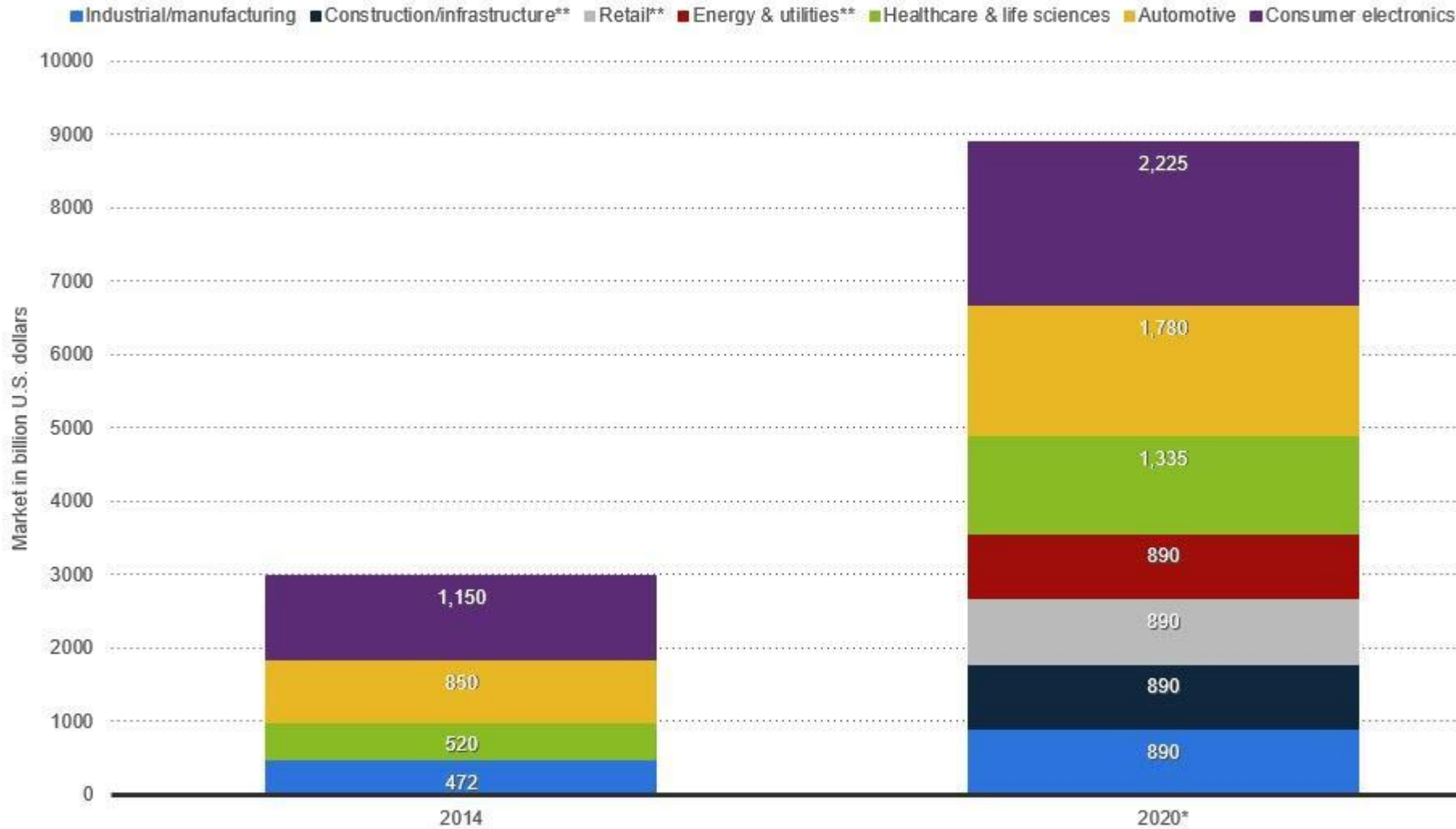


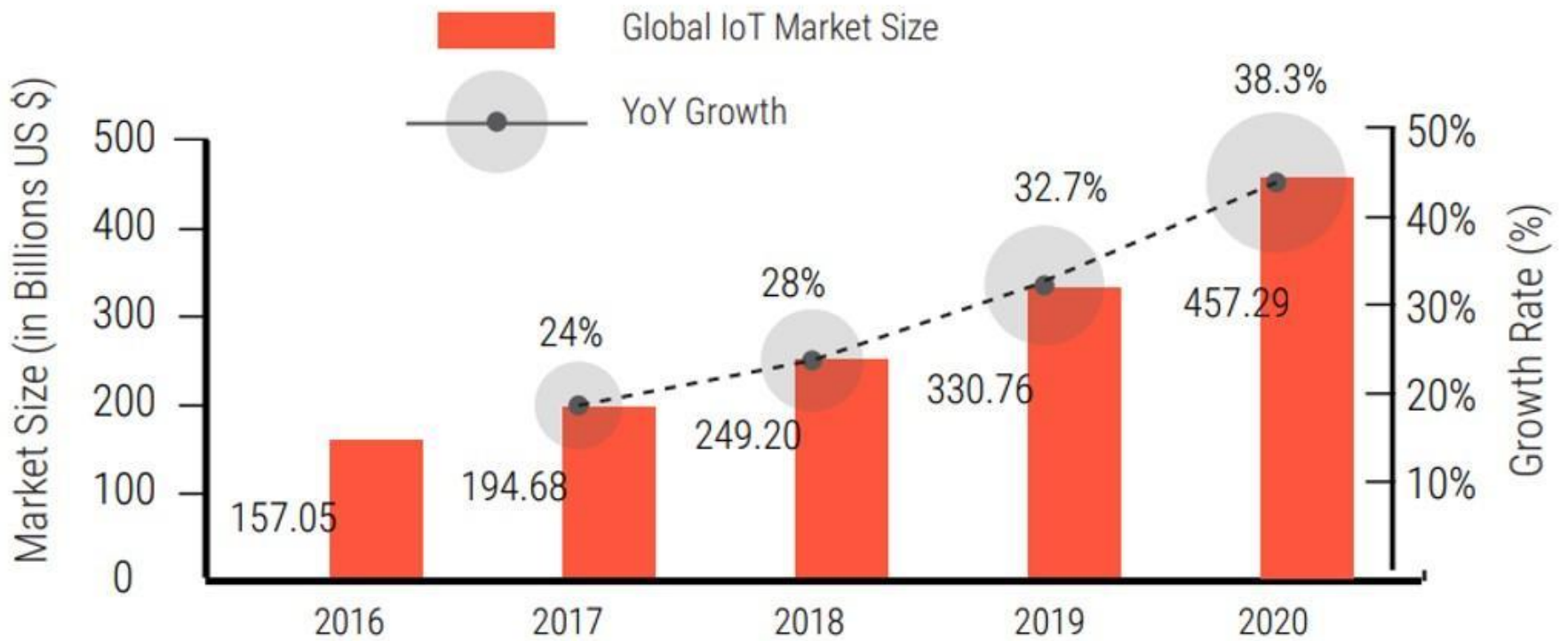
# Mindboggling Numbers (Billions!!!)

Source	2015	2020	2025
IHS	15.4	30.7	75.4
Gartner	8.4	20.4	62.8

- Forbes: \$157B in 2016 -> \$457B in 2020
  - CAGR 28.5%
- Bain: \$300B in 2020, incl \$85B Industrial sector
- BCG: \$267B by 2020

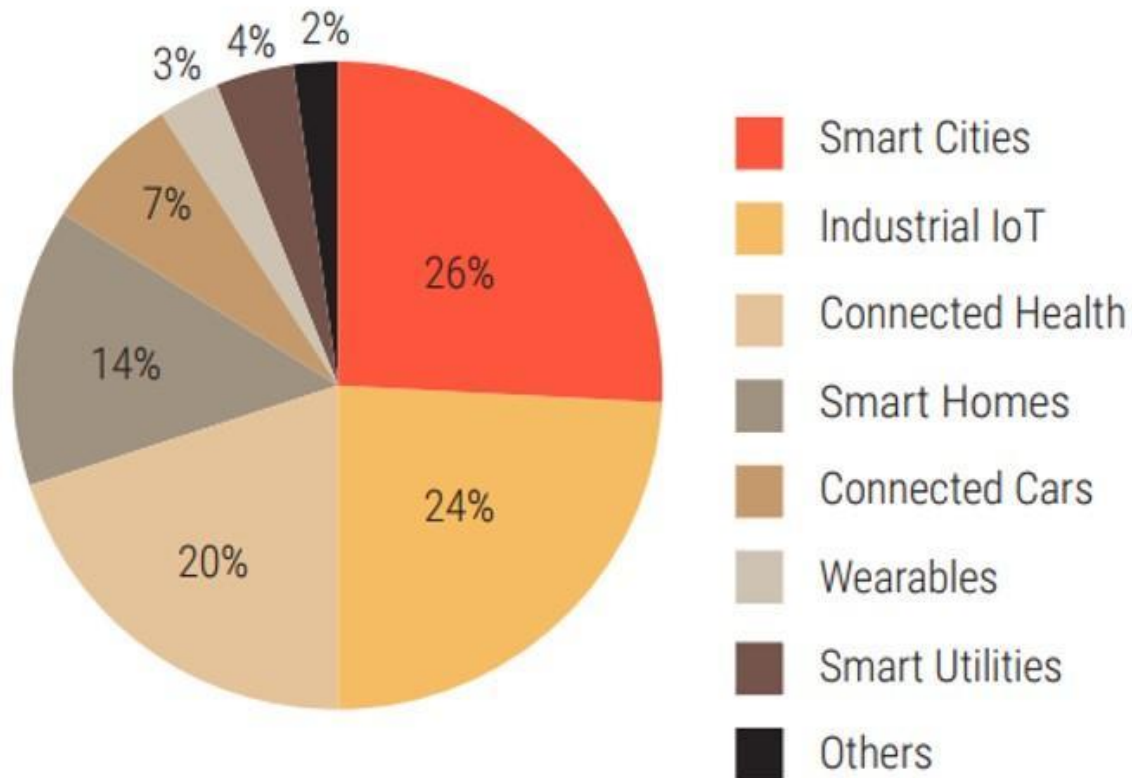
# Size of the Internet of Things market worldwide in 2014 and 2020, by industry (in billion U.S. dollars)





[Sources: GrowthEnabler Analysis/MarketsandMarkets]

## Global IoT Market Share by Sub-Sector



[Source: GrowthEnabler Analysis]

# Tracking and Monitoring Connected Assets

## Global asset monitoring

Cars being shipped globally

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## IoT connectivity

Local SIM configuration

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## Monitoring KPIs

Connectivity & Performance

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## Global and centralized

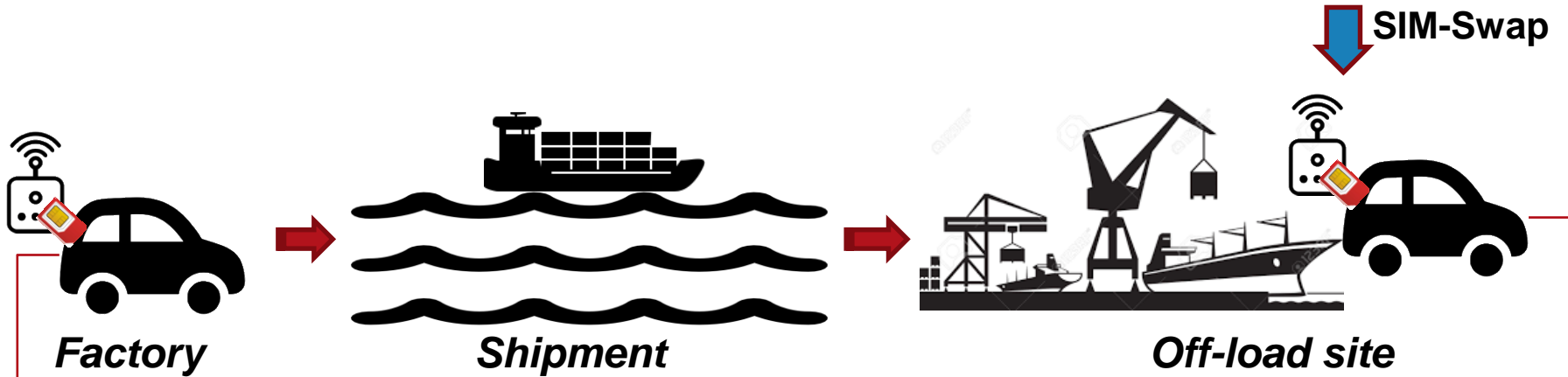
Visibility, Analytics, Alarms,  
Reporting



Global IoT tracking & monitoring solution



# Assurance Issues in a Nutshell



## #1 Critical-Site

- Network quality
- SIM swap efficiency

#3

## Pre-Deployment

- SIM swap
- Interoperability

#2

## Post Deployment SOC

- Monitoring
- Alerts & reports

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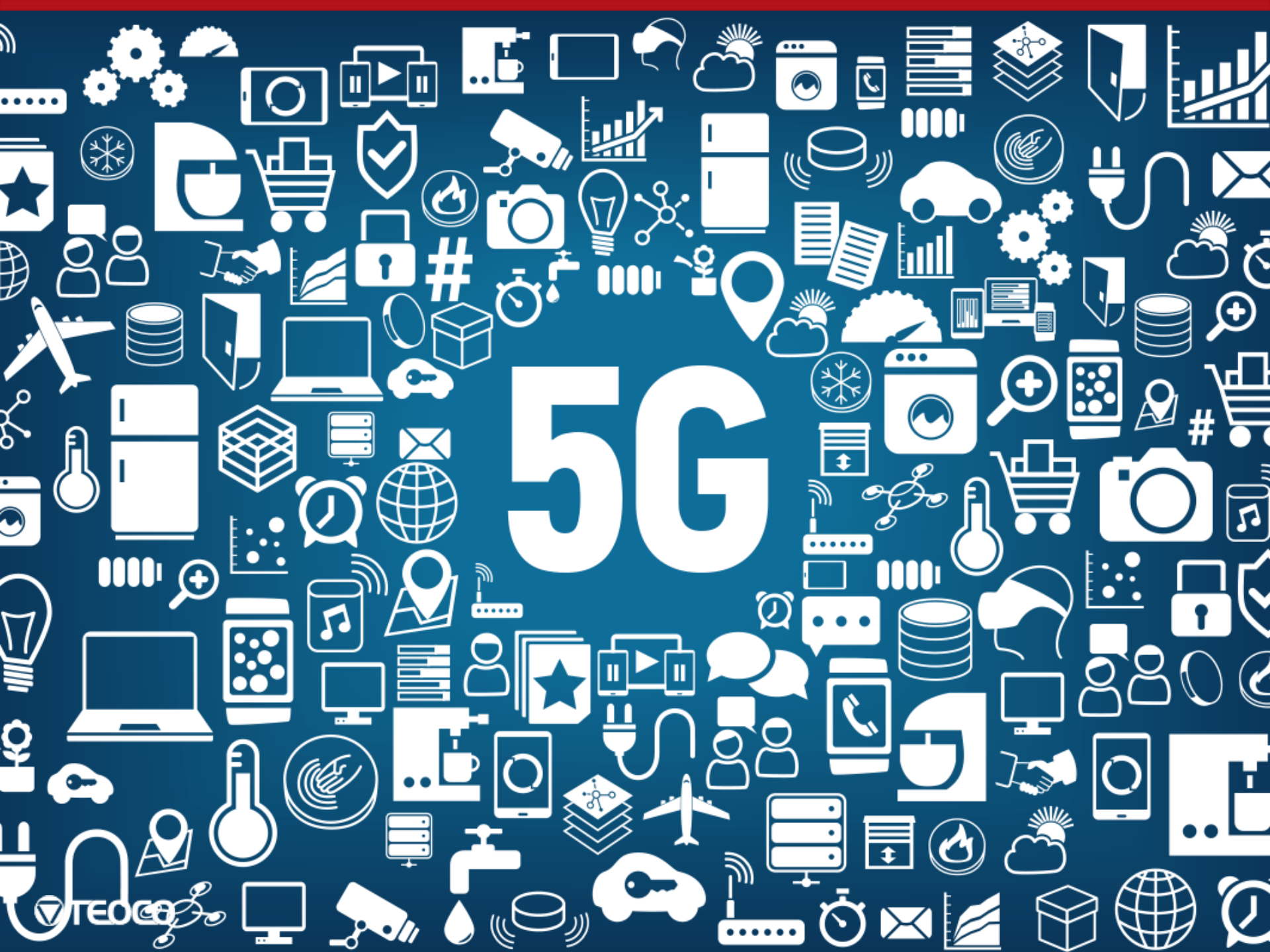


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5G

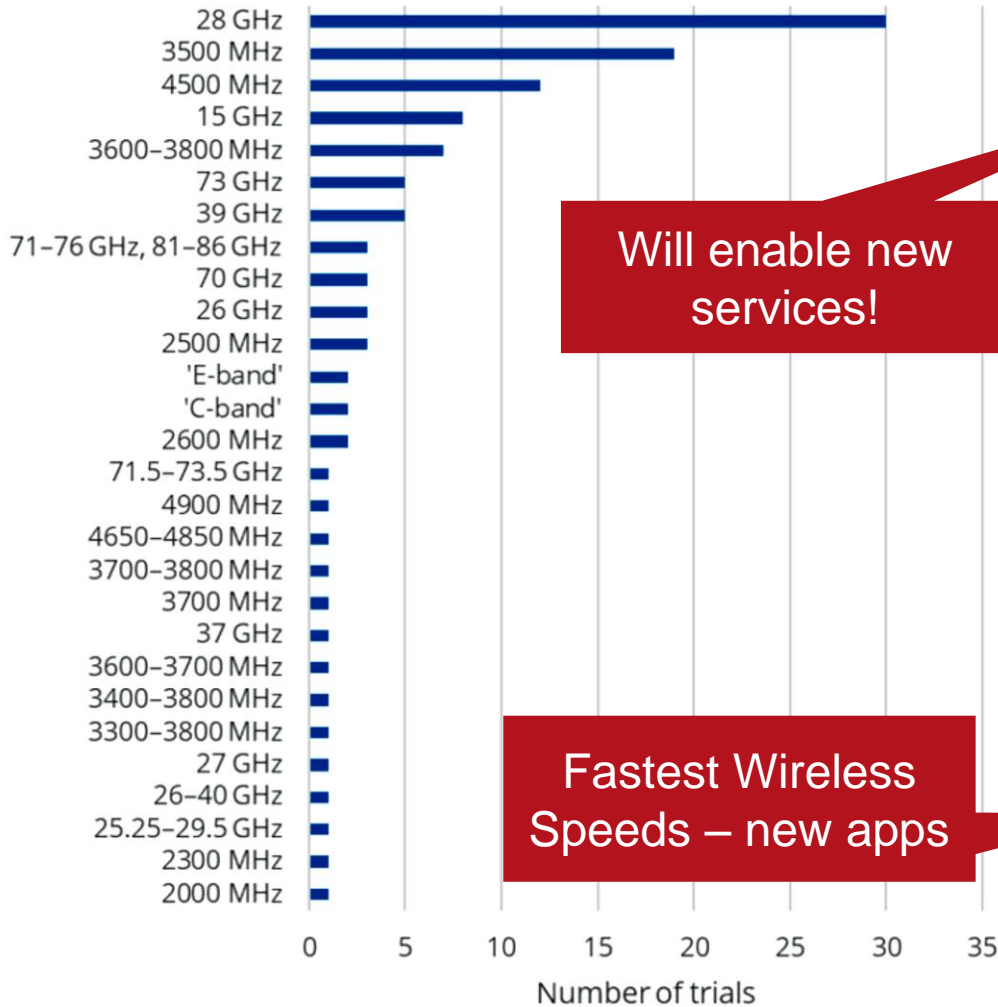


# 5G Deployment Status (Apr 2018)

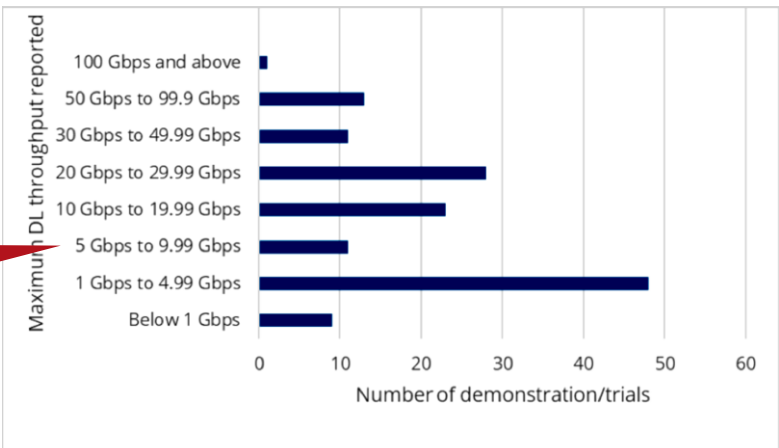
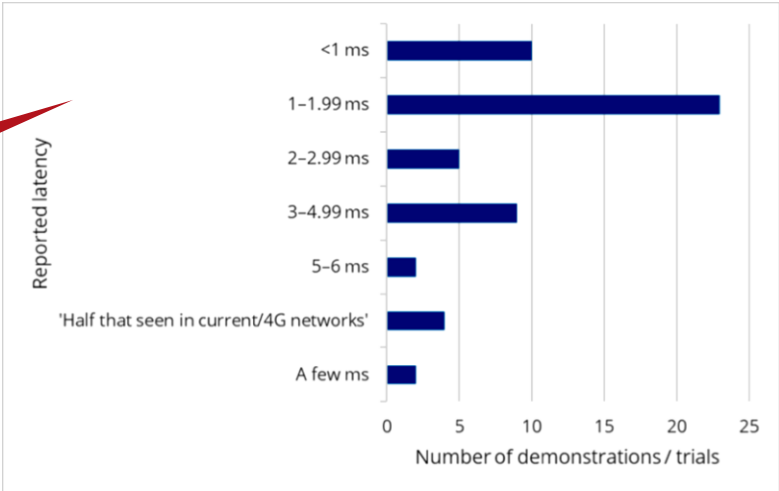


- 134 operators in 62 countries investing in 5G projects

# 5G Deployment/Trial Status (Apr 2018)



**Fastest Wireless Speeds – new apps**



# Killer Apps in 3G & 4G

**Killer Apps**

**3G**

  
Email

  
Music download

  
Maps & Navigation

  
Smartphones are indispensable

**Killer Apps**

**4G**

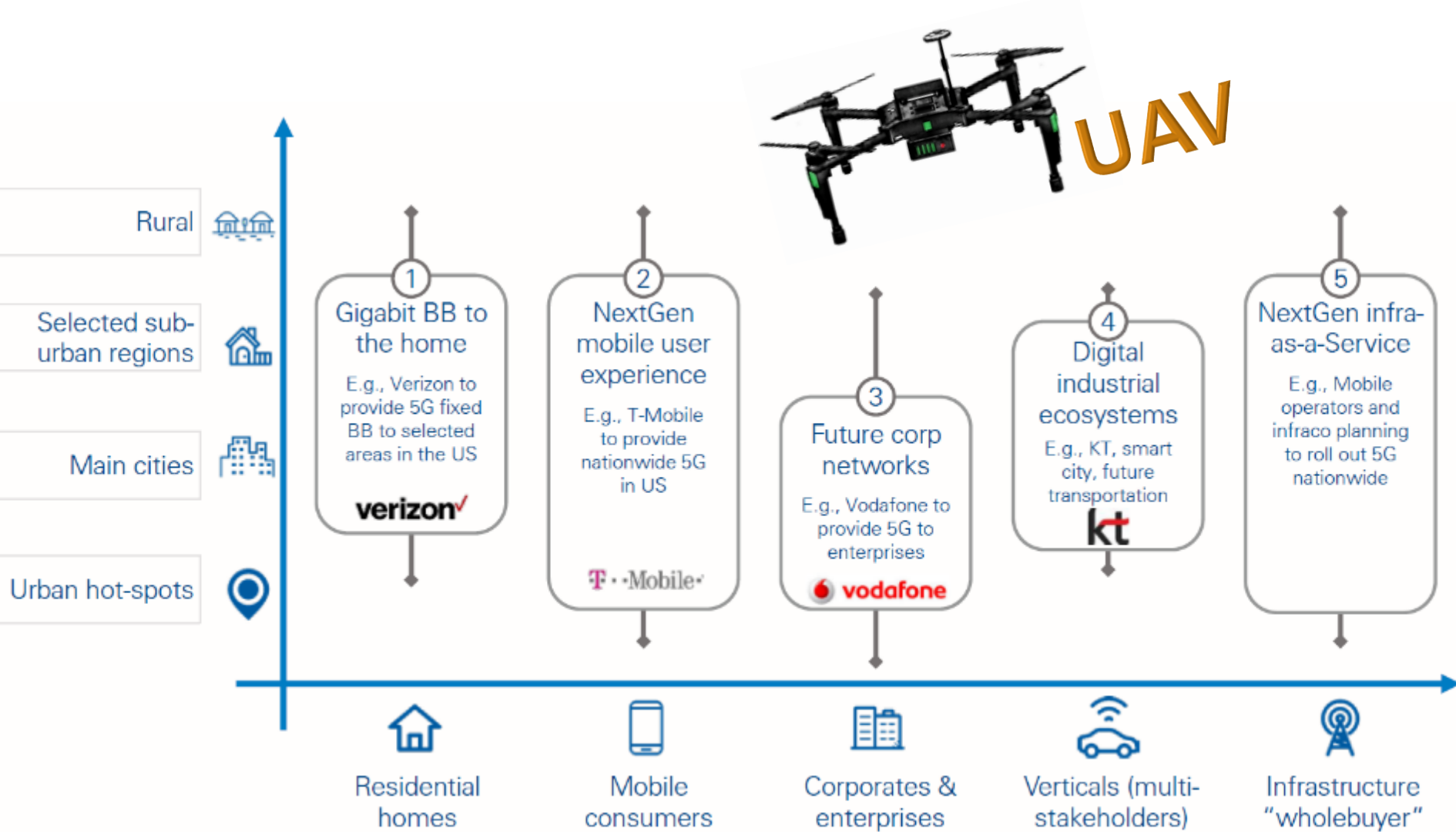
  
WhatsApp

  
FaceTime

  
Streaming Videos

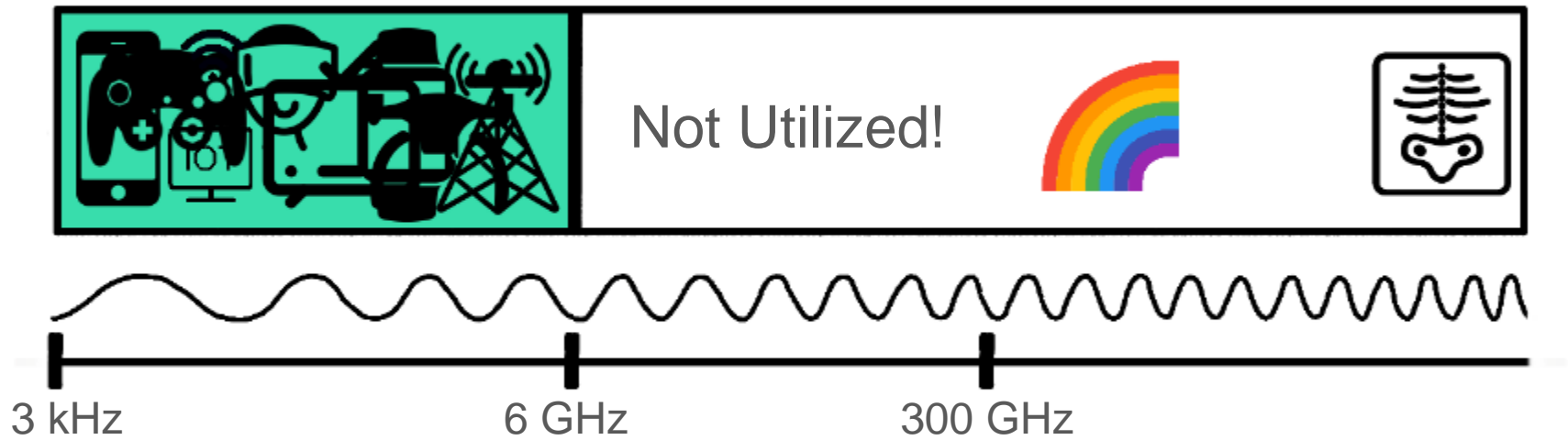
  
Facebook Videos

# 5G: Announced Business Cases



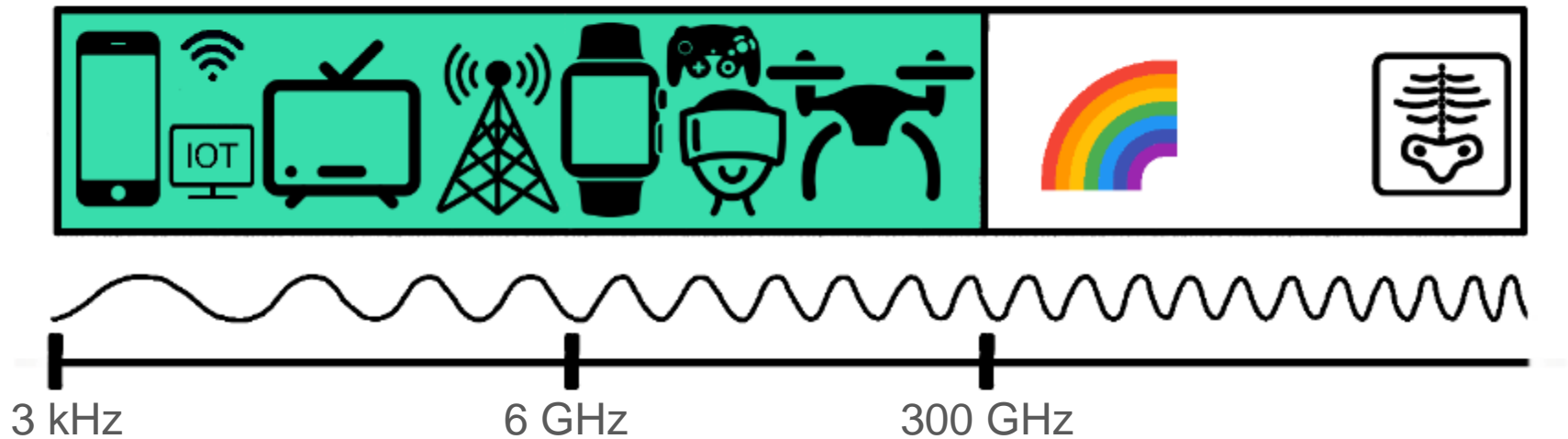
Source: ADL, Aug 2017

# Expand to Millimeter Waves (> 6 GHz)





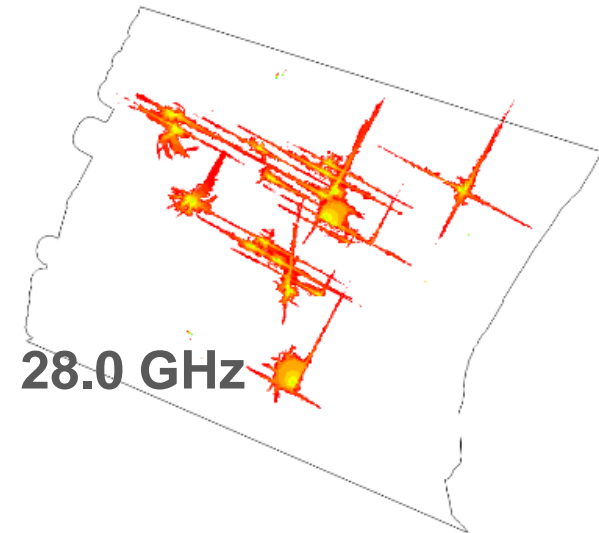
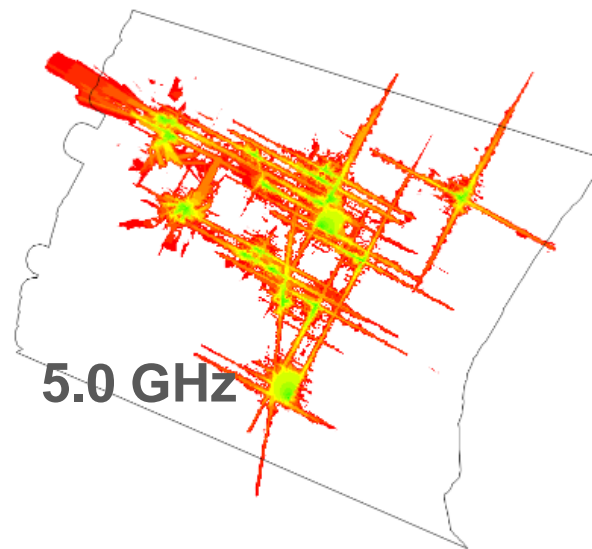
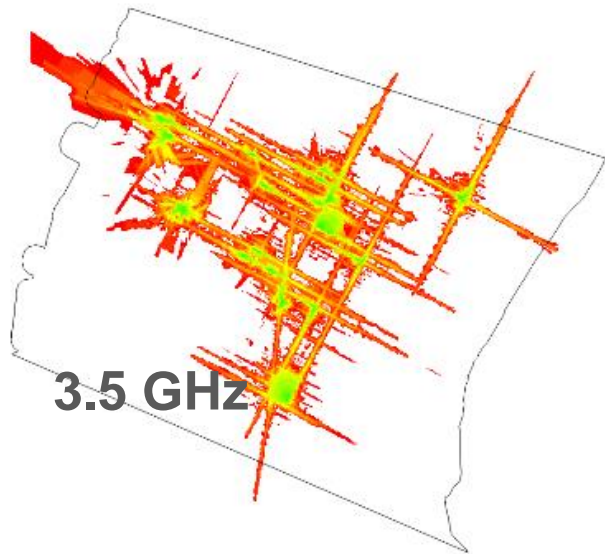
# Expand to Millimeter Waves (> 6 GHz)



**New bands: 28 GHz, 39 GHz, 60 GHz, 73 GHz ...**

# 5G Multi-band Analysis (I)

- ASSET supports all FDD and TDD bands from 600MHz to 40 GHz
- Propagation model support – using ray tracing models:



# 5G Multi-band Analysis (II)

- ASSET supports standard 3GPP 5G NR frequency band and ARFCN definitions (ref. 3GPP TS 38.101-2 V15.0.0 (2017-12)):

NR operating band	UL operating band	DL operating band	Duplex mode	Range of NR-ARFCN
n257	26500-29500 MHz	26500-29500 MHz	TDD	2054167 – 2104166
n258	24250-27500 MHz	24250-27500 MHz	TDD	2016667 – 2070833
n260	37000-40000 MHz	37000-40000 MHz	TDD	2229167 – 2279166

The screenshot shows the ASSET software interface. At the top, there is a list of 5G NR bands: 5G NR n257, 5G NR n258, and 5G NR n260. Below the list are buttons for Add, Remove, Modify, Commit, Restore, and History. The main area is divided into Downlink and Uplink settings. Each section has a table of E-ARFCN and Frequency (MHz) values. The Uplink table shows E-ARFCN values from 2054167 to 2054173 and corresponding frequencies from 26500.0 to 26500.4 MHz.

The screenshot shows the Frequency Band Editor dialog box. It has a title bar with a close button (X). The dialog is divided into sections for Downlink and Uplink. The Frequency Band Name is set to "5G NR n260". The Duplex Mode is set to TDD (radio button selected). The Downlink section has Frequency Coefficients (Start Frequency: 37000.000000 MHz, Channel Raster: 0.060000 MHz) and E-ARFCN Range (Min: 2229167, Max: 2279166). The Uplink section has the same Frequency Coefficients and E-ARFCN Range. At the bottom, there are OK and Cancel buttons.

# 5G Multi-band Analysis (III)

- ASSET supports 5G NR ASSET carrier configurations; e.g.:
  - 200 MHz carrier bandwidth
  - n260 NR operating band (37 – 40 GHz band)
  - 5G 60kHz sub-carrier spacing
  - 264 maximum transmission bandwidth (number of resource blocks)

The screenshot shows the 'LTE Carriers' configuration window. On the left, a list contains '5G carrier A' with a checked checkbox. The main configuration area is for '5G carrier A'. The Duplex Mode is set to TDD. The Frequency Band is '5G NR n260', # Resource Blocks is '264', FFT Size is '2048', Frame Structure is '5G 60kHz SCS', Sampling Factor is '0.6', Bandwidth (MHz) is '200', and Licensing Status is 'Licensed'. Below this, there are tabs for 'Frequency\E-ARFCN', 'Overhead', 'ICIC Schemes', 'eMBMS', and 'History'. The 'Frequency\E-ARFCN' tab is active, showing 'Downlink Parameters' and 'Uplink Parameters'. Both sections have 'Low' and 'High' frequency fields (39799.960 and 39999.940 MHz) and 'E-ARFCN' fields (2275833 and 2279166). The 'Attenuation (dB)' is set to 33.00. At the bottom, there are buttons for 'Apply', 'Commit', 'Restore', and 'Close', and a checkbox for 'Hide Inactive Carriers'.

# 5G Dynamic Frame Structures

- ASSET will model dynamic FDD and TDD frame structures
  - TDD reconfiguration up to 1ms
  - Reconfiguration affects ratio of DL to UL sub-frames

Outdoor and  
macro coverage  
FDD/TDD <3 GHz



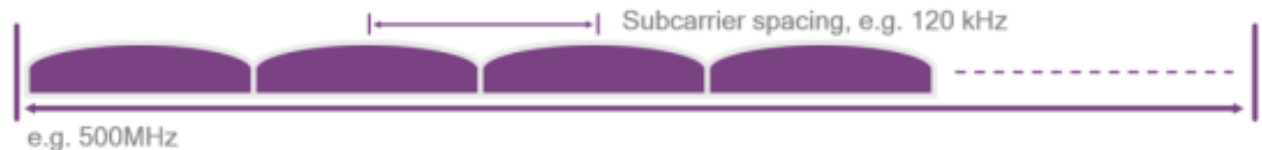
Outdoor and  
small cell  
TDD > 3 GHz



Indoor  
wideband  
TDD e.g. 5 GHz (Unlicensed)

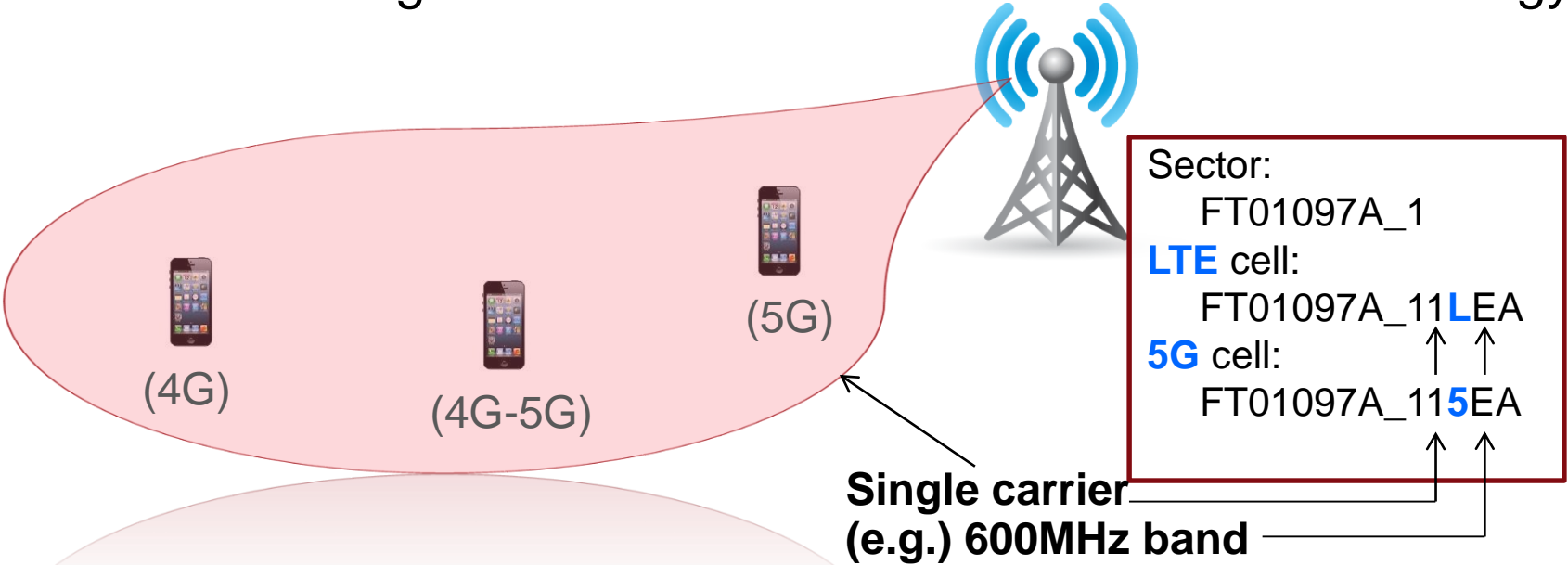


mmWave  
TDD e.g. 28 GHz



# 5G Spectrum Sharing: Carrier Setup

- For LTE-5G spectrum sharing use cases, LTE and 5G carriers would be same “entity” = common ASSET carrier object
- Common LTE-5G carrier to be allocated to both LTE and/or 5G cells
- In ASSET, existing LTE carrier definition will be extended to include 5G attributes.
- Cells remain single-carrier but the carrier is now multi-technology.



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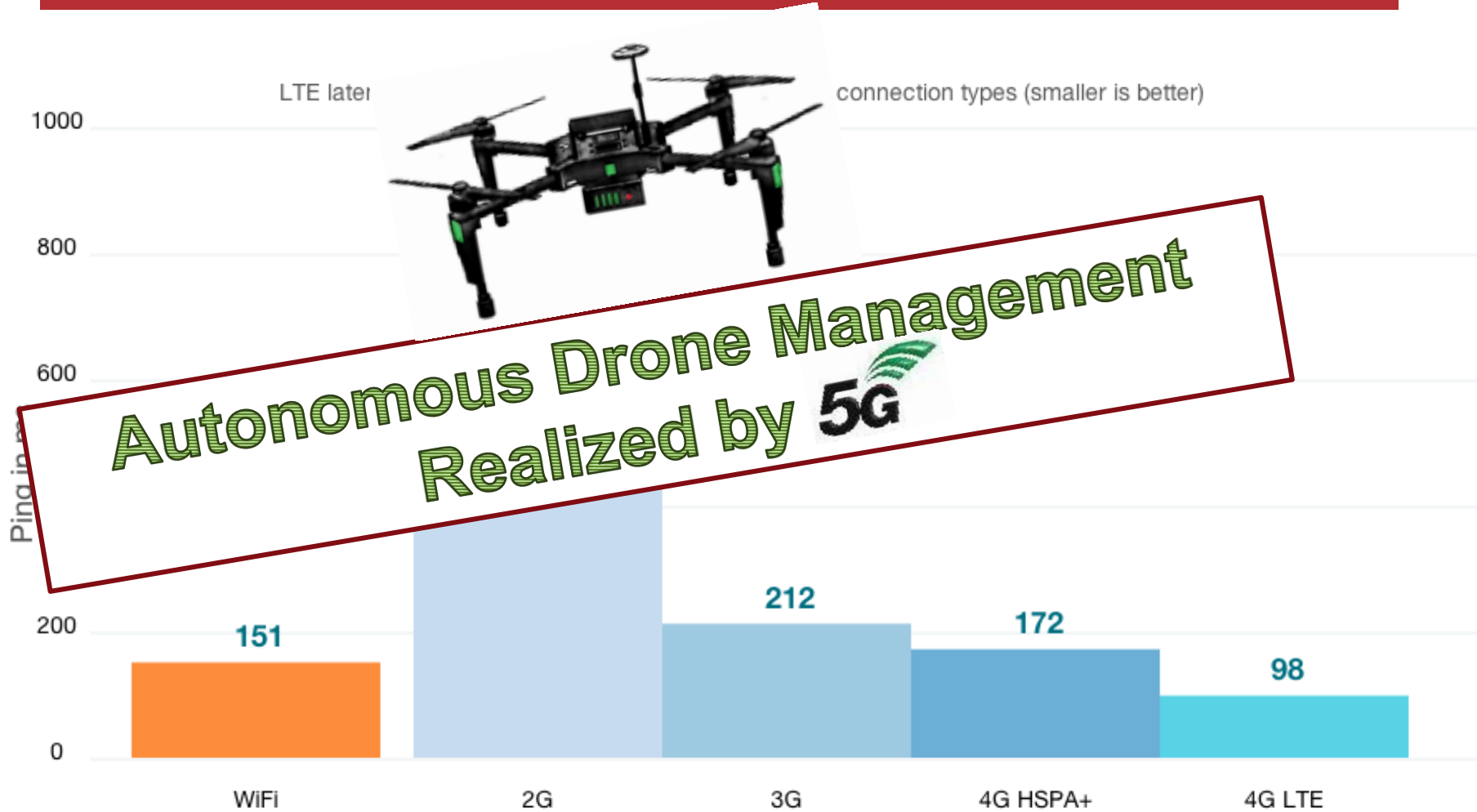
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Summary

# Autonomous Drones: Latency is Critical

5G Latency is going to be ~10 mSec -> ~1 mSec





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Summary

# QoS for IoT

- QoE not applicable due to M2M
- QoS requirements vary widely
  - Fire prevention: high SLA, low latency
  - Field quality sensors: medium SLA, latency not critical
  - Earthquake monitors: high
- Wildly diverse QoS requirements
- Network Slicing
- Dynamic QoS management

# Summary

- IoT revolution has incredible rate of growth
- 5G evolution will be offered commercially in 2018
- Many 5G applications: strong QoS & QoE need
- IoT has diversity in the type of devices
  - Different QoS requirements
- Diversity of QoS, type of devices, and higher bands
  - More careful network design with end goal in mind