



# 5G and the Path to 5G

Oct 19, 2016

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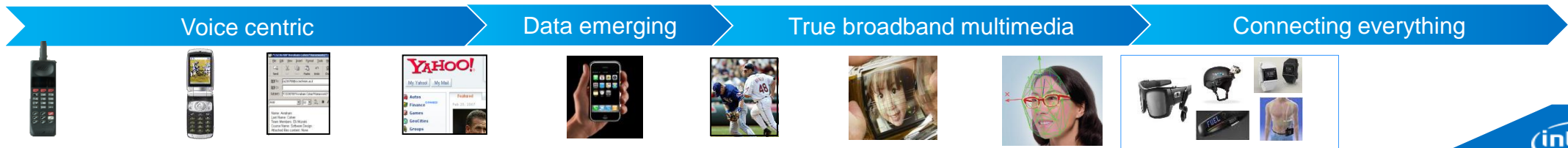
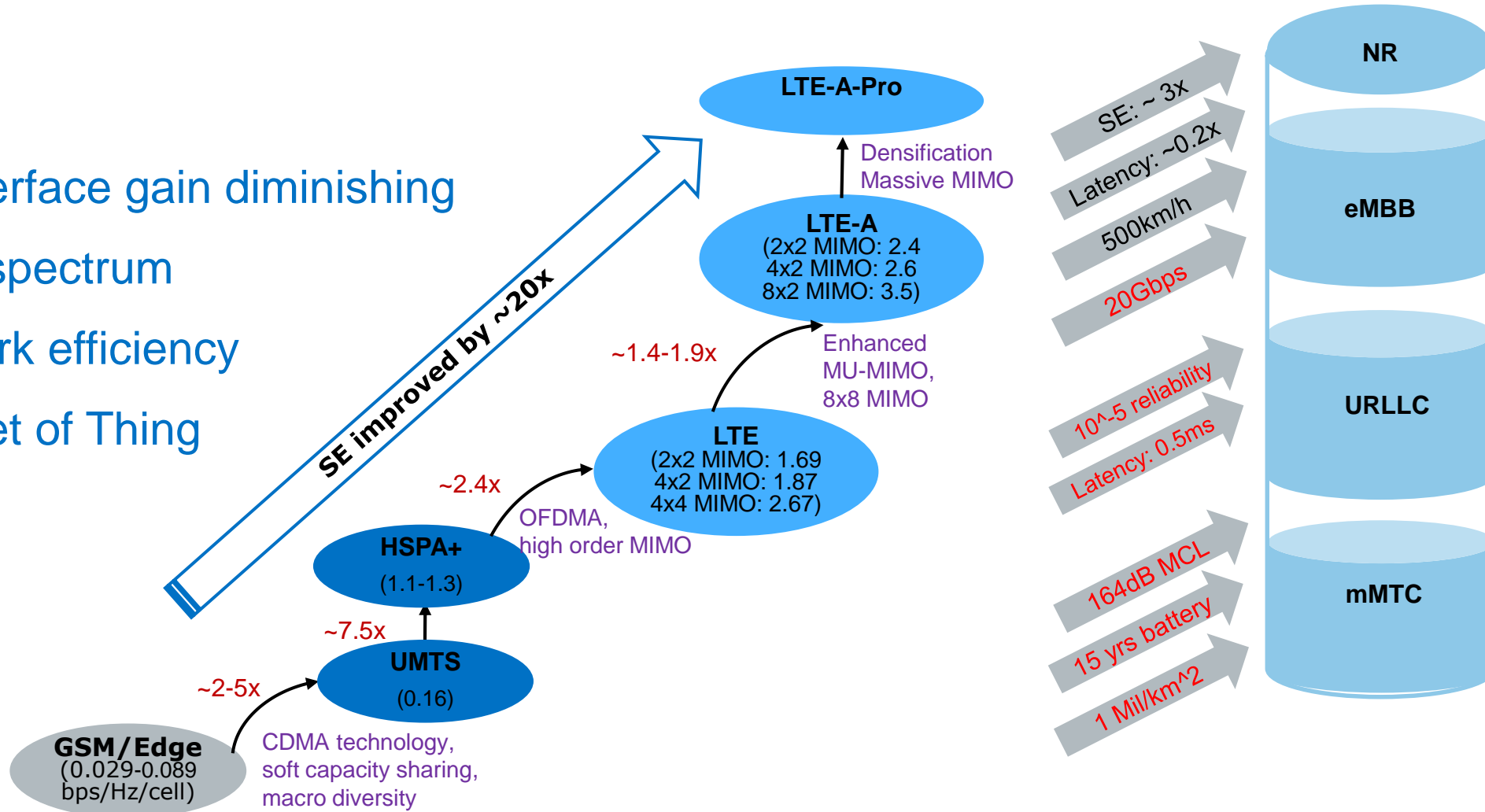
Intel Corporation



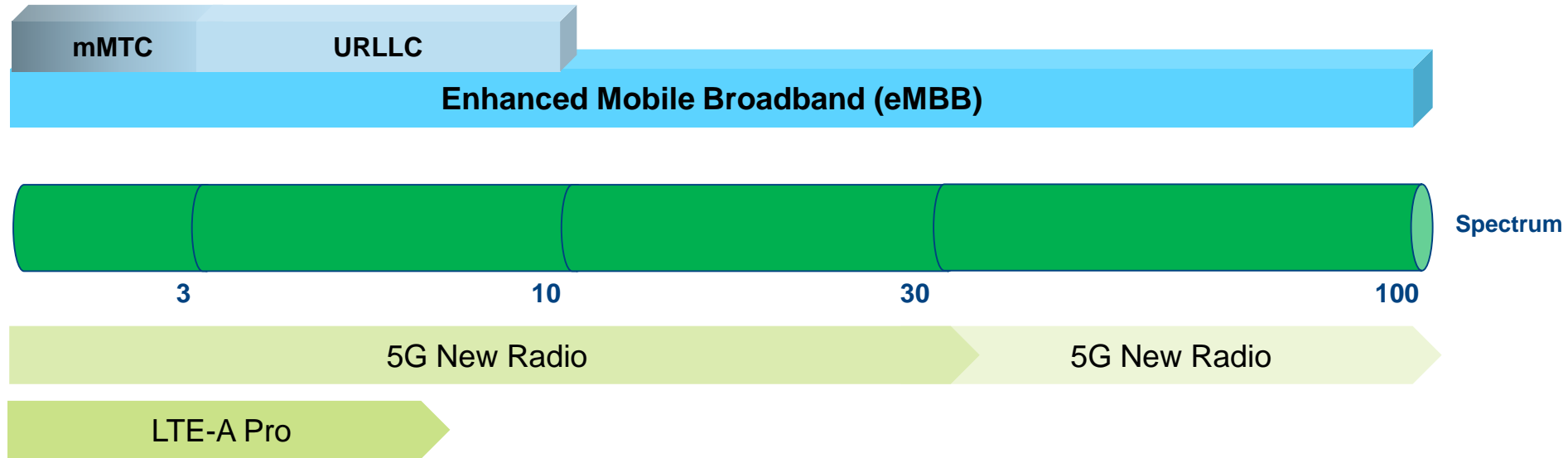
5G

# 5G Era

Air interface gain diminishing  
 More spectrum  
 Network efficiency  
 Internet of Thing



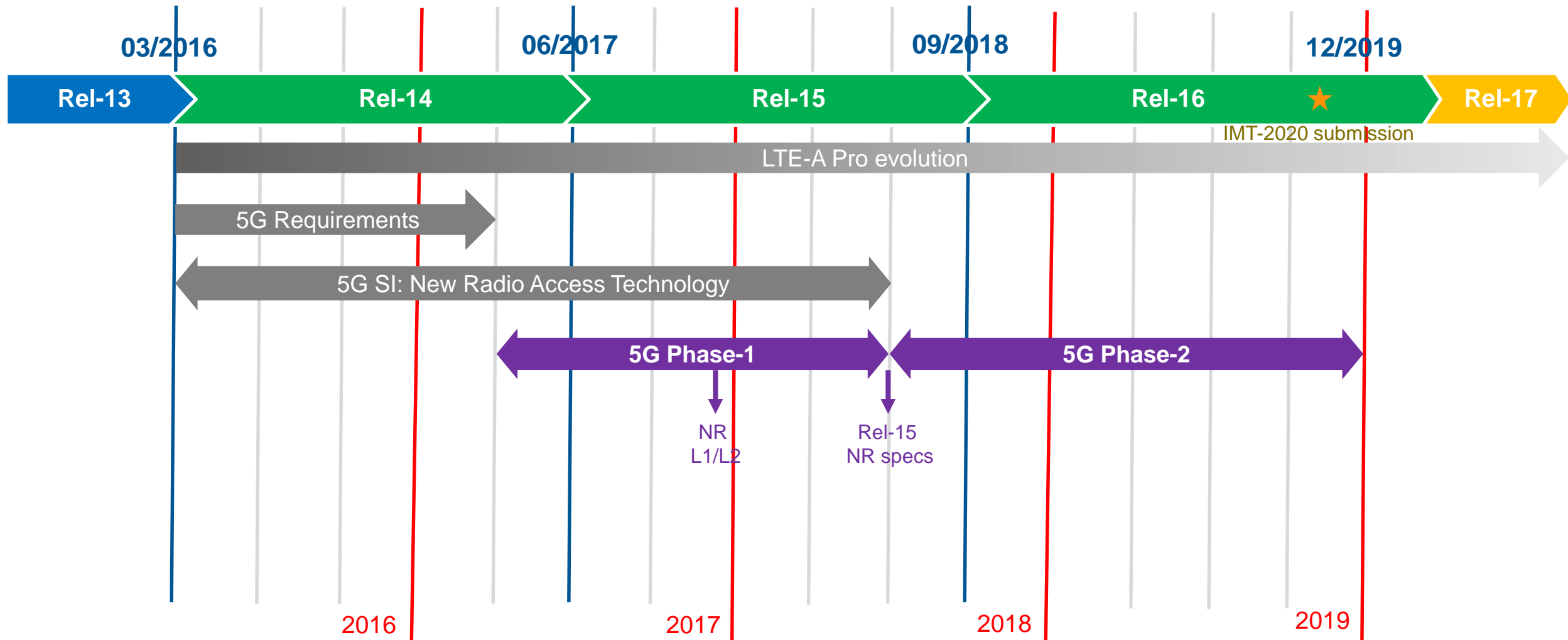
# Services and Spectrum in 5G Era



Sub-6GHz to 100GHz with scalable bandwidth

Multi-band and multi-mode support

# 3GPP 5G New Radio (NR) schedule



# 3GPP 5G NR Phased-approach

## 3GPP Release 14/15

### 5G Phase 1

- Common design covering Sub-6GHz to ~40GHz
- Support eMBB with forward computability to address mMTC and URLLC
  - Delivering Peak Rates of 20Gbps+
- LTE-assisted and standalone operations
- New 5G Core Network (NextGen)

## 3GPP Release 16

### 5G Phase 2

- Extend up to 100GHz Spectrum
- Potential new waveforms for mMTC and >40GHz spectrum
- Full support of IMT-2020 and 3GPP NR requirements

# 5G NR Phase 1: Key Technology Areas

## Advanced PHY design:

- Low latency and self-contained subframe design;
- Multiple numerologies for different use cases with efficient in-band multiplexing design;
- Common design across various link directions, UL, DL, sidelink, backhaul, etc;
- Enhanced channel coding and MIMO/beamforming technologies;

## Advance L2/3 protocol design:

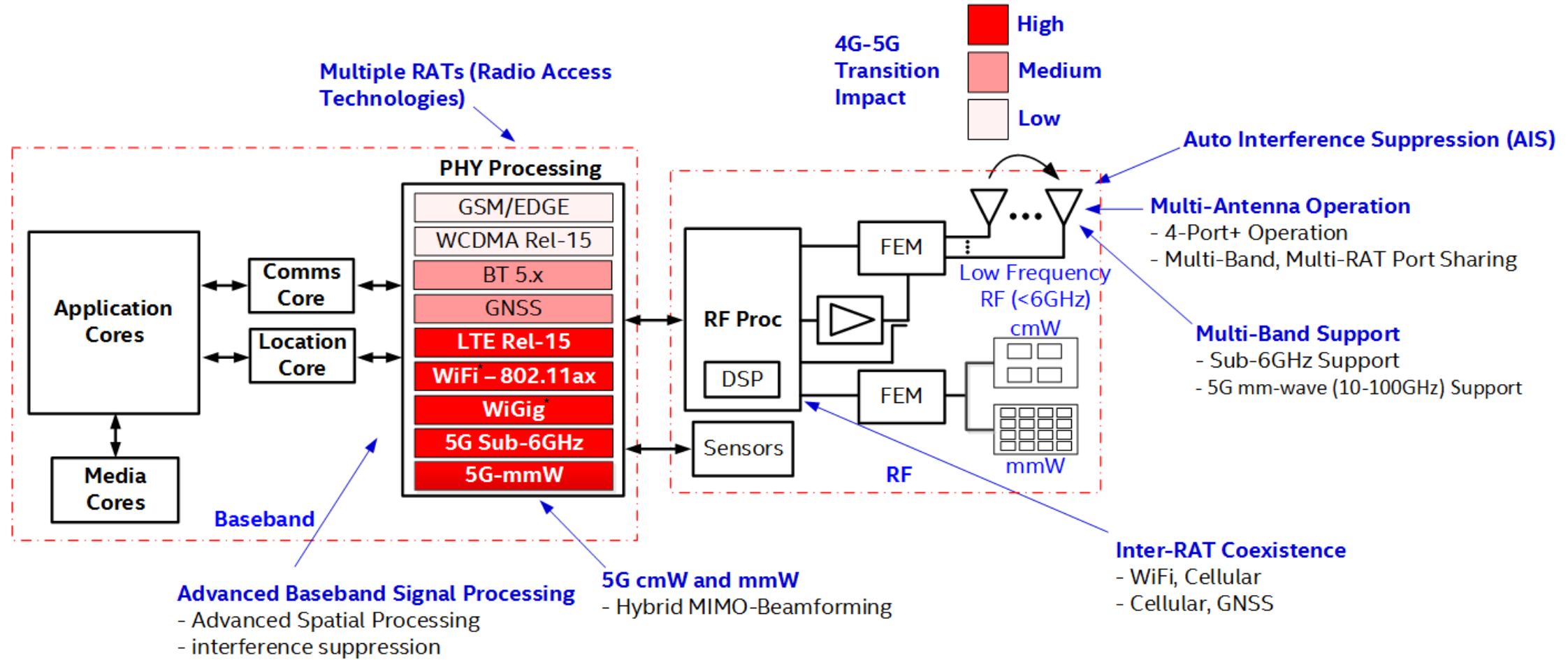
- High data rate friendly UP protocol;
- Standalone NR operation;
- LTE-NR tight interworking yet allowing the independent evolution of LTE and NR;
- Power-efficient and signaling efficient mobility handling, as well as optimized intra-5G and inter-RAT mobility;
- Flexible QoS handling;

# The Path to 5G



# 5G Device Implementation

## Baseband and Stack Technology



# Technical Viability – Silicon Performance

Manufacturing

**14 nm**

Development

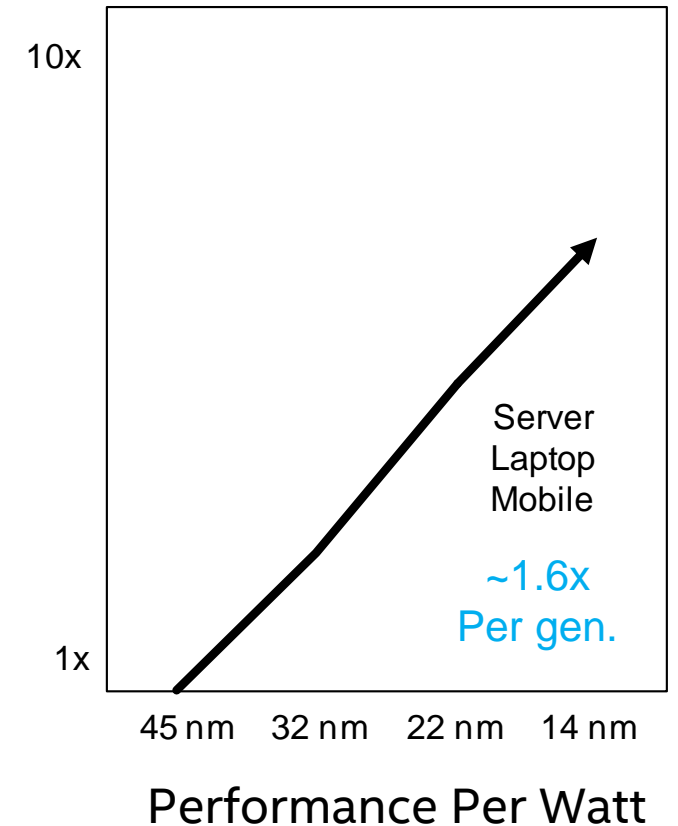
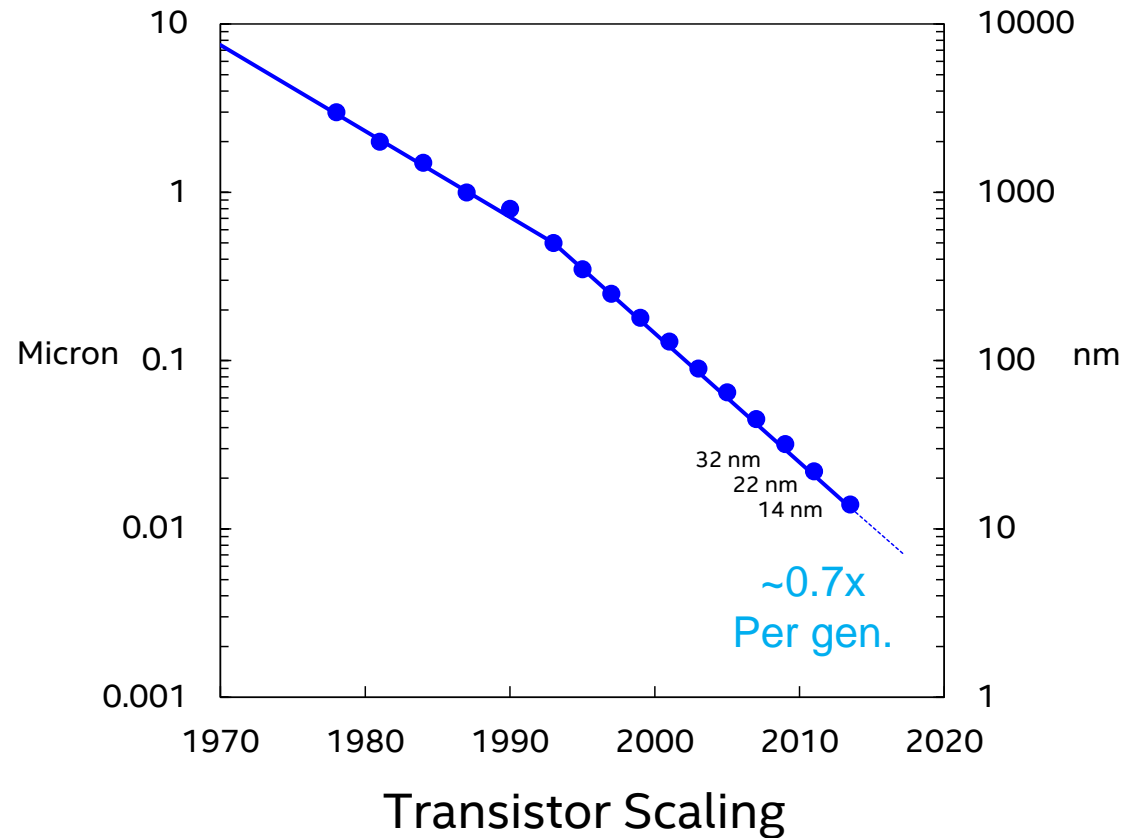
**10 nm**

Research

**7 nm**

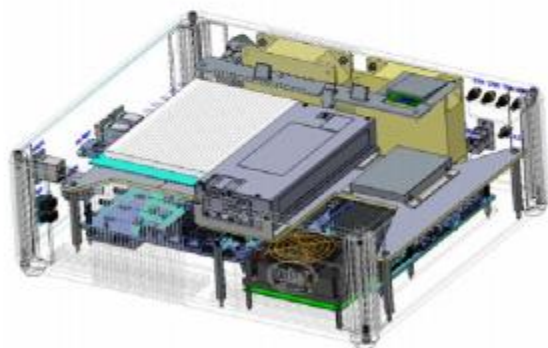
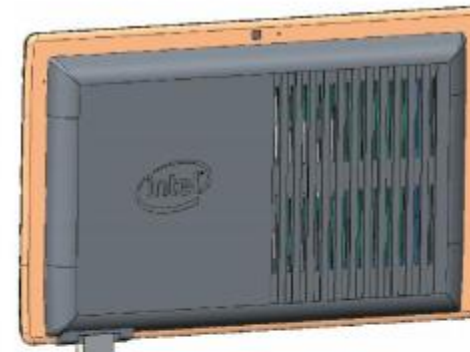
Process Node

Maturity



Advances in Process Technology Point to 5G Era Performance

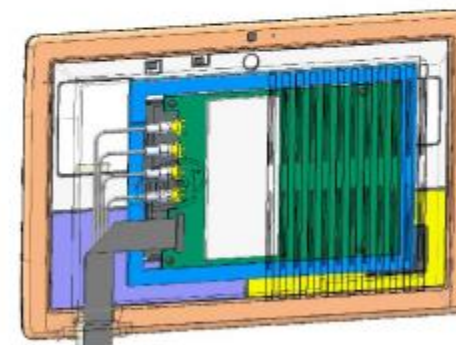
# Intel 5G Mobile Trial Platform (5G-MTP)



5G Modem Chassis  
2<sup>nd</sup> Generation



Skylake Mounted in 5G  
Modem Chassis



28GHz and 4GHz Antennas  
Mounted on Rear of Skylake

# 5G-MTP Phase1.0 Baseband

Altera Arria 10 FPGA (5x)

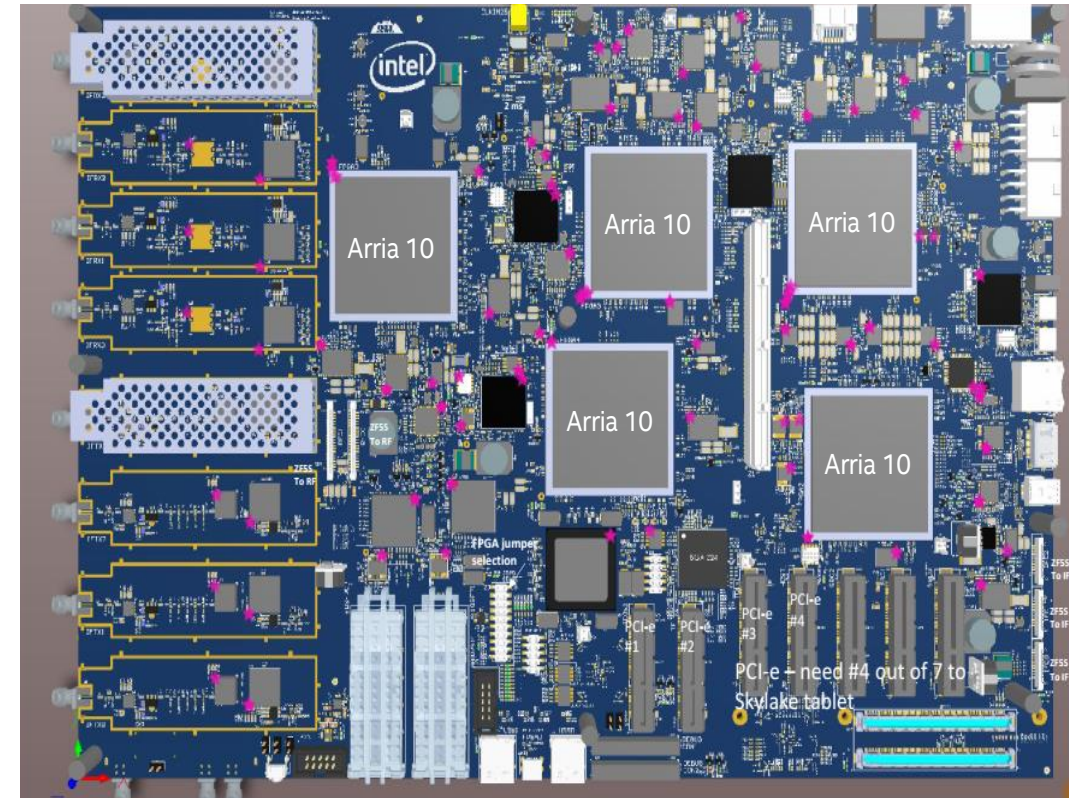
800MHz RF bandwidth

Sub-6GHz and mmW Support

- 3.4-5.9GHz
- 26.5-29.5GHz

Compliant to 5GTF V5G specs & Track 3GPP NR

- Low latency self-contained subframe structure
- Advanced channel coding
- Advanced beamforming
- Support LTE-assisted and standalone operations



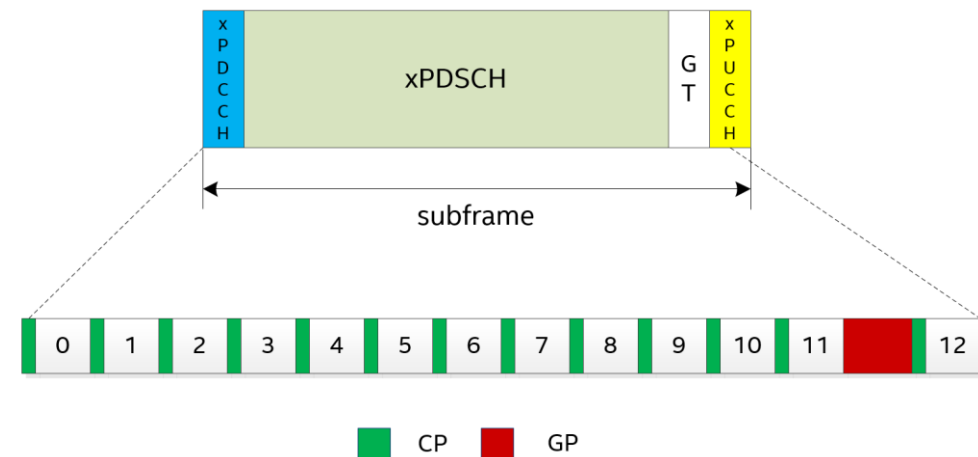
# Baseband Features

Parameter	Value
Carrier Bandwidth	100MHz
Waveform	OFDM
Sampling Rate	153.6MHz
Subcarrier Spacing	75kHz
Symbol Duration	13.3us
OFDM Symbols per TTI	14
CP Length	0.94/1.04us
TTI Length	0.2ms
Radio Frame Duration	10ms

## Numerology Example

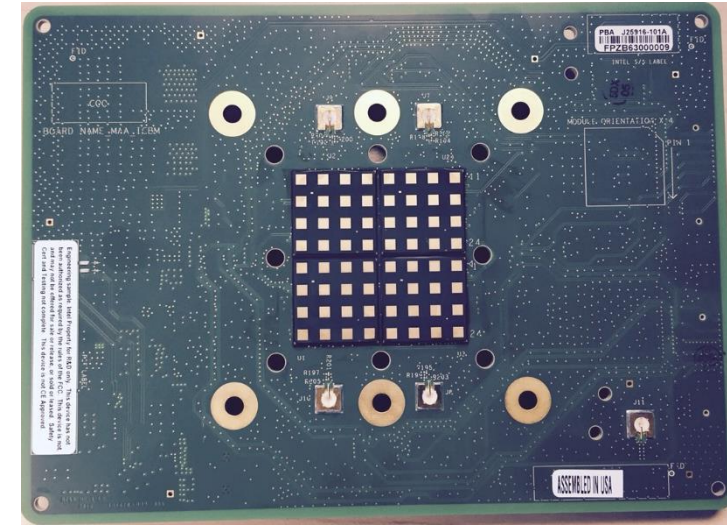
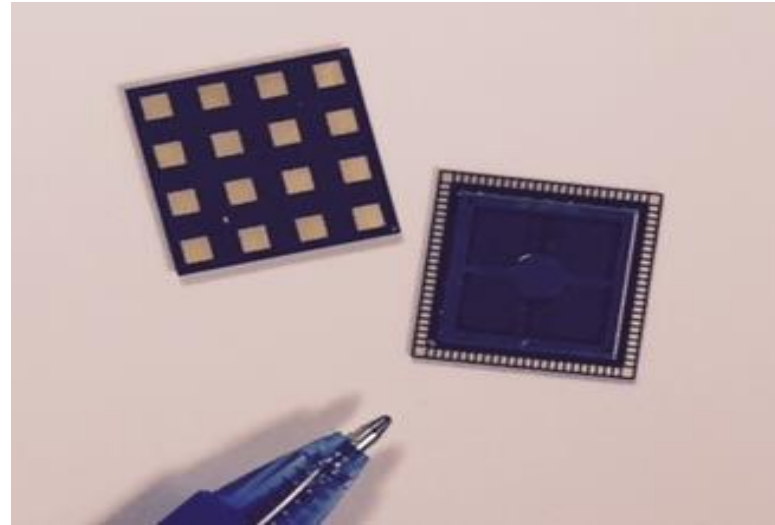
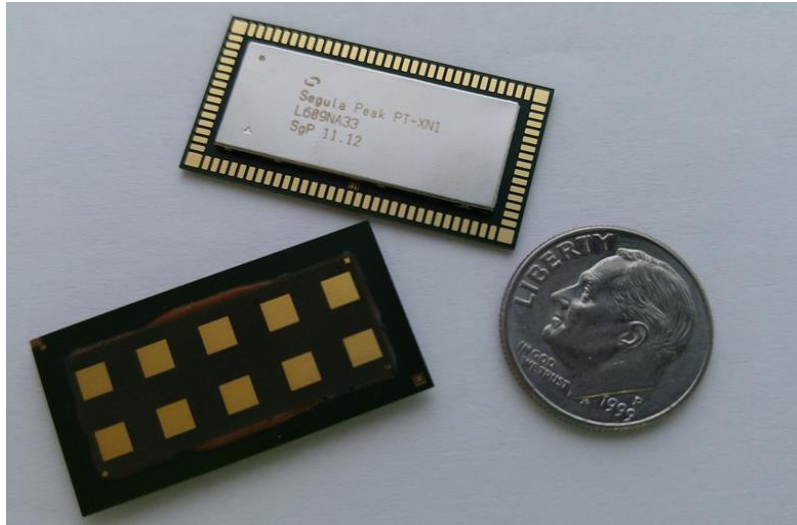
Parameter	Value
Peak Rate (DL) – UE	3~10Gbps
BS-UE Delay RTT	2ms

## Primary Performance



## Frame Structure

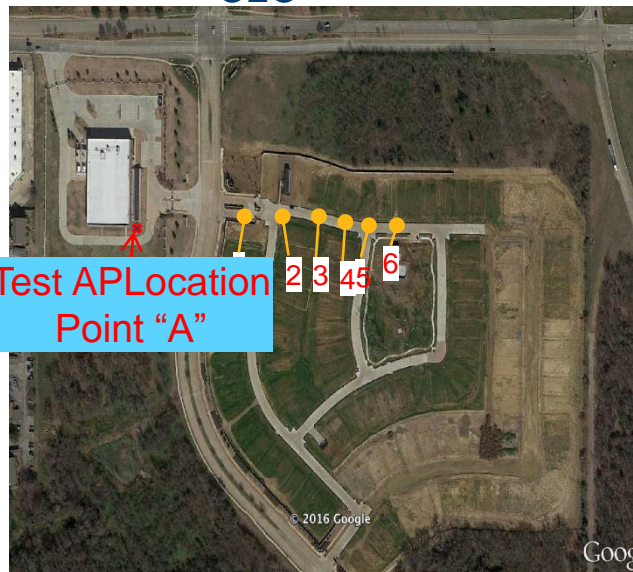
# 5G 28GHz RFIC



mmWave RF IC Feature	Details
RF Bands	26.5 – 29.5 GHz
Max Number of Tx/Rx	8/8 (4x2 ant array) 16/16 (4x4 ant array) 64/64 (8x8 ant array)
RF BW	up to 800MHz
Polarization	H & V

# Field Trial At a Glance

O20



Material Obstruction

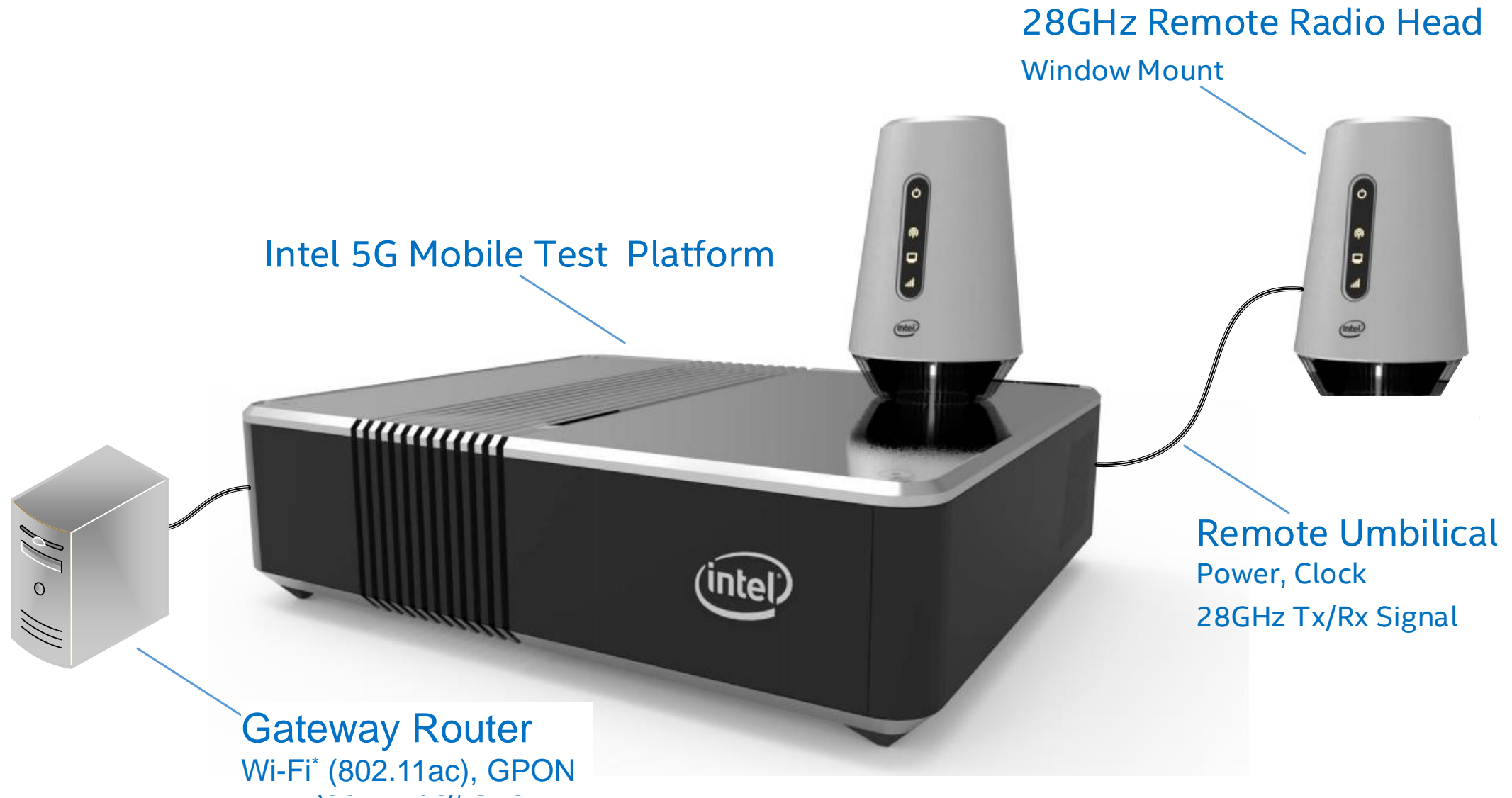


O21



Beam angle

# 28GHz 5G-MTP: CPE Variant





# Summary and Outlook

5G Era – Forward compatible unified system design to support all services in 5G era

Frequency Bands – Both sub-6Hz and mm-wave bands key

Technical Viability – Process node technology placing 5G within reach

Timing – On track for 2017 fixed wireless and 2020 3GPP NR

