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Internet of Things

By 2016...

6.4B connected things¹

By 2019...

$1.3T worldwide spending on the Internet of Things²

By 2020...

20-50B Internet connected devices³

¹ Gartner Group http://www.gartner.com/newsroom/id/3165317
³ Gartner Group http://www.gartner.com/newsroom/id/3165317 & Cisco Virtual Networking Index
Data Demand

Growth from 2014-2019 expected to be 6-10X

5G is expected to provide 1,000 – 10,000x capacity gains

Source: FUTURE MOBILE SPECTRUM REQUIREMENTS, GSMA, 2015
The Next Mobile Era: Computing + Communications

SMART DEVICES

CLOUD AND DATA CENTER

Workloads Will be Shared & Coordinated
Smarter clients. Smarter networks
Smart Packet Processing, Network Offload, Data Analysis
5G End-to-End: Network and Device Transformation

Smart Devices

Radio Access Technology

Network infrastructure

Core Network

Cloud

- Small Cells
- C-RAN (Remote Radio Heads)
- Network Functions Virtualization
- SDN

5G

4G licensed + unlicensed

2G/3G Integrated heterogeneous connections

Cellular + WiFi

Integrated heterogeneous connections

Secure

Operating System

Hypervisor

- Compute
- Block Storage
- Network
Standards
Diverse Set of Competitive 5G Specifications Targeting 2019-2020
3GPP LTE-Advanced Pro (Rel-13+)

LTE-Advanced Pro

- Multi-site MIMO/beamforming
- Light-weight Protocols & Latency Reduction
- LSA, LAA, V2V/V2X Enhancements

5G Rate Contribution

- 80MHz – 40MHz Licensed + 40MHz 5GHz Unlicensed
- 160MHz – 40MHz Licensed + 40MHz 3.5GHz CBRS + 80MHz 5GHz Unlicensed
- Latency Reduction – HARQ and Frame Adjustments to Tackle Enhanced Latency

<table>
<thead>
<tr>
<th>Category</th>
<th>Max. DL Bandwidth (MHz)</th>
<th>Max. DL Rate (Mbps)</th>
<th>Max. UL Rate (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>60</td>
<td>450</td>
<td>100</td>
</tr>
<tr>
<td>16</td>
<td>100</td>
<td>1050</td>
<td>150</td>
</tr>
</tbody>
</table>

Example LTE Categories

<table>
<thead>
<tr>
<th>Bandwidth (MHz)</th>
<th>Achievable Date Rate (Gbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>1.6</td>
</tr>
<tr>
<td>160</td>
<td>3.2</td>
</tr>
</tbody>
</table>

LTE Achievable Data Rates

Enhancements in LTE can Approach 5G eMBB

Note 1: Assumptions: 4-Stream MIMO, 256-QAM
3GPP 5G New RAT

5G Phase 1
- Flexible OFDM numerology delivering peak data rate of 20 Gbps+
- Common support for sub-6 GHz to ~40 GHz
- Unified support for eMBB, looking forward to mMTC and uMTC
- Dynamic TDD/FDD, flexible frame structure supporting beamforming
- Cell virtualization, massive multi-site MIMO
- Tight interworking with LTE using new 5G core network

3GPP Rel-14/15

5G Phase 2
- Extend up to 100 GHz spectrum within same the unified flexible framework
- New waveform for mmWave spectrum
- In-band full duplex

3GPP Rel-16
Intel 5G Device (Concept)

Inter-RAT Connection Management
- WiFi Offloading
- Multi-RAT Aggregation

Multiple RATs (Radio Access Technologies)
- Evolution of LTE, HSPA, WiFi, BT basebands, addition of 5G RAT(s)

4G-5G Transition Impact
- High
- Medium
- Low

Auto Interference Suppression (AIS)
- Suppress inter-CA or GNSS harmonic and inter-RAT self-interference

Multi-Antenna Operation
- 4-Port+ Operation
- Multi-Band, Multi-RAT Port Sharing
- Active Impedance Matching

Multi-Band Support
- Variable Frequency Operation
- >40 LTE bands, >10 HSPA bands, plus WiFi, BT, GNSS bands
- 5G mm-wave (10-100GHz) Support

PA Efficiency
- Low power, low cost operation

Location Processing
- A-GNSS Computation
- Sensor Fusion

Advanced Baseband Signal Processing
- Blind co-channel suppression
- Multiple MIMO modes
- MU-MIMO co-scheduled interference suppression

Multiple GNSS Evolution
- Multiple waveforms – GPS, Glonass, Galileo, Beidou, IRNSS, Ancillary Terrestrial Systems

Advanced Sensors
- MEMS

Very Low Power Operation
- Advanced Power Management
- Delegated Cores

Media Cores
Application Cores
Comms Core
Location Core

PHY Processing
- GSM/EDGE
- WCDMA Rel-15
- BT 5.x
- GNSS
- LTE Rel-15
- WiFi – 802.11ax
- WiGig – 802.11ay
- “5G”

RF Proc
FEM
Low Frequency RF (<6GHz)

DSP

Sensors

RF

mm-Wave

Integration

Integration

cm- and mm-wave Antennas
- Low power, low cost operation

Note: Critical technologies indicated in red.
## Intel 5G Mobile Trial Platform (MTP)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Target Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td>Advanced FPGA &amp; RFIC</td>
</tr>
<tr>
<td>Carrier Frequency</td>
<td>27.0 ~ 29.5GHz &amp; 3.4-5.9GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>Up to 800 MHz (Progressive Q1-Q4'16)</td>
</tr>
<tr>
<td>MIMO</td>
<td>4-layers</td>
</tr>
<tr>
<td>Data Rate (Peak)</td>
<td>1.5-7.0Gbps (2016-17)</td>
</tr>
<tr>
<td>LTE Support</td>
<td>Yes – XMM7360</td>
</tr>
</tbody>
</table>

4 GHz and 28 GHz Discrete Transceiver: Q1’16  
28 GHz RFIC Phased Array: Q2’16
MTP Phase 1 Visual