The (simple) Case for a New 5G Air Interface... and a few other things

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20150508 Washington D.C.
Agenda

- Overall Evolution
- First Step
- 5G Air
- 5G Network
- Timing
3.9Bn
People connected to the Internet in 2017

720%
Increase in video traffic 2012–2017

320M
More tablets sold in 2014 than laptops and desktop computers combined

>50Bn
Enterprise networking market revenue in 2017 (US $)

>70Bn
Things connected to the Internet in 2020

440%
Increase in cloud and data center traffic 2012–2017

3X
Increase in average broadband speed 2012–2017

2X
Increase in cloud computing market 2013–2017

More of everything

Every success has its network
## IoT key requirements

<table>
<thead>
<tr>
<th>Factor</th>
<th>Requirements - low end</th>
<th>Requirements - high end</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak data rate</td>
<td>&lt;100 bits/s UL (e.g. smart metering)</td>
<td>&gt; several Mb/s UL (e.g. security cameras)</td>
<td>10000</td>
</tr>
<tr>
<td>Latency</td>
<td>&gt;1 s (e.g. smart metering without control)</td>
<td>&lt; 10 ms (e.g. ITS Intelligent Transportation Systems - ITS)</td>
<td>100</td>
</tr>
<tr>
<td>Usage</td>
<td>&lt;1 event/day (e.g. intrusion alarm)</td>
<td>“continuous” (e.g. security cameras)</td>
<td>∞</td>
</tr>
<tr>
<td>Coverage</td>
<td>Normal (e.g. outdoor devices)</td>
<td>+20 dB (e.g. indoor devices located in basements)</td>
<td>100</td>
</tr>
<tr>
<td>Mobility</td>
<td>“none” (stationary devices)</td>
<td>“seamless” (e.g. ITS devices)</td>
<td>∞</td>
</tr>
<tr>
<td>Device cost</td>
<td>“not an issue”</td>
<td>&lt;4$ for e.g. smart meters</td>
<td>10</td>
</tr>
<tr>
<td>Battery lifetime</td>
<td>“N/A” (e.g. remotely-powered devices)</td>
<td>&gt;10 years (e.g. smart meters)</td>
<td>∞</td>
</tr>
</tbody>
</table>
4G
Radios
BBU Hardware
IT+ Router
IT
Small cell
CA

Evolve.
Radios
VRAN
vEPC
vI MS
NFV
CoMP
DC & MultiX
LTE-U
Conn-less
CA

5G
Radios
VRAN
vEPC
vI MS
New radio I/F
mm Wave
Massive MIMO
Conn-less
SDN
Policy
DC & MultiX

Every success has its network
Operator drivers for a new architecture

New architecture needed that:

1. Easily adapts to changing demand patterns
2. Delivers higher capacity and end user quality of experience (QoE)
3. Optimizes Total Cost of Ownership (TCO)

Traffic uncertainties
- Where?
- What kind? - apps and devices mix changing

Resource uncertainties
- Spectrum
- Sites
- Backhaul
- Capital

vRAN addresses challenges and unlocks new opportunities
What is a vRAN?

vRAN
- Virtualized, centralized, and pooled functions hosted in the RAN
- Includes vBBU function hosting L2/3 processing of LTE base station
- Implements additional functions and applications for control, performance and delivery optimization

Virtualization (applications abstracted from hardware)
- Continuous cost/performance benefits from simplified operations and higher reliability
- Flexible capacity: Application scaling separated from hardware scaling
- Capability to host different virtualized functions/applications on the same hardware platform
High level vRAN architecture
Virtualizes ran functions and optimizes hosting of new functions
Benefits of vRAN

- Applications implemented at the edge of the network for greater end-user QoE
- Fast access to local metadata for low latency applications

Lower TCO
- Simplified site acquisition, build and upgrade
- Hardware economies of scale
- Simplified operations
- Lower cost redundancy

vRAN

Better network performance
- Better performance using cell coordination features
- Easier load balancing across centralized cells
- Applicable to macro, metro sites and HetNets

Differentiation and new revenue streams
**Efficient use of hardware with vBBU**

**DRIVERS**

Cell site BBU must meet peak load:
- Mobile apps driving increasingly peaky traffic
- IoT devices introducing new traffic patterns
- HetNets driving increasingly dynamic load per cell

**BENEFITS**

Virtualizing BBU enables scaling and pooling among cells
- Statistical dimensioning
- Pooling of a larger amount of cells
- Scaling of user load sensitive L2/L3 part of baseband processing
- Tuning of active user capacity between macro and metro cells

**CELL SITE BBU MUST MEET PEAK LOAD**

| Load cell 1 |
| Load cell 2 |
| Load cell 3 |
| Load cell 4 |

**VBBU ENABLES SCALING & POOLING AMONG CELLS**

- Cumulated peak dimensioning
- BBU capacity gains
- Statistical gains delivered by pooling

Every success has its network
Small Cells and WiFi: Wireless Unified Networks for near-wireline QoE
Multi-RAT and LTE-U

- Small cell innovation (home, enterprise, metro)
- LTE-Unlicensed (LTE-U) / Licensed Assisted Access (LAA)
  - Dynamic co-existence of Wi-Fi and Cellular (LTE)
- “Boost”
  - Blending of Wi-Fi and Cellular (LTE & W-CDMA)
Small Cells
Site Challenge: Integration in advertisement panels

One or two compact metro cell outdoor hidden between the two advertising panels for multi-operator use.

External antennas high enough for excellent performance.

Wi-Fi access point.

Multi-operator LTE and Wi-Fi connectivity with microwave backhaul.
Agenda

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## 9 Key use cases @NGMN

<table>
<thead>
<tr>
<th>Use case family</th>
<th>Example use case</th>
<th>Key technical requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadband in dense areas</td>
<td>Pervasive video</td>
<td>Massive spectrum on small cell pushing need for new “high” band to achieve traffic density of up to 750 Gb/s per km2 in dense urban areas</td>
</tr>
<tr>
<td>Broadband everywhere</td>
<td>50 Mb/s everywhere</td>
<td>Significant improvement to cell edge bitrate to offer consistent user experience at target bitrate over 95% locations for 95% of time</td>
</tr>
<tr>
<td>Ultra-low cost networks</td>
<td></td>
<td>Flexible radio parameters for cost reduction when offering limited services (&lt;10 Mb/s, &gt;50ms, &lt;20 Device/km2)</td>
</tr>
<tr>
<td>Higher user mobility</td>
<td>High speed train</td>
<td>Flexible radio parameters for speeds up to 500 km/h</td>
</tr>
<tr>
<td>Massive Internet of Things</td>
<td>Sensor networks</td>
<td>Connectionless service to offer scalable solution for device densities of up to 200kDevice/km2 and extended battery life</td>
</tr>
<tr>
<td>Extreme real-time</td>
<td>Tactile internet</td>
<td>Flexible radio parameters for low latency down to 1 ms</td>
</tr>
<tr>
<td>Lifeline</td>
<td>Natural disaster</td>
<td>High availability and service recovery resilience mechanisms to ensure availability of basic communications (voice, text, etc.) with large battery life</td>
</tr>
<tr>
<td>Ultra-reliable</td>
<td>Public safety</td>
<td>High reliability rates up to 99.999% (5 nines) implying need to eliminate single points of failure from network design</td>
</tr>
<tr>
<td>Broadcast like</td>
<td>Broadcast services</td>
<td>Reuse of SFN techniques from LTE to offer efficient wide area service delivery</td>
</tr>
</tbody>
</table>
Where does 4G stumble? = 6 requirement drivers for 5G

**BROADBAND**
- Massive traffic capacity
- Reduce Cost
- Spectrum efficiency
- Access new spectrum

**MISSION CRITICAL**
- Very low latency
- High reliability
- High availability
- Security

**INNOVATIVE SERVICES**
- Flexible bearer design
- 3rd party policy

**BATTERY LIFE**
- Signaling reduction
- Energy optimization

**EXTREME DENSITY**
- Massive user density
- User content

**NON TRADITIONAL DEVICES**
- Short packet
- Sporadic access
- More devices and more device types

**INNOVATIVE SERVICES**
- Flexible bearer design
- 3rd party policy
A divergence is coming: 2 asymptotes

- **2G**
  - Mobile voice, traffic scaling proportional to number of subs.

- **3G**
  - Start of mobile broadband. Usage per subscriber increasing.

- **4G**
  - Mobile entertainment, total traffic driven by average data usage instead of number of subscribers.

- **5G**
  - At the same time as ultra-broadband continues to grow, the rise of M2M traffic and number of subscribers causes diverging requirements, both technical and economical.
Driving vision

5G will be a **unified** ecosystem that serves both traditional as well as potential new applications like drones, real-time video surveillance, mobile augmented and virtual reality, IIoT...

**Ultra-broadband** = the evolution of communications and entertainment = a network that serves:
- Human-2-Human: communications, be it voice or video
- Human-2-Machine: photos, video, upload to the cloud
- Machine-2-Human: mobile entertainment; video, games, internet

**Ultra-narrowband** = the evolution of sensing, command and control = a network that serves:
- Machine-2-Machine: sensors & control (latency!), exchanges between devices or applications (mobile devices, gateways, …).
Technology evolution
The broadband scenario is “clear”
Technology evolution

The broadband scenario is “clear” - the narrowband is what we need to agree on!

- **LTE**
  - 2015
- **LTE-U**
  - 2017
- **LTE-A** evolution
  - 2019
  - **<6GHz**
  - **5G**
- **WiFi**
  - 802.11n
  - 2015
  - 802.11ac
  - 2017
  - 802.11ad
  - 2019
- **LTE-A** evolution
  - 2021
  - **mmWave**

**triggers:**
- LTE control overload; low latency control & command applications
- marketing; latency for augmented reality, games; enabling massive MIMO
- last drop wire/fiber replacement

**direct path:** continues to serve traditional mobile BB case.
5G Radio: New air-interface needed

• Unified framework for multiple services with different requirements
  - Spectral efficiency improvement for short bursts
  - High battery life for short packet IoT devices
  - Very low latency for critical applications
  - Acceptable performance out to cell edge

• Flexibility to optimize the parameters for different situations
  - Service needs (latency, activity, performance)
  - Vehicle speeds (static/nomadic to 500 km/hr)
  - Environments & Propagation (indoor/small cell/macro in urban/rural)
5G radio: Adding contention access within air interface

- Challenge:
  - Combine broadband and small packet traffic
  - Be resource efficient (energy, spectrum, network)
  - Allow for low overhead, low complexity, simple terminals
  - Offer high reliability & low latency options
  - Add new contention mode to support connectionless services for bursty traffic

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>Synch?</th>
<th>Access Type</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>closed-loop</td>
<td>scheduled</td>
<td>classic high volume data services</td>
</tr>
<tr>
<td>II</td>
<td>open-loop</td>
<td>scheduled</td>
<td>HetNet and/or cell edge multi-layered high data traffic</td>
</tr>
<tr>
<td>III</td>
<td>open-loop</td>
<td>sporadic, contention-based</td>
<td>few bits, supporting low latency, <em>e.g. smartphone apps</em></td>
</tr>
<tr>
<td>IV</td>
<td>open-loop/none*</td>
<td>contention-based</td>
<td>energy-efficient, high latency, few bits</td>
</tr>
</tbody>
</table>

*: none for maximal energy savings at Tx, open-loop for reduced complexity at Rx
5G Radio: UF-OFDM

- Designed to meet new requirements
  - Contention based access for connection-less services
  - In-band optimization to devices and services
  - Higher capacity
- Universal Filtered OFDM (UF-OFDM)
  - New filter stage applied per sub-band
  - Cyclic prefix replaced by filter time response
  - More tolerant to power and timing errors
  - Reduced guard band requirements
  - May re-apply huge knowledge base of LTE processing

[2] 5GNOW deliverable D3.2

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5G Radio: High band to add massive capacity

- “High band” (>20 GHz, known as mm-wave)
  - Enormous blocks of spectrum available for short range outdoor or indoor access
  - BUT should not plan to re-farm microwave backhaul bands
  - Will offer high peak bitrates for well placed users but will not significantly improve cell edge bitrates
  - Radio parameters may not be harmonised with low band systems (open issue)

- Expected to be used as a “secondary carrier”
  - Using Carrier Aggregation or Dual Connectivity
  - While control plane and coverage ensured by “lower band” (<6 GHz) connection
5G Radio: are we addressing the key drivers?

<table>
<thead>
<tr>
<th>Driver</th>
<th>LTE Evolution</th>
<th>WLAN</th>
<th>Low band (&lt; 6 GHz)</th>
<th>High band (&gt;20 GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile broadband</td>
<td>MIMO, HetNet and CoMP features</td>
<td>Multi-RAT and Boost</td>
<td>Higher spectrum efficiency</td>
<td>Peak bitrates Massive capacity</td>
</tr>
<tr>
<td>Innovative services</td>
<td>Capacity</td>
<td></td>
<td>Short packet Low latency</td>
<td>Scheduled low latency service</td>
</tr>
<tr>
<td>Crowds</td>
<td>Capacity</td>
<td>Capacity</td>
<td>Contention access</td>
<td>Massive capacity</td>
</tr>
<tr>
<td>Mission critical</td>
<td>Public safety features</td>
<td></td>
<td>Low latency</td>
<td>Scheduled low latency service</td>
</tr>
<tr>
<td>Battery life</td>
<td></td>
<td></td>
<td>Contention access</td>
<td></td>
</tr>
<tr>
<td>Non traditional devices</td>
<td>MTC features (to bridge gap until 5G)</td>
<td>Short range access</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5G Radio: Complements 4G and WLAN

5G Radio: Macro and Small Cell layers, low and high bands plus LTE and WLAN

5G (<6 GHz) on MACRO and SMALL CELL
- Coverage
- Connectionless service
- Low latency bearers
- Capacity

5G (>20 GHz) on SMALL CELL
- Massive Capacity
- Extreme low latency
- But unlikely to match lower band coverage

LTE EVOLUTION on MACRO and SMALL CELL
- Coverage for 4G
- Capacity for 4G and 5G
- Fallback coverage for 5G

WLAN on SMALL CELL
- Capacity for 5G and 4G
- Standalone service for any device

MULTIPLE CARRIERS AND SITES
Combined using Carrier Aggregation and Dual Connectivity
Combining 5G, LTE and WLAN interfaces
So: Why do we need a new & unified 5G radio interface?

• When we talk about M2M subscribers, these are not just devices. Applications on smartphones are already generating a large amount (30%) of short bursty traffic. Similarly M2M gateways using cellular uplink will contribute to the total amount of narrowband traffic. M2M subscribers = # devices × # applications/device

Ultra-broadband already acts as a channel for part of the ultra-narrowband traffic.

• The ultrabroadband track will require the integration of many different networks. In order to steer traffic quickly, seamlessly, without impacting the end-user, an efficient control system need to be present.

Efficient low latency narrowband communications benefit ultra-broadband as well.
5G Services: More complex requirements

Device and service needs

- Machine-Type, Internet of Things, Sporadic traffic, Battery-efficient
- High data rates
- MTC

Abstraction

Richer Set of Service Options

- Bitrate: description GBR/N-GBR, peak, expected, sufficient
- Latency (Packet delay): finer granularity, new Low latency option, average vs. first packet delay
- Loss rate: finer granularity
- Priority information (e.g. ARP): Availability class: best effort / prioritized
- Activity: Background, streaming, very infrequent, etc.
- Mobility category: fixed / nomadic / vehicular
- Traffic type: Scheduled, Sporadic vs. Contention
- UE power category: very low power (MTC), high power (WLL)
- Security: Application privacy level, networking restrictions
- Reliability: use case dependent
- Networking: Routing restrictions, recommendations

Profiles & Configuration

- UL data rate (1Gb/s)
- DL data rate (1Gb/s)
- Battery efficiency (10y)
- Mobility (500km/h)
- Latency (3ms)
- Availability (99.9%)
- User density (200k/km2)

Video
Broadband
Sensor
Industrial
Messaging
Logistics

User density
(200k/km2)
5G Network: Policy based to adapt the network to the user

Wireless and networking control
- Rules, resources and topology
- Wireless control
- Networking control

Policy based service management
- Network APIs
- Policy framework
- Service APIs

Charging
- Mobility
- Security
- QoS
- Monitoring
- Optimization

Applications

Every success has its network
Defining 5G - What’s involved?
5G Global activities - work on 5G have started

Global
- Next Generation Mobile Networks (NGMN): 5G project
- 3GPP: Study item proposals for Rel14, first specifications Rel15
- IEEE 802.11: Parallel evolution of Wi-Fi including mm-wave “WiGig”
- ITU-R: IMT-2020

Europe
- Multiple projects within FP7 including 5GNOW, METIS - EU
- 5G Infrastructure Public Private Partnership (5GPPP) - EU
- .. And 18 projects within FP8 starts mid 2015 - EU
- Universities: UK, Germany, Finland, etc.

Asia
- IMT-2020 (5G) Promotion Group - China
- 5G Program (National 863 program) - China
- Korean 5G Forum - Korea
- 2020 and Beyond AdHoc - Japan
- Tokyo Institute of Technology and NTT docomo - Japan

Americas
- 4G Americas
- Universities: Polytechnic Institute of New York University, VA Tech - Broadband Wireless Access & Applications Center, Wireless@MIT Center
- Intel Strategic Research Alliance - Academia & Industry
• **LTE**
  - Evolution continues well after 5G launch

• **5G**
  - Low band deployed from 2020 first on macro cell then on small cells
  - High band on small cell follows as 5G capacity needed
Universal take-aways

**ULTRA BROADBAND**
- Anticipating 8x data growth by 2018 with peaks of 20x for 25% of sites
- LTE, WiFi & small cells needed to address capacity/congestion/QoE

**MOVE TO CLOUD**
- NFV/SDN will drive scale, lower cost, and improve performance
- Dedicated HW → GPP platforms

**5G ON THE HORIZON**
- Understand what the shift may be and how your network fits
- User centric networks
- Have your architecture ready, low band first

All will be needed to tackle the opportunity of IoT as well.
Every success has its network
Resources

- NGMN: http://www.ngmn.org/work-programme/5g-initiative.html
- GSMA: https://gsmaintelligence.com/research/?file=141208-5g.pdf&download
- 3GPP: http://www.3gpp.org
- 5G-PPP: http://5g-ppp.eu