Towards 5G – an operators perspective

Evolution or Revolution?

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Mobile, Wireless & Network Services
BT Research & Innovation

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Towards 5G – an operators perspective

Evolution or Revolution?

Contents

BT Research and Innovation
5G – Needs and Expectations
Capacity technical challenges
IoT technical challenges
Low latency technical challenges
New Services
Conclusions
BT has a long history of ‘purposeful innovation’

*With many world first achievements*

**World Firsts**

1846: Telecommunications company: Electric Telegraph Company

1926: Two way transatlantic telephone conversation by radio

1943: Programmable computer: Colossus

1962: Telephone call via satellite

1968: Digital exchange

1980: Purpose-designed optical fibre submarine cable

1984: 140 Mbit/s commercial single mode optical fibre link

1989: Satellite telephone system: Skyphone

1999: GPRS live data call over a mobile network

2013: World’s first G.fast trial

2014: 3 Tb/s optical fibre link in the core network
Adastral Park – ‘a key UK engineering centre’
Using the power of communications to make a better world

Purpose

Innovation

Science

Ultra-Hi-Definition Entertainment

Assist living

Always best connected

The Internet of Things

Engineering
What is 5G?
Revolution or Evolution

Tomorrows citizens
Cellular Data Growth

Cellular Data in Western Europe (TB)

46% CAGR for Western Europe

Source: CISCO VNI Feb 2, 2015
The drivers for the next generation of mobile

Gaming

UHD Video

Mission Critical IoT

Interactive Services

Video

Internet of Things

The tactile internet

8K UHD

4K UHD

1080p HD

SD

Massive Machine to Machine

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5G is in the research phase

- 1000x capacity
- 10Gbps Peak data rates
- 1Gbps Average data rates
- Sub 1ms latency
- “Ultra reliable”
- “Low energy”

4.5G?  5G
Consensus is slowly forming on the future of 5G
How will 5G achieve the capabilities?

Innovation is required in three dimensions:

**Capacity**

- LTE-A
- **x2**

**Spectrum efficiency**
- Information rate /Hz
- MIMO / Beam forming
- Small Packets

**More Spectrum**
- mmWave
- Unlicensed
- Shared
- Aggregating Channels

**Smaller Cells**
- Pico
- Femto

x50
Where will more Spectrum come from?

Auctions:
- 2.3GHz
- 3.4GHz
- 700MHz

Spectrum Sharing:
- TVWS

Unlicensed:
- LTE-LAA
- LWA
- Wi-Fi

mmWave

Wave Length
- 100km
- 10km
- 1km
- 100m
- 10m
- 1m
- 100mm
- 10mm
- 1mm

Frequency
- 3KHz
- 30KHz
- 300KHz
- 3MHz
- 30MHz
- 300MHz
- 3GHz
- 30GHz
- 300GHz

Nav Aids
Submarines
Radio clocks
AM radio
SW radio
FM radio
Mobile TV
Wi-Fi Radar
Radio astronomy
Auctions

Regulators are releasing more spectrum for mobile broadband, sometimes it is not straightforward.

2.3GHz is very close to Wi-Fi working in the 2.4GHz band.

Our research has concluded that a suitable separation needed between a 2.3GHz LTE UE and a Wi-Fi Access Point at 2.4GHz ranges up to 12m for the least resistant access points.
Spectrum Sharing: TV White Spaces

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>470 MHz - 550 MHz</td>
<td>Digital TV + PMSE + “white spaces”</td>
</tr>
<tr>
<td>550 MHz - 606 MHz</td>
<td>Auction (600 MHz)</td>
</tr>
<tr>
<td>606 MHz - 790 MHz</td>
<td>Digital TV + PMSE + “white spaces”</td>
</tr>
<tr>
<td>790 MHz - 862 MHz</td>
<td>Auction (800 MHz)</td>
</tr>
</tbody>
</table>

TV Ch. | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 |

TV Ch. 60 example

TVWS server
TVWS base station
TVWS compute engine
TVWS clients

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LTE-U / LTE-LAA
Using unlicensed spectrum in conjunction with LTE

Indoor / Outdoor smallcell

LTE-U will operate in one of two modes:

**Supplemental Downlink**: Additional downlink data capacity.

**(1) Carrier Aggregation**: Additional downlink and uplink data capacity

**(3) Using 5GHz spectrum will give access to additional 20MHz channels**

The key issue to resolve is co-existence between LTE & Wi-Fi
LWA – LTE Wi-Fi Aggregation
Combining LTE and Wi-Fi

A concept being carried forward into 5G

Source: Rukus
Where data carried today
Does using Wi-Fi bands increase capacity?

Wi-Fi is carrying >80% data traffic

Overall Android Data Usage (2012)

Source: BT Wi-Fi Survey 2012 (~600 participants recruited by ICM)
mmWave

Research and development driven form vendors, notably Samsung and Huawei.

Samsung have build a proof of concept for a small cell; 28GHz 500MHz bandwidth, beam forming

Harmonised spectrum probably not available before 2025
Harmonised new bands above 6GHz unlikely before 2025

5G candidate frequency bands

Low-frequency bands below 6GHz are always necessary for IMT

- Exploit the bands identified for IMT in the Radio Regulations, including 450~470MHz, 698~806MHz and 3400~3600MHz

High-frequency bands within 6~100 GHz can be introduced in 2019 and beyond

- Several potential candidate bands within 6~100GHz are selected.
- Different bands have different channel properties and coexistence situations.
- Studies on channel measurement, modeling and coexistence are ongoing.
- To promote establishing a new agenda item in WRC-19.

Source: China Mobile, 5G Huddle Copenhagen Oct 2015
Small cells

BT’s Approach ‘Inside-Out’ rather than ‘Outside-In’

- Deploy small cells indoors for **capacity**
- Use MNO partner for **coverage**
- Integration of WiFi and LTE services

- Brings together the benefits of LTE and WiFi
- Open-mode system analogous to BT FON/BT WiFi
- ‘Fixed meets mobile’

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“a hub that includes Wi-Fi and a 4G cell; a combined router”

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Inside / Out is a novel application of Femtocells

Historic Femtocell Application
- Coverage In-fill
- Simple home appliance

BT Femtocell Application
- Inside-out capacity
- Part of a contiguous network

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Managing a dense Femto network requires automation.

**Macrocellular**

- ~3 x 18,000 cells (3 sector sites)
- Manual optimisation by large team of radio planners.

**“Femtocellular”**

- ~5,000,000 cells
- Manual planning not possible due to scale. Alternative is an automated solution “a Self Organising Network, SON”.

SON is a range of automated functions which cover a number of capabilities:

- **Self configuration**
- **Self Healing**
- **Mobility Management**
- **Interference Mitigation**
- **Energy Saving**

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SON Testing at the Building Research Establishment in Watford

September 2014 working with Qualcomm

Cluster 1, six cells
Cluster 2, seven cells

The Building Research Establishment has clusters of unoccupied residential buildings, built in typical UK materials and styles available for hire. This is ideal for early testing of dense femtocell deployments to establish the efficacy of SON techniques.
Examples of SON in action based on real test data

- Adjusting transmit power to improve network performance
- Resolving a user ‘Ping-Pong’ between femtocells

### Testing Results

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Auto-configuration of cell IDs and neighbour lists are essential because manual setting is untenable for a large dense deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interference Mitigation</td>
<td>Automatic power management improves reliability and performance</td>
</tr>
<tr>
<td>Mobility optimisation</td>
<td>Frequent Handover (ping-pong) Mitigation can reduces unnecessary handovers by up to 15x</td>
</tr>
</tbody>
</table>
Emerging radio technology is driving the need for Cloud Radio Access Network (C-RAN)

CoMP – Co-ordinated Multipoint
Device receives transmissions from multiple sites
Increases data rates available to users at cell edge
Connectivity between sites must be high bandwidth, low latency
Air interface efficiency achieved at the cost of more capable backhaul

This is a drive to Cloud RAN
Split the base station electronics
Centralise the baseband units (BBU)
CPRI (Common Public Radio Interface) to the remote radio head (RRH)

and Cloud RAN can also:
Reduce site footprint
Optimise equipment costs
Alternatives to CPRI

Base station functional split

Function split impact

<table>
<thead>
<tr>
<th>Connection</th>
<th>CPRI</th>
<th>Split PHY</th>
<th>MAC-PHY</th>
<th>Split MAC</th>
<th>PDCP-RLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data rate</td>
<td>2500Mbit/s</td>
<td>1075Mbit/s</td>
<td>152Mbit/s</td>
<td>151Mbit/s</td>
<td>151Mbit/s</td>
</tr>
<tr>
<td>Latency</td>
<td>&lt;0.25ms</td>
<td>0.25-2ms</td>
<td>2ms</td>
<td>6ms</td>
<td>30ms</td>
</tr>
<tr>
<td>Impact on CoMP gain</td>
<td>0%</td>
<td>-5%</td>
<td>-15%</td>
<td>-25%</td>
<td>-55%</td>
</tr>
</tbody>
</table>
Cloud RAN over G.fast

G.Fast CPE

Ethernet

Remote Radio Head

LTE

Copper <300m

G.Fast

MAC/PHY Split

RRM  OAM  SON

API

L4

RRC  PDCP  RLC

GTP-u  S1  X2

UDP, SCTP  IPSEC/IP

L2/L3

MAC (sched)

CAL

Ethernet

Central site

G.Fast Distribution Point

Ethernet

BBU/EPG/APP

THUNDERX

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Smart Cities can improve the lives of millions

- Milton Keynes is the UK’s fastest growing city, economy set to grow 67% by 2026
- City infrastructure under strain
- Target: enable growth of 20% with no net increase in water, energy, waste collection, and reduce congestion
- SME incubator of up to 90 SMEs, with projects in transport, energy, water, home, and education

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The Information Exchange is at the heart of the Smart City

- **End Users**
- **Applications**
  - e.g. Smart Parking, Smart Waste Management
- **APIs**
- **Service Management**
- **Developer Environment**
- **Analytics**
- **IT Services**
- **Information Spine**
- **Data**
  - (e.g. sensors, smart phones, historical...)
- **Data providers**
- **Sensor Network Providers**
- **Service Providers**
- **Government**
Current examples
From GiTex Dubai  October 2015

LoRa network with launch plan 2016

Robotic receptionist
Latency in 4G networks

GSMA suggest:
- Content needs to be within 1km of device
- Network sharing would be preferred
- New business models should be explored

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Low Latency in 5G networks

Figure 1: Bandwidth and latency requirements of potential 5G use cases.

Source: GSMA Intelligence
5G Core Network needs to address future customer needs as well as optimal operational efficiency.

**Operator requirements**

- **Optimisation**
  - Optimal traffic routing
  - Simplified Operations
  - Infrastructure reuse

**Future requirements**

- **5G Vision**
  - Full convergence of fixed and mobile services (under debate)
  - Extremely low latency
  - Increased bandwidth
  - High traffic density
  - Massive capacity
  - High mobility

**Architecture and Technology**

- **Network Function Virtualisation (NFV)**
  - Operational savings
  - Infrastructure re-use
  - Flexible scaling

- **Software-defined networks (SDN)**
  - Application-driven networking
  - Network optimisation
  - Flexible resource allocation (5G)

**“Flat distributed cloud” (FDC) architecture**

- Multi-Radio/Fixed Access Technology support
- Optimal functional distribution
- MEC (Mobile Edge Computing) proposal controversial

**Flexible routing /dynamic resource allocation**

- Pre-flow allocation of functional elements
- Optimal decomposition of functional architecture
- Full service flexibility

**Network slicing**

- Application-dependent “network slices”
- New business models

**User/control plane separation**

- Optimal network deployment
- QoE improvements

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5G architecture to support new use cases

**Today**
Mobile Broadband
Telephony

**Capabilities**
Universal mobile Broadband
IoT
Low Latency

**Verticals**
Automotive
Sensor networks
Health
FMC

Source: NGMN white paper
LTE Enhancements – what’s next?

LTE Release 13: addressing the mobile broadband demand

- LTE Carrier Aggregation enhancements
  - Aggregate up to 32 Component Carriers
  - Useful in particular for LAA where large blocks of spectrum are available

- Elevation Beamforming / Full-Dimension MIMO
  - Support of two-dimensional antenna arrays to exploit the vertical dimension for beamforming and MIMO
  - Support of high-order MIMO systems with up to 16 antenna ports at the eNB

- Study on Low latency LTE*
  - Study of techniques that can significantly reduce the latency of the LTE air interface, including solutions for fast uplink access, shortening of the Time-Transmission Interval (TTI) and reduced processing time
  - The goal is to improve performance and user experience of existing services as well as to enable new delay critical services

- Study of downlink multi-user transmission using superposition coding*

* Note: normative work (if any) for this item is targeted for Release 14

Source: Dino Flore Chair 3GPP RAN
5G access network

- Dense indoor
- Base band hotel
- Multi connected devices
- Shared Spectrum
- mmWave small cell
- TDD small cell
- Wi-Fi
- Femto
- Macro
- Control
- Control and data
- WiMob 2015
What is the time line for 5G?

- **4G Standards**
  - Rel 10
  - Rel 11
  - Rel 12
  - Rel 13
  - Rel 14
  - Rel 15
  - Rel 16

- **5G Standards**

- **5G Deployment**

- **3GPP**

- "5G" Research

- In commercial confidence
Conclusions

• 5G has the ambition and capability to become fundamental to the future digital economy

• There is much more work to do with added emphasis on extending the capabilities to support industry use cases

• Keeping costs low should be a key factor as 5G moves into standardisation
Questions?