WHY 5G?

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PERCEIVED INFINITE CAPACITY

New communication paradigm
For 5G and Beyond
CONTENTS

- Drivers for 5G
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  - Perceived Infinite Capacity
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- New approach to 5G
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WHY 5G?
Impact of Broadband on GDP

- US could increase its GDP by $100 billion with an increase of 10 additional broadband lines per 100 individuals (30 million lines)

- Similar figures are also reported by the EU Commission that 50% of economic growth in the European Union is driven by ICT

- Broadband Communications regarded as stimulus of economy (Source: OECD 2011 report)

Broadband Mobile Internet

**Problems**
- Mobile data traffic 1000x by 2020 compared with 2010
- Mobile Data traffic is doubling every year
- If trend holds –1000,000x by 2030
- Capacity doubles every 10 years
- Facing radio spectrum/Capacity crunch

**Current thinking**
- 1000x traffic ≠ 1000 x capacity
- 10 (more cells) x 10 (BW) x 10 (spectral efficiency)
- Advance radio access technologies (new waveforms, massive MIMO, etc.), WiFi-offloading,
- New Frequency bands –mm bands, 1000 MHz new spectrum

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**TOTAL spectrum Requirement (MHz)**

<table>
<thead>
<tr>
<th>Demand Scenario (UK)</th>
<th>2012</th>
<th>2014</th>
<th>2016</th>
<th>2018</th>
<th>2020</th>
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</thead>
<tbody>
<tr>
<td>(Profile &quot;A&quot;) - Working pop. London</td>
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<tr>
<td>TOTAL Demand (Gb/s/km²)</td>
<td>2.10</td>
<td>6.89</td>
<td>14.88</td>
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<td>72-80</td>
<td>190-395</td>
<td>400-840</td>
<td>880-1800</td>
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<td>24-48</td>
<td>32-66</td>
<td>70-144</td>
<td>143-305</td>
<td>313-653</td>
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<td>(Profile &quot;D&quot;) - UK Peak</td>
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<tr>
<td>TOTAL Demand (Gb/s/km²)</td>
<td>0.47</td>
<td>1.54</td>
<td>3.33</td>
<td>7.06</td>
<td>4.68</td>
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<tr>
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<td>118-158</td>
<td>156-356</td>
<td>330-720</td>
<td>710-1546</td>
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<tr>
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<td>6-12.2</td>
<td>20-41</td>
<td>42-88</td>
<td>96-188</td>
<td>192-413</td>
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<td>2-4.5</td>
<td>7-15.2</td>
<td>15-32</td>
<td>32-68</td>
<td>70-146</td>
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<td>(Profile &quot;F&quot;) - UK Mean</td>
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<tr>
<td>TOTAL Demand (Gb/s/km²)</td>
<td>0.04</td>
<td>0.14</td>
<td>0.31</td>
<td>0.65</td>
<td>1.40</td>
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<td>6.7-14.5</td>
<td>14.4-31.4</td>
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<td>1.6-3.3</td>
<td>4.6</td>
<td>9.6-17.3</td>
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<td>0.6-1.4</td>
<td>1.4-3</td>
<td>3-6.3</td>
<td>6.5-11.3</td>
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</table>

- SU-MIMO 2 x 2
- SU-MIMO 4 x 2
- SU-MIMO 4 x 4
- SU-MIMO 8 x 2
- MU-MIMO 4 x 2
- MU-MIMO 8 x 2
- CS/CB-CoMP 4 x 2
- CS/CB-CoMP 8 x 2
- JP-CoMP 4 x 2
Cellular Standards Evolution

Timescale getting shorter between Research/Standardisation and Commercialisation

Systems tend to co-exist rather replacing previous generations

Enabled by smart phones and broadband mobile

The Internet!
What is 5G?

“Always Sufficient Rate” to give users the perception of Infinite Capacity”

Question

In a limited resources world can we achieve Infinite Capacity?
Infinite Capacity - is it possible?

» Point to Point
  ◦ \( C_s = \) Shannon Capacity Limit

» Point to Multi point – Cellular: 2G–4G
  ◦ \( C_{\text{actual}} \propto C_s \times \text{Cell\_density} \)
  ◦ Limited to one degree of freedom – only spatial freq. re-use

» Point to Multi-cells and multi-users: 5G, 6G,…….
  ◦ \( C_{\text{perceived}} \propto C_s \times \text{Cell\_density} \times 1/T_{\text{re-use}} \)
  ◦ \( T_{\text{re-use}} \): Time between resource re-use
  ◦ Two degrees of freedom: Spatial and temporal re-use
  ◦ \( T_{\text{re-use}} \Rightarrow \text{QoE}, \ C_{\text{perceived}} \Rightarrow \infty \)

Infinite Capacity ... An example...

Infinite Capacity

In a limited resources world only possible by perception

Spatial and Temporal re-use of resources + QoE
Infinite Capacity

In a limited resources world only possible by perception
Spatial and Temporal re-use of resources + QoE
Infinite Capacity
In a limited resources world only possible by perception
Spatial and Temporal re-use of resources + QoE

Actual £1 but Perceived £10

Happy bunch!
5GIC approach

- Research starts from end user QoE (H2H, H2D, D2D)
  - Unlike 2G....4G, designed for end device
  - Data rate is not the differentiation between 5G and previous generations
  - Area spectral & energy efficiencies, Latency (radio and end to end) ..
  - Spectrum packing

- No difference between licenced and licenced-exempt bands
  - Broadcast, Cellular, WiFi technologies
    - Differences in Freq Bands
      - ......while service offered the same or converging...
    - Data, Video, Audio

5GIC Research Approaches

Two complementary

- Content, User and Network Context
  - Dynamic user profiling
  - Data Handling
    - Intelligent Content (Storage, Search, Delivery) Networking

- Efficient use of radio spectrum
  - Area Spectral Efficiency
  - Energy Efficiencies
  - Spectrum Uniformity
    - licensed (and exempt) bands
**Key Features of 5G**

- Capture and use the User context, Content context and Network context
- QoE and resources efficiency based on user profile
- Utilisation of telecom and IoT Big Data
- In-network processing (storage, transmission) for content
- Dense small cell
- Device to device
- Spectrum Sensing
- Utilize the licensed and unlicensed band
- New frequency bands: including mm-Wave
- Split data and control radio network architecture
- Multi cell cooperation
- Massive MIMO
- Full duplex

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**Why Higher Speed**

3 reasons

- Low latency: Full utilisation of advanced techniques potentials
- QoE: Fast network responses
- See next...
Fixed & mobile data rate evolution

- 100 Mbps: FTTH 100Mbps, VDSL 25Mbps, LTE 10-100 Mbps
- 10 Mbps: HSPA+ 5-30Mbps
- 1 Mbps: ADSL 3Mbps, HSPA 2-4Mbps
- 100 kbps: ADSL 1Mbps, 3G R9 384k
- 10 kbps: GPRS 38 kbps, GSM 9.6 kbps
- 2.4k: 1985
- 4.8k: 1990
- 28.8k: 1995
- 56k: 2000
- 128k: 2005
- 256k: 2010

Coverage and Capacity

- One size does not fit all!
- Low+ Medium+ High Dense cells
  - Capacity limited
  - Coverage limited
Why New Air-Interface?

- Low to medium density cells
- 4G (LTE-A,B,C) large cells
- High Density Cells
  - Objectives is NOT link spectral efficiency
  - Very low control signalling overhead for management, relaxes the stringent time-frequency control inherent in OFDMA
  - Flexible implementation of carrier aggregation across highly fragmented spectrum including license-exempt band
  - Highly energy efficient
  - Allow full-duplex operation
  - Sub-millisecond Air-Interface latency
  - Support fast and reliable spectrum sensing for opportunistic spectrum sharing with and without database support
  - Support distributed MAC between network and mobile device
    - Support of device to device communications
    - Scalable for Machine type communications
  - ...

New Radio Access Architectures

Conventional Uplink  Cooperative  MIMO

Cooperation converts the distributed cellular system into a MIMO system with distributed antennas

Interference is good
Larger Cells – Fundamental capacity limits results

Smaller Cells – Fundamental capacity limits results
New RA Architecture-SDN principles to Radio Access

- Dynamic provisioning of resources
- Data and Signalling resources separation
- Reduce in signalling
- Reduce in energy consumption
- Cutting Energy, Cost and RF Emission

5G system approach - Summary

- 5G includes: All other National Critical infrastructures including mobile broadband
- New business models
- Old approach to 2G, 3G and 4G not sustainable
- Focus: Perceived infinite capacity
  - Latency
  - Energy Efficiency
  - Scalability
  - Reliability and Robustness
    - Distribute control between Network and Devices
  - Uniformity between licensed and license-exempt bands (including Broadcast)
  - Dense cell technologies
  - Explore and understand new frequency bands
5G Targets

- Maximum, Average or Percentile as cell rates not relevant

- Targets:
  - Area Spectral Efficiency...
  - Energy Efficiency....
  - Latencies: E2E and Over The Air...
  - QoE....

Let’s make infinite capacity a reality

Thank you