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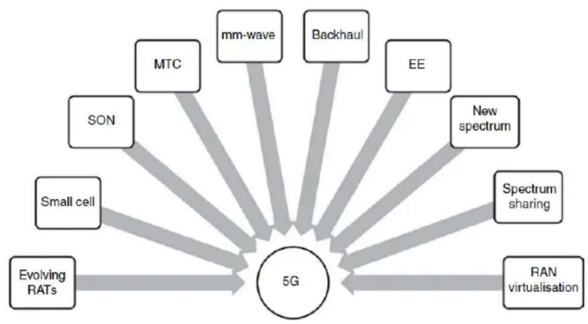
Introduction

- We have been witnessing an exponential growth in the amount of traffic carried through mobile networks. According to the Cisco visual networking index, mobile data traffic has doubled during 2010–2011; extrapolating this trend for the rest of the decade shows that global mobile traffic will increase 1000x from 2010 to 2020.
- The surge in mobile traffic is primarily driven by the proliferation of mobile devices and the accelerated adoption of data-hungry mobile devices – especially smart phones



1. Evolution of Existing RATs

- 5G will hardly be a specific RAT, rather it is likely that it will be a collection of RATs including the evolution of the existing ones complemented with novel revolutionary designs.

- The first and the most economical solution to address the 1000x capacity crunch is the improvement of the existing RATs in terms of SE, EE and latency.

1. Evolution of Existing RATs

Needs to evolve to support massive/3D MIMO to further exploit the spatial degree of freedom (DOF) through advanced multi-user beamforming.

Enhance interference cancellation and interference coordination capabilities in a hyperdense small-cell deployment scenario.

Wi-Fi also needs to evolve to better exploit the available unlicensed spectrum.

4G LTE

Wi Fi ™

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1. Evolution of Existing RATs

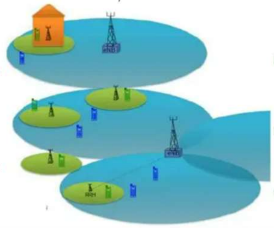
Qualcomm have recently been working on developing LTE in the unlicensed spectrum as well as integrating 3G/4G/Wi-Fi transceivers into a single multi-mode base station (BS) unit.

2. Hyperdense Small-Cell Deployment

Hyperdense small-cell deployment is another promising solution to meet the 1000x capacity crunch, while bringing additional EE to the system as well.

Large cell
- High power eNB
- Macro-eNB site can be difficult to find

Small cell
- Low-power base station or RRH
- Hot-spot coverage
- Coverage in area not covered by the macro network
- Indoor coverage
- Small site size



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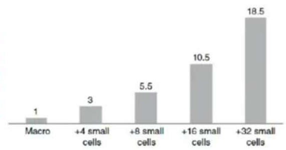
2. Hyperdense Small-Cell Deployment

- In general, there are two different ways to realize HetNet:
  - Overlaying a cellular system with small cells of the same technology, that is, with micro-, pico-, or femtocells;
  - Overlaying with small cells of different technologies in contrast to just the cellular one (e.g. High Speed Packet Access (HSPA), LTE, WiFi, and so on).

2. Hyperdense Small-Cell Deployment

Capacity scales linearly with the number of added small cells. That is, the capacity doubles every time we double the number of small cells. However, reducing the cell size increases the inter-cell interference and the required control signaling.

- To overcome this drawback, advanced inter-cell interference management techniques are needed at the system level along with complementary interference cancellation techniques at the UEs.



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3. Self-Organizing Network (SON)

- As the population of the small cells increases, SON gains more momentum.
- Almost 80% of the wireless traffic is generated indoors.
- To carry this huge traffic, we need hyperdense small-cell deployments in homes – installed and maintained mainly by the users – out of the control of the operators.
- These indoor small cells need to be self-configurable and installed in a plug and play manner.
- Furthermore, they need to have SON capability to intelligently adapt themselves to the neighboring small cells to minimize inter-cell interference.

4. Machine Type Communication (MTC)

Machine type communication (MTC) is an emerging application where either one or both of the end users of the communication session involve machines. MTC imposes two main challenges on the network:

- The number of devices that need to be connected is tremendously large.
- The accelerating demand for real-time and remote control of mobile devices (such as vehicles) through the network

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5. Developing Millimeter-Wave RATs

Extremely high frequency (EHF) is the International Telecommunication Union (ITU) designation for the band of radio frequencies in the electromagnetic spectrum from 30 to 300 gigahertz (GHz).

Radio waves in this band have wavelengths from ten to one millimeter, giving it the name millimeter band or millimeter wave, sometimes abbreviated MMW or mmW. can be used for high-speed wireless broadband communications.

5. Developing Millimeter-Wave RATs

There are three main impediments for mmWave mobile communications.

- The path loss is relatively higher at these bands, compared to the conventional sub-3GHz bands.
- Electromagnetic waves tend to propagate in the Line-Of-Sight (LOS) direction, rendering the radio links vulnerable to being blocked by moving objects or people.
- The penetration loss through the buildings is substantially higher at these bands, blocking the outdoor RATs for the indoor users.

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5. Developing Millimeter-Wave RATs

Advantage for mmWave communications

- An enormous amount of spectrum is available in mmWave band; for example, at 60 GHz, there is 9GHz of unlicensed spectrum available.
- The small antenna sizes ($\lambda/2$) and their small separations (also around $\lambda/2$), enabling tens of antenna elements to be packed in just one square centimeter.

6. Redesigning Backhaul Links

In parallel to improving the RAN, backhaul links also need to be reengineered to carry the tremendous amount of user traffic generated in the cells.

Otherwise, the backhaul links will soon become bottlenecks, threatening the proper operation of the whole system. The problem gains more momentum as the population of small cells increases.

Different communication mediums can be considered, including optical fiber, microwave and mmWave.

7. Energy Efficiency (EE)

- Today, Information and Communication Technology (ICT) consumes as much as 5% of the electricity produced around the globe and is responsible for approximately 2% of global greenhouse gas emissions roughly equivalent to the emissions created by the aviation industry.
- What concerns more is the fact that if we do not take any measure to reduce the carbon emissions, the contribution is projected to double by 2020. Hence, it is necessary to pursue energy-efficient design approaches from RAN and backhaul links to the UEs.

8. Allocation of New Spectrum for 5G

Another critical issue of 5G is the allocation of new spectrum to fuel wireless communications in the next decade.

The 1000x traffic surge can hardly be managed by only improving the spectral efficiency or by hyper-densification. In fact, the leading telecom companies such as Qualcomm and NSN believe that apart from technology innovations, 10 times more spectrum is needed to meet the demand.

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9. Spectrum sharing

The efficient use of available spectrum is always of critical importance.

Innovative spectrum allocation models (different from the traditional licensed or unlicensed allocation) can be adopted to overcome the existing regulatory limitations.

Plenty of radio spectrum has traditionally been allocated for military radars where the spectrum is not fully utilized all the time (24/7) or in the entire geographic region.

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10. Ran virtualization

The last but not least critical enabler of 5G is the virtualization of the RAN, allowing sharing of wireless infrastructure among multiple operators.

Network virtualization needs to be pushed from the wired core network (e.g. switches and routers) towards the RAN.

For network virtualization, the intelligence needs to be taken out of the RAN hardware and controlled in a centralized manner using a software brain, which can be done in different network layers.

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10. Ran virtualization

Virtualization can also serve to converge the wired and the wireless networks by jointly managing the whole network from a central orchestration unit, further enhancing the efficiency of the network.

Finally, multi-mode RANs supporting 3G, 4G or WiFi can be adopted where different radio interfaces can be turned on or off through the central software control unit to improve the EE or the Quality of Experience (QoE) for the end users.