FutureWorks

looking ahead to 5G

Building a virtual zero latency gigabit experience

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1. Three key development areas in 5G

The continuing growth in demand from subscribers for better mobile broadband experiences is encouraging the industry to look ahead at how networks can be readied to meet future extreme capacity and performance demands. Nokia, along with other industry partners, believes that communications beyond 2020 will involve a combination of existing and evolving systems, like LTE-Advanced and Wi-Fi, coupled with new, revolutionary technologies designed to meet new requirements, such as virtually zero latency to support tactile Internet, machine control or augmented reality.

5G will be the set of technical components and systems needed to handle these requirements and overcome the limits of current systems.

Limits will be reached. Current systems do not scale to requirements **beyond 2020.**

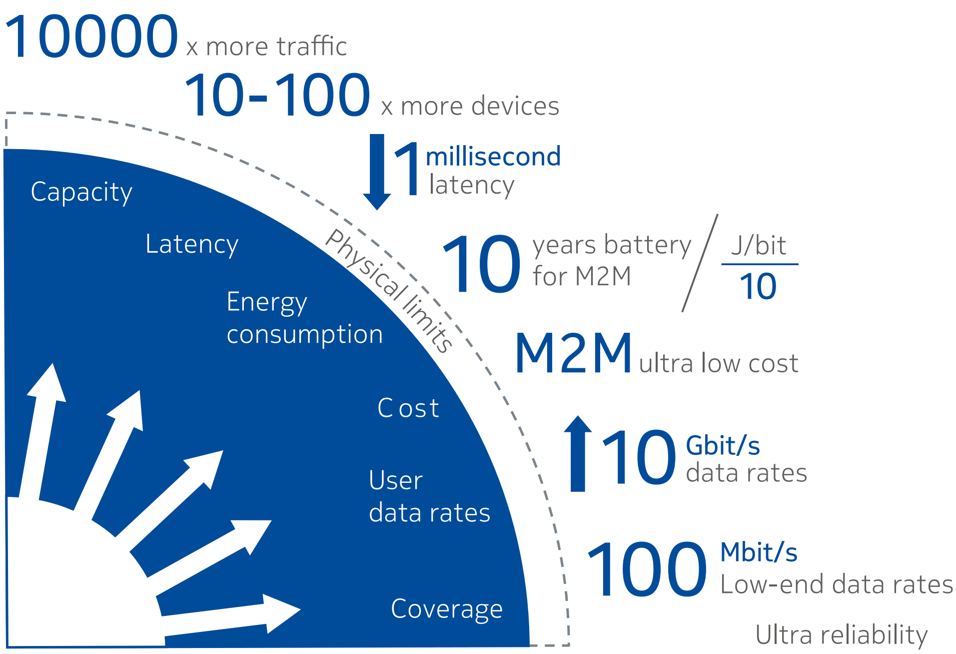

Fig. 1. Existing mobile technologies will not be able to provide the capabilities to meet market demands beyond 2020. Sustained research will be needed to create a high performance 5G environment.

Unlike 2G, 3G and 4G, it is unlikely that 5G will be a single new Radio Access Technology (RAT) nor will it replace macro cells. It will be a combination of existing RATs in both licensed and unlicensed bands, plus one or more novel RATs optimized for specific deployments, scenarios and use cases. In particular, Nokia has identified the need for a new RAT for ultra-dense deployments, with the aim of providing a virtual zero latency gigabit experience.

Nokia is already undertaking extensive research to map out the scope of 5G and has a clear vision of the three key pillars that will make this future network a reality.

More spectrum must be pressed into service

More radio spectrum for mobile networks is vital to meet the increased capacity and coverage demand. New spectrum will need to be allocated and put into use quickly. Without sufficient spectrum, communities beyond the reach of wired broadband will miss out on the benefits of future services and entire countries could lose ground.

The amount of spectrum available needs to be expanded by adopting new frequency bands and by using available spectrum more efficiently, both in terms of frequency and with regard to when and where it is employed.

Networks will become much denser with many more cells

The second pillar of 5G will be to use many more base stations, deployed in a heterogeneous network (HetNet), combining macro sites with smaller base stations and using a range of radio technologies. These will include LTE-A, Wi-Fi and any future 5G technologies, integrated flexibly in any combination.

Raising the overall performance of networks

The third major goal will be to get the best possible network performance by evolving existing radio access technologies and building new 5G wireless access technologies. For example, it is generally accepted that latency must decrease in line with rising data rates.

Sustained research and development in these three areas will be necessary to create a 5G environment that can meet market demands such as 10,000 times more traffic, virtually zero latency and a much more diverse range of applications. What's more, all this must be achieved at an affordable cost to enable operators to maintain and improve their profitability.

The Nokia vision is that: "5G will enable a scalable service experience anytime and everywhere and where people and machines obtain virtual zero latency and gigabit experience where it matters".

Let's now look at each of the three development areas in more detail.

2. Bridging the spectrum gap with 5G

Much more spectrum will be needed to meet increased traffic demand. To date, spectrum for mobile communications has focused only on frequency ranges below 6 GHz. To meet demand in the 2020-2030 time frame, spectrum above 10 GHz and potentially up to 100 GHz will be needed. Depending on the carrier frequency, spectrum needs will include: large chunks of spectrum in high(er) bands, TDD mode in unpaired bands and flexible use of spectrum through advanced spectrum sharing techniques (for example Co-primary sharing).

Systems for low and high frequency bands are designed differently. Traditional frequency bands require more focus on increased area spectral efficiency (including gains from denser and more efficient small cell deployments) because spectrum is scarce. However, in new frequency bands, especially millimeter wave, there is no need for fine-tuning to achieve extreme spectral efficiency because huge chunks of contiguous spectrum are available at these higher frequencies.

Affordability is also crucial, so the harmonization of radio frequency bands will be important to enable economies of scale and roaming. This will also minimize interference across borders. Nokia believes harmonization should be a key policy objective at a regional level at least, in line with International Telecommunication Union (ITU) recommendations.

In the short term, Nokia sees four aspects to ensuring spectrum scarcity does not impede growth:

- Additional harmonized spectrum must be allocated and used.
- 100 MHz of additional spectrum below 1 GHz will provide improved rural broadband.
- 500 MHz of additional spectrum between 1 and 5 GHz will provide capacity for data.
- Spectrum shall be dedicated to mobile broadband on a technology-neutral basis.

However, these measures are just the start.

Over the next few years, the core 3GPP bands of 900, 1800, 2100 and 2600 MHz will be used for new LTE networks and HSPA network capacity upgrades. LTE deployments on the 800 MHz band will then help to provide ubiquitous mobile broadband availability, followed by the arrival of 700 MHz across ITU region 1 after the World Radio Communication Conference in 2015. The long-term vision is to converge broadcast and broadband services in joint multimedia networks covering the UHF band below 700 MHz (472-694 MHz).

Small cell deployments will play a vital role in high-capacity hotspots, and the spectrum for that could come from the 3500 MHz band (3400-3800 MHz), where there is as much as 400 MHz being used for fixed broadband wireless access and satellite services. In addition, other smaller spectrum blocks can be made available ahead of 2020, either exclusively, or by using novel spectrum sharing methods.

Unlicensed bands such as 5 GHz, or in the future 60 GHz, offer additional traffic offload options for best-effort traffic of less critical applications without guaranteeing Quality of Service (QoS).

The result is that up to 1.5 GHz of the scarcest <6 GHz spectrum can be made available within this decade. At least 1 GHz of that will be traditional exclusive spectrum, while new spectrum-sharing techniques, such as Authorized Shared Access (ASA), can unlock more spectrum for mobile broadband.

Another potential 5G enabler is using millimeter wave communication (and centimeter bands not previously used) for access and backhaul. High frequency communication is not suitable for providing umbrella coverage and new opportunities in the millimeter wave region will not replace traditional band allocations. However, with 10 GHz of bandwidth available in the 70-85 GHz band, this spectrum can help to cope with large volumes of small cell traffic.

Optimizing the use of spectrum

Dedicated spectrum for exclusive use is still the “gold standard” preferred to meet the expected demand from future 5G networks, but it’s also vital to use the available spectrum as efficiently as possible – even if that means sharing it. Many bands already host important services that must have access to spectrum but do not necessarily use it fully.

New regulatory regimes will be needed to allow more flexible, shared spectrum allocation. Topics such as Authorized/Licensed Shared Access, Licensing Light and Co-Primary Sharing are rising up the agenda for regulatory and standardization bodies.

Authorized Shared Access (ASA), also known as Licensed Shared Access (LSA) is a regulatory concept to allow spectrum sharing under well-defined conditions. ASA could be a solution for bands that can’t be totally vacated by their incumbent users, but where that usage is low.

Co-Primary Shared Access models and cognitive radio access procedures enable higher peak data rates for end users as well as higher capacity and wider coverage. Essentially, a band is shared between network operators, rather than divided between them, making it easier for any one operator to cope with temporary peaks in demand. This leads to better spectrum utilization.

Adapting radio access technology to frequency band in use: two sides of the coin

We expect that systems currently operated in licensed bands (such as LTE-A) will play a major role in providing coverage for 5G. Furthermore, Wi-Fi will continue to be a relevant solution for low-cost, best effort data, in particular indoors. However, ultra dense deployments with high traffic demand and low latency requirements will be the environment in which revolutionary technologies will emerge and the system design will vary according to the carrier frequency.

Nokia foresee the introduction of a new local area communications concept for centimeter waves based on a modified OFDMA numerology, modified MAC and novel higher layer concepts. This will allow a significant reduction in air interface latency and prepare the ground for built-in support of interference management and efficient device-to-device communications, machine-type communications and self-backhauling. More precisely, we propose a new frame design with a flexible UL/DL pattern which itself will support more flexible adaptation to different scenarios: UL and DL traffic imbalance, self backhauling, easier device-to-device communication and faster dormancy for lower energy consumption. A higher degree of interference coordination is inherent in such an autonomous system and with distributed synchronization.

The use of millimeter wave bands will open the door to an abundance of spectrum, but the very different propagation properties in these bands create challenges that require novel deployment, network infrastructure and management that have to be established. We foresee that high frequency communication is a very promising solution for wireless backhaul of future small nodes (also including multi-hop backhauling), but in addition we also see a large potential in using millimeter wave band (70-90 GHz) for access links in very dense small cell deployments.

The propagation characteristics in high frequency ranges mean that transmission should be through a few selected paths (without relying on scattered energy), the strongest being the line-of-sight (LOS) path. The design of a system for such bands must overcome the challenges of radio wave propagation rather than in increasing spectral efficiency.

These two concepts will revolutionize how 5G targets will be met - designing a system in 'traditional' bands that is optimized for dense local area deployments (not the case for existing technologies) and venturing into new frequency bands where large chunks of spectrum are available, but where the design of communication technology changes completely. The success of 5G will ultimately depend on a smart integration of such novel concepts with existing radio access technologies and a context-aware mapping of services and devices to evolved or novel technology components.

3. Networks to become denser with small cells

Network densification is needed to meet the throughput and latency demands likely to arise in 2020 and beyond. By 2020, small cells are expected to carry a majority of traffic with overall data volume expected to grow up to 1,000 times (compared to 2010). Nokia's analysis shows that sufficient network capacity at a minimum downlink user data rate of 10 Mbit/s can be achieved using a LTE heterogeneous network configuration (LTE, small cells and well integrated Wi-Fi), which is how networks are expected to evolve until 2020.

Beyond this date, a new approach will be needed to achieve ultra-dense small cell deployments and this is where we expect to see innovative 5G components emerging. Whether deployed in 'traditional' frequencies (<6 GHz) or in new centimeter and millimeter wave bands, these new technology blocks will need to enable ultra-low latency, higher data rates (peak rates exceeding 10 Gbps, with user data rates greater than 100 Mbps even under high load conditions or at the cell edge) and more flexibility, for example in backhaul or duplexing schemes.

The key to meeting these requirements is to bring the access point closer to the user, with smaller cells making more radio resources available to active users. This will also substantially reduce the radio round trip time for lower latency and increase overall network efficiency by creating sub-networks to handle a proportion of the traffic locally.

The increase in achievable data rates for 5G (10,000 times more traffic) cannot be achieved without reducing the cell size and increasing the frequency re-use rate. This is already happening today, especially for indoor traffic that is inefficient to handle with outdoor macro cells. Over the next few years this trend will accelerate as the use of data-hungry applications rises. Ultimately, the need for small-cell-optimized RAT will be one of the triggers for 5G.

New applications will require ultra-low latency to support online gaming, augmented reality and to control uses such as tactile Internet and remote surgery. It is clear that the need for low latency will become much more important in the future and will need to be addressed. New, small-cell-optimized RAT for 5G can deliver latency as low as 1ms.

The mass roll out of IPv6 and the emerging 'Internet of things' will lead to more connected devices and also new use cases for small cell deployments. 5G will use some IP mechanisms (e.g. IPv6 Neighbor Discovery Protocol) to simplify the creation of sub-networks that will handle some traffic locally, while autonomous deployment mechanisms, such as mobility and traffic steering, will make roll out more efficient.

With such an increase in access point density there will be ongoing development of interference coordination schemes for data offload from bigger to smaller node types and resource usage coordination between nodes. With many different equipment types and devices, HetNets will have a wide range of performance demands, making self-aware networks essential.

4. Network performance

With 5G, a range of performance measures will become more important – a multitude of applications and different use cases need to be addressed, with novel technologies for each specific case to ensure the limitations of mobile communications systems don't limit the overall development of the technology.

In particular, it is not economically feasible to build ultra-dense networks everywhere and it must be accepted that a virtual zero latency gigabit connectivity will only become available "where it matters". Therefore, while 'traditional' performance indicators, such as peak data rates, will improve, the key to 5G will be flexibility and support for new use cases.

More important than just peak data rate or spectral efficiency will be enabling the same 5G system (integrated from different radio access technologies including new ones) to support requirements such as:

- Few devices demanding huge downloads
- Ultra-high numbers of sensors sending just small data packages
- Remotely-controlled robot applications (low latency needed for control) sending back UHD video (high upload capability required).

The scalable service experience in 5G will be all about tailoring the system to extremely diverse use cases in order to meet specific performance requirements. A uniform service experience can still be achieved in most use cases by tighter coupling between RAN and transferred content, for example, making APIs between the application and network layer to adjust application demands or by caching data locally. Furthermore, local sub-networks can be set up, where several devices create a high performing direct connectivity within a local area.

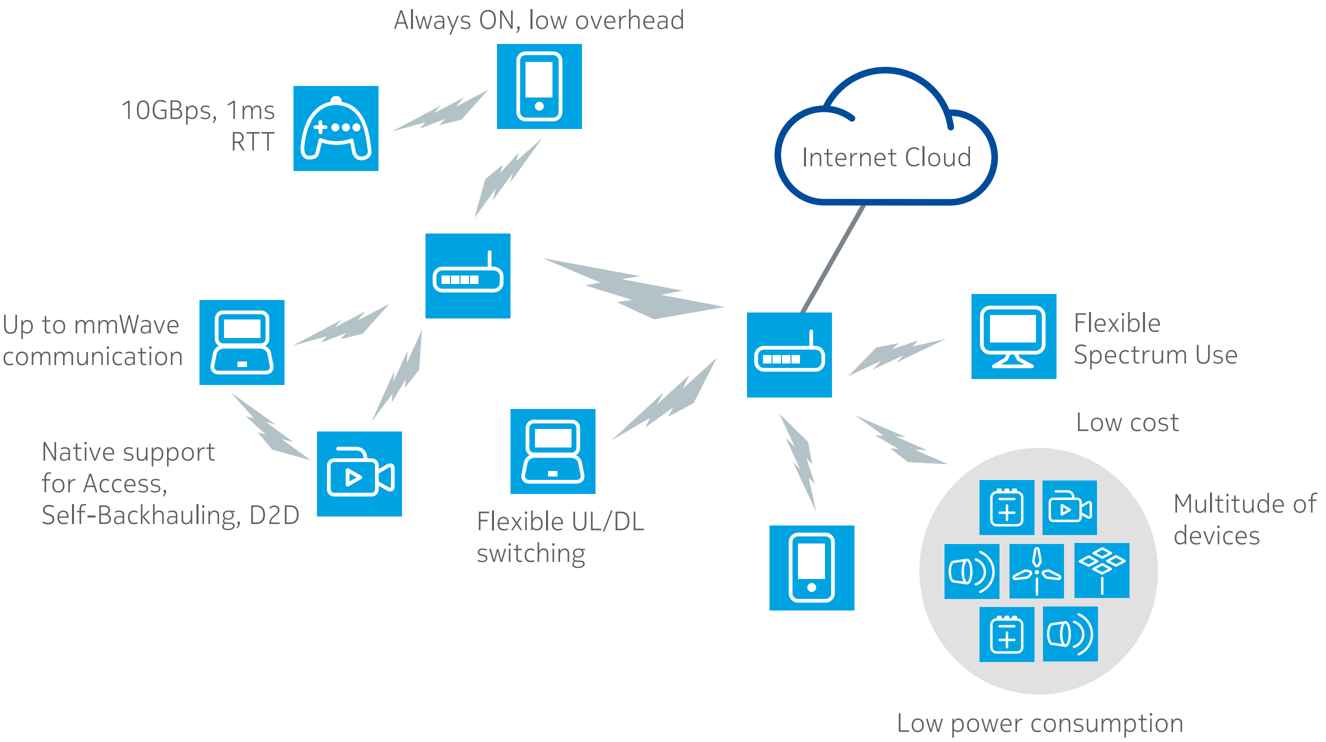

Fig. 2. Ultra dense deployments with many diverse use cases and scenarios set a variety of targets and functional requirements for a new system.

The key performance measures that will need to be met include:

Round Trip Time (RTT)

Ultra-low latency will be a key aspect of 5G communications systems because we are moving towards the era of the tactile Internet where wireless communications will be increasingly used for distributed control rather than merely content distribution. Also it is predicted that the maximum data rates per device will increase substantially faster than Moore's law, meaning that if the cost of, for example, HARQ buffers at the device side is to be kept constant, any increase in air interface bandwidth must be complemented by a decrease in air interface latency.

The target RTT for 5G is likely to be lower than 1 ms to provide a virtual zero delay experience and to facilitate a new palette of time critical Machine Type Communications (MTC).

Spectral efficiency

We will still see improvements and demanding requirements for spectral efficiency in terms of average bit/s/Hz/cell for ultra-dense deployments. However, this will probably not be as important as in the past for the design and optimization of 3G and 4G radio access technologies, which were mainly optimized for wide area deployments. Using higher frequency bands, large transmission bandwidth combined with low transmit power automatically limits the coverage. What matters more for the new radio access design is the total deployment cost in terms of cost/area considering a certain traffic density and a typical experienced user data rate.

Self-backhauling and direct device-to-device

In terms of connectivity, a new RAT must support radio access between a terminal and an access point connected to the Internet cloud by wire or wirelessly. For ultra-dense deployment, self-backhauling and direct connectivity is becoming important to balance cost and performance of connectivity.

Low power consumption

Nokia believes that power consumption for mobile networks must be kept to a minimum. Low power consumption is also essential for battery operated terminals to prolong time between battery charges. Many new potential MTC use cases are more limited by a power hungry radio access than the offered data rate or latency.

Ultra-low cost per access node

As networks become denser, it is of utmost importance that the cost per access node is reduced substantially, with an OPEX virtually close to zero. This means that 5G will have to be fully "plug and play". Therefore, the radio access technology needs to be fully auto-configured and auto-optimized, and any hierarchy or relation between network entities, for example, to centralize or distribute radio resource management, has to be fully self-establishing.

Higher layer protocols and architecture

The Internet of things will greatly multiply the number of connected devices and this connectivity will be heterogeneous. The adoption of IPv6 is accelerating and the protocol will probably have become mainstream by 2020 after which 5G will be launched. Ethernet is another technology becoming more widespread. "Ethernet over Radio" could become a simple and cost-effective solution to encompass 5G HetNets.

5. Nokia at full speed in its 5G Research

Nokia is already advanced in its 5G research, both internally and externally. Good examples of this work include partnerships with key universities around the world, leading the work on heterogeneous deployments as part of the EU collaborative research project METIS, and collaboration within ITU-R, China IMT-2020 and 3GPP. Nokia sees the new generation of mobile as a chance for omnipresent connectivity for both communication and control beyond 2020.

Nokia's research is primarily focused on the flexible use of spectrum and its propagation in new, higher bands, as well as system design for ultra-dense small cell deployments. In this latter area, Nokia's work aims to deliver the high data rates and ultra-low latency that will be needed to support future uses such as augmented reality, tactile Internet and others.

Other major research areas for Nokia include wide area enhancements, 5G architecture to integrate all systems, analysis of how 5G may adapt to novel use cases.

Millimeter wave communication is an example of a very promising spectrum opportunity and Nokia has made this one of focus topics for its research into how to overcome design challenges, how to deal with new propagation rules and how to arrive at sufficiently accurate channel models. Nokia is already seeing the first results and is launching a global industry and academic forum, the Brooklyn summit in spring 2014, for sharing and discussing propagation measurements for both centimeter and millimeter wave bands.

Nokia is also maintaining substantial effort and focus on new use cases that 5G can support and to this end is seeking input from external parties and striving for industry-wide alignment on what new opportunities 5G may create.

6. Summary

5G is on its way and rather than being another 'next generation' it will be a better integration of old and new technologies.

This integration of different systems will enable more stringent requirements in some areas to be met, relaxed needs in others, with a focus on keeping overall costs and energy dissipation low.

The combination of evolution and revolution, wide and local area, big and small cells and different carrier frequencies will enable a fully scalable service experience on demand, where people and machines will enjoy a virtual zero latency gigabit experience when and where it matters.

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