FutureWorks

5G use cases and requirements

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1. What 5G will be and why it will come

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. Although the path towards 2020 has already been set out in our Technology Vision 2020, the growth in demand will not stop there.

Nokia, along with other industry partners, believes that communications and control beyond 2020 will involve a combination of existing and evolving systems. This includes existing 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.

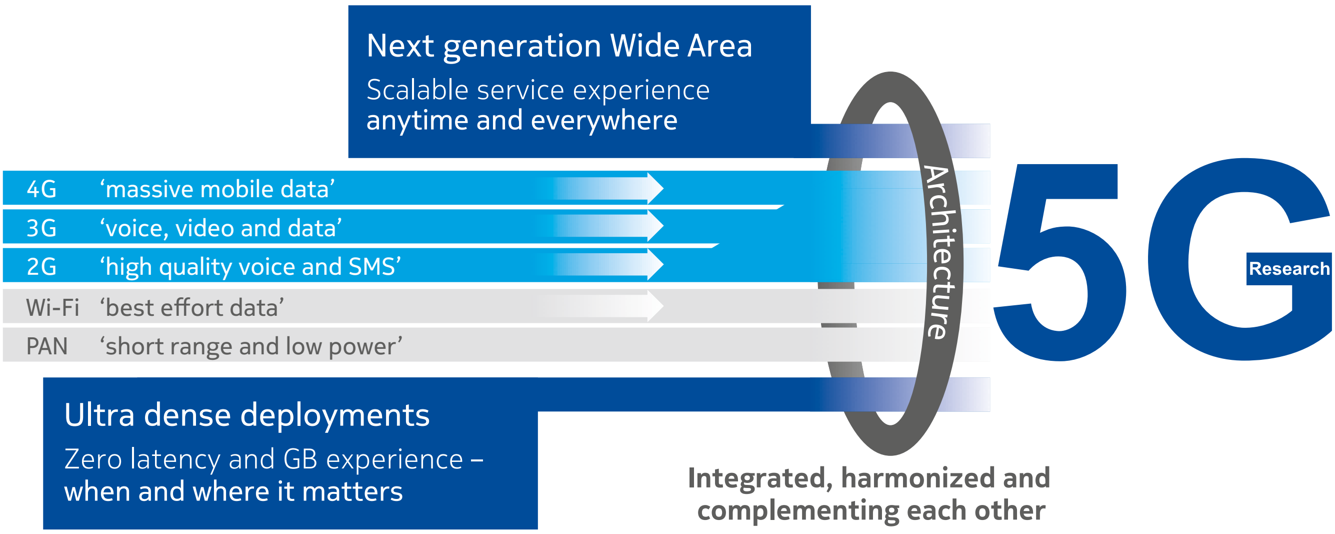
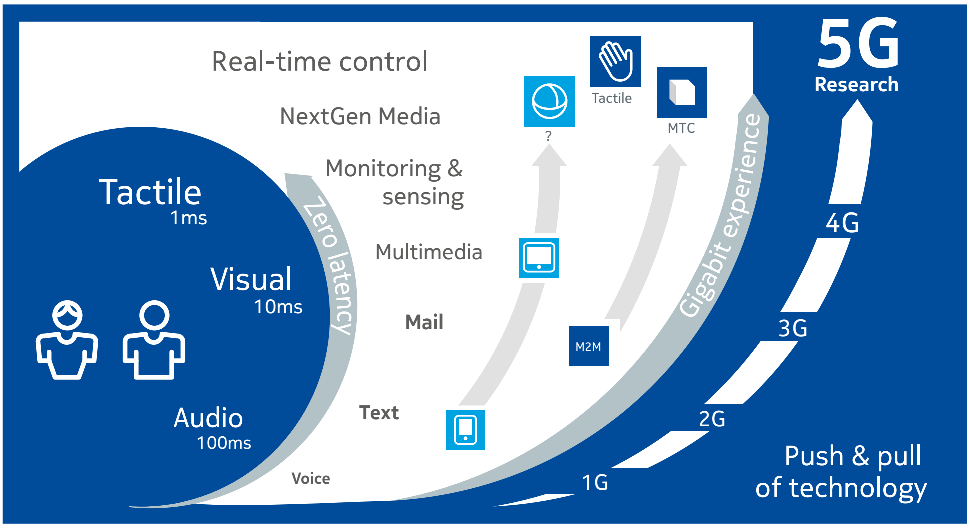


Fig.1. 5G: symbiotic integration of existing and new technologies

Cellular networks were originally designed for voice only application, using analogue transmission channels. When digital technology evolved and more voice channels were required, digital 2G systems emerged in the 1990s. Digital transmission enabled new services such as text messaging and circuit switched data access.

The low data rate services provided by 2G systems did not fulfill the need for mobile Internet access. This lead to a demand for new 3G standards, which evolved to provide fast data services and more capacity for voice. The recent (4G) mobile communications system LTE was developed to provide high capacity and highest rate data service for mobile multimedia. Seen from a historical point of view, each of the cellular standards has evolved around a set of key use cases:

- 1G – Voice services
- 2G – Improved voice and text messaging
- 3G – Integrated voice and affordable mobile Internet
- 4G – High capacity mobile multimedia



Flexibility for what is unknown today.

Fig.2. 5G Demands - Higher capacity, lowest latency and more consistent experience

Figure 2 shows the evolution of the cellular standards driven by the communication needs of both humans and objects. A “Zero latency gigabit experience” is what we foresee users/objects will expect from 5G. Both parts – an increase of data rates and a reduction of latency - are equally important.

Of course, the term “Zero latency” does not mean no delay at all – it simply represents the fact that 5G needs to deliver latencies low enough that the radio interface will not be the bottleneck, even for the most challenging use cases. The next generation mobile communications system will not be used for human interaction alone. Instead we will see a huge growth in machine type communications, sometimes referred to as the ‘Internet of Things’. The devices will also not only be remotely controlled and managed by people, but will also communicate with one another. Therefore the Internet of Things requires more reliable communication links but also lower transmission delays (latencies) – machines can simply process information much faster than people.

Human interactions will also be more demanding in the future – for the 2G system, the main focus was voice, where latency requirements were driven by the human audible delay constraint, in the order of 100 milliseconds. For multimedia applications, the human eye is more sensitive and delays of less than 10 milliseconds are required. The ‘tactile interaction’ stands for the increasing use of touch interfaces, where a delay requirement as low as one millisecond can sometimes be observed.

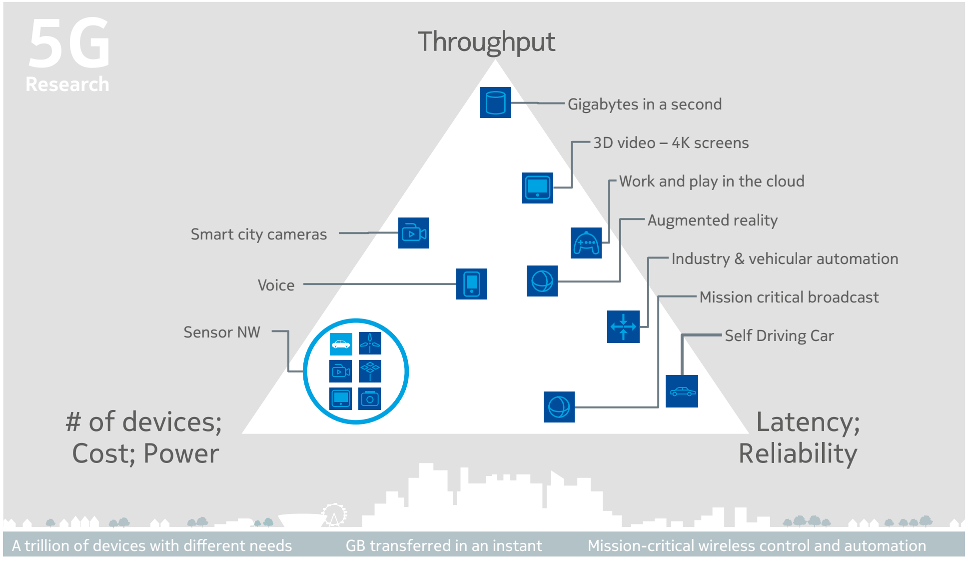
“Gigabit experience” will mean data reception and transmission speeds of Gigabits per second to users and machines. Again, this does not mean providing high-capacity networks everywhere, but the centers of big cities will be the first places where the demand for a new system will be felt. The overall demand growth in both user data rates and network capacity is still the main driver for technological evolution – higher capacities of networks will require better performance, cell densification and access to new, broader carriers in new spectrum. Part of the capacity growth can of course be met with existing systems, but around 2020, limits will be reached and 5G technologies will be needed.

Nokia has already published a white paper describing our general views on what 5G will be and in this current white paper we will look more closely at the use cases for the new system and the resulting requirements.

The next section describes a number of new use cases envisioned for 5G. Flexibility for a wide range of these use cases and services will be one of the key design principles for the next generation mobile communications systems. The 5G requirements supporting these demands will be summarized at the end of this paper.

2. Use Cases

New services and use cases are envisioned for 5G and will likely be the driver for the technology. Figure 3 shows the diversity of some of the expected 5G services.



Building a scalable service experience

Fig.3. Diversity of services, use cases and requirements

As shown in Figure 3, there are three main requirement dmensions: Throughput/capacity, number of devices/low cost and latency/reliability. Some use cases may require multiple dimensions for optimization while others focus only on one key performance indicator (KPI). One of the main challenges for 5G will be to support such diverse use cases in a flexible and reliable way.

2.1 Mobile broadband

Mobile broadband is the key use case today and it is expected to continue to be one of the key use cases driving the requirements for 5G. It goes far beyond basic mobile Internet access and covers rich interactive work, media and entertainment applications in the cloud or reality augmentations (both centralized and distributed).

Data will be one of the key drivers for 5G and in new parts of this system we may for the first time see no dedicated voice service - in 5G, voice is expected to be handled as an application, simply using the data connectivity provided by the communication system. Data is growing at a rate between 25% and 50% annually and is expected to continue towards 2030. See Figure 4.

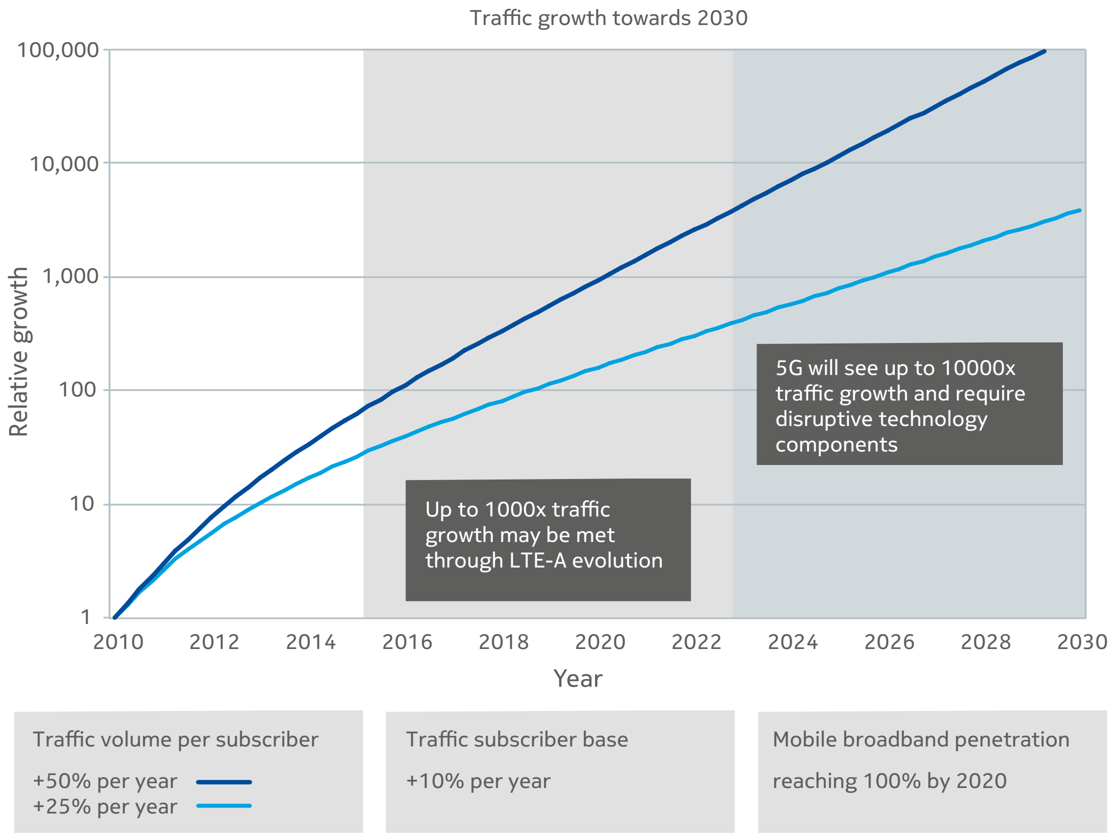


Fig.4. Predicted traffic volume towards 2030

The main drivers for the increased traffic volume are the increase in size of content and the number of applications requiring high data rates. Factors include increases in camera resolution, the rise in screen resolution with the recent introduction of 4K (8K is already expected beyond 2020) and the developments in 3D video. Streaming services (audio & video), interactive video and mobile Internet connectivity will continue to be used more broadly as more devices connect to the Internet. Many of these applications require always-on connectivity to push real time information and notifications to the users.

Cloud storage and applications are rapidly increasing for mobile communication platforms. This is applicable for both work and entertainment. Cloud storage is one particular use case driving the growth of uplink data rates – in the past, content was mostly downloaded.

5G will also be used for remote work in the cloud which, when done with tactile interfaces, requires much lower end-to-end latencies in order to maintain a good user experience.

Entertainment, for example cloud gaming (including 'serious games') and video streaming, is another key driver for the increasing need for mobile broadband capacity. Entertainment will be very essential on smart phones and tablets everywhere, including high mobility environments such as trains, cars and airplanes.

Another very interesting but also very demanding use case is augmented reality for entertainment and information retrieval, which requires very low latencies and significant instant data volumes. In current networks, the first such use cases are enabled with Nokia's Liquid Applications and in the future we will see a wide variety of augmented reality usage, including scenarios where content caching in the base station is difficult.

2.2 Automotive

The automotive sector is expected to be a very important new driver for 5G, with many use cases for mobile communications for vehicles. For example, entertainment for passengers requires simultaneous high capacity and high mobility mobile broadband, because future users will expect to continue their good quality connection independent of their location and speed.

Other use cases for the automotive sector are augmented reality dashboards. These display overlay information on top of what a driver is seeing through the front window, identifying objects in the dark and telling the driver about the distances and movements of the objects.

The previous two use cases are related to content provisioning for the car users, but the cars themselves will also be connected. Many car manufacturers are already adding driver assistance systems based on 3D imaging and built-in sensors. In the future, wireless modules will enable communication between vehicles themselves, information exchange between vehicles and supporting infrastructure and between vehicles and other connected devices, for example, those carried by pedestrians. Additionally, use cases for traffic safety are now widely discussed in the EU-funded project METIS. These include cars detecting safety critical situations, such as black ice, accidents within reach of the car and other hazardous road conditions. Safety systems will also guide drivers on alternative courses of action to allow them to drive more safely and lower the risks of accidents.

The next phase will be remotely controlled or even self-driven vehicles, which will require ultra reliable and very fast communication between different self-driving cars and between cars and infrastructure. In a plausible future, a self-driving car takes care of all driving activity, allowing the driver to rest and concentrate only on traffic anomalies that the car itself cannot identify. Ideally, reading the morning newspaper while commuting will become possible. The technical requirements for self-driving cars call for ultra-low latencies and ultra-high reliability, increasing traffic safety to levels humans cannot achieve.

2.3 Smart Society

Smart cities and smart homes, often referred to as smart society, will be embedded with dense wireless sensor networks. Distributed networks of intelligent sensors will identify conditions for cost -and energy-efficient maintenance of the city or home. A similar setup can be done for each home, where temperature sensors, window and heating controllers, burglar alarms and home appliances are all connected wirelessly. Many of these sensors are typically low data rate, low power and low cost, but for example, real time HD video may be required in some types of devices for surveillance. The task for 5G will be to integrate the management of these very diverse connected devices.

2.4 Smart grids

The consumption and distribution of energy, including heat or gas, is becoming highly decentralized, creating the need for automated control of a very distributed sensor network. A smart grid interconnects such sensors, using digital information and communications technology to gather and act on information. This information can include the behaviors of suppliers and consumers, allowing the smart grid to improve the efficiency, reliability, economics and sustainability of the production and distribution of fuels such as electricity in an automated fashion. A smart grid can be seen as another sensor network with low delays.

2.5 Health

The health sector has many applications that can benefit from mobile communications. Communications systems enable telemedicine, which provides clinical health care at a distance. It helps eliminate distance barriers and can improve access to medical services that would often not be consistently available in distant rural communities. It is also used to save lives in critical care and emergency situations.

Wireless sensor networks based on mobile communication can provide remote monitoring & sensors for parameters such as heart rate and blood pressure.

2.6 Industrial

Wireless and mobile communications are becoming increasingly important for industrial application. Wires are expensive to install and maintain and the possibility of replacing cables with reconfigurable wireless links is a tempting opportunity for many industries. However, achieving this requires that the wireless connection works with a similar delay, reliability and capacity as cables and that its management is simplified. Low delays and very low error probabilities are new requirements that need to be addressed with 5G.

2.7 Logistics / freight tracking

Finally, logistics and freight tracking are important use cases for mobile communications that enable the tracking of inventory and packages wherever they are through using location based information systems. The logistics and freight use cases typically require lower data rates but need wide coverage and reliable location information.

3. 5G Design Principles

The new, 5th generation of mobile will be built around two key design principles that guide all requirements and technical solutions.

3.1 Flexibility

The use cases for 5G will be more diverse than ever and will require very diverse link characteristics. Some examples are:

- Massive data transmissions require large packet sizes and a lot of allocated resources
- Non-stationary sensors may need only small packet sizes and rare resource allocations but in turn require a battery efficient sleep mode

- Flexible adaptation to fast traffic variations in uplink and downlink
- Cloud gaming or remote machine control require low end-to-end latency
- Video streaming requires latency matching with the data rate

Communication systems beyond 2020 will need to be flexible enough to accommodate all the diverse use cases without increasing the complexity of management.

Another reason that flexibility is the first key design principle of 5G is that any new technology or system we design for 5G needs to be future proof and last at least until 2030. This means that it is unlikely that we can currently foresee all future use cases. However, we will need to design all new components of 5G in a way that makes it easy to extend them to accommodate these unknowable scenarios.

3.2 Reliability

As a key design principle for 5G, reliability is related to flexibility - with the flexible integration of different technology components, we will see a step away from best effort mobile broadband towards truly reliable communication. Reliability is not only about equipment up-time, it also relates to the perception of infinite capacity and coverage that future mobile networks need to deliver. This in principle means that for all the use cases and the vast majority of the users, the required data will be received in the required time and will not be dependent on the technology used.

Furthermore, reliability is becoming more critical as we start to relay on mobile communications for control and safety. A reliable connection can be defined as the probability of a certain data package being decoded correctly within a certain timeframe. This means that retransmission may be needed to ensure reception of a correct data package, a process which will inevitably delay the transmission. Therefore, even to obtain LTE latency numbers with higher reliability, a lower system delay will be required.

Putting reliability as a key design principle for 5G means that:

- in all concepts of system design focus should be put on fairness
- the requirement is expressed in % of the users and not the locations/coverage, because even the reliable network needs to be cost-effective for the service providers
- the mechanisms for trade-off between link reliability (so low packet error rate) and throughput and/or latency are introduced in a simple and efficient way
- multiple network layers and radio access technologies are used to provide the most reliable link based on the user's application needs, location and mobility

4. Requirements

The use cases, key design principles and vision of the 5G system lead to requirements that the future mobile broadband system will need to meet.

10,000 times more traffic will need to be carried through all mobile broadband technologies at some point between 2020 and 2030. We made our prediction in 2010 and since then have gathered information from the market which shows that the growth we foresaw is actually happening. The need for more capacity goes hand-in-hand with access to more spectrum on higher carrier frequencies. The new 5G system needs to be designed in a way that enables deployment in new frequency bands.

We will see growth between ten and a hundred devices for each mobile communications user – even now many people have a phone, tablet, laptop and a few Bluetooth-enabled devices. This trend will continue and 5G needs to be designed to accommodate such growth in device numbers.

Another factor is radio latency lower than one millisecond, which is important for:

- achieving high data rates while keeping equipment cost low
- ensuring fast procedure response times in the system (e.g. fast wake up and dormancy, fast scheduling, fast link reconfiguration)
- a whole new range of use cases like remote control of machines and objects in the cloud or tactile Internet

The requirement for low radio latency is followed by other requirements - jitter (latency deviation) of 20μs or end-to-end latency targets that vary between different service types.

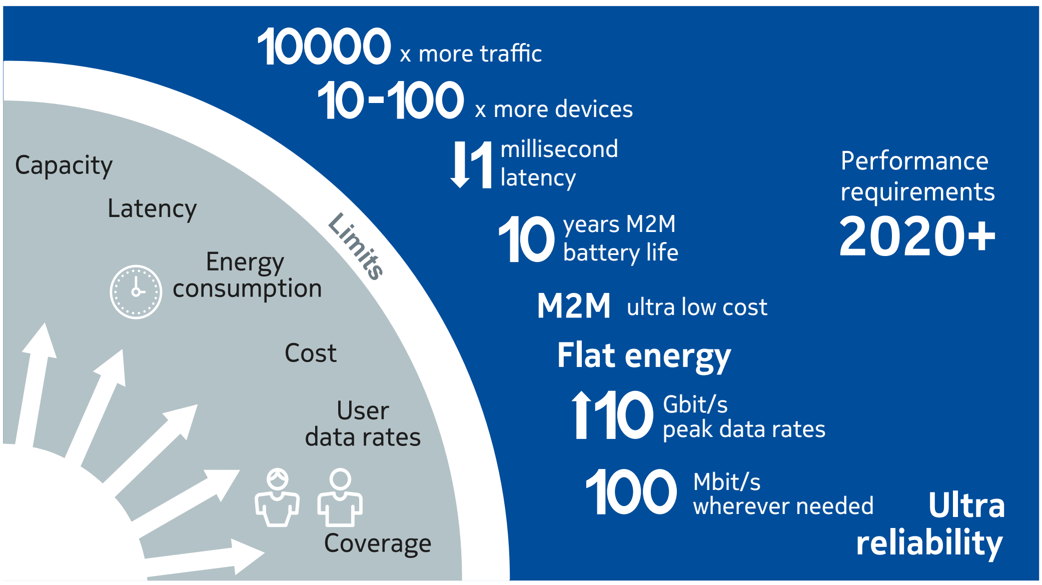


Fig.5. The summary of key requirements for 5G

The exploration phase for a high performance 5G has started!

A battery life of 10 years needs to be achievable. Part of this lifetime extension will come from the evolution of battery technology but part will come from efficient handling of machine type traffic in the 5G system. Reduced power consumption and increased battery life will also be very important for more complex devices, such as smartphones, tablets or laptops, as the time that such devices run on a fully charged battery is a very important factor for end users. Furthermore, energy consumption for the operators needs to decrease.

The possibility to handle devices with very low cost has to be ensured. This means for example, that using very high frequency bands may only be an option for simple devices, as transceiver capabilities don't need to be the same for all devices. Following this example, in some frequency bands, smartphones will use a 100MHz carrier but it is feasible that sensors will have only 10MHz capable hardware. These sensors should also be able to access the system. 5G will need to be flexible enough to handle efficiently very simple devices that only send small, rare bursts of data, yet also handle advanced ones that send large amounts of data quickly.

Peak data rates of a 5G system will be higher than 10 Gbit/s but more importantly the cell-edge data rate (for 95% of users) should be 100 Mbit/s. This will allow the use of the mobile Internet as a reliable replacement for cable wherever needed.

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, taking into account a particular traffic density and a typically experienced user data rate.

Mobility should be ensured for velocities as of today or higher – of course, small cells will be optimized for nomadic mobility but higher speeds will also be supported. Overall, the 5G ecosystem will ensure possibilities to provide high (but not peak) data rates even to high speed users.

Accurate positioning of the device shall also be possible with 5G, indoors as well as outdoors. Location-based services are becoming more important and will be followed by location-based reality augmentations. Another use for locating devices more precisely than currently may be radio resource allocation based on device positions.

Security will be a very important requirement for 5G and the trend is already visible and addressed now. In the new system, not only security of sensitive personal data, but also safety from inserting false information to the system should be ensured, with procedures made as simple as possible.

Many more requirements of the transport network and overall architecture will also develop with the introduction of 5G:

- smooth mobility between cells, layers and radio access technologies needs to be assured
- support for any-to-any communication (so not only uplink or downlink but also device to device and node to node self backhauling) needs to be assured
- 5G networks need high capacity and low latency backhaul without a significant increase in cost compared to today's backhaul
- 5G networks will need to be programmable, software driven and managed in an integrated way

5. Summary

The number of use cases for a next generation mobile communications system will grow rapidly and the scenarios will place much more diverse requirements on the system. In this White Paper we have outlined the use cases and requirements for 5G but also the key design principles – flexibility and reliability. The future may seem far ahead but the phase for defining the requirements is now and what's more, any new technology or system that we design for 5G needs to be future proof and last at least until 2030.

5G will come and even though we are still in an exploratory phase, Nokia is already setting out what 5G will deliver and how it will deliver it.

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