

Before the  
**FEDERAL COMMUNICATIONS COMMISSION**  
Washington, DC 20554

In the Matter of )  
 )  
Use of Spectrum Bands Above 24GHz For ) GN Docket No. 14-177  
Mobile Radio Services )

**Comments of Nokia (d/b/a Nokia Solutions and Networks US LLC)**

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Nokia Solutions and Networks US LLC (“Nokia”) hereby submits the following reply comments to the Commission’s *Notice of Inquiry* (“NOI”) regarding the use of spectrum bands above the 24GHz range. Nokia is a leader in the fields of network infrastructure, location-based technologies and advanced technologies. With operations around the world, Nokia invests in the technologies of the future, including those necessary to enable a robust future for 5G. Nokia’s 5G leadership activities include a partnership with the NYU Wireless Research Center to organize and host Brooklyn 5G summits, the first of which was held in April of 2014 and the second one to be held on April 8 - 10, 2015.<sup>1</sup> The 2nd summit will build on what was achieved last year and will focus on spectrum assets above 6 GHz and progress in channel modeling at these higher frequencies. Further, Massive MIMO and Beamforming solutions for 5G systems will be a focus topic for this summit. Nokia will also serve as the inaugural chair of 5GPPP. Nokia also attaches its white paper on 5G as an appendix to provide some additional insights into its 5G Vision to the Commission.

**I. 5G implications:**

As noted in Nokia’s initial comments, the 5<sup>th</sup> generation of wireless technology (“5G”) has significant implications for consumers and the mobile broadband ecosystem because:

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<sup>1</sup> See <http://brooklyn5gsummit.com/>

- Consumers generate an increasing amount of mobile traffic, requiring ever-increasing capacity, continually improving user experiences, and reduced latency. 5G will offer an expected peak data rate higher than 10 Gbit/s compared and cell edge rates higher than 100 Mbps combined with virtually zero latency. 5G will support applications and industries of the future such as innovative health care services that provide real time monitoring capabilities, self-driving cars, and deliver the next generation of industry automation. This will mean 5G will mean stepping away from a best effort approach and towards truly reliable, highly predictable communication. Flexible integration of existing access technologies such as LTE and Wi-Fi with new technologies creates a design that is future proof.
- 5G supports the huge growth of Machine Type Communications (MTC), also called the Internet of Things, through flexibility, low costs and low consumption of energy. At the same time, 5G will be reliable and quick enough for even mission-critical wireless control and automation tasks such as self-driving cars.
- 5G will lower costs and consumption of energy. Energy efficiency is an integral part of the design paradigm of 5G, not an afterthought. Virtualized and scalable technologies will further facilitate global adoption and improved coverage.

## II. Challenges to 5G:

A successful transition to 5G will require overcoming several challenges and establishing a policy environment that enables robust research and development. Among the key challenges facing 5G are:

**Need for harmonization:** Various 5G initiatives are competing to lead the definition of 5G, including:

- The EU's 5GPPP (or 5G Public-Private-Partnership), the flagship initiative under Horizon 2020;
- China's IMT-2020 (5G) Promotion Group and the 2020 and Beyond Ad-Hoc Group;
- Korea's national research program supported by 5G Forum;
- Russia's, 5GRUS program; and
- The United States' 5G programs led by the National Science Foundation.

Establishing a common definition and foundational research base are key to making rapid progress

toward 5G. Lack of coordination and cooperation will promote fragmentation and delay in vital standards work.

**Spectrum needs:** Additional radio spectrum for mobile networks needs to be allocated and put into use quickly to meet the increased capacity and coverage demands of 5G. This means looking at new spectrum bands such as millimeter wave and centimeter wave, and using available spectrum efficiently. Nokia's initial comments urged the Commission to take a broad view of spectrum opportunities, not just those above 24GHz.

**Density:** 5G networks will need to have considerably more base stations to meet the performance needs of future applications. These dense networks will be deployed as heterogeneous networks, combining macro sites with smaller base stations and using a range of radio access technologies including LTE-A, Wi-Fi and any future 5G technologies. These technologies will be used in macro, small and super small cells and will integrate various radio technologies flexibly and in various combinations.

**Performance:** In 5G, the best possible network performance will not be just about peak speed. There will be a wide range of performance measures to meet individual requirements imposed by each use case. Some real-time applications, such as driverless cars, will require virtually zero latency, while others, such as 3D video capture, will be more tolerant to latency but will require high capacity upload instead.

### **III. Policy enablers:**

Because 5G must be compatible with previous technologies and evolvable to include use cases and challenges not currently identified, it will require a substantial amount of new research into advanced network capabilities. Policymakers can facilitate robust investment by adopting policies that increase value throughout the mobile broadband ecosystem, incentivize and reward innovation, promote standardization, and empower consumers. Several ongoing policy discussions could have significant implications for 5G, including:

- **Intellectual property/standardization:** A key enabler of 3G and 4G has been the existence and success of multi-stakeholder standards organizations that encourage competitors to share technology and the time of key engineering staff to develop solutions to technical challenges.

The resulting standards, frequently adopted in multiple markets, create scale for manufacturers and lower deployment costs for mobile operators. Unfortunately, the incentives to participate and standardization and share technology are being threatened by disputes over the value of standards-essential patents (SEP).

Efforts led primarily by handset makers to limit the right of SEP holders to seek injunctive relief against infringement, and to add restrictions on reasonable royalty rates are raising concerns about the ability of SEP holders to obtain fair, timely portfolio level royalties for technologies shared through standardization. While this is not traditionally within the FCC's policy domain, Nokia has repeatedly encouraged the Commission to add its voice to the current debate among U.S. government policy stakeholders. A successful transition to 5G depends on the wide availability of the key technologies at reasonable price points, and which include key solutions to technical challenges like latency and power consumption. Failure to ensure that innovators like Nokia have appropriate incentives and opportunities to receive fair value for shared technology will lead to a recalibration of standardization.

- **Spectrum policy:** Nokia believes in a varied, and aggressive approach to spectrum supply. Single-use spectrum is preferred by many mobile operators, and is an important ongoing input to facilitate innovation, coverage, and performance. However, Nokia strongly supports efforts to increase spectrum-sharing opportunities between commercial and government users in bands currently occupied by federal government agencies. Increasing testing opportunities, as the Commission contemplates through efforts like the Model City inquiry, are critical to innovation. Nokia supports these efforts and encourages the Commission to continue pursuing opportunities for collaboration, demonstration, and testing.

#### **IV. Recommendations:**

Nokia included a number of recommendations with its technical discussion in its initial comments. Nokia continues to believe that this proceeding is important and commends the Commission for seeking a wide range of technical and policy inputs. Nokia offers reasserts the following recommendations for the Commission's consideration:

- 5G will use existing and new IMT spectrum below 6 GHz, as well as from 6-100 GHz. Therefore, while we applaud the Commission for exploring new spectrum above 24GHz to expand mobile broadband connectivity to consumers across the nation, we urge the Commission not to exclude other bands, below 6GHz and from 6-100GHz, that may become relevant for 5G, especially if there is potential for harmonization with other parts of the world and ITU.
- While TDD is a good candidate for 5G millimeter wave systems (mmW), at this early stage of 5G research, the Commission should not mandate TDD for mmW systems, but should leave the door open to FDD and other new types of duplexing that may be available in the future.
- Nokia also recommends that the Commission extends every effort to make large blocks of contiguous spectrum (e.g., at least 400MHz) available to the extent possible.
- Some parts of the mmW range, like 57-64GHz, could play the same role as WiFi plays in the bands below 6GHz. For these unlicensed 5G bands, a decentralized Wi-Fi-like deployment, in which network elements are mostly deployed by end users, could be used. This model offers service with limited coverage utilizing low-power access points.
- Phased array solutions with integral antennas are likely in mmW bands. Therefore, it would be appropriate to define EIRP limits but also allow them to be not only measured but also calculated based on independent measurements of Transmit Output Power and antenna gain. Both spectral density and aggregate channel power values are pertinent to the assessment of incumbent service protection.
- A mobile allocation is one of the most important criteria for the identification of bands for advanced mobile wireless services and all but the 24GHz band in the 5G mmW NOI have existing mobile allocations. The 24GHz band is still a viable band because they are available in other countries.
- The Commission should add a mobile allocation in the 24GHz band and develops mobile service rules for all of the bands identified in the 5G mmW NOI. Nokia also support other

bands below 6GHz and from 6-100GHz.

- To maximize the positive outcome of identification of the right bands at the WRC 2019 several aspects related to new frequency bands need to be assessed and studied, including:
  - Frequency ranges that contain bands which already have worldwide primary allocation to Mobile Service should be considered as more likely options for possible spectrum designation and need to be further studied.
  - Spectrum bands that are harmonized at least regionally should be given high priority.
  - Availability of contiguous spectrum (e.g. at least 300MHz) should be taken into account.
  - Current use of these frequency ranges should be further investigated.
  - Minimum bandwidth requirement should also be considered as a criterion for the selection of frequency ranges.
  - Coexistence with systems in the bands under consideration and in adjacent bands.

Respectfully submitted,

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FutureWorks

# looking ahead to 5G

Building a virtual zero latency gigabit experience

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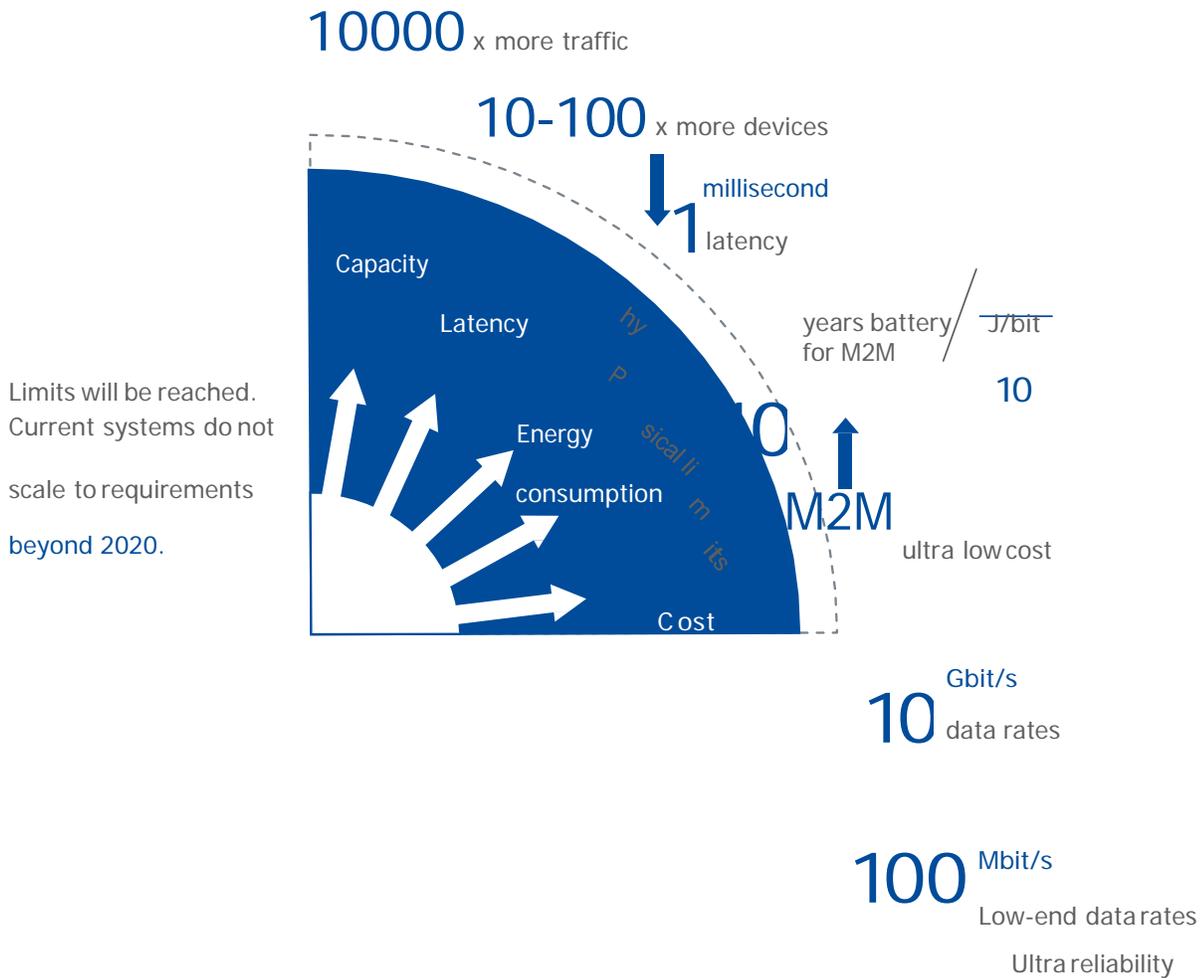
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## 1. Three key development areas in 5G

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.



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 0 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 foresees 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.

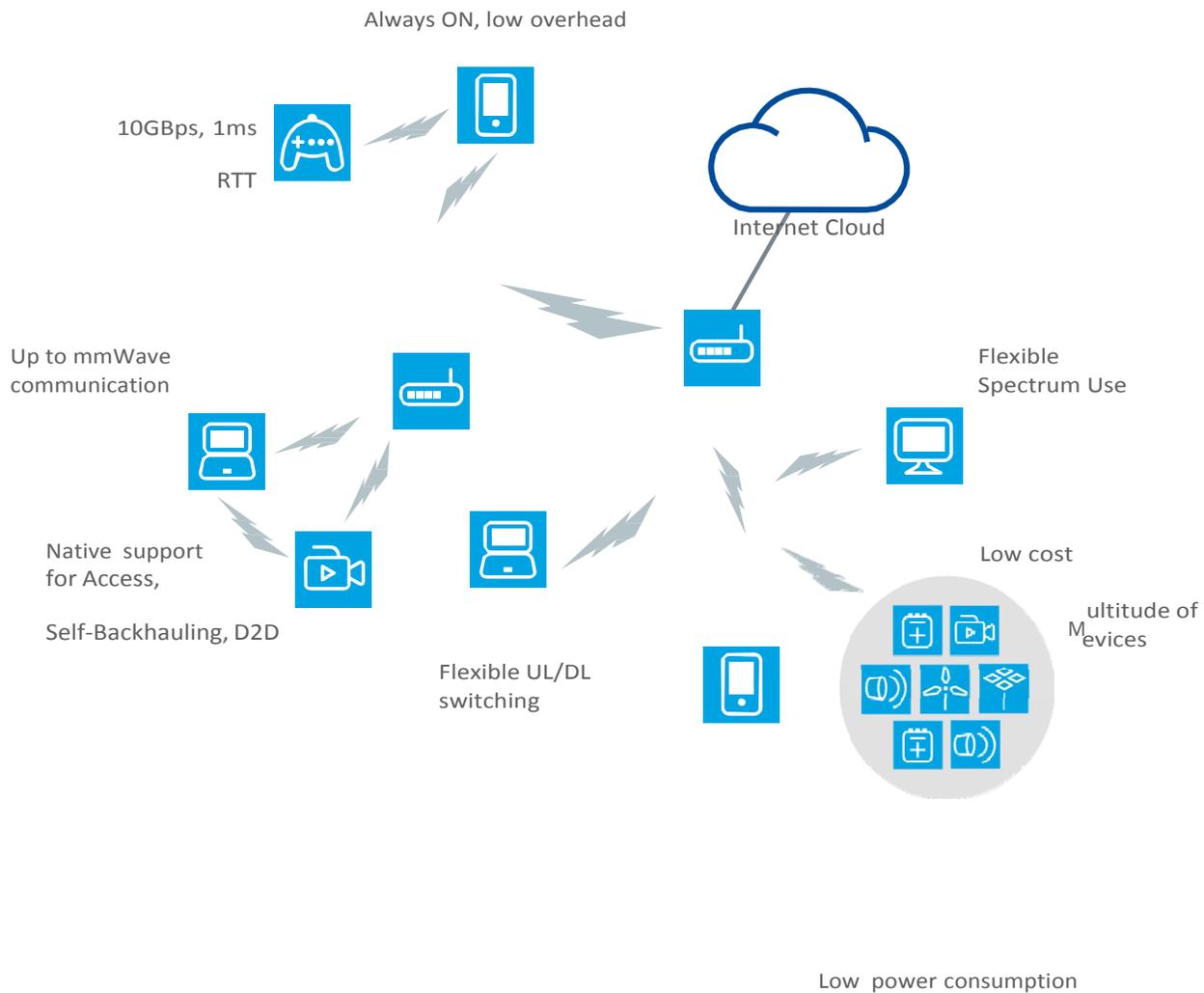


Fig. 2. Ultra dense deployments with many diverse use cases and scenarios set a variety of targets and functional requirements for a new system.

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.

### **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.