ERILLISVERKOT

Mission Critical Top Tech Trends 2023

5G technology and Erillisverkot: review of new possibilities

21st September 2023

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1. Background and purpose of the review

The basic communication and information retrieval needs of the authorities do not differ from the needs of everyday consumers. The world has permanently switched to mobile broadband and we all benefit from the new services it enables. Authorities and other Mission Critical actors should also follow this development which, if implemented well, will make their processes and operations more efficient. The adoption of new technology is complicated due to the special requirements posed by the Mission Critical operating environment, such as those relating to security, availability and reliability of services, and contingency preparedness.

The technology roadmap for Erillisverkot ensures the development of services offered to its customers and helps to choose suitable technologies when developing new services. The roadmap describes the development prospects for Erillisverkot's services (mobile data, group calls, group video, cloud, situational awareness and network operator services). These areas include numerous development targets that utilise or even require features provided by 5G networks.

This 5G technology review describes the possibilities provided by 5G technology for the development of Virve 2 services.

2. 5G – what's changing, or will anything change?

What can 5G technology be used for? Are 4G broadband services not enough for the authorities and other Mission Critical actors? These are pertinent and understandable questions. 5G technology and the new features and possibilities it brings are frequently discussed in a variety of contexts, but rarely from the point of view of the authorities' operations.

5G technology alone will not solve all problems. New technologies are always interesting, but it is essential to test them to fully understand the new possibilities they bring. This helps us to judge whether we at Erillisverkot could use those to enhance existing or new services provided to the public safety authorities and at what price.

Mobile technology has developed steadily since the 1990s, with about one new technology generation (GSM/3G/4G/5G) per decade. At the same time, the way mobile phones are used has changed from voice to text messages, mobile e-mail and finally, supported by the mobile internet, to numerous social media applications and games, for example. The numerous applications created in the wake of the mobile internet and smartphones paved the way for the triumph of mobile services. Today, a smartphone or other mobile device can be used anywhere and at any time to handle all the things that previously required at least a phone, calculator, computer, (video) camera and fax, as well as a lot of time to physically visit a bank, for example.

Until now, mobile network functionalities have mainly focused on consumer services. Exceptions include functions enabling the prioritisation of the authorities' traffic, the development of mission-critical voice/video/data communication services (MCS) and non-public networks (NPNs) isolated from public mobile networks that are suitable for a variety of purposes. 5G is the first generation of technology that has genuinely been developed with the aim of taking different user groups and use cases into account.

As devices and networks develop, 5G services will gradually become available to the authorities and make operations more efficient by offering many new possibilities and improving the availability of existing services. At the same time, older generations of

technology are gradually being phased out. 3G services will be the first to be phased out in Finland with the mobile operators aiming to complete the 3G shutdown by the end of 2023.

The features brought by 5G technology, such as

- lower latency
- higher data rate and capacity
- edge computing
- augmented and virtual reality (AR/VR)
- more effective use of network resources for group communication
- improved data security
- massive IoT[1]
- new possibilities for expanding the service area

enable new innovative solutions that can improve the efficiency of the authorities' operations and the security of society as a whole.

There is no need to fear 5G technology, but we can also live without it — at least for now. However, smartphones already support all current network technologies, so the adoption of new technology might first only be seen as better availability and speed of services.

The Virve 2 network produced by Erillisverkot and the related services utilise the radio networks of a commercial operator. The availability and service area of 4G networks are currently the most comprehensive in Finland, so 4G networks are still best suited for the authorities' use. By the end of the 2020s, the service area of 5G networks will develop to the same level as the current 4G networks. During the technology transition, the Virve 2 end user will automatically be served by both 4G and 5G technology in their various forms.

Some services, such as data-intensive applications that utilise augmented reality, require more network capacity. Without special solutions, such capacity will only be available in sufficient quantities in urban areas where higher frequency bands and their broader bandwidths – up to 100 MHz – can be utilised. However, nationwide basic-level coverage for 5G will be built in frequencies below 1GHz, with only 10MHz bandwidth available. As a result, radio networks may not necessarily provide a uniform level of service everywhere if the highest data rates are not available. However, if necessary, the situation can be slightly improved by certain special solutions, such as tactical bubble networks and locally implemented services.

2.1. Significance of standardisation in the development of mobile technology

The 3GGP[2] is responsible for producing mobile technology specifications for standardisation organisations globally. Completed in 2019, Release 15 was the first release of the 3GPP standards that included specifications for 5G mobile technology. This release included, among other things, the definition of 5G radio technology (New Radio, NR). In the following year, Release 16 was released, which included additions and improvements to 5G. In addition to new

[1] https://www.thalesgroup.com/en/markets/digital-identity-and-security/mobile/massive-iot

[2] 3rd Generation Partnership Project, https://www.3gpp.org/

features that improve broadband and reliability, it defined a completely new network architecture to support future use cases.

These first releases of 5G are still relevant. The benefits of 5G, in terms of better data rates (especially downlink) and lower latency, are today typically provided by the first phase (Release 15) 5G NSA (Non-Standalone) networks. This means that so far we have only seen a fraction of the potential inherent in 5G. However, mobile network operators are beginning to transition to the phase two (Release 16) 5G architecture called 5G SA (Standalone). Using the 5G SA network architecture and evolving it further (Releases 17–19), mobile operators around the world will be able to provide the full benefits of the 5G technology.

For example, the 3GPP Release 17 (2022) includes the first version of 5G NTN (Non-Terrestrial Network) technology, which allows ordinary smartphones to take advantage of the 5G radio network provided by LEO[3] (Low Earth Orbit) satellites. The 5G NTN technology would improve the reliability of public safety operators' terrestrial networks by, for example, further expanding the network coverage area and introducing NTN connections as a backup connection to support the terrestrial radio network.

In each release of the 3GPP standard, new functionalities are defined, existing services are improved and, if necessary, corrections are made to old specifications. Towards the end of 2023, 3GPP is mostly working on Release 18, which was launched under the 5G Advanced title. In that release, the features of the NTN technology of the previous release, for example, are supplemented by adding various architecture options to the standard and enabling direct satellite-to-satellite communication. For Release 19, the first phase of use case specification is being carried out regarding, for example, IoT technology that utilises ambient energy (Ambient IoT).

2.2. 5G enables better security

2G and 3G mobile technologies are outdated in view of today's security threats and should no longer be used in critical communications. For historical reasons, all commercial operators also in Finland continue to rely on these technologies, for which extensive geographical coverage has been built over the years. However, all the services provided by the above-mentioned technologies can already be provided with newer and significantly safer technologies (4G, 5G). Virve 2 service has been designed to only work in Finland on 4G/5G and future technologies.

In 4G, which is a packet-switched technology, both network and end-user data security and data protection have been better taken into account than in 3G or 2G. However, it should be kept in mind that this technology, which was first released as early as in 2009 (3GPP Release 8) and has since been updated several times, also involves challenges. Thanks to extensive international cooperation at various levels, these have been successfully solved over the years to make services built on the 4G technology safe to use.

Today, 5G is clearly the safest of the mobile technology generations. 5G technology can take full advantage of several built-in security-enhancing features, such as newer encryption

[3] https://en.wikipedia.org/wiki/Low_Earth_orbit

algorithms, enhanced network security and roaming security features. Deployment of these features is decided by each mobile operator on its own – often commercial – standpoints.

2.3. 5G enables better energy efficiency

In a digitalised world, the energy consumption of various information systems and networks is significant, and the provision of services related to mobile data naturally plays a part in this. In 5G networks, energy savings have not been specifically taken into account in accordance with the current principles of sustainable development, but 5G technology is still significantly more energy-efficient than previous mobile technologies. This can already be seen in the 50% better spectral efficiency (bps/Hz) of radio technology compared to 4G. With regard to the latest 3GPP releases, we will see more ways to save energy, and they will also be developed by equipment suppliers and operators outside technology specifications.

2.4. 5G and non-public networks

As 5G has become more common, companies have started to increasingly build closed 5G radio networks (Non-Public Network, NPN) tailored for their own use. In addition to base stations, these 5G networks have dedicated core networks and other necessary functionalities. They are usually implemented completely isolated from commercial networks, allowing services to be built to suit each specific purpose, such as automation of industrial plants, airports or mines. Non-public networks require the use of a dedicated SIM card (or eSIM) and do not normally provide the service to other users. The availability, performance and data security of the network are the network owner's responsibility, as is maintenance of the network. Non-public networks have their own frequencies, so the presence and interference of other networks do not affect their operation.

In terms of mission critical communications, the role of non-public networks is twofold. If a non-public network has already been built at the site, it may not be desirable from the network users' point of view to build additional Virve 2 network coverage for the authorities' operations (e.g. mines). Using non-public networks as part of the nationwide Virve 2 critical communications service would be challenging, but potentially feasible under certain conditions. This would require interconnecting the networks and, for example, prioritising services of the authorities in non-public networks.

It should also be kept in mind that every NPN implementation connected to Virve 2, including its use cases, must be carefully considered in advance, and planned, tested and maintained carefully, also taking data security aspects into account. This will not only cause extra work for the design, testing and maintenance of Virve 2, but also impose requirements for NPN operations. In some cases such as nuclear power plants, this may be the most economically advantageous and sensible solution, in which case the non-private network could be connected as part of the Virve 2 network. However, this requires more detailed investigations and policy guidelines, as well as case-specific detailed planning.

3. 5G provides new possibilities

We are only starting to use 5G technology and it has not been possible to utilise all of its potential yet. Even the first phase of 5G NSA offers advantages over 4G technology. As the development progresses towards end-to-end independent 5G SA networks with more

advanced 5G services, new services will also emerge for mission-critical communications purposes.

3.1. 5G network development trends

In 2015, the International Telecommunication Union/Radiocommunication Sector (ITU-R) published the first visions[4] of the requirements and main development trends set for 5G networks and services, including different 5G use cases for different operating environments. In Figure 1 (p. 8), the services enabled by Virve 2 have been placed under these three main development trends of 5G networks, which are:

- Enhanced Mobile Broadband (eMBB) services
- Ultra-reliable and Low-Latency Communications (URLLC)
- Massive Machine Type Connectivity (mMTC).

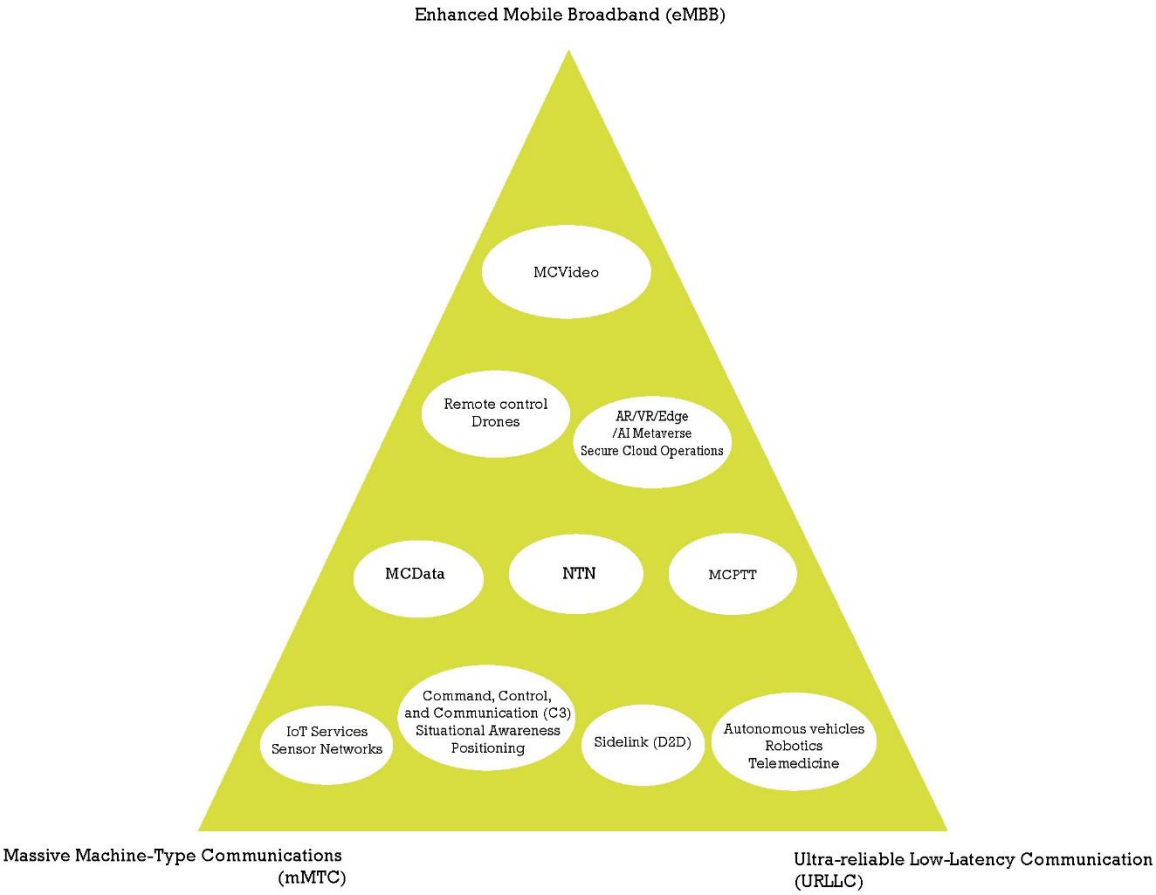

Figure 1. Virve 2 services utilise 5G development. (Adapted from the ITU-R IMT 2020 use cases)

[4] https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

3.1.1. Network slicing

One of the new features provided by 5G networks is network slicing, which allows some of the mobile network resources to be reserved for a specific purpose, such as the authorities' data traffic or IoT services, according to service specific needs. Wider use of network slicing is still limited due to the challenges posed by the new network capabilities it requires, the complexity of it, and the lack of use cases that could not be implemented without network slicing.

3.1.2. Edge computing

Where necessary, data processing in 5G networks takes place near the end users using edge computing instead of transferring the data to a non-public or public cloud for processing. This enables, for example, virtual and augmented reality (VR/AR) services that require very low latency. If implemented correctly, edge computing can also further improve data security and data protection related to data processing as the data remains genuinely local. In Virve 2, edge computing could be realised with dedicated base stations in the customer's high security premises keeping both the customer's mobile use and the data local.

3.1.3. 5G device to device communication

The reliability and availability of communication services are crucial to the operations of public safety authorities. However, mobile networks are not always available, in which case device to device communication between devices is required. This is a device feature that requires support from the chip set used inside the device.

There are several technologies available for implementing device to device communication, of which 5G Sidelink, as defined by 3GPP, is one potential solution. However, equipment suppliers will still need more time to work on making Sidelink available to the end user. In the meantime, Virve 2 device to device communication may be implemented by other technologies.

In the future, new 5G functionalities such as relaying the radio signal via intermediary devices (5G Relay) can be used to expand the range between two devices.

3.1.4. Drones

The use of drones in the authorities' operations has increased considerably in the past few years. The 4G network can already be used, for example, to monitor the common operational picture transmitted by drones. 5G technology expands drone use cases even further. In future, the integration of drone operations with 5G networks will enable their autonomous operation and a secure and reliable operating environment.

As the 5G evolution progresses, the utilisation of drones also in consumer use and business activities will become more controlled and easier to monitor. As the technological development and properly implemented regulation of autonomous drone operations evolve in stages during the 2020s, new possibilities for their use will emerge for many public safety actors.

3.1.5. Reliability of data transmission

For mission critical communications, it is essential that the service is always available when needed and that it works reliably also in various challenging situations. In fixed telecommunications networks, service availability and data traffic can be ensured by, for example, duplicating transmission connections.

In practice the same applies to mobile networks, but so far the functionality has not been implemented to the radio interface between the device and the base station. 5G will improve reliability significantly in the future as data transmission in 5G networks can be secured by sending the same information via two different base stations or even via two different networks. Both of these aspects related to 5G URLLC development will be become possible following Release 18 (5G Advanced). This part of 5G networks and services will be developed further as time goes on.

3.1.6. 5G and positioning

Many current mobile applications need positioning to function (for example, map applications) or to improve their functionality (additional application information tied to positioning). Triangulation already provides fairly accurate positioning from mobile networks for the needs of emergency calls. However, application-specific positioning today mainly relies on various global navigation satellite systems (GNSS), such as GPS or Galileo. However, satellite-based positioning involves its own challenges related to, for example, availability and reliability. The Galileo PRS service will help to solve those challenges in the future.

5G will also provide improvements in mobile network positioning. In future 5G mobile networks, positioning based on base stations will also include altitude data. Accurate vertical positioning can be used to identify the floor where the maker of an emergency call is, for example. In addition, 5G's reliability of positioning and positioning accuracy (<1m) will be a clear improvement to what the previous network technologies could offer.

The need for satellite positioning will not disappear, but there will be alternatives available for it. Especially in applications used for contingency preparedness purposes.

3.1.7. AR/VR, metaverse and other possibilities

Augmented and virtual reality (AR/VR) and digital twins will bring a major transformation to especially different learning environments in the future. Internationally, there are already examples of virtual learning environments that have achieved significantly better learning outcomes at a fraction of cost, such as replacing aircraft cockpit simulators with virtual reality glasses and environments. As part of cooperation with the authorities, 5G technology can be used to provide solutions tailored to different needs from educational use to field operations.

The development of mobile network technology enables completely new types of services based on information brought into the user's field of vision. These services are most frequently referred to as:

- Augmented reality (AR). The user can perceive the physical world, which is enriched by information augmented to it. For example, virtual internal organs of the person being treated, and the related common operational picture and measurement data seen by a paramedic with AR glasses.
- Virtual reality (VR). The user sees a completely artificially created environment. The view reacts to head movements and possibly to other user actions. For example, the Finnish Defence Forces' fully virtual training environment for training operations of different military branches before moving on to practical exercises.
- Mixed reality (MR). The user can perceive the physical world, which is enriched by information augmented to it. The physical world and the artificial world interact. For

example, a view from surveillance cameras near a police patrol projected onto a police car windscreen; the possibility to choose between showing real-time video from them and enriching situation information with, for example, additional information about the fleeing car thief or a map application helping the patrol to take the fastest route to reach the thief.

- eXtended reality, XR. A generic term covering the solutions mentioned above.
- Metaverse – a virtual multi-user world where interaction between physical (people present, things, objects, etc.) and virtual elements (real people, augmented objects and information placed in the virtual world) is real-time, interactive, and seamless. For example, the Rescue Department's training environment for extinguishing various fires, where the extinguishing work as such takes place in the real world, but some of the fires, people and environment are real and some are virtual.

When there is a lot of information available and its content depends on the movement of the head or reacts to the physical world, very short latency and latency variation are needed to achieve a good user experience. As the data transmission requirements are considerable, it is essential that both the 5G and the transport network provide high quality end-to-end connections. For example, some metaverse or augmented reality solutions can leverage network edge computing capabilities to meet the above-mentioned needs. Some of these solutions require separate application features that are developed for this purpose and are more closely integrated into the 5G network.

For public safety actors, XR solutions bring some new possibilities, the most important of which are creating a training environment and obtaining a better situational awareness. In training use, different situations can be simulated at lower costs than those of a physical environment while keeping the training conditions constant if needed when the exercise is repeated. XR also makes it possible to practice situations that are not simple or safe to create in the physical world. While XR will not completely replace training in the physical world, it complements it well.

Augmented reality helps both the people operating in the field and, for example, the field commander operating remotely in creating a common operational picture. For example, static safety-related information or information that reacts to the physical world, such as other persons, buildings, vehicles or directions, can be projected into the field of vision of a person operating in the field.

The technologies listed above are present in the future plans of telecommunications solution providers. Metaverse solutions are considered important in the visions for the future of Nokia, Ericsson, Samsung and Qualcomm, among others. Apple also released a device suitable for AR and VR use in 2023. XR solutions can be deemed to enjoy remarkably good support from different suppliers.

3.2. LEO satellites and 5G NTN services

3.2.1. LEO satellite services

In LEO constellations, telecommunications satellites orbit the Earth at an altitude of about 600 to 1,200 kilometres. The main differences from geostationary (GEO) satellite services above the

equator at an altitude of 36,000 kilometres are the low latency of the data transmission services provided by LEO satellites, the small size of the receiving antennas, and the availability of services at high latitudes. MEO satellites at an altitude of 5,000 to 20,000 kilometres are located between the LEO and GEO satellite services. Each LEO satellite constellation has several orbits, so the availability of services at higher latitudes depends on the tilt of the orbits relative to the equator. As a rule, the use of LEO/MEO/GEO satellite services always requires an antenna and a receiver tailored for the service concerned.

Currently, only Starlink (SpaceX) and Oneweb (UK) offer commercial LEO satellite services in Finland. For example, the constellation of the Kuiper LEO satellite service, designed by Amazon, does not serve high latitudes, at least not for the time being. Starlink's LEO constellation has thousands of satellites in different orbits, some of which also fly over the poles.

LEO satellite constellations are expensive to build; for example, the Kuiper service is estimated to cost nearly $10 billion (US), so many companies (Facebook/Meta Athena) have cancelled their plans or cut the numbers of satellites (e.g. Telesat/Lightspeed).

Figure 2. IRIS^2

On 22 November 2022, the EU launched its own IRIS^2[5] (Infrastructure for Resilience, Interconnection & Security by Satellites) satellite service, which consists of services provided by a combination of LEO, MEO and GEO satellites. The aim of the project is to build secure and reliable satellite services for the EU Member States by the end of 2027. The total cost of IRIS^2 has been estimated at around €6.4 billion.

3.2.2. 5G NTN services

3GPP completed the technology specifications that allow ordinary mobile phones to utilise satellites as a single transmission path without a separate satellite receiver in Release 17. This

[5] https://www.euspa.europa.eu/newsroom/news/new-iris%C2%B2-constellation-will-be-beneficial-eu-citizens-several-ways-find-out-5-them

https://defence-industry-space.ec.europa.eu/eu-space-policy/iris2_en

technology is called 5G NTN (Non-Terrestrial Networks). 5G NTN satellites operate alongside terrestrial 5G networks as one of the connectivity technologies for mobile networks. 5G NTN services use LEO satellites as an alternative 5G radio path between the 5G devices and the servers on the ground. In the first phase, the satellite will act as a transponder of the 5G signal, but later it will also be possible to have base station functions to the LEO satellite in the sky. This solution will improve the radio network functionality and will enable new features, e.g. direct communication between satellite base stations.

NTN solutions have already been successfully tested by several operators (e.g. AST SpaceMobile, Omnispace). If commercially realised, NTN networks would enable the use of 5G network services in areas where there are no terrestrial networks at all, they are unavailable for some reason, or their coverage is poor, such as in sea areas, wilderness and desert areas, rainforests, and polar regions. However, the spread, schedule and availability of 5G NTN services, especially at high latitudes (> 60°N), is still unclear.

Satellite services will play an important role as part of the Virve 2 services, as they can be used to provide transmission for mobile Virve 2 base stations. Later, when IRIS^2 will offer 5G NTN services, they can be utilised for data services independent from the terrestrial network complementing the Virve 2 services. However, data security must always be considered. In critical communications, it is essential to identify all the nodes involved in data transmission and the entire route end-to-end, using only reliable operators.

The real breakthrough in the performance and availability of NTN networks is not likely to occur until the 2030s with the advent of 6G and vLEO satellites (vLEO = very low earth orbit at an altitude of ~300 km).

4. What after 5G – 6G?

In this review, we discussed the possibilities provided by the 5G technology, especially for public safety actors. Some of these are already available. However, mobile technology is constantly evolving and the technology of next-generation 6G mobile networks has also been the subject of research for a few years now. 3GPP is expected to start the technical specification based on 6G research in the next few years. The first services based on 6G networks are expected to become available at the turn of the 2030s.

The new generation of 6G technology will continue to increase mobile network capacity and data rate and reduce latencies. In addition, 6G technology will bring new possibilities for connecting to and using the network, taking better account of the needs of different user groups. 6G networks are expected to provide further improvements related to authorities needs, especially in the areas of network reliability and application specific traffic needs. In addition, 6G research has already revealed new technologies that are likely to benefit public safety actors.

In the 2030s, artificial intelligence, autonomous devices (e.g. drones), AR/VR as well as metaverse and NTN services will be commonplace also in the authorities' operations. Alongside them, new technologies are evolving:

- Sensing capability in both the devices and the radio network, which could make it possible to, for example, map out in real time a floor plan of a smoke-filled and previously unmapped building for a smoke diver or produce various security controls for critical sites
- IoT devices utilising ambient energy collection, enabling extensive autonomous solutions independent of traditional sources of electricity for the needs of border control, for example
- Wearable sensor technology to ensure the functioning capability of field officers, collecting the energy needed for the sensors from the user's own kinetic energy.

Many research projects have also highlighted the need to develop technology that supports sustainable development and is more energy efficient, taking into account the UN's Sustainable Development Goals[6], which are expected to become key starting level requirements for technical specification work in future.

It can be concluded that, in addition to technological development, 6G technology seeks to integrate as part of society and its core values in a way that is more extensive, responsive to the different user needs and inclusive than the previous generations.

It is important to participate in the specification work of 6G technology and at the same time influence the development of mission critical technology from research desks to technical standards. Erillisverkot works in co-operation with many countries' public safety authorities, mission critical communication associations, industry, various research projects and standardisation organisations and can thus highlight the mission critical communication needs of public safety users. In addition, continuous dialogue with customers about future needs and visions is of paramount importance, as 6G networks and services are built together.

5. Summary – future possibilities for public safety actors

Compared to previous generations of technology, 5G offers faster data rates, higher capacity, more reliable connections, and more accurate positioning. The new 5G technology enables the reliable transmission of larger amounts of data over the radio network in nearly real time, which increases the efficiency and accuracy of communication between different parties. In addition, connecting various smart IoT devices and sensors to the 5G network wirelessly becomes easier. Various IoT devices can be used to predict, detect, monitor the environment and report dangerous situations, such as fires or dangerous goods, and transmit information reliably, safely and quickly to those who need it with the help of the Virve 2 network.

The introduction of 5G technology enables the integration of Virve 2 services with other actors as well as with other networks, devices, and applications. This enables seamless cooperation and exchange of information between different public safety authorities and other actors critical to society, as well as towards citizens. With 5G, communication and exchange of information between different networks and services will be even smoother, which will contribute to more efficient management of operations and improve the overall situational awareness. The continuous development of technology and innovations increase the possibilities to improve the functionality and efficiency of Virve 2 services.

[6] https://sdgs.un.org/goals

Virve 2, which is currently in the deployment phase, provides its end users jointly developed, reliable and secure mobile services already today. Networks, devices and services based on 5G technology will provide public safety actors even more advanced services and better data security.

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