5G IN THE ACTIVITIES OF THE FINNISH TRANSPORT INFRASTRUCTURE AGENCY
FTIA as a user and enabler of fast data connections
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Abstract

The purpose of the study was to identify the benefits, needs and challenges of digital infrastructure in the activities of the transport infrastructure authorities, and to find out how the Finnish Transport Infrastructure Agency (FTIA) can enable and promote the development of telecommunications networks. The objective of the study was to provide input for the planning and development of FTIA's activities, increase the awareness of various parties with regard to infrastructure management connected with the impact of telecommunications issues on operating methods, and identify the division of duties between public and private actors.

The future development needs of data connections in road traffic are mainly related to the increased communication by vehicles and the development of autonomous traffic. The current understanding is that the communication between future vehicles will not occur via mobile networks alone; rather, some of the applications that require delay-critical or large-scale data transfer rely on direct communication between vehicles. In principle, however, many of the new services and development steps in traffic do not require a 5G network; instead, a large portion of the development in the near future can already be implemented using the current networks. For road traffic, network coverage can be considered a more important factor than significantly faster connections. One of the factors slowing down the development of data connections in road traffic is the lack of clear road traffic revenue models that would allow the operators to cover the costs of developing data connections.

The key future development needs of railway traffic are linked to the replacement of the Finnish train control system (JKV) with the European ERTMS system. There are several issues connected to the deployment of ERTMS that must be resolved before taking a position on the possibilities of using a 5G network in railway traffic. Currently, the most benefit in the cases of use in railway traffic is being gained by increasing the mobile network coverage and improving the connections in general. In their current state, the new IoT networks can already offer cost-effective solutions for using remote sensors, for instance – especially for functions that are not safety critical.

5G is the next generation of mobile technology, and it will be implemented more extensively during the 2020s. The 5G network does not eliminate the need for older network generations; instead, 3G and 4G connections will also be sufficient for many purposes in the future. In addition to the traditional mobile networks, operators have launched NB-IOT and LTE-M networks on the market; they enable the use of IoT sensors. These networks should be operational throughout Finland in the early 2020s. According to the current understanding, the 5G network will most likely be built in three individual frequency ranges, the characteristics of which complement each other. The low frequencies enable a cost-effective way of implementing comprehensive 5G coverage, while the high frequencies enable a high data transfer capacity at specific sites. Users’ needs and the costs of
network implementation are the most important factors for the establishment of a 5G network.

In the current understanding, the 5G network will initially be built on the existing 4G and 3G base station sites. Using the existing base station sites does not require significant construction of masts or a fibre network, with some individual exceptions. The 5G network coverage will mainly be implemented by using low and medium frequencies. According to the current views of various actors, implementing an extensive and comprehensive high-frequency 5G network next to the main routes seems very unlikely in the near future. At most, high-frequency 5G base stations will be implemented at specific sites in order to offer a higher data transfer capacity than before.

During the study, methods that the Finnish Transport Infrastructure Agency can use to promote the realisation of the 5G network and other data connections along the main roads and railways were identified. In order to determine measures having the right scope, the role of the infrastructure manager as a promoter of data connections should be clarified first, however. During the study, the following measures for promoting telecommunications issues were identified:

**Strategic management**
1. The role of the transport infrastructure authorities in promoting telecommunications issues requires clarification.
2. Data connections should be more closely linked to infrastructure development and service level goals

**Development of operating models and processes**
3. The joint use of digital infrastructure should be promoted in traffic areas
4. Co-operation between authorities and operators should be closer and more systematic
5. Data connections should be taken into account earlier in transport infrastructure authorities’ project procedures
6. The co-ordination of cable relocation should start during the planning stage
7. The implementation process can be made smoother by developing siting permit procedures

**Technical incentive measures**
8. Cost-effective preemptive construction requires co-operation with operators
9. Preemptive construction of passive infrastructure must focus on the right targets
10. The exact measures required for the construction of a high-frequency 5G network will only become apparent in the future
Foreword

The transport sector is undergoing major changes and its development is being simultaneously affected by several change drivers. One future development path will be an increase in automated traffic, which may also lead to new kinds of requirements for data connections on main transport routes. Promoting the implementation of 5G networks has been placed at the forefront of many new national strategies and programmes. 5G is expected to bring new services and business opportunities in, for example, transport and industry.

The purpose of this preliminary report is to identify the benefits, requirements and challenges that digital infrastructure will bring to the transport infrastructure authority’s activities, and to find out how the Finnish Transport Infrastructure Agency (FTIA) can enable and promote the development of telecommunications networks. The report’s primary goal is to examine these activities from the perspective of road and rail transport in particular.

The analysis was carried out in the period May–October 2019. It is based on a total of 25 interviews with representatives of the Finnish Transport Infrastructure Agency, telecommunications operators, ELY Centres, cities, research institutes, and traffic management companies. The interviewees were asked about the development of 5G data connections, and in particular about connections along main transport routes and the opportunities and challenges involved in developing data connections.

The conclusions drawn from these interviews were further detailed and expanded on at a separate workshop in September 2019. This workshop went through various parties’ perspectives on the development of data connections, the key enabling measures required from transport infrastructure authorities, and the developments that various parties would need to make in order to ensure smooth collaboration.

This preliminary report was commissioned by the Finnish Transport Infrastructure Agency, and Jari Myllärinen and Jan Juslén have been responsible for steering and commenting on the draft report. The report was drawn up by Sitowise Oy, whose project team consisted of Olli Jokinen (project manager), Juha-Pekka Piuva, Laura Riihentupa and Mikko Mäkipää.

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1 Background and objectives

1.1 Background

The transport sector is undergoing major changes and is being simultaneously affected by several change drivers. Some of these drivers are based on climate change and the challenges posed by increasing traffic. Others relate to digitalisation and other opportunities afforded by technology. These changes will affect passenger and freight traffic, industry, and transport services. Legislation, technologies, business models and customer requirements are all evolving in these sectors. Initially, these changes will be most visible in major cities, where new types of business models and services are generally launched.

Developments to traffic and main transport routes will also be steered by a variety of European and national strategies and programmes. The objectives of Prime Minister Rinne’s Government Programme highlight functional transport infrastructure and functional communications and data transfer. The programme lists several methods of achieving these objectives, including building a nationwide fibre-optic network, promoting the joint construction of infrastructure, and promoting the realisation of digital infrastructure strategy. The programme states that the fibre-optic network is to be constructed primarily through a market-based approach and only secondarily with government, municipal and EU funding.

According to the Ministry of Transport and Communications’ Digital Infrastructure Strategy 2025, Finland’s goal is to develop a digital infrastructure that at the very least meets the European Union’s broadband objectives. The European Commission’s objectives state that Member States’ major cities and their key transport routes should be covered by 5G networks by the end of 2025. Finland’s digital infrastructure strategy defines technology-neutral broadband objectives for 2025 along with ways of achieving them. This strategy includes measures to both promote the adoption of 5G and support fibre-optic construction. The measures related to transport routes involve promoting the fast and cost-effective construction of networks combined with tax policies that will support the development of automated and smart traffic.

The significance of changes within the transport industry has also been noted outside the transport sector. The Ministry of Economic Affairs and Employment steered efforts to draw up the National Growth Programme for the Transport Sector 2018–2022, which primarily seeks to promote corporate-led development, growth and internationalisation in the sector. The purpose of this programme is to promote Finland’s position as an internationally recognised pioneer in research and innovation, top expertise, new business and investments in the transport sector. One element of this is for the Finnish transport sector to be an unbiased, pioneer market for user-oriented pilots of new technologies and services.
1.2 Objectives

The purpose of this preliminary report is to identify the benefits, requirements and challenges that digital infrastructure will bring to the transport infrastructure authority’s activities, and to find out how the Finnish Transport Infrastructure Agency (FTIA) can enable and promote the development of telecommunications networks. Its objective is to provide input for the planning and development of FTIA activities, and to make all parties involved with transport infrastructure management more aware of how telecommunications-related issues will impact operating methods. The report also identifies how tasks should be divided between private- and public-sector actors.

The report seeks to answer the following research questions:

- In what ways will the transport infrastructure authority be able to act as an enabler of telecommunications infrastructure and the services that will arise around it?
  - How will this work be divided between the Finnish Transport Infrastructure Agency and other actors?
  - What kind of development requirements will arise for operating methods and guidelines related to the construction and development of telecommunications infrastructure?

- What must the Finnish Transport Infrastructure Agency do to ensure that it can harness telecommunications infrastructure and services in transport infrastructure management?
  - What kinds of requirements will be placed on the agency’s own operational planning?

- What kinds of co-operation models should be developed with various parties?
  - What kinds of synergies can be identified between different actors, and in particular with cities, operators, and traffic management companies?
  - What kinds of expectations do operators have with regard to the Finnish Transport Infrastructure Agency’s activities?
2 Data connections

2.1 Wireless data connections

2.1.1 5G network

5G is a term used to describe the next generation of mobile networks. The previous generations – 3G and 4G – primarily resolved challenges arising from increased data transfer requirements and enabled faster speeds for users. 5G will enable more than simply faster speeds. It will also bring brand-new kinds of functionalities and features, such as splitting physical network capacity with the aid of network virtualisation.

2.1.1.1 5G technology will enable new use cases

The 5G network is a next-generation mobile network with improved radio network features. These include the use of more frequency bands and the capacity to transfer a larger volume of data. In a 5G network, it is easier to bring smart solutions even closer to users and reduce latency with the aid of edge computing, that is, to provide network services with the aid of cloud services in closer physical proximity to the user.

5G network capabilities will enable brand-new use cases for next-generation technologies. The ITU-R (International Telecommunication Union, Radio-communications Sector) has determined the three most important applications: eMBB, uRLLC and mMTC.

**eMBB (Enhanced Mobile Broadband)** – 5G enables extremely fast connections (up to 10 Gbit/s) and greater capacity over mobile networks. This means that, for the first time, wireless technologies will be able to offer a genuine alternative to fixed connections.

**uRLLC (Ultra-Reliable Low-Latency Communications)** – 5G will significantly increase the reliability of wireless networks and also reduce their latency to a level that will even be able to compete with optical fibre. 5G is the first wireless technology that will be able to offer reliable, low-latency connections.

**mMTC (Massive Machine Type Communications)** – 5G Network technology enables a great number of devices to be connected to a network within the same cell. Increased cell density will enable an mIoT (massive internet of things) to be created using 5G technology.
2.1.1.2 5G network will bring new capabilities

The features and functionalities of 5G networks will make it easier to create and provide new low-latency services. New capabilities will create both a foundation and opportunities for new use cases.

**Basic capabilities** – Fifth-generation mobile networks will bring not only faster connection speeds but also a seamless package consisting of new technologies, physical and virtual architecture and network topology – and this package will have a lot of expectations to live up to. Terminal devices should have access to a network whose speed, latency and reliability is comparable to a fibre-optic connection. At the same time, radio network cells must have the capacity to serve a much greater device density. If the fifth-generation mobile network meets these expectations, mobile connections will, for the first time, be able to compete almost equally with – and in some use cases even outperform – fixed fibre-optic connections.

<table>
<thead>
<tr>
<th>Speed</th>
<th>Latency (on air)</th>
<th>Device density</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Gbit/s</td>
<td>1 ms</td>
<td>1*10^6 / 1 km²</td>
</tr>
</tbody>
</table>

**Small cells** – The use of higher frequencies will be one of the most important factors behind the higher speed and capacity of wireless networks, and their lower latency. Transferring to higher frequencies also means switching to even smaller mobile network cell sizes, as signal range, coverage and penetration are all weaker at higher frequencies. On the other hand, reduced cell size enables lower latency.

**Edge computing** – In edge computing, computing resources are brought even closer to either the network user or the device using the network. Edge computing is required to lower network latency and reduce network congestion. For example, reaping all the benefits of an mIoT will require MEC (multi-access edge computing).

**Slicing** – Network slicing enables separate virtual networks for specific applications, user groups or customers to be created within a network. Slicing also enables these virtual networks to be equipped with their own speed and capacity. This feature also enables increased security, as traffic between terminal devices travels within its own virtual network.

**MA-MIMO** – ‘Massive Multiple Input and Multiple Output’ antennas are large antennas that are capable of sending and receiving multiple signals simultaneously. This enables a cell’s capacity and device density to be increased. These antennas can also be used for beamforming.

**Beamforming** – Beamforming means that a receiving device in a mobile network will receive a signal from the broadcasting antenna or antennas that has been optimised specifically for that receiver. Beamforming utilises several antennas to send the signal, and the signal is also reflected off surfaces. This improves the quality and speed of the connection. Beamforming can also be used in device locationing.
2.1.1.3 The 5G network will operate on several different frequencies

In addition to the advancements made in 5G network architecture, a significant proportion of the growth in connection speeds will be achieved by transferring to higher frequencies. During the first phase, 5G networks will be based on mid-range frequencies (the 3.5 GHz band) that were auctioned in 2018. In this auction, permits to use three 130 MHz frequency bands in the 3,410–3,800 MHz range were granted to Elisa, DNA and Telia. These permits for the 3.5 GHz frequency band came into force at the beginning of 2019.

The next phase will see the distribution of permits for the 5G network’s high frequencies (24.5–27.5 GHz). The distribution of these user rights is expected to begin during 2020. The use of high frequencies will enable increased data transfer speeds and capacity. The weaknesses of high-frequency bands include a shorter signal range and a greater sensitivity to signal disturbance due to, for example, obstacles in the signal’s path (such as buildings). In general, when challenges related to 5G signal reception and range are mentioned, they often refer to the use of the 26 GHz frequency band.

In addition to mid-range and high frequencies, 5G networks may also use low frequencies, such as the 700 MHz band, in the future. The 700 MHz band, which is currently used by the 4G network, was auctioned to operators and has been in use since 2017. Although 700 MHz frequencies will not be able to achieve the same data transfer speeds as higher frequencies, the signal’s longer range is a technical advantage that can be utilised to cost-effectively expand 5G coverage. In time, at least some 5G features will be migrated to frequencies previously used by earlier mobile network generations.

In theory, 5G network capabilities (such as low latency and network slicing using a 5G core) can also be implemented in all frequency bands – according to current understanding, they are not tied to any particular frequency band. In theory, 5G also enables the use of technologies on so-called licence-free frequencies: by using the network identity provided by operators, it would be possible to utilise 5G technologies on, for example, WLAN frequencies.

The table below gives a rough idea of the capabilities of various frequency bands. The actual figures will depend on many factors. More precise figures will be available when data from real 5G environments is available.

<table>
<thead>
<tr>
<th></th>
<th>4G</th>
<th>5G Low frequencies (700 MHz)</th>
<th>5G Mid-range frequencies (3.5 GHz)</th>
<th>5G High frequencies (26 GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data transfer (download)</td>
<td>5-300 Mbit/s</td>
<td>‘tens of Mbit/s’</td>
<td>~1 Gbit/s</td>
<td>~10 Gbit/s</td>
</tr>
<tr>
<td>Data transfer (upload)</td>
<td>5-30 Mbit/s</td>
<td>-</td>
<td>~1 Gbit/s</td>
<td>~10 Gbit/s</td>
</tr>
<tr>
<td>Latency (ms) (terminal device–base station)</td>
<td>&gt; 10 ms</td>
<td>&gt; 1 ms</td>
<td>&gt; 1 ms</td>
<td>&gt; 1 ms</td>
</tr>
<tr>
<td>Base station’s range (in an unobstructed, forested transport route environment)</td>
<td>2–15 km</td>
<td>2–15 km</td>
<td>500m – 2 km</td>
<td>30–300 m</td>
</tr>
<tr>
<td>Support for network splicing</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
2.1.2 Older mobile network technologies and other radio networks

Mobile network technologies have been developing rapidly due to the requirements placed on them by continually increasing data volumes and data transfer speeds. Although the introduction of 5G technology will enable new services, older mobile network technologies will continue to provide sufficient data connections for many purposes. Some 5G features have already been provided, or will be provided, for devices using 4G technology.

3G technology (third-generation mobile technology) was designed not only for voice traffic but also for data transfer via the internet. The biggest difference between 3G and the previous generations (1G and 2G) was the speed and method of data transfer. In Finland, 3G uses the UMTS standard. The data transfer capacity of 3G technology is 5–35 Mbit/s receiving and 0.1–4 Mbit/s sending. Compared to previous generations, there was increased processing of traffic at base stations. That is to say, base stations were made smarter, so that the load and signalling volume between the base station and centre could be reduced.

In 4G networks, it was the terminal devices that were made smarter, and more signalling interfaces were created between the network and its various elements. This was done to give users’ data traffic the most direct route over the IP network, thereby enabling increased capacity and lower latency. The data transfer capacity of a 4G mobile network is 5–300 Mbit/s receiving and 5–30 Mbit/s sending. 4G generally achieves a latency of 30–40 ms, which means that 4G can already be used for services that require considerably more real-time data transfer.

NB-IoT enables low-powered devices As its name suggests, NB-IoT technology was developed for IoT terminal devices. All of Finland’s commercial mobile operators have begun to introduce NB-IoT technology in their LTE networks, and almost nationwide coverage is expected by the end of 2020. NB-IoT was designed with an eye to low data transfer capacity and low-powered devices. The network’s maximum data transfer speed is 250 kbit/s and it has a delay of about 1.6–10 seconds. It offers good signal range and penetration, meaning that sensors and probes based on NB-IoT networks can be placed underground or inside buildings. NB-IoT technology is suitable for fixed sensors, detectors and probes. Sensors utilising NB-IoT technology can function for many years without being recharged. They can be programmed to send and receive data continually, at specific times, at specific intervals, or on the fulfilment of specific conditions. The terminal devices also have a standby mode.

LTE-M supports mobile sensors and enables fast connections Like NB-IoT, LTE-M is also based on 4G technology. It was designed to consume less power than traditional mobile technologies. Although LTE-M technology is not as low-powered as NB-IoT technology, it enables faster connection speeds (1 Mbit/s) and lower latency (15 ms), and also supports two-way voice/audio transfer over a 4G network (VoLTE). This technology is suitable for both fixed devices and mobile sensors.

Private companies have developed several other technologies for IoT sensors, and wireless networks have been developed for other terminals. Only NB-IoT and LTE-M were developed by 3GPP, and only they have been widely adopted by commercial telecommunications operators.
2.2 Network architecture and topology

A 5G network is based on both physical telecommunications infrastructure and software-based decentralised cloud services that provide network capabilities and services. The fixed network is based on more traditional network capabilities implemented using active devices.

5G architecture is based on a fixed network infrastructure that has been implemented using fibre-optics or other media that will provide sufficient speed. Connections between base stations can also be implemented using links, but this is only done in exceptional circumstances and you will eventually find a physical cable network behind these links.

A 5G network consists of three topological elements: a core network, a transport network and an access network. The access network can be described as the final branch in which the end user connects to the operator’s network. The interface between the access network and the end user may be an antenna located in the operator’s base station or a fixed cable network socket in a building wall. The size of access networks varies, but they can, for example, cover an entire district of detached homes.

The interface between the access network and transfer network is nebulous. Theoretically, the network becomes the transfer network when a connection is forwarded from the first base station or machine room that collates customer connections. For example, a mast containing an operator’s antenna will collate connections from several end users and forward them along the mast’s active device connections. Transfer networks are physically located within the infrastructure of the largest city streets and partly also alongside transport routes.

At the other end, the transfer network connects to the core network, which connects all of the transfer networks together, and through them also all of the access networks. From a data transfer perspective, the core network has the greatest capacity. Core networks are often connections between cities, and are therefore often situated along transport routes.

![Diagram of network architecture](image)

Figure 1. Topologically, the 5G network consists of three parts: the core, transport and access networks
As the number of 5G services increases, the physical data network will no doubt have to be extended and made denser to ensure sufficient coverage and service reliability. The physical structure of the network will aim to minimise the physical distance between the user's device and the required resources, such as edge computing servers. One of the reasons for the 5G network's low latency is that services are provided in the transfer network with the aid of edge computing. In previous network generations, services were often topologically located in the core network.

Reliability is often quoted as one of 5G's major advancements. This refers to capabilities such as slicing certain frequency bands to ensure data transfer speeds for a user's service, and reducing the processing delay for data packets being switched between devices. On the physical side, the 5G network's backup connection and other backup measures, such as the use of reserve power, are similar to those used in previous mobile generations and fixed networks. Cable connections in the core and transport networks have been built along at least two different physical routes, so that if one cable breaks the connection can be switched to the backup cable. In the access network, no backup connections are usually built for mobile base stations or fixed network access points unless the users' requirements particularly require them (such as hospitals, production facilities, etc.) and the end users are ready to pay for these backup services. In practice, backup connections in the mobile network are generally implemented so that when a particular base station is experiencing problems, data traffic will be directed to the mobile operator's closest base station or previous mobile generation network. One exception to this basic rule will probably be VIRVE 2.0 (version two of the radio network for public authorities' communications), in which legislation will allow the use of any operator's mobile network in the event of a disturbance in the service.

2.2.1 Core network

Topologically, the core network lies at the core of the telecommunications network. For example, connections between countries and continents run through the core network. The core network connects metro networks to each other via the metro network's active device connections. In terms of connection capacity and data processing, the core network's devices are more powerful devices and can reach connection speeds of up to 400 Gbit/s if required. The core network consists of the fixed network's transfer connections and core devices. These core devices can be physically located next to base station devices, but they are often placed in large machine rooms in cities. Although these devices don't require a great deal of physical space (they will fit inside a standard device cabinet), the redundancy of these critical devices must be ensured with reserve power equipment or batteries.

Core network connections often run between cities and are therefore often placed in fibre-optic cables that run along main transport routes. Cable sizes vary according to requirements, generally within the range of 48–432 fibres, although the most common size for core network cabling is 192-fibre cables. The core network will be implemented as a redundant core network by looping active devices and using reserve power equipment and batteries. A malfunction in the core network will impact a very large area, but thanks to the redundancy of the core network's connections and devices, damage to cabling should not break connections for more than a moment while traffic is switched to the backup
route. In the core network, operators' traffic is combined at shared nodes, that is, through so-called sinks.

From the perspective of 5G architecture, the 5G network's core is based on network capabilities that have been implemented in the cloud via virtualisation. Virtualising network services is beneficial in, for example, network administration, as changes to network tasks can be made using software. For example, network slicing (one of 5G architecture’s most essential capabilities) is carried out in the 5G core. Virtualisation makes network capabilities more flexible, efficient and scalable than they were using earlier technology.

2.2.2 Transport and Metro Ethernet networks

The transport network can be described as the section of the network between the access and core networks. In urban areas, the transport network runs between city districts and also alongside transport routes. (Although this is a slightly simplified picture.) The term ‘Metro Ethernet’ is often used to describe the fixed network's transfer network. When it comes to 5G, the transport network handles two tasks. Firstly, it transfers data between the access and core networks. Secondly, it is the part of the network in which edge computing is performed, in the so-called ‘Edge Cloud’. Edge computing can have a significant impact on the latency of a 5G network, as using a decentralised cloud will bring the computing resources required to provide network capabilities closer to the end user or application. Previously, these computing resources were located in, for example, datacentres in major cities. Edge computing will probably not need to be located in close proximity to the user, but lag can be significantly reduced by bringing these resources closer to the operator’s machine rooms, which in urban areas will often be located 0.5–10 km from the user.

Transfer networks are usually looped; that is, the core connection has been implemented in two or more directions. Due to their redundancy, severing a fibre-optic cable running alongside a transport route should not lead to a fault. Traffic will either be automatically redirected or it will be directed to its destination via another loop. A transfer network's active devices are, almost without exception, located in machine rooms administered by the operator. Depending on its requirements, a city may have multiple devices, such as for every city district. Some devices may also be located near transport routes, but normally not. To guard against a variety of faults, a transfer network’s active devices are usually connected to a reserve power supply.

2.2.3 Access network

The access network can be described as the section of the network that is closest to the end user or application. Two examples of access networks are a fibre network that covers a detached home neighbourhood, and a mobile phone base station through which end users' devices are wirelessly connected to the operator’s network. In mobile networks, an access network will be called a Radio Access Network (RAN). Base stations and their radios are part of the access network. Users connect to the operator’s wireless network via the access network. The access network contains all of the network components, from cables to active devices, between the end user and the service provider’s interface. The technology used in the access network depends on the end user’s needs.
RAN networks consist of cells of various sizes. A cell is an individual element of the coverage area and covers a particular geographical area. The sizes of the cells vary and are defined by, for example, their purpose, the number of users, and the geographical area covered. Microcells are defined for coverage areas of tens of metres, whilst macrocells are defined for sparsely populated areas with coverage areas measured in kilometres. Access networks do not usually run alongside main transport routes. If future traffic requires the construction of network base stations for high-frequencies, the final metres alongside transport routes will probably be implemented as an access network. The trunk cabling to the access networks’ branch point (often a distribution cabinet) usually consists of 48–192-fibre cables, whilst the cabling from the distribution cabinet to properties often consists of 4–24-fibre cables, depending on the property’s requirements. Traditional 110 mm casings or microducts are used to protect these cables. If there is a fault in the access network, connections will be lost, as the access network does not usually have inbuilt redundancy.

2.3 Physical components of the telecommunications network in traffic areas

2.3.1 Base stations

The position of a base station is usually selected on the basis of its purpose and geographical location. Base stations are often placed in masts and posts, in the walls and roofs of properties, in lampposts, and in other special sites according to requirements. Mobile base stations can, for example, be implemented for major events or construction sites using base station wagons. The height of base station masts and posts typically varies between 30–150 metres, depending on the location and purpose of the base station. The frequency used also impacts the base station’s location and implementation method. Due to the short range of the high frequencies used by the 5G network (mainly the 26 GHz frequency band), it has been proposed that base stations be placed in the close vicinity of roads. When building the 5G network, no new base stations will initially be required, as 5G will first use lower frequencies to implement the required coverage area.

A base station’s equipment typically consists of a central unit, a base station antenna, and a Radio Frequency Unit (RF Unit). The base station’s antenna is used to send and receive electromagnetic waves. The size of the antenna will depend on the purpose of the base station, and on the technology and frequency used. A cable connects the antenna to the RF unit, and fibre-optic cables are then used to form connections from the RF unit to the transfer network via the central unit. The central unit and RF unit control the activities of the antenna circuit and direct the signals to the correct locations. The RF unit can be located either in a mast or, for example, in an equipment rack inside a base station cabinet. Batteries can also be placed inside base station cabinets or machine rooms in the event of a power outage. A base station’s machine room could be a property’s distribution station or a cabinet built at the base of a mast, which will usually be 4–12 m² in size.
2.3.2 Above-ground passive infrastructure

Above-ground passive infrastructure consists of cabinets, distribution centres, and a variety of other technical facilities in which a network’s active devices may be placed. Cabinets and distribution stations are small, above-ground technical areas for forward or cross connections, and may be located in either internal or external premises. Their purpose is to enable easy access to cables, so that twin and fibre cables can be tapped off and their connections can be easily reorganised. Cabinets and distribution stations are typically located in places where larger cables must be tapped off into smaller cables, cables must be extended, or the cable type must be changed. Cabinets and distribution stations are placed as required, and their exact locations will only become apparent after detailed network planning.

Cables and other physical data connections are placed in technical facilities, such as telecommunications machine rooms or cross-connection stations. They typically contain the data network’s active devices, reserve power equipment, and batteries. They may also contain access, metro or core network devices related to a mobile or fixed network. The size of these technical facilities can vary from a single room to multiple rooms, large halls, entire buildings or even caves. However, these facilities are often single rooms in carparks, attics or basements and other subterranean floors. Although they may also be found in road, rail and metro tunnels.

2.3.3 Power grids, reserve power equipment and batteries

Mobile base stations require a continuous supply of electricity. They often use local and national power grids. The future construction of mobile stations may require provisions to be made for power grid capacity. It is estimated that a completely new base station will require approximately 5–7 kW of electricity per operator. There is as yet no precise data for the electrical consumption of high-frequency 5G base stations, but preliminary estimates for one 5G small-cell station are in the range of up to 1–3 kW. A base station’s power requirements are dependent on data traffic. Future technological advances may also lower power requirements. However, a high-frequency base station will most likely require more power than streetlighting, which consumes about 100–500 W. Base stations must also be reliable, so their power supply must also be backed up in the event of problems with electricity distribution. RF units at least can be backed up with UPS batteries.

Reserve power technology can be used to safeguard data traffic in the event of problems with electrical supply. ‘Reserve power equipment’ refers to generators that use a variety of combustion engines or fuel cells, and which can be started up in the event of a power outage. Next-generation mobile network solutions will significantly increase both capacity and quantity requirements for reserve power equipment. Legislation and official regulations specify the reserve power technology to be used at base stations and in other types of technical facilities.

In addition to reserve power equipment, batteries can also be used to improve security of supply for data traffic. Capacity and quantity requirements for batteries will therefore increase as well. In particular, the increasing number of batteries will pose significant challenges related to the load-bearing capacity of structures.
2.3.4 Subterranean passive infrastructure

Subterranean passive infrastructure refers to subterranean elements and structures that enable, protect and promote the construction of a telecommunications network. Key components of subterranean passive infrastructure include casings, cable channels and cable wells.

Cable channels are typically open or closed containers for housing and fixing cables. They can be made of plastic, metal or concrete, and can be placed on the ground or within other structures. Cable channels are typically installed in places where there is a need to protect cables from greater-than-average stress, such as at crossroads or in shallow installations. Open channels often run alongside railway lines.

Casings are used to protect cables, but they also enable cables to be placed in subterranean structures at a later date without having to dig up the ground, surfaced roads, other road and street structures, or track beds. In addition to traditional 110 m casing, so-called micro-conduit technology has also been used in the construction of data networks. Micro-conduits are pipes (either single pipes, twin pipes or bundles of pipes) that are less than 20 mm in diameter, and into which micro-cables can be 'blown' at a later date.

Cable wells enable access to cable channels located either underground or within structures. Cable connectors can also be placed inside cable wells, enabling cables to be tapped off or cable types to be changed. Cable wells are usually made of plastic or concrete. They are located underground, beneath grassy areas or railway areas, and in road and street structures.

2.4 Building telecommunications infrastructure

2.4.1 The importance of joint construction in telecommunications installations

Installing telecommunications infrastructure is usually easier and more affordable when it is done in conjunction with other construction. An estimated 60–80 per cent of the total cost of building a fibre-optic network is generated by earthworks. The remaining costs relate to equipment, materials and connection points. When telecommunications installations are carried out in conjunction with other construction, it will prevent further disturbances to traffic, as the construction site will not need to be opened up again so soon. It will also reduce the amount of construction required, as road surfaces and structures will remain intact, and there will be no danger of accidentally damaging any existing infrastructure during excavation work. Building infrastructure in one go also improves safety, as roadworks always require traffic control and increase the risk of accidents.

Although it is not always possible to prepare for everything in advance, long-term planning and co-operation between a variety of organisations can help to predict future requirements. Before launching a construction project, it is necessary to determine all parties' potential requirements with regard to infrastructure, if only to divide the costs correctly. Joint construction also enables joint supervision of construction sites.
2.4.2 The importance of preemptive construction in telecommunications installations

If casings, microducts or cable channels have been installed in advance in conjunction with other construction, it will greatly facilitate the later installation of new cables. Thanks to preemptive construction, cables can be drawn through existing pipes so that even long sections of cabling can be laid relatively quickly. For example, several kilometres of a fibre-optic cable can be laid in one day by utilising microducts, compared to only 100–300 m per day via excavation, depending on the soil and area.

The preemptive construction of special sites in particular can significantly reduce costs, thereby promoting telecommunications construction. For example, it is important to consider bridges, undercrossings, groundwater areas and soil types in advance, as this can significantly reduce costs. Undercrossings can also be built later using, for example, horizontal directional drilling, but this will require sufficient space for the drilling equipment. It is also relatively expensive to build undercrossings later on. Building an undercrossing costs more than EUR 100 per metre using horizontal directional drilling and about EUR 60 using jacking. In comparison, it costs approximately EUR 10 per metre to build a fibre-optic network using cable channels. Casing is a very cost-effective way to reduce costs, as casing only costs about EUR 1 per metre. If subterranean casing has been built beneath a road junction in advance, it will generate significant savings on future costs, reduce the amount of installation work required, and speed up schedules.

Put simply, all provisions made for future data network construction are beneficial. In order to boost cost-efficiency, it is worth planning the location and other requirements of casing early on in collaboration with operators, to ensure that preemptive construction is also planned in sufficient detail. The benefits of preemptive construction will quickly be lost if the use of casing requires a lot of twists and turns in cable lines.

Installation techniques include drawing cables through 110 mm casings or blowing them along microducts. Cables can be drawn through existing casings along distances of anything from several metres to hundreds of metres. One casing can usually house 2–4 trunk cables. Placing several cables in one duct or removing cables from the duct mid-journey will make it more difficult to use the ducts. A cable well or separate pit will be required at the end of the channel to enable the cable to be drawn through the channel.

Blowing is an installation technique used for microducts. A fibre-optic cable is blown into a previously installed microduct with the aid of compressed air or a cable pushing device. Blowing cables into a carefully and correctly installed microduct is quick and easy, and several hundreds of metres of cables can be blown at once. When building microducts, two challenges are overly sharp corners and dents caused by insufficient protective gravel cover. Both of these will slow down the blowing process.
2.4.3 Telecommunications installations without preemptive construction

The largest costs incurred from installing telecommunications without the preemptive construction of passive infrastructure arise from excavation, surface renewal, and special sites along the route. If no provisions have been made in advance (such as casings), construction costs will rise considerably depending on the technique used. In the vicinity of transport routes, telecommunications cables are usually placed in side-slopes, paying attention to existing cables. During installation and planning, places may be encountered where it is impossible to build or where the benefits would not justify the costs incurred. In such cases, routes may have to be changed.

The most common way of laying subterranean telecommunications infrastructure is excavation. Excavation is expensive and relatively slow, but it is often the only option for laying cables in road structures. Ploughing is an installation technique that uses a cable-laying plough to make a trench in the ground, into which the cable is then embedded. Although ploughing is faster and more economical than traditional excavation, it requires flat, stoneless and non-rocky ground. Rocky or stony areas may require changes to cable routes or the need to dig up certain areas using traditional excavation techniques. Jacking is an installation technique that is particularly suited to building undercrossings. It requires the excavation of an entrance pit and receiving pit at either end of the crossing. The jacking head strikes through the ground, from the entrance pit to the receiving pit, using a forward-and-backward motion to create a pipeline. One challenge faced when jacking is the lack of remote control – the jacking drill head can easily turn in the wrong direction due to a stone or rock. Horizontal directional drilling is a installation technique for demanding undercrossings. It can be used in places where subterranean infrastructure needs to be installed without breaking surface structures. Horizontal directional drilling can be used to drill distances of up to hundreds of metres, which means that it is also suitable for building crossings beneath rivers and waterways. A drill pipe consisting of drill rods bores the desired hole. This hole is then expanded using a hole-opening bit, and the casing is installed. In horizontal directional drilling, the drill head can be remotely controlled, but the large size of the rig means that it cannot be used in confined spaces. Micro-trenching is a relatively new installation technique in Finland and is mainly used in urban areas. A trench of, on average, 30–40 cm is sawn into the asphalt. A microduct or microduct bundle is installed in the sawcut trench, after which the trench is filled with protective gravel or bitumen-based material. Micro-trenching is relatively affordable (approx. EUR 50 per metre) and fast (up to 100–500 metres per day). The advantages of micro-trenching include minimum space requirements for the sawing equipment and therefore also less redirection of traffic. There will also be a significant reduction in the amount of resurfacing work required, which will reduce installation costs.
3 Data connections along highways

3.1 Operating environment

3.1.1 The current state of road transport

The Finnish road network comprises highways, municipal street networks and private roads. The Finnish road network totals approximately 454,000 kilometres in length. This includes around 350,000 kilometres of private and forest roads and 26,000 kilometres of municipal streets. The Finnish Transport Infrastructure Agency (FTIA) is responsible for approximately 78,000 kilometres of highways.

In collaboration with regional ELY Centres, the FTIA is responsible for the maintenance and development of the state-owned road network. The FTIA is an expert organisation consisting of about 400 specialists. It focuses on the planning, development and maintenance of road, rail and sea transport networks, and for reconciling transport and land use. The FTIA maintains the traffic service level, thereby promoting both social wellbeing and the competitiveness of trade and commerce. Its mission is to respond effectively and responsibly to customer needs created by changes in mobility, and to provide society with a platform for growth in the form of safe and functional infrastructure. The FTIA also promotes responsible construction and the development of the infrastructure sector. The FTIA ensures that a nationwide service level is maintained.

Under the guidance of the FTIA, ELY Centres are responsible for road safety and traffic flow in their own regions. They also promote road safety and traffic flow by improving roads and building pedestrian and cycle routes. ELY Centres are responsible for regional road maintenance, and also handle the maintenance of highways and their associated facilities and equipment. ELY Centres issue cable laying and transport-related permits for the roads they administer. ELY Centres participate in transport system-related work in co-operation with municipalities and provinces. They also play a key role in organising public transport. It is the task of ELY Centres to highlight national policies and adapt them to the requirements of the transport system in their own regions. Tendered contractors handle daily road maintenance and, when necessary, repair and construction work.

Intelligent Traffic Management Finland Oy (ITM Finland) is responsible for traffic management on Finnish roads. ITM Finland provides and develop services that enable safe and smooth traffic flow in the road network. These services include road weather information systems, operative traffic control at road traffic management centres, maintaining technical systems in road tunnels and handling changes to road signs, as well as ICT services for all of the aforementioned. ITM Finland also provides a great deal of real-time open data about road traffic and weather conditions that can be used by anyone.

The new Finnish Transport and Communications Agency (Traficom), which was established at the beginning of 2019, is responsible for transport-related figures, competencies, supervision and safety.
3.1.2 Development trends in the road traffic operating environment

3.1.1.1 Diversifying communication appears to be based on a hybrid solution

In the future, vehicles will communicate with their surroundings. One key theme in the future development of road traffic will be an increase in communication and data exchange, which will place greater demands on data transfer and the reliability of data transfer connections. In the future, vehicles will receive information about their surroundings, and also collect and transmit data for use by other vehicles and services. More diverse data will be transferred between vehicles, and large data transfer capacities will be required in both directions (upload/download). Future road traffic communication will most likely be based on both short-range and long-range data exchange (a so-called hybrid solution).

Short-range communication will enable latency-critical connections to the surrounding environment. Short-term communications will occur within a radius of one kilometre, and will enable latency-critical communications in particular. Short-term communications will involve vehicles or road-side devices connecting with their environment without going through an external mobile phone network. This will enable vehicles to communicate with each other in mobile network blind spots. Communicating outside the mobile network will reduce latency and enable large volumes of data to be transferred between vehicles without congesting the network. With the aid of short-range communications, vehicles will be able to exchange information with each other (V2V – vehicle to vehicle), which will make it easier and safer to, for example, change lane or merge onto highways. Vehicles can exchange information about location, speed, intentions, and driving lines. Vehicles will also be able to communicate with road traffic infrastructure (V2I – vehicle to infrastructure). For example, traffic lights could send vehicles information about upcoming light changes in order to optimise driving speeds. Vehicles could also be in contact with other road users, such as pedestrians, cyclists and road workers (V2P – vehicle to pedestrian), to receive warnings about sudden movements.

Figure 2. Road traffic communication is divided into short-range communication and long-range communication, which occurs via the mobile network.
Long-range communication occurs via the mobile phone network and enables the use of non-latency-critical services and external analytics. Vehicles are in contact with distant subjects via a separate road traffic network, such as the mobile phone network (V2N – vehicle to network). With the aid of long-range communications, vehicles can send information about congestion or other information gleaned along their route. Long-range communications can also be harnessed in traffic optimisation with the aid of system automation (I2N2I). Data collected by traffic cameras and other sensors is sent to a centralised cloud service for analysis. The results of this analysis can be used to reprogramme traffic lights or change priorities to improve traffic flow. Long-range communication can also utilise edge computing to provide centralised, high-performance services.

Developments in vehicle communication will be governed by technical requirements for services, technological advancements, changes in operating models, and developments in data connections. Many services that use data connections are still at the development stage. Similar services have often been implemented using a variety of different solutions, and the requirements for data transfer are still open. Typical solutions involve data being transferred directly between vehicles or alternatively via a mobile network. Depending on the service’s implementation method, data can be sent directly to the recipient as raw data (for example, an HD video) or, in a more advanced service, only essential data is sent to users in a pre-analysed format. In particular, sending unanalysed video and other raw data between parties would require a multifold increase in data transfer capacity compared to today. Technical advancements in the computational power of vehicles and applications will mean that some collected data will no longer need to be transferred raw or immediately – some data can be processed immediately in the vehicle itself or analysed close to the user. When fast analysis and low-latency is required, the more pressure there is to bring computational power out of centralised machine rooms and closer to the network edge, that is, closer to the user. Edge computing can be understood as computational power that helps in data storage, data processing, and creating the service between the data source and the user. From a traffic perspective, edge computing could be, for example, in a vehicle (On Board Units, OBU), at the roadside (Road-Side Units, RSU) or on a nearby server. Finding a suitable solution depends on the use case’s actual requirements for latency and computational power. This will reduce unnecessary data transfer, as only essential data will need to be sent to the network. Improved analytics and increased storage capacity at OBU and RSU level, extracting essential data from large files, and data packaging could therefore reduce the actual need for a data transfer compared to the largest estimates being made for road traffic.
3.1.1.2 Guidelines for road traffic communication technologies remain open

Guidelines for key road traffic data connections are currently open. The 5.9 Ghz frequency band has been reserved for short-range traffic communication and this should, according to current understanding, be sufficient to meet the needs of the near future. There are currently two competing methods for road traffic communication: Cellular-V2X (C-V2X), which uses the mobile phone network, and the WLAN-based ITS-G5. The key question in European debate has been whether technology specifications should be technology-neutral and approve 5G as a communication channel for smart traffic alongside ITS-G5. The European Commission had been driving ITS-G5 as the sole communication method with a delegated regulation, but the Council of Europe voted against the Commission’s regulation in July 2019. No official information has yet been received, but one option is to reopen the regulation.

C-V2X (Cellular Vehicle-to-Everything) is a method of communication that uses a mobile network to run services that increase road traffic safety and efficiency. C-V2X is based on two communication interfaces: the short-range PC5 protocol and the long-range Uu protocol. The PC5 protocol enables short-range communications (less than 1 km) between vehicles, roadside infrastructure, and pedestrians. PC5 also enables communication when no external mobile network is available. The UU protocol enables long-range communication between, for example, vehicles and cloud services via a mobile network. In the future, Uu can be used for services that require low latency. As there are no 5G networks available except for test networks, the current communication method is often called LTE-V2X.

ITS-G5 (also known as IEEE802.11p, WaVE, pWlan, DSRC) is a wireless technology and protocol for short-range data transfer based on the WiFi Standard. This technology enables data transfer between vehicles (V2V) and between vehicles and infrastructure (V2I). Depending on the terrain, ITS-G5 currently has a range of between 500 m and 1 km. Vehicles will therefore be able to communicate with a variety of radar, cameras, road weather stations and built-in road sensors. For example, ITS-G5 technology enables information to be shared about congestion, weather and other conditions, safety announcements and accidents. ITS-G5 does not support long-range communication, which should instead be implemented indirectly via infrastructure (V2I) or a separate mobile network. The data produced is only available locally and is not centrally collated anywhere.

In Europe, the development of data transfer for road traffic automation is based on the ITS-G5 standard, and the automotive industry has traditionally considered it to be the most suitable data transfer technology for networked systems and autonomous vehicle safety. In recent years, several vehicle manufacturers (including Audi, BMW, Daimler, Volvo and Ford) have been investing in the use of LTE and 5G in collaboration with the telecom sector. Proponents of 5G claim that C-V2X technology, which uses the mobile network, is more diverse, more effective and more reliable that WiFi-based ITS-G5. There are differences in opinion not only on technological issues, but also on the business opportunities afforded by the various technologies. Using 5G requires vehicles to be equipped with operators’ SIM cards. From the operators’ perspective, this will provide a mechanism that will enable them to make the required network investments.
Although ITS-G5 has already been on the market for a while, no clear business models have sprung up around it, and no common desire has been shown in making the roadside infrastructure investments required by ITS-G5.

3.1.1.3 C-ITS services will define the basic level of road traffic communications

Co-operative Intelligent Transport Systems (C-ITS) services are services that aid co-operative driving. In practice, this means adapting information and communication technologies to transport. In recent years, the European Commission has been promoting the development of smart, interoperable traffic systems by, for example, publishing its own strategy for implementing C-ITS services. The Commission’s strategy is seeking to start the implementation of C-ITS services in 2019, when all new type-approved vehicles should be equipped with a device that is capable of processing C-ITS data traffic, and the services provided in all countries should be compatible with each other.

C-ITS services were initially envisaged as using short-range data transfer, but a need for long-range data transfer was later identified, particularly in services that are not time- or safety-critical. The collaborative driving services being championed by the Commission will most likely be extensively implemented over the coming years, but will also most probably rely more extensively on the mobile network than had originally been thought.

The Commission’s strategy also defines C-ITS services and divides them into two categories: the standardised services that will be implemented first (Day 1 services) and the next services to be standardised and implemented (Day 1.5 services).

When it comes to V2I applications, road managers will be responsible for providing certain roadside infrastructure to enable C-ITS, and also for equipping those devices with appropriate data transfer connections. If C-ITS standardisation ends up approving the use of mobile data transfer as a data transfer connection (a so-called hybrid solution), V2I applications can at least be implemented technically using a V2N connection. Technically, the majority of C-ITS use cases can be directly based on short-range communication (V2V and V2I) or alternatively communication can be implemented via a network (V2N).

3.1.1.4 Trends in autonomous traffic will determine data connection requirements

The various levels of driving automation are usually classified in accordance with the Society of Automotive Engineers' (SAE) six-level system. Levels 0 and 1 are already currently in use. They include technologies such as parking assistance, lane keeping assistance, adaptive cruise control, and collision warning. Levels 2–3 are higher-level automation systems in which a driver is still necessary, but is assisted by a variety of aids of differing levels. Level 4 denotes a very high level of automation and the vehicle is able to function almost independently in predictable circumstances, but the driver can take control of the vehicle if necessary. Level 5 is complete autonomy, and the vehicle is able to function independently under all circumstances.
The report ‘Traffic management on main transport routes in the Helsinki region 2030’ suggests that SAE Level 4 applications will come onto the Finnish market in the 2020s. The introduction of these applications is expected to occur in technically or geographically restricted areas, or in otherwise controllable areas (such as ports, terminals and certain connecting routes or areas).

![Diagram of vehicle types and locations](image)

**Figure 3.** An estimate of when automated driving applications will come onto the market (Source: Traffic management on main transport routes in the Helsinki region 2030)

The development of autonomous vehicles requires improvements in both vehicle automation and communication between vehicles. Vehicle automation places great demands on AI development and information processing.

Autonomous traffic seems to require some kind of data connections, but there is still great uncertainty surrounding the actual volume of data. According to some estimates, the volume of data transferred by a single vehicle would total thousands of gigabytes per day, meaning that one car would be equivalent to the daily use of thousands of smartphones. Other vehicle manufacturers do not share this view, but are of the opinion that vehicle autonomy should be sufficient for them to function without data traffic. In any case, self-driving vehicles must themselves be able to collect and transmit data to other vehicles, traffic management centres, central servers, and infrastructure devices such as traffic lights.

The applications that will eventually be used, along with their technical requirements, will be determined by the data transfer and latency speeds required for main transport routes. For example, a vehicle’s emergency braking must be transmitted to other vehicles within milliseconds in order to avoid an accident. The autonomy and technical development of vehicles will ultimately depend on whether data about emergency braking will be transferred between vehicles or whether vehicles’ internal cameras, radar and analytics will develop to such an extent that exterior data transfer will not necessarily be required.
3.1.3 The challenges that highway environments place on digital infrastructure construction

From the perspective of telecommunications construction and the implementation of 5G connections, highways constitute a very distinctive operating environment compared to, for example, urban areas. When it comes to opportunities for promoting and steering telecommunications, the Finnish Transport Infrastructure Agency plays a very different role than it does in urban areas.

There are fewer buildings and structures along main transport routes, which means that mobile network base stations cannot be placed on building roofs in the same way. Instead, they must be erected using dedicated masts or supporting pillars. Cities are responsible for authorising the siting of base stations and masts. Building regulations also mean that they will have to take a stand on ensuring sufficient preparedness. In urban street areas, cities are responsible for siting permits and seek to promote joint construction in order to reduce disturbances caused by roadworks and prevent streets from falling into disrepair. The masts and fibre connections required by main transport routes will not necessarily be located within the area administered by the Finnish Transport Infrastructure Agency. The FTIA will have less opportunity to exert an influence, as it is only responsible for the road itself.

Highways are primarily located in uninhabited areas. As there are no densely built-up areas in close proximity to traffic areas, it is not worth laying cables beneath the road, as in urban areas. Laying cables along the side of the road makes telecommunications construction faster and more economical on main transport routes, as the road’s structure does not have to be broken, thereby avoiding the costs that would otherwise be incurred by resurfacing. On highways, laying casing for lengthwise connections does not play such a big a role as it does in urban areas where, in addition to expensive construction, there is usually very little space for new pipes beneath the roads. It can often be more affordable to build alongside the road than to use casing that is poorly implemented, maintained and documented.

A continual challenge in the highway environment is the lack of information about existing cables and passive infrastructure. ELY Centres have found it challenging to obtain information about cable ownership, and this has hindered co-operation in, for example, cable relocation. Another challenge is the lack of information about exact cable locations, as the precise position of cables has not been documented and cabling may not have adhered to the instructions provided. In such instances, improvement work involves the risk of accidentally severing cables. A further challenge is the poor documentation of existing passive infrastructure. For example, information about existing casing may not be available to operators.

From the perspective of building new base stations, one challenge encountered on highways arises from the long distances involved and the relatively low numbers of users, which inevitably makes the construction of individual base stations expensive. Existing base stations have mainly been located close to urban areas. In order to create a mobile network with full coverage, there will probably be a need for new base stations in areas with little surrounding habitation. The construction of these new base stations will most likely require
relatively long fibre and electrical connections, which will raise construction costs. As there is little surrounding habitation, the new base stations would primarily serve road traffic. The roads would therefore have to have sufficient traffic volumes to make the construction of new base stations worthwhile. In order to cover their investments, telecommunications operators will need new use cases and services, as well as new earnings models to support them. Currently, the challenge facing operators is that there is no separate earnings logic for road traffic. Any earnings would be generated through mobile network services for road users.

3.2 Data connections in highway environments

3.2.1 The ownership and management of data connections in highway environments

Highway data connections can be divided into two: the data connections required by road users and the data connections required for traffic management. They utilise existing fixed and mobile connections.

In highway traffic, fixed connections are primarily used for safety-critical traffic management functions, such as tunnel supervision and control, traffic barrier devices, and variable speed limits. Mobile connections are used for non-critical traffic management functions, such as information boards, observation devices, central reservations, and data transfer for contractors and road users. Mobile connections are mainly provided by commercial service providers (Elisa, DNA and Telia) and Erillisverkot Oy, which provides the public authorities’ network (Virve).

The main owners of telecommunications cables along highways are commercial actors such as Elisa, Telia and DNA. The state-owned company Cinia also operates in road areas, as do smaller local actors (such as BLC, MPY and TDC), regional telephone companies, and Finnet-yhtiöt. Based on project interviews, operators’ fibre-optic trunk cabling is generally in good condition along main transport routes, with the exception of more northern areas.

In conjunction with the incorporation of road traffic management centres, all associated telecommunications infrastructure was transferred to Intelligent Traffic Management Finland (ITMF). The Finnish Transport Infrastructure Agency therefore no longer owns or manages the data connections used in road traffic. ITMF owns the telecommunication cables, technical facilities and machine rooms, as well as a variety of terminal devices for traffic management (cameras, sensors, LAM nodes and control devices). ITMF does not have a full-coverage fibre network. Instead, it leases data connections from other actors as required.

In urban areas, there are also fixed connections on highways or in close proximity to them. They are used for traffic lights and other traffic control tasks. The fixed connections used by traffic lights are partially owned by municipalities and partially acquired from operators. In the future, wireless connections may also be seen in traffic operation.
Ownership of the national power grid used by highway traffic is divided between the ITMF and the FTIA. The FTIA mainly owns the grid used to power street-lighting. The ITMF owns the grid used to power smart lighting and traffic management. It also primarily uses power grids owned by others.

One challenge in highway environments is the possible lack of accurate common knowledge about the ownership and exact location of telecommunications cables and power grids. Highway contractors do not always follow instructions and cables have not always been laid in the agreed places. Cable locations are not systematically documented either.

When it comes to road traffic infrastructure (casings and distribution wells), there are also some uncertainties on the division of ownership and control between the FTIA and ITMF. Management responsibilities vary on a case-by-case basis. No precise divisions have been made and assets have not been documented. It has been suggested that the ownership of cable channels should be more clearly transferred to the owner of the infrastructure, although it has been difficult to see the benefits associated with pipeage.

### 3.2.2 The use of highway data connections and their developmental needs

#### 3.2.1.1 Road users

Road users are some of the major users of mobile connections these days. Road users mainly utilise commercial operators’ data connections for navigation and entertainment. Demand for entertainment in particular is expected to grow in the future. Some of the newest vehicles are already able to use mobile connections directly.

#### 3.2.1.2 Professional transport

A variety of services for real-time route optimisation, fleet monitoring and driving style optimisation are expected to become commonplace in professional transport. A variety of services for vehicle automation and autonomous traffic (such as platooning and remote control) are expected to develop first in professional transport.

#### 3.2.1.3 Transport infrastructure authorities

Transport infrastructure authorities do not have their own data connections for road traffic. Instead, they primarily use data connections provided by commercial operators in the construction and maintenance of roads and engineering structures. In construction, data connections are used on both fixed construction sites and mobile construction sites. The latter have their own set of requirements. On fixed construction sites, such as major road projects and individual bridge repair projects, typical challenges often include insufficient data transfer capacity and coverage issues outside urban areas. Contractors have brought additional antennas to their construction sites to ensure sufficient coverage. In the future, construction sites’ main data transfer requirements will increasingly relate to model-based implementation, machine control, audio-visual data transfer, and precise location data. Alongside construction automation, there is also the potential for increased real-time information about construction sites from, for example, cameras and sensors, and also for the
exchange of more real-time data between planners, designers and construction sites. Real-time monitoring will also enable the supervision of contractors' contractual obligations during roadworks (for example, road signs, speed limits and roadwork warnings) and their compliance with safety regulations. Real-time data can also improve traffic management status updates, temporary traffic arrangements and construction site safety, as approaching vehicles can be warned of roadworks, temporary traffic arrangements and roadworkers. In the future, mobile construction sites will have a need to improve the precision of their work and provide 'as built' documentation in, for example, surfacing and cable contracts.

From a maintenance perspective, the most common use case for data connections will be collecting information for monitoring purposes and about work that has been carried out – about winter maintenance, for example. 4G connections are sufficient for this. The challenge mainly lies in individual blind spots. Maintenance will also have a need to use digital materials in the field. One opportunity for future development lies in the analysis of sensor data and camera images. This information could help to provide better assessments of the condition of property and to gather more extensive data about environmental conditions – whilst also making the process more affordable. This data could also be used by contractors to develop automated work supervision. The majority of these requirements can already be met using either existing connections or connections than can be developed with a market-based approach.

3.2.1.4 Road traffic management

Requirements for road traffic management can be divided in two: critical connections and non-critical connections. Critical connections require fixed, reliable data connections. They include loop control, variable speed limits, traffic barrier devices and other traffic management requirements such as tunnel supervision and remote control. Non-critical requirements can also be implemented using mobile connections. They include information boards, central reservations, and observation devices such as cameras and sensors. At the moment, ITMF mainly uses fixed data connections supplemented by connections acquired from operators.

From a road traffic management perspective, the current status of data connections is generally good in relation to the identified needs of existing and future services. The main requirement for these data connections will be reliability, which is why the majority are based on fixed connections. Data transfer volumes themselves are not high, with the exception of camera surveillance, and no unconditional requirements for ultra low-latency have been identified. From a technical perspective, many of these requirements can be implemented using existing 4G or IoT networks.

The key areas for future development that have been identified mainly relate to an increase in data collection, particularly from sections of the road network that are congested, critical for safety, or important for traffic flow. Planned measures involve expanding the road weather station network by adding new stations and also increasing the number of variable speed limits and weather cameras. These requirements can be met using either fixed or mobile connections. However, they will also require a power supply in addition to data.
connections, which is why it is often worthwhile to build power connections at the same time as fibre connections.

As traffic communication and automation develop, the role of traffic management will also change dramatically. One key change driver that has been identified is a change in how data will be collected and utilised. Vehicles already collect a variety of data (for example, about road conditions and traffic), which they send to car manufacturers and other service providers. Combined cloud services can inform road users about congestion, suggest alternative routes, and provide warnings about dangers such as slippery roads. Car manufacturers and other service providers have already bypassed official systems to some extent. This line of development challenges the traditional view of a need for new, official observation points – that is, if vehicles will be continually collecting data about the highway environment and sending it to other road users without help from the authorities.

Car manufacturers, operators and major actors are interested in providing end-to-end services for road users. If this happens, some driving-related decisions will be transferred away from vehicles, which will require a new approach to traffic management. If new information and services will more often 'bypass' the authorities, the traditional roles of infrastructure owners and traffic management will change dramatically in the future, as will requirements for data connections. It is expected that physical operations will continue to be required in traffic control at critical points in road infrastructure (such as tunnels), even if it is possible to digitalise many traffic barrier and restriction functions.

### 3.2.1.5 Use cases for future traffic

Road traffic is expected to become more automated in the near future. The data transfer requirements arising from increasing automation will in turn create requirements for the development of data connections. At the same time, available data connections will determine the level of services that can be developed and how widespread they will become. The adoption of future use cases is therefore dependent on both the availability of data connections and the development of services and technology.

Vehicle communication related to future use cases primarily appears to require latency-critical, short-range communication, with only secondarily requirements for non-latency-critical communication via networks. One exception is remote vehicle control, which requires fast and reliable mobile connections. The greatest data transfer requirements seem to relate to the transfer of video between various functions. The data transfer capacity required by many use cases can be lowered by reducing the transfer of large data volumes (such as raw video) and improving data processing. Currently, the main challenges preventing many use cases from becoming more widespread lie in the development of service architecture and technologies, in the commercialisation of services, and in inadequate data transfer speeds. Many services, such as remote control and platooning, can already be implemented using existing 4G connections. The table below shows a selection of future use cases and their estimated data connection requirements. The table has been drawn up using both 3GPP and 5GAA materials.
Table 1. A selection of future use cases and estimated telecommunications requirements (Source: 3GPP and 5GAA)

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Communication</th>
<th>Data transfer requirement</th>
<th>Latency (ms)</th>
<th>Service reliability requirement</th>
<th>Location (m)</th>
<th>Communication distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving assistance</td>
<td>V2V/V2N/V2I</td>
<td>1.28 Mbit/s</td>
<td>30</td>
<td>&gt; 99.9%</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>See Through service</td>
<td>V2V</td>
<td>5–15 Mbit/s</td>
<td>50</td>
<td>&gt; 99.9%</td>
<td>1.5</td>
<td>short</td>
</tr>
<tr>
<td>Platooning</td>
<td>V2V</td>
<td>0.5–150 Mbit/s</td>
<td>10</td>
<td>&gt; 99.9%</td>
<td>-</td>
<td>100m</td>
</tr>
<tr>
<td>Automated driving</td>
<td>V2V/V2N/V2I</td>
<td>10–500 Mbit/s</td>
<td>10</td>
<td>&gt; 99.9%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Utilising vehicles' external sensors and collaborative observation</td>
<td>V2V/V2N/V2I</td>
<td>0.1–2000 Mbit/s</td>
<td>3–100</td>
<td>&gt; 99.9%</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Remote control of vehicles</td>
<td>V2N</td>
<td>5–30 Mbit/s (upload)</td>
<td>20</td>
<td>&gt; 99.9%</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Remote monitoring of vehicles</td>
<td>V2N</td>
<td>&lt;1 KB/message</td>
<td>&lt;30 sec</td>
<td>&gt; 99.9%</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>Hazard warnings between vehicles</td>
<td>V2V</td>
<td>&lt;1 KB/message</td>
<td>10–400</td>
<td>&gt; 99%</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>General warnings (disturbances, warnings)</td>
<td>V2N/V2I</td>
<td>&lt;1 KB/message</td>
<td>1000–2000 ms</td>
<td>50–90%</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>Vehicle software updates</td>
<td>V2N</td>
<td>1.5 GB/update</td>
<td>-</td>
<td>&gt; 99%</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>HD maps</td>
<td>V2N</td>
<td>3 Mbit/s</td>
<td>30 ms</td>
<td>&gt; 99%</td>
<td>-</td>
<td>kilo-metres</td>
</tr>
</tbody>
</table>

Driving assistance services include support for changing lane and merging, collaborative collision prevention, and the transfer of various speed, direction and overtaking data between vehicles. Data transfer mainly consists of individual messages.

A See Through service lets a vehicle 'see through' the vehicle that it is following, that is, the front vehicle's view is sent to the rear vehicle. The majority of the data transfer capacity required stems from the real-time transfer of livestream video to the rear vehicle. The volume of data that needs to be transferred can be significantly reduced if information about dangerous situations or overtaking opportunities could be sent to the rear vehicle without a video link.

Platooning enables two or more vehicles to drive close to each other. The vehicles need to exchange information about changes in speeds, distances, and joining and leaving the platoon. The data connection between the vehicles must be reliable and unbroken, but the volume of data that needs to be transferred will not necessarily be that large.
Automated driving encompasses a broad range of capabilities that enable vehicles to move without the driver's assistance. The level of this automation will largely determine data transfer requirements. The volume of data that a completely autonomous vehicle needs to transfer may be many times that of an almost self-driving vehicle, even though the average volume may be generally comparable.

Utilising vehicles' external sensors and collaborative observation Using this service, a vehicle can utilise the sensor data collected by other vehicles and other actors (such as camera and radar data) to form a picture of its surroundings. A status update collated from external sources can help a vehicle to prepare for the emergence of another vehicle from a blind spot, or for an accident around the corner.

Remote monitoring enables the optimisation of fleet usage and the efficient monitoring of vehicle locations, wear-and-tear and maintenance requirements. Remote monitoring is based on individual data items that are sent at regular intervals or in the event of a fault. The volume of data sent at one time is usually small.

Remote control is often based on a continual connection between the vehicle and remote controller. Data requirements largely stem from sending a real-time image of the vehicle's environment to the controller, and the commands sent back to the vehicle. A video image is required for control, that is, data transfer requirements will be determined by the number of cameras and the video's quality.

Hazard warnings between vehicles and general warnings encompass warnings about other vehicles (emergency braking, lane changes and changes in speed) and warnings about congestion, dangerous places, and other road users. These warnings are usually concise individual messages that do not require continual or large volumes of data transfer.

Vehicle software updates are updates to vehicle software that are sent at regular intervals to ensure that the vehicle remains drivable. Software updates may contain very large files, but could be downloaded over a longer period of time to avoid the need for large data transfer capacity.

HD maps provide self-driving cars with information about critical and variable road conditions. The majority of map data will most likely be downloaded to the vehicle before departure, so only information about changing conditions will be updated while driving. The nature of any content that must be continually updated will determine the data transfer capacity required.
4 Data connections on main rail transport routes

4.1 Operating environment

4.1.1 The current status of rail transport

About 87.5 million passenger journeys were made in 2018, and a rising trend has been seen since 1990. The same trend is also being seen in freight traffic, with about 40 million tons being transported on Finnish railways in 2018. Rail traffic volumes are expected to increase over the long term. This growth is being supported by increased energy-saving and energy-efficiency targets arising from climate change, the increased appeal of rail travel due to improved service quality and pricing, and changes in society and population structure. New projects to facilitate rail transport operations and further increase its appeal are planned for the coming years.

Rail transport will face pressures to change over the coming years, and this will have some impact on development requirements for data connections. Opening rail transport up to competition will bring new actors into the picture, and their requirements will need to be considered when developing data connections. Competition with other modes of transport will change the role of rail transport. However, it will also open up new opportunities for seamless transport chains in both passenger and freight transport. Railways have traditionally held a strong position in Finnish trade and commerce due to the country’s long distances and industrial structure. Changes in industrial production and commercial structure arising from urbanisation may further consolidate transport and passenger movements onto certain transport connections.

Data connections will provide opportunities for the rail network. One of the main features of the Finnish rail network is that it is single-tracked (about 90%), which places special requirements on rail traffic signalling and management. Winter conditions also affect the operation of routes, traffic management, and the maintenance of the rail network. From a traffic management perspective, adequate data connections must cover the entire rail network, which means that cost-effective solutions must be found for less-busy sections.

The main users of rail transport data connections are currently the Finnish Transport Infrastructure Agency (FTIA), Finrail, railway operators, passengers, and contractors working in railway areas. The FTIA is responsible for the rail network, maintenance of the rail network, and platform areas. The FTIA is also responsible for key data systems, such as automatic train protection (ATP) and safety systems. Finrail, the company in charge of rail traffic management, is responsible for traffic management systems, traffic management services, reconciling planned trackwork with train schedules, operating centres, and passenger information services. ‘Railway operator’ refers to railway companies, railway maintenance companies, infrastructure managers operating on the railway network, and museum train operators that require data connections for their own operations. Many rail passengers also require data connections to support their journey.
4.1.2 Trends in the rail transport operating environment

4.1.1.1 ERTMS

Finland’s own automatic train protection (ATP) system is reaching the end of its lifecycle and Finland will be adopting the European ERTMS/ETCS system. The requirements this will place on data connections will largely depend on the level to which the ERTMS system is implemented in Finland. ERTMS can be implemented on three levels:

- **Level 1** would provide an intermittent train control system. This would be most comparable to the current system, in which data is transferred between trains and the track-side at certain points with the aid of balises.

- **Level 2** would provide a continuous train control system that would give a better view of the rail network’s capacity. At Level 2, the signalling control would verify that the track is clear, but the green signal would be sent to the locomotive and driver using a wireless Radio Block Centre (RBC). Fewer signals and balises would be required than at Level 1, unless a Level 1 backup system is built.

- **Level 3** would provide a continuous train control system in which trains wirelessly send their locations to the Radio Block Centre. At Level 3, track-side equipment is not used to determine the position of trains. Instead, train positions are determined using a tachometer that counts wheel rotations; inertia measurements taken with a gyroscope and acceleration transducer; satellite radiodetermination; or a combination of the aforementioned. As at Level 2, train locationing requires a wireless network. Level 3 is not currently in use anywhere in the world, and is not yet technically feasible. The main challenges that must still be resolved relate to reliability issues with overall train specifications, which cannot yet be determined to the level required by safety devices.

A key component of Levels 2 and 3 is the Radio Block Centre (RBC), which processes signal information and relays it to the locomotive. The RBC is connected to a signalling control, and data is continually transmitted via a wireless network. It would not be cost-effective to build RBC interfaces into the signalling controls currently in use in Finland. Level 2 would therefore require the renewal of all signalling controls. Most connections to signalling controls and traffic management centres will probably be implemented using fixed and existing connections. In principle, connections between RBCs and individual signalling controls could also be implemented using wireless connections. With the introduction of ERTMS, a considerable number of existing railway safety devices will need to be replaced by 2040. The availability of ATP spare parts may force the schedule to be accelerated.
The data transfer capacity required by safety devices will need a radio connection. At ERTMS levels 2 and 3, data connections and components must be backed up and/or duplicated. Every train must have sufficient, backed-up capacity at all times, even if all trains are simultaneously in contact with a signalling control. This may have an effect on the base station coverage required. Existing requirements for track and signalling control response times are in the range of about one second. It can therefore be assumed that, with regard to latency, 5G would be able to provide a sufficient service level for data connections between the remote controller, signalling controls, RBCs and trains' terminal devices. As yet, no system-specific response times, response time requirements for data connections, or any other precise requirements have been defined – they will be specified in the future.

There are several issues connected to the deployment of ERTMS that must be resolved before any opportunities for harnessing the 5G network could be proposed. Open questions include:

- **Implementation order and ERTMS level** According to Finland’s ERTMS implementation plan, which was drawn up in 2017, the plan is to equip and pilot a quieter section of track in Northern Finland with an ERTMS Level 1 system, and also to investigate the potential benefits of Level 2 before busy southern tracks begin to be equipped in the 2030s. It has been proposed that pilot sections be equipped with both ATP and ETCS. The Finnish Transport Infrastructure Agency and Finrail launched a joint project in 2019 – the Digirail project – which aims to conduct a more extensive analysis of the development of ERTMS and rail traffic management systems. The knowledge and understanding obtained from the Digirail project will probably create a need to revise the implementation plan. It is currently unclear what ERTMS level the Finnish rail network is aiming for. Depending on their capacity requirements, different solutions may be implemented for different sections of track. However, in order to appropriately identify the need for preemptive 5G construction, it would be helpful to get a better understanding of which sections will be equipped with Level 2 and Level 3 systems.

- **Implementation schedule** According to the 2017 implementation plan, track devices will be piloted in 2020–2023, after which actual implementation will be carried out in six phases from 2024–2038. The FTIA and Finrail’s Digirail project may alter this preliminary schedule. The new timetable will also create a framework for the preemptive construction of data connections in railway environments. The closer implementation is moved to the 2030s, the greater the uncertainty surrounding preemptive construction. Rescheduling will also bring new perspectives on the opportunities and limitations surrounding 5G technology.

- **Changes in network topology** Building new Radio Block Centres and updating existing signalling controls to meet Level 2 requirements may require changes to current topology, which could in turn require the implementation of new data connections. A comprehensive picture of telecommunications requirements will require more precise specifications for both data connection requirements and RBC and signalling control dimensions.
Wireless connections between Radio Block Centres and trains

In ERTMS materials, the wireless connections between Radio Block Centres and trains are shown to use the GSM-R radio network. In Finland, this has been wound down and replaced with the Virve 1.0 network. In Europe, a new 4G/5G radio network is being specified to replace the railway GSM-R network: the Future Railway Mobile Communications System (FRMCS). When it comes to ERTMS development, it will be important to resolve which data network will be used in Finland. The following have been identified as alternatives in Finland: using the next version of the Virve network (Virve 2.0), using networks provided by commercial operators (5G), or creating a dedicated railway network (FRMCS/GSM-R). Another option is to assess the potential for using hybrid solutions. The technoeconomic cost-effectiveness of ERTMS 2 solutions will determine the implementation and commissioning costs for the chosen network solution. The choice of network solution must take into account the implementation schedules and scope of commercial 5G networks and the Virve 2.0 network.

4.1.3 The challenges that railway environments place on digital infrastructure construction

In the future, data connections will be increasingly important in all operations and consumer experiences. Maintaining the appeal and functionality of the rail transport operating environment will require not only data connections for rail traffic management, but also sufficient and reliable connections for passengers, railway operators and other rail transport actors.

The operating environment is more challenging for rail traffic than it is for road traffic. Working close to railway lines is dangerous, due to both the trains themselves and track electrification. From the perspective of data connections, the main challenge will lie in device construction and maintenance – not all track sections have proper maintenance access roads, which will make maintenance expensive.

It is a challenging operating environment for small actors and passengers, as they do not have sufficient volume to induce commercial operators to make investments in comprehensive rail network coverage. Individual sections of track may have adequate fibre infrastructure, and data connections may satisfactorily meet the Finnish Transport Infrastructure Agency and Finrail’s requirements. However, existing data connections are rarely available to other actors. One of the financial challenges in implementing commercial mobile networks is that railway tracks often run through the edge of inhabited areas, which means that any required data connections would be built solely for railway use. There is also another challenge from the perspective of business and technical dimensioning: when a train passes a base station, a large number of moving devices will connect to the base station, possibly requiring a great deal of capacity from it. However, for most of the time, the base station will not necessarily have any traffic at all.
4.2 Data connections in railway environments

4.2.1 The ownership and management of data connections in railway environments

Rail transport uses both fixed and mobile connections. Commercial service providers (Elisa, DNA and Telia) mainly provide mobile connections that are utilised for drivers’ terminal devices, contractors’ mobile connections and passengers’ data transfer. In addition to commercial mobile connections, rail transport can also use Virve (1.0), which is operated by Suomen Turvallisuusverkko Oy, a member of the Suomen Erillisverkot Group. The Virve network is used for voice communications between authorities, and between authorities and rail traffic. The Virve (1.0) mobile network is primarily intended for voice communication and does not support data transfer, unlike existing commercial mobile connections. Virve 1.0 will be replaced by Virve 2.0 in the early 2020s. According to current plans, the existing Virve network will be maintained alongside the new network until the end of the decade.

Rail transport’s key data connections, such as connections for safety devices, are implemented using fixed connections. These fixed connections are based on both copper and fibre-optics. The telecommunications cables that serve rail transport are owned partly by the Finnish Transport Infrastructure Agency and partly by Cinia. Cinia has ended up owning railway telecommunications cables for historical reasons. There is no common knowledge about the precise location and ownership of telecommunications cables, and investments in new cables are made as required. Finrail owns the majority of fixed connections at stations, which mainly serve station and railyard camera surveillance and passenger information and announcement services. Finrail acquires station connections from commercial operators. Finrail does not own the fibre connections it requires for its own traffic management system. Not all of the cables located in railway areas serve rail traffic alone. Operators have some telecommunications cables that serve other purposes.

The power grid that serves the Finnish Transport Infrastructure Agency’s rail traffic has primarily been implemented to meet the needs of track electrification (overhead power lines) and other track-related functions (such as lighting, point heaters and buildings). Electrical cabling may be placed on the ground, in cable channels, or as overhead wires. Electrical connections in railway areas are mainly controlled by the Finnish Transport Infrastructure Agency, although some are in joint ownership.

The location of fixed connections varies greatly in railway areas. According to current guidelines, new rail projects and improvements to existing tracks must build concrete cable channels alongside the track for telecommunications and electrical cables. These cable channels are considered to be good technical solutions. Some of the existing cable channels are already full, making it difficult to lay new cables or extend existing cabling. From now on, the dimensioning of cable channels must also pay particular attention to future needs. On older sections of track, telecommunications cables also run through macadam and as overhead lines. In certain cases, cables may also run beneath the tracks in a loaded structure. In practice, it is impossible to maintain these cables and their renewal will, almost without exception, require the implementation of new fixed connections.
From the perspective of railway operation, data connections are currently good in relation to current and future service requirements. In railway environments, there are many fixed connections that have been implemented for rail traffic management purposes, and thereby provide sufficient data connections. Due to the safety levels required, the data connections related to safety systems are kept separate from other data networks, and there will probably be justification for a separate fixed network in the future as well. At the moment, the main areas for development relate to the renewal of old cables and the improvement of wireless connections along more remote sections of track. Improved wireless connections would in particular benefit passengers, contractors, rail traffic controllers and train drivers (the use of terminal devices and voice communication connections).

4.2.2 The use of rail transport data connections and their developmental requirements

4.2.1.1 Passengers

Mobile phone users' data transfer volumes have long been increasing and look set to increase even further. Watching videos in particular takes a great deal of bandwidth, as does downloading large files for remote working. The existing data connections are based on mobile phone operators' mobile networks, either directly or indirectly via the long-distance rail traffic's wireless WiFi network, which is also based on a commercial mobile network. For passengers, 5G will bring improved data connections through extra capacity. From their perspective, more extensive 4G coverage to remove existing blind spots in the rail network is more important than faster connections.

4.2.1.2 Rail traffic management and train protection systems

Rail traffic management is responsible for safety in the rail network. Safety devices ensure clear routes and, according to current understanding, these safety devices will continue to be based on fixed connections in the future.

In the state-owned rail network, rail traffic management and control uses an intermittent train protection system (ATP) that is based on devices installed in both the track and rolling stock. These devices are connected to remote control devices using a fixed copper or fibre-optic connection that is managed by the Finnish Transport Infrastructure Agency. These fixed connections are owned partly by the FTIA and partly by Cinia (as the service provider). During basic track improvements and replacements, old connections will be partially replaced with fibre cables. Railway operators are responsible for the terminal devices in their existing rolling stock. On some sections of track, there would be a need for better automatic train protection. However, considerable investment plans for the construction of new connections will probably not be made before ERTMS plans are clarified. In the future, 5G connections could create new opportunities for train protection if they are able to improve train location data.

Voice communication concerning railway safety currently uses the RAILI service, which is provided by the FTIA. At rail traffic management centres, the RAILI service is used with fixed communication devices. In railway environments, the service is used either directly with telephones operating in the Virve 1.0 network, or via commercial networks using smartphones equipped with the RAPLI login app. According to national regulations, rail transport communication in rolling
stock must always use Virve 1.0 network phones. The FTIA’s Unified Railway Communication and Application (URCA) platform enables the use of a variety of radio networks. Special functionality for rail communications can be offered to all radio or mobile network users who are connected to the URCA platform. With the aid of URCA, communication services could also be transferred to mobile networks in the future, such as Virve 2.0 or the FRMCS, which are currently under development. Ownership of the fixed fibre and local networks that are required to connect the RAILI service to various network devices is split between the FTIA and Cinia (the service provider).

Finrail is responsible for the technical control room, which monitors and maintains the functionality of the control device network. The control room collects data from RFID readers, wheel force indicators, hotbox detectors and current collector cameras. Any warnings received will be forwarded to the technical control room and traffic management centre for the section of track in question, from where they will be forwarded to the driver. In the future, 5G connections and IoT networks will offer new opportunities for devices to monitor rolling stock.

4.2.1.3 Railway operation

In addition to voice communication, train drivers also use data connections via the KUPLA app. KUPLA (the driver’s terminal device) enables the driver to exchange digital information with traffic management centres and traffic control systems. The application provides the driver with real-time scheduling and location data, advance reports, and communication connections. Finrail is responsible for this service, which is provided in commercial operators’ mobile networks. As KUPLA will function adequately with a 3G connection, 5G will not necessarily bring any particular development opportunities. Extending the coverage of the mobile network and removing any existing blind spots is more important for this service.

One future development path involves autonomous and remote-controlled trains, and this is partly linked to the development of automatic train protection. Trains are already remotely controlled in railyards with the aid of radio control. However, remote control from a centralised control centre would require continual, lag-free video footage from trains and railyards. This would require low-latency data connections with considerable data transfer capacity. In order to create an adequate overall response time, the network’s overall latency is just one of the challenges being faced – there are greater challenges related to video processing and improving the mechanical response time of rolling stock. However, autonomous trains and remote control will primarily require advancements in the modernisation of train control systems, train locationing, and data connections.

4.2.1.4 Transport infrastructure authorities

The Finnish Transport Infrastructure Agency acquires passenger information and announcement services from Finrail. Finrail owns the passenger information displays and tannoy systems at stations and on platforms, the fixed copper and fibre-optic connections used by station devices (LAN network), and passenger information servers. Finrail acquires the network connections for stations from commercial operators, as these services have not been able to use the FTIA’s existing fixed connections. However, mobile networks could constitute
a potential alternative in the future, particularly for those stations and stops that do not yet have connections.

Camera surveillance at traffic operating points and in open sections mainly focuses on monitoring railyards and sidings, identifying trains, and shunting traffic control. It seeks to provide the railway operator with a better picture of the current status. Security control centres use camera surveillance at stations and on platforms to improve personal safety and prevent vandalism. As railyards are not currently fully covered by camera surveillance, there will likely be a need to extend coverage in the future. Finrail is responsible for camera surveillance at stations, the cameras themselves, and the fixed connections they require. At least some less security-critical connections could also be implemented using mobile connections. As camera surveillance is usually implemented using at least HD images, 5G connections could bring new opportunities for developing and extending camera surveillance in particular, even though most surveillance cameras already work well in the 4G network.

4.2.1.5 Contractors and others working in railway environments

Contractors use data connections for voice communication and locationing. In the future, they will also use, process and maintain files that will contain increasingly large volumes of data, for example, by using model-based design in the field. Contractors use commercial mobile networks for non-safety-critical communications and to utilise a variety of different materials. The Virve network’s RAILI service is used for safety-critical communications, such as emergency calls, locationing based on base station coverage, authorities' voice communications, and communications about disturbances in rail traffic.

More accurate locationing will be required in the future, in order to enable mobile use and meet larger data transfer requirements. Current locationing is often based on GPS (such as RUMA), which in itself is not accurate enough to define positions in a railway environment. New radio technologies enable micro-locationing, and will be able to provide a supplementary solution to GPS. For example, precise locationing can be used on construction sites, where several accurately defined temporary location points can be used by traffic management centres to precisely determine the location of construction workers.

RAPLI is an Android smartphone app designed for voice communication. It works in all commercial 2G, 3G and 4G networks. The app is used by railway contractors in particular, but also by, for example, conductors. RAPLI is also available to train drivers as a backup communication tool. RAPLI enables users to log in to the RAILI service with a unique ID showing their professional position and work task. It also enables user-friendly voice communication between trackwork teams and traffic management centres. RAPLI users can make and receive railway emergency calls.

RUMA is a service targeted at railway contractors. It seeks to improve trackwork safety by showing the location of trackwork teams and digitalising existing paper forms. RUMA uses the locationing services provided by mobile devices to determine the user’s location, and then sends it to the traffic management centre, other members of the trackwork team, and those in charge of trackwork. RUMA operates in mobile networks provided by commercial operators. Existing data connections are adequate for using the app, and extending coverage and removing blind spots are more important for this app.
4.2.1.6 Common developmental themes

The use of cameras and computer vision is a trend that could be used more in rail transport as a result of improved data connections. In rail transport, computer vision could be used to identify train carriages, to determine train locations, in track maintenance, to identify track faults, and to identify any potential obstacles on or alongside the track. As a result of advancements in 5G and IoT networks, new cameras could be installed in rolling stock or wirelessly along sections of track that currently lack fixed connections. Even a mid-range 5G network would provide adequate data transfer capacity and a level of reliability that would almost be comparable to fixed connections. This would enable real-time video to be transmitted from rolling stock or the surrounding terrain. Implementing a 5G network at individual sites, such as stations and railyards, would enable HD video data collected by trains to be wirelessly transmitted from the train to a cloud service. Camera images could also be used in different ways, including for pattern recognition.

5G and IoT networks will provide increased opportunities for cost-effective remote sensors and remote control. With 5G, it will be possible to place more sensors within the scope of a single base station, and the sensors’ battery life will also be extended. This will reduce the need for sensor maintenance and make sensor use more affordable for users. IoT sensors can be used in a variety of ways in rail transport. In the maintenance of bridges, track structures and track devices (such as point heaters), they can provide analytics for planning preemptive maintenance. Sensors can also aid in the maintenance and remote monitoring of rolling stock, which can make maintenance requirements easier to predict. Train carriage monitoring can also be developed with the aid of remote sensors. IoT solutions can also enable the wireless remote control of level crossing gates and warning lights in areas where no fibre connections are available.
5 The outlook for developing data connections in road and railway environments

The development of Virve 2.0 may lend extra impetus to completing the 4G network

4G connections currently cover the majority of Finland with the exception of its most remote areas. The sections of main transport routes that run in close proximity to urban areas are fully covered by the 4G network. Telecommunications operators' 4G networks do not yet fully cover the road network in Northern and Eastern Finland. Between urban areas, there are even some blind spots on sections of important main transport routes. 4G permits were issued on the condition that the network would be built to cover all highways, main roads, regional roads and connecting roads in mainland Finland and the entire state-owned rail network by February 2020. However, these permit conditions only cover the availability of connections and do not take any stand on data transfer speeds.

The introduction of Virve 2.0 (the network used by authorities) in the early 2020s will provide another clear development path for improving 4G connections and removing blind spots in the near future. Erillisverkot will be responsible for the Virve network. It will mainly be used by the authorities and will be implemented by commercial operators. Implementation of the new Virve network will probably require the construction of new base stations in close proximity to main transport routes and smaller roads, in order to achieve sufficient coverage for the Virve network. The construction of these new base stations will also pave the way for improvements to commercial 4G and 5G networks alongside main transport routes. A great deal will depend on scheduling, implementation requirements, and the desired scope.

IoT networks will become globally available

Even before the widespread extension of the low-frequency 5G network, operators have been implementing NB-IOT and LTE-M networks that enable the use IoT sensors. According to operators, these networks will already become globally available during 2020. In many places, they can be used by infrastructure maintenance providers to collect data about road/rail conditions, to monitor traffic, and to monitor the condition of roads, tracks and buildings.

The first phase of the 5G network will be based on low frequencies

According to current understanding, the first 5G phase will be based on the 3.5 GHz frequency band, with the potential introduction of the 700 MHz frequency band. The 5G network will be implemented by commercial operators to whom frequency bands have been auctioned. One realistic option for implementing a 5G network is to provide basic 5G capabilities and full coverage using the 700 MHz frequency band, and to use the 3.5 GHz band to offer faster data transfer in certain areas. It has also been estimated that, over the coming decade, other licensed frequencies will be at least partially migrated to 5G technology.
Harnessing 5G technology will require more than simply introducing higher frequencies. It will require technological advancements from device manufacturers and lower prices for devices. During the first phase, the 5G network will mainly provide users with faster connection speeds.

According to operators, the 5G network will be built in line with habitation. It will first be implemented in city centres and the suburbs of major cities, where mobile networks have almost reached capacity in places. From the perspective of main transport routes, this means that 5G connections based on low and mid-range frequencies will probably first be available in the vicinity of cities, that is on major internal access routes, ring roads and harbour connections. Outside urban areas, the 5G network will largely follow the needs of residential areas.

Building base stations solely to meet the needs of traffic will easily run into challenges associated with a lack of good commercial opportunities. Investments in new base stations on solely commercial bases appear unlikely, unless transport use cases requiring significant data transfer capacity or other 5G capabilities arise – along with functional business models for them. One major direction that development may take would be the widespread introduction of data connections in vehicles. This would give operators a financial interest in implementing full-coverage networks.

The existing base station network in cities will largely be sufficient to implement a 5G network based on low and mid-range frequencies. It is likely that no new base stations will be required, as the challenge faced in cities is often more to do with capacity issues in individual cells rather than the coverage areas of base station cells. In cities, the 5G network can be largely implemented without significant new construction by updating base station devices. Outside cities and larger urban areas, there will probably be a need to build a denser base station network if the intention is to implement a low and mid-range 5G network with
the same coverage as the current 4G network. It is estimated that a mid-range-frequency 5G base station will have a range of less than half the range of a 4G station. The implementation of a 5G network based on mid-range frequencies will therefore require the construction of a considerable number of new masts. The implementation of an unbroken mid-range-frequency 5G network along main transport routes would probably require the construction of hundreds of new base stations. The main construction requirements would be for new stations, as well as electrical and fibre connections to these stations.

These new base stations would not necessarily be located on or even in close proximity to the traffic area, even if they would at least partially serve road and rail traffic. Depending on the type of terrain, they could also be located at some distance from the transport route. This could enable electrical and fibre connections to be extended from nearby urban areas without the need for construction in the traffic area. According to operators’ estimates, data traffic in core connections along main transport routes is generally good. There will not, therefore, be a significant need to build data connections in traffic areas, with the exception of northern regions that will not necessarily have the required core connections. The Finnish Transport Infrastructure Agency does not therefore have much direct influence or means of enabling the construction of individual base stations outside traffic areas.

The implementation of a high-frequency 5G network along main transport routes seems improbable

Based on interviews with operators, the broad-ranging implementation of a 5G network based on high frequencies along main transport routes by 2025 seems very unlikely. On the other hand, the transport use cases that have been identified for the near future do not include any applications or services that would specifically require the implementation of a high-frequency 5G network.

In road transport, new services with relatively large data transfer requirements have been identified with regard to automation and inter-vehicle communication. Many road traffic services are still at the developmental stage and it will probably take several years before they become widespread in vehicles that are available on the market. The development of related technology and architectural solutions will also reduce the data transfer requirements of these services. On the other hand, the majority of road traffic’s increasing and safety-critical communication seems to be based on direct communication between vehicles using short-range connections and without the need for an external network. If these services become widespread in areas with large traffic volumes, data transfer connections may easily become overloaded and 5G networks with large capacities would need to be implemented. One challenge in road traffic is that vehicles are not generally equipped with data connections, although this will provide operators with a new kind of earnings logic. Although if the vehicle base renews relatively slowly, the arrival of new services on the market will not necessarily mean that they will be adopted immediately or become widespread.
In rail transport, no significant use cases have been identified that would specifically require a 5G network based on higher frequencies (with the exception of the development of ERTMS Levels 2 and 3). On the basis of the interviews, the 5G network could potentially function as one component in the overall solution, for example, as a backup connection, but is unlikely to be used as the primary connection. In terms of scheduling, it appears that ERTMS implementation will begin at the earliest in the late 2020s, so no implementation requirements have been identified for it in the near future.

According to current understanding, a full-coverage high-frequency network would not be implemented in cities. Instead, it would be implemented as individual 'hotspots' and in restricted environments where there would be a need to supplement a low-frequency 5G network (such as ports, campuses, production facilities, and events). In these areas, the use of higher frequencies would provide either very high data transfer speeds or moderate data transfer capacity for a large number of terminal devices. The implementation of hotspots would require use cases and services with real commercial potential.

An extensive high-frequency 5G network with full coverage along main transport routes appears unlikely, even over the longer term. However, as data transfer requirements increase, it is possible that there will be a need for individual high-frequency base stations along main transport routes as well. From the perspective of main transport routes, this may mean the implementation of transport hotspots where there is a need for large data transfer capacity or where a specific data transfer speed is required. These 'super sections' could, for example, be located on busy sections of main road transport routes. They could include highway junctions or intersections where it would be possible to transfer large volumes of data quickly. For example, downloading HD map content for route planning or uploading recorded journey data to a cloud service. In rail transport, these sections could be busy station and railyard environments or hotspots along certain sections of track. In these environments, there is theoretical potential for the creation of new use cases that would require data connections with very large data transfer speeds or high levels of reliability.
6 Identified suggestions for further measures

In principle, telecommunications operators will implement the 5G network and the majority of the other telecommunications infrastructure along main transport routes. Many things are already running smoothly in transport environments, and neither transport infrastructure authorities’ activities nor current operating principles are creating bottlenecks for the construction of 5G networks. The practical challenges will most likely come from elsewhere, such as in finding business to cover the cost of new investments. However, by further developing the operations of transport infrastructure authorities, it will be possible to promote the construction of 5G networks and other data connections along transport routes.

Identified suggestions for further measures have been divided into three groups: strategic steering, developing operating models and processes, and the preemptive construction of passive infrastructure. Strategic steering seeks to clarify the role played by the transport infrastructure authority in promoting telecommunications issues and to clarify the target level for telecommunication development in traffic areas. When it comes to the development of operating models and processes, areas for development have been identified in the transport infrastructure authorities’ activities, and these measures should further promote the construction and availability of data connections along main transport routes. The preemptive construction of passive infrastructure seeks to identify concrete measures by which the Finnish Transport Infrastructure Agency can pave the way for the future construction of effective data connections in conjunction with new projects and basic improvements.

**Strategic management**
1. The role of the transport infrastructure authorities in promoting telecommunications issues requires clarification.
2. Data connections should be more closely linked to infrastructure development and service level goals

**Development of operating models and processes**
3. The joint use of digital infrastructure should be promoted in traffic areas
4. Co-operation between authorities and operators should be closer and more systematic
5. Data connections should be taken into account earlier in transport infrastructure authorities’ project procedures
6. The co-ordination of cable relocation should start during the planning stage
7. The implementation process can be made smoother by developing siting permit procedures

**Technical incentive measures**
8. Cost-effective preemptive construction requires co-operation with operators
9. Preemptive construction of passive infrastructure must focus on the right targets
10. The exact measures required for the construction of a high-frequency 5G network will only become apparent in the future
The role of the transport infrastructure authorities in promoting telecommunications issues requires clarification.

Their current role focuses on the planning, development and maintenance of road, rail and sea transport, and on reconciling traffic with land use. Some aspects of promoting telecommunications issues lie outside the FTIA’s role, even though telecommunications issues will most likely become a more integral component of smooth running transport systems and transport routes.

According to the Government Programme, data connections will largely be implemented by telecommunications operators using a market-based approach. In order to clarify the development of telecommunications on main transport routes and in other traffic networks, to identify the correct measures for transport Infrastructure authorities to take, and to assess the costs of preemptive passive infrastructure construction, it will be necessary to clarify the role played by transport Infrastructure authorities in telecommunications issues.

Three alternative roles have been identified for the transport Infrastructure authorities:

- **Alternative 0: Transport Infrastructure authority** The transport infrastructure authority’s goal is to ensure functional infrastructure and lifecycle management. Development and preemptive construction are largely directed at activities that primarily seek to protect the value of transport route assets. For example, this means investments in passive infrastructure in specific places where it can protect transport structures from later construction or ensure smooth traffic flow.

- **Alternative 1: Enabler** In addition to its basic tasks, the transport infrastructure authority’s goal is to support data connection projects along transport routes. Development and preemptive construction are largely directed at promoting the overall cost-effective construction of telecommunications infrastructure, even if this would not always be justified through its role as the transport infrastructure authority. This could require separate funding to be allocated to investments in passive infrastructure that lie outside the scope of the transport infrastructure authority’s role. In this role, the transport infrastructure authority would treat operators equally and impartially. As the level of investments and preemptive construction would be considered on a case-by-case basis, current principles could lead to individual implementations, the creation of overlapping infrastructure, and a monopoly for the first investor.

- **Alternative 2: Promoter and creator** In addition to its basic tasks, the transport infrastructure authority’s goal is to promote the creation of a functional telecommunications operating environment in conjunction with main transport routes. Development and preemptive construction are largely directed at ensuring that data connections are adequate for transport requirements, and that the operating environment develops in a way that makes the development and maintenance of data connections universally cost-effective. Investments in passive infrastructure are made to promote joint usage, and to prevent the creation of commercial monopolies and unnecessary overlapping investments. For example, this could mean investing in new base stations that will clearly be used by traffic, or renewing streetlighting solely to meet telecommunications requirements. This role could require separate funding to be allocated to investments in passive infrastructure that lie outside the scope of the transport infrastructure authority’s role.
2 Data connections should be more closely tied to infrastructure development and service level goals

Data connections on main transport routes and their development should be more closely tied to both service level goals and development measures, as the future development of road and rail traffic will require more smooth-running data connections that can be used by all actors.

Transport’s requirements for data connections will depend on traffic volumes and the services utilised by users. This means that different routes, and even different sections of certain routes, may have very different requirements for data connections. Route-specific service level targets should pay better attention to both trends in traffic and user volumes and the actual requirements of data connections that serve transport. When considering service levels for main transport routes, it is a good idea to consider not only data connections for traffic management, but also those required by road users and traffic automation. In addition to setting service level targets, the actual status and adequacy of data connections should be monitored from the perspective of different route users, and the same goes for traffic service development paths.

The service level for data connections on main transport routes and at key traffic nodes should be collaboratively specified by the transport infrastructure authorities, cities and operators. A jointly specified target state for data connections would create both an overall picture and a long-term approach for the various parties’ promotional and developmental measures, and also for cooperation between these parties. A more consistent concept of where developments are heading would also help the preemptive construction of passive infrastructure to be targeted at areas in which data connections would be most important for transport. Particularly on internal city access routes and ring roads, co-operation between cities and operators would be important for ensuring the sufficient and standardised development of data connections on transport routes.

3 The joint use of digital infrastructure should be promoted in traffic areas

The Finnish Transport Infrastructure Agency and traffic management companies would benefit from closer co-operation on both state-owned digital infrastructure (passive infrastructure, telecommunications cables and the power grid) and externally acquired data connections. The Finnish Transport Infrastructure Agency and traffic management companies have been responsible for their own data connections and have not always engaged in extensive co-operation. These days, actors implement the data connections they require for their own use. Parallel connections have been implemented across some sections of transport routes, and it has not been possible to utilise other actors’ existing connections and undercapacity. On the other hand, some sections of transport routes would completely lack data connections if an actor’s own needs had not been sufficient to warrant investments. Investment principles have also varied. Some actors have implemented new connections for their own use, whilst others have acquired connections as a service from commercial service providers.
Closer co-operation would help to:

- prevent the construction of more overlapping connections
- identify opportunities for joint investments
- find ways for different actors and different modes of transport to co-operate on utilising existing fibre connections, for example, as backup connections
- find opportunities for making cost savings through joint maintenance and operation.

In order for the Finnish Transport Infrastructure Agency and traffic management companies to co-operate on the development of data connection requirements for road and rail traffic, it would be useful to create a common picture of how this development and co-operation should work. It will be good to examine the future of telecommunications in various areas and on various sections of transport routes from the perspective of, among other things, data requirements, safety devices, data security, maintenance and transport users. This analysis should pay attention to the need for new connections, the principles for their implementation and acquisition, and opportunities for the joint utilisation and maintenance of existing connections. One mode of co-operation could be to investigate the possibility of transferring the ownership, acquisition and maintenance of new and existing connections to a single, centralised organisation.

Whenever possible, it would also be good to extend the joint use of digital infrastructure in traffic areas to operators. Implementing a full-coverage 5G network along transport routes and removing blind spots in the 4G network will probably require the construction of new base stations in uninhabited areas. In non-urban areas in particular, the construction costs of new base stations could be reduced if cable networks or power grids that have already been built to meet transport needs could be utilised.

It would be good to clarify opportunities and principles for co-operation with operators, so that data networks and power grids that are operating under capacity could be opened up at specific points to support the construction of new base stations. This is particularly true with respect to power grids. As legislation will place some restrictions on the use of power grids, further collaboration will require not only technical solutions, but also a variety of models that the Finnish Transport Infrastructure Agency can use to provide power grids to third parties for the development of data connections and other transport network needs.

It is also worth examining what kind of joint investment models and operating principles would enable the implementation of new data and electrical connections in traffic areas, in order to meet the needs of transport infrastructure authorities, traffic management companies, operators and other actors.
4 Co-operation between authorities and operators should be closer and more systematic

Although co-operation between ELY Centres and telecommunications operators has been going well, it is important to continue and further develop this co-operation in the future. Co-operation with ELY Centres is currently centred around two networks.

- **Asiakasfoorumi (Customer Forum)** The Pirkanmaa Centre for Economic Development, Transport and the Environment set up this forum for representatives of electricity and telecommunications companies and their interest organisations. Representatives of the Finnish Transport Infrastructure Agency and the Pirkanmaa ELY Centre have also participated in the forum. This customer forum discusses topical issues for electricity and telecommunications companies, the FTIA and Pirkanmaa ELY Centre, as well as amendments to legislation, regulations and guidelines. It aims at open discussion on both sides, an understanding of activities, and collaborative preparation for future issues.

- **Regional co-operation meetings for network constructors** These meetings seek to exchange information leading to joint construction. Regional practices at different ELY Centres have apparently varied. The Pirkanmaa ELY Centre arranges co-operation meetings twice a year. Participants include ELY Centres, electricity and telecommunications companies, and occasionally representatives from the Finnish Communications Regulatory Authority and Johtotieto. The meetings mainly focus on presenting upcoming investment projects, finding potential joint construction projects, and developing co-operation procedures.

In the future, it would be beneficial for ELY Centres to exchange information about co-operation in a variety of forums. It is important to ensure that each ELY Centre engages in sufficient co-operation with operators. In addition to exchanging information, ELY Centres should also share best practices.

It would also be good to further develop co-operation between and the FTIA and electricity and telecommunications companies, and to make it more systematic. The FTIA and operators have to date co-operated directly on projects, which has meant discussing details related to these projects. A need has been identified for more systematic co-operation between the FTIA and operators, as this would provide an opportunity to discuss and develop collaboration on a more general level. For example, this co-operation could occur twice a year at a joint Co-operation Forum. Among other things, the following issues could be handled at the Co-operation Forum:

- Each party's upcoming projects and other investments
- Opportunities for joint construction and investments
- The development of joint operating methods and the co-ordination of development measures
- Predicting changes in the transport operating environment and monitoring data connection requirements
- Opportunities for co-operation in the development of data connections required by transport
Interviews have highlighted a need for the FTIA to provide ELY Centres with more detailed policies on how and in what manner the Finnish Joint Construction Act should be applied to operators in practice.

It would also be beneficial for the FTIA to clarify its strategic co-operation with Erillisverkot in order to monitor the development of Virve 2.0 and to identify opportunities for co-operation in the construction of data connections.

5 Data connections should be taken into account earlier in transport infrastructure authorities’ project procedures

If operators could be involved in the design process at an earlier date, this would promote the development of data connections. At the moment, co-operation on transport projects sometimes begins only at the construction phase, which is often too late for preemptive measures. Operators would benefit by being included in projects at the preliminary, general, road and rail design phases. Early-stage co-operation enables more preemptive development of data connections.

Both parties have a need to keep this co-operation light, and to avoid overly heavy processes that would overload the parties involved. From the operators’ perspective, it is vital to identify new projects in good time, to be able to familiarise themselves with design solutions that affect data connections, to be able to impact the preemptive construction of passive infrastructure, and to understand the project’s implementation schedule. Contacting operators and considering telecommunications issues in planning could extend to, for example, guidelines for consulting agreements.

During workshops, it has been noted that co-operation can be improved by exchanging information early on. Making better use of the online service Verkkotietopiste has been identified as one potential channel for exchanging data. Both the Finnish Transport Infrastructure Agency and ELY Centres currently send project data to Verkkotietopiste. Although it is then transferred to operators’ planning systems, projects have usually already reached the construction phase before this information is made available to them. Operators would benefit by receiving project data at an earlier date, for example, at the general planning stage, as this would enable greater preparedness and reconciliation. Detailed project descriptions and an estimated implementation schedule would make it easier for operators to anticipate and reconcile their
operations. It would also be important to send operators information about funding decisions and confirmed schedules as soon as possible.

One concrete development measure that has been identified is the development and clarification of a common process in different types of transport projects. Development should result in key information and co-operation requirements being described at every stage of planning.

6 The co-ordination of cable relocations should begin during the planning stage

Good project planning paves the way for successful and cost-effective cable relocations. When it comes to cable relocations being made in conjunction with new projects or basic improvements to roads and tracks, preemptive measures should be launched systematically at the planning stage in co-operation with operators. There is no clear practice in place at the moment, and operators are occasionally contacted only just before the launch of construction, by which time it is challenging for them to prepare for cable relocations.

It is important to contact cable owners at an early enough date, so that operators will be able to:

- **plan alternative routes for cables** If changes are made to the line of an existing transport route or new structures built, cables may need to be relocated. In order to arrange easy access to telecommunications infrastructure for future maintenance, it is a good idea for operators to be able to influence cable routes in good time.

- **take a stand on the preemptive construction of passive infrastructure** Co-operation with operators in conjunction with cable relocations can identify the correct and most suitable type of preemptive measures. On heavily trafficked routes that may require at least individual mini base stations in the future, sufficient preemptive construction of passive infrastructure can be planned in collaboration with operators in conjunction with cable relocations.

- **analyse the need for new cable investments** Some cables may have reached the end of their lifecycles and ought to be replaced rather than relocated. Sometimes cables will also need to be renewed in order to increase capacity. Early co-operation would also enable operators to better prepare for new cable investments in their budgets.

- **plan the alteration work and connection downtime caused by cable relocations in a controlled manner** Telecommunications cable relocations will, almost without exception, lead to breaks in data connections. Operators should be aware of this and be able to plan breaks in good time, so that they can be implemented in a controlled manner. Telecommunications should be redirected to backup routes whenever possible, or then customers should be informed of downtime.

Consolidating cable transfer projects can reduce the disturbance caused to operators. Co-operation at the contract tender stage can ensure that the relocation of existing cables, the positioning of new cables and any preemptive construction of passive infrastructure will all be included in the project. It will also ensure that the costs are evenly distributed between the various actors. Joint competitive tendering and contracting can also have a significant impact on operators’ costs. If operators are forced to tender out cable relocations as separate contracts, contractors will often be able to dictate the price of
relocation work and thereby cause relatively high costs for operators. If cable relocations and other measures were included in the contract, operators' costs would remain under control, as they would not usually have a major impact on the contract's overall workload and price. Co-operation on the construction and maintenance of data connections can enable cost savings. Paying better attention to cables during contracts can also reduce the risk of severing cables.

7 The implementation process can be made smoother by improving siting permit procedures

Clarifying siting procedures in railway environments will aid operators. Operating in railway environments will always be challenging, as factors such as track electrification and safety must be considered. However, developing better data connections requires operators to be able to operate smoothly in railway areas within the agreed frameworks. Operators have identified three major areas for development in siting permit procedures that would help them to operate in railway environments.

On the basis of interviews, it was found that the Finnish Transport Infrastructure Agency's terms and conditions for siting agreements (which came into force on 1 January 2019 in conjunction with the amended Railway Act) have significantly hindered operations in railway environments. In order to enable smooth operations, the terms and conditions related to responsibilities in particular should be made more moderate. The Finnish Transport Infrastructure Agency and operators have already begun addressing the most challenging points in these contractual terms.

The siting fee for cables in railway environments has been found to be many times the fee for the comparable procedure in road environments. Operators consider this to be unequal treatment of railway environments in comparison to road environments, and also a factor that lowers the appeal of siting data connections alongside railway lines.

Operators also think that clearer and more standardised siting permit practices and conditions would promote operations in railway environments. Operators consider the current guidelines for road environments to be good, and think that practices for railway environments should be standardised and developed in a similar way, while also taking the special features of railway traffic into consideration. In particular, operators like the clear cost division principles for cable siting that are currently used for road environments. They also consider more predictable principles and increased transparency to be important.

Siting permit procedures in road environments are considered to be working well overall. According to operators, areas for development include replacing the siting permit procedure with a notification procedure when new cables are added to existing casing.

Under the current procedure, a siting permit must be granted for every new cable that is laid, even if it will be laid in casing that already contains cables with valid siting permits. Operators consider the current procedure to be unnecessarily burdensome, and that a notification procedure would facilitate their operations.
Interviews have identified a need to preempt the installation of devices related to IoT sensors, base stations and other data connections in transport route structures and fixtures. Even if there is no precise information yet available about the devices and the scope of their placement in traffic areas, it would be good if the associated siting permit procedures could be preliminarily outlined in collaboration between the Finnish Transport Infrastructure Agency, ELY Centres and operators. Siting permit principles can then be revised through increased understanding. Another area for development would be a clearly outlined procedure for what devices can be sited along transport routes, where they can be located, and how these devices may be attached to different structures and on what principles. Siting permit procedures should take a preliminary stand on issues such as ensuring adequate outlooks, and impacts on upkeep and other maintenance (and in particular snow removal).

8 The cost-effective preemptive construction of passive infrastructure requires co-operation with operators

The preemptive construction of passive infrastructure should be planned in collaboration with operators to ensure that measures can be targeted at the most influential areas. The method and scope of preemptive construction will be impacted by factors such as existing telecommunications infrastructure in the area, its location in telecommunications topology, the route’s location in relation to habitation, the soil in the traffic area and how easy it is to build on, and future land use and traffic development requirements in surrounding areas. As the situation will differ on each section of road or rail, and may also change over time, the most cost-effective preemptive construction will identify project-specific co-operation with operators at the planning phase.

Cost-effective preemptive construction requires passive infrastructure to be

• **targeted at the right areas** Infrastructure should be targeted at areas and routes where operators and other cable owners will have a later need to use it, as preemptive construction for its own sake is not sensible. It would be easier to co-ordinate preemptive construction if the areas that will most probably require construction in the near future could be identified together with operators. It would likewise be beneficial to identify geographical areas in which preemptive construction is probably not worthwhile.

• **correctly implemented on a detailed level** In order for it to be worthwhile for operators to utilise preemptively constructed passive infrastructure, it should be correctly planned and implemented on a detailed level. This means that passive infrastructure should be easily accessible and located in the right places. The benefits of preemptive construction are soon lost if passive infrastructure is not located sufficiently close to planned cable lines, or if cable routes must be diverted in order to utilise it. Passive infrastructure must also be planned so that it can actually be used (for example, casing should not be laid with overly sharp corners.)

• **documentation and information about passive infrastructure must be available** Preemptive construction is only beneficial when it has been used. Its use requires good documentation and information to be made available to operators. Operators should receive information about the passive infrastructure that is available, so that they can take note of this in their own planning. One possible method would be to systematically collect information about casings and make this information directly available to operators in planning systems.
appropriately serviced and maintained  On a technical level, utilising casing requires it to have been correctly installed and probably marked in the terrain, and for it to be properly maintained throughout its lifecycle. If casing has for some reason been allowed to fall into disrepair and has been filled with soil, it may be impossible to use or will at least incur extra costs. There is good reason to clarify lifecycle management models, joint work processes and responsibilities (planning, construction, use, maintenance and repair) for passive infrastructure.

cost effectively priced  In order for the use of passive infrastructure to be financially viable, sales and leasing principles should be supportive. The Finnish Transport Infrastructure Agency has to date provided operators with casing without charge. Operators have considered this to be a good practice that encourages them to make use of passive infrastructure.

The preemptive construction of passive infrastructure must focus on the right targets

The most cost-effective passive infrastructure for roads is targeted at individual sites that can facilitate the construction of data connections and prevent road structures from falling into disrepair. Cost-effective preemptive construction of passive infrastructure focuses on special sites (such as tunnels, bridges, ramps, intersections and other challenging road and special structures) where it would be expensive to build data connections at a later date, as it would require the disturbance of existing infrastructure. At intersections, this would mean ensuring sufficient undercrossings using, for example, casing or cable channels. The scope and location of passive infrastructure should be planned in collaboration with operators. As the geographical size of special sites is often quite small, the absolute metrical volume of passive infrastructure would also remain relatively small. During the preemptive construction of special sites, it is worth planning the scope of passive infrastructure (for example, the amount of casing) to meet the requirements of a sufficiently long period, as preemptive construction rarely has a significant impact on the overall cost of a project.

Operators did not originally identify a need for passive infrastructure that ran alongside roads, for example, in the form of casing. This was for two reasons. Firstly, operators thought that their telecommunications cabling was already sufficiently good along main transport routes and there was no need for large-scale investments in sight. Upcoming investments would probably be targeted at individual connections whose planning and preemptive construction could be better agreed on separately. Secondly, it is not always necessary to implement passive infrastructure alongside transport routes in order to build core connections. If there is space alongside the route, implementing a new connection using excavation or ploughing can be a sufficiently good alternative. Lengthwise passive infrastructure can be useful at cuttings or where there is rock very close to the surface, as excavation will be expensive and diversions may be required. Preemptive construction at these kinds of sites should be planned on a case-by-case basis.

In railway environments, the Finnish Transport Infrastructure Agency has built cable channels for laying cables alongside tracks. All parties have considered this to be a good technical solution that is worthwhile continuing in connection with new projects and basic improvements. The issue with existing cable channels is that they are already full, which makes it challenging to use existing
cables or add new cables. During future projects, all parties should collaborate in checking cable channel dimensioning to ensure sufficient capacity for future needs.

Railway lines constitute significant obstacles to the construction of data connections. In addition to cable channels running alongside tracks, sufficient undercrossings and overcrossings should be planned with operators in conjunction with major basic improvements or the construction of new tracks. As undercrossing and overcrossings are usually very difficult and expensive to build at a later date, preemptive construction can also promote the overall availability of broadband.

10 The exact measures required for the construction of a high-frequency 5G network will only become apparent in the future

High-frequency bands will be available for use during 2020 and operators estimate that they will initially be introduced in cities. All parties consider the large-scale construction of high-frequency base stations alongside transport routes to be very improbable in the near future. Currently, the most advisable measure is to monitor the situation. At a later stage, it is likely that, instead of full high-frequency coverage along main transport routes, high-frequency 5G networks will be implemented at hotspots to supplement a 5G network based on lower frequencies. It is essential to monitor how extensively and to what schedule 5G networks will be implemented in urban environments to meet the needs of transport. It will be useful for operators to gather data from pilots and implementations, about both their experiences and the solutions employed. It will be much easier to suggest recommended measures on the basis of actual experiences. By the early 2020s, there will probably be sufficient information to identify the correct technical measures. According to current understanding, this should be sufficiently early to prepare for railway developments and the automation of road traffic.

However, if provisions for the construction of high-frequency small cells in traffic areas are for some reason considered necessary, a general measure for both road and rail traffic should be to conduct a preliminary analysis of the key requirements for building base stations near main transport routes in the near future. This analysis should assess route-specific requirements for the base stations to be located both within the traffic area and in its surrounding area. The analysis can then be used to create a route-specific estimate for the number of new base stations required, their location and implementation schedule, and any requirements they will have with regard to data connections, power grids and other provisions. A variety of implementation and investment models for the construction of new base stations can also be identified at a preliminary level. Existing coverage, current blind spots and the development outlook for data connections should be assessed in order to evaluate the need for new base stations. From the Finnish Transport Infrastructure Agency’s perspective, it is essential to monitor the development of road and rail traffic use cases that will either form bottlenecks for users or require very large data transfer capacities. These analyses should be revised to reflect any changes. These analyses of route-specific base stations can be used both in transport infrastructure authorities’ own planning and during collaboration with cities.
A secondary method would be to make provisions in planning and construction for those areas in which high-frequency 5G networks will first be implemented. The first road transport sites will most likely be hotspots within major cities, on internal ring roads and access routes with large traffic volumes. For rail transport, it will primarily be railyards and areas around stations. The construction of new base stations will require considerable investments, as it will probably require both major new construction and changes to existing transport route infrastructure. Provisions in these areas would mean the identification of suitable locations for base stations in connection with projects and basics improvements, so that their later implementation can be taken into consideration in technical solutions. Although basic principles for preemptive construction can be identified, there are currently many uncertainty factors surrounding the implementation of the high-frequency 5G network. This means that preemptive construction should always be planned with operators on a case-by-case basis.

In principle, the construction of base stations alongside main transport routes will require the following measures:

- **A need for fibre-optic connections** In practice, every new base station will need a fibre-optic connection. Although base stations can also be wirelessly connected to each other, total capacity would then be divided between base stations and the advantages of a large data transfer capacity will easily be lost. The key requirements for implementing fibre connections will relate to connecting each base station to operators' core networks.

- **A need for power** Every base station will need a continual supply of electricity. In future transport projects and track electrifications, provisions can be made for the siting of new base stations by dimensioning power grids to enable the siting of new base stations, by paying attention to base stations' need for an unbroken supply of electricity, and by planning power grids to technically enable the construction of new base stations by, for example, correctly locating and dimensioning electrical cabinets, distribution centres and connections. The existing power grid for streetlighting cannot be directly utilised, as lighting is controlled from the lighting centre and electricity will be disconnected when the lights are off. Secondly, base stations require significantly more power than streetlighting, which should be noted when dimensioning the network.

It is difficult to define concrete measures for constructing base stations, as the following uncertainties still surround the implementation of 26 GHz base stations:

- **Base station range** Sufficient experience of the 26 GHz network's range has yet to be gleaned from actual use cases, and different actors have differing opinions of the range of base stations. Different estimates place the range of base stations in unobstructed terrain at between 30–300 metres. Such large variation will have a significant impact on both topology and the size of the investments required.

- **Base station density** Even if extensive data connections are implemented within a traffic area, the base station network will not necessarily need to provide full coverage. If base stations have long ranges, transport users can be provided with average data connections even without full coverage from a high-frequency network. The challenge faced in
preemptive construction is to target measures at the correct sections of transport routes.

- **Location along the route** There is currently no clear view on how base stations should be located within a traffic area in order to create a full-coverage high-frequency network. In principle, base stations can be located in the central reservations of main roads, or along one or both sides of the road. All of the alternatives have good and bad sides with respect to construction and maintenance. Without clear implementation solutions, it is challenging to make provisions for passive infrastructure.

- **Device size and location** Manufacturers have released the first versions of base station devices, but there is still uncertainty about the eventual size and weight of these devices when they become commonplace in the market. Device size will have a direct impact on the kind of structures they can be attached to, the kind of wind loading they will be subject to, and the kind of obstructions they may cause. Lampposts, pylons and dedicated 5G network masts or poles have been suggested as locations for high-frequency network base stations. Siting base stations in connection with streetlighting would probably require the streetlighting to be renewed. In practice, streetlighting has only been built in urban areas, which means that alternative locations will anyway have to be found for the majority of base stations in the transport network.
Sources

3GPP. 2018. 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Study on enhancement of 3GPP Support for 5G V2X Services (Release 16) TR 22.886 V16.2.0

5GAA. C-V2X Use Cases Methodology, Examples and Service level requirements
