Nordic Council of Ministers

ACCELERATING **5G** IN THE NORDIC AND BALTIC REGION: STEPPINGSTONES FOR CROSS BORDER COLLABORATION

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The Nordic and Baltic countries feature a vast range of testbeds and other test activities for 5G

Executive Summary

The Nordic region should be the "first and most integrated 5G region in the world", and the region should become a "common Nordic 5G space". Those goals were stated in a Letter of Intent (LoI) signed in April 2018 by the prime ministers of the Nordic countries. This letter followed the Nordic-Baltic ministerial declaration Digital North, adopted a year earlier.

The ministerial declarations acknowledge the disruptive power of 5G, and the fact that 5G is more than a new generation of mobile technology. Unlike previous shifts from 2G to 3G and from 3G to 4G, the major impact of 5G will be found in almost all sectors of society, from industry, harbours, airports and energy companies to media, farms, fisheries, hospitals and entire cities. Analysts agree that each such vertical holds a business potential in the billions of euros.[1]

Testbeds are widely recognised as instrumental in this development, for developing new products, services and not least business models. Hence the interest from the Nordic Council of Ministers in mapping the 5G test activities, measuring the temperature of 5G activities and creating regional 5G SWOT analyses, and subsequently commissioning RISE to do so with this report.

The Nordic and Baltic countries feature a vast range of testbeds and other test activities for 5G. This report lists almost 50 such testbeds,[2] serving a range of purposes from network research to application in agriculture and aquaculture. Numbers indicate, though, that the strongest impact will be made within the manufacturing industry and transport. This is also where the first business cases based on the new 5G functionalities can be found – using 5G for the continuous digitalisation of industrial production and digitalisation of transport issues.

Manufacturing industries probably hold the key for Nordic-Baltic 5G leadership. However, there's also a potential for strong global impact within agriculture, given the proper incentives for collaboration among the stakeholders in the region.

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[1] See for instance "The 5G Business Potential", Ericsson, 2019.
[2] The appendix is available on request from the Ministerial Council for Digitalisation

Setting the scene – introduction 1

The spring of 2019 marked the start of commercially available 5G services. In South Korea, the USA and several other countries, the first commercial 5G networks have already been rolled out, with some 10 million 5G subscribers expected by the end of the year. The Nordic and Baltic region will, along with other countries in Europe, debut commercial 5G during 2019–2020, with subsequent rollouts over the coming years.

5G will not only offer faster and more secure broadband connections, it will also feature radically shorter response times (latency), the ability to handle a hitherto unseen multitude of nodes, and private networks (network slicing), while also significantly lowering the cost and energy needed per communicated byte.

The 5G enthusiasts emphasise the huge business opportunities. Globally, projections point towards almost 2 billion 5G subscribers within 5 years, accounting for 20% of all mobile subscriptions (source: Ericsson Mobility Report, June 2019). By 2026, analysts foresee a 1.2 trillion dollar market for 5G-enabled digitalisation products and services, as categorised in figure 1.

The testbeds serve an important role in harnessing these business opportunities. Testbeds are instrumental for learning not only the technology but also the operational, organisational and business aspects of the new opportunities. Testbeds can be public, offering services for anyone interested, but can also be closed, serving the needs of e.g. a factory, a port, or a hospital. They can be for research only or have commercial interests. Some of the testbeds in this survey are also driven by other forces, some more esoteric examples being observing the impacts of global warming or assisting athletes in their ambition to win Olympic medals.

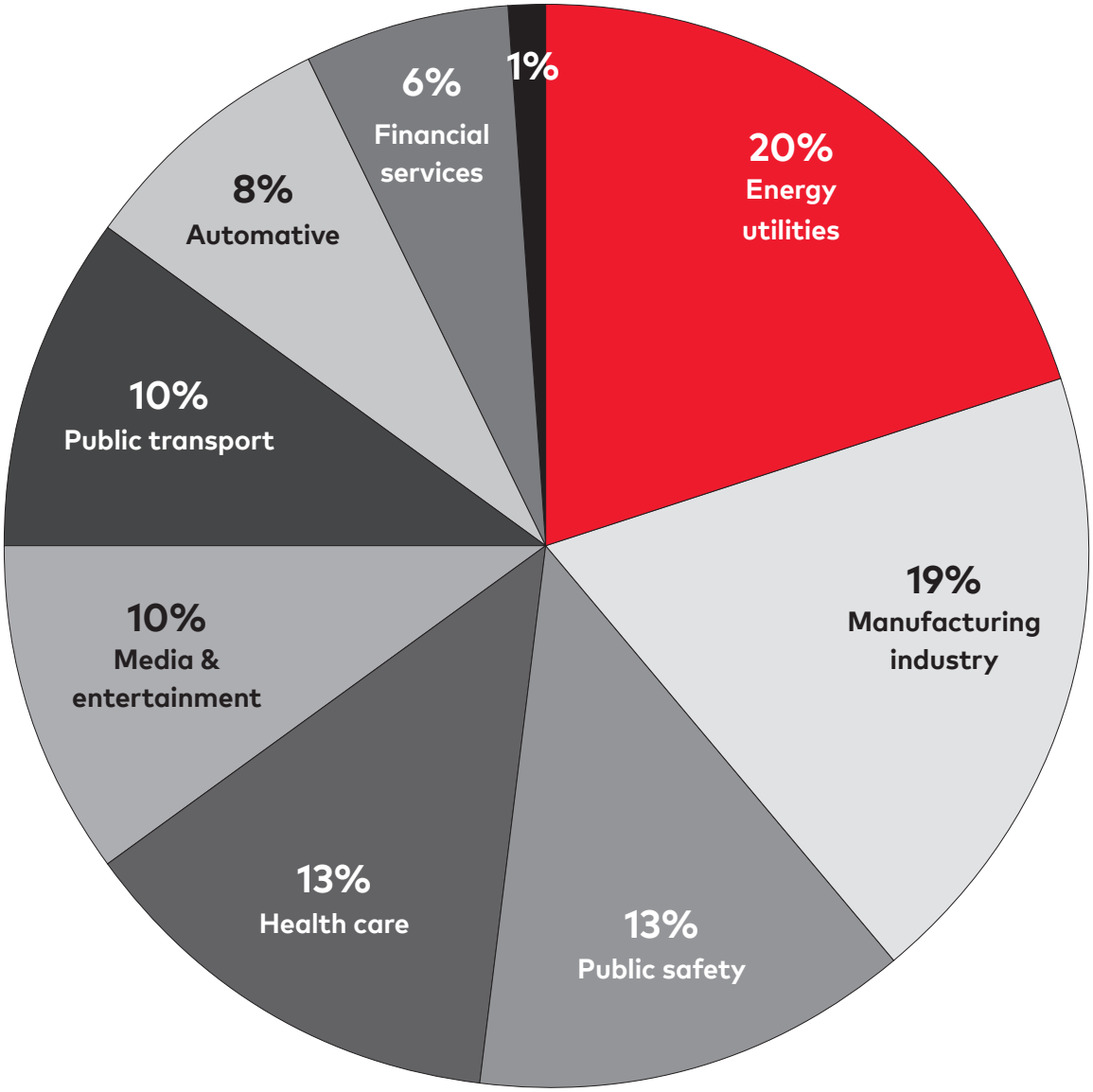
What all the testbeds have in common, though, is their ambition to as quickly as possible learn what opportunities 5G will bring to their particular field of interest and how to make the most out of these opportunities. In many cases – particularly where corporations are driving the testbeds – this also includes how to make money from these insights. Early-use cases where 5G contributes to industrial digitalisation might be more about saving money, but there are examples of more forward-leaning companies developing new offerings using 5G. One example is the traffic safety testbed AstaZero in Sweden, whose customers – the big automotive manufacturers – simply demand 5G access for their trials.

The test activities have until now been hampered by low terminal availability. This situation should be rectified during the summer of 2019, as the telecom industry rolls out new terminals for 5G with a range of different capacities. The ramp-up of terminal production is expected to be quite steep, ensuring that the testbeds – and indeed the public at large – can dig into the brave new 5G world.

Figure 1:

5G-enabled digitalisation products and services 2026, a 1.2 trillion dollar market.

Source:
The 5G Business Potential, Ericsson, 2019.



Driving forces, strengths and weaknesses 2

The 5G movement is quite complex, with many different driving forces. Geographically, it's fair to say that Finland is a bit ahead of the other Nordic and Baltic countries, with Sweden coming in second. Norway and Denmark are accelerating.

The 5G activities seem to be local or national, with very limited transnational visibility. Corporations use their testbeds mainly for learning and digitalisation purposes. Cities use them for projects aimed at ameliorating life for inhabitants and local business. Universities use testbeds for research, obviously, but also for profiling. If the testbeds are aspiring for commercial viability – i.e. to make money by themselves – it's definitely too early to judge their success. Nor have they excelled in finding new business opportunities.

As shown in the regional SWOT analysis to the right, the Nordic-Baltic region features many strong 5G points. The large number of testbeds indicate great interest from many stakeholders, particularly within the transport and manufacturing industries. However, the test activities suffer from a lack of terminals. The few 5G terminals that have been available are mostly prototypes, and not all of them are in the common mobile phone form. This situation will change soon as several phone vendors, e.g. Huawei, LG and Samsung, have started or announced the imminent start of regular 5G phone sales.

The goal of a "common Nordic 5G space" as stated in the LoI signed by the Nordic prime ministers seems still to be quite distant. There's very little co-ordination of activities between spectrum authorities – one example is the lack of transnational spectrum allocation. Governments seem to regard spectrum as a natural resource of national importance. Pan-Nordic spectrum allocation could potentially not only create an unprecedented scale of communication opportunities, it would also encourage and enable cross-border business and collaboration projects.

Another challenge for cross-border activities is the lack of dedicated funding targeted towards Nordic-Baltic 5G projects. The test activities in the region are today mainly funded by national sources or by European research projects such as Horizon 2020 and thus there is a lack of incentive for Nordic or Nordic-Baltic collaboration. 5G tests, like most business activities, tend to follow the money, so if policymakers would like to see more Nordic-Baltic collaboration, they should also create a funding scheme for such activities.

Agriculture could be low-hanging fruit for Nordic-Baltic 5G collaboration. Sweden has a testbed, currently with 4G but with plans for 5G, for agricultural purposes. Denmark has a strong agriculture industry but currently no testbed for this vertical. Finland has taken some 5G initiatives within the forest industry, and in Norway there's an ambitious aquaculture testbed with plans for 5G experiments. A well-funded project where these activities could combine forces and learn from each other could form the basis for a 5G knowledge resource for the entire region. Stakeholders such as Lantmännen – a co-oper-

ative owned by 25,000 Swedish farmers – could seize the opportunity to act as intermediary in this vertical, defining, designing and developing appropriate services. The large Swedish and Finnish forestry companies would probably welcome such an initiative, as would the large Danish farms and agriculture companies and the Norwegian fish farmers.

It should be noted that most of the testbeds in this survey are run with support and equipment from Ericsson or Nokia, with Huawei also showing up in a few cases. Not surprisingly, Ericsson dominates the testbeds in Sweden and Nokia in Finland. However, it's definitely too early to predict which vendor will dominate the market once 5G is rolled out on a larger scale.

Regional SWOT Nordic and Baltic Countries	
Strengths	**Weaknesses**
• Many 4G (aspiring for 5G) and 5G testbeds are very active • Letter of Intent signed between the Nordic prime ministers • Several strong verticals, particularly manufacturing industries and transport • Home of telecom industry leaders Ericsson and Nokia • History of IT leadership • Universities with world-class telecom research	• Little co-ordination of 5G activities across regional borders • Several verticals with little 5G activity (agriculture, health and emergency services) • Lack of available terminals • Difficulties in identifying new business models • Lack of "killer application" • Few obvious intermediaries to develop new 5G services
Opportunities	**Threats**
• The region could take a leading position within the manufacturing industries and transport • 4G and NB IoT have cleared the path for 5G • Plethora of local 5G initiatives, from cities, municipalities, universities and industries	• Little co-ordination between governments and public authorities across the region • China, the USA and South Korea are way ahead in development • Other countries invest more money in development and research • 5G revenue could cannibalise 4G investment

Globally, the commercial roll-out of 5G networks has started in South Korea and the USA, with China not far behind. It should be noted that the driving forces are somewhat different in those markets. In South Korea, the demand for enhanced mobile broadband seems insatiable. In the USA, many places have a shortage of fixed broadband opportunities and 5G will offer a cost-effective way to install fixed mobile broadband. China diverted from the standard for 3G and 4G, and now has a strategic interest in taking the lead for 5G, with a nationally driven 5G agenda and with Huawei as a strong national equipment manufacturer.

Finland

Finland is the only country in the region where 5G networks have been launched, based on a conducted spectrum allocation being conducted and resulting in operators Telia, DNA and Elisa being licensees. Telia has launched a 5G network in Helsinki and an industrial 5G environment in Oulu. Elisa has launched 5G currently available in the Helsinki, Tampere, Jyväskylä and Turku city areas. DNA has launched precommercial networks in 5G in Helsinki and Vantaa, and will soon launch commercial 5G in major cities.

SWOT Finland	
Strengths	**Weaknesses**
• The driving force is public organisations in collaboration with operators, academia and cities • Commercial spectrum has been allocated • A strong national testbed network • Strong tradition within telecom industries • High degree of IT maturity among the public and industry • Proactive government facilitating 5G expansion • Strong, co-ordinated academia and research institute • Financing for test projects is available through Business Finland and the EU • Strong operators with healthy competition	• Unclear business case, lack of "killer application" • No specific vertical is driving • Limited research in some verticals (health and agriculture) • Low demand from customers
Opportunities	**Threats**
• There is a new market opening for actors that will develop new services in relation to 5G • Viable aspirations for global 5G leadership • Testbeds at ports in Oulu and HaminaKotka • Initiatives in forestry • Strong 5G research, particularly within the transport and manufacturing industries	• 4G NB IoT solutions are enough for many use cases • 5G revenue could cannibalise 4G investment

In Finland, public organisations – in particular Traficom (the Finnish Transport and Communications Agency), Business Finland and the Finnish Ministry of Transport and Communications – have been very proactive, enabling early spectrum licensing and investing money in 5G testbeds. Public organisations are important driving forces for 5G in Finland, in collaboration with operators, universities, municipalities and some industries. Finland features more 5G projects than any other country in the region, many of them co-ordinated by public organisations, financed either by national sources – primarily Business Finland – or by the European Union.

Oulu stands out as the hotbed of 5G development, with strong university research, a proactive municipality, a port and a hospital engaged in 5G activities and not least a multitude of startups.

Traficom leads the national ecosystem project 5G Momentum, with the goal of making Finland number one in 5G technology. This ecosystem promises to promote the development and introduction of 5G services by creating a co-operation network for 5G trial activities. One of its activities is to promote co-operation between cities and operators, e.g. by harmonising building permit procedures and identifying common bottlenecks.

There is also a national 5G effort called 5GTNF – 5G Test Network Finland – consisting of eight 4G/5G networks in seven cities, connected by a core network. For details please see the list of testbeds in Chapter 8.

Sweden

In Sweden, the driving forces are mainly industry and some cities. There are a plethora of 5G testbeds, some public but mostly private. Compared to Finland there is hardly any co-ordination or collaboration between them, although Ericsson and the operator Telia are active in a majority of them.

Public testbeds can be found in some cities, notably Umeå, Luleå and Kista, as well as at some universities, e.g. KTH in Stockholm and Mid-Sweden University in Sundsvall. Private networks have been set up at a number of industries, including Volvo CE in Eskilstuna, SKF in Gothenburg, the Kankberg mine in Boliden, ABB in Västerås and Scania in Södertälje, and at vertical testbeds such as AstaZero, a traffic safety testbed outside Borås. Many of these testbeds are built around 4G networks with hitherto limited 5G functionality.

Most of the 5G activities within Swedish industry are aimed at finding out how 5G can contribute to the general efficiency of manufacturing. This is very much in line with other digitalisation and Industry 4.0 initiatives. However, the incentives to share knowledge and research results outside these companies are limited.

The publicly funded mining testbed in Kankberg is an exception. Here, industrial stakeholders Boliden, Volvo CE, ABB and Epiroc, in collaboration with Ericsson and Telia and the research institute RISE, have joined forces to climb a learning curve with publicly available results. Insights gained include the fact that the 5G network quickly becomes an integral part of the industrial process, underscor-

ing the need for uptime and data about network status. The need for redundancy, and possibility of running parts of the network independently, were also underlined, as was the need to figure out data ownership, i.e. what data created in the industrial process is owned by whom. Another insight was the need for an operator. Someone has to shoulder the responsibility of operating the network. This could, of course, be a national operator like Telia, but it could also be the industrial company itself, or potentially a third party, e.g. an IT consultant or another independent entity.

SWOT Sweden	
Strengths	**Weaknesses**
• The driving force is industry • Two strong verticals traditionally (manufacturing industries and transport) • Test-licences for 5G are free • Several cities are active • Strong tradition in telecom industries • Strong operators with healthy competition • High degree of IT maturity among the public and industry • Private actors put money into testbeds • Strong vehicle industry with many 5G test initiatives • Manufacturing industries with strong history of digitalisation and proactive efficiency work	• Public authorities and governments are reactive • Limited public funding available for testbeds • Unco-ordinated and limited impact from institutes and academia • Unclear business case, lack of "killer application" • Existing stakeholders are conservative • Industrial stakeholders don't communicate – development in silos • The allocation of spectrum is still very reactive • Low demand from customers
Opportunities	**Threats**
• Sweden could be a leader in manufacturing industries • "Late" allocation of spectra – seeing new opportunities and learning from others • The is a new market opening for actors that will develop new services in relation to 5G • The degree of maturity of 4G creates an opportunity to scale up to 5G when needed and an opportunity to further streamline processes	• 4G NB IoT solutions are more than enough in most cases • 5G revenue could cannibalise 4G investment

Norway

In Norway, the operator Telenor has been identified as the major driving force. Telenor founded the first Norwegian 5G testbed in Kongsberg in 2018, which now, with industrial support, has grown to become a viable 5G innovation hub. Telenor is currently setting up an extensive 5G operation in Trondheim with some 50-100 base stations as well as a handful of base stations in the small municipality of Elverum.

SWOT Norway	
Strengths	**Weaknesses**
• Strong operator • Free 5G test licences • Roadmap for 5G spectrum • Two strong verticals traditionally (smart cities and offshore) • Active cities, strong public support from Oslo and Trondheim • High degree of IT maturity among the public and industry • Strong culture of equal opportunity	• Delayed spectrum allocation due to government • Unclear business case, lack of "killer application" • No strong traditional telecom industry • Low demand from industry and customers
Opportunities	**Threats**
• Initiatives within offshore, autonomous shipping and aquaculture • Premium prices for mobile internet • High number of connected vehicles	• 4G NB IoT solutions are more than enough in most cases • 5G revenue could cannibalise 4G investment

Other 5G initiatives in Norway include Telia in Oslo with an early but limited 5G test in a cinema theatre, and a drone initiative on Svalbard for monitoring global warming effects.

Norway is also instrumental in the EU project 5G VINNI, where Telenor, Ericsson Norway and Huawei Norway among others are pushing 5G technology development.

The Norwegian communications authority Nkom has published a roadmap for 5G spectrum allocation and conducted its first auction for 5G in the 700 MHz band in May 2019, with licences expected to be valid from November.

Norway's strengths within shipping, offshore and fishing are obvious also within the Norwegian 5G testbeds. Worth noting is a project for autonomous cargo ships, where the control elements are developed by a start-up company. The ship Yara Birkeland aspires to be the first autonomous and fully electric cargo ship in the world, saving 90% of operating costs as neither fuel nor crew will be needed. The goal is to save 40,000 truck journeys per year.

Denmark

In Denmark, the Danish Energy Agency, responsible for telecom regulations, has published an ambitious roadmap called "5G Action Plan for Denmark". That document contains plans for frequency allocation, roll-out, regulations and use cases for 5G, and emphasises how public and private stakeholders – including testbeds – could collaborate to make Denmark a leading 5G nation.

Denmark conducted a spectrum auction in March 2019 in the 700, 900 and 2300 MHz bands. Some of these frequencies will be used for 5G.

SWOT Denmark	
Strengths	**Weaknesses**
• Ambitious 5G action plan from Danish Energy Agency • Initial spectrum auctions conducted • Strong operator driving the development of 5G • Focused on two verticals, smart city and health, also activities in transport and TV production. • Operators have big plans and the spectra to realise them • Increased capacity for 4G • Strong tradition of mobile leadership • High degree of IT maturity among the public and industry	• Few test licences are used (perhaps due to charging for them) • 5G rollout lagging in comparison • No public facilitation network for 5G • No identified leading testbed in any vertical • Limited financing, public and private, of testbeds • Low initial demand from customers • Low apparent industrial interest
Opportunities	**Threats**
• Denmark could be leading in 5G for agriculture due to strong stakeholders in this field. • Initiatives in tv production, health, transportation and data security • Strong willingness to learn from 5G forerunners in e.g. China or South Korea	• 4G NB IoT solutions are more than enough in most cases • 5G revenue could cannibalise 4G investment

The Danish Energy Agency is, together with operator TDC, the prime 5G driving force in Denmark. TDC says, however, that 5G on 2300 MHz will not happen until 2020. Until then, the focus will be on strengthening the 4G network.

It's worth noting that Denmark charges standard fees for 5G trial licences, although the sums are relatively low since these licences are limited in geography and time.

TDC currently runs a 5G trial in Copenhagen focusing on high speed broadband connections, and another with DR (the Danish public service broadcaster) exploring how 5G can be useful for TV production, including aspects of net neutrality.

Other 5G testbeds in Denmark include a trial run by Telia and Telenor with Ericsson equipment and a hospital in Odense researching opportunities for e.g. robots transporting blood samples. Also, Aalborg University plans 5G tests for robotics applications in factory automation, and there's a testbed in Aarhus for precision positioning and autonomous system, paving the way for precise and fast positioning in dense urban areas.

Iceland

Iceland is the smallest country in the region, but it nevertheless features some 5G activities. The driving forces can be identified as the operators and the spectrum authority, in tandem. There is a testbed run by the operator Nova, with equipment from Huawei. Nova is an entrepreneurial operator, previously pioneering 3G, 4G and 4.5G in Iceland. A more major operator, Síminn, signed a contract in May 2019 with Ericsson for upgrading its 4G network to 5G.

The spectrum authority Post and Telecom Administration in Iceland has issued two test licences for 5G, in Reykjavik (to Nova) and in Akranes, with the purpose of testing basic 5G functionality. The country is currently finalising consultations for spectrum allocation through an auction planned for late 2019 or early 2020. Enhanced mobile broadband is foreseen as the first 5G application in Iceland. The industrial interest is currently quite low. The Post and Telecom Administration is ready to give e.g. aluminum melters a 5G test licence if such interest should appear. No other vertical has shown any 5G activity.

Probably due to geography, the Icelandic 5G movement currently has little collaboration with other countries. The Post and Telecom Administration takes part in European projects for network security, but no other collaboration has been identified.

Estonia, Latvia and Lithuania

In the Baltic countries, the governments are committed to implementing 5G. Latvia made commercial frequencies available from 1 January 2019, and the Ministers of Transportation for the three countries have signed an Memorandum of Understanding (MoU) to build a 5G-enabled digital highway through the Baltic region. This agreement is arguably the best example of transnational 5G collaboration at ministerial level in the Nordic-Baltic region.

The highway, called Via Baltica North, consists of about 1000 km along the European route E67, from Tallinn via Riga and Kaunas to the Lithuanian border to Poland. Here, 5G rollout will be accelerated while ensuring unrestricted cross-border system functionality. According to the plan, vehicles on the highway will use 5G for data transfer between themselves, as well for data collection through various sensors for infrastructure purposes. Testing autonomous vehicles will be an integral part of the highway. The Baltic authorities stress that this development is very much in line with the EU connectivity goals.

SWOT Baltic Countries	
Strengths	**Weaknesses**
• MoU between ministers of transportation for a 5G transnational highway, highlighting Baltic 5G collaboration • Academia driving the development of 5G • High degree of IT maturity among the government, public and industry • Strong culture of collaborating • Organising large conferences in 5G • 5G collaboration with Poland and Germany	• No strong industry to drive the development • Unclear business case, lack of "killer application" • Low demand from industry and customers • Limited national financial strength
Opportunities	**Threats**
• 5G highway for autonomous vehicles • Drone traffic between Finland and Estonia for delivery • Smart cities • Manufacturing industries • Close cooperation between ministries, clusters and NGOs. • Well-developed IT industry	• Small countries, strong need for collaboration • 4G NB IoT solutions are enough for many use cases

The Latvian operator LMT demonstrated its first 5G test network in September 2018 and has since installed more than 180 5G-ready base stations, delivered by Nokia, around the country. A functional 5G network will launch during Q2 this year. LMT also runs a number of 5G trial activities – for details please see the appendix. Planned use cases in Latvia include TV delivery by mobile network, transportation tracking and data collection using machine vision for intelligent transport systems, as well as artificial intelligence for drones.

Latvia also stands out as the most proactive Baltic country in terms of outreach, organising the event 5G Techritory, which aims to become an annual, world-leading 5G technology conference.

Most other Baltic 5G initiatives centred around universities with testbeds are focusing on research. A notable exception is the Ericsson factory in Tallinn, where Ericsson and ABB are collaborating on a 5G project for manufacturing antennas.

Åland, Faroe Islands and Greenland

There is a 5G initiative in Åland, run by local operator Ålcom. In the Faroe Islands and Greenland no 5G activities have been identified.

Business opportunities – from a testbed viewpoint

3

It's quite clear from the interviews done for this survey that the transition from 4G to 5G will be gradual and take several years. The promises of 5G – massive broadband, low latency, network slicing and the ability to handle a large number of nodes – can for many use cases be fulfilled by 4G and the 4G derivative NB-IoT, Narrowband Internet of Things. Commercial NB-IoT networks are already up and running, and since no "killer application" for 5G has been identified that will by itself pay for the rather big investments associated with 5G for spectrum and for equipment, the conclusion is that the demand for 5G will initially result in a patchwork of hotspots interacting with existing 4G networks. Early business cases will probably be found in local spots where decision chains are relatively fast, e.g. digitalisation of a factory or a port. Businesses with more complex decision chains, e.g. within health or emergency services, will need more time to develop 5G use cases, and by that time the 5G coverage will probably also have increased to support their needs better.

Equipment vendors and operators – and several public agencies as well – agree unanimously in interviews that new business cases and new business models will be necessary for 5G success. These new business models will probably not be the same for every vertical. The telecom vendors seem reluctant to change their business models, preferring to keep selling their equipment more or less in bulk to operators. The operators indicate in interviews that they probably will develop some new horizontal services, which is expected to be needed in a large number of verticals, but have little intent of developing specialised services for particular vertical use cases with a low economy of scale. Some early industrial adopters realise and accept that they will have to develop some services themselves, but they don't intend to market these solutions outside their own companies. Thus, there seems to be room for intermediaries, but the question of who will develop the new services and new business models needed for the various verticals remains unanswered. Contenders include large IT consultancy companies such as Tieto in Finland, Sweden and the Baltics, Atea in Norway and Sweden and HiQ in Sweden. Tieto agrees in an interview that these companies must carefully balance their interests in 5G business with their current customer relations with operators as well as within the various verticals.

New technology usually means new opportunities for startups, and 5G is no exception here. However, startups need business cases with a relatively short lead time to profit, and since the 5G networks are in their infancy, it's probably too early to identify 5G leaders in the startup community. It should be noted, though, that there is plenty of 5G activity among startups in e.g. Oulu, Kongsberg and Kista.

One reason for the lack of new or emerging business models could be a limited understanding of what 5G really is. It would be a mistake to regard 5G simply as an extension of 4G with some new features and functions. Instead, it could be viewed as a "software-defined execution environment", i.e. more of an IT environment than a mobile phone system, adaptable to a vast range of public and commercial needs. Business interfaces within this environment, defining e.g. where

information is exchanged or stored or where the execution capacity should be situated, will have to be developed for each vertical or even each use case.

Business verticals where 5G is suggested as a solution provider include transport, emergency services, manufacturing industries, energy, agriculture, aquaculture, environment and health and welfare technology. Media and entertainment, as well as Smart cities, are also suggested as promising verticals. As the list of testbeds and projects indicates, transport has shown the most activity, closely followed by the manufacturing industry.

Transport 5G stakeholders include some industry giants such as Volvo and Scania in Sweden, but also some medium-sized operations such as the testbed AstaZero in Sweden, the harbours of Oulu and HaminaKotka – as well as the harbour test environment in Tampere – in Finland and the planned drone operation between Finland and Estonia.

Within the manufacturing industry some large corporations are clearly driving development. Industrial 5G forerunners include multinational companies such as ABB, Ericsson, Scania, Boliden, SKF and Volvo in Sweden, Stora Enso and Nokia in Finland and Ericsson/ABB in Estonia.

PHOTO: UNSPLASH.COM

There are 5G networks up and running within all these operations in transport and manufacturing, but access is mostly limited to insiders. The knowledge gained within the testbeds is, though, judged as very advanced, and could, given the right incentives, become a foundation for Nordic-Baltic global leadership within these verticals.

Agriculture is, as stated above, another vertical with potential for Nordic collaboration with subsequent global impact. The testbed in Ultuna, Sweden combined with the Danish strength in agricultural business, Norwegian aquaculture and Finnish forestry 5G initiatives would offer interesting opportunities given proper incentives.

The only environmental 5G activity identified in this survey is the drone operation on Svalbard for measuring the impact of global warming. The Norwegian autonomous ship described above will have environmental impact, but the business case is clearly sorted under Transport.

There are initiatives by some energy companies to use 5G, but they mainly concern logistics and should probably be regarded as transportation trials. One promising example is an oil and gas platform off the Norwegian coast, where staff could be reduced for safety and cost reasons by installing a large number of sensors controlled by a 4G or 5G network, communicating to land over fibre. Such a trial is today being run by Telia at a platform in the North Sea, utilising IoT technology. Also, the Finnish project 5G VIIMA includes research and trials for 5G on smart grids.

Within health and welfare we have so far identified only a small number of testbeds, which are still in the early planning stages. The project CareUseCase in Oulu seems to be the most advanced of these, with a project for 5G assisted living for people with memory disabilities. In the adjacent vertical, sports, the Swedish Olympic Committee and its partners have plans for a 5G sports testbed at the Stockholm Stadium, using the 5G network established at the neighboring university, KTH. There is a substantial health 5G project, aptly named "Future e-Health powered by 5G", with project members from Sweden and Finland. This project was kicked off in March 2019 and is currently defining its content. The actual trials will take place in various testbeds across Europe – the project will procure testbed services in due course.

The Smart City vertical is more often than not initiated by municipalities. Some, e.g. Umeå and Luleå, are particularly active, as are Sundsvall, Helsingborg and Kista in Sweden. Oulu and Espoo in Finland, as well as Trondheim and Elverum in Norway, should also be mentioned in this context. Whether or not Smart City 5G activities should be sorted into the other verticals or remain as a vertical on their own merits can be discussed.

As indicated, many so-called 5G testbeds are today operated with 4G technology. The availability of 5G terminals is definitely a limitation. As of today, only two vendors offer 5G terminals, both with limited 5G features, mainly broadband. 5G terminals supporting low latency will probably be available during 2020.

Concluding remarks and recommendations 4

The mapping of 5G testbeds, trials and projects indicates a huge and widespread commercial, governmental and academic interest in the new opportunities offered by the technology. If a bet should be placed on where the Nordic-Baltic region could take a global lead, the odds would probably favour the manufacturing industries. This area has many test activities in the region and has sound financial reasons for adopting 5G quite early. An outsider could be agriculture. As shown above, agriculture, including aquaculture and forestry, is a field where the Nordic-Baltic strengths could be combined into a potential 5G powerhouse.

For this to happen, new incentives are needed. The obvious reason for the low level of cross-border Nordic-Baltic collaboration is the lack of funding for such projects. As stated previously, most stakeholders tend to regard 5G testing and development as a local or national interest – or as European for projects funded by the EU. Very few test projects have any transnational component. A noteworthy exception is the Baltic agreement on a ministerial level for joint 5G coverage of a highway across the three Baltic countries. The annual conference 5G Techritory in Riga also strongly signals a collaborative ambition.

Policymakers have several opportunities to ameliorate and accelerate the 5G development in the region. Some suggestions are discussed below:

- Although much of the spectrum available for 5G has already been auctioned, it could be worth evaluating whether future licensing auctions could be better synchronised. The goal would be to make it possible for operators to acquire licences for the entire Nordic-Baltic region for at least a designated part of the suitable spectrum. This would create scale for the operators and the equipment vendors, while also making it easier to do transnational business for their corporate clients – the companies in the various verticals. The individual countries have shown many examples of "best practice" for spectrum allocation – these should be exchanged between the countries and built on for further collaboration.

- Consider opportunities for new stakeholders, not only the traditional telecom operators, to license spectrum. As indicated by some of the testbeds, this would allow for a new, more dynamic business environment, where operators and their customers as well as third parties could develop new business cases and innovations.

- New regulation could be needed for several aspects of 5G. For a start, one issue might be to harmonise the regulation practices for how network slicing can coexist with network neutrality. Network neutrality states that all network traffic should be treated on equal terms. However, with network slicing the traffic in that slice by definition gets a more favourable treatment than the traffic outside the slice. How these regulations are applied in practice

differs between the countries in the region, which slows down development, as some operators are unwilling to allow for network slicing, fearing legal retribution. The Body of European Regulators for Electronic Communication (BEREC) is addressing this issue, and the Nordic-Baltic members should speak with a common voice in those discussions and of course implement the BEREC recommendations in the same way.

- It should be noted that network slicing can be done manually in today's 4G networks, but the technical opportunities are much better, and the slicing can be done dynamically and be fully automated, in the 5G networks.

- Innovation in the 5G space would also benefit from deregulated experimental zones, where the need for e.g. building permits (for antennas etc.) and concession fees would be waived, and vehicles and other equipment wouldn't need type approval. Such zones could be established around existing testbeds, universities or science parks.

- Speak with a common Nordic-Baltic voice in the European Union on matters of 5G policy and funding for 5G projects. Encourage collaboration in the Nordic-Baltic region by directly allocating money to Nordic-Baltic projects or money to assist in Nordic-Baltic applications for EU funding. Incentives for Nordic-Baltic collaboration could also stem from more synchronised national funding.

- Creating a dedicated funding scheme for Nordic-Baltic 5G collaboration could also be an option. If, for instance, the Nordic countries agreed to co-finance a five-year, EUR 10 million/year project to accelerate 5G development within e.g. the manufacturing industry or agriculture, with a clear objective to find new business opportunities, the companies and other stakeholders in those fields would most probably agree to co-finance such a project with similar amounts of money. The value and feasibility of such a project should at least be properly evaluated.

If Nordic-Baltic 5G leadership is to have a chance to manifest itself, time is of essence. The opportunities offered by the 5G rollouts will be quickly harnessed by new entrepreneurs and existing businesses. Without Nordic-Baltic incentives, be they political, financial or of another nature, the alliances and collaborations necessary for leadership will be built where those incentives can be found.

Method and approach 5

The Nordic Council of Ministers commissioned RISE in March 2019 to carry out a baseline study for a cross-sectorial mapping of 5G testbeds with the following tasks and deliverables:

- Identify and describe for each area the most important, competitive and advanced test environments/testbeds/innovation hubs/demo facilities related to high-speed mobile internet connections (4G and 5G) in the Nordic-Baltic region.

- Based on the results of the baseline study, identify regional strengths, weaknesses, opportunities and threats in the application and innovation of wireless connected products, services and businesses based on 4G and 5G.

This mapping was based on a combination of desk and primary research conducted from March to June 2019, detailing key features of 5G testbeds and how various organisations aspire to develop or use this emerging technology. An early version was presented in April 2019 and a second version in May 2019. Input has continuously come from members of the 5G expert group and further interviews with telecom vendors, telecom operators and other stakeholders from the IT and telecom industries and from universities and research institutes, as well as from testbeds and from various verticals (agriculture, the manufacturing industry, transportation, health, energy, smart cities etc.).

In total, some 20 physical interviews have been held, plus more than 50 Skype/telephone meetings, two conference visits, numerous email contacts and a vast amount of Internet searches. Based on this input we have established a list of 5G testbeds and 4G testbeds with plans to proceed to 5G, as well as a list of relevant 5G research and development projects, more often than not connected to one or more of the testbeds.

The definition of a 5G testbed is something of a challenge. The choice for this report is to be inclusive – test sites that today use 4G but have plans for 5G are included as testbeds in the longlist. Relevant 5G research encompassing more than one testbed or not necessarily implemented in a testbed yet is referred to as "projects". European projects with Nordic participation are listed under the predominant Nordic country. This choice should serve the purpose of highlighting the current 5G action hotspots.

The mapping and the interviews carried out are also the basis for the SWOT analyses for the Nordic-Baltic region and for the individual countries. These SWOT analyses indicate complementarities and should be regarded as food for thought for further Nordic and Baltic collaboration discussions.

Verticals and current testbed status 6

Initially, this survey was supposed to cover testbeds divided into five verticals: Transport, Mission-critical Communications, Manufacturing Industry, Energy Environment Agriculture and Aquaculture, and Health and Welfare. For practical purposes, the mapping was extended to seven verticals, adding Smart Cities and 5G Research and Development to the original list.

Identified verticals:

Transport

a. Sustainable and climate-efficient transport solutions
b. Transport system and connected vehicles
c. Remote-controlled airborne services (drones)

Mission-critical communications

a. Emergency services
b. Law enforcement

Advanced automation in the manufacturing industry

a. Augmented reality for employees
b. Interconnected factories
c. Robust and low latency communications

Energy, environment, agriculture and aquaculture

a. Energy-saving measures, smart grids, power management
b. Increased yield in food production
c. Detailed monitoring

Health and welfare technology

a. Hospital effectivisation
b. Transport in hospital environment

Smart cities

a. A vertical that includes several of the verticals above to interconnect a city
b. Entertainment

5G R&D

a. Research and development of 5G technology
b. Network research
c. Security research

Several testbeds and projects represent more than one vertical, as they offer services within multiple fields. The projects are defined as specific projects with importance to 5G, usually within a testbed but they could also be larger, multinational, EU-funded projects with multiple partners.

Below is a summary of all the testbeds and projects organised in the respective verticals. More details on each testbed and project can be found in the appendix. This list does not aspire for completeness; it should rather be regarded as a best effort to map current 5G activities.

Transport: This vertical is the most active, with 17 testbeds and 19 projects.

Testbeds:
Testbed in Aarhus for Precision Positioning and Autonomous Systems (TAPAS) (Denmark)
Gate Denmark 5G in Aabenraa (Denmark)
Taltech University in Tallinn (Estonia)
5GTNF (Finland)
Port of Oulu (Finland)
Port of HaminaKotka (Finland)
Digital road and connected cars with 5G & MEC (Latvia)
Longyearbyen in Svalbard (Norway)
KTH Royal Institute of Technology in Stockholm (Sweden)
AstaZero in Borås (Sweden)
Urban ICT Arena (Sweden)
Scania in Södertälje (Sweden)
Västervik Drone Testbed (Sweden)
Volvo in Skövde (Sweden)
Volvo CE in Eskilstuna (Sweden)
Luleå University of Technology (Sweden)
Environmentally friendly self-driving vehicles in Jönköping (Sweden)

Projects:
Detecting pollution in Port of Riga (Latvia)
Rescue drone for wildfire (Latvia)
Mobile Network for UAVs (Latvia)
Transportation of laboratory samples with drones (Latvia)
5GMOBIX (Finland)
5G Drive (Finland)
GOF U-Space (Finland)
Drone weather (Finland)
FABULOUS (Finland)
5G Safe+ (Finland)
SecurePax (Finland)
NordicWay2 (Finland)
NordicWay3 (Finland)
TACK (Attack-Resistant Internet of Things Networks) (Finland)
5G project – 5G in marine time automation (Finland)
5G project – Smart roads/Arctic transport (Finland)
5G project – Spectrum share/smart roads (Finland)
MAMIME (LTE, WIFI and 5G Massive MIMO Communications in Maritime
Propagation Environments) (Norway)
AURORA BOREALIS – Intelligent corridor (Norway)

Mission-critical communications: 1 testbed and no projects

Testbeds: Public safety and defence (Latvia)

Projects: No projects found

Advanced automation in the manufacturing industry: 12 testbeds and 4 projects

Testbeds: 5G at Aalborg University (Denmark)
Ericsson factory in Tallinn (Estonia)
5GTNF (Finland)
Sensible Things that Communicate (Sweden)
Kankberg mine in Boliden (Sweden)
The Smart Industry lab (Sweden)
ABB in Västerås (Sweden)
Scania in Södertälje (Sweden)
Enabled Manufacturing in Gothenburg (Sweden)
Volvo in Skövde (Sweden)
Volvo CE in Eskilstuna (Sweden)
Luleå University of Technology (Sweden)

Projects: Telia/Oulun Nuottasaari (Finland)
5G VIIMA (Vertical Integrated Industry for Massive Automation) (Finland)
5G project – Industry/Public safety (Finland)
5G project – Smart harbours (Finland)

Energy, environment, agriculture and aquaculture: 7 testbeds and 2 projects

Testbeds: 5G trial in Copenhagen (Denmark)
5G for TV production (Denmark)
5GTNF (Finland)
LMT 5G Laboratory (Latvia)
LMT public 5G Testbed (Latvia)
Salmar fish farming (Norway)
Testbed for digitised agriculture (Sweden)

Projects: Rescue drone for wildfire (Latvia)
Mobile Network for UAVs (Latvia)

Health and welfare technology: 4 testbeds and 1 project

Testbeds: 5G for hospital applications in Padborg (Denmark)
5GTNF (Finland)
Umeå 5G (Sweden)
Stockholm Stadium (Sweden)

Projects: Health 5G (Finland/Sweden)

Smart cities: 14 testbeds and 14 projects

Testbeds: 5G pilot in large city (Denmark)
Testbed in Aarhus for Precision Positioning and Autonomous Systems (TAPAS) (Denmark)

5GTNF (Finland)
Nova headquarters, Reykjavik (Iceland)
LMT 5G Laboratory (Latvia)
Digital road and connected cars with 5G & MEC (Latvia)
Kongsberg in Oslo (Norway)
Trondheim city (Norway)
Elverum municipality (Norway)
Odeon Cinema in Oslo (Norway)
Umeå 5G (Sweden)
KTH Royal Institute of Technology (Sweden)
Urban ICT Arena (Sweden)
Luleå University of Technology (Sweden)

Projects:
5GKIRI (Finland)
LuxTurrim5G (Finland)
Healthy Outdoor Premises for Everyone (HOPE) (Finland)
UrbanSense (Finland)
5G-XCAST (Finland)
A-WEAR/5G and mmWave capabilities in wearable applications (Finland)
Telia/Finavia (Finland)
5G-selvitys/Suomen kasvukäytävä (Finland)
5G Delta/5G Suomen kasvukäytävälle (Finland)
5G project – Operational and business models for smart city 5G networks (Finland)
5G project – Media and entertainment (Finland)
5G project – Public safety (Finland)
5G project – Air quality (Finland)
5G project – 5G applications for smart cities (Finland)

5G R&D: 5 testbeds and 13 projects

Testbeds:
5GTNF (Finland)
LMT NB-IoT network technology testbed (Riga, Latvia)
LMT LTE-M network technology testbed (Riga, Latvia)
Cybersecurity Testbed (Latvia)
Sensible Things that Communicate (Sweden)

Projects:
Mikrotīkls 5G Laboratory (Latvia)
Internet at high altitude in Vecumnieki (Latvia)
5G FORCE (Finland)
5G-RANGE (Finland)
Sat5G (Finland)
ASCENT – Demonstrator of licence-assisted spectrum access satellite networks (Finland)
6Genesis (Finland)
FUWIRI (Finland)
Terranova (Finland)
Cognitive Self-organising Networks (CSON) for 5G (Finland)
5G reliability measurements (Finland)
5G-VINNI (Norway)
Secure Consolidated Trustable Things (SCOTT) (Norway)

Accelerating 5G in the Nordic and Baltic region: steppingstones for cross border collaboration

Sofia Målberg, Adam Edström and Torbjörn Jonsson

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Nordic co-operation
Nordic co-operation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland, and Åland.

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Nordic Council of Ministers
Nordens Hus
Ved Stranden 18
DK-1061 Copenhagen
www.norden.org

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Nordens Hus
Ved Stranden 18
DK-1061 Copenhagen
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Testbeds are pivotal in developing and deploying 5G infrastructure in the Nordic and Baltic region. This publication investigates the challenges, potentials and opportunities in a differentiated 5G regional landscape based on a SWOT analysis and mapping of the most advanced test facilities of the region. It aims to take the temperature of 5G activities, identifying valuable verticals such as the manufacturing industry, and indicating progress in a regional, national and cross-sectorial perspective. It provides insight into the region's weaknesses and strongholds, as well as how important cross-border collaboration is in the fast-forwarding 5G global race.