5G deployment models are crystallizing

Opportunities for telecom operators to facilitate new business ecosystems

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Arthur D Little

Content

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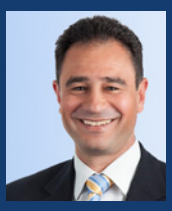

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Executive summary

5G comes with the promise of unseen services and futuristic use cases. Telecom operators and other industry players are making big bets on next-generation services. 5G will bring new interactive and immersive experiences to customers. Use cases are already being built around immersive sports viewing and augmented-reality applications. Beyond consumer applications, enterprises are actively investigating how they can benefit from 5G, and indeed thinking of deployment models themselves (e.g., smart manufacturing). We are also seeing whole industries organize themselves into ecosystems that would collectively benefit from 5G networks and related computing infrastructure (e.g., smart cities). It is yet to be seen what role operators will play in these ecosystems, beyond facilitating their emergence, but some operators have already begun to shape the value chain and tune their services accordingly. For the first time, operators can play a key role in bringing corporates and industry verticals together, to deliver not just connectivity, but also solutions.

Meanwhile, 5G deployment models are crystallizing. New 5G pilots or technology updates are announced every month. We observe five distinct rollout models used by operators. 5G can be used to…

1. …provide gigabit broadband to residential homes and an effective last-mile complement to existing fiber or cable networks.
2. …deliver a next-generation, nationwide mobile experience that enables new use cases driven by virtual reality, tactile internet, etc.
3. …deliver highly reliable, low-latency connectivity and solutions, improving both efficiency and productivity for corporates.
4. ...enable digital industrial ecosystems with machine-to-machine connectivity, facilitating new service ecosystems with multiple partners, providers and end users.
5. ...deliver next-generation infrastructure-as-a-service for the entire country.

Non-telecom players are already active in the 5G-enabled product space, with pilots in autonomous driving, virtual reality-based infotainment services and other use cases. If telecom operators don't act fast, these new players will take an increasingly large share of this new ecosystem.

There are concrete steps that telecom operators can already take to place stakes in their 5G futures. Building an application ecosystem with start-ups and service providers, is key to facilitating future 5G use cases. Preparing the spectrum and infrastructure for future 5G macro and hundreds of thousands of small cells is another step that can be kick-started. Fiberization of fixed-access network, which will assist in aggregating and backhauling multi-gigabit traffic, as well as cloudifying the core to enable easy scale-up and external partnerships will eventually be required. Lastly, they will have to prepare their computing infrastructure to handle this gigabit traffic.

Arthur D Little

Disclaimer

This paper expresses the views of Arthur D. Little (ADL) based on a review of announcements, blogs, videos, and other information in the public domain. ADL is working with multiple telecom operators[1], vendors, corporates, regulators and other industry players to develop 5G business models.

5G is a technology that is still being developed, refined, and standardized. Future commercial, financial, regulatory and competitive conditions will play a large role in how this technology will ultimately evolve. The five models described in the paper express our opinion on the starting point of 5G rollout taken by major operators that have made communications at this point in time. These 5G models will adapt, change and evolve in the future, and we will see a combination of them eventually.

1 Arthur D. Little has described in detail multiple 5G-enabled business models in the report "Creating a Gigabit Society – The role of 5G" in Apr 2017 – http://www.adlittle.com/viewpoints.html?&no_cache=1&view=809

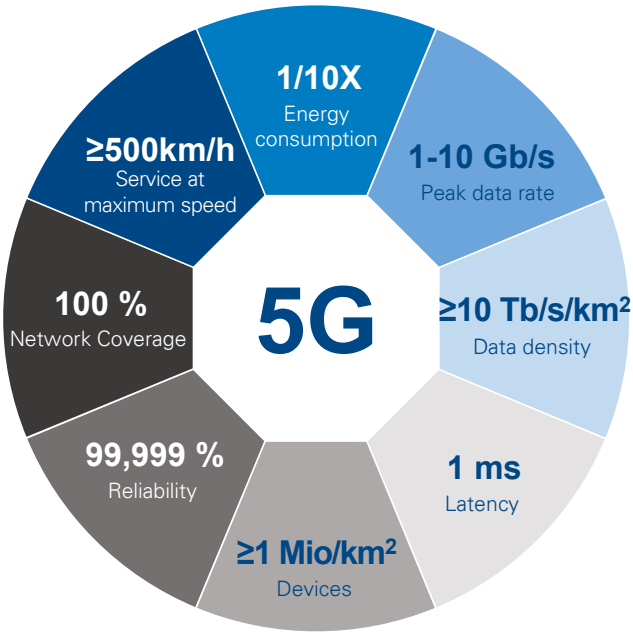
1. 5G – the next big wave in telecom

5G is becoming a strategic priority for telecom operators. Telecom operators and vendors are announcing 5G rollout plans or launching pilots each month. Operators are also collaborating with other industry players such as vehicle manufacturers, city administrative authorities, sports authorities and governing bodies to announce plans for smart mobility, smart city, immersive Olympics, and many other use cases.

5G is expected to embrace and integrate partially existing and partially new innovative technologies. It will bring together small cells, MIMO[2], beam forming, true duplex and edge computing, and will extend spectrum support to both low-band (e.g., 600 MHz) and high-band millimeter wavelength[3] (mm wavelength) in order to deliver many of the above requirements.

5G is expected to push the digitization of the economy further – cloud-based services, next-generation transactions (e.g., block chain requiring large, widespread computing in a short time), big data, virtual reality (VR), augmented reality (AR), artificial intelligence (AI), and Internet of Things (IoT) – due to its ability to handle large volumes of data with low latency in real time. Users will continue to expect new services such as augmented reality-based applications built on high-speed, low-latency communication, with imperceptible resulting delay, jitter or interruptions and an immersive customer experience as well as enterprises will do with business critical application.

Figure 1: Commonly discussed 5G requirements



Source: Arthur D. Little, European Commission

2 MIMO – multiple-input multiple-output is a wireless technology that uses multiple transmitters and receivers to transfer higher data rates. It is already in use in some WiFi, HSPA+ and LTE networks. 5G is expected to use the next generation of MIMO technology.

3 Millimeter wavelength is spectrum in the 30 to 300 GHz range that is expected to be used for 5G and small cells. The wavelength is between 1mm and 10mm, thus the name millimeter wavelength.

2. 5G has the potential to disrupt the market

Aggressive mobile-broadband strategies are not new. In the past, 4G-based strategies resulted in some operators winning market share. Recent examples illustrate this:

- Everything Everywhere (EE) in the UK attained the number-one market position (from approximately 30 percent in 2012 to approximately 32 percent in 2016) driven by its strong 4G network, which was facilitated by re-farming its extensive 1,800 MHz spectrum holdings. It also increased its monthly handset usage fees by £4 during this period.
- Reliance Jio in India, a 1.1 billion, highly competitive and fragmented mobile subscriber market, obtained approximately 80m subscribers (a six percentage point market share) in just six months after launching a newly deployed 4G-only network and a compelling (and somewhat controversial) customer proposition.
- Drei in Austria followed an aggressive fixed-mobile substitution strategy, with its Drei Box 4G-based routers providing competitive speeds compared to other fixed products. Since 2011, when Drei first launched such a product, we estimate that around 25 percent of fixed-broadband subscribers in Austria use one of Drei's fixed-mobile broadband products. Drei is estimated to have the highest mobile data consumption in Austria, and Austria is number two[4] in Europe in data consumption per capita.

We believe operators can leverage 5G to improve their positioning and win back market share. Early adopters of new technologies have, in the past, been able to use them to change market dynamics to their advantage and gain market share. In 5G, the risks are bigger, since it also involves new investments while clarity around the technology, performance, regulatory and customer demand is still materializing. The potential for success is also high – driven not just by possible differentiation and market share gains, but also by rolling out successful use cases and being pioneers and trusted partners in the building of new ecosystems.

We expect 5G to support the strategic shift of telecom operators from being predominantly providers of high-speed connectivity, to becoming true enablers of next-generation ecosystems. Some telecom operators are taking a strategic lead in 5G deployment – announcing their future plans with "big bets", which will impact the course of future 5G rollout and the development path for the technology.

4 'tefficient' 2016 mobile data industry analysis report

3. 5G deployment models are crystallizing

Arthur D. Little (ADL) has been monitoring announcements and moves by telecom operators in the 5G space from several years. We are developing 5G use cases and go-to-market strategies with telecom operators. Beyond this, we also participate in forums where technology definition and spectrum prioritization are discussed. From these experiences, ADL has identified five differentiating deployment models that operators are considering or now using for 5G deployment. Each model addresses a distinct opportunity and leverages a particular infrastructure advantage of the telecom operator.

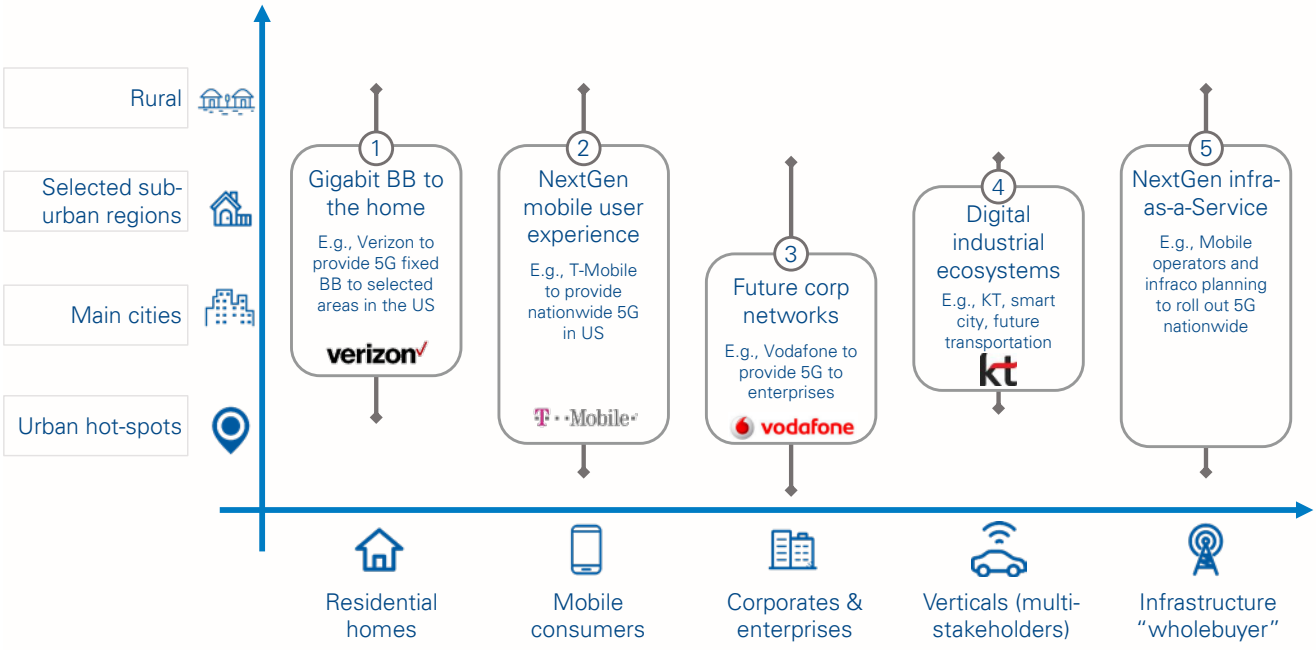
In this paper, we aim to highlight the starting point of deployment some of the leading telecom operators are taking, often addressing initial customer segments with specific 5G rollout plans that have dedicated value propositions. Based on the chosen deployment option, operators choose…

- …different geographical rollout approaches (e.g., suburban homes),
- …to build specific capabilities (e.g., rolling out hundreds of thousands of small cells),
- …to offer features that are segment specific (e.g., immersive sports viewing at home),
- …to partner with new stakeholders (e.g., sports-content producers)
- …to offer specific solutions to these segments (e.g., immersive sports experience for homes)
- …to leverage new network functionalities (e.g., heterogeneous networks)
- …new spectrum technologies (e.g., millimeter wavelength with beam-forming solutions)
- …to enable new business models (e.g., based on partnerships between the telco and Olympic stadiums)

The choices made must be consistent with the 5G deployment model being pursued.

We observe five types of 5G deployment models pursued by telecom operators:

Figure 2: Initially observed 5G rollout models



Source: Communication of CEOs of respective operators, publicly available data

Figure 3: Summary of 5G rollout models

#	5G rollout model	Target customer segment	Description	Key success factors for the telco	Benefit to the telco
1	**Gigabit broadband to the home**	Urban & sub-urban homes for high-speed BB	Provide gigabit speeds and better infotainment services to homes	Spectrum: mm wavelength spectrum Infrastructure: Complementary gigabit coverage to existing fiber with small cells, beam forming, MIMO, full duplex **Verizon** plans to provide 5G BB to 11 cities (Feb 2017)	Gigabit broadband to offer next-gen services to households, such as virtual reality, immersive sports
2	**NextGen mobile user experience**	Mobile customers	Provide high-speed enhanced mobile broadband and related services such as augmented reality	Spectrum: Low, high & mm wavelength spectrum Infrastructure: Nationwide mobile coverage, small cells, beam forming, MIMO, full duplex **T-Mobile** plans nationwide 5G in USA (May 2017)	Enhanced mobile broadband (eMBB) driving customer experience, augmented reality, etc.
3	**Future corporate networks**	Large corporates, enterprises, manufacturers	Provide high-speed and high-reliability networks to improve productivity and reduce costs	Spectrum: High band spectrum Infrastructure: Coverage of key business areas, FTTX, small cells, beam forming, MIMO, full duplex **Vodafone** plans to provide 5G to businesses – driving agility, efficiency, digital transformation	Position telcos as partners of corporates to drive efficiency and productivity for corporates
4	**Digital industrial eco-systems**	Multiple application/ services providers in a specific industry	Provide an ecosystem that brings multiple solution providers together	Spectrum: Different bands based on use case Infrastructure: High density coverage, massive machine type communication (mMTC), mastering IoT **Korea Telecom** developing 5G platform for 2018 Olympics with broadcasters, other vendors	Participate in value creation in ecosystems, e.g., smart city
5	**NextGen Infra-as-a-Service**	Other telecom operators	Provide high-quality, low-cost, nationwide 5G infrastructure	Spectrum: Low, high & mm wavelength spectrum Infrastructure: Nationwide mobile coverage, FTTX, small cells, beam forming, MIMO, full duplex	Enabling the ICT industry in the country by providing nationwide carrier-neutral 5G infrastructure

Source: Arthur D. Little

3.1 Gigabit broadband to the home

5G can be used for **gigabit speeds to homes**. There will be a need to provide hundreds of megabits, if not gigabits, speeds to a significant proportion of households in the near future, initiated by competition and stimulated by bandwidth-intensive applications (beyond 4K TV). Many telecom operators have not yet upgraded their legacy fixed-access infrastructure to gigabit capabilities at scale. 5G can be used to provide high-speed, fixed-wireless broadband to selective urban and suburban regions, complementing FTTH/Cable Docsis[5] networks.

We expect that the **Commercial model** will not only rest on revenues from gigabit connectivity, but potentially on revenue-sharing models with next-generation service providers. One such example may be an immersive sports experience with virtual reality, or hologram beaming, which enables the user to experience a live sporting event as if he were actually sitting in the best seat in the stadium. Several vendors are entering the living room with new devices, e.g., Apple with HomePod, making the home a new virtual environment to deliver immersive experiences[6] – not only established brands, but also

Figure 4: An NBC Sports advertisement of a virtual reality-based sports broadcast

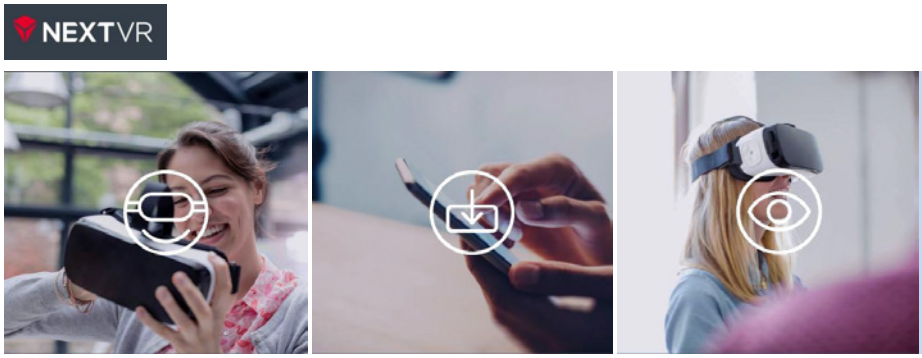
NBC Sports broadcasts certain sporting events (e.g., some NBA games) **on virtual reality** platforms with partners such as NextVR, Oculus and Google Daydream.

5G will enable the quality, "realness" and responsiveness of such broadcasts.

Source: Arthur D. Little analysis, NBC Sports

5 Cable Docsis, simply known as "cable," is used to provide TV, broadband and other services to homes; FTTH – Fiber to the Home
6 Watch further use cases here: The 10 Most Awesome Things You Can Do With Google Daydream VR – https://goo.gl/QR86bt

Figure 5: An advertisement for NextVR sports virtual-reality viewing service



NextVR provides **virtual reality-based** broadcasts of live events in partnership with sports and other broadcasters.

It shows live events with features such as immersive view, multi-camera view, live stats, etc. – all of which require several hundred Mbps speeds and low latency that is best delivered by 5G.

Source: Arthur D. Little, http://www.nextvr.com/getvr

start-ups. For example, Devialet, a French start-up, is producing high-quality sound equipment for the home. It is partnering with live content creators (e.g., the Opera House in Paris) to create an opera-in-the-home experience. Such applications will require not only high-fidelity sound, but also immersive video, in the future.

Another example is virtual-reality gaming in which users play interactive games sitting in their respective homes, but seemingly together virtually in the gaming world, and can communicate with each other as if they were face to face. There are initiatives by many start-ups as well as large gaming companies towards expansion of such services.

In terms of **technology**, 5G will provide an attractive alternative to complement existing provisioning of gigabit home broadband. In some situations, such as greenfield, this may be at lower costs compared to FTTH due to the avoidance of digging/ducting to roll out fiber all the way to the home. Four network technologies in particular can be leveraged – existing spectrum (especially high band and millimeter wavelength spectrum) for both local access and backhaul transmission; MIMO to increase throughput on the given spectrum; and beam forming to direct signals to specific households, minimizing interference and reducing power. The aggregation points in the access network should also be strengthened to handle multiple-gigabit throughput. Additionally, providers of next-generation services (such as virtual-reality gaming) will have to closely integrate their core servers that provide the content with telecom operators' edge network servers to ensure that the service can be seamlessly delivered end to end with millisecond latency. All these technological levers are continuously improving and coming to fruition with 5G to deliver next-generation infotainment at home.

Figure 6: A Red 6k virtual reality-filming camera

Red dual 6k virtual-reality cameras are already used to record live events such as USGA (Golf).

In order for a viewer to watch an 8k virtual-reality sporting event, a throughput of 200–300 Mbps would be needed, which can be best delivered by 5G.

Source: Arthur D. Little, http://www.red.com, https://apnews.com/

Key success factors are for operators to jointly develop next-generation services for the end user with service providers. This, in turn, requires close cooperation between the telecom operator and the service creator. This will help to stimulate demand and improve chances of success in the market. An example is the partnership between Netflix and Spotify with operators in some markets to stimulate the upgrade to better performing connectivity infrastructures. Telecom operators should complement their macro-fiber networks (FTTC/N) with 5G to connect homes with gigabit speeds. Access to new spectrum (including millimeter spectrum) and partnership with owners of strategic sites (e.g., utilities) are also key to rollout success.

Verizon was one of the first operators to announce[7] plans to offer 5G-based fixed wireless access to 11 cities in the US as a

7 Verizon 5G Technology Forum – http://www.verizon.com/about/news/verizon-deliver-5g-service-pilot-customers-11-markets-across-us-mid-2017 The cities are – Ann Arbor, Atlanta, Bernardsville, Brockton, Dallas, Denver, Houston, Miami, Sacramento, Seattle, Washington DC.

pilot program in February 2017. The chosen locations provide a variety of terrain, neighborhood layouts and population density. The company plans to use millimeter wavelength spectrum (28/39 GHz) to achieve gigabit throughput. It is also testing multi-gigabit speeds in the 15 GHz and 64 GHz spectrum in other cities. They are collaborating with a specific vendor in each of these cities to roll out pilots.

Figure 7: A Verizon February 2017 video[8] describing its 5G rollout plans in the US

Verizon plans to roll out 5G-based fixed-wireless access in 11 cities in the US.

It plans to use millimeter wavelength spectrum and 5G technologies to provide multi-gigabit speeds to homes

Source: Arthur D. Little, Verizon 5G Technology Forum – http://vz.to/2kZyql7 The cities are – Ann Arbor, Atlanta, Bernardsville, Brockton, Dallas, Denver, Houston, Miami, Sacramento, Seattle, Washington DC. Verizon to deliver 5G service to pilot customers in 11 markets across U.S. by Mid 2017 – http://bit.ly/2mbTtou.

In the past, some telecom operators have began investments into gigabit fiber, but they stopped for various reasons. For example, Verizon has considerably slowed down its FIOS – fiber rollout program – in the US since 2010. We expect that the new 5G-based fixed-wireless access can now be used to provide gigabit broadband to homes.

3.2 NextGen mobile-user experience

5G can be used to provision **gigabit nationwide mobile connectivity**. Operators are also planning to leverage 5G to create new digital experiences for mobile consumers. By focusing on introducing human- and mobile-centric next-generation services building on augmented reality, virtual reality and tactile internet, a "wow" customer experience can be created with 5G.

Commercial models likely rest on charging end users for greater speeds and lower latencies. However, 5G also enables telecom operators to establish partnerships with service providers that can use gigabit data throughput and low latency to provide end users with a better customer experience and high-quality service, thus providing the telecom operator with additional sources of revenue. In the past attempts at such partnerships between telecom operators and service providers that heavily use the telecom network were usually acrimonious, but at other times they worked very well.

Figure 8: Wonder Glade, a multi-player virtual-reality game

Wonder Glade by Resolution Games Sweden is a multi-player virtual-reality game.

Multi-player games are expected to further evolve to augmented reality, which involves interaction with the real environment. This, in turn, requires low latency and high bandwidth, which can be best delivered with 5G.

Source: Arthur D. Little analysis, http://www.resolutiongames.com/wonderglade/

Virtual reality, tactile internet, gigabit broadband with low latency can be provisioned reliably and practically when the telecom operator and provider of the service partner to fully utilize the benefits of the new technology. Attractive commercial use cases can then be developed that enable high and reliable data rates.

In terms of **technology**, success of rolling out a nationwide 5G network will require access to low-band spectrum for coverage of large areas, as well as high-band spectrum for providing high data speeds to hundreds of thousands of small cells in urban areas, in order to deliver enhanced mobile broadband (eMBB). Services will have to be activated on demand using new 5G features such as millisecond latency and gigabit throughput, based on end-user requirements.

In the 5G world, gigabit speeds and millisecond latency can be better managed with greater integration between the IT systems of the telecom operator and the service provider. The telecom operator should be able to dynamically manage its access network to ensure quality of service.

8 Verizon to deliver 5G service to pilot customers in 11 markets across U.S. by Mid 2017 – https://goo.gl/z4WqPU

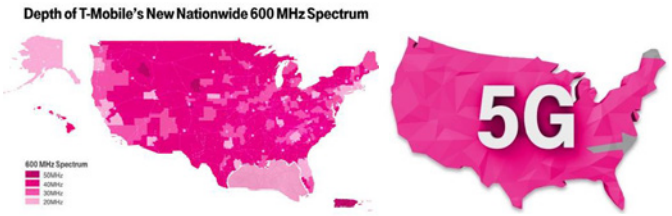
Figure 9: An example of a virtual meeting

5G can enable a **virtual-reality meeting** which requires high bandwidth and millisecond latency, coupled with holographic rendering and spatial audio, to simulate a real meeting environment.

Source: Arthur D. Little

The **key success factor** for operators is to develop partnerships with other service providers, so that their 5G services are not just about gigabit speeds, but can also deliver a truly new customer experience. The telecom operator can leverage its nationwide network and brand possibly with its partners to provide innovative services. A telco that has a strong relationship with a thriving start-up ecosystem, anchored in the entertainment industry and with community-driven marketing, is vital for new service stimulation and adoption.

Figure 10: A May 2017 T-Mobile technology blog showing its 5G plans



T-Mobile USA is the first telecom operator in a large country such as the US to announce "nationwide 5G."

This requires large investments in low-band and millimeter wavelength spectrum and making big bets on new 5G technologies.

Source: Arthur D. Little, T-Mobile press release – http://t-mo.co/2oRnnRK and T-Mobile Vlog on YouTube – http://bit.ly/2t6gOfb

T-Mobile USA has been vocal in announcing[9] an aggressive plan to rollout 5G across the US by 2020, aiming to pre-empt strategic moves by competitors. It plans to deploy macro cells for coast-to-coast coverage, as well as small cells for high-speed capacity in dense urban areas. In April 2017, T-Mobile won 31 MHz (on average) of attractive low-band 600 MHz spectrum, which it plans to use for nationwide 5G coverage. It also holds licenses for mid-band spectrum, as well as 200 MHz of millimeter wavelength spectrum (28/39 GHz), which can be used for small cells.

3.3 Future corporate networks

Operators can leverage 5G to move closer to being trusted partners of **enterprises**, in order to **improve their overall productivity and efficiency**. Corporates are seeking new technologies to run their enterprises more efficiently (reducing opex and capex), with higher reliability and better security, reducing time to market when launching new services, improving productivity and fostering new products. 5G, with its ability to handle large volumes of data with low latency within controlled quality-of-service parameters, provides a valuable tool for telecom operators to co-design solutions with corporates for their core businesses. Several corporation decided to design and launch their 1st innovative services directly on 5G leapfrogging 4G to take advantage of the inherent top 3 features of 5G namely: slicing, security and milli-second latency.

In terms of **commercial** model, it is an opportunity for telecom operators and corporates to **jointly plan** their network architecture and production models. The exact business model is yet to crystallize, but we see multiple options being elaborated, including build-operate-manage, build-operate-transfer, build-to-manage, benefit sharing, co-innovation programs, JVs, etc. While some customers will require dedicated network deployments, others may be satisfied with dedicated capacity. Clear interfaces between the network and the client's applications and control systems will gain importance.

Technical models will require close cooperation between the telecom operator and the corporate. 5G network feature requirements for such corporate solutions may go beyond just gigabit speeds to ultra-reliable and low-latency communication networks (URLLCs), resource multiplexing and isolation (dedicated routing, mobility support, customized flow handling, in-network processing), low latency, high-density connectivity, low power usage and other features. Some corporates also seek physical and cyber resilience, which is not part of the 5G standards per se, but could be part of the overall design of the customer solution required in that specific industry.

9 T-Mobile press release – https://newsroom.t-mobile.com/news-and-blogs/nationwide-5g.htm and T-Mobile Vlog on YouTube – https://goo.gl/T2kNbE

Network-slicing[10] techniques – which span various core and access technologies – are key to delivering on the "dedicated network" promise. Network slicing becomes a requirement in situations in which the 5G network supports critical infrastructure and must not be impeded by neighboring traffic situations. Examples include mining, autonomous driving (both train and car) and robotics. None of these use cases can be supported in non-dedicated networks suffering from interference, traffic prioritization conflicts and the like.

A **key success factor** for telecom operators is to build intimate network-oriented cooperations with enterprises that have distinctive networking requirements. Hence, early co-design and deployment are required in order to deliver specific solutions to improve efficiency and deliver real business results to the corporate using the "follow-the-customer" approach. Solutions developed for particular corporates should be able to be scaled up and replicated. This may mean different agreements with the first corporate customer, versus later customers, to better reflect the initial investment and risk sharing.

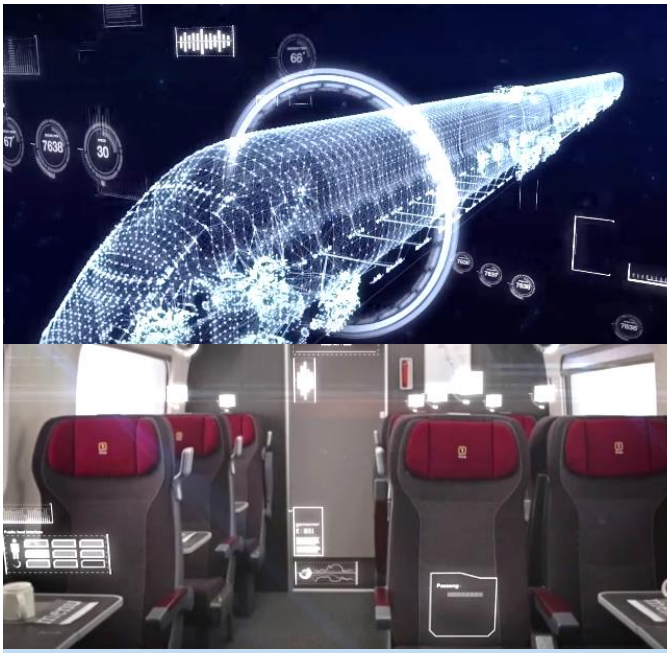
Vodafone Global Enterprise recently announced[11] that it would leverage 5G technologies to give its corporate clients not just much higher speeds and reliability, but also the ability to develop specific solutions for integrated supply chains, machine-to-machine and various industrial applications supported by big-data analytics. Vodafone is moving away from plain connectivity to providing industry-specific solutions.

Figure 11: Vodafone DE 5G testing apparatus

Source: Arthur D. Little, https://www.vodafone.de

As an example, **Vodafone and Hitachi**[12] are jointly developing a next-generation rail analytics and operations management system, which uses global the IoT, cloud technology and multi-terabyte data handling to enable next-generation public transportation. Each of Hitachi's trains in operation would be part of a worldwide connected network. In this network, passenger load would be dynamically managed, sensors would measure and share information, operations would be centrally monitored, and preventive maintenance could be managed proactively, based on detailed telemetry, acoustic and imagery data, and statistical analysis.

Figure 12: An April 2017 Hitachi video showing an IoT smart-train



Vodafone and Hitachi are working together on a IoT-based smart-train solution.

Each one of Hitachi's trains will be part of a global IoT network provisioned by Vodafone, which will enable real-time monitoring and optimizing, and pro-active operations.

Source: Arthur D. Little, Hitachi - Smart Trains for a Smart Future - https://www.youtube.com/watch?v=aBq1CFgNkZI

3.4 Digital industrial eco-systems

In order to address certain segments of the market, some corporate entities and service providers need to operate as parts of **industrial clusters or ecosystems**. Such ecosystems are usually specific to particular industries, e.g., transportation, agriculture, healthcare, each with their own sets of rules,

10 Network slicing enables the creation of an end-to-end network that functions to defined service levels and performance criteria, while spanning and being agnostic tomultiple underlying access technologies.
11 Vodafone – https://www.mobileworldlive.com/featured-content/top-three/enterprises-key-for-5g-opportunity/
12 Hitachi – Smart Trains for a Smart Future – https://goo.gl/qboENi

infrastructure, communication and enabling technologies bound by a common value chain.

Examples of such ecosystems are:

- **Smart agriculture** – implementing green strategies to improve food production efficiency and security – facilitating interactions between land owners, farmers, agricultural-equipment manufacturers, farm workers, seed suppliers, fertilizer suppliers, pesticide suppliers, logistics providers, large and small retail outlets, national planning commissions, local representatives of federal ministries, statistics and data collection departments, irrigation and water departments, climate experts, etc.
- **Smart city/smart mobility** – solving urban mobility in a sustainable manner through better transportation planning, facilitating interactions between multiple stakeholders – government, transportation ministry, public-transport authorities, traffic management authorities, parking authorities, etc. 5G will help to introduce new solutions such as digitalized and fully integrated public transportation, autonomous transportation, multi-modal transportation, park-and-ride services and rent-instead-of-own services.
- **Smart healthcare** – empowering the digital-healthcare ecosystem from the patient to the hospital, integrating hospitals, clinics, doctors, nurses, medical transportation services, medicine suppliers, bio-medical device developers, insurance providers, etc.

Operators can take a pivotal role on these platforms for industry-specific ecosystems. This, in turn, will enable the operator to create new services and improve efficiencies across multiple stakeholders.

The **commercial model** rests on operators providing neutral infrastructure to industry participants, at reasonable fees, that scale with the growth of the ecosystems themselves. This is particularly true for ecosystems in which each participant has a limited appetite for sharing information, unless many others share too. If operators facilitate the process of overcoming such hurdles, e.g., by providing very low entry barriers to encourage new users, these ecosystems can thrive by themselves – e.g., smart cities.

In terms of **technology**, a digital industrial ecosystem network would require, in addition to ultra-reliable, low-latency communication networks (URLLCs), dedicated features that depends on the particular use case. These could be vehicle-to-everything (V2X) communication, edge computing, support of third-party services in the core network, etc. Hence, we believe additional investment in industrial iAPPs (service-based, template-driven configurations) may be necessary.

The **key success factor** for telecom operators is to win over "flagship tenants." The success of such a model is "platform play" – the higher the number of users of this platform, the more attractive the platform and the lower the cost for each participant.

Such business models have not yet been proven by a telecom operator. The closest early example we see is the model adopted by some smart-city operators. The smart-city operator (in some cases we see telcos taking that role) has invested in platforms to support mobility management, street lighting, waste management, etc. Actual services are provided by multiple local, specialized entities, which all use the smart-city platform. Each service provider pays a small fee to be part of the platform, using a "pay-as-a-service" concept. A common smart-city platform that can support multiple services – transportation, communication, waste management, security, and other services – benefits all service providers and reduces costs for everyone. Of course, smart-city concepts can be devised in 3G, 4G and 5G environments. However, when utilizing 5G, certain use cases become possible that otherwise would not be in particular we can see in several cities in China Auto OEM joining effort to test eCars and self-driving fully integrated in a mobility solution of a city. These uses cases are only designed on pre-5G platforms.

Figure 13: An Olympics 2018 5G promotional poster from the KT website

KT in Korea is in the process of setting up a 5G ecosystem for the upcoming 2018 Winter Olympics in Korea.

It plans to set up a platform so that multiple broadcasters, athletes, users and sponsors can plug into this ecosystem to provide or consume services.

Source: Arthur D. Little

For example, **KT** is planning[13] to set up a 5G ecosystem in Korea for the upcoming 2018 winter Olympics. It plans to connect key stadiums and Olympics locations with 5G-based networks, with a platform for broadcasters, athletes, users and sponsors to each plug into this ecosystem. Some of the services expected

13 KT – https://torchrelay.kt.com/

to be offered are a 360-degree virtual-reality view of key events, "Omni Focus" (multi-view streaming), "Time Slide" (multi-view videos), "Hologram Live" (to bring spectators closer to athletes), a 5G autonomous bus for transportation, drone-equipped remote video, and others.

Vodafone is working with multiple partners on a drone-as-a-service concept for smart-agriculture and precision-farming use cases. Vodafone already provides drone-based services using 4G, and the ability to control drones using 5G can yield better real-time analysis and remote assessment of crops. These drones can capture high-resolution images of crops transmitted in real time to cloud servers, which can then determine which crops – on a plant-by-plant-level – need water, fertilizers or pesticides, and which areas are ready for harvest. This results in optimal use of resources that can result in higher crop yields and more sustainable agricultural practices.

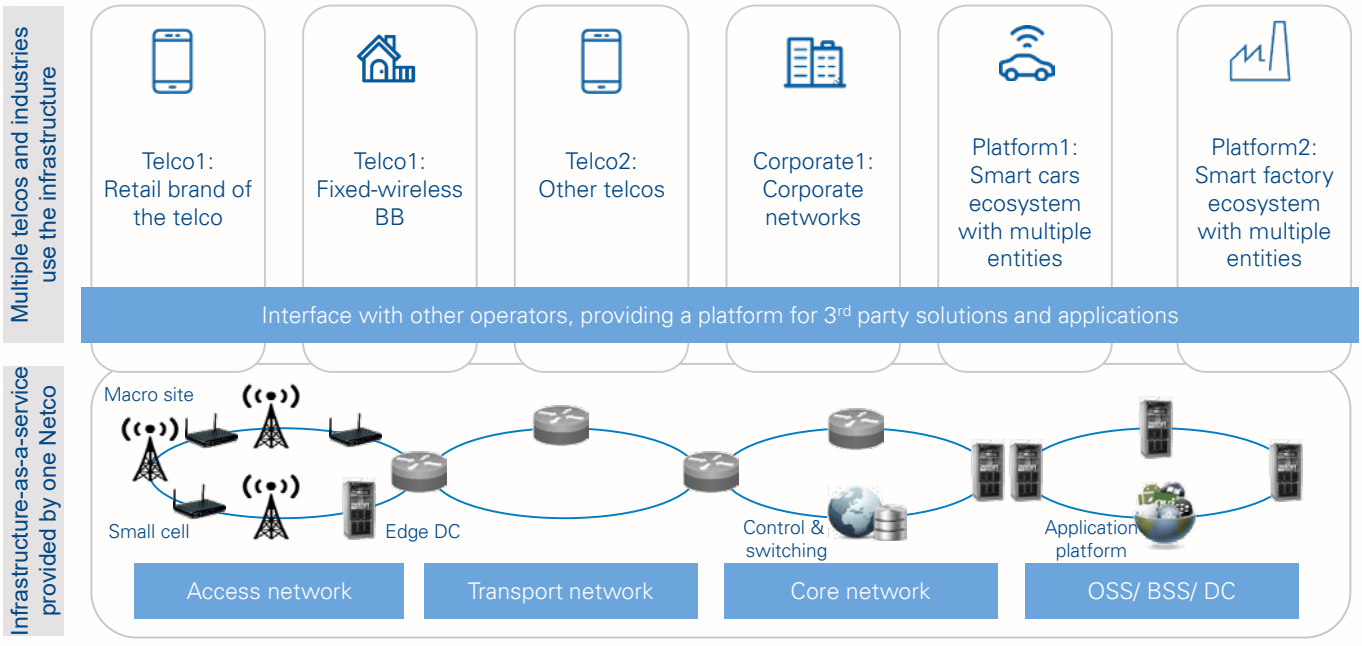
Telecom Italia[14] is working with the city of Turin on a "Turin 5G" project that involves both rolling out next-generation communication networks and hosting services such as public security, public transportation and information services within a smart-city framework.

3.5 NextGen infrastructure-as-a-service

5G infrastructure-as-a-service is addressing the fact that not all telecom operators are able to invest in a nationwide 5G network – Many are still investing in 4G, and others are still recovering from investments in 4G. Some countries may not have the size and scale economics to support this level of competitive infrastructure. Deploying an operator-neutral 5G network for the purpose of sharing it with partners such as other telecom operators, the government and local city authorities will make 5G investments more feasible. Funding of such an investment could be done with the operators' own funds, via infrastructure funds, via vendor financing or via investment by city authorities. Usually the host telco brings in the existing infrastructure and operating expertise, vendors want to test new solutions, city authorities have access to valuable on-the-ground infrastructure (e.g., street lights, manholes), and infrastructure funds can bring in long-term capital – together building a sustainable business model with a more open platform.

The **commercial model** is a "5G infrastructure-as-a-service" business model. Widespread 5G networks, in addition to macro cells, will require hundreds of thousands of small cells using millimeter wavelength spectrum, which will dramatically increase capex for the radio interface (millimeter wavelength, MIMO, true duplex), front haul (beam forming) and backhaul (traditional fiber). Operators are thinking of an open access model for two main reasons – to compete with larger operators with deeper pockets, or because they anticipate new business

Figure 14: 5G Infrastructure-as-a-service



Source: Arthur D. Little

14 Turin 5G – http://www.telecomitalia.com/tit/en/innovazione/rete/5G-Torino.html

models and are looking for partners to co-invest and share the risk. The ownership models can be build-operate-transfer, or build-and-jointly-operate. The risks of investment and subsequent utilization of infrastructure can be fairly shared by both parties.

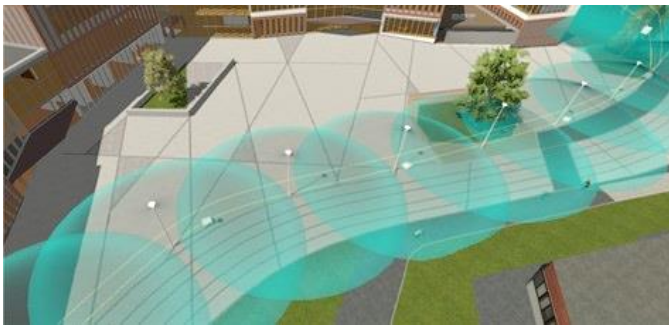
So far, a large-scale, nationwide model for 5G has not yet been announced or rolled out in any country. There have been many attempts in the past to roll out nationwide, carrier-neutral infrastructure-as-a-service models. But these have not yet succeeded for various reasons – spectrum ownership and use, investment sharing, pricing of services, asymmetry of contribution and use, etc. However, we believe that in 5G there is a stronger business case for operators and other entities to cooperate to jointly roll out a 5G infrastructure-as-a-service model, because of larger investments and better risk sharing.

In terms of **technology**, such a network will have to encompass features such as enhanced mobile broadband (eMBB), ultra-reliable and low-latency communication (URLLC), massive machine-type communication (mMTC) and network slicing to manage multiple tenants. It must also support multiple spectrum bands on either a pooled or logically separated basis, depending on the nature of the infrastructure service delivered.

The **key success factor** of such a 5G infrastructure-as-a-service model is to find the right partner to help the telecom operator fill the gap that prevents it from rolling out this infrastructure itself, with the right commercial terms. Examples of such include: a financing partner (e.g., long-term infrastructure funds), a local partner (e.g., local municipalities and city authorities), a rollout partner (e.g., construction companies), an operating partner (e.g., other telecom operators) or a vendor/vendor-backed financier. Regulatory certainty is also a key requirement to facilitate such an infrastructure-as-a-service model.

The **city of Espoo in Finland**, together with Nokia Bell Labs, Spinverse[15] and eleven other partners, is piloting an ambitious project, "LuxTurrim5G," in 2017. This project aims to roll out a 5G-based network using existing street lighting and other infrastructure in the city for mobile broadband and IoT networks. Some of the use cases expected for this infrastructure are smart lighting, security, navigation, weather monitoring, information sharing and advertising. Vodafone is working with the city of Dusseldorf in Germany on the "Dusseldorf 2020 Smart City" initiative.

Figure 15: LuxTurrim5G – Concept showing a 5G network built on streetlights



The city of Espoo, in Finland, is partnering with eleven other entities – telecom and non-telecom – to roll out a 5G network in the city using existing infrastructure such as street lights that can be used for mobile broadband and IoT.

Source: Arthur D. Little analysis

Infrastructure companies may pursue similar strategies, and state-backed entities may even appear in some jurisdictions, especially where market scale might preclude the viability of competitive infrastructure rollout, yet the authorities wish to ensure that enabling services arrive early in the market. All of these models remain to be tested for longevity, but regardless, they could certainly prove disruptive, or at least enabling, in the interim.

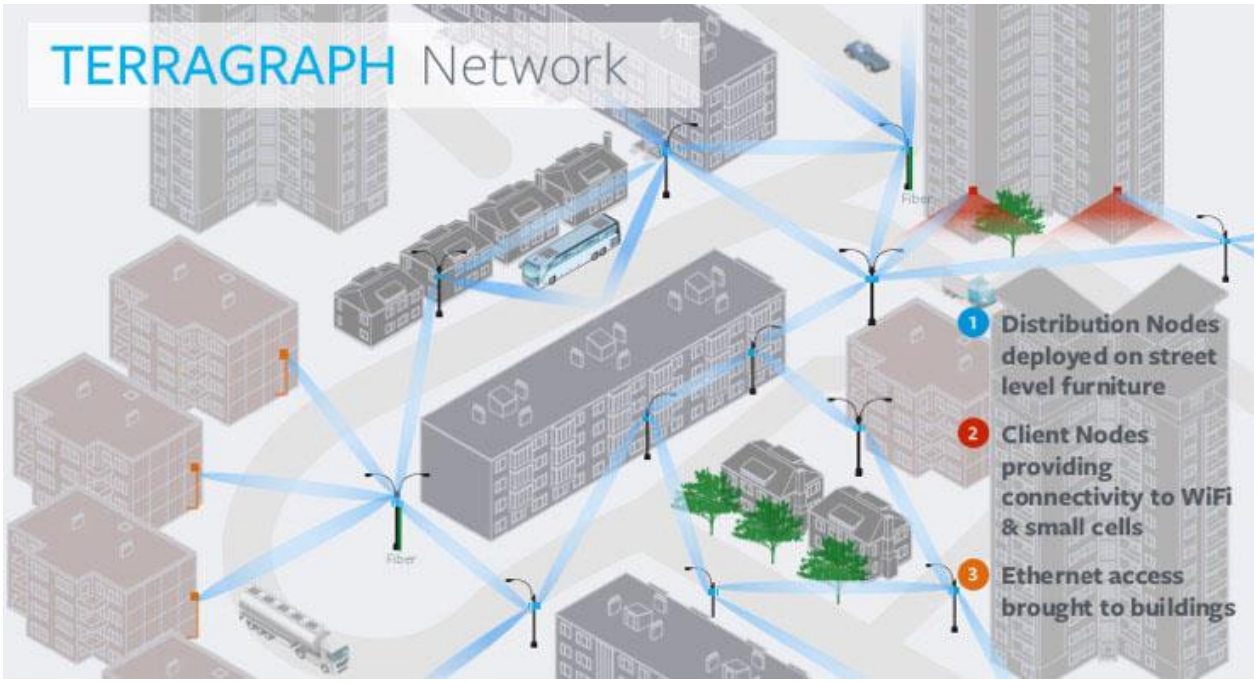
15 Spinverse – 5G on Smart Lights http://www.spinverse.com/luxturrim5g-builds-key-enablers-digital-smart-city/

4. Non-telecom players are moving into the 5G space

While telecom players and vendors have a key role to play in future 5G, we expect certain non-traditional players to deploy 5G networks and introduce 5G-based services. These non-traditional players usually focus on specific use cases or solutions and make big bets on them. **Google** announced Daydream, virtual-reality and autonomous-car initiatives; **Facebook** announced its small cell-based Terragraph[16] and Aries pilots in San Jose and project Aquila drone-based internet; and **Apple** announced its autonomous-car pilots and others. City municipal authorities, as seen in the example of **Espoo in Finland**, as well as engineering companies such as **Hitachi, Scania, and NEC**, are also working towards future 5G-based use cases. Almost every big telecom vendor is partnering with multiple industry entities to develop specific 5G-based solutions – for example, Ericsson and Scania for truck platooning, and **Ericsson and Comau** for industrial manufacturing.

Truck manufacturer **Scania** and Ericsson[17] are working on the use of 5G in autonomous driving and connected vehicles, especially in its application to platooning. Platooning is the concept of more than one truck driving in a convoy, following a lead truck, in very close proximity to each other and at a constant speed. This is to reduce air drag on the trucks in the convoy, and thus reduce fuel consumption and improve transportation efficiency. Platooning is implemented using existing features such as radar and cruise control. Improved platooning is also being implemented using onboard cameras and vehicle-to-vehicle communication. With 5G networks,

Figure 16: Facebook's 5G pilot with millimeter wavelength and MIMO in San Jose

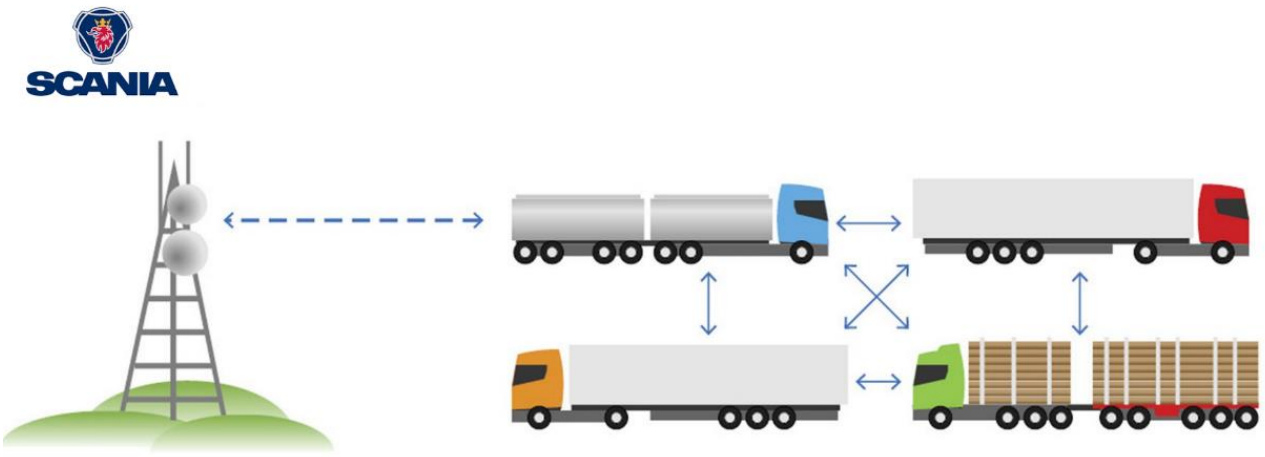


Source: Arthur D. Little, http://bit.ly/1XvXldx

16 Facebook Terragraph and Project Aries – https://code.facebook.com/posts/1072680049445290/introducing-facebook-s-new-terrestrial-connectivity-systems-terragraph-and-project-aries/

17 https://www.scania.com/group/en/scania-links-up-with-ericsson-to-test-5g-mobile-technology/

Figure 17: A Scania press release from May 2016 showing platooning with 5G



Source: Arthur D. Little, http://bit.ly/2tG1Ee9

the communication can be complemented and extended nationwide to all motorways, critical information such as traffic and road conditions ahead can be fed to the trucks, and real-time analysis of the data from hundreds of sensors on board can be processed so as to further reduce the distance between trucks, thus improving the efficiency of platooning.

Figure 18: A NEC video surveillance solution

Source: Arthur D. Little, http://bit.ly/2t2DvAK and http://bit.ly/2t6sqiF

NEC provides smart security[18] video-monitoring solutions. It is now working on using 5G to further develop this use case. Historically, security cameras recorded videos, but processing of the videos was done by trained human specialists sitting in a back room, or it was done offline using specialized image-processing software. With 5G networks, large amounts of data can be transmitted live. With more computing power, the video stream can also be processed for security intrusions in real time. Thus, the ubiquitous security camera of the future need not just silently watch, but can also make autonomous decisions, such as opening doors or triggering alarms. In such a use case, 5G will play a key role in transmitting huge amounts of data with low latency, complementing the large-scale image processing happening in the background.

Figure 19: Ericsson and Comau partnership for smart manufacturing using 5G

Source: Arthur D. Little, http://bit.ly/2t6Bapn and http://bit.ly/2rNDXzi

Ericsson[19] **and Comau**[20] are working together to develop 5G-based smart-manufacturing solutions for Industry 4.0. Ericsson brings its expertise in advanced mobile networks, while Comau is a leader in automated manufacturing solutions. Together, they plan to leverage 5G network technologies, IoT platforms, cloud and big-data solutions in order to improve

18 http://www.nec.com/en/global/solutions/nsp/sc2/prod/mimo_aas.html and https://www.necam.com/Docs/?id=bc9849df-1273-4554-987c-d2fb0cceeca8
19 https://www.ericsson.com/en/press-releases/2017/2/2082484-ericsson-and-comau-partner-to-explore-potential-of-5g-for-smart-manufacturing
20 http://www.comau.com/EN/media/news/2017/02/EricssonComauPartnership

efficiency in manufacturing, maintenance and quality control, and competitiveness with innovative smart-manufacturing solutions. Another example is the auto industry, in which new collaborations are being built between auto manufacturers, OEMs, start-ups and internet heavyweights such as Google, Apple and Microsoft. Telecom operators are also part of this ecosystem, but not yet main players. Telecom operators should anticipate the needs of new ecosystems in traditional industries such as auto manufacturing and move fast to play a bigger role.

With so many new players entering the 5G market, 5G may be more fragmented than expected. Telecom operators should move fast while they still have the space to drive the technology forward and set up new ecosystems, so that they don't lose momentum to new players

Figure 20: Next-generation collaboration in the auto industry

Source: Arthur D. Little analysis, http://bit.ly/1GmTYfX, May 2016

5. Telecom operators should place their stakes in the 5G ground

Telecom operators should move quickly to place their stakes in the 5G ground. They can take two approaches to prepare for future 5G: A big-bang approach, investing heavily in future 5G technologies, or an evolutionary approach, moving from 4G to 4.5G to 5G sequentially. The boundary between 4G to 5G is not always clear. We believe that 5G is not just about gigabit speeds but also millisecond latency, network slicing to manage quality of service and improved corporate security. These latter three features truly differentiates 5G from 4G.

A **big-bang approach** could give telecom operators a head-start on competition, enabling them to offer gigabit speeds with millisecond latency and next-generation services with network slicing. An **evolutionary approach** spreads out investment into multiple buckets over multiple years, but eventually also takes the telco closer to 5G. In both cases telecom operators should place themselves in the driver's seat to shape the future market.

Even though the 5G standards are not yet finalized, there are many key activities and investments that a telecom operator can already undertake to lay out the roadmap to future 5G. In a big-bang approach, a telecom operator will undertake multiple activities simultaneously; while in an evolutionary approach, a telecom operator will invest in some of the activities sequentially. Even an evolutionary approach involves a change from one state to another. In some models, it will involve a change in the relationship and interfaces between the operators and corporates, moving towards a joint plan-build-deploy-operate model. In other models, it will mean reconfiguration of the core networks, linking more closely the core networks

Figure 21: Incremental investments into 5G

1 **Build application ecosystem**	■ Set up standardized interfaces ■ Partner with application providers ■ Partner with solution providers, HW vendors, etc.
2 **Prepare spectrum for future macro 5G network**	■ Re-farming low-band spectrum (ideally 700, 800, 900, 1,800 MHz) ■ Regulatory – new low-band, mm wavelength spectrum
3 **Prepare for future small cell 5G network**	■ Deploying WiFi hotspots (future upgrade to 5G) in key urban areas ■ Rolling out "Home Spot"-capable CPEs in homes
4 **Fiberization of fixed access network**	■ Increase FTTx in urban areas ■ IPization of mobile backhaul
5 **Cloudify the core**	■ Upgrade core to NFV/SDN ■ Build mini data centers at edge network ■ Heterogeneous networks
6 **Prepare the computing & networking infra.**	■ Set up multi-gigabit access between computing, storage and access network elements

Source: Arthur D. Little analysis, http://bit.ly/1GmTYfX, May 2016

of the telecom operator with its corporate customers. It also requires updates to the transport and backhaul networks with greater fiberization[21] and IPization[22]. In addition, large changes to the access networks, with heterogeneous networks coming together and new 5G technologies being deployed, such as small cells, MIMO and beam forming, will be necessary.

Telecom operators usually classify 5G projects around six key areas

1. Build application ecosystem
2. Prepare spectrum for future macro 5G network
3. Prepare for future small-cell 5G network
4. Fiberization of fixed-access network
5. Cloudify the core
6. Prepare the computing and networking infrastructure

5.1 Build application ecosystem

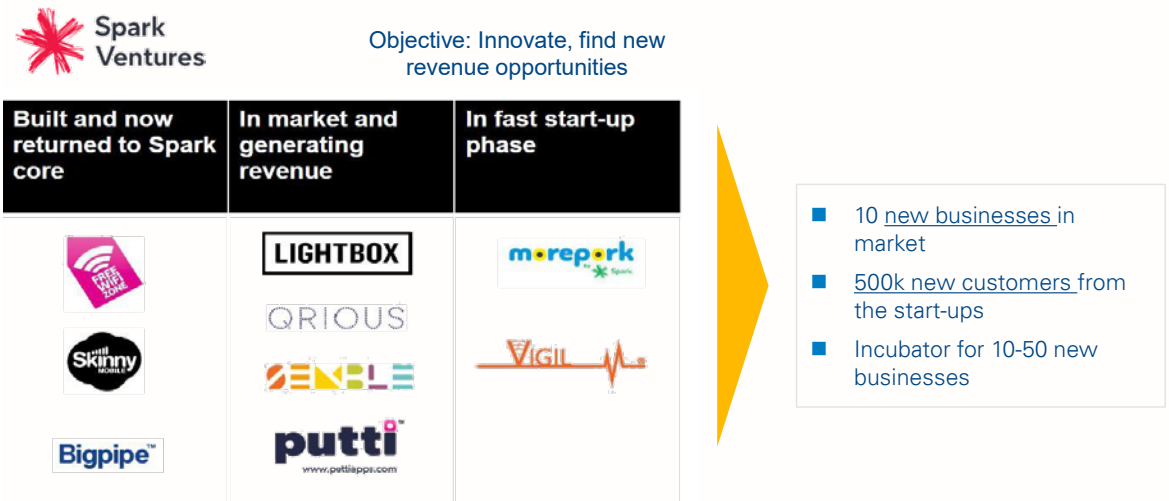
Successful 5G depends not just on fast connectivity, but also on an ecosystem of next-generation applications built upon that connectivity. Telecom operators should start forging partnerships with a variety of application and service providers. This, in turn, will create a healthy ecosystem of synergies between offering connectivity and relevant services built around using that connectivity. The life cycle of applications is much shorter and riskier than the life cycle of investing in a telecom network and providing connectivity. Telecom operators usually find it difficult to be sufficiently agile and responsive in developing applications on their own. A partnership approach helps both the telecom operator and the application provider.

Spark in New Zealand established a successful application ecosystem by creating a new business unit called Spark Ventures, which incubates and partners with a variety of start-ups active in the ICT sphere. In just three years since its launch in 2014, Spark Ventures has successfully incubated hundreds of start-ups, commercially launched 10 new business ventures, and is reported to have obtained 500,000 new subscribers from these new ventures.

5.2 Prepare for future macro 5G network

Preparing the macro access network for 5G involves obtaining the right spectrum in both low band and high band. Telecom operators should prepare for re-farming of existing low-band spectrum, especially in the 700-, 800-, 900- and future 600 MHz bands that can then be deployed for 5G coverage in the future. Operators should also re-farm high-band spectrum in the 2,500-, 2,600- and 3,500 MHz bands, which can be used for future small-cell deployment. Additionally, operators should engage in discussions with their telecom regulators and related spectrum authorities to start the process of future releases in the millimeter wavelength bands. Current bands being used for 5G pilots are 5.2GHz and 28/39/60 GHz.

Figure 22: Spark Digital Ventures NZ has incubated and partnered with multiple start-ups



Source: Arthur D. Little, spark.co.nz

21 Fiberization – using a greater proportion of fiber in the backhaul and transport network (especially from the site to the aggregation points)
22 IPization – using IP switching instead of traditional circuit switching of the backhaul, transport and aggregation network

5.3 Prepare for future small-cell 5G network

Future 5G will require not just thousands of macro sites, but hundreds of thousands of small cells, each of which will be backhauled with a fiber connection. A key challenge to invest in small cells is to have access to hundreds of thousands of locations on the ground (e.g., public areas, public buildings, shopping malls, corporate locations, main streets, side streets, street-side infrastructure and inside people's homes), and each of these locations should have high-speed (preferably fiber) backhaul.

Telecom operators can start deploying "WiFi home spot"-ready CPEs to their customers' homes. These CPEs usually can broadcast two of more SSIDs (networks), one of which can be used by the customer for his home, and the other of which can be remotely configured and controlled by the telecom operator to be used as part of a public WiFi network. The know-how gained by deploying and operating such a vast network will be valuable for a future 5G small-cell network. In the future, the operator will also be able to offer small-cell-as-a-service to other operators.

Home spots are fast becoming a big investment item for telecom operators. Comcast is estimated to have rolled out a massive 16 million home spots in the US, while UPC is estimated to have rolled out 6 million home spots in six countries in Europe. New players such as Fon are partnering with traditional telecom operators, and Fon is reported to have rolled out 20 million hot spots/home spots in more than 50 countries around the world. These thousands of hot spots and home spots take time to roll out, configure and set up; hence, operators should consider beginning this activity now.

5.4 Fiberization of fixed-access network

5G requires gigabit speeds to be delivered to the handset; hence, each mobile site (both macro and small cell) needs to backhaul multi-gigabit throughputs to the aggregation network. The only technologies that can deliver such backhaul throughput over distances of more than a few hundred meters are fiber and Docsis (cable). Therefore, 5G will require a wide and capillary network of fiber in the country. Many incumbent telecom operators (and, in some, cases the challengers) are already in the process of investing in fiber – FTTH, FTTB, FTTC, FTTN, etc. This fiber-access network will be valuable in backhauling gigabit traffic from the hundreds of thousands of small cells and macro sites in the future on an end-to-end network or wholesale basis. An IP-based backhaul built on a fiber network is better able to handle traffic than a traditional circuit-switched backhaul network.

5.5 Cloudify the core

By "cloudifying" the core, telecom operators can configure services on a dynamic, elastic, real-time basis. Telecommunication networks are slowly moving away from monolithic hardware stacks to software-based modules that can be remotely configured and scaled up when needed using NFV/SDN-based technology. The transport network is automated and simplified, and the control plane is virtualized and extended in scope to allow end-to-end control of the network[23]. This will enable dynamic management of internet traffic and provisioning of services centrally, all the way to the end user.

Many telecom operators are already investing in data centers. However, instead of centralized large data centers, operators can consider decentralized topographies of data centers, so there is a data center in each urban area at network-density nodes. Such an arrangement brings the "cloud closer to the user." In a future 5G world, there will be a need for multiple distributed data centers at the network edge to deliver millisecond latency. Beginning rollout into such a data center topography will be a step in this direction.

5.6 Prepare the computing and networking infrastructure

Many 5G use cases depend on computing intelligence. If these use cases are to perform as described in this paper, operators will need to prepare their computing and networking infrastructure accordingly. If, for example, server clusters with hundreds to thousands of servers are required to perform real-time analysis (such as in video-based analysis, natural language processing or other AI applications), these servers must be accessible at the same speed that the access network communicates with the end devices. In certain cases, centralizing the processing is not feasible or sensible. Hence, edge computing must be used, for both processing and retrieval of data from storage systems.

We have evidence that traffic flowing to and from a server cluster is a factor five to 10 times less than traffic flowing between servers or between storage systems and servers. So there will be five to 10 times more traffic-handling capability required to connect the computing intelligence and storage

23 For more details see "Major strategic choices ahead of TelCos: Reconfiguring for value" published by Arthur D. Little in Dec 2016

infrastructure. Thus, networks need to be able to handle multi-gigabit traffic not only in the access network, but also in parts of the core network that connect the different computing and storage elements.

Beyond bandwidth, this is also true for latency. Storage systems operate in a 10 micro-second space, outperforming 5G with a factor of 100 – which is good enough to support the processing, but the network needs to support similar latencies when transporting stored data to and between servers. MPLS, the most commonly used protocol, increases latency at every hop. As such, it may not be optimal for low-latency use cases in which not all data can be placed into the edge. New technologies such as virtual cut-through (VCT) and wormhole (WH) routing might be needed in the future to provide multi-gigabit connectivity to multiple nodes.

It is worth noting that the deployment model, to some extent, influences the type of edge infrastructure that operators will need to build. If, for example, the bets are on consumer entertainment, CDNs and related infrastructures seem most useful. Meanwhile, if the bets are on image analytics-heavy use cases, CDNs will be of lesser importance than computing infrastructure.

6. Operators should choose models now that maximize their future chance of winning

Telecom operators are approaching crossroads at which they must decide when and how to prepare for 5G deployment in a manner that will best suit their current market positions and future market needs. The five models described above are only a starting point for an operator planning to move towards 5G. An operator might start with one model, and subsequently expand to other models or use a combination of models. In the future, non-telecom players such as Google, Apple and Amazon, which are active in the IoT space, might also join with 5G-based solutions of their own. Hence, it is important that telecom operators and vendors play an active role in driving the 5G standardizations in the right direction.

At this point it is hard to predict which 5G rollout model will be most common. However, one thing is certain: 5G will be the stepping stone for some telecom operators to move from being providers of communications to enablers of solutions and future ecosystems. 5G will not just be human centric, but also machine centric, connecting people, enterprises and billions of devices at the same time.

At this stage, we think delivering productivity to corporations and enabling new business models are likely to be the initial drivers for 5G. Telecom operators are still testing the appetite for 5G with third parties to determine the pace and extent of rollout. 5G may advance in some of these verticals faster than in others, in tandem with related technology developments (e.g., robotics, haptics and virtual reality). We believe 5G will not just be a communications-technology migration towards higher speeds, as seen in the past with 3G to 4G. Rather, 5G will be an enabler of new business models – efficiency driven for corporates, B2B2X partnership driven for verticals – inviting new stakeholders from different industry verticals to benefit from new and efficient ways of doing business. 5G will also encourage the use of new platforms and business models to deliver products and services to customers.

Notes

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