NETWORK SLICING BENEFITS AND THE IMPLICATIONS FOR SPECTRUM LICENSING

Introduction

With the advent of 5G and, with it, a technology called network slicing, many parties, ranging from mobile network operators and enterprises to policymakers, are re-examining how to deploy customized networks that were previously unfeasible. The flexibility afforded by network slicing will allow wireless operators to more efficiently meet the needs of their enterprise customers, particularly those customers concerned about the potential costs or burdens of "do-it-yourself" or outsourced private networks. Alternatively enterprises may choose to deploy a private wireless network to meet their needs. This would require a specific plan to utilize spectrum they obtain or lease from another entity along with a private network managed by an operator, network supplier, or viable third party.

Network slicing allows a network operator using the same physical wireless network to provide virtual slices with different characteristics to serve different customer needs. It allows the operator to tailor the technical characteristics such as bandwidth, latency, and security for certain types of applications. This is especially significant for enterprise customers whose desire to enjoy the economic benefits associated with large-scale network operators; instead of defaulting to largely homogenized offerings, companies and operators now enjoy unprecedented flexibility to develop customized solutions at a much lower cost.

- Flexibility comes from the move towards virtualization and software-defined networking, where network infrastructure that was an integrated software and hardware component becomes disaggregated into a software program running on general purpose computers and servers.
- Cost savings come from the shared use of physical infrastructure when the new specialized tasks only require the installation of a new software application solving, the enterprise's specific need.

The enhanced capabilities and cost savings allow enterprises to switch from a production process that has been hardwired to a flexible wireless approach, just as mobile phones have replaced landline phones as the preferred way to communicate. In particular, the development of network slicing allows providers and customers throughout the wireless ecosystem to continue to enjoy the efficiencies of flexible use licenses and larger geographic license sizes, while also benefitting from small-scale customization.

5G Network Slicing

Over the last five years, the concepts of software defined networking (SDN) and network function virtualization (NFV) have taken large strides in the telecom world. The change from application-specific hardware to networks that are built on a general-purpose computing foundation, implemented and orchestrated by software, is a watershed event. The typical wireless network of 2015 consisted of roughly 30,000 to 50,000 different pieces of hardware with integrated software. The hardware elements (also called SKU for Stock Keeping Units) included base stations, internet routers, messaging gateways, multimedia gateways, switches and many other components. For every function in the network, one new SKU was created. These SKUs are highly efficient at running the specific task for which they are designed as long as they are close to being fully utilized. The networks are also designed around the busiest time of the day for the specific function, plus a significant margin for growth so that customers can always use any function they might want to at any time of the day. Usage is highly variable both over time and across functions which are being used, leading to a significant amount of idle capacity and significant cost.

As MNOs have transformed their networks from hardware-centric to software-centric, wireless networks have become a lot more flexible. By being able to use each network function as an application, these developments have allowed MNOs to create network slices that provide service assurance by creating virtual wireless networks as part of the overall wireless network.

The key advantages of network slicing are:

1) Enhanced mobile broadband. It allows the operator to guarantee reliable, ultra-high speed data connections for applications such as live 4k video streams.
2) Very low latency. It makes applications such drone flying beyond visual range possible and among other things opens up the ability to inspect power lines and buildings.
3) Massive IoT. Thousands of IoT devices such as sensors can be installed per square mile allowing for a range of applications such extremely even temperature control on a shop floor where material variances are measured in mu requiring temperatures to be within one degree for product uniformity.

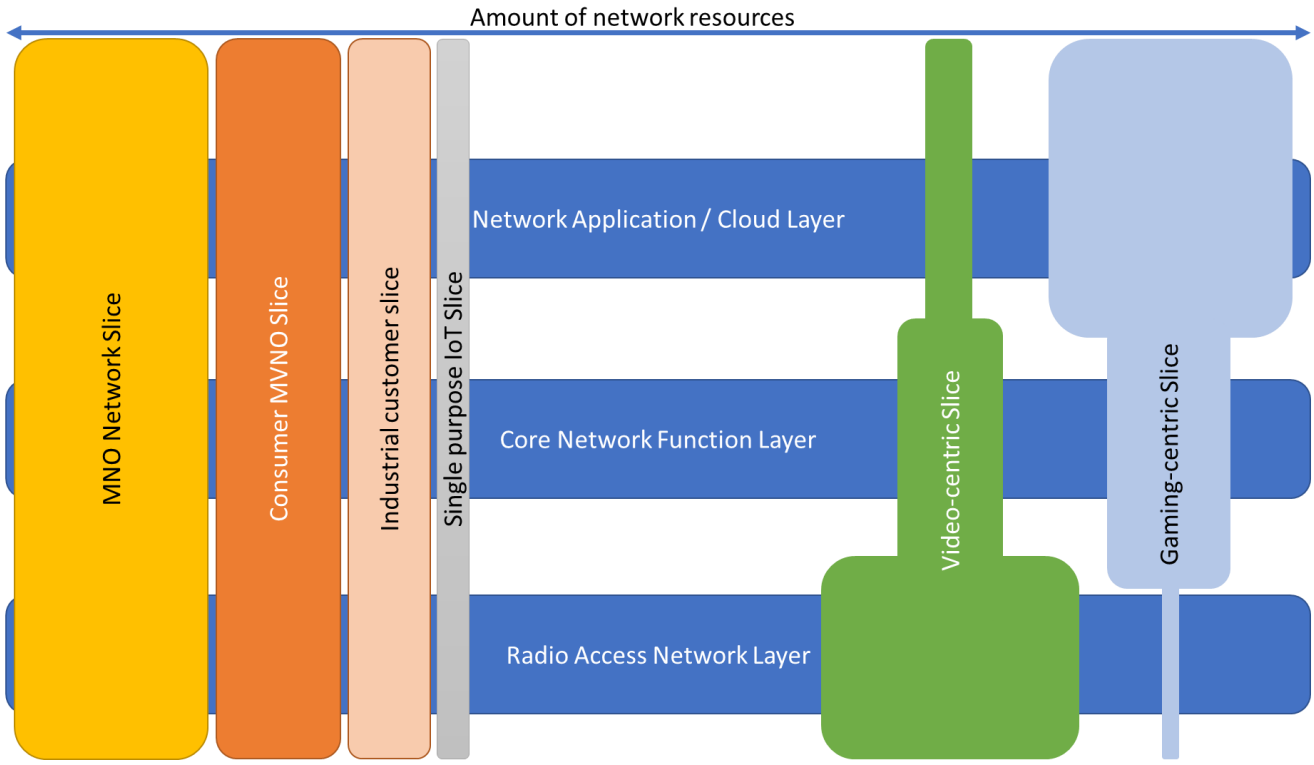
Importantly, these key advantages can be mixed and matched to suit different industry verticals, all over the same physical network.

Below in Exhibit 1, we have abstracted the network into three layers: The radio access network (RAN) layer, which is responsible for the wireless connectivity between the device and the network; the core network function layer (core) that controls how voice calls and data sessions are connected; and the network application layer on which the various services run. The network application layer consists of either a private or public cloud, centralized or at the edge of the network. This way, a specific amount of resources can be allocated to every network task. In the exhibit, the width of the bars is the amount of resources guaranteed to each slice. The MNO can thereby guarantee all customers who have bought a network slice a minimum performance through a service level agreement (SLA.)

For example, the MNO has set aside a specific amount of network resources for its retail or consumer customers (the MNO Network Slice). Since its customers are using a balanced number of applications, it needs a corresponding amount of core and RAN resources to serve all of its customers, both consumers and enterprise customers, well. The MNO is also hosting an MVNO which is smaller than the MNO and has therefore purchased fewer network resources that are

also balanced. The same with a large industrial provider and an IoT provider who have created their own private networks by acquiring smaller slices of the network. On the right side of the exhibit are two examples that show the strength of the network slicing model. In the green case, a customer purchases a video-centric slice, either for internal use like a large close circuit video network or a company providing video services to its customers. Video is the RAN killer app, both in terms of popularity and in terms of RAN resources needed. For that reason, the company purchases a significant amount of RAN resources. At the same time, a single use needs less core resources and even fewer resources at the network application layer, may it be in the form of a private, public or mobile edge cloud, as it streams the video. A contrasting example would be a game-centric slice. Multi-player online games are not data intensive, using only a small fraction of the data bandwidth that a video stream uses, but are highly latency dependent. To ensure the required latency, gaming demands a service with a higher amount of core resources and an even higher amount of network application resources where the processor-intensive calculation takes place.

Exhibit 1:



Source: Recon Analytics, 2021

Network slicing allows MNO administrators to custom tailor which resources are needed to deliver the services that the customer wants and needs by guaranteeing their availability at the network level.

Building a wireless network involves a significant amount of investment regardless of whether the network serves one customer or one hundred million customers. Building a RAN with towers, antennas and radio heads, a core network and application network layer with servers is a significant undertaking, even for established MNOs. Network slicing allows non-telecom companies to have the benefits of a private, secure, custom-tailored network meeting their needs without having to build, manage, maintain and upgrade it themselves. It is the difference between building your own car and leasing a car to drive to work every day.

Telecom engineers were determined to discover better ways to run a network than with 50,000 individual components. Using data centers and even personal computers as an example, they posited that it would be more efficient, flexible and agile to virtualize network functions (NFV), turning the vast majority of SKUs into computer programs and using general purpose computers or servers to create what is known as software-defined networking (SDN). This solves various issues:

1) Agility: With an SDN it is much easier to launch new products and services. Instead of having to justify the cost and complexity of having to add another SKU to the network, mobile network operators (MNOs) can simply launch the service by starting the software program. Adding a new service becomes (almost) as easy as installing a new browser or word processor on a PC. If the service is successful, it takes up more data center resources, using excess capacity of a service that has fallen out of favor. If wildly successful, the MNO can simply add more servers. If the service fails to catch on, the application either uses minimal network resources or is deleted. Thus there is no need to pay for, install, and potentially remove hardware from the network.
2) Reduction in network complexity and cost: As mentioned before, an average mobile network has 30,000 to 50,000 different SKUs performing different network functions. The fully virtualized SDNs that are operational today have reduced that number to six.. Fewer network elements means less complicated and expensive maintenance and purchasing costs as well as fewer hardware incompatibilities that need to be overcome. With fewer network elements, fewer people are needed to operate the network, thereby lowering operating costs. Since the network runs on a large number of commoditized servers that are interchangeable, costs are lower due to larger purchase volumes of generally available commoditized hardware.
3) Speed and scale of innovation: By using standardized, general purpose server hardware, wireless networks are joining the larger and faster speed of innovation rather than continuing to rely on the speed of innovation in niche applications. Furthermore, by shifting innovation to the software layer, many more companies can develop new software than what would be possible in an integrated hardware and software model.
4) Security and vendor independence: By using standardized hardware to run the network, it becomes less likely that malware gets introduced to the network through compromised hardware as the removal of compromised hardware is expensive and time consuming. If any software is compromised, it can quickly and inexpensively be replaced by a competing product. Furthermore, by relying on software over standardized hardware, MNOs can much more easily switch from one vendor to another for technical or commercial reasons.
5) Ease of management: In an SDN, all virtualized network functions can be controlled and changed from one platform and one location. In a traditional wireless network, individual network elements have to be individually changed and monitored, often with different applications that do not work together, and the changes have to be made locally. Most importantly, when network software runs on standardized hardware, it is possible to allocate specific resources to predetermined tasks, something that is called network slicing.

Until now, enterprise customers whose operations were dependent on features like these were incented to build and operate (or outsource) their own customized networks, entailing significant capital and operational expenses since this approach would not incorporate the efficiencies passed through to customers by large-scale traditional mobile network operators. Network slicing now allows enterprise customers to share in those efficiencies of scale, while still gaining the advantages of network customization – the best of both worlds.

Network Slicing Use Cases

5G network slicing allows guaranteed network performance that was not possible in 4G. This allows mobile network operators to offer a whole new set of capabilities that were previously not possible.

Industrial use case

5G is ideal for factories as it removes the need to lay cables to run different machineries that cost in the hundreds of thousands of dollars depending on the size of the factory floor. Network slicing, with its guaranteed performance, allows factories to connect precision machinery that needs to react to changes in the production process with less than 10 millisecond reaction time, like metal works or chemical processes. It also allows the production process flow on the shop floor to be changed according to new and different tasks without incurring cost prohibitive expenses and time of rewiring the shop floor. In addition, the material flow on the shop floor can be automated and, with below 10 millisecond reaction time, centrally controlled. Work-in-progress material vehicles can shuttle material from work station to station. By shifting the work-in-progress material flow from manual labor to an automated process, the number of work-related accidents on the shop floor can be significantly reduced, improving employee health and decreasing work related healthcare costs.

Just like in the hospital use case, the industrial company can choose which elements and functions it wants to source from the mobile network operator and which parts it wants to own itself for maximum flexibility. For example, in an automobile manufacturing plant, the automobile manufacturer installs its own antenna network, uses its own industrial applications to run the robots and manufacturing street, but relies on the mobile network operator to integrate it and run it on the mobile operator core.

Drones beyond visual line of sight

One of the advantages of 5G and network slicing is the guaranteed low latency and high data through put. What has been an exclusive purview of the military, is coming to the civilian sector: Flying drones beyond the visual line of sight (BVLOS.) The FAA approved BVLOS flights for public safety in August 2020, with a commercial application approved in January 2021. Due to the reaction time limits by traditional technology the drone cannot be further away that 1,500 feet from the pilot and more than 50 feet above or within 400 feet horizontally of any obstacle. The 5G and network slicing operators can guarantee a stable connection and low latencies that will allow drones to fly wherever there is a network connection and much closer to buildings, cables, and anything else the FAA describes as obstacles. Powerlines, local and long-distances, as well as cell cites need to be visually inspected in regular intervals to ensure the structural integrity of the units is still warranted. Currently, a lot of these inspections are done either by car or on foot with binoculars or personnel has to climb up the structure to inspect it. Due to OSHA regulations, they have to be turn off to be inspected, which impacts customers. When the industry switches to BVLOS one drone pilot can inspect these structures from a central location leading to lower cost and improved inspections as the drone will deliver a 4k video stream that is then recorded. Successive videos of the same structures can be compared against previous recordings to evaluate how quickly the structure is withstanding environmental impacts and aging. This will allow for preventive maintenance reducing cost and uptime. For the public safety community, BVLOS provides the opportunity for firefighters to have a better view on forrest fires than what is possible with planes. Drones can fly closer and slower to the ground than planes or helicopters, without endangering a pilot, giving firefighters a better understanding of conditions before they fight the fire in person. Futhermore, use of augmented reality (AR) and virtual reality (VR) technology can aid flying the drones and better help with inspecting various pieces of equipment.

Augmented and virtual reality use case

Combining 5G with network slicing allows reliable and predictable performance of augmented and virtual reality applications. For example, television programs can use 5G to holographically capture interviews and events, transmit them to a TV studio, and project the live images, allowing people in the studio to interact with the holographic images. Examples of this include interviews from sports events where the athletes are projected straight into the studio to be interviewed. Network slicing is particularly useful for large, highly latency-sensitive data streams for multimedia applications, since it allows for the dedication of bandwidth and computational resources needed to ensure flawless delivery.

Secure banking use case

Mobile payment and banking applications that are currently operating on the common network can be enhanced by creating a network slice that is dedicated only to a bank or payment system's dedicated network slice. This allows a complete separation of the payment and banking app from the commonly shared wireless network, allowing for greater security and flexibility.

International examples

The advent of network slicing increases the efficiency and attractiveness of larger geographic license sizes. Internationally, the most prevalent way spectrum is licensed is through nationwide licenses. Some large countries like Canada and Brazil follow the US model of splitting the country into a number of licenses. In particular, Canada with regional telecom providers has a similar system for the same reasons as the United States, namely to allow regional providers an opportunity to participate in the wireless market place.

With the advent of 5G, several European countries have set aside spectrum for Industry 4.0 companies in the 3.7 GHz to 3.8 GHz band. Despite its moniker, the licenses are available for all companies at costs that are in the thousands of dollars per year. One of the leading examples is Germany, with its significant manufacturing sector. The German government lays out four scenarios[1] of how German companies can get use a 5G campus network, ranging from a slice of a public network, a hybrid-shared RAN where the public RAN is supplemented with private small cells, a hybrid RAN with a private core, and a fully separate stand-alone network.

The premise of this approach is that allocating spectrum in smaller parcels to individual companies would be more efficient than allocating larger flexible use licenses to MNOs, but experience has not borne this out as the uptake has been limited and is projected to continue to be minor. The first companies that have made announcements on starting 5G private networks are either stand-alone networks or network slices, but almost all of them are being built together with an MNO, either as the provider of a slice or as the lead partner to the customer. For example, General Motors and Honeywell have a 5G indoor system deployed in the United States with Verizon[2]. In Germany, Lufthansa together with Vodafone has launched a stand-alone private 5G network[3] and OSRAM together with Deutsche Telekom has launched a hybrid slice network[4]. In the UK, Ford together with Vodafone[5] and Air France and Groupe ADP are planning a 5G

[1] https://www.bmwi.de/Redaktion/EN/Publikationen/Digitale-Welt/guidelines-for-5g-campus-networks-orientation-for-small-and-medium-sized-businesses.pdf
[2] https://www.verizon.com/about/news/verizon-5g-ultra-wideband-general-motors-honeywell
[3] https://www.vodafone.com/business/news-and-insights/company-news/lufthansa-technik-and-vodafone-business-launch-5g-private-network
[4] https://www.telekom.com/en/company/details/5g-technology-in-campus-networks-556692
[5] https://newscentre.vodafone.co.uk/news/how-ford-and-vodafone-are-creating-the-5g-factory-of-the-future/

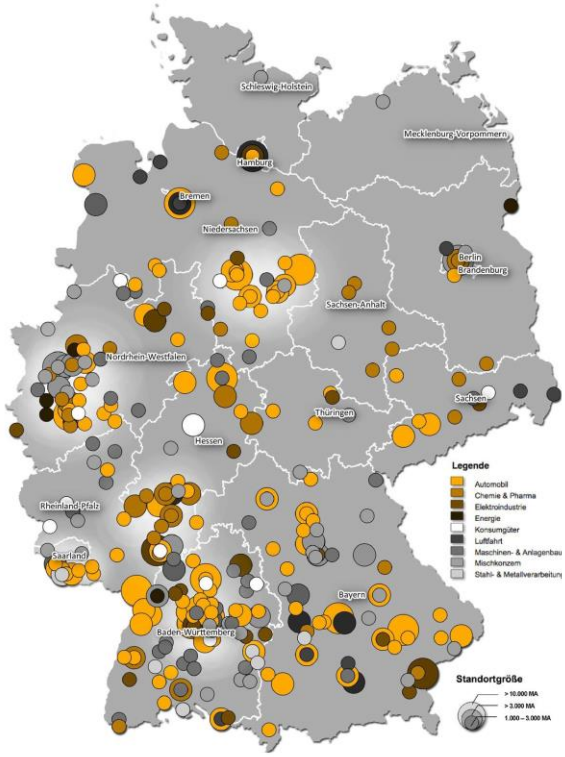
network[6], and in China multiple companies are building or have already built 5G networks with China Mobile, China Telecom and China Unicom respectively[7].

Bitkom, the 2,700-member German industry association for the digital sector, conducted a survey of companies regarding their plans for 5G[8]. Half of all companies considered 5G an important factor for their company in the future. Thirty-six percent of companies are planning or discussing using a network slice from an MNO for their 5G needs and six percent are planning to use the 100 MHz license that the German government has set aside for private company networks. As one of the leading high-tech manufacturing countries in the world, the survey result showing that only six percent of German companies are interested in deploying a private 5G network, where the enterprise owns the radios, network core and applications, on dedicated spectrum is sobering. The advent of network slicing allows enterprises to avoid taking on those responsibilities while still enjoying the benefits of customization.

Opportunity cost of different license area sizes or licensing schemes

Private networks, like the industrial networks envisioned in Germany, still require network design, someone who builds the network, operates it and maintains it. This is a challenge for even the largest industry providers. As a result, they are either looking to either large system integrators or mobile operators to provide these services.

Exhibit 2: Industrial locations in Germany with more than 1,000 employees



An additional challenge is the relatively small license areas for these networks. The smaller the license area, the more challenging network design becomes. In the low- and mid-band, radio waves inevitably will travel further than the smallest, city-block-size census blocks in major metropolitan markets. This creates interference issues with neighboring antennas, especially if they are owned by a different licensee. The interference issue gets smaller with higher frequency spectrum as the signal is increasingly attenuated and has problems penetrating walls.

Another issue to consider is that if only a small number of companies are willing or eligible to use the spectrum, the unused spectrum lays fallow and cannot be used otherwise. This is particularly a problem for low and mid-band spectrum that would otherwise be deployed in wider areas.

Even in a country as large as Germany, with twice as many people than California on half the geography, larger businesses with more than 1,000 employees are highly

[6] https://www.air101.co.uk/2020/02/adp-group-company-hub-one-gets-10-year.html
[7] http://www.xinhuanet.com/english/2020-05/09/c_139043925.htm
[8] https://www.bitkom.org/Presse/Presseinformation/Grossteil-der-deutschen-Industrie-plant-mit-5G

concentrated as we can see in Exhibit 29. In large swaths of Germany, 100 MHz of 5G spectrum that is reserved for companies will lie fallow as indicated by the large area of grey land and cannot be used for important tasks such as wireless broadband solutions to the home or businesses. This runs counter to the idea that MNOs in both urban and especially rural areas can solve connectivity issues driven by inadequate landline solutions. Network slicing by MNOs allows enterprise customers to avoid the inefficiencies of small license sizes, while still achieving the customization benefits of private networks,

Conclusion

5G and Network slicing are opening up new opportunities for consumers and businesses alike. It terms of added flexibility network sliceing is the best thing that happened to mobile networks since sliced bread. 5G, SND and network slicing eliminate the delineation between telecom and information technology and create a contiguous development space for software engineers. As software is eating the world, this includes wireless networks, just as wireless is eating the world as well. This development opens up new opportunities ranging from augmented and virtual reality to drones to more fully optimized factories.

The cost savings from replacing expensive cabling to reducing workplace accidents are significant as wireless connections replace wired connections. The increased flexibility of changing the workflow on a factory floor is substantial. The ability to fly drones beyond the line of sight will simplify many tasks requiring people on the ground to inspect structures. Considering that the core competency of regular companies is their specific focus and not that of running IT systems or even highly sophisticated 5G networks on a limited scale, the deployment scenarios we see in Germany and other European companies will be that of network slicing or a hybrid solution that MNOs will manage. While it is a possibility that we will see stand-alone networks, the trend in corporate support functions is towards outsourcing as it often provides a better solution at a lower cost.

Most companies have outsourced their entire IT segment to specialist companies that can provide a superior experience for a lower cost. Even email, a relatively simple application, has become a hosted solution provided by large IT companies. Network slicing allows for custom network applications previously deployed on private networks or not at all by essentially creating a network as a service approach, where connectivity is just one of the components of an enterprise solution. Network innovations that would take a separate investment in a private network come when using a network slice as the overall MNO network is being upgraded. By working with an MNO and using a network slice allows companies to benefit from technical innovation for free as the MNO will upgrade their network to remain competitive. As a stand-alone network the enterprise would have to bear the cost for it. Private networks are also an option, but each enterprise should consider the requirements to develop and manage such a network – from spectrum, to design, development, and ongoing operations.

Network slicing allows enterprises to have all the benefits of customized private networks without having to build, operate and keep current the network increasingly becoming essential to remain competitive.

This paper has been commissioned by CTIA – The Wireless Industry Association

9 https://www.jpnaumann.de/fileadmin/user_upload/Publikationen/JPN_Publikation_Industriestandorte.pdf