Network Slicing in Smart Cities

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Smart Cities

- Cities large and small are looking to "smarten" up - planning to evolve from rather passive cities into "smart cities".
- Coordinated efforts by local government, businesses, and other organizations to tap into networking technologies that enhance sustainability for the people who live and work there.

- But do these cities have the network infrastructure in place to deploy new, innovative technologies and really take advantage of them? As metropolitan populations keep growing — can networks keep up?

- **What Does a Smart City Look Like?**
- Millions of devices already deployed in cities, and billions more coming, that can make a city "smarter" by collecting data on traffic, weather, energy, water usage, etc. often in real-time.
- That data can be analyzed and the resulting knowledge put to work to understand what's happening now and predict what will happen in the future.
  - For example, monitoring traffic patterns might alert city planners of the future need for a widened lane or new traffic light. Knowing this information well in advance will allow cities to contract with construction firms in plenty of time with detailed information on where new traffic implementations will be most effective.

https://www.sdxcentral.com/articles/contributed/smart-cities-lining-slice/2017/05/

5G Will Drive the Smart City

- Smart city of the near-future, and in some cases the present – require uninterrupted and reliable flow of data from interconnected wired and wireless networks. When data needs to be real-time, it absolutely cannot be interrupted or bogged down by latency problems.

- 5G expectations –
  - increase in bandwidth (up to 1,000 times per unit area),
  - number of connected devices (up to 100 times more), and
  - network energy utilization (up to 90 percent reduction), along with up to 10 Gb/s connection rates to mobile devices in the field.

- 5G mobile networks brings with it a new capability to combat disruption and makes sure that the various requirements for latency, bandwidth, and reliability for different services can be met all on the same physical network - network slicing.

- Partition–or slice–the network to guarantee the required performance for various applications.
- Networks are to be broken up into numerous portions that can be managed independently, customized, and, most importantly, not affect one another if one portion is overloaded or down. This technique allows for various use cases to coexist on a common physical network. It also creates flexibility that will allow network operators to meet the needs of services in the future, including those not even invented yet.

Why is Network Slicing Important?

- To meet the needs of smart cities, smart services will rely on low latency to offer essential real-time and ultra-reliable connectivity and interactivity.
  - For example, autonomous drones are going to need incredibly fast response times, but won’t necessarily require fast data rates.
  - On the other hand, things like cloud based services will be reliant on fast data rates, but not necessarily need low latency.

- This is where network slicing comes in. It will allow providers to “slice up” their 5G networks to meet the different requirements of different services based on such metrics as capacity, latency, security, duration, reliability, and geographic coverage.

- This is particularly important for smart city implementations as devices involved in the smart city could directly or indirectly have an impact on individuals’ lives.

- For example, a first responder network that has been outfitted with advanced communication tools to help those responders coordinate fast and effective rescues during emergencies. If a disaster strikes and the city’s inhabitants all jump onto social media to send texts, pictures, and videos at the same time, mobile network operators would still be able to guarantee connectivity to emergency responders by assigning them the highest priority access to the 5G mobile network — their slice is priority number one.

Prepping the Network: SDN and NFV

- As cities become smarter and more connected, network operators need to make sure their networks are flexible and capable of slicing to meet the growing and increasingly varied needs of the smart city and its population.

- Key to this is virtualization in the form of software-defined networking (SDN) and network functions virtualization (NFV); 5G networks will have to be adaptable, dynamic, and programmable from end-to-end using virtualized constructs. Then, as individual slices of the network are implemented, their performance will be tailored autonomously and programmatically.

- SDN involves the complete abstraction of physical network infrastructure allowing network behavior to be adapted to a guaranteed service performance for each individual use case.
- NFV allows network functions to be deployed and implemented strictly through software rather than buying, shipping, installing, and turning up physical appliances.
- One of the most promising benefits of NFV is the ability to execute a variety of virtual network functions (VNFs) independent of physical location, meaning VNFs can be dynamically deployed and executed in different parts of the greater network for each network slice.

Revenue Opportunities

- SDN- and NFV-ready networks will open the gates to new and yet-to-be-developed use cases - will contribute to innovative, ongoing revenue streams that go beyond simple connectivity and capacity.

- The ability to guarantee top network slices for essential services that need guaranteed metrics (like driverless cars and public services provided by the city itself—emergency response, public safety, public data visibility, and more)—will help not only drive revenue for operators, but also ensure the effectiveness of cutting-edge smart city technologies to improve the lives of citizens.


Some 5G use cases and challenges
Latency.Reliability.Throughput.Density.Speed.Flexibility
1 Autonomous vehicles
L.R.T.D.S.F
2 Smart traffic management
L.R.T.D.S.F
3 Emergency networks
L.R.T.D.S.F
4 Factory automation
L.R.T.D.S.F
5 High speed rail
L.R.T.D.S.F
6 Short lived massive outdoor
L.R.T.D.S.F
7 Internet of Things
L.R.T.D.S.F
8 Any media anywhere
L.R.T.D.S.F
9 Remote medical
L.R.T.D.S.F
10 Smart city/ Grids
L.R.T.D.S.F
11 Virtual reality
L.R.T.D.S.F
12 Fixed wireless access
L.R.T.D.S.F

Who Are Doing It?

- Many vendors and mobile operators are already cooperating in the development of 5G network slicing.

- Perhaps the most progress has been made by Ericsson. In 2015 Ericsson and South Korea's SK Telecom agreed to develop and deploy network slicing technology optimised for 5G services, continuing their existing partnership. That year the two companies demonstrated the creation of virtual network slices optimised for services including super multi-view and augmented reality/virtual reality, massive Internet of Things offerings and enterprise solutions.

- In 2016, Huawei and Deutsche Telekom showed the results of a 5G end-to-end network slicing demo - how different network slices can be created automatically and in an optimised way on a shared RAN, core and transport network.
  - Huawei's network slicing router (NSR) slices network resources as according to control and management, protocols, and forwarding. It creates E2E network slices according to specific scenarios, with each network slice acting as a logical, self-sufficient network.
  - The bearer network used Huawei's 5G slice router to divide the network into three isolated slices, ensuring different latency requirements were met for each service. Network congestion due to heavy traffic in one slice was shown not to affect the bandwidth and latency of another slice
- NTT DOCOMO, Nokia, ZTE… UK operators

Network Slicing as a Service: Enabling Enterprises' Own Software-Defined Cellular Networks

- In this article, authors discuss how operators agilely provide a customized network slice for their customers as a service, which is called NSaaS.

- According to the relationships between service providers and consumers, the business models of NSaaS can be categorized into three classes as below:
- **Business to Business (B2B):** Operators sell the network slice to a company who owns both the network and terminals, such as video surveillance networks for security companies and smart factory networks for manufacturing companies. In the B2B case, operators not only provide customized wireless connections to enterprises, but also release full control of terminals to the enterprise.
- **Business to Consumer (B2C):** End consumers are able to purchase customized data pipes from operators for their terminals like smart home devices. Generally, customers just use the customized network, but do not possess the network with service separation.
- **Business to Business to Consumer (B2B2C):** The operator plays the role of wholesale provider; meanwhile, a broker like an mobile virtual network operator (MVNO) helps operators to be engaged with end customers. In this case, operators just provide dedicated connections, called MVNO as a service, to the broker, without involving the business part.

From NFV to NSaaS

- Based on NFV, NS realizes the service separation for multi-tenancy so as to virtually build an exclusive network for each tenancy.

- However, NSaaS is a more business-oriented concept than a technological one, with features of mapping service demands automatically from a customer to functionalities, topology, policies, and parameters of a network slice, as well as providing component-based and auto-configured network functionalities for operators to design and launch network services more conveniently.

Comparison of NFV, network slicing and NSaaS

Form	NFV	Network slicing	NSaaS
Features	Hardware/software decoupling [2]	Multi-network separation	Service auto-mapping
Managed object	Virtual machines	Virtual networks	Customized services
Value to operators	Better resource utilization	Tenancy separation	Agile product development
Value to consumers	None	Monopolized network	Customized service

X. Zhou, R. Li, T. Chen and H. Zhang, "Network slicing as a service: enabling enterprises' own software-defined cellular networks," in *IEEE Communications Magazine*, vol. 54, no. 7, pp. 146-153, July 2016

- Key technology of NSaaS is service mapping, which translates service requirements into service models of operators and vendors.
- In order to better match network slices to various vertical applications, we can differentiate necessary service models of mobile network into three levels: application level, network function level, and infrastructure level.

General deifinition

- A “Network Slice” represents an agreement between a User and a Service Provider to deliver network resources according to a specific service level agreement. In this context a “User” is any application, client network, or customer of a Service Provider. And a “Service Provider” is a network operator that controls a server network or a collection of server networks.
- “Network resources” are any features or functions that can be delivered by a server network. This includes connectivity, compute resources, storage, and content delivery. A “service level agreement” describes multiple aspects of the agreement between the user and the service provider:
  - the quality with which the features and functions are to be delivered and includes measures of bandwidth, latency, and jitter
  - the types of service (such as the network service functions or billing to be executed)
  - the location, nature, and quantities of services (such as the amount and location of compute resources and the accelerators require).
- A network slice does not necessarily represent dedicated resources in the server network, but does constitute a commitment by the service provider to provide a specific level of service. Thus, a network slice could be realised as a virtualisation of (consider virtual private wires and VPNs), or as a partitioning and dedication of server network resources.
- A network slice can further be a detailed description of a complex service that will meet the needs of a set of applications. Such a service may be requested dynamically (that is, instantiated when an application needs it, and released when the application no longer needs it), and modified as the needs of the application change.

https://metro-haul.eu/2017/11/08/to-slice-or-not-to-slice-that-is-the-question/

Generic questions

- Lastly, a lot of effort is needed to identify and develop the tools that are needed to support network slicing in the metro network. These will include planning, orchestration, and provisioning tools.

- Does slicing result in partitioning of the network, and if so, at what granularity and with what level of dynamicity?
- Or is slicing a form of aggregation?
- Does network slicing enable guarantees of quality of service delivery (such as end-to-end delay), and if so is this a function of virtual connectivity across the network, or is it a dynamic property?
- All of these are questions about the operation and management of the metro network, of how services are requested, and whether the application layer (the end-to-end user) can cause provisioning in the metro network or whether the metro network is configured and provisioned with a variety of connections that can be used (and scaled according to use) according to the features demanded by each use case.

Network Orchestration for Dynamic Network Slicing

- Authors demonstrate a hierarchical Transport-SDN (T-SDN) architecture that dynamically creates, modifies and prioritizes network slices over fixed (up to the customer premises entities: CPEs) and mobile (up to the central offices: COs) structurally-converged transport infrastructure.

- As depicted in Fig. 1, the network orchestrator coordinates provisioning of services. Services with very different constraints on bandwidth, delay and availability may be provided by setting up service-specific network slices. The allocation of resources to the slices dynamically adapts to the requirements and the state of the network.

- We refer to a hierarchical T-SDN control plane, composed by SDN controllers and a network orchestrator on top (see Fig. 1): this is the best approach to handle the complexity and heterogeneity of transport networks.

- The hierarchical T-SDN allows to deploy SDN technology in the transport network by integrating it with protocols coming from the legacy control plane, reducing the replacement costs. As shown in Fig. 1, the SDN controllers interface only with CPEs, COs and Provider Edge (PE) nodes, while the control plane of Provider (P) nodes (or core nodes) remains distributed and based on distributed control protocols, such as RSVP, ISIS and BGP. The southbound interface we adopted are BGP-LS, PCEP and NETCONF, while OpenFlow is not needed.

Rodolfo Alvizu, Sebastian Troia, Van Minh Nguyen, Guido Maier, Achille Pattavina, “Network Orchestration for Dynamic Network Slicing for Fixed and Mobile Vertical Services”, OFC, 2018.

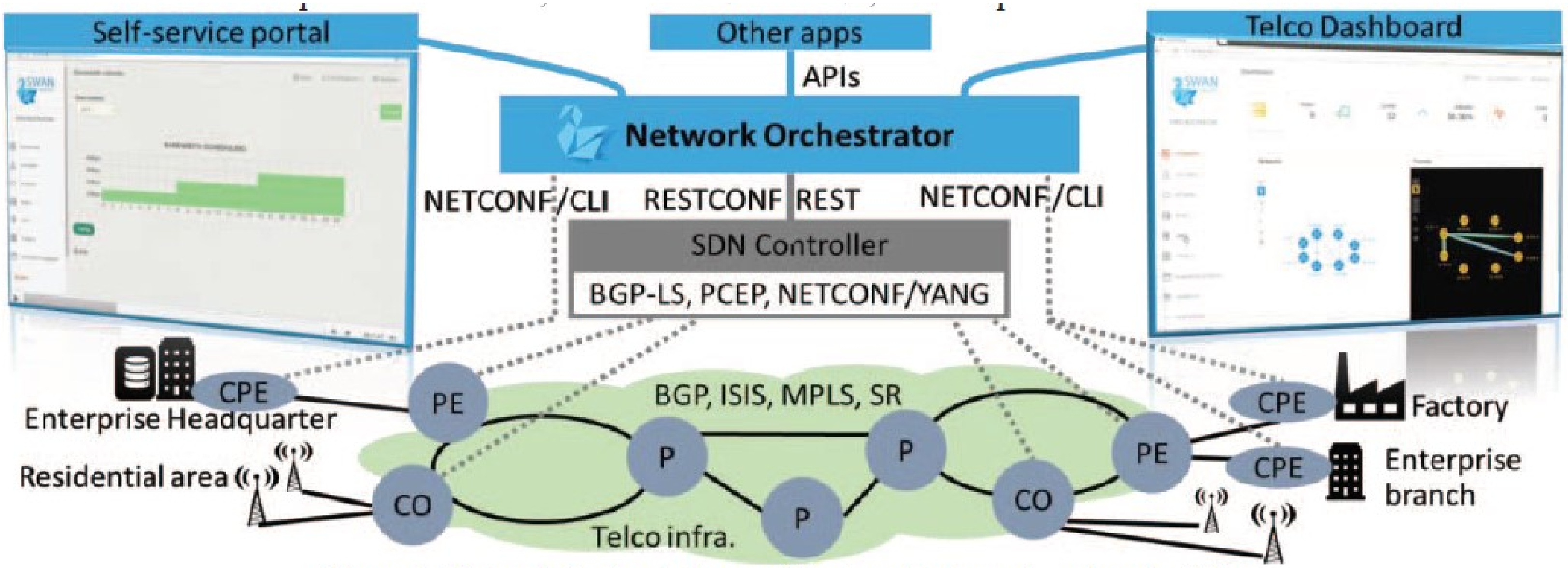

Figure 1: Network Orchestration architecture for dynamic network slicing

- Authors demonstrate a hierarchical T-SDN control plane that dynamically creates, modifies and prioritizes end-to-end connectivity, based on guaranteed MPLS tunnels, that provide customizable virtual topologies. The orchestrator configures the virtual topologies, access lists and policy based routing to provide dynamic network slices. The customizable slices provide different degrees of service level agreement (SLA) in terms of bandwidth, delay and availability requirements, and are associated through access lists (based on protocol, port, destination) to specific types of traffic or services at the CPEs and COs.

- The SDN control plane introduces two degrees of flexibility of the tunnels: path and bandwidth adaptation, so the resource allocation adapts to network conditions and bandwidth requirements. The amount of guaranteed bandwidth requested by the end-users (or by the service) can be modified on demand via web interface (or via API). This is achieved by defining a bandwidth calendar that specifies the required bandwidth at each hour of the day.

JUNO2 – Tentative Project Timeline

Duration	Year 1			Year 2			Year 3		
Task # **Months**	4	8	12	16	20	24	28	32	36
1: Design of disaster-resilient communication networks									
2: Big-Data protection									
3: Post-disaster immediate relief techniques									
4: Post-disaster intelligent relief techniques									
Progress Reports (J is to JST and X is to NSF)	**J**		**XJ**			**XJ**			**XJ**

Research Problems

- Study how the SDN control plane should interact with different network slices
  - Investigate how one or multiple controllers can manage different slices, e.g., one controller per slice or multiple slices per controller.
- Controller placement solutions that can manage slices considering their specific latency and availability requirements, while minimizing resource usage (note that the limited redundancy inherent to NG-MANs imposes constraints on the best locations to place controllers)
- Differential cost of setting up slices
- Dynamic priority of slices
- SLA class
- Redundancy as a means of protection (limited redundancy inherent to metro networks)
- Protection strategies in network slicing - how disaster-resilient slices can be obtained using a content connectivity