Perspectives on Network Slicing – Towards the new 'Bread and Butter' of Networking and Servicing

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Abstract: This paper provides an analysis of the challenges of Network Slicing in the context of 5G Networks. It represents also a synthetic perspective on the results presented in the special edition – published in the December 2017 and January 2018 issues of the SDN newsletter. It covers a summary of 5G network characteristics and advantages, network slicing concepts and terms and key challenges in network slicing.

Introduction: 5G networks are conceived as extremely flexible and highly programmable end-to-end connect-and-compute infrastructures that are both application- and service-aware, as well as being time-, location-, and context-aware.

These 5G networks [5GARCH] represent an evolution

- Of native flexibility and programmability conversion in all radio and non-radio 5G network segments including Fronthaul and Backhaul Networks, Access Networks, Aggregation Networks, Core Networks, Mobile Edge Networks, Software Networks and Clouds, Satellite Networks and Edge Networks; as well as
- In terms of capacity, performance, and spectrum access in the radio segments of the network

5G networks enable new business opportunities by meeting the requirements of a large variety of use cases as well as enabling 5G to be future proof by means of:

- Implementing network slicing in a cost efficient way
- Addressing both end-user and operational services
- Supporting softwarization natively
- Integrating communication and computation, and
- Integrating heterogeneous technologies (including fixed and wireless technologies).

To take advantage of these opportunities new mechanisms or updated mechanisms will be needed in all network domains. Equally important is the requirement for 5G networks to take a novel approach as to how to orchestrate, deploy, and manage services in 5G networks as exemplified in the following figure.

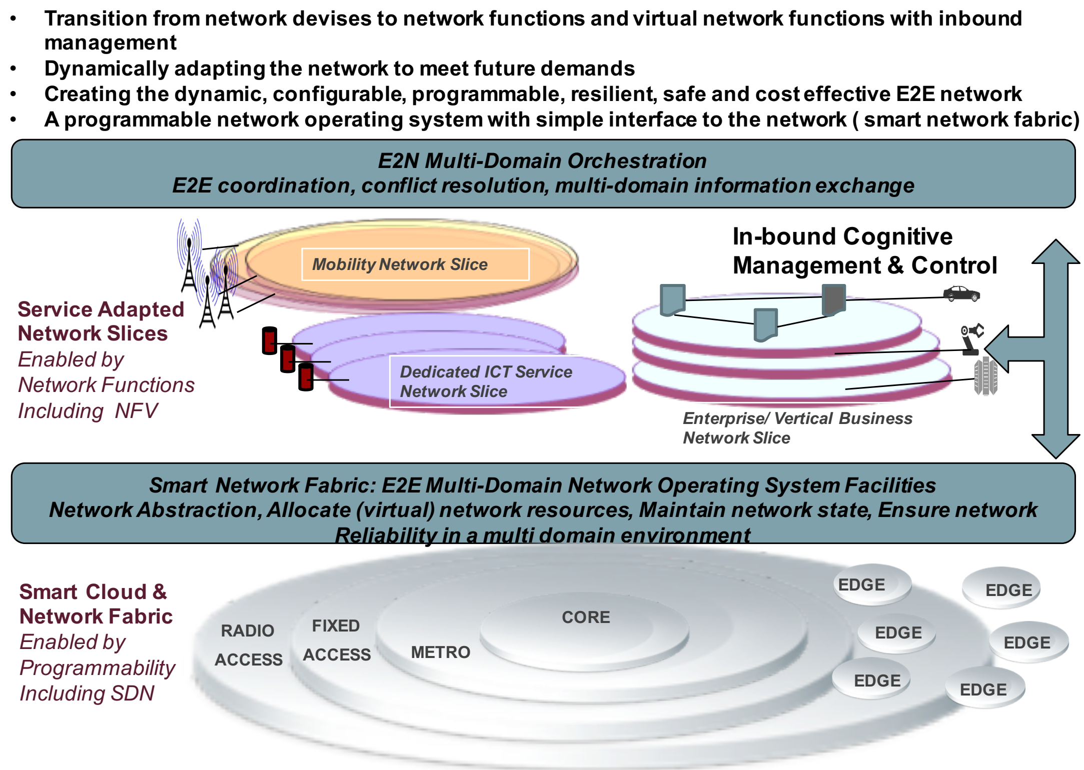

Figure 1 – 5G Networks Environment - http://clayfour.ee.ucl.ac.uk/5g-integration/index.html

5G networks are expected to present a number of advantages. One in particular, is a high degree of flexibility. They enforce the necessary degree of flexibility, where and when needed, with regard to capability, capacity, security, elasticity, and adaptability. These networks will serve highly diverse types of communication – for example, between humans, machines, devices and sensors – with different performance attributes.

Further advantages of 5G emerge in the areas of autonomous management, control of systems and resources. 5G networks enable uniform management and control operations that are becoming part of the design of dynamic software architectures. They can thereby host and execute services in one or more distinct network slices.

Network Slicing Context and Definitions: A number of definitions for network slicing as partitions of network resources were used in the last 10 years within the context of research into distributed and federated testbeds [GENI] and in future Internet research [ChinaCom09]. More recently in 5G research in SDOs revised definitions were used [NGMN], [ONF], [IMT2020], [NGS-3GPP], [IETF].

Network Slicing (NS) is an end-to-end concept covering all network segments. It enables the concurrent deployment of multiple logical, self-contained and independent shared or partitioned network resources and a group of network functions on a common infrastructure platform [GALI] [CONT] [CECC], [QIAN], [NAKA], [SABO], [QIAN], [NIKA], [ODIN].

From a business point of view, a slice includes a combination of all the relevant network resources, functions, and assets required to fulfill a specific business case or service, including OSS, BSS and DevOps processes.

From the network infrastructure point of view, network slice instances require the partitioning and assignment of a set of resources that can be used in an isolated, disjunctive or non- disjunctive manner for that slice [CONT] [CORS].

From the tenant point of view, network slice instance provides different capabilities, specifically in terms of their management and control capabilities, and how much of them the network service provider hands over to the slice tenant. As such there are two types of slices: (1) Internal slices, understood as the partitions used for internal services of the provider, retaining full control and management of them. (2) External slices, being those partitions hosting customer services, appearing to the customer as dedicated networks. [CONT]

Currently Network Slicing refers to the managed fully functional dynamically created partitions of physical and/or virtual network resources, network physical/virtual and service functions that can act as an independent instance of a connectivity network and/or as a network cloud [GALI] [CONT] [CECC], [SABO]. Network resources include connectivity, compute, and storage resources.

Network Slicing considerably transforms the networking perspective by abstracting, isolating, orchestrating, softwarizing, and separating logical network components from the underlying physical network resources and as such they enhance the network architecture principles and capabilities.

To support Network Slicing, the management plane creates a group of network resources (whereby network resources can be physical, virtual or a combination thereof); it connects with the physical and virtual network and service functions as appropriate, and it instantiates all of the network and service functions assigned to the slice. For slice operations, the control plane takes over governing of all the network resources, network functions, and service functions assigned to the slice. It (re-) configures them as appropriate and as per elasticity needs, in order to provide an end-to-end service. In particular, ingress routers are configured so that the appropriate traffic is bound to the relevant slice.

The establishment of slices is both business-driven as slices are the support for different types and service characteristics and business cases, and technology-driven as slices are a grouping of physical or virtual resources (network, compute, storage) which can act as a sub network and/or a cloud. A slice can accommodate service components and network functions (physical or virtual) in all of the network segments: access, core, and edge / enterprise networks.

Network operators can use NS to enable different services to receive different treatment and to allow the allocation and release of network resources according to the context and contention policy of the operators. Such an approach using NS would allow a significant reduction of the operations expenditure. In addition, NS makes possible softwarization, programmability and allows for the innovation necessary to enrich the offered services. NS provides the means by which the network operators can provide network programmable capabilities to both OTT providers and other market players without changing their physical infrastructure. NS enables the concurrent deployment of multiple logical, self-contained and independent, shared or partitioned networks on a common infrastructure. Slices may support dynamic multiple services, multi-tenancy, and the integration means for vertical market players (such as the automotive industry, energy industry, healthcare industry, media and entertainment industry, etc.)

Network Slicing Challenges for 5G Networks

In order to implement and use network slice functions and operations, there is a clear need to look at the complete life-cycle management characteristics of Network Slicing solutions based on the following architectural tenets:

- Underlay tenet: support for an underlay data plane the transport network uses to carry that underlay.
- Governance tenet: a logically centralized authority for the entire network slices in a domain.
- Separation tenet: slices may be independent of each other and have an appropriate degree of isolation from each other.
- Capability exposure tenet: allow each slice to present information regarding services provided by the slice (e.g., connectivity information, mobility, autonomicity, etc.) to third parties, via dedicated interfaces and /or APIs, within the limits set by the operator.

In pursuit of solutions for the above tenets towards a new type of 'bread and butter' of networking and servicing there is a need to address the following challenges and outcomes:

I. Architectural Challenges

- A Uniform Reference Model for Network Slicing that describes all of the functional elements and instances of a network slice. It also describes shared non-sliced network parts.

- Slice Templates: Providing the design of slices to different scenarios. This outlines an appropriate slice template definition that may include capability exposure of managed partitions of network resources (i.e. connectivity compute and storage resources), physical and/or virtual network and service functions that can act as an independent connectivity network and/or as a network cloud.

II. Challenges in Realising Network Slice Capabilities

- Networks Isolation - Efficient slice creation with guarantees for isolation in each of the Data / Control / Management / Service planes. Having enablers for safe, secure and efficient multi-tenancy in slices. Methods to enable diverse requirements for NS, including guarantees for the end-to-end QoS of a service within a slice.

- Network Slicing Service Mapping – creating an efficient service mapping model binding across network slicing; specifying policies and methods to realize diverse service requirements without re-engineering the infrastructure [GALI] [IETF] [CECC]

- Recursion, namely methods for NS segmentation allowing a slicing hierarchy with parent–child relationships [GUER] [KARL].

- Customized security mechanisms per slice - In any shared infrastructure, security is a key element to guarantee proper operation, and especially a fair share of resources to each user including Resource isolation and allocation policy at different levels and Isolation of network service management for multiple tenants [CONT], [NAKA].
- Network Slices Reliability - Maintaining the reliability of a network slice instance, which is being terminated, or after resource changes [NAKA].
- Optimisation, namely methods for automatic selection of network resources for NS; global resource views; global energy views; Network Slice deployment based on global resource and energy efficiency; slice mapping algorithms [GALI].
- Capability exposure for NS (allowing openness); with APIs for slice specification and interaction [GALI].
- Programmability and control of Network Slices [GALI].
- Per-tenant Policy Management - In a multi-tenant, multi-slice end-to-end hosting and networking scenario, closed-loop automation requires both per-tenant policies, as well as the network operator's own. Per-tenant policies would be set to limit compute, storage and network resource usage, block the execution of unauthorized operations, trigger actions including scaling, healing, and topology reconfiguration to meet the service-level agreement (SLA) with a tenant [KHAN].
- Slice lifecycle management including creation, activation / deactivation, protection, elasticity, extensibility, safety, and sizing of the slicing model per network and per network cloud for slices in access, core and transport networks; for slices in data centres, and for slices in edge clouds [GALI].
- Dedicated network - Each slice must behave as a dedicated network while sharing underlying resources, physical and virtual. Monitoring the status and behaviour of NS in a single and/or muti-domain environment and maintenance mechanisms have to be defined in order to show and abstract the proper information for each slice customer [CONT].
- Radio Access Network (RAN) slicing targeting flexible customization and multiplexing over disaggregated RAN infrastructures [KHAN].
- Scalability: In order to partition network resources in a scalable manner, it is required to clearly define to what extent slice customers can be accommodated or not on a given slice. The application of different SLAs on the offered capabilities of management, control and customization of slices will directly impact the scalability issue [CONT].
- Slice dimensioning: Over-dimensioning has been the normal way in the past for avoiding any kind of congestion. With slicing the traffic sources and destinations become much less predictable, if at all. Appropriate planning, dimensioning and enforcement are needed to make sustainable the transition to this new form of service [CONT].
- Autonomic slice management and operation, namely self-configuration, self-composition, self-monitoring, self-optimisation, self-elasticity for slices that will be supported as part of the slice protocols [IETF].
- Automated instantiation, scaling and topology reconfiguration of slices [KHAN].
- Slice stitching / composition by having enablers and methods for efficient stitching / composition / decomposition of slices: vertically (through service + management +

control planes); horizontally (between different domains as part of access, core, edge segments); or a combination of vertically + horizontally [GALI] [IETF].

- End-to-end network clouds orchestration of slices [GUERZONI], [KARL], [CONT].
- Service Mapping, by having dynamic and automatic mapping of services to network slices [GALI] [CECC].
- Efficient enablers and methods for integration of the above capabilities and operations.

III. Network Slices – Deployment & Economic Considerations

• **Deployment Options:** There are architectural, engineering, performance, flexibility and service agility without disruption challenges in terms support of many next-generation services in a NS enable infrastructure. In terms of deployment options an operator could deploy a single multi-service network, with a shared physical layer supporting a shared functional layer. Alternatively, the operator could deploy separate physical sub-networks, each with their own physical resource layer and functional layer on top of that; Or the operator could deploy discrete virtual networks, built on one shared physical resource layer, with multiple functional layers dedicated to each application or service type [CORS] [DANN].

• **Economy of Scale in Slicing**: The benefits of slicing grow as the number of service types that you are trying to launch grows. In addition significant investment is needed in automation to be able to do this at scale, otherwise the complexity and operational challenges are likely to mount up. It's key that the rest of the organisation gears up to support this ambition – development, delivery, marketing, operations and so on - otherwise the operator won't be able to exploit the technology commercially [CORS] [DANN].

• **Service Diversity:** the key challenge is how to support and operate different kind of services with very distinct needs onto the same infrastructure. One practical approach is to position segregated services on specialized partitions, designed and optimized for the type of service to be provided [CONT].

• **Interaction with the vertical customers**: Proper abstractions and templates have to be defined for ensuring the provision of a consistent service portfolio and their integration with the internal network management and orchestration [CONT] [ODIN].

Acknowledgement

This work has been performed in the framework of the H2020 project 5GEx (Grant Agreement no. 671636), project SONATA (Grant Agreement no. 671517) and EUB project NECOS (Grant Agreement no. 777067), which are partly funded by the European Commission.

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