TELECOM INFRA PROJECT

Creating Ecosystems for End-to-End Network Slicing

Project Phase 1: 4G LTE E2E-NS

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Introduction

The Telecom Infra Project (TIP) is an engineering-focused initiative driven by operators, suppliers, developers, integrators, and start-ups to disaggregate the traditional network deployment approach. The collective aim of the TIP community is to collaborate on new technologies, examine new business approaches and spur new investments in the telecom space.

Formed in 2017, the End-to-End Network Slicing (E2E-NS) project group is aimed at developing a commercially viable End-to-End Network Slicing ecosystem that can be deployed over fixed-mobile operator networks. The project aligns with the high-level goals of Network Slicing in general; making the mobile internet a more reliably good user experience, and enable monetization opportunities leveraging the new technology.

This whitepaper outlines the goals and deliverables of this project as it moves from a high-level conceptual phase, to its current, first production phase (4G E2E-NS), focused on integrating required technologies to support a number of identified 4G E2E-NS Use Case Proofs-of-Concept (PoC) in TIP Community Labs along with a preview of future phases in 5G.

We begin by providing a synopsis of project core objectives, how it differs from other Network Slicing initiatives and how – through the achievement of our roadmap milestones, a series of practical, realizable PoCs – we focus on advancing the understanding, practice and commercial viability of Network Slicing.

As the NS concept is still in an early stage, we will provide key background on the subject, showcasing high-level definitions and architectures of E2E-NS drawn from the work of standards bodies including NGMN, 3GPP and ETSI NFV as well as number of private/public consortia including 5G-PPP. For readers not familiar with the Network Slicing concept, it provides the opportunity for carriers to tailor connectivity services to the precise requirements of any given application, user, device or context, by logically isolating virtualized network resources. When applied appropriately, SLAs may be attached that provide the building blocks of the business model.

For the purposes of this introductory (first in a series) whitepaper, we'll provide an overview of the E2E-NS project in its current evolution; Phase 1: 4G E2E-NS, with brief summaries of the Proofs-of-Concept we've developed and look to demonstrate in the TIP Community Labs. Each PoC in this phase will be broken out into its own whitepaper to accommodate the required focus and detail. Here, we'll introduce the rationale behind Phase 1, introduce its champions and contributors and the core 4G LTE architecture supporting it, with an overview of its Lab Use Case implementations along with a timeline for these deliverables.

Looking ahead, we'll present our take on what we see as the Network Slicing roadmap as it will evolve through 4G LTE and 5G and provide a preview of future trials the project is considering to undertake.

Project Charter & Overview

The long-term objective of the E2E-NS project is to identify E2E Use Cases to be researched, developed and demonstrated as PoC addressing key challenges for 4G, and emerging 5G Network Slicing arenas. It aims to seize opportunities afforded by TIP membership to involve different players; telecom operators, equipment vendors, orchestration suppliers, application providers, network integrators & technologists within the ecosystem. Further, the group looks to build on identified Use Cases to help carrier trials and deploy real-world Network Slicing offerings at scale.

With this in mind, the goals of the project are to establish:

- **Low-Barrier Entry Points to Network Slicing** in each current and emerging generation to help guide carriers on deploying NS offerings that improve the mobile internet experience and drive new top-line revenues
- **A Selection of Market-Ready, Operator Sponsored Use Cases** in each phase with their own unique rationales, business opportunities and challenges to address and overcome
- **Common, Open Architectures** that demonstrate how Network Slicing can be applied in multi-vendor, multi-domain, multi-operator contexts for a range of candidate use cases and services. This will help develop slicing solutions that can serve many different needs.
- **Integrated RAN & Core Network Slicing Ecosystems** that will provide repeatable blueprints for carriers looking to build and launch End-to-End NS service offerings
- **Clear Use Case Business Model Benefit Statements** that communicate their value to stakeholders and operators, ahead of decisions to trial and deploy in real world networks

Points of Differentiation

The recent period has yielded an abundance of Network Slicing-related research projects and PoC. Naturally, the most influential work is that of various telecom standards bodies including NGMN, IEEE, 3GPP, the 3rd Generation Partnership Project, 5G-PPP the 5th Generation Infrastructure Public Private Partnership (e.g. 5G MONARCH, 5G NORMA, 5G-Ex, SLICENET; the latter two through direct consultations with the TIP E2E-NS project), ITU-T and ITU-R Telecommunication Standardization Radio communication Sector respectively and the Internet Engineering Task Force (IETF). As these organizations define the specs, they also provide a critical roadmap for all comers in the space.

Outside of these groups, various Academic, Commercial, Governmental or public/private consortia undertake "real-world" Network Slicing PoCs focused on delivering technological "proofs". While 5G projects tend to occur in isolated environments that by definition cannot

yet scale or be taken to market, this TIP project group is following a phased approach where the purpose of this initial phase, is to demonstrate that End-to-End Network Slicing can be deployed and scaled in today's 4G networks.

Our project's key differentiator would thus be its focus on current capabilities, and new solutions that bridge the gap between RAN and Core and demonstrate what can be achieved today, with scalable blueprints for operator. Equally important is the need to bridge the commercialization gap by elaborating business models to help carriers create the business case. Thus, our mission is not just to create PoCs, but a viable critical path for full-scale End-to-End Network Slicing deployments for consumer, business and government segments.

Network Slicing Definition

In our opinion, NGMN's definition of NS stands as the most concise and useful for the purposes of our project, defined in their words as:

"A Network Slice Instance is a set of run-time network functions, and resources to run these network functions, forming a complete instantiated logical network to meet certain network characteristics required by the Service Instance(s)". [1]

As we will demonstrate, this TIP Project is implementing the above definition, leveraging cumulative learning from industry actors and going through the whole life cycle of E2E-NS deployment project, from design to instantiation, testing and performance measurement.

Network Slicing Benefits

The core value proposition of Network Slicing is that of delivering a specified level of service to an endpoint or endpoints (an application, device or user). End-to-End Network Slicing extends the SLA across the entire chain including the device, the access, the transport and the core potentially, knowing that this may span multiple operator domains (i.e. fixed and mobile or geographic).

Benefits for Users

We identify several major positive implications for users including:

Dramatically Improved Mobile Internet Experience – Users don't care what technology delivers their Internet experience; they are concerned with the content, apps and connectivity it provides. Whether business, government or consumer, Network Slicing users will be delivered an optimized QoE for which they are willing to pay

Application, Context-Awareness – Users navigate from context to context (work or play), and application to content via different communication channels hoping their network can catch up to the frenzied interplay of all of these. Adaptive, App-Aware Network Slicing delivers on this promise.

Intelligent Billing – Whether leveraging free (sponsored) data in a mall, billable data at work or personal charges when at play users of any stripe hope network billing systems adapt to the multi-context nature of their network usage. Network Slicing directly addresses this.

Benefits for Operators

This has several major positive implications for the operators both from a technological and business perspective including:

A Common Shared Infrastructure – Given that multiple slices can run on a common shared infrastructure, including costly components (i.e. Nodes, Base Stations, Fiber), operators enjoy the economy of scale that any shared infrastructure provides.

Agile Market Testing & Scaling – Software based instantiation and update allows product, marketing and sales to quickly and cost-effectively test market and deploy new differentiated SLA/QoE-assured services to targeted micro-segments, removing traditional bottlenecks that have hampered agile service creation.

Template Based Slice Creation and Management – Operators can rapidly clone slices from a catalogue of "off the shelf, field-tested slices", with predefined service logic and parameters for instant deployment or customization.

Flexible Billing Models – Network Slicing also provides improvement to the mobile operator wholesale business and host of emerging services (U2U communications, Video, IoT, MTC, CAV, AR etc.) that provide charging details per slice instance.

Aligning with Net Neutrality – Network Slicing is expressly allowed, even encouraged in some of the strictest Net Neutrality regulations (e.g. EU BEREC) as long as it is: 1) Used to achieve normal traffic management measures, or 2) Supports differentiated QoS for the unique demands of 'Specialized Services' universally applied to all services in that category and available to all users.

There has been a number of studies anticipating the financial benefits of Network Slicing. Ericsson and consultancy Arthur D. Little have estimated the "5G effect" of which Network Slicing is the central component at 34% growth over the next 6 years. This would seem a relatively small uplift, but in the context of an industry that has struggled to reach 2% growth for the last decade it is significant indeed. And as the figure below illustrates, the choice is clear between an undifferentiated "Best Effort" service model and an evolved, Network Slicing powered Network-as-a-Service (NaaS) model.

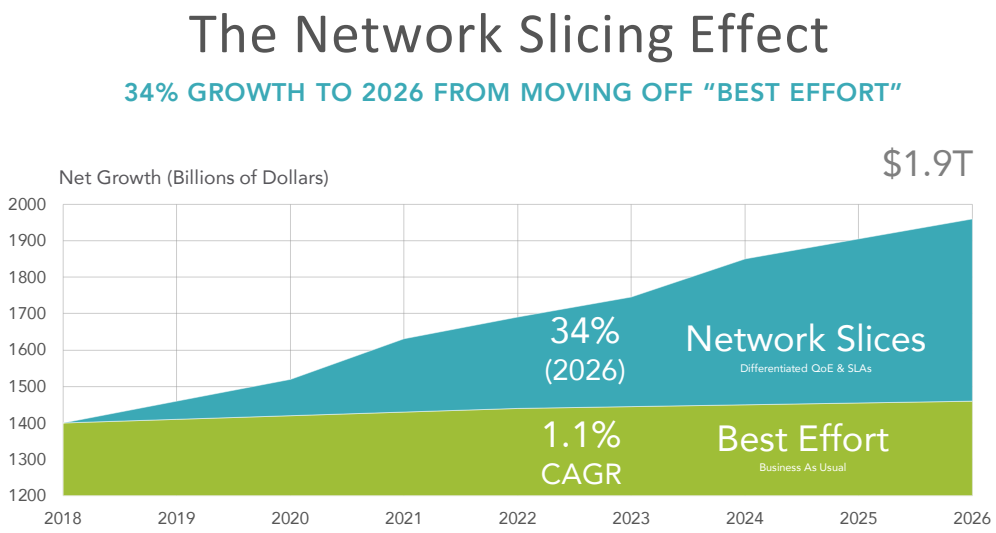


Figure 1: Source Ericsson, Arthur D. Little

Immediate Benefits

Network Slicing has been positioned as a 5G technology differentiator, but it can be applied to 4G LTE, now a mature standard that is available today and will remain for the next decade and beyond. As such, and as we will present in our Approach & Roadmap section, there are many promising Use Cases quickly and easily supported by 4G that will improve through the evolution to the hybrid 4G/5G networks and emerge as fully automated experience in the coming years. This, "start small and scale" strategy will also provide an invaluable instructional test bed for long-term refinement of the practice that will only accelerate large-scale roll outs in our 5G future.

Approach & Roadmap

Based on current, as well as emerging 3GPP 5G architecture, we see four phases for End-to-End Network Slicing:

Phase 1: 4G LTE ("Light") Slicing – Leveraging bearer-based, dynamic, application-aware, on-demand capability that depending on the carriers' motivations may provide operational efficiencies, expand customer footprint and/or generate new revenues today.

Phase 2: 4G/5GNR ("Light-Hybrid") Slicing – Introduce dedicated 5G New Radio to 4G static slices to leverage new spectrum and 5G radio capabilities expand management capabilities to support Includes Pre-emptive Slice, Adaptive Monitoring and Healing.

Phase 3: Slicing with 5G-Core – Support E2E 5G slices with 5G Standalone but also in co-existence with 4G and handover. Leverage cloud native service based architecture and slicing lifecycle management to serve full scale 5G offering while supporting LTE and hybrid 4G-5G slicing as well.

Phase 4: Slice-as-a-Service – Fully automated, adaptive, self-organizing, self-healing slices and sub-slices that introduces a much more streamlined on-demand Slice-as-a-Service model to support the full array of eMBB, URLLC, and mMTC categories.

While these phases are to an extent technology and standard dependent, we are already well into the first stage with 4G slicing and a number of viable Use Cases can be very quickly scaled and commercialized. Moving forward with 5G more use cases will be enabled. The graphic below provides a more detailed, architectural look at these phases.

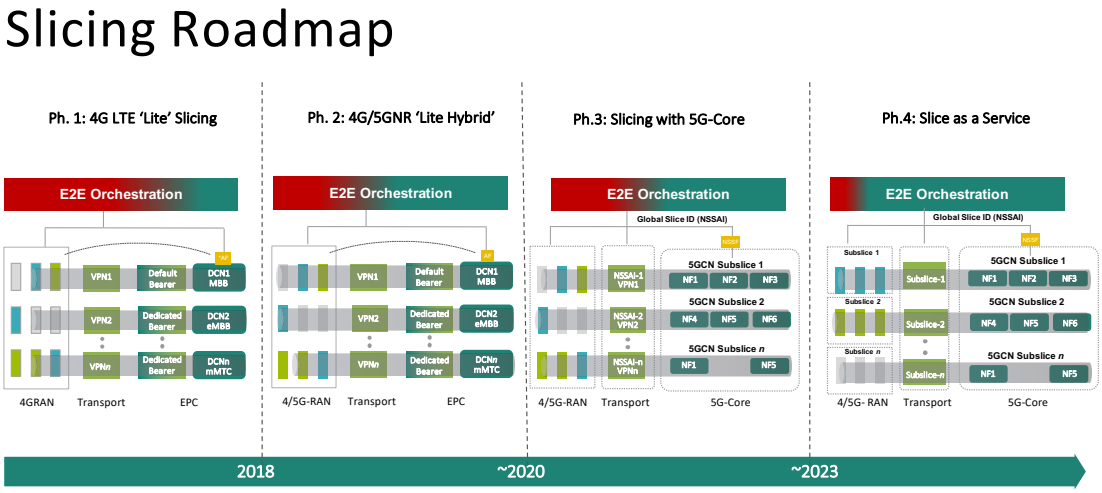


Figure 2: E2E-NS-Architecture-Roadmap-TIP

Network Slicing Ecosystem Players

Network Slicing can enable new business models, and in some cases, entire ecosystems which bring new players to the mobile value chain. Before we introduce our Phase 1: PoC we'll take a look at the various entities that may come into play and the business opportunities they establish.

Entity	Opportunity
Application Provider	Drive service providers and network providers to use slices to deliver services that meet specific application needs and KPIs/SLAs, allowing the application provider to distinguish their own service in the market
Consumer-focused Service Provider	Consume slices on their own network to deliver their own services; tune & optimise the slice resources to innovate with next generation services in the market
Network Wholesaler	As one potential segment of an E2E slice, provide capabilities such as Slice-as-a-Service, sliceable backhaul/transport networks, orchestration & assurance APIs, metrics & analytics, to help their customers deliver what is needed
Integrator	Offer to integrate sub-slices from different network segments/providers together, and integrate those to external network domains/cloud providers
Enterprise Provider	Use the flexibility of slicing to tailor solutions to meet the needs of specific businesses or vertical market customers; to help those customers identify the right network connectivity solution (at the right quality & reliability) needed within their larger solution context

Project Phase 1 Proofs-of-Concept

TIP E2E-NS Project team defined the following criteria for this initial phase of PoCs:

1) Can it be done today at market scale and can carriers easily follow suit?

2) Does the Use Case provide an improved mobile user experience?

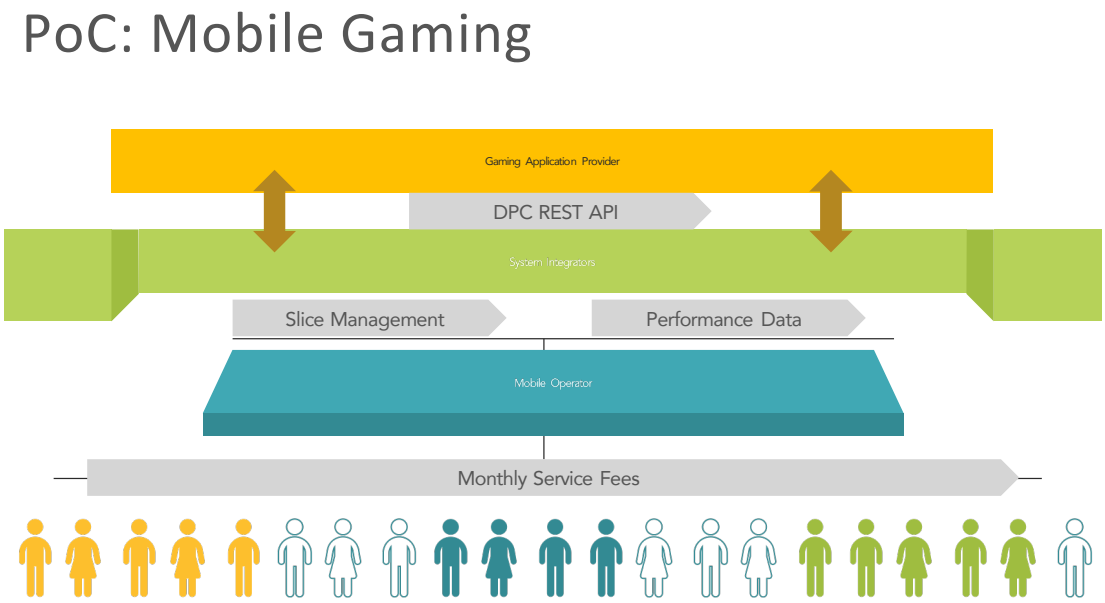
3) Will it drive carrier revenues?

Additionally, we are looking, particularly in this first phase, to demonstrate a range of capabilities and very different implementations of the technology. We'll briefly outline these here, and as stated, deliver more detailed descriptions of each PoC in stand-alone whitepapers to follow.

4 use cases have been defined, with the first two at the PoC stage:

E2E-NS Phase 1 | PoC 1: Mobile Gaming

This BT-sponsored PoC demonstrates the ability to support dynamic, multi-game, application-aware network slices and a dramatically improved mobile gaming experience. Enabling an ecosystem that connects the gaming application-providers, operators, integrators and gamers, this Use Case holds enormous promise for Carriers in a high growth market for mobile games predicted by IDC to top 100Billion by 2021. Our PoC will show how in a current 4G LTE network, game-aware slices can be triggered instantly upon user action, in this case starting a game. Cloudstreet's network slicing application/network function, the Dynamic Profile Controller™ (DPC™) and REST API will provide slice definition, creation, management and business logic, while the EXFO testing product will provide precise real-time and historical performance data to back any SLAs that would be provided.

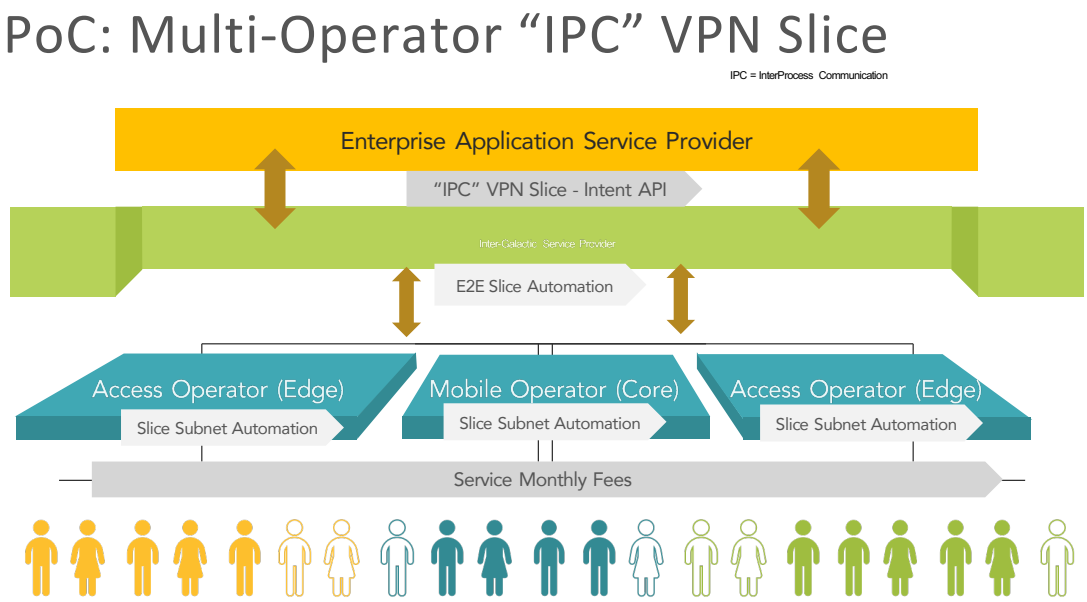


E2E-NS Phase 1 | PoC 2: Multi-Operator "IPC" VPN Slice.

This BT-sponsored PoC is demonstrating a solution for multi-domain end-to-end network slices. Here, a service provider is assumed to offer an appropriate "on Demand" network

slice to an Enterprise. The slices are used for either connecting to a core data centre hosted service, edge data centre hosted service or peer-to-peer hosted service, depending on the context of the service.

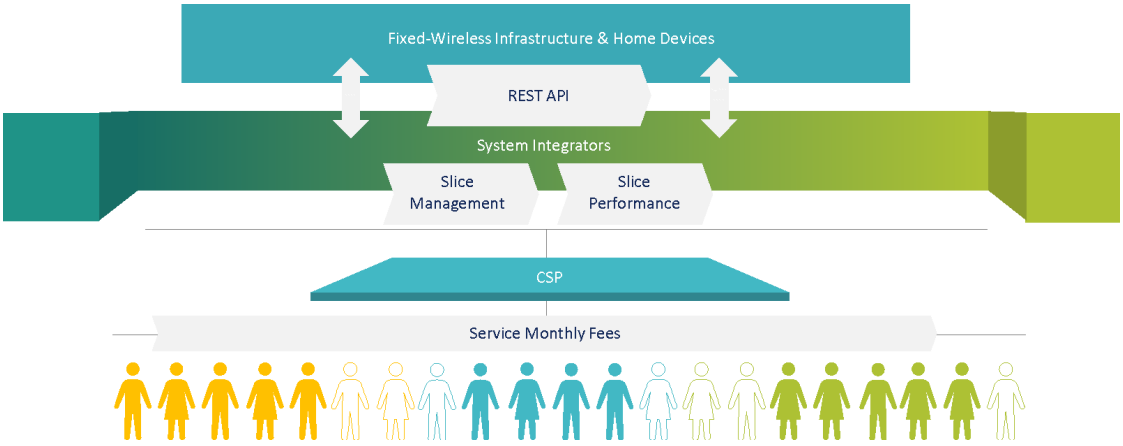
In this PoC the service provider uses other networks such as those of "last mile" operators in order to deliver an orchestrated multi-domain network slice for the Enterprises. The solution leverages the Recursive Inter Network Architecture (RINA) software stack for VM Networking and multi-domain APIs for orchestration to automate delivering the appropriate E2E network slice across the multiple providers. The approach involves minimal protocol support, Inter-Process Communication (IPC), and service intent information sharing between ecosystem actors for instantiation and managing service QoS spanning different domains.



Project Phase 1 Use Cases

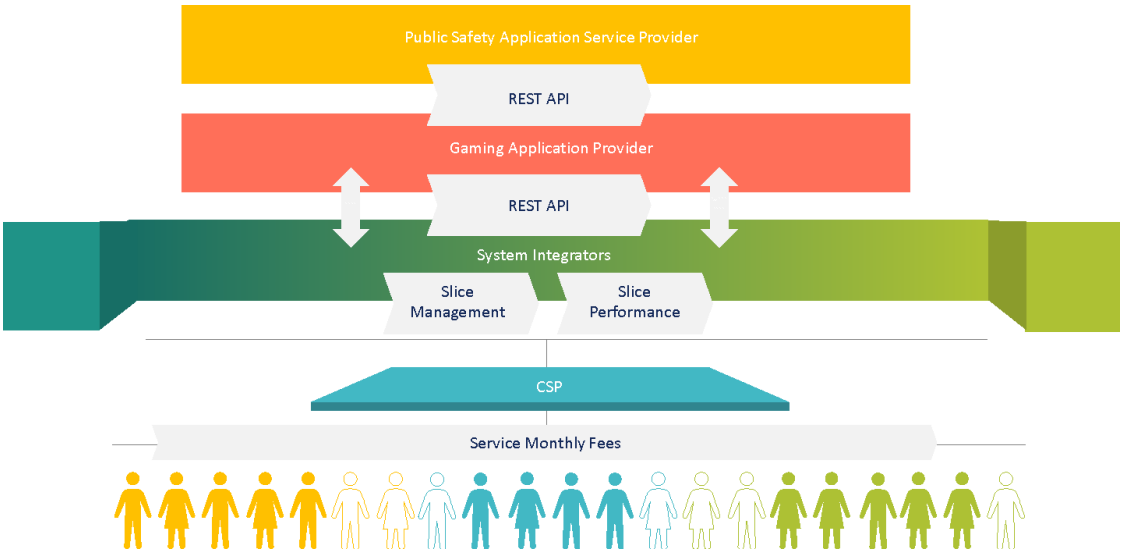
E2E-NS Phase 1 | Use Case: Fixed Wireless

Rural Broadband – Project providing a real-world framework for extending fixed wireless coverage to underserved, remote and rural communications. Allows the carrier to extend "fiber-over-the-air" QoE to customers areas un-served by terrestrial networks with definable slices, greatly expanding subscriber footprint & gaining flexibility over consumer & enterprise services. Leveraging slice-enabled fixed wireless transmitters leveraging high performance fiber backhaul, the PoC will demonstrate an improved user experience via assured slices catered to different users and apps within the home (e.g. gaming & OTT).



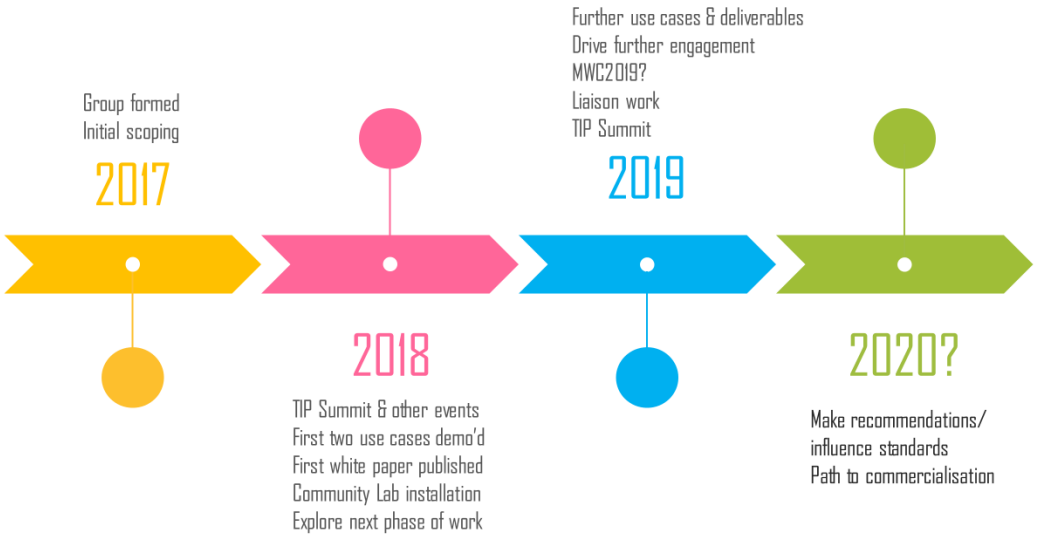
E2E-NS Phase 1 | Use Case: Public Safety

This Use Case describes a solution for delivering sub-slices within a slice, local control for First Responders. Public safety personnel in many authorities require guaranteed connectivity with high bandwidth when responding to an incident, provisioned to Critical Communications/Public Safety authorities by the carrier (often via a Government wholesaler, e.g. FirstNet), to ensure failsafe voice and data communications, e.g. body/vehicle mounted video cameras for real-time surveillance & situation analysis. Network Slicing allows the Carrier commercial network to serve dedicated public safety requirements by deploying one or multiple isolated virtual networks. SLAs for guaranteed secure bandwidth is purchased from the carrier. Slice management and orchestration ensures public safety users do not congest the network themselves during major incidents.



Project Deliverables & Timeline

As of the publication of this introductory whitepaper, our first public deliverable, we have completed all key milestones of the project, and according to the slicing roadmap we presented earlier. We are now poised to attend the TIP Summit'18 in London and demonstrate two 4G LTE "Light" Slicing Proofs of Concept among the 4 Use Cases that were identified for Phase 1. Moving forward, our plan is to expand into more use cases, introduce 5G NR and Core, liaise with other entities working on slicing or adjacent topics and provide recommendations to influence standards.



Contact Information

How to contact TIP:

https://www.telecominfraproject.com/contact/

How to join the E2ENS Project Group:

https://www.telecominfraproject.com/end-to-end-network-slicing-e2e-ns/

APPENDIX

Glossary:

3GPP: 3rd Generation Partnership Project

5G-PPP: 5th Generation Infrastructure Public Private Partnership

5G MoNArch: 5G Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond

5G NORMA: 5G Novel Radio Multiservice Adaptive Network Architecture

NGMN: Next Generation Mobile Networks

IEEE: Institute of Electrical and Electronics Engineers

IETF: Internet Engineering Task Force

ITU-T: Telecommunication Standardization Radio communication Sector

ITU-R: Telecommunication Standardization Radio communication Sector

LTE: Long Term Evolution

MANO: Management and Organization*

mMTC: Massive Machine Type Communication

***NFV MANO:** Network Function Virtualization Management and Organization

NSSAI: Network Slice Selection Assistance Information

PoC: Proofs-of-Concept

RAN: Radio Access Network

UC: Use Case

End-to-End Network Slicing: The ability to ensure required service levels of a network slice across one or multiple network environments (operators and/or domains) from endpoint to endpoint (device, or application)

Sub-Slices: Sub-Slices (or Sub-Netslices) are the actual Endpoint or UE slices that serve the specific needs of an application, device, user or all three. A given user may have multiple sub-slices available to them up to a maximum of 8.

Dynamic Slicing: describes the ability to deliver slices on-the-fly based on demands that may relate to location, time, priority, scheduling, RF conditions and/or ad hoc incidents. This evolved capability generally relates to mobile devices and users and covers a wide range of

use cases including location-based slice handoffs for any application be it Public Safety / Critical Communications, Broadcasting, IPTV/OTT VOD, Industrial AR/VR and Autonomous Vehicles to name but a few.

Categories of Network Slicing: There are three standard slice types defined by 3GPP – Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), and Massive Machine-Type Communications (mMTC) – and these are positioned to be representative of different extremes of requirements.

Slice Type	Bandwidth	Latency	Number of Connections	Mobility
eMBB	High	Medium	Medium	High
URLLC	Medium	Low	Low	Low
mMTC	Low	High	High	Low

These, at times extreme, performance requirements mean that slicing as a capability will need to allow different virtual networks to behave very differently, even though they are built on the same physical infrastructure.