Network Slicing Proof of Concept - Power Grid

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Description

The goal of this Proof of Concept is to bring network slicing from the theoretical level to practical implementation, and to validate the key concepts.

The plan is to use standard procedures defined by the Standard Developing Organisations and GSMA NG.116 Generic network Slice Template (GST). Based on the specific use case requirements a NEST will be produced and used for the network configuration and performance management.

Use Case

Use cases in smart grid scenarios can be divided into two categories: control and collection. Control use case include intelligent automation of power distribution, precise load control, and distributed energy regulation. Collection use cases include low-voltage collection, smart-grid large video applications (including sub-station inspection robots, transmission line drone inspections, integrated monitoring of power distribution room video feed, mobile field construction operation control, emergency site ad hoc network comprehensive applications, and so on.)

Control business scenarios: At present, the overall communication feature is to apply a sub-station to master-station connection mode, using star connection topology. The master station is relatively concentrated, meaning that the delay of general control business is in the order of seconds. With the widespread application of intelligent distributed network terminals in the future, there will be more distributed point-to-point connections in the connection mode. With the application of precise load control and distributed energy regulation, the master station system will gradually move to the edge, and there will be more near-site control. The delay will move to be in the order of milliseconds.

1. **Bandwidth**: According to the Guiding Opinions on the Construction of Precision Load Control Communication System (Xintong Communication [2017] No. 33), a single terminal is currently about 48.1 kbps. In the future, the peak bandwidth of a single terminal is 1.13Mpbs. For the Distribution Network Differential Protection service, the bandwidth per terminal is 2.8Mbps, but with the communication interval of 833ms (24 sample times per 20ms), the DOU would be as high as up to 886GB per month.

2. **Delay**: The maximum delay of the system refers to the delay from the start of the collection of fault information to the completion of the terminal jump-off. The above delays include the collection and decision time of fault information, the channel transmission time, the delay time of the user site switching device, and the shunt Switch trip time. The channel transmission time includes the secure access, backbone network transmission, access network transmission, and store-and-forward time of intermediate nodes on the transmission channel. For the millisecond based Precision Load Control Communication service, the channel transmission delay requirement is less than 50ms; for the Distribution Network Differential Protection service, the channel transmission delay requirement is less than 15ms;

3. **Reliability**: High requirement: 99.999%

4. **Isolation requirements**: For the power grid vertical, all the services belonging to the I / II (production and control area) require complete physical isolation from the III / IV

(management and information area) business. Besides that, the service of I area would also be isolated from the II area logically, as well as the III area and IV area.

5. **Number of connections**: around X * 10 / km2.

Collection business scenarios: Currently, most of the collection business in the power grid vertical is via small package and low frequency based. In the future, there will be enormous changes in collection objects, content, and frequency.

Collection object: At present, it is mainly aimed at the production and operation of electric power, mainly using electric primary equipment. The metering mode is mainly used for metering, and the number of connections is 100 / km2;

Collection content: At present, basic data and images are mainly used, and the bit rate is 100kbps. With the rapid development of smart grids and the Internet of Things, the collection target will be extended to power secondary equipment; various environment, temperature and humidity, Internet of Things, and multimedia scenarios, and the number of connections is expected to double at least. If the medium and long-term future is driven by the industry, the collection method passes to the user, and the number of connections is expected to increase by 50-100 times. In addition, the content of the collection also tends to be video and high-definition from the original simple data, especially in unmanned inspections, video surveillance, and emergency scenes. Ad hoc network applications and other scenarios will have a large number of HD video backhaul requirements, and local bandwidth requirements are in the 4-100Mbps class.

Collection frequency: At present, it is collected in units of months, days, and hours. In the future, applications such as precise load control and user real-time pricing will not be met. The collection frequency will drop to the second level to achieve quasi-real-time capabilities.

1. **Bandwidth**: According to different scenarios, a sustainable and stable guarantee of 4 ~ 100Mbps is required.
2. **Delay**: The delay of multimedia information return is less than 200ms. The delay of control information return is less than 100ms.
3. **Reliability**: 99.9% for multimedia information return reliability, 99.999% for small control information return reliability
4. **Isolation requirements**: Belong to area III / IV business of the power grid, and the security requirements are lower than those in area I / II. A small number of control functions, such as control information for remote inspection robots, belong to the I / II area.
5. **Number of connections**: Around N * 100~1000 / km2

NEST

Template for Domain I/II of Grid (Production and Control Area)

Attribute	Sub-parameter	Value	Notes
Availability		-	Not defined in NG.116-v2.0 yet
Area of Service	Area of Service	SHENZHEN	City Name
	Region specification	1	Full city
Delay Tolerance		0	Not Supported
Deterministic Communication	Availability	1	Supported
	Periodicity	0.000833	833µs periodic comm. for "Differential Protection" Service
Downlink Throughput Per Network Slice	Guaranteed downlink throughput	5Gbps	Supported by Flex-E Resource Isolation
	Maximum downlink throughput	5Gbps	Supported by Flex-E Resource Isolation
Downlink Throughput Per UE	Guaranteed downlink throughput Per UE	10Mbps	2.4Mbps/UE for uplink and throughput for downlink would be N*uplink based on the multicast comm. for "Differential Protection" Service
	Maximum downlink throughput	10Mbps	
Energy Efficiency	Network slice energy efficiency	-	Customer has NO requirement now

	Time frame of the measurement	-	Customer has NO requirement now
Group Communication Support		2	Broadcast/Multicast
Isolation Level	Isolation	1	Physical Isolation
	Physical Isolation	2	Physical network isolation
	Logical Isolation	-	
Location Based Message Delivery		0	Not Supported
Maximum Supported Packet Size		500Bytes	245Bytes for “Differential Protection” Service and two times for redundancy
Mission Critical Support	Mission Critical Support	0	non-mission-critical
	Mission-critical capability support	–	
	Mission-critical service support	–	
MMTel Support		0	not supported
NB-IoT Support		0	no
Network Slice Customer network functions		–	All the network functions are provided by the CMCC
Number of connections		1000	the terminals are limited for the PoC
Number of Terminals		1000	the terminals are limited for the PoC
Performance Monitoring	Availability	–	

	Monitoring sample frequency	-	III/IV area : per 30s I/II area : Per second
Performance Prediction	Availability	-	
	Prediction Frequency	-	
Positioning Support	Availability	-	
	Prediction Frequency	-	
	Accuracy	-	
Radio Spectrum		N41	CMCC 2.6GHz: 2515-2675MHZ
Reliability		-	Not defined yet
Root Cause Investigation		2	active investigation
Session and Service Continuity Support		1	SSC mode 1
Simultaneous Use of the Network Slice		3	Cannot be used with another network slice
Slice Quality of Service	3GPP 5QI	84	
	Resource Type	1	Delay critical GBR (Intelligent Transport Systems)
	Priority Level	19	
	Packet Delay Budget	10ms	
	Packet Error Rate	10-4	
	Jitter	3ms	

	Maximum Packet Loss Rate	10-4	
Support for Non-IP traffic		1	Supported MAC based comm. for “Differential Protection” Service
Supported Device Velocity		1	Stationary: 0 km/h
Synchronicity	Availability	1	between BS and UE
	Accuracy	0.0000001	1µs
Terminal Density		1000	devices per km2
Uplink Throughput Per Network Slice	Minimum	5GE	
	Maximum	5GE	
Uplink Throughput Per UE	Minimum	2.5Mbps	
	Maximum	4Mbps	
User Management Openness		1	supported
User Data Access	Data access	{1,2}	1: Termination in the private network 2: Local traffic (no internet access)
	Tunnelling Mechanism	{2,3}	2: VPN Tunnel 3: Label bases routing
V2X Communication Mode		0	No

Template for Domain III/IV of Grid (Management and Information)

Attribute	Sub-parameter	Value	Notes
Availability		-	Not defined in NG.116-v2.0 yet
Area of Service	Area of Service	SHENZHEN	City Name
	Region specification	1	Full city
Delay Tolerance		0	Not Supported
Deterministic Communication	Availability	1	Supported
	Periodicity	900	15min periodic comm. for “advanced metering” Service
Downlink Throughput Per Network Slice	Guaranteed downlink throughput	1Gbps	Supported by Flex-E Resource Isolation
	Maximum downlink throughput	1Gbps	Supported by Flex-E Resource Isolation
Downlink Throughput Per UE	Guaranteed downlink throughput Per UE	2Mbps	
	Maximum downlink throughput	2Mbps	
Energy Efficiency	Network slice energy efficiency	-	Customer has NO requirement now
	Time frame of the measurement	-	Customer has NO requirement now
Group Communication Support		0	not available
Isolation Level	Isolation	1	Physical Isolation

	Physical Isolation	2	Physical network isolation
	Logical Isolation	-	
Location Based Message Delivery		0	Not Supported
Maximum Supported Packet Size		1500Bytes	Video surveillance
Mission Critical Support	Mission Critical Support	0	non-mission-critical
	Mission-critical capability support	–	
	Mission-critical service support	–	
MMTel Support		0	not supported
NB-IoT Support		0	no
Network Slice Customer network functions		–	All the network functions are provided by the CMCC
Number of connections		1000	the terminals are limited for the PoC
Number of Terminals		1000	the terminals are limited for the PoC
Performance Monitoring	Availability	–	
	Monitoring sample frequency	-	III/IV area : per 30s I/II area : Per second
Performance Prediction	Availability	-	
	Prediction Frequency	-	
Positioning Support	Availability	-	

	Prediction Frequency	-	
	Accuracy	-	
Radio Spectrum		N41	CMCC 2.6GHz: 2515-2675MHZ
Reliability		-	Not defined yet
Root Cause Investigation		2	active investigation
Session and Service Continuity Support		1	SSC mode 1
Simultaneous Use of the Network Slice		3	Cannot be used with another network slice
Slice Quality of Service	3GPP 5QI	7	
	Resource Type	2	Non-GBR
	Priority Level	70	
	Packet Delay Budget	100ms	
	Packet Error Rate	10-3	
	Jitter	10ms	
	Maximum Packet Loss Rate	10-3	
Support for Non-IP traffic		0	Not supported
Supported Device Velocity		3	Vehicular: 10 km/h to 120 km/h Applicable for patrol UAV
Synchronicity	Availability	0	Not supported
	Accuracy	1µs	

Terminal Density		10000	devices per km2
Uplink Throughput Per Network Slice	Minimum	10GE	
	Maximum	10GE	
Uplink Throughput Per UE	Minimum	200Mbps	
	Maximum	200Mbps	
User Management Openness		1	supported
User Data Access	Data access	{1,2}	1: Termination in the private network 2: Local traffic (no internet access)
	Tunnelling Mechanism	{2,3}	2: VPN Tunnel 3: Label bases routing
V2X Communication Mode		0	No

From NEST to Implementation

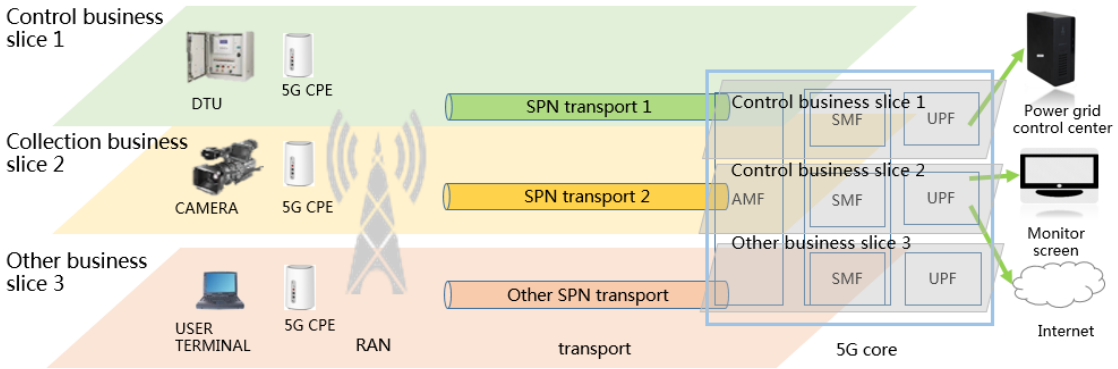

Figure 1 Implementation of three different slices

In the implementation, the control business and monitoring business run in two different slices, which are logically and physically isolated from other business. These slices share the access network. The transport network domain uses three different SPN FlexE transport tunnels to

achieve physical isolation. In the core network domain, three slices use dedicated UPF, isolated SMF based on different virtual machines, and share AMF.

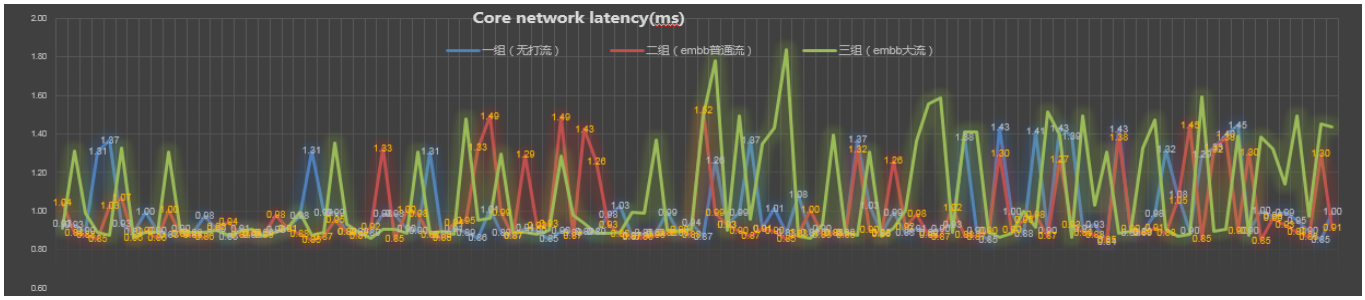

Figure 2 Core network latency of different slices

The average delay of the power business after the core network service is flooded is about 1ms, which is basically the same as the average delay before the flooding of 0.98ms. The maximum delay before and after the flooding is not more than 2ms, EMBB congestion has almost no impact on power business.

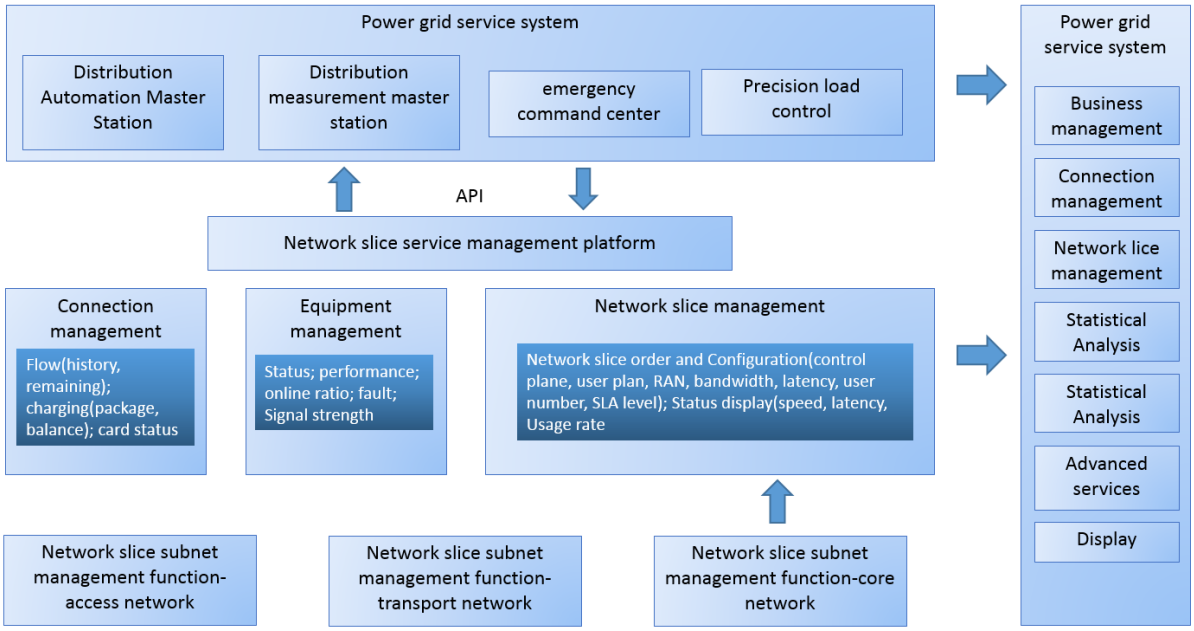

Figure 3 Network slice platform support management

Lessons learnt

1. For isolation, the existing attribute with three levels (no isolation, logical isolation and physical isolation) is not enough for verticals to select. It's recommended to place isolation in three domains, and consider the possible combination with different selections in these three domains. It would also be highly recommended to separate the isolation attribute into three domains: 5G NR, 5G backhaul and 5G Core, as they may need to use different isolation levels.

2. For KPI monitoring, it's recommended to consider KPIs and the related frequency together since different KPIs may require different monitoring frequencies.
3. For security, it's recommended to add a description of security requirements, as different slices may use different security methods to guarantee different vertical scenarios such as the IPSec, Air Interface Completion Protection etc.
4. For the Session and Service Continuity Support, it's recommended to add one Enum of NA, since for some scenarios in the power grid, the terminals have no mobility requirement.

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