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Pre-commercial Network Slicing Trials Major Conclusions

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PRE-COMMERCIAL NETWORK SLICING TRIALS MAJOR CONCLUSIONS

by NGMN Alliance

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Abstract

While several documents have already been produced on the network slicing concept, technical details, and business cases, this White Paper tackles a more challenging, complex and practical domain by consolidating the pre-commercial network slicing test results from different chipset platforms and indicates that 5G smartphones and 5G S-modules have been able to support network slicing. Tests were performed based on the testing framework White Paper [1], where all test objectives, pre-configurations, procedures, and success criteria were defined.

The network slicing tests for 5G devices use different kinds of Device Under Test (DUT), including 5G smartphones and 5G Superior Universal Modules (S-Modules). Some signalling test cases and service specific test cases were executed, including the configuration and usage of Network Slice Selection Assistance Information (NSSAI), interworking with Evolved Packet Core Network (EPC), UE Route Selection Policy (URSP) configuration and application, video service and FTP/Speedtest download service. However, due to the difference of devices, the test methods vary.

- 5G smartphones can be tested directly using the applications on smartphones for URSP related test cases.
- 5G S-Modules can be tested by AT command with the assistance of computers. Some URSP related test cases cannot be performed in 5G S-Modules.

Due to limited time and product maturity, some test cases from the previously published testing framework White Paper have not been executed yet and may be included in the future update of this White Paper. Observations introduced here give the insight of some future improvements in network slicing.

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1 INTRODUCTION

The Network Slicing for Operating Systems of 5G Smart Phones Project Phase 2 focuses on the network slicing trials based on the actual network elements, and has the following scope:

- Develop a testing framework for 5G Network Slicing Devices, which allows the harmonisation of the testing methodologies among different parties conducting trials;
- Test 5G network slicing capabilities by lab tests/field trials with different kinds of devices, e.g. 5G smartphones, 5G S-Modules;
- Consolidate the results from different industry players and draw conclusions. Analyse the test results and provide observations that could lead to future improvement.

This White Paper focuses on the results of the network slicing test with different kinds of devices, including 5G smartphones and 5G S-Modules, and provides some observations based on the test results.

Sincere thanks to all the operators and manufactures for their great efforts in the network slicing trials, including China Mobile, Huawei, MediaTek, OPPO, Qualcomm, Quectel, Samsung, SK Telecom, Turkcell, UNISOC, vivo, Xiaomi and ZTE (in alphabetical order).

Operators who have shared their 5G network slicing trial results in this White Paper are:

2 TRIAL RESULTS

2.1 General

Due to the difference between 5G smartphones and 5G S-Modules, some test cases are not suitable for 5G S-Modules, as shown in Table 1 below.

Table 1: Test Cases Applicability to 5G Smartphones and 5G S-Modules

Test Cases	Smartphones	S-Modules
NSSAI Handling in Initial Registration	√	√
NSSAI Handling during Mobility Registration Update	√	√
Default Configured NSSAI Pre-configuration and Update	√	√
Generic UE Configuration Update for NSSAI	√	√
NSSAI Inclusion Mode A	√	√
NSSAI Inclusion Mode B	√	√
NSSAI Inclusion Mode C	√	√
NSSAI Inclusion Mode D	√	√
URSP Configuration in Initial Registration	√	√
Update and Deletion of URSP	√	√
Traffic Descriptors in URSP --- APPID	√	×
Traffic Descriptors in URSP --- DNN	√	×
Traffic Descriptors in URSP --- IP	√	×
Traffic Descriptors in URSP --- IP 3 Tuple	√	×
Traffic Descriptors in URSP --- FQDN	√	×
Traffic Descriptors in URSP --- OSID+OSAPPID	√	×
Traffic Descriptors in URSP --- Match-all	√	×
Multiple URSP Rules --- URSP Rules Precedence	√	×
Single URSP Rules --- Route Selection Descriptor Precedence	√	×
Single URSP Rules --- Multiple Traffic Descriptors	√	×

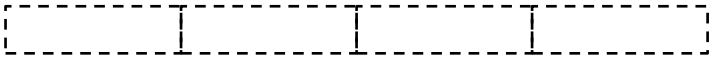
Multiple URSP Rules --- Concurrency of Multiple Services	√	×
Handover from 5GC to EPC	√	√
Redirection from EPC to 5GC	√	√
Handover from EPC to 5GC	√	√
Handover from 5GC to EPC, then Redirection back to 5GC	√	√
Handover from 5GC to EPC, then Handover back to 5GC	√	√
Notes: '√' indicates the test case is applicable to the DUT. '×' indicates the test case is NOT applicable to the DUT.		

2.2 Trial Results for Common Requirements

2.2.1 The Configuration and Usage of NSSAI

Based on the testing framework White Paper, some DUTs with the mainstream chipset platforms were tested. For the test cases of configuration and usage of NSSAI, 5G smartphones and 5G S-Modules were tested as shown in Table 2 and Table 3 respectively, where one box means one 5G smartphone or S-Module. Take the test case 'NSSAI Handling during Mobility Registration Update' in Table 2 as an example, four boxes as '  ' mean four 5G smartphones have executed this test case and two of them have successfully passed this test case.

Table 2: Test Cases of Configuration and Usage of NSSAI for 5G Smartphones

Test Cases	**Four 5G Smartphones**
NSSAI Handling in Initial Registration	
NSSAI Handling during Mobility Registration Update	
Default Configured NSSAI Pre-configuration and Update	

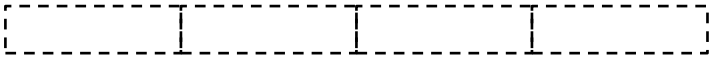
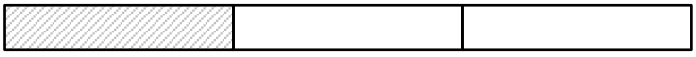
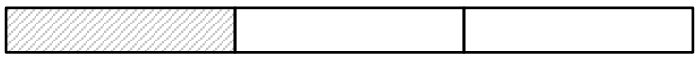
Generic UE Configuration Update for NSSAI	
NSSAI Inclusion Mode A	
NSSAI Inclusion Mode B	
NSSAI Inclusion Mode C	
NSSAI Inclusion Mode D	
Notes: ‘ ’ indicates the test case has been executed. ‘ ’ indicates the test case has been passed. ‘ ’ indicates the test case has NOT been executed.	

Table 3: Test Cases of Configuration and Usage of NSSAI for 5G S-Modules

Test Cases	**Three 5G S-Modules**
NSSAI Handling in Initial Registration	
NSSAI Handling during Mobility Registration Update	
Default Configured NSSAI Pre-configuration and Update	
Generic UE Configuration Update for NSSAI	
NSSAI Inclusion Mode A	
NSSAI Inclusion Mode B	
NSSAI Inclusion Mode C	
NSSAI Inclusion Mode D	
Notes: ‘ ’ indicates the test case has been executed. ‘ ’ indicates the test case has been passed. ‘ ’ indicates the test case has NOT been executed.	

Key Observations:

- The signalling test cases in this section are applicable for both 5G smartphones and 5G S-Modules.
- The DUTs, including 5G smartphones and 5G S-Modules, can successfully perform the initial registration to the 5G network with the requested NSSAI or not.
- Some DUTs can perform mobility registration update procedure with the requested NSSAI, while some test smartphones need to be further optimised.
- For the inclusion mode A/B/C/D test cases, four scenarios were tested for each mode, including the initial registration, mobility registration update, periodic registration update and service request. Some DUTs need to be further optimised in mobility registration update and periodic registration update scenarios.
- The network slicing parameter configuration of the devices has significant impact on the behaviour of the 5G devices in the network slicing test. It is necessary for the network and the devices to jointly decide on the network slicing parameter configuration.

2.2.2 UE Route Selection Policy

The test cases of URSP are different for 5G smartphones and 5G S-Modules. 5G smartphones and 5G S-Modules were tested as shown in Table 4 and Table 5 respectively, where one box means one 5G smartphone or 5G S-Module. Take the test case 'Update and Deletion of URSP' in Table 4 as an example, four boxes as '  ' mean four 5G smartphones have executed this test case and three of them have successfully passed this test case.

Table 4: Test Cases of UE Route Selection Policy for 5G Smartphones

Test Cases	Four 5G Smartphones
URSP Configuration in Initial Registration	
Update and Deletion of URSP	
Traffic Descriptors in URSP --- APPID	
Traffic Descriptors in URSP --- DNN	

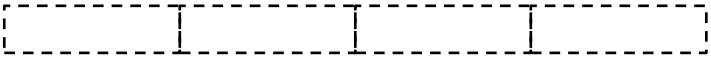
Traffic Descriptors in URSP --- IP	
Traffic Descriptors in URSP --- IP 3 Tuple	
Traffic Descriptors in URSP --- FQDN	
Traffic Descriptors in URSP --- OSID+OSAPPID	
Traffic Descriptors in URSP --- Match-all	
Multiple URSP Rules --- URSP Rules Precedence	
Single URSP Rules --- Route Selection Descriptor Precedence	
Single URSP Rules --- Multiple Traffic Descriptors	
Multiple URSP Rules --- Concurrency of Multiple Services	
Notes: ‘ ’ indicates the test case has been executed. ‘ ’ indicates the test case has been passed. ‘ ’ indicates the test case has NOT been executed.	

Table 5: Test Cases of UE Route Selection Policy for 5G S-Modules

Test Cases	**Three 5G S-Modules**
URSP Configuration in Initial Registration	
Update and Deletion of URSP	
Notes: ‘ ’ indicates the test case has been executed. ‘ ’ indicates the test case has been passed. ‘ ’ indicates the test case has NOT been executed.	

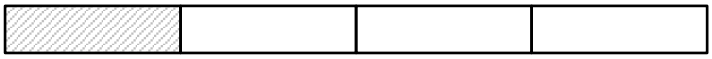
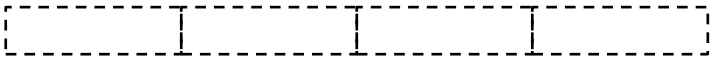
Key Observations:

- The test case applicability for 5G smartphones and 5G S-Modules in this section is different. Since the tested 5G S-Modules do not have applications, some test cases that need to use applications are NOT applicable to 5G S-Modules but only applicable to smartphones.
- The DNNs tested in this section are all standardised DNN, while customised DNNs need to be further considered.
- For 5G smartphones:
  - The URSP configuration and provision test was successfully completed.
  - For different types of traffic descriptors, all tested smartphones support using APPID, FQDN and IP 3 tuples to match URSP rules, and succeeded in establishing PDU session with the corresponding S-NSSAI in URSP rules.
  - All DUTs support the concurrency of multiple services with multiple network slices.
  - Not all the Traffic Descriptors provided in 3GPP specifications have been well supported, which need to be further promoted.
- For 5G S-Modules:
  - The URSP configuration, update and deletion tests were successfully completed.

2.2.3 Interworking with EPC

For the test cases of interworking with EPC, 5G smartphones and 5G S-Modules were tested as shown in Table 6 and Table 7 respectively, where one box means one 5G smartphone or 5G S-Module. Take the test case 'Handover from 5GC to EPC, then Redirection back to 5GC' in Table 6 as an example, four boxes as '  ' mean three of the four 5G smartphones have executed this test case and two of them have successfully passed this test case.

Table 6: Test Cases of Interworking with EPC for 5G Smartphones

Test Cases	Four 5G Smartphones
Handover from 5GC to EPC	
Redirection from EPC to 5GC	
Handover from EPC to 5GC	
Handover from 5GC to EPC, then Redirection back to 5GC	

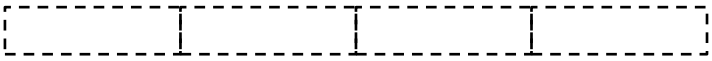
Handover from 5GC to EPC, then Handover back to 5GC	
Notes: ‘ ’ indicates the test case has been executed. ‘ ’ indicates the test case has been passed. ‘ ’ indicates the test case has NOT been executed.	

Table 7: Test Cases of Interworking with EPC for 5G S-Modules

Test Cases	**Three 5G S-Modules**
Handover from 5GC to EPC	
Redirection from EPC to 5GC	
Handover from EPC to 5GC	
Handover from 5GC to EPC, then Redirection back to 5GC	
Handover from 5GC to EPC, then Handover back to 5GC	
Notes: ‘ ’ indicates the test case has been executed. ‘ ’ indicates the test case has been passed. ‘ ’ indicates the test case has NOT been executed.	

Key Observations:

- All tested 5G S-Modules support handover from 5GC to EPC. Most tested smartphones support handover from 5GC to EPC, and only one tested smartphone needs further improvement for the handover from 5GC to EPC.
- Some tested 5G smartphones and 5G S-Modules support redirection from EPC to 5GC.
- Some tested 5G smartphones and 5G S-Modules can support handover from 5GC to EPC, then redirection back to 5GC. However, other tested devices need further optimisation.
- The support of the test cases in the interworking with EPC section needs to be further promoted.

2.3 Trial Results for Service Specific Requirements

2.3.1 Video Service

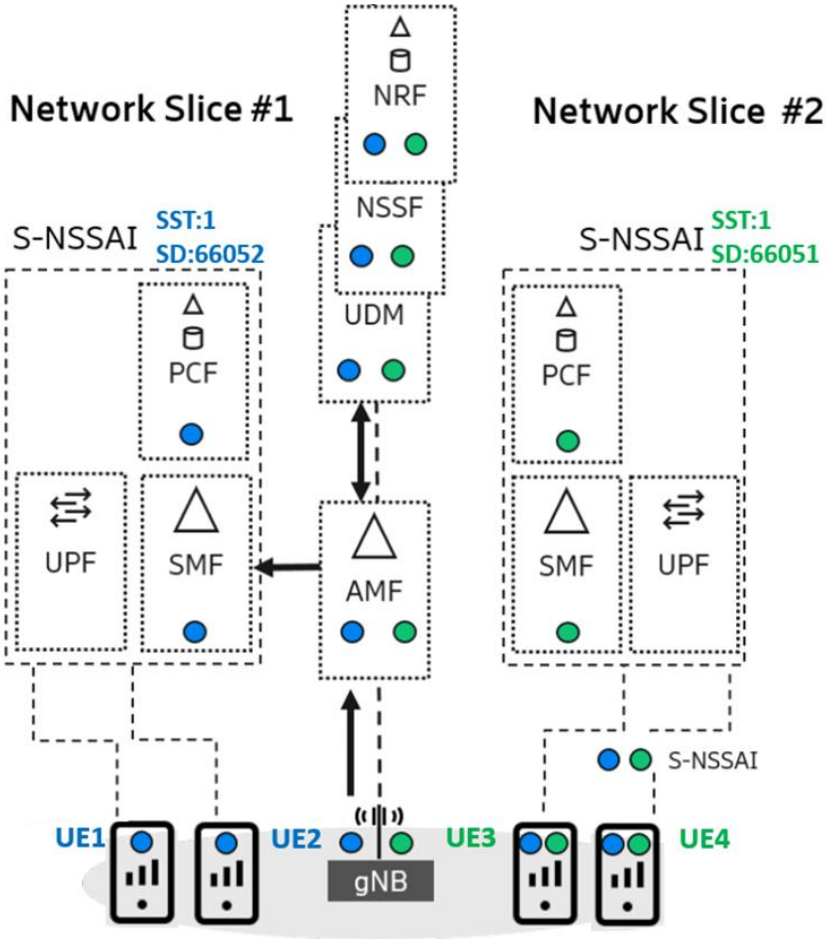


Figure 1: Network Topology for 5G Network Slicing Resource Reservation Test

Trial Setup:

- Attach UE1 and UE2 to Slice #1 (SST=1 & SD=66052)
- Attach UE3 and UE4 to Slice #2 (SST=1 & SD=66051)
- Make sure that Slice #1 and Slice#2 have the same priority, which means no dedicated resources are reserved for any of them either in Radio or in Core network

Key Observations:

- Initial State (without resource reservation):
  - UE1 and UE2 started a video call over Video Server application
  - After cell was loaded with high UL/DL traffic via UE3 and UE4, packet retransmissions were observed on video call service as in Figure 2. Packet retransmissions occurred due to lack of air interface resources.

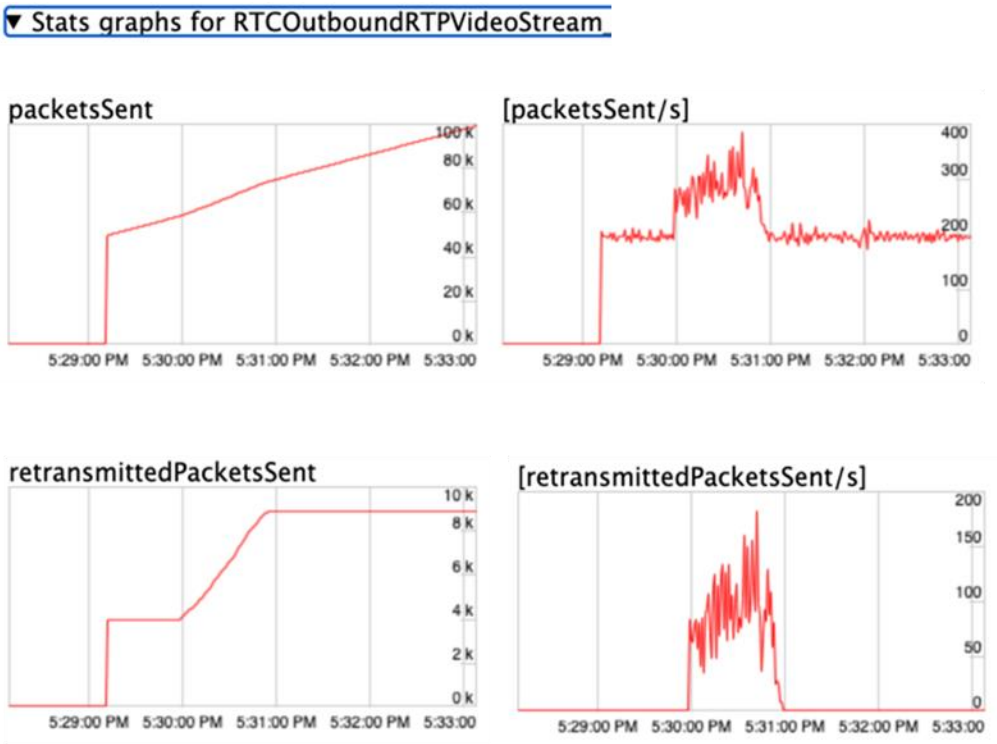
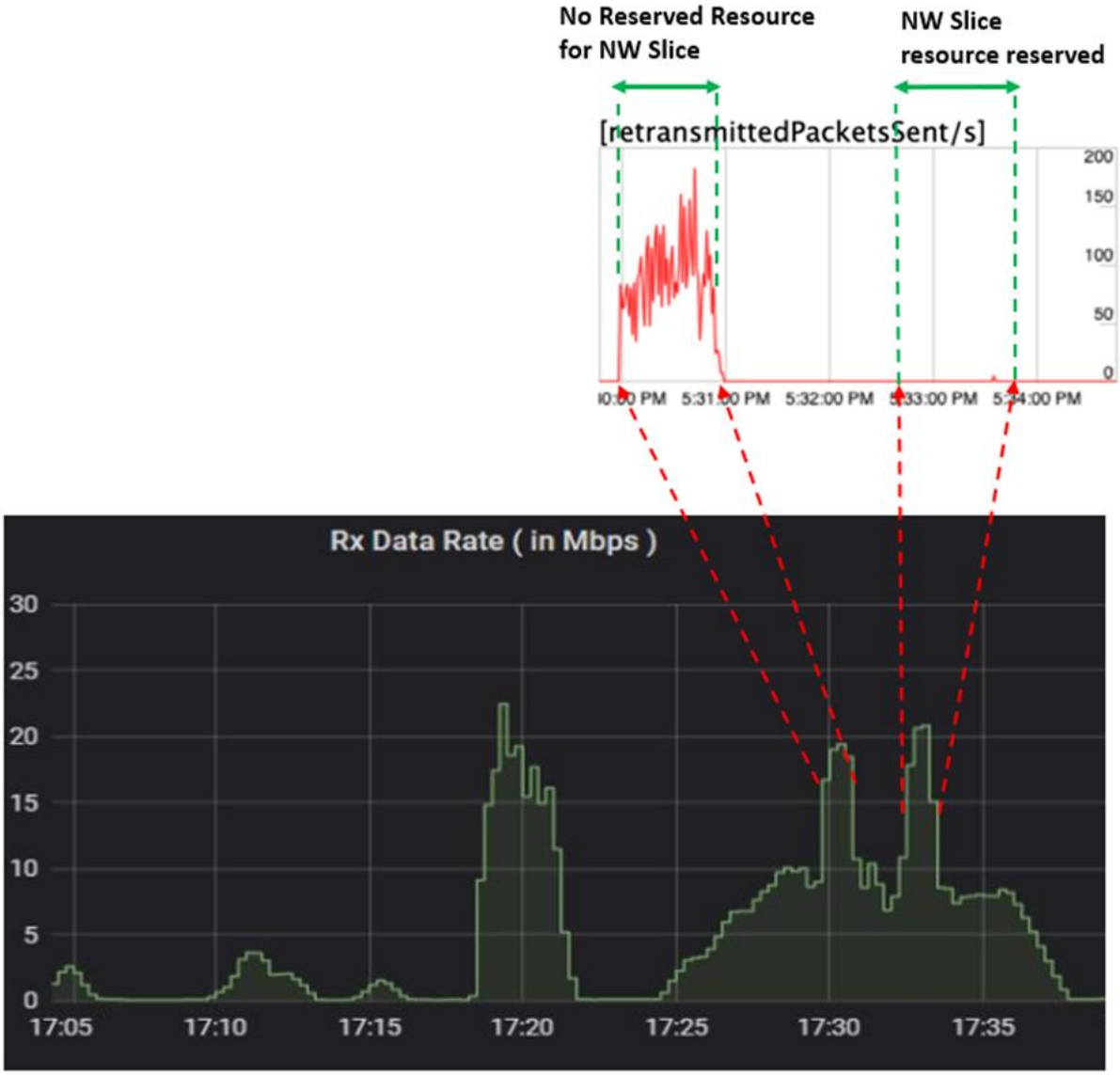


Figure 2: Retransmissions because of Packet Losses Observed between 5:30 PM and 5:31 PM

- Final State (with resource reservation):
  - Some air interface resources, e.g. 40% of Resource Blocks (RBs), were assigned to Slice#1 on gNodeB.
  - Then cell was loaded with high UL/DL traffic via UE3 and UE4 again. Because of dedicated resource per slice, no packet retransmissions were observed as in Figure 3.



Total User Plane Uplink Traffic

Figure 3: No Retransmissions between 5:33 PM and 5:34 PM after Second Traffic Load. After First Load, Retransmissions because of packet losses observed between 5:30 PM and 5:31 PM as in Figure 2

Conclusion:

- It is shown that when services are assigned to different network slices with dedicated resources assigned, QoS can be assured. Otherwise services are affected because of other traffic e.g. under high traffic load.

2.3.2 FTP/Speedtest Download Service

2.3.2.1 Radio Resource Reservation for Slice

Trial Setup:

- Similar test setup with video service slice reservation as in Figure 1
- Attach UE1 and UE2 to Slice #1 (SST=1 & SD=66052)
- Attach UE3 and UE4 to Slice #2 (SST=1 & SD=66051)
- Air interface resources, e.g. 40% of downlink RBs, were assigned to Slice#1 and 60% of downlink RBs were assigned to Slice#2 on gNodeB.
- NR cell capacity was intentionally reduced (e.g. lower MIMO order, lower modulation) to load cell easily during the test to make sure all the RBs were used. This is why lower maximum throughputs were observed during the test.

Key Observations:

- Slice #1 terminals (UE1 and UE2) got approximately 1,5 times lower DL throughput than Slice#2 terminals (UE3 and UE4) after resource reservation to slices as in Figure 4.
- It is shown that when air interface resources were assigned to specific network slices, the UEs got DL throughput proportional to the assigned RB resource ratio.

Figure 4: Slice #1 Terminals (UE1 and UE2) on the Left Side Approximately Get 1,5 times Lower DL Throughput than Slice#2 Terminals (UE3 and UE4) on the Right Side after Resource Reservation to Slices.

2.3.2.2 Core Throttling for Specific Slice

Network Topology:

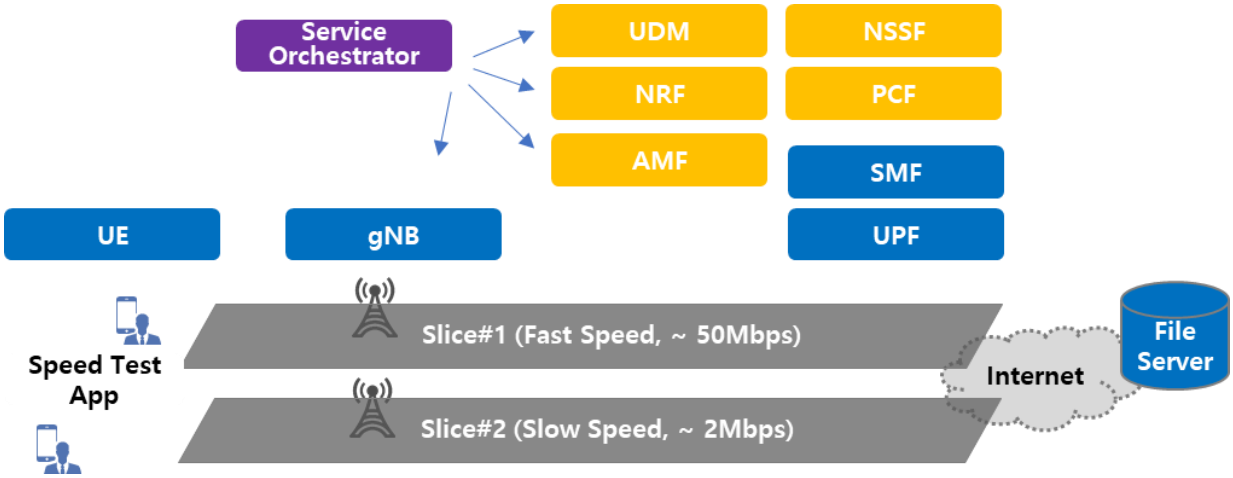


Figure 5: Network Topology for 5G Network Slicing in SK Telecom

The Service Orchestrator manages the slice template, SLA attribute, life cycle, and supports the fast network provisioning and network slice configuration of network functions for the B2C/B2B services which have different traffic characteristics.

UDM, NRF, NSSF and PCF have the network function information, network slice configuration and customers' subscription. The gNBs and core network equipments come from different vendors and jointly provide services to different network slices as defined by network slice policy and subscription of customers.

Speed Test App is capable of URSP defined by App-Id and can handle traffic route toward the network slice for the specific app service.

Trial Setup:

- Network Slice #1 (fast speed, ~ 50Mbps): URSP (set by DNN)
  - Traffic descriptor type = DNN
  - 5g.sktelecom.com
  - Default rule: downlink 50Mbps / uplink 50Mbps

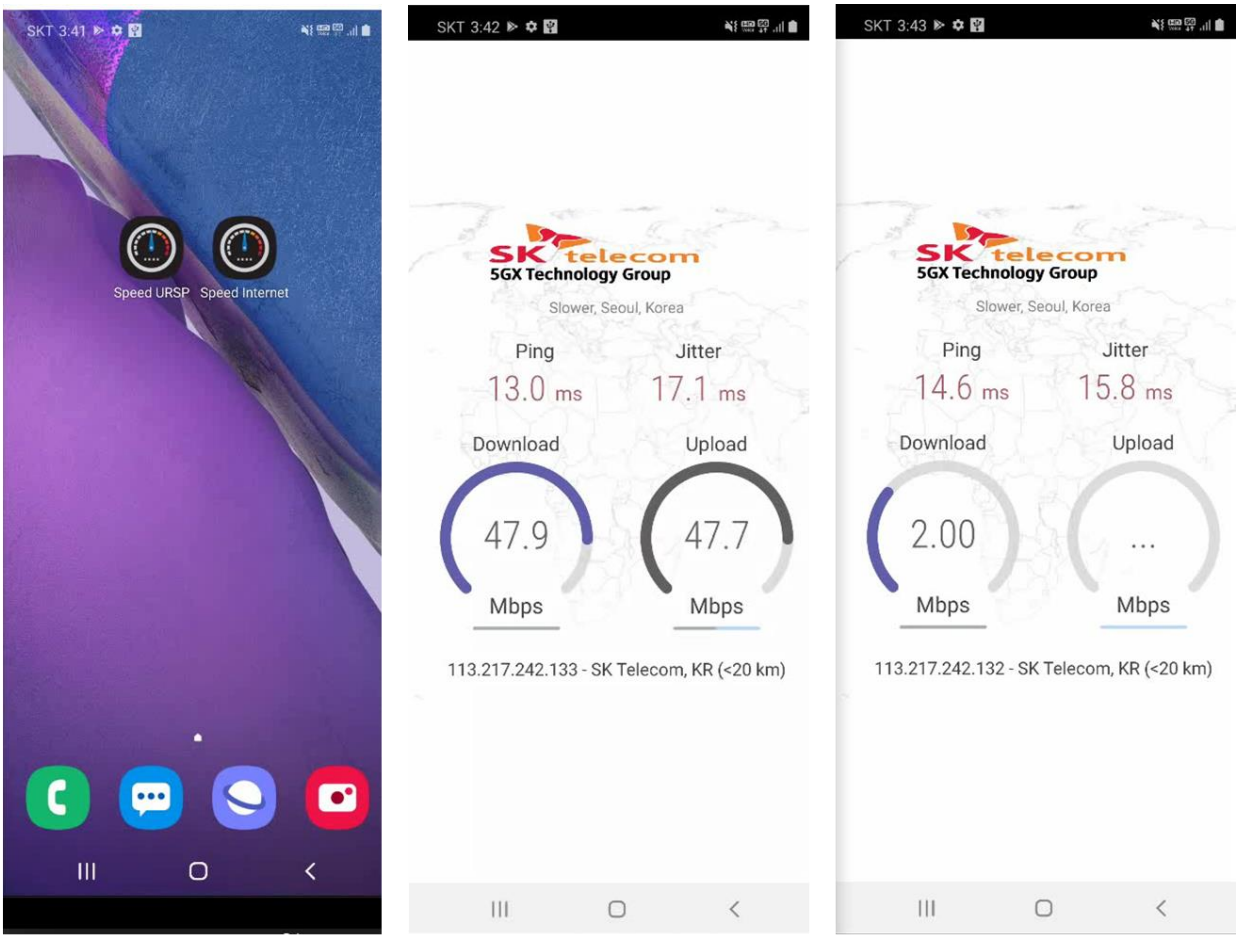
- Network Slice #2 (slow speed, ~ 2Mbps): URSP (set by App-Id)
  - Traffic descriptor type = OS APP ID
  - skt.speedtest.ursp
  - Default rule: downlink 2Mbps / uplink 2Mbps

- Speed Test App and File Server
  - Develop the speed test application for UE URSP test
  - Parsing the URSP and extracting the traffic descriptor to classify the traffic

Key Observations:

- Speed test app downloaded a file from the file server at a speed of approximately 47.9Mbps on network slice #1 which was defined by network slice policy of DNN.
  - Traffic descriptor type = DNN
- Speed test app downloaded a file from the file server at a speed of approximately 2Mbps on network slice #2 which was defined by network slice policy of App-ID.
  - Traffic descriptor type = OS APP ID

- "Speed URSP" App and "Speed internet" App worked simultaneously in the same UE.
- End-to-end service control was possible through the UE's service detections and specific network slice allocation function.



(a) Speed Test App (b) Network Slice #1 (Fast) (c) Network Slice #2 (Slow)

Figure 6: Speed Test Results

(a) Speed Test App

- "Speed Internet" App: Execute and test the DNN based DL/UL speed
- "Speed URSP" App: Execute and test the App-ID based DL/UL speed

(b) Network Slice #1

- DNN based network slice policy
- Downlink 50Mbps / uplink 50Mbps

(C) Network Slice #2

- App-ID based network slice policy
- Downlink 2Mbps / uplink 2Mbps

LIST OF ABBREVIATIONS

5GC	5G Core Network
5G S-Module	5G Superior Universal Module
DL	Downlink
DNN	Data Network Name
DUT	Device Under Test
EPC	Evolved Packet Core Network
FQDN	Fully Qualified Domain Name
MIMO	Multiple-Input Multiple-Output
NR	New Radio
NRF	Network Repository Function
NSSAI	Network Slice Selection Assistance Information
NSSF	Network Slice Selection Function
PCF	Policy Control Function
QoS	Quality of Service
RB	Resource Block
SLA	Service Level Agreement
S-NSSAI	Single Network Slice Selection Assistance Information
UDM	Unified Data Management
UL	Uplink
URSP	UE Route Selection Policy

REFERENCES

[1] NGMN Alliance, Definition of the Testing Framework for 5G Device Network Slicing Pre-commercial Trials, March 2022