

5G K-Simulator & 5G Device Test bench

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❖ Project:

» Research and Development of Open 5G Reference Model ('16.8 ~ '19.2, 31 months)

❖ Consortium:

» 9 Universities:

- KAIST, ChungnamNat. Univ., HankyongNat.Univ., HanyangUniv., Korea Univ., DonggukUniv., Seoul Nat. Univ., Yonsei. Univ., DankookUniv.

» 4 Institutes:

- KTL (Korea Testing Laboratory), TTA (Telecommunications Technology Association), GERI (Gumi Electronics & information technology Research Institute, KANI (Korea Association of Network Industries)



❖ Main Goal

Development of 5G Standard-based **Open Simulator Platform** and 5G Device **Test bench**

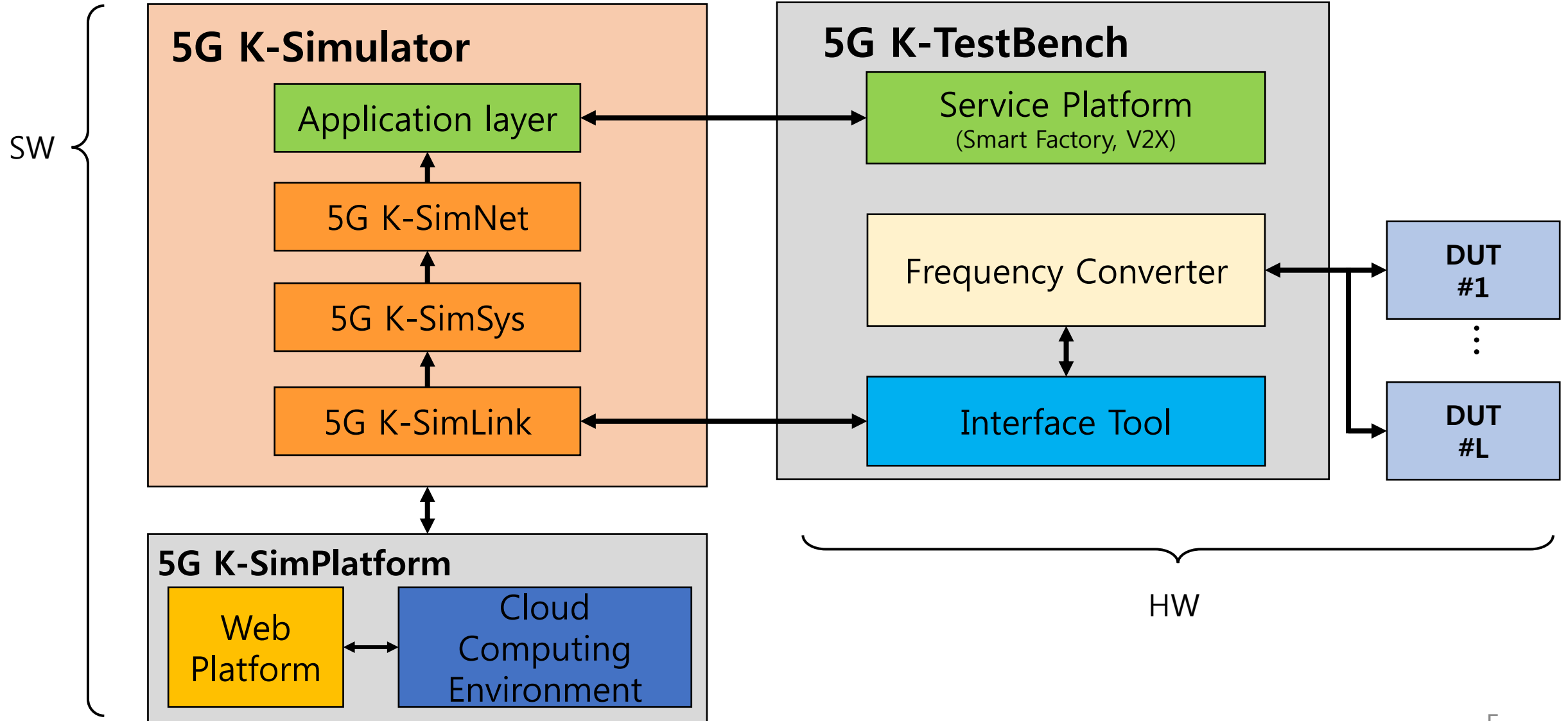
❖ Detailed Research Goals

» Development of 5G Simulators & Platform

- **5G K-SimLink, SimSys, SimNet** *FOM software architecture
- **Interpolation** between each simulators: 5G K-(SimLink-SimSys), (SimSys-SimNet)
- **5G K-SimPlatform**: web-based GUI & cloud computing environment

» Development of 5G Test bench

- mmWave RF devices testing environment using up/down converter
- 5G test bench evaluates the waveform generated from 5G K-SimLink

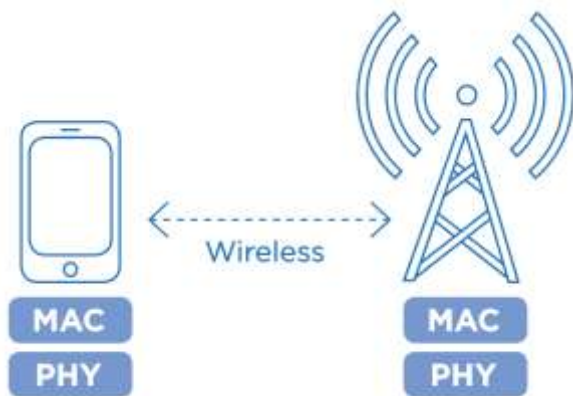


	Simulator	Characteristics				
		Code	User Manual	Platform	Cloud Computing	Accessibility (download/install)
A	LTE simulator (DL/UL LLS, DL SLS)	OPEN (C++)	○	X	X	△
B	5G Channel model	OPEN (C++)	○	○ (exe file)	X	△
C	LTE simulator	OPEN (C++)	△	X	X	△
5G K-Simulator : 5G WISE	5G simulator (DL/UL LLS, SLS, NS)	OPEN (C++)	○	○ (web-based)	○	○ (web-based)

5G K-SimLink

Link Level Simulator

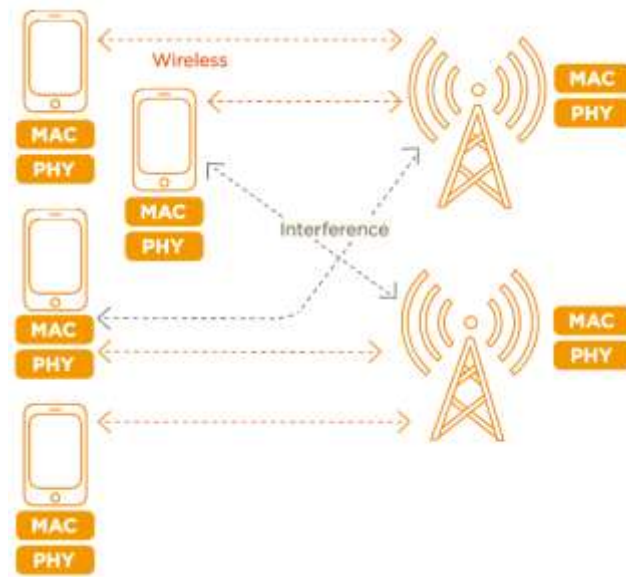
Single link: Single cell,
Single user



5G K-SimSys

System Level Simulator

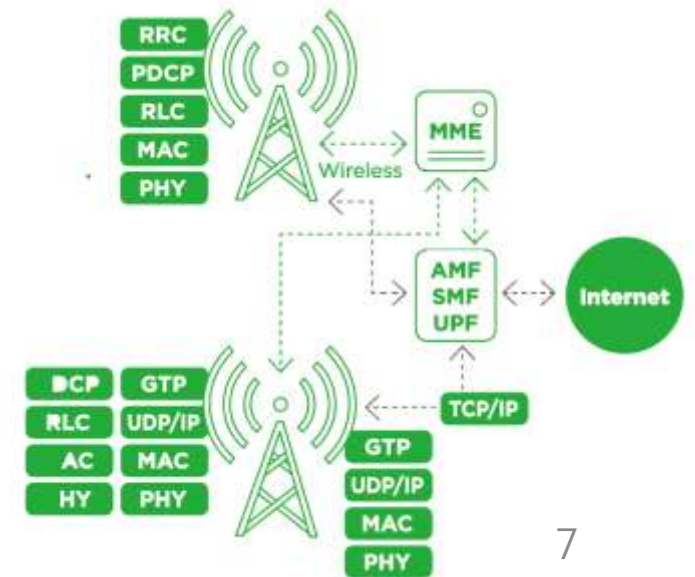
Multiple links: Multi-cells,
Multi-users



5G K-SimNet

Network Simulator

Core Network



❖ FOM (Flexible/ Open/ Modular) structure

Flexible *(Reconfigurable)*

- Fluidic architecture
- Functional abundance
- Simulator-level verification

Open *(implantable)*

- Web based open access (Domestic → Global)
- Documentation
- Interoperable database
- User Interface design
- Overall verification
- Annotation

Modular *(Reusable)*

- System architecture design
- Modular implementation
- Module-level verification

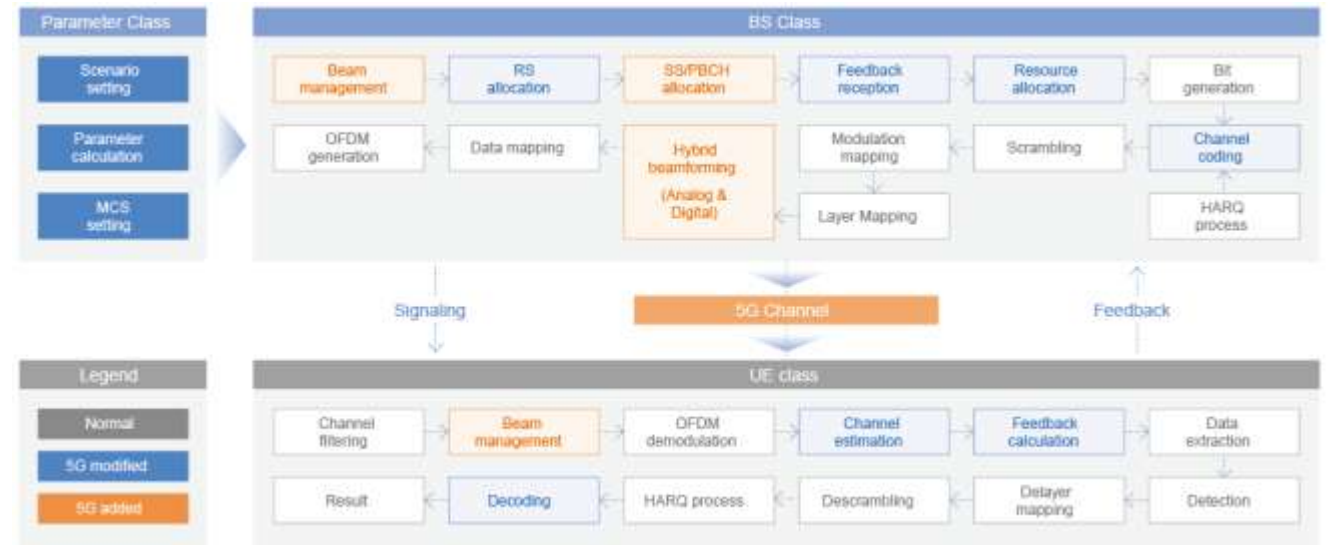
Extensible / Interoperable / Implementable

- Industrial dissemination
- Standardization

Features

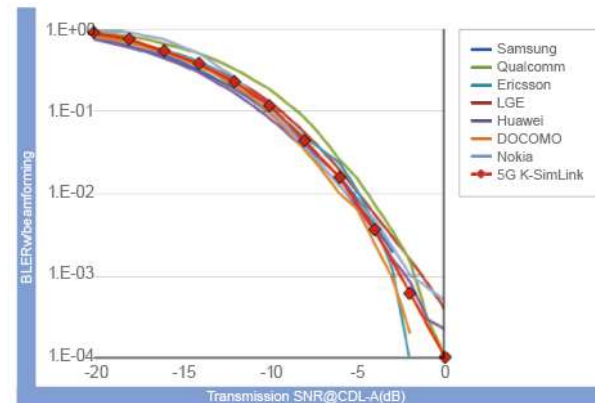
Category	Scope
Waveform	TS 38.211 based CP-OFDM, DFT-s-OFDM
Numerologies	TS 38.104, TS 38.211 based subcarrier spacing: • [15, 30, 60, 120] kHz
Reference signal	TS 38.211 based • DM-RS • CSI-RS • SRS
Channel coding	TS 38.212 based LDPC code
Hybrid Beamforming & Beam management	TS 38.214, R1-1707604 based • Wide-beam selection • Narrow-beam selection • Beamforming • Codebook precoding
Channel model	• AWGN • PedA, PedB, VehA, VehB • TS 38.901 based - CDL-A to E - TDL-A to E
Channel estimation	• Perfect • LS • MMSE
Detection method	• ZF • MMSE • Sphere decoding
Performance evaluation	• BLER, BER • Throughput • Calibration: TS 38.802, R101701823, R1-1703535 based BLER and CDF of received SNR

Structure



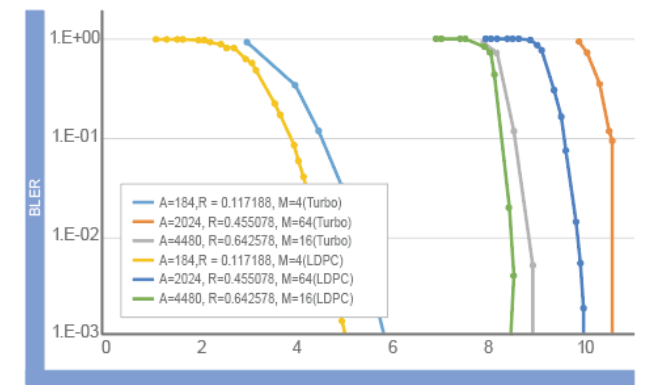
Calibration

Calibration for 5G data transmission for LLS



□ R1-1715254 Calibration results for Phase 2 NR MIMO link level calibration

Results: Channel coding LDPC (5G) vs Turbo code (LTE)

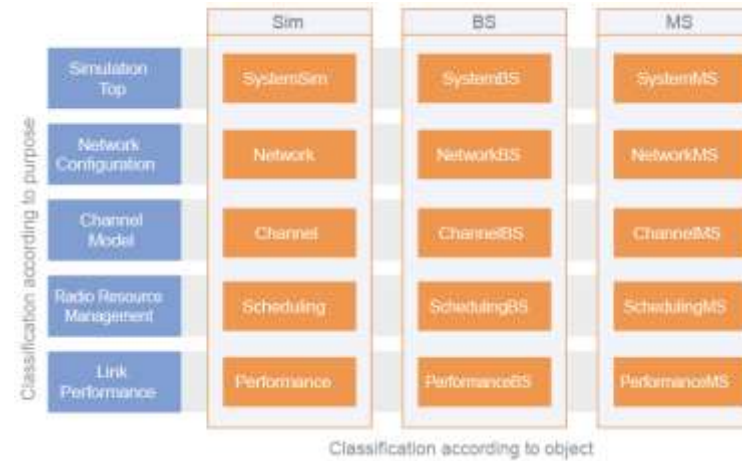


A: Payload size R: Code rate M: Modulation order

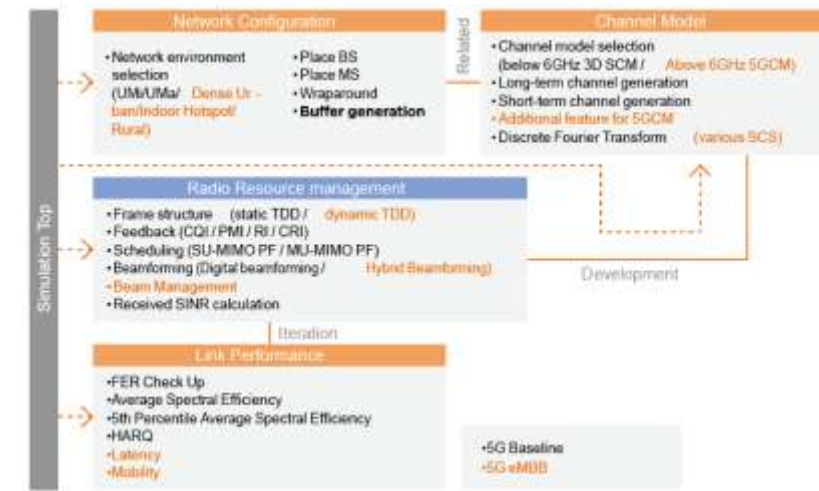
Features

Category	Scope
Network configuration	TR 38.802 based <ul style="list-style-type: none"> Indoor hotspot, Dense urban, Urban macro, Rural
Carrier frequency	TR 38.802 based <ul style="list-style-type: none"> 700MHz, 4GHz, 30GHz, 70MHz
Bandwidth	TR 38.802 based <ul style="list-style-type: none"> Up to 1 GHz
Channel model	TR 38.802, TR 38.901 based <ul style="list-style-type: none"> Below/above 6 GHz: Indoor hotspot, Dense urban, Urban macro, Rural
Hybrid Beamforming	TR 36.897 based <ul style="list-style-type: none"> Beamformed CSI-RS
Beam management	TR 38.802 based <ul style="list-style-type: none"> Beam determinant, Beam measurement, Beam reporting, Beam sweeping
Traffic mode	TR 38.802 based <ul style="list-style-type: none"> Full buffer, Non-full buffer model
Numerologies	TS 38.104, TS 38.211 based <ul style="list-style-type: none"> [15, 30, 60, 120, 240] kHz
Transmission scheme	TS 38.214 based <ul style="list-style-type: none"> DL, UL codebook/non-codebook

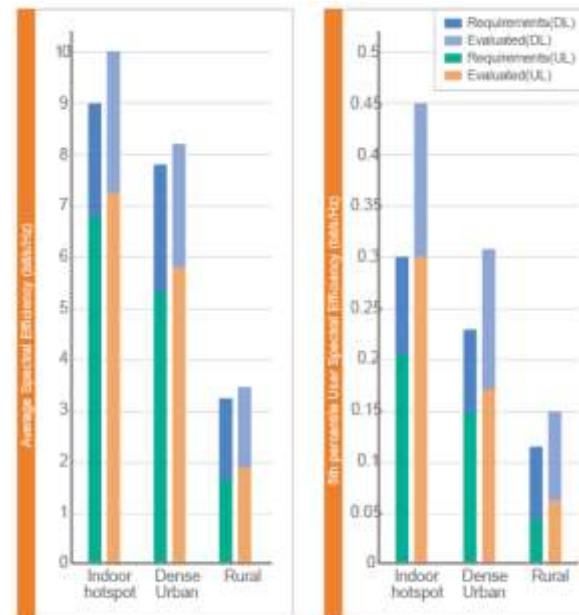
Software structure



Software structure

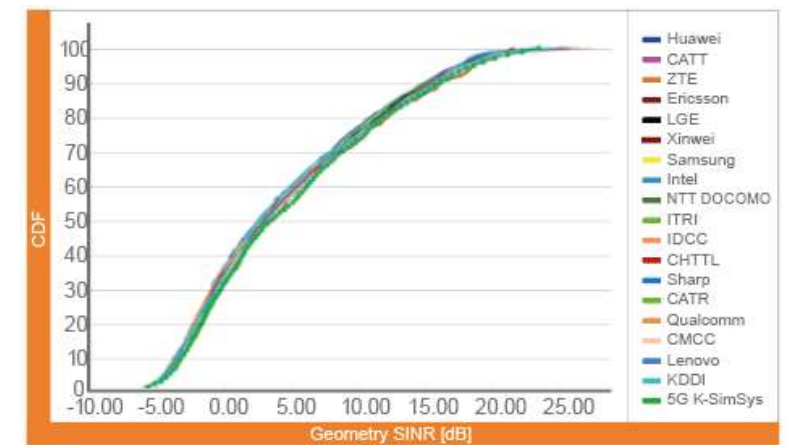


Results: example



<Simulation results for spectral efficiency: 5G eMBB scenarios>

Calibration: Phase 1 calibration – large scale parameter

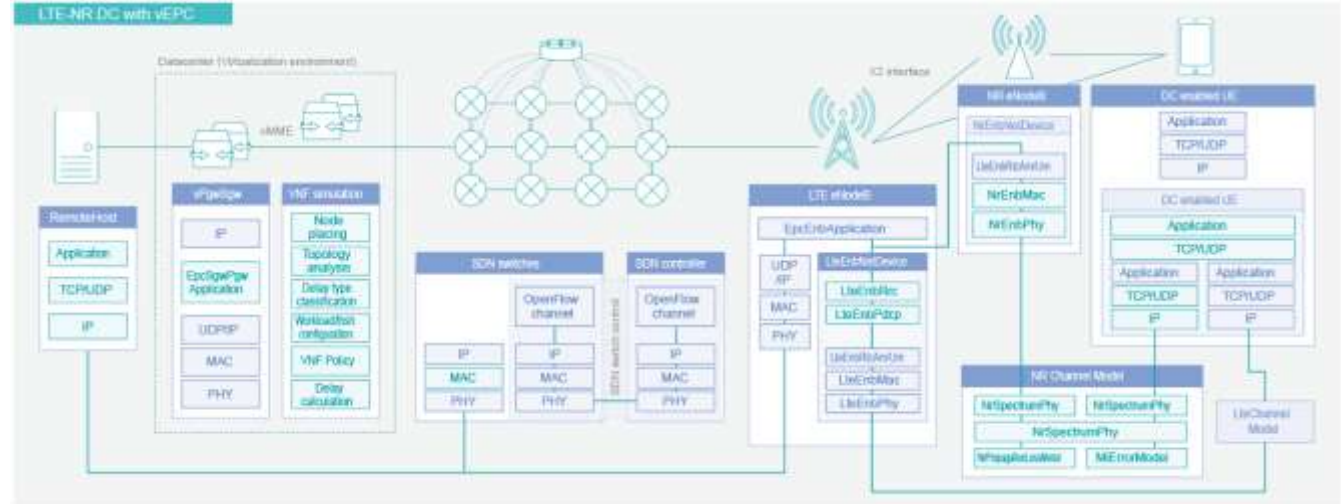


Features

Category	Scope
Dual connectivity	TS 37.340 based <ul style="list-style-type: none"> Alternative 3C and 1A
RRC Layer	<ul style="list-style-type: none"> New state for SN connection
PDCP Layer	TS 37.340 based <ul style="list-style-type: none"> PDCP reordering enabler/timer Splitting algorithms <ul style="list-style-type: none"> Splitting to single eNB Alternative splitting scheme to two eNB
Channel model	TS 38.901 based <ul style="list-style-type: none"> PathlossModel Scenario ChannelCondition OptionalNlos
X2 interface	<ul style="list-style-type: none"> Link data rate Link delay
Data center topology	<ul style="list-style-type: none"> Node location, Link bandwidth, Link edge node CDF of inter/intra ToR delay CDF of intra PM OVS forwarding
SDN	<ul style="list-style-type: none"> Inter-switch data rate Switch-gNB data rate Switch- GW data rate Output port group QoS weight
NFV	<ul style="list-style-type: none"> VM cpu, memory, disk, bandwidth, capacity VNF workloads Scaling policy VM provisioning delay

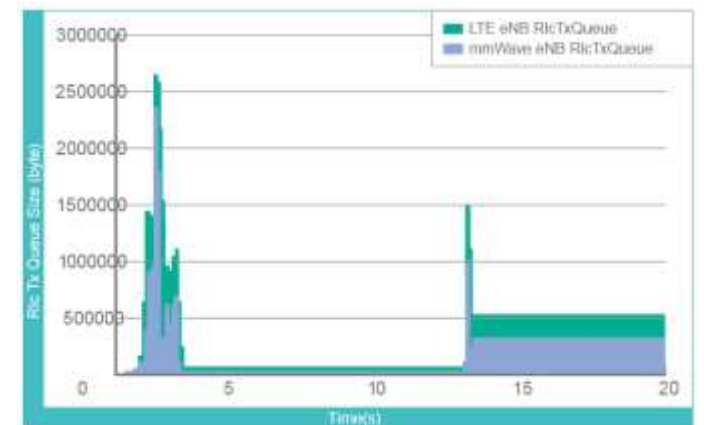
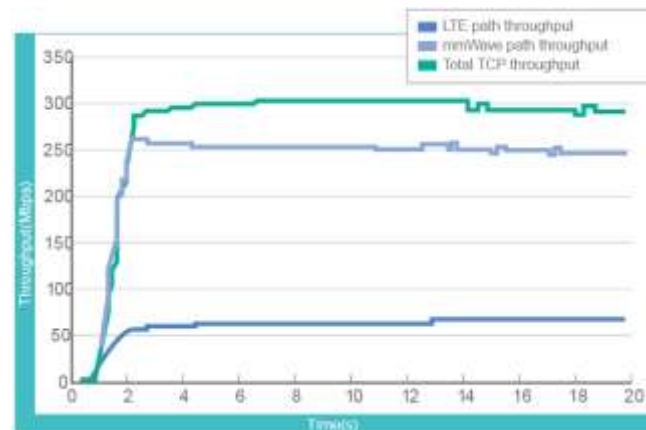
Structure

5G K-SimNet is being expanded from NS-3.



Results: examples

Performance of dual connectivity



❖ Function of 5G K-SimPlatform

» Education for students or beginner

- Easy to understand the structure of 5G K-Simulators (SimLink, SimSys, SimNet)

» Web-based platform

- Easy to access (Internet !)
- No need to download or install
- Possible to share the results between users

» Cloud computing environments

- Capable of providing fast simulations
- Independent on personal computing power

» History

- Capable of checking the previous simulation history.

» Export

- Capable of saving the output on the web to PC in raw data format and figure.

❖ <http://5gopenplatform.org/>



5G K-SimLink

- Scenario
 - Downlink SU-SISO
 - Downlink SU-MIMO
 - Uplink SU-SISO
 - Uplink SU-MIMO
- Performance metric
 - BLER/ Throughput

5G K-SimSys

- Scenario
 - eMBB (Urban macro, Rural)
 - eMBB (Dense Urban, Indoor hotspot)
 - uRLLC / mMTC
- Performance metric
 - BS, MS Beamforming
 - SE/ Throughput
 - Buffer Status/ MCS/ MU-MIMO Group

5G K-SimNet

- Scenario
 - Dual Connectivity
 - SDN/NFV
 - Handover
- Performance metric
 - Path throughput
 - RLC TX Queue Size/ Queuing Delay

❖ Example: 'Description' page

SLS main page description

5G-K SLS architecture

5G-K SLS consists of 15 modules and those modules are defined according to object and purpose. With respect to the purpose, there are simulation top, network configuration, channel model, radio resource management, link performance. And with respect to the object, there are Sim, BS, MS. The instance 'Sim' has these 5 instances and also the instance 'BS' and 'MS' has these 5 instances. By modifying or expanding the contents of these modules, users can evaluate their algorithm or schemes. If you want to get more information, please click the modules of picture.

	Sim	BS	MS
Simulation Top	SystemSim	SystemBS	SystemMS
Network Configuration	Network	NetworkBS	NetworkMS
Channel Model	Channel	ChannelBS	ChannelMS
Radio Resource Management	Scheduling	SchedulingBS	SchedulingMS
Link Performance	Performance	PerformanceBS	PerformanceMS

Network Configuration

Function :

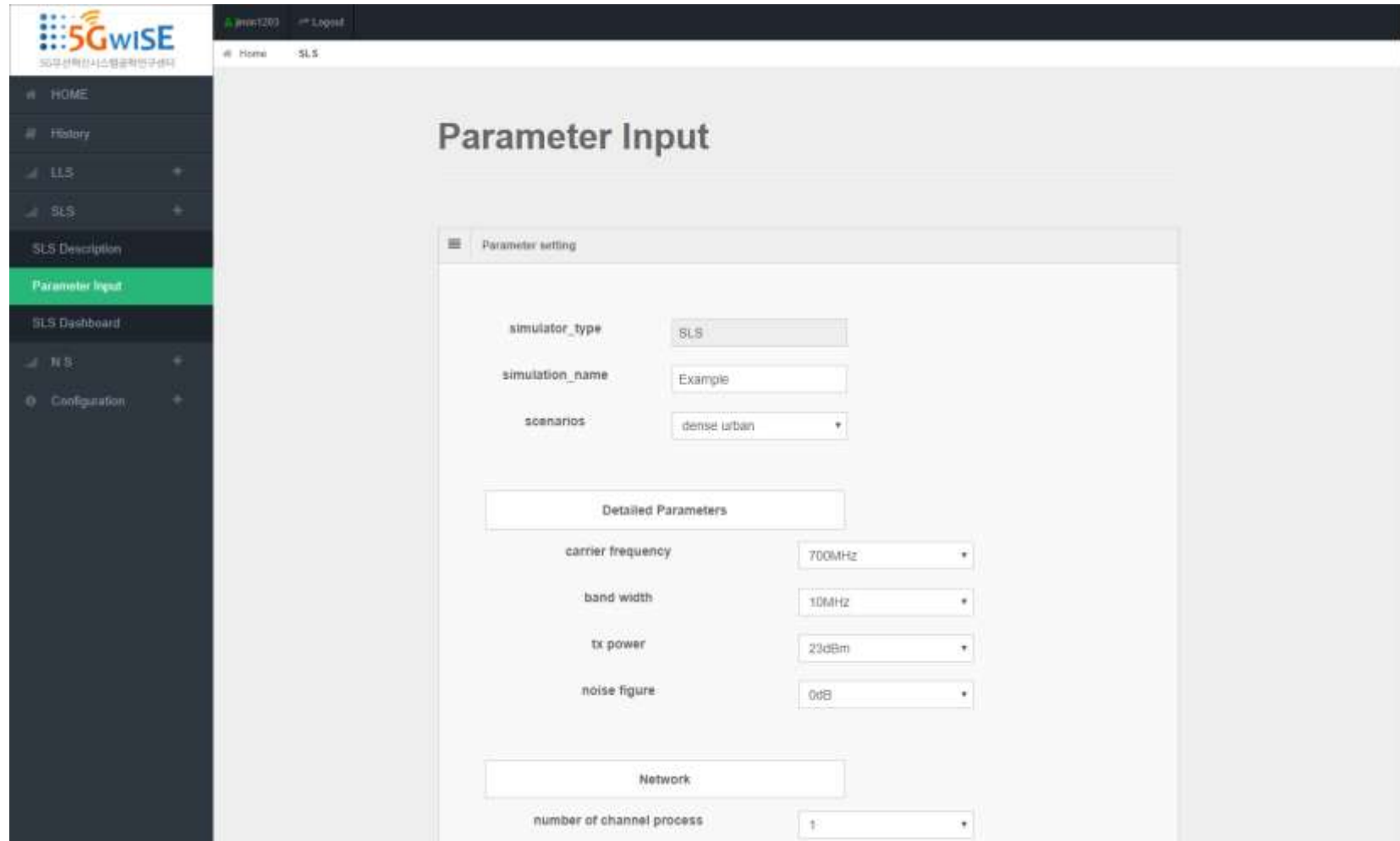
- BS/MS placement
- Mobility
- Association
- Admission control
- etc.

< Network Configuration >

Related Directory

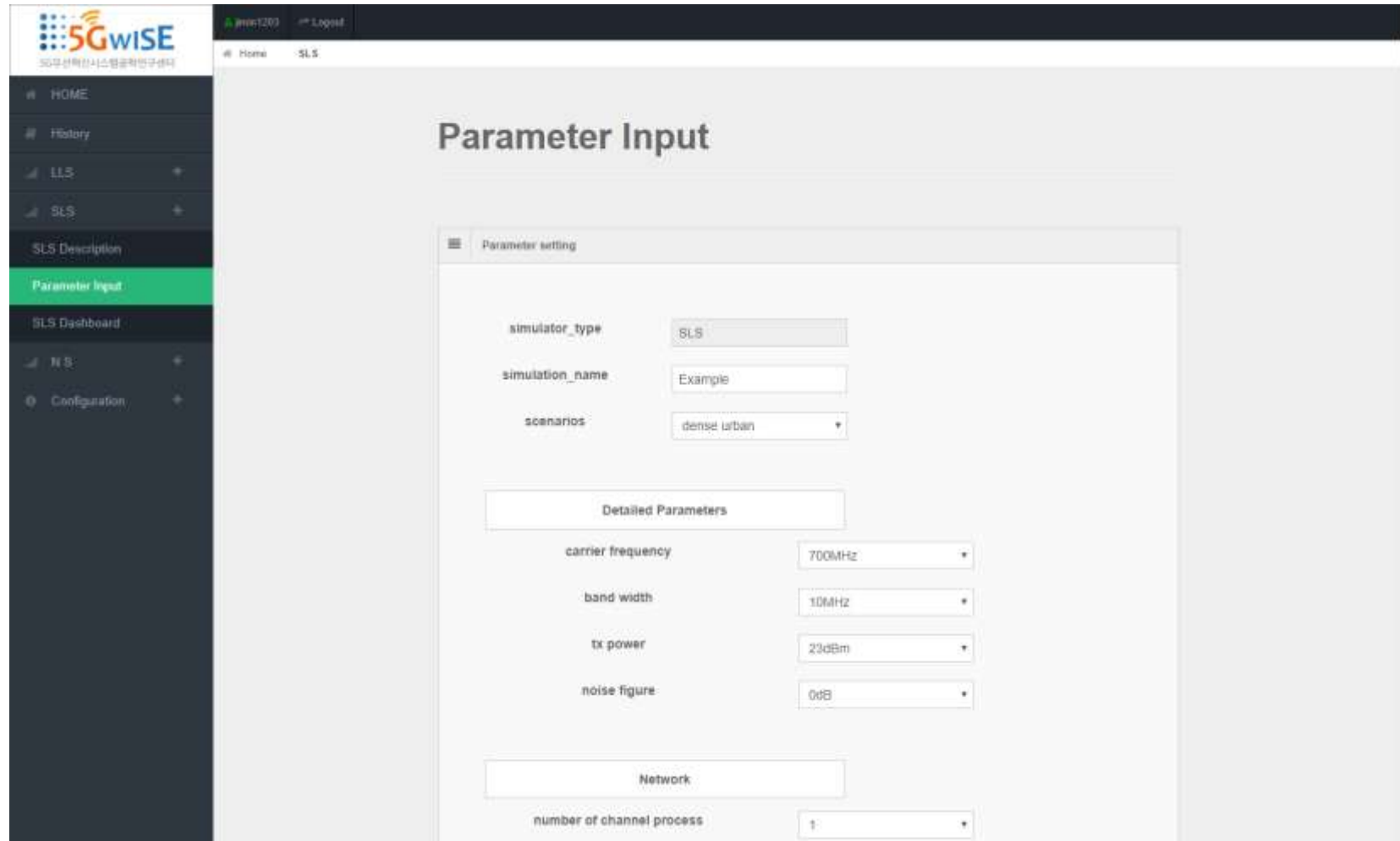
Simulator → Network Configuration → Call Assignment

❖ Example: 'Parameter Input' page



The screenshot displays the 'Parameter Input' page of the 5G K-SimPlatform. The interface includes a dark sidebar on the left with navigation options: HOME, History, LLS, SLS, SLS Description, Parameter Input (highlighted in green), SLS Dashboard, N S, and Configuration. The main content area is titled 'Parameter Input' and contains a 'Parameter setting' form. The form has three sections: 'Parameter setting' with fields for simulator_type (SLS), simulation_name (Example), and scenarios (dense urban); 'Detailed Parameters' with fields for carrier frequency (700MHz), band width (10MHz), tx power (23dBm), and noise figure (0dB); and 'Network' with a field for number of channel process (1). Each field is a dropdown menu.

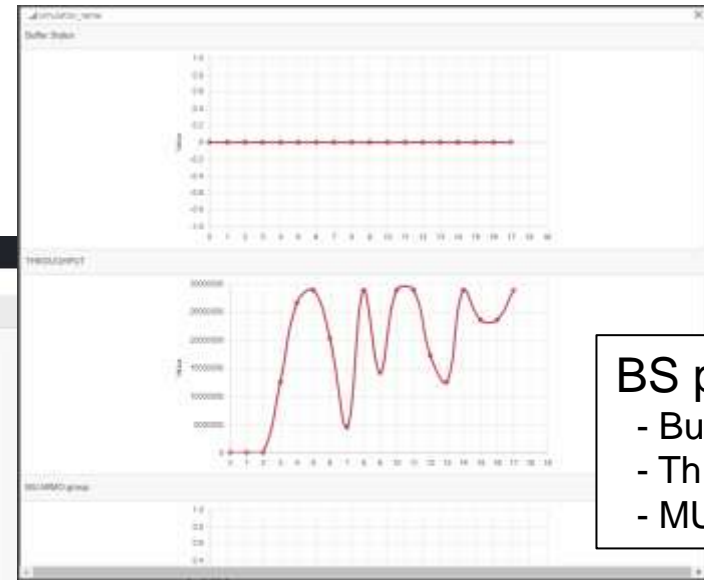
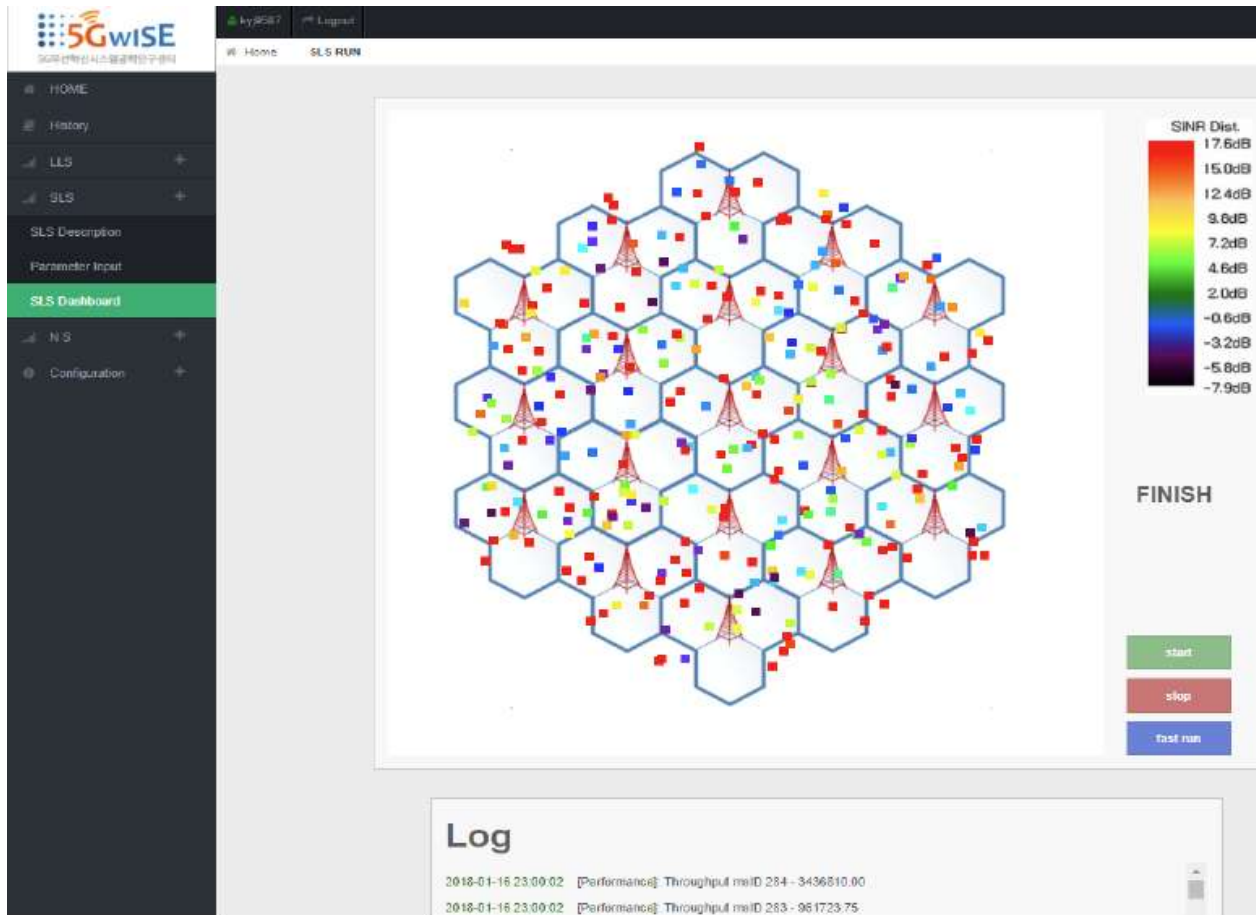
❖ Example: 'Parameter Input' page



The screenshot shows the 'Parameter Input' page of the 5G K-SimPlatform. The page is divided into a left sidebar and a main content area. The sidebar contains navigation links: HOME, History, LLS, SLS, SLS Description, Parameter Input (highlighted in green), SLS Dashboard, N S, and Configuration. The main content area is titled 'Parameter Input' and contains a 'Parameter setting' form. The form has three sections: 'Parameter setting', 'Detailed Parameters', and 'Network'. The 'Parameter setting' section includes fields for 'simulator_type' (SLS), 'simulation_name' (Example), and 'scenarios' (dense urban). The 'Detailed Parameters' section includes fields for 'carrier frequency' (700MHz), 'band width' (10MHz), 'tx power' (23dBm), and 'noise figure' (0dB). The 'Network' section includes a field for 'number of channel process' (1).

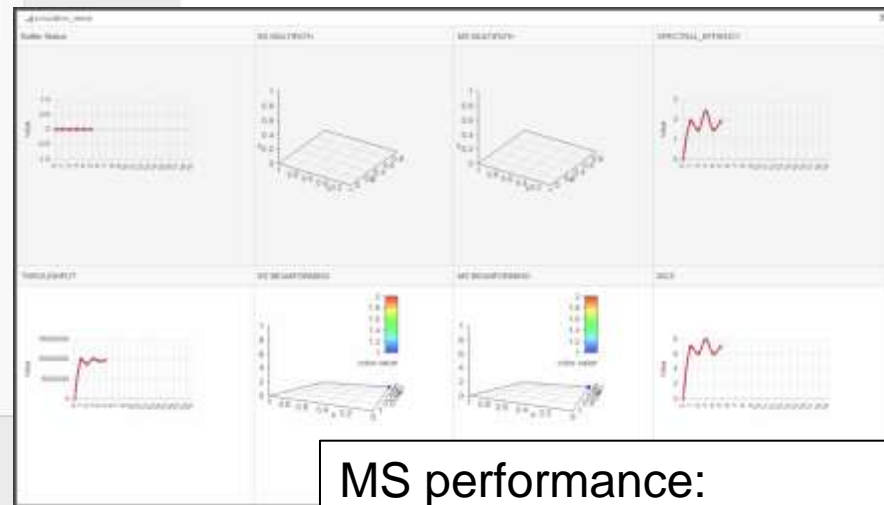
Section	Parameter	Value
Parameter setting	simulator_type	SLS
	simulation_name	Example
	scenarios	dense urban
Detailed Parameters	carrier frequency	700MHz
	band width	10MHz
	tx power	23dBm
	noise figure	0dB
Network	number of channel process	1

❖ Example: 'Dashboard' page



BS performance:

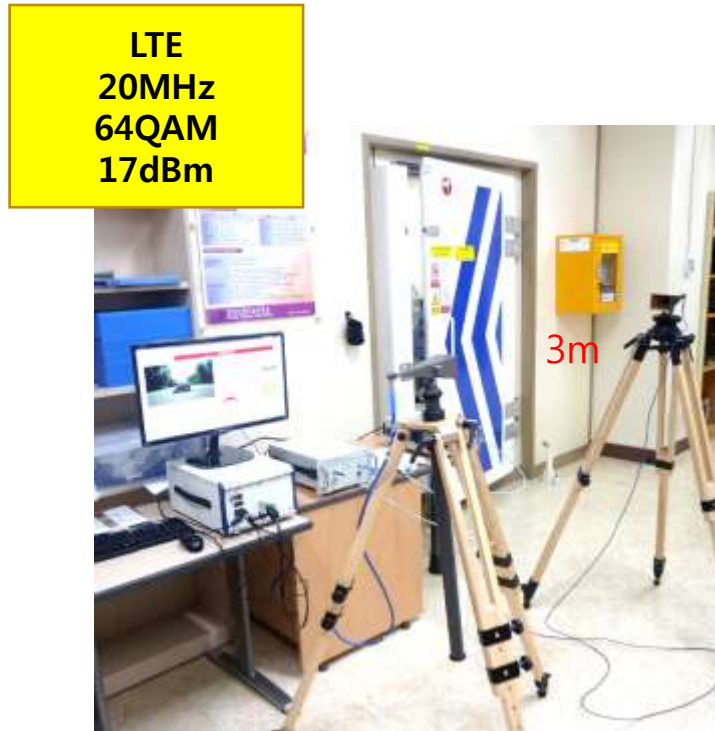
- Buffer status
- Throughput
- MU-MIMO group status



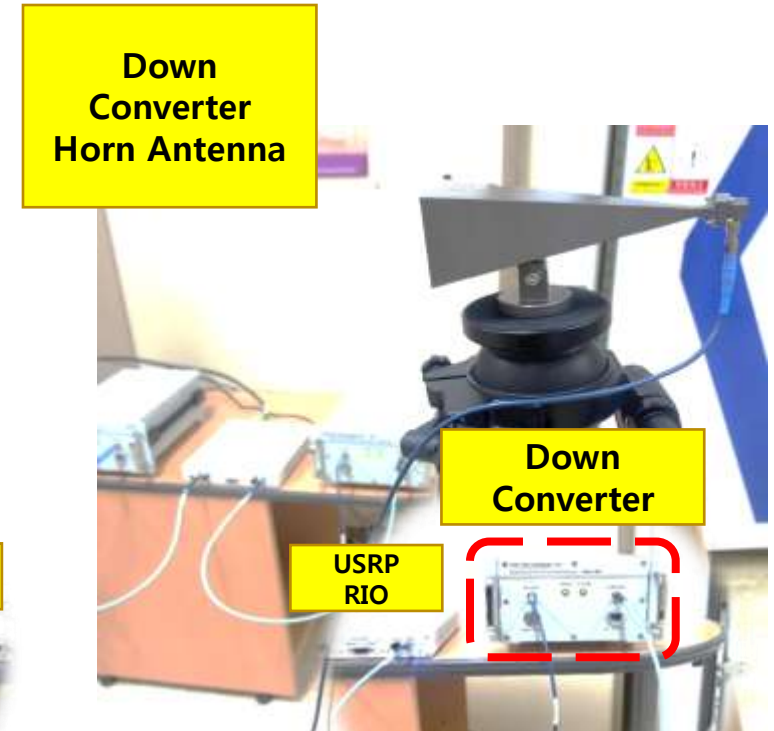
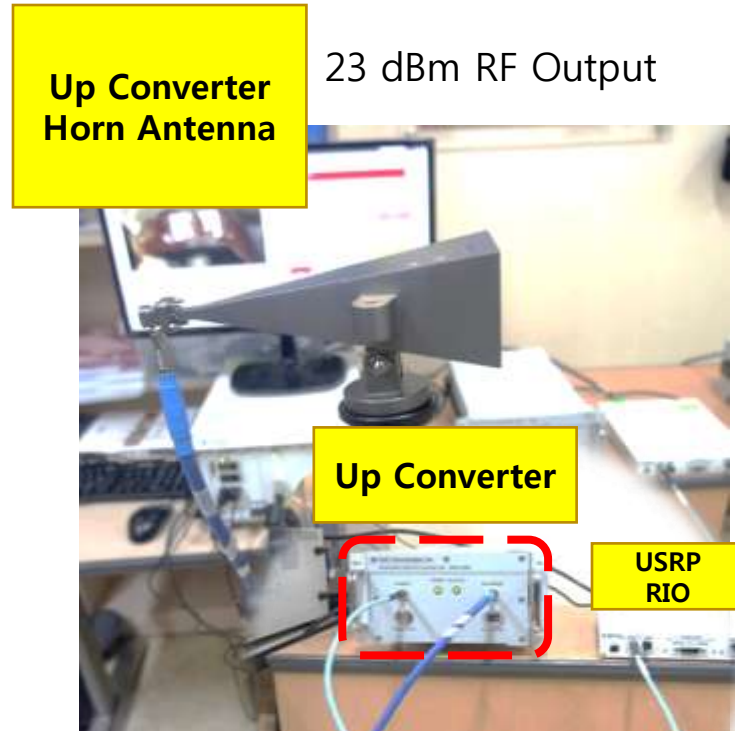
MS performance:

- Buffer status
- Throughput, Spectral efficiency
- Beamforming, MCS level

Utilizing NI USRP platform to build 5G Testbench with external Up/Down Converter for 28 GHz



Horn Antenna Gain : 25 dBi





Technical Aspects

- Enabling comparison & verification of 5G candidate technologies
- Enabling cumulative technology and saving human resources
- Sharing information and opinions using web-based services

Social Aspects

- Securing global leadership in international cooperation, including 5G international standardization group
- Improved quality of life by increasing telecommunication speed & enabling massive connections through 5G key technologies development

Industrial Aspect

- Strengthen competitiveness of SMEs through efficient component development/service verification
- Enabling activation various application & industries utilizing 5G mobile communications
- Development of application services of 5G based vertical industry & creation of added value

❖ Beta Test: '18.06 ~ '18.08

» 5G K-SimLink

- Language : MATLAB (MATLAB 2017a)
- Environment: Windows
- Scenarios: DL SU-SISO, DL SU-MIMO, UL SU-SISO, UL SU-MIMO

» 5G K-SimSys

- Language: C++ (Visual Studio 2015 (v140) compiler)
- Environment: Windows
- Scenarios: Urban macro, Dense urban, Indoor hotspot, Rural
 - 5G K-SimPlatform: Urban macro, Rural

» 5G K-SimNet

- Language: C++ (NS-3 ver. 3.28 based)
- Environment: Linux
- Scenarios: Multi-connectivity, Handover, SDN/NFV

❖ Workshop for beta test participants: '18.05.31

❖ Beta Test Report: '18.08.31