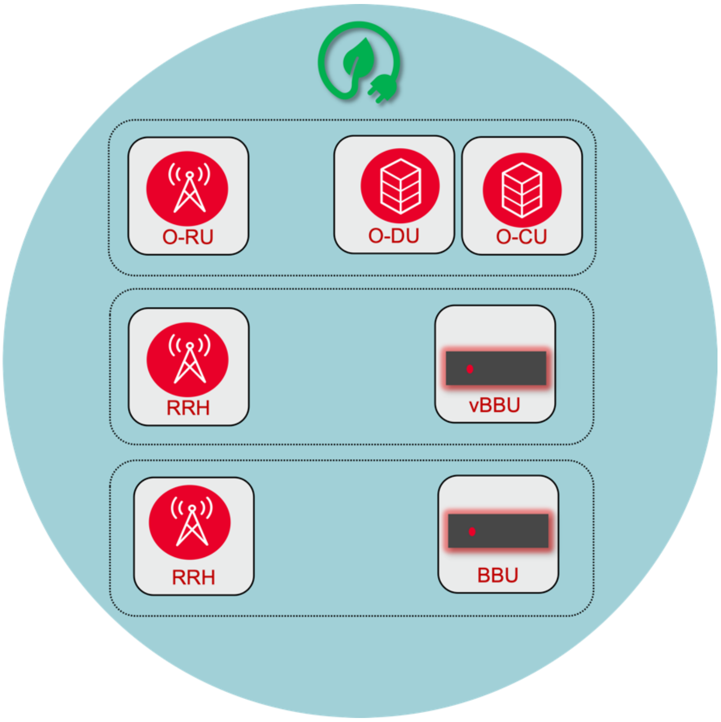
Energy Plane (E-Plane) Test Suites for RAN / vRAN / O-RAN

Measure Energy Consumption (EC) & Energy Efficiency (EE) in RAN/vRAN/O-RAN components and characterize Energy Savings (ES)

Introduction

The E-Plane ETSI Test Suites measure Energy Consumption (EC) and Energy Efficiency (EE) in O-RU (O-RAN Radio Unit), O-DU/O-CU (O-RAN Distributed/Central Unit), and gNodeB, based on ETSI standards. The E-Plane Design Test Suites go a step further to characterize the Energy Savings (ES) performance of O-DU/O-CU and gNodeB, using advanced data analytics and reporting. EC statistics are cross-correlated with traffic, platform performance, and quality of service to completely characterize the platform.



KEYSIGHT

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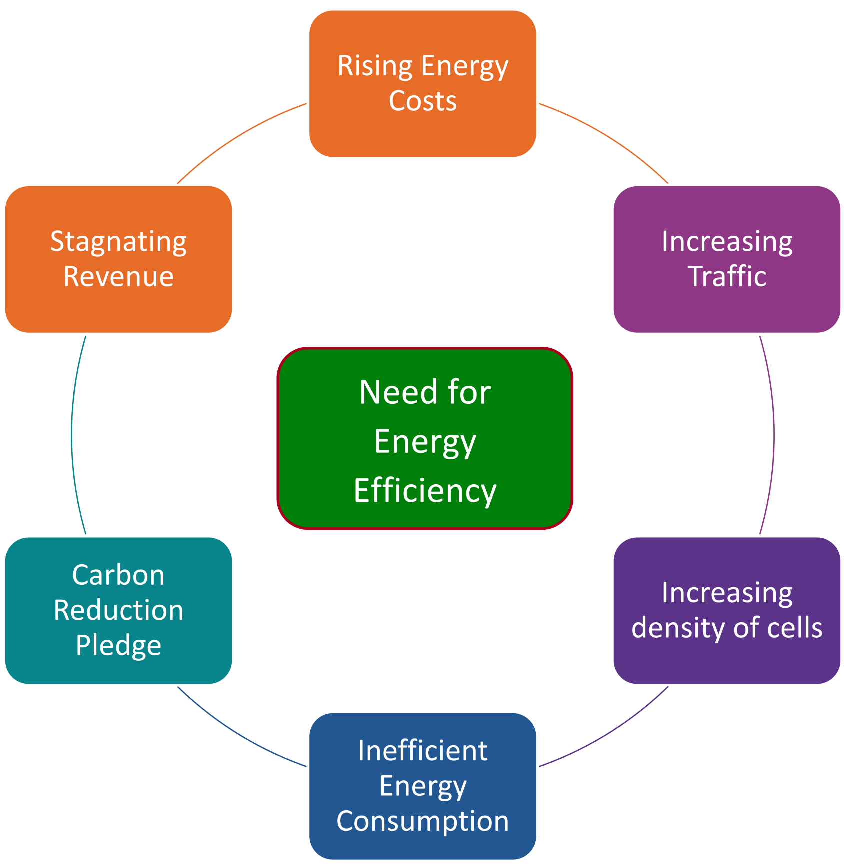
Overview

Why is Energy Efficiency becoming so important?

For calculating the energy used in a cellular network, the industry standard metric used is ***"number of bits transmitted per joule of energy used."***

As technology has progressed from 2G through to 5G, this number has improved considerably because of better and more efficient modulation techniques that improve the quality of transmitted signal while using less energy per bit. Although 5G transmission is far more efficient than 4G, energy consumption is expected to skyrocket if no efforts are made to check it, because cellular networks are expected to get denser, to support the increasingly higher data rates that are demanded by users. Energy consumption (EC) has become a key contributor to operators' OPEX and this is a global concern.



How Do We Calculate Energy Efficiency?

Let us define some of the commonly used phrases:

1. **Energy Consumption (EC):** Integral of power consumption over time
2. **Energy Savings (ES):** The difference between the EC needed to provide a certain service and the EC needed to provide the same service with energy saving mechanisms in place.
3. **Energy Efficiency (EE):** The relation between the useful output (Telecom services etc.) and Energy Consumption (EC)

A cellular network consists of the radio access network (RAN), the core network (CN) and all the supporting services. There are also all the mobiles within the network, all of them, consuming energy to operate.

This document shall concentrate on the energy that is used in the RAN which is made up of Base Stations (BS). In 3GPP 5G parlance, that would be gNodeB.

Point to note is, as RANs move towards disaggregation and virtualization, we also need to take into consideration vRAN (virtual RAN) and O-RAN based networks.

A Base Station is more energy efficient when doing more work with same energy, doing same work with less energy or in the best case doing more work with less energy.

Challenges to calculating Energy Efficiency

For networks based on O-RAN, the component systems undergo three step testing before being deployed.

O-RAN Conformance: Largely protocol domain testing involving some, or all of User Plane (U-Plane), Control Plane (C-Plane), Management Plane (M-Plane) and Synchronization Plane (S-Plane)

3GPP Conformance: When the O-RU is combined with the Distribution Unit (O-DU) and Centralized Unit (O-CU), to form gNodeB, the entire system undergoes RF domain (and performance) testing.

Energy Plane Testing: E-Plane testing combines power measurement with protocol and RF domains, requiring a cross-domain measurement system and cross-correlation of the data to gain meaningful insights into the overall energy performance of the RAN components.

The standards that govern the three types of testing above were developed in isolation and therefore it is necessary to have a unified framework to cover protocol domain, RF domain and E-Plane testing in the set-up, for maximum leverage of existing resources.

Benchmarking is a critical requirement for selection of network elements, and also for improving the equipment design, especially for better energy efficiency. So, established and standards-based methodologies and test vectors are required to facilitate benchmarking.

O-RAN and 3GPP are fast evolving standards and equipment manufacturers have to ensure continuing compliance of their products to the latest versions. Automation of the test cases and report generation is the key to ensure compatibility with the latest standards with regression testing.

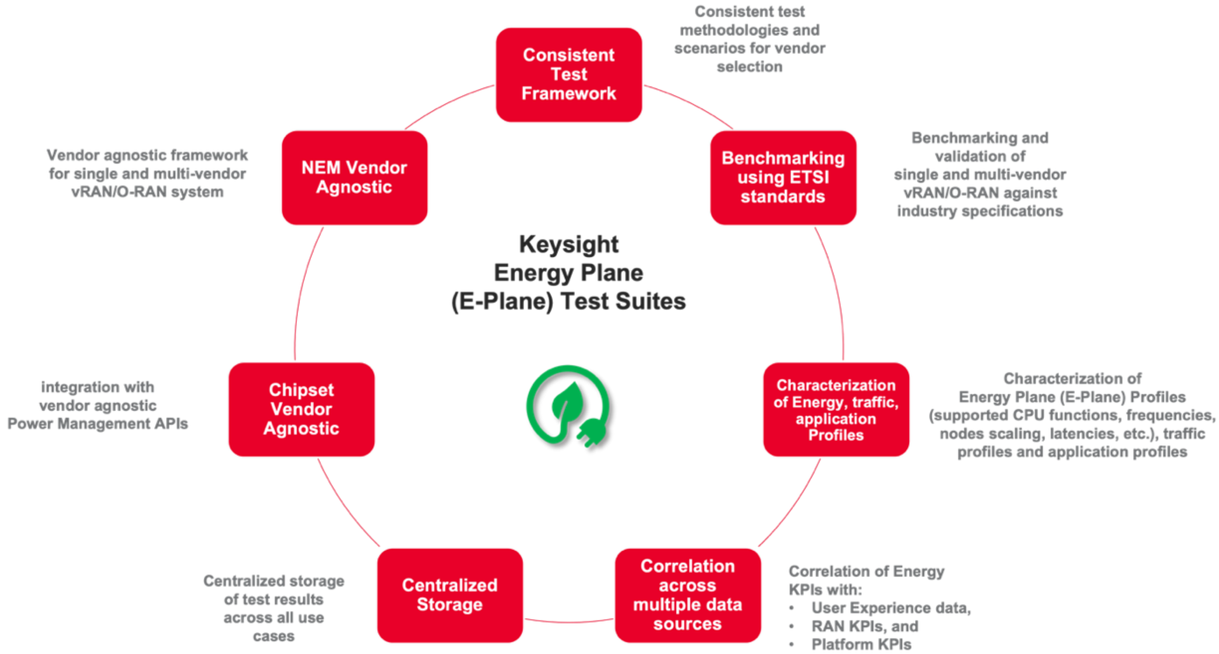
Keysight E-Plane Test Suite

There are 5 E-Plane Test Suites:

1. E-Plane ETSI Test Suite for O-RU
2. E-Plane ETSI Test Suite for O-DU/O-CU
3. E-Plane ETSI Test Suite for gNodeB
4. E-Plane Design Test Suite for O-DU/O-CU
5. E-Plane Design Test Suite for gNodeB

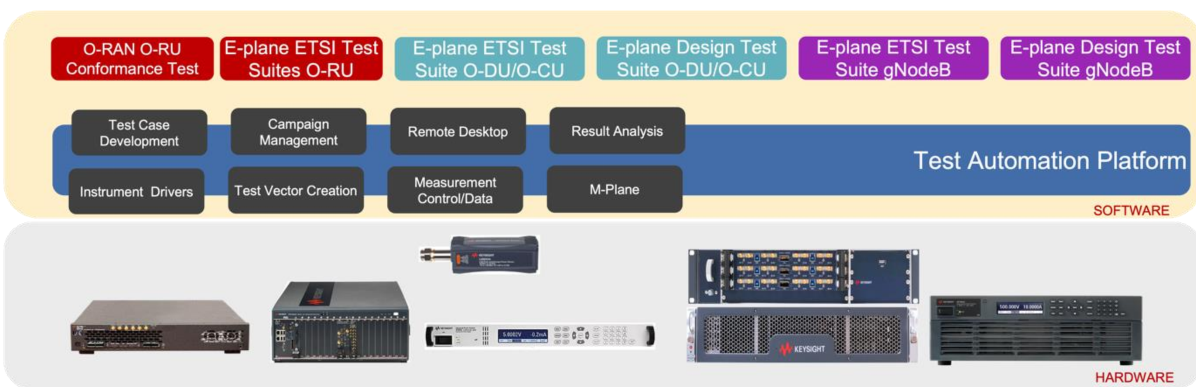
Highlights

- **Unified framework**: the E-plane Test Suites combine O-RAN, 3GPP, and E-Plane tests across protocol, RF, and energy domains with centralized data collection and cross-correlation of data to create measurement insights.
- **Based on ETSI standards**: RAN systems have a very wide range of performance classes. Thus, benchmarking of products from different vendors is not straight forward. Keysight has adapted ETSI standards for Base Station EC measurement to meet the test requirements of vRAN and O-RAN components, creating uniform test conditions for benchmarking.
- **NEM Vendor agnostic framework:** The Test Suites are based on static and dynamic traffic profiles from ETSI standards, and leverage the test set-up used for O-RAN conformance. The test framework is vendor agnostic and can be used for benchmarking equipment from multiple vendors
- **Chipset Vendor agnostic framework:** The Test Suites utilize Redfish statistics and power APIs that can be used across a broad range of chipsets without having to use any proprietary controls or methods of test.
- **Coverage of vRAN & O-RAN:** The Test Suites cover the main components of the vRAN/O-RAN: O-RU, O-DU+O-CU, or gNodeB, providing test coverage spanning from vRAN to O-RAN as the networks evolve.
- **Investment protection:** The E-Plane Test Suites leverage the O-RAN Conformance and 3GPP Conformance Test set-up.
- **Design Test Suites:** These enable characterization of E-Plane performance under changing CPU functions, node scaling, frequencies, latencies, and user experienced throughput. These also provide insights to maximize the Energy Saving (ES) performance of the equipment.



Structure of the E-plane test suites

The E-Plane Test suites leverage the test set-up used for O-RU conformance test as well as O-DU/O-CU functional and performance tests.



A unified software framework is used to control the instruments, develop test vectors, run test campaigns, manage the generated measurement data, and generate standards-compliant reports.

There is complete flexibility in the set-up, with the ability to include only the required hardware and software licenses for each Test Suite while keeping the framework intact.

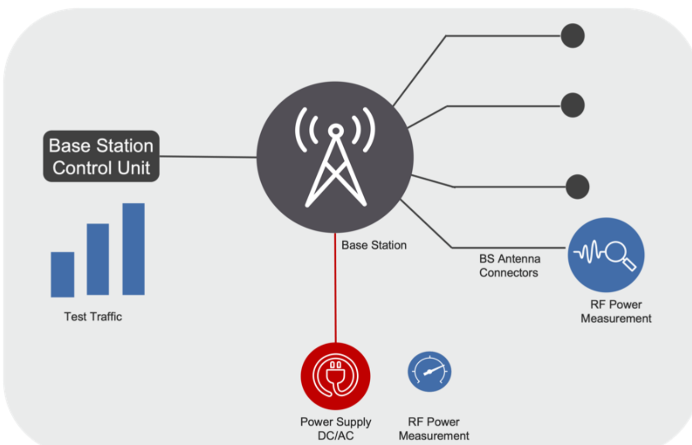
E-Plane ETSI Test Suite for O-RU

This is a set of automated test cases and analytics tool used to test the O-RU in isolation for EC, EE, and ES based on ETSI standard **ES 202 706-1**

ETSI test methodology

ETSI has two methods to calculate EE, based on static (ETSI **ES 202 706-1**) and dynamic traffic conditions (ETSI **TS 103 786**). In both methods, ETSI specifies the traffic models to be used to calculate EC under various conditions. The energy consumed by the Base Station (BS) is also measured and EE calculated.

Static traffic conditions



The BS is powered either by a DC or AC power supply and operated by the BS test control unit. This control unit provides the BS with control signals and traffic data which are required to perform the static measurements. Each RF output (antenna) connector is terminated with a dummy load. The RF output power is measured at each antenna connector and reported in the measurement report.

The RF output power, and corresponding input power consumption, are measured at the lower, mid and upper edge of the relevant radio band, for the Low load case. For Medium load and Busy Hour load, measurements are made only at middle frequency channel. For the evaluation, the single values as well as the arithmetic average of these three measurements, (only for low load) are stated in the measurement report. The arithmetic average is taken for BS reference power consumption evaluation.

Traffic conditions

Four types of 5G NR traffic loads are defined.

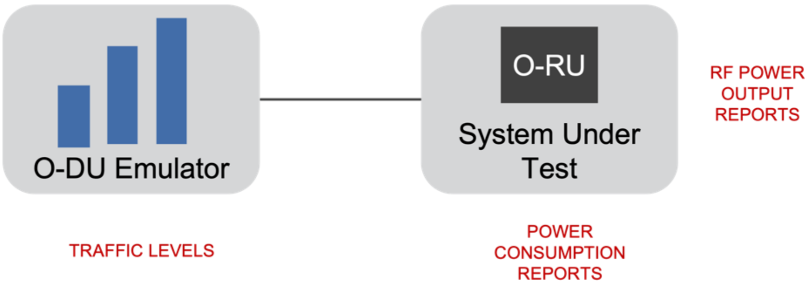
Low Load	Medium Load	Busy hour Load	Full Load
All REs dedicated to PBCH, PSS, SSS, and RMSI shall be transmitted	All REs dedicated to PBCH, PSS, SSS, and RMSI shall be transmitted	All REs dedicated to PBCH, PSS, SSS, and RMSI shall be transmitted	All resource blocks shall be transmitting.
REs dedicated to PDCCH and PDSCH (except RMSI) shall not be transmitted.	REs dedicated to PDCCH and PDSCH shall be limited as following: - 30 % of PRBs dedicated to PDSCH shall be transmitted in each 20 ms SSB set period. – For PDCCH, an amount corresponding to 2 PRBs per slot (~30 % of available PDCCH resources in NR-TM1.1) shall be transmitted in each 20 ms SSB set period. – Placement of PDSCH PRBs and PDCCH PRBs within the 20 ms SSB set period is free, but the average load over the period shall be 30 %.	REs dedicated to PDCCH and PDSCH shall be limited as following: - 50 % of PRBs dedicated to PDSCH shall be transmitted in each 20 ms SSB set period. – For PDCCH, an amount corresponding to 3 PRBs per slot (50 % of available PDCCH resources in NR-TM1.1) shall be transmitted in each 20 ms SSB set period. – Placement of PDSCH PRBs and PDCCH PRBs within the 20 ms SSB set period is free, but the average load over the period shall be 50 %.	

Measurements made

Power consumption measurements are then made for each load condition, Daily average power consumption measurements are made with traffic load defined in the ETSI specification, which is a combination of the 4 traffic load levels.

EE is defined as the ratio of output RF power to input DC power.

Test set-up



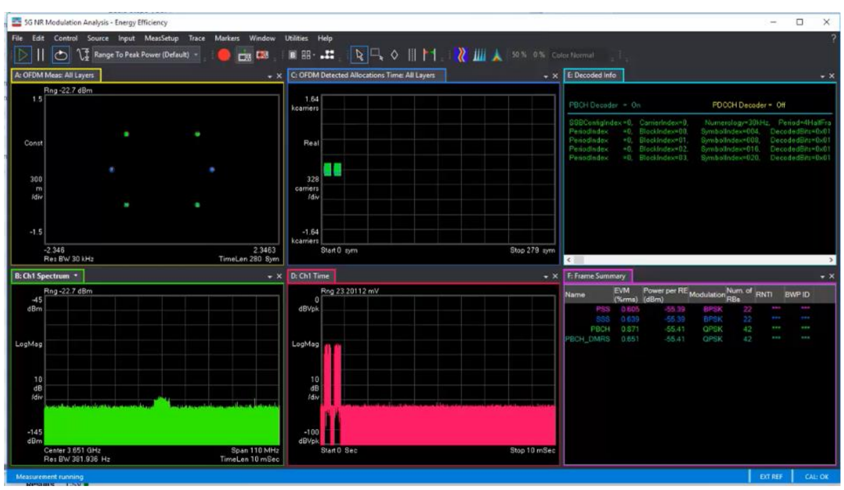
The static traffic model (ETSI **ES 202 706-1**) is adapted to suit O-RU testing by utilizing an O-DU emulator which generates the different traffic levels from the standard. A DC power supply provides power and makes measurements of the consumed power. The RF power output at the antenna connector port is measured using a RF power sensor.

For details of this test setup using Keysight equipment, please refer to the section: Test Set-up: For O-RU (Page 24)

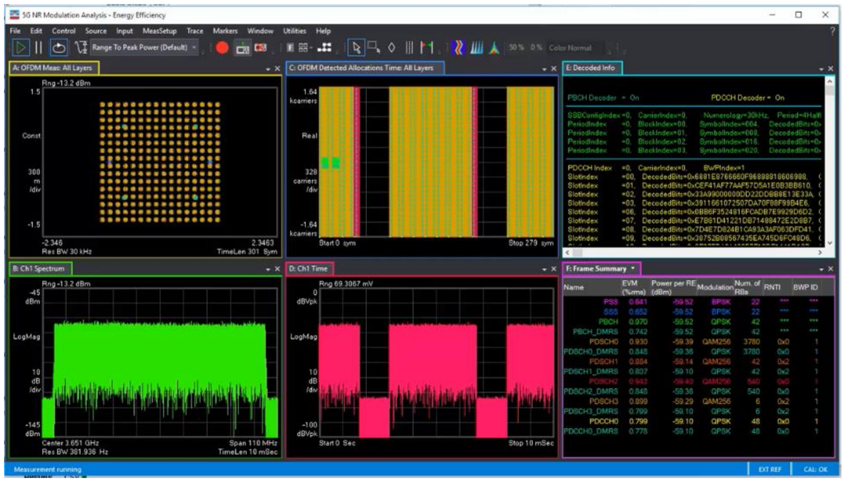
Traffic model generation

The O-DU emulator generates static traffic data corresponding to Low, Medium, and Busy hour traffic. Each level corresponds to set number of PRB allocations. Examples of Low and Busy hour traffic transmitted by the O-RU are seen as decoded by a Vector Signal Analyzer below

Low Traffic



Busy hour traffic



The VSA view above shows decoded constellation, signal spectrum, allocated PRBs, EVM per modulation type and decoded bits.

Measurement results

Following are samples of the automated test reports generated.

General Information

Table A.1: Test general information		
S.No	**Items**	**Remarks**
1	Test report reference and version	-
2	Date of the test	-
3	Standard Used as test methodology	-
4	Location of the test	-
5	Name of test organization and responsible person	-
6	**Tested equipment**	
6.1	Tested HW unit names and serial numbers	-
6.2	Software version of tested equipment	-
7	List of used measurements equipments including type, serial number and calibration information	-

O-RU reference Parameters

Table A.2: O-RU reference parameters to be reported			
S.No	**Parameter**	**Value**	**Unit**
1	**O-RU configuration**		
1.1	Number of sectors	-	
1.2	Nominal max RF output power per sector	-	W
1.3	**Number of Carriers per sector**		
1.3.1	Number of carriers the O-RU is able to support	-	
1.3.2	Number of carriers, for which the HW was enabled	-	
1.3.3	Number of carriers used during the test	-	
1.4	TX diversity	-	
1.5	RX diversity,(number)	-	
1.6	Type of RF signal combining	-	
1.7	Remote Radio Head (Yes/No)	-	
2	**Frequency**		
2.1	Downlink band	-	MHz
2.2	Uplink band	-	MHz
2.3	Channel bandwidth	-	MHz
2.4	Sub-carrier spacing (only for NR)	-	kHz
3	**Environment**		
3.1	Temperature range	-	°C
3.2	Type of air filter	-	
4	**Features**		
4.1	Power saving features	-	
4.2	Coverage and capacity features	-	
4.3	Downlink ciphering used? (Y/N)	-	

Table A.3: Daily load distribution profile to be reported			
S.No	**Load level duration**	**Value**	**Unit**
1	Low load duration/day (tlow)	-	h
2	Medium load duration/day (tmed)	-	h
3	Busy hour duration/day (tBH)	-	h

Table A.4: Measurements conditions and results to be reported			
S.No	**Parameter**	**Value**	**Unit**
1	**Test environment**		
1.1	*Temperature during test (measured)*		*°C*
1.2	*Pressure (measured)*		*kPa*
1.3	*Relative humidity (measured)*		*%*
2	**Frequency used at test**		
2.1	downlink Centre frequency of low end channel	-	MHz
2.2	downlink Centre frequency of middle channel	-	MHz
2.3	downlink Centre frequency of high end channel	-	MHz
2.4	*Uplink Centre frequency of middle channel*		*MHz*
3	**Supply voltage**		
3.1	DC voltage (measured)	-	V
3.2	*AC voltage (measured, phase to neutral)*		*V*
3.3	*AC frequency (measured)*		*Hz*
4	**Static power consumption (measured)**		
4.1	Full load, Middle frequency channel	-	W
4.2	Busy hour load, Middle frequency channel	-	W
4.3	Medium load, Middle frequency channel	-	W
4.4	**Low load**		
4.4.1	Low end frequency channel	-	W
4.4.2	Middle frequency channel	-	W
4.4.3	High end frequency channel	-	W
4.4.4	Average consumption with low load	-	W
5	**RF output power**		
5.1	Full load, Middle frequency channel	-	W
5.2	Busy hour load, Middle frequency channel	-	W
5.3	Medium load, Middle frequency channel	-	W
5.4	**Low load**		
5.4.1	RF output power at low end channel	-	W
5.4.2	RF output power at middle end channel	-	W
5.4.3	RF output power at high end channel	-	W
5.4.4	Average RF output power with low load	-	W
6	*RX receiver sensitivity at middle channel*		*dBm*
7	*Expanded uncertainty*		*%*

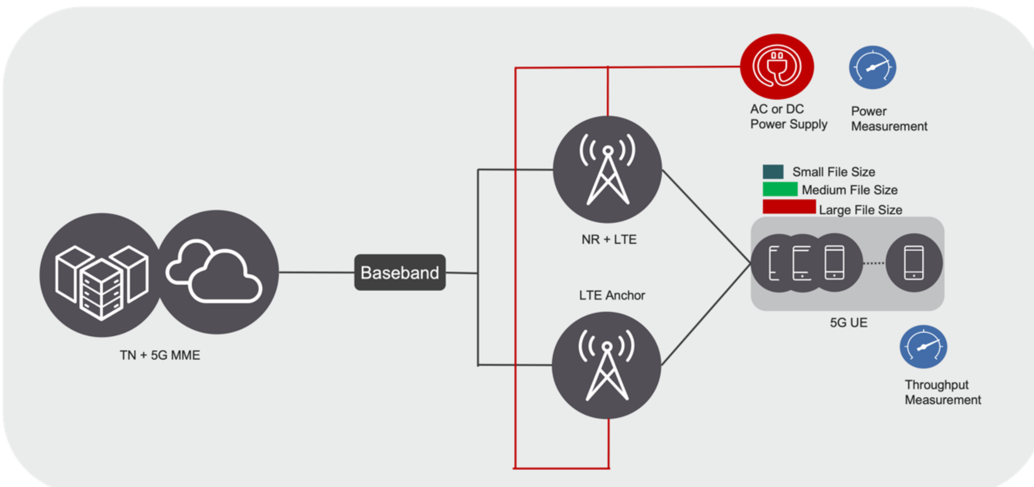
Table A.5: Average power consumption reporting			
S.No	**Parameter**	**Value**	**Unit**
1	*Pequipment of integrated RU power consumption*		*W*
3	**Pequipment of distributed RU power consumption**		
3.1	*Pequipment of distributed RU power consumption for central part*		*W*
3.2	Pequipment of distributed RU power consumption for remote parts	-	W

Table A.6: Daily energy consumption reporting			
S.No	**Parameter**	**Value**	**Unit**
1	*Eequipment of integrated RU energy consumption*		*Wh*
3	**Eequipment of distributed RU energy consumption**		
3.1	*Eequipment of distributed RU energy consumption for central part*		*Wh*
3.2	Eequipment of distributed RU energy consumption for remote parts		Wh

E-Plane ETSI Test Suite for O-DU/O-CU and gNodeB

This is a set of automated test cases and analytics tool used to test O-DU/O-CU (without O-RU) and gNodeB, for EC and EE, based on ETSI standard **TS 103 786 [1]**

ETSI test methodology



A UE emulator and a channel emulator are connected to the BS under test. A traffic generator is used to generate data traffic requested by the UEs and to measure the received data by the UEs during the measurement period. The test setup is applicable for 5G NR and LTE as an anchor – Non-Stand Alone (NSA).It can also be applicable for only 5G NR, Stand Alone (SA) case by just removing the LTE Anchor from the test setup.

Traffic conditions:

The UEs are distributed in three different path loss regions, low path loss, medium path loss, and high path loss regions. The number of allocated UEs in each region are specified in the standard. The path loss value for each region is also specified. The measurements are carried over a period corresponding to active file transfers and then over a period when the BS is idle after having completed all the file transfers.

Measurements made:

After this idle time has elapsed the measurement is stopped. The energy consumption, the received data by the UEs and the total measurement time are noted.

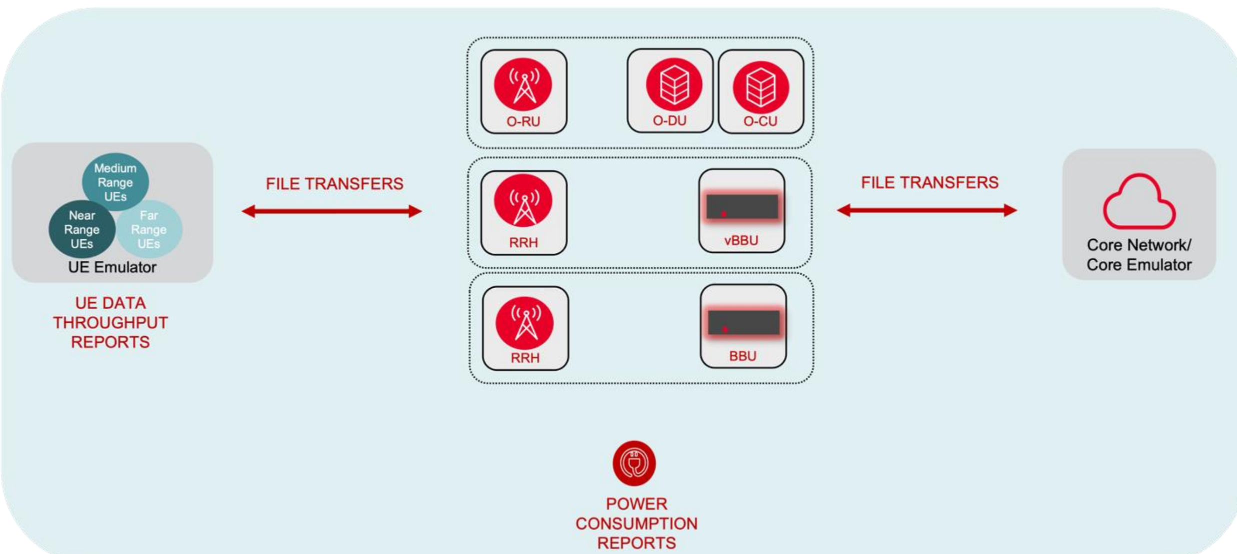
EE is defined as the ratio of delivered bits and consumed energy and consists of delivered useful bits in the numerator and consumed energy in the denominator. The test report also contains the UE throughput data, so that it can be ensured that lower EC was not at the cost of lower QoS.

Test set-up

The ETSI standards for calculating EE were developed for Base stations before disaggregated and virtualized Base Stations became commonplace. Keysight has therefore adapted the ETSI specifications and made them suitable for use in those cases.

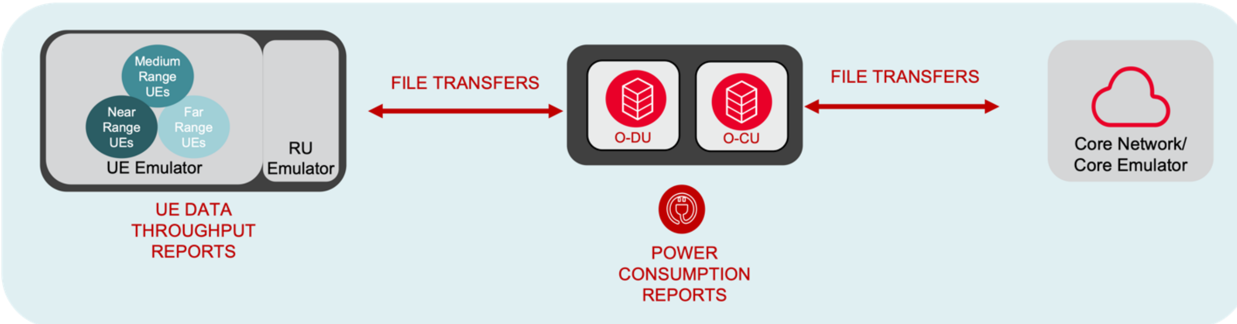
Disaggregated Base Stations have evolved over time, and we can broadly categorize them under 3 types:

1. Simple separation of network functions in an integrated BS, into a Remote Radiohead (RRH) and a Baseband Unit (BBU)
2. Virtualization of network functions in software platforms, based on general-purpose processors– vRAN
3. Open and standardized interfaces within the vRAN, defined by the O-RAN association – O-RAN



For each category of gNodeB, data transfer is set up using a UE emulator and a core network emulator while simultaneously measuring data throughput and input power (EC)

For details of this test setup using Keysight equipment, please refer to the section: Test Set-up: For gNodeB on page 27.



The E-Plane Test Suites also enable EC and EE measurements on components of the gNodeB, such as the O-RU or the O-DU/O-CU using the static traffic method for testing O-RU and the dynamic traffic method for testing O-DU/O-CU and gNodeB.

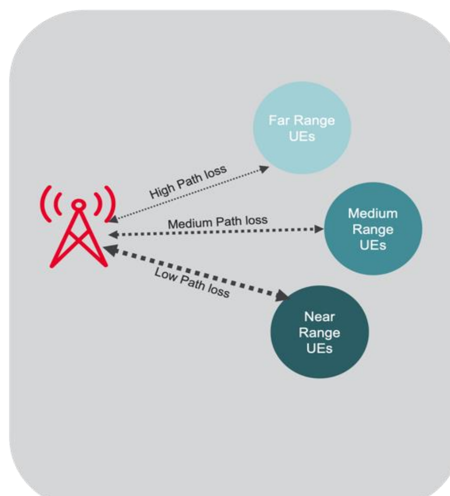
The Design Test Suites utilize Redfish statistics from the servers in the O-DU/O-CU or in the gNodeB and characterize the E-plane performance under changing CPU functions, node scaling, frequencies, latencies, and user experienced throughput.

For details of the test setup using Keysight equipment, please refer to the section: Test Set-up: For O-DU/O-CU on page 25.

UE emulation

The UE Emulator fulfils the following requirements:

- Multiband radio interfaces 400 MHz to 4000 MHz
- NR release 17
- Simulation capacity of 1000 UEs
- Full stack E2E UE simulation
- Capability of mobility simulation
- Fading simulation capability (3GPP models)
- Ability to control every UE position (Pathloss), data traffic, fading etc. individually.
- Logging of UE performance



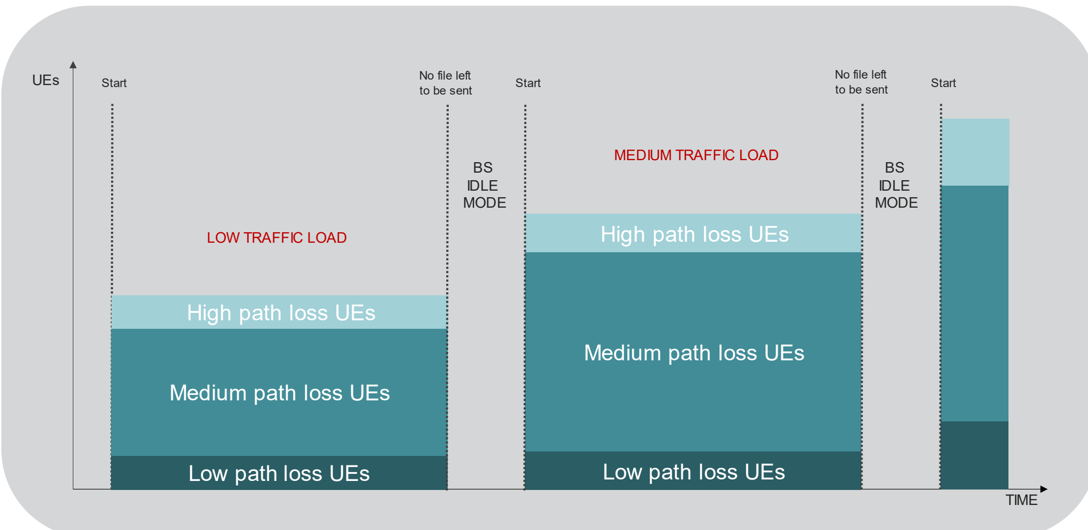
Note:
1. For testing the gNodeB, it is enough to emulate the UEs, but for testing the O-DU/O-CU, the UEs + O-RU are simulated as a combination.
2. When testing the gNodeB, the EC of the radio is not measured and thus not included in the calculation.

Power (Energy) consumption measurement:

There are two methods to measure the EC.

1. Using Redfish KPIs: For using Redfish KPIs, the server (DUT) must support Redfish. Detailed requirements of redfish version and server type compatibility can be found in the user guide.
2. Using an inline power analyzer: This method is independent of the server type used.

Traffic model generation



The emulated UEs fall under 3 groups:

1. High path loss (130 dB)
2. Medium path loss (110 dB)
3. Low path loss (85 dB)

The number of UEs within each group varies with the traffic conditions being emulated.

For instance, during busy-hour traffic conditions, 24 UEs are in the high and low path loss conditions, while 112 are in the medium path loss condition.

The data transfer is done with 3 different file sizes by these UEs:

1. Small file (0.1 Kbyte)
2. Medium file (1 Kbyte)
3. Large file (250 Kbyte)

Measurement results

1. Power consumed by the BS during the entire measurement period, including times of data transfer and idle times.
2. UE throughput.
3. Accumulated volume of data transferred during the measurement period.

Table A.1: Test general information		
S.No	**Items**	**Remarks**
1	Test report reference and version	-
2	Date of test	-
3	Standard used as test methodology	-
4	Location of the test	-
5	Name of test organization and responsible person	-
6	**Tested equipment**	
6.1	Tested HW unit names and serial numbers	-
6.2	Software version of tested equipment	-
7	List of used measurements equipment including type, serial number and calibration information	-

Table A.2: Reference parameters to be reported			
S.No	**Parameter**	**Value**	**Unit**
1	**O-DU/O-CU configuration**		
1.1	Number of sectors	-	
1.2	Nominal max RF output power per sector	-	W
1.3	**Number of Carriers per sector**		
1.3.1	Number of carriers the O-DU/O-CU is able to support	-	
1.3.2	Number of carriers, for which the HW was enabled	-	
1.3.3	Number of carriers used during the test	-	
1.4	TX diversity	-	
1.5	RX diversity (number)	-	
1.6	Type of RF signal combining	-	
1.7	Remote Radio Head (Yes/No)	-	
2	**Frequency**		
2.1	Downlink band	-	MHz
2.2	Uplink band	-	MHz
2.3	Channel bandwidth	-	MHz
2.4	Sub-carrier spacing	-	kHz
3	**Environment**		
3.1	Temperature range	-	°C
3.2	Type of air filter	-	
4	**Features**		
4.1	Power saving features	-	
4.2	Coverage and capacity features	-	
4.3	Downlink ciphering used? (Y/N)	-	

Table A.3: Measurements conditions and results to be reported for Energy Performance				
S.No.	**Parameter**	**Test case 25 °C**		**Unit**
1	**Test environment**			
1.1	*Temperature during test (measured)*			*°C*
1.2	*Pressure (measured)*			*kPa*
1.3	*Relative humidity (measured*			*%*
2	**Frequency used at test**			
2.1	*Downlink Centre frequency of middle channel MHz*			*MHz*
2.2	*Uplink Centre frequency of middle channel MHz*			*MHz*
3	**Supply voltage**			
3.1	*DC voltage (measured)*			*V*
3.2	*AC voltage (measured, phase to neutral)*			*V*
3.3	*AC Frequency (measured)*			*Hz*
4	**Weighting Factors**			
4.1	Wlow	-		hour
4.2	Wmedium	-		hour
4.3	Wbusy-hour	-		hour
5	**Dynamic energy consumption (measured)**	**Power Analyzer**	**Redfish**	
5.1	Low traffic level	0	0	Wh
5.2	Medium traffic level	0	0	Wh
5.3	Busy-hour traffic level	0	0	Wh
6	**Accumulated measured data volume**			
6.1	Low traffic level	0		bits
6.2	Medium traffic level	0		bits
6.3	Busy-hour traffic level	0		bits

Table A.4: Calculated results to be reported for Energy Performance				
S.No.	**Parameter**	**Value**		**Unit**
1	Total delivered data in bits during the test	-		bits
		Power Analyzer	**Redfish**	
2	Total energy consumption	-	-	Wh
3	*Coverage*			*km2*
		Power Analyzer	**Redfish**	
4	O-DU/O-CU Energy Performance (BSEP)	-	-	bits/Wh
5	**PRB Utilization**			
5.1	*Low load PRB Utilization*			*%*
5.2	*Medium load PRB Utilization*			*%*
5.3	*Busy-hour load PRB Utilization*			*%*
6	Average UE throughput	-		kbps
7	*Expanded uncertainty*			*%*

E-Plane Design Test Suite for O-DU/O-CU and gNodeB

Description

As mentioned earlier, the Design Test Suites provide advanced capabilities in terms of characterization and benchmarking of ES and performance analytics that are not covered by the ETSI specifications. These Test Suites provide deep insights to the equipment designers and users to understand the performance under stress.

The Design Test Suites employ advanced analytics by correlating the EC with subscriber experiences, network application, infrastructure, and load to characterize the server performance under various traffic conditions and power profiles.

Test set-up

The Design Test Suites use the same hardware test set-up as the corresponding ETSI Test Suites. The Software licenses are configured based on the specific user requirements.

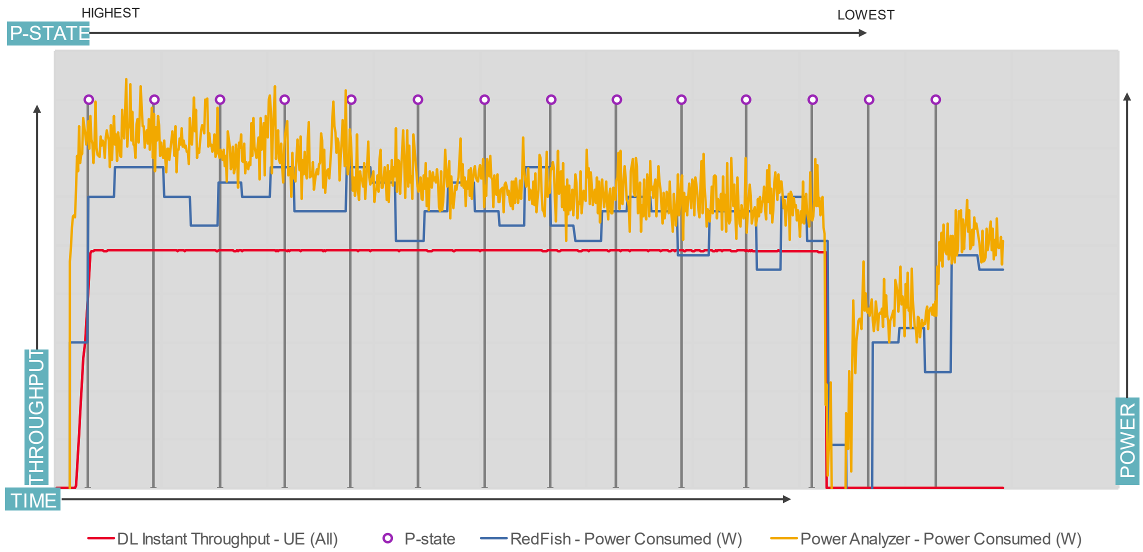
For details of this test setup using Keysight equipment, please refer to the section: Test Set-up: For O-DU/O-CU (Page 25)

For details of this test setup using Keysight equipment, please refer to the section: Test Set-up: For gNodeB (Page 27)

Measurement insights

Described below are only three among many examples of the insights gained into the server performance:

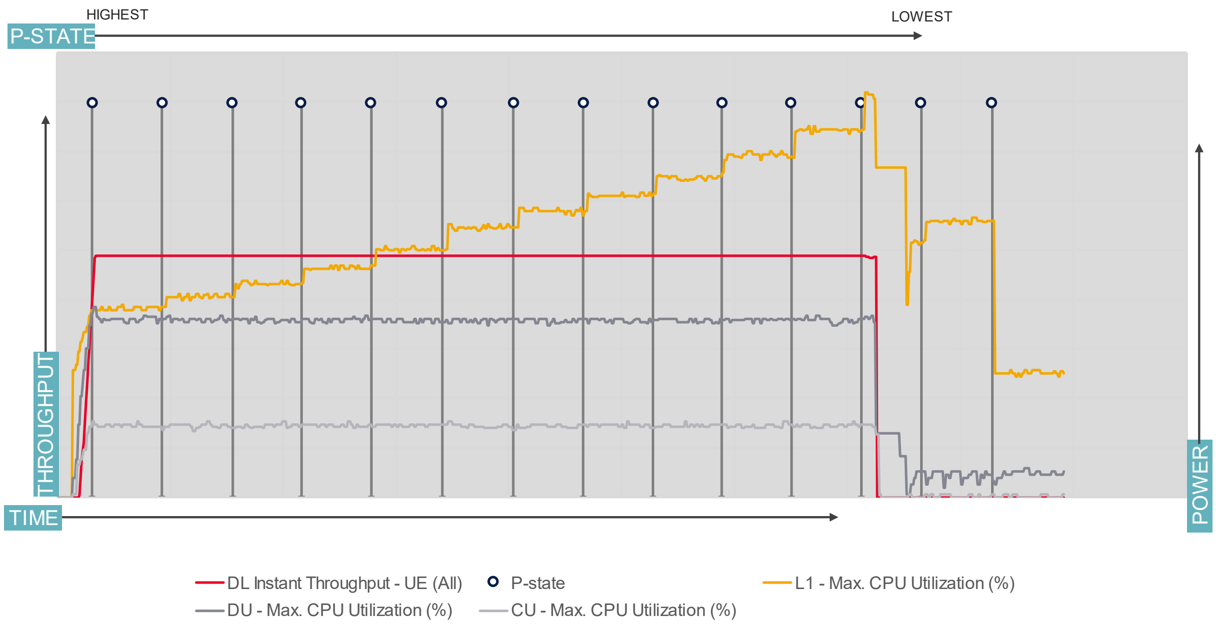
Use Case 1: User Perceived Throughput vs Power Consumption:



The P-state of the server was reduced from the highest to the lowest frequency, while maintaining the data throughput at a constant level. As the P-state was reduced, EC also reduced, which was measured by the Power Analyzer as well as Redfish KPIs. The throughput could be maintained constant up to a certain P-state. Any further reduction in P-state impacted the end-user performance. This process was repeated for each traffic model to identify the corresponding lowest P-state that doesn't impact the end-user performance.

We can conclude that if all other conditions remain constant, energy consumption could be reduced by tuning the P-state.

Use Case 2: User Perceived Throughput vs CPU Utilization for L1 (High-PHY)



The E-Plane Design Test Suite can identify the cores that are assigned to the L1, DU, and CU functions.

This use case focuses on L1 (High-PHY), so the P-state was updated only for the cores that were mapped to the L1 function. To study the effect of P-state on CPU utilization, the traffic model emulated by the UE Emulator was maintained at a constant level while lowering the P-state for L1 (High-PHY) function. This process was repeated for each traffic model and for DU and CU applications.

Use Case 3: Evaluate Energy Savings

This use case was demonstrated during the MWC 2023 Barcelona and O-RAN Fall 2022 PlugFest.

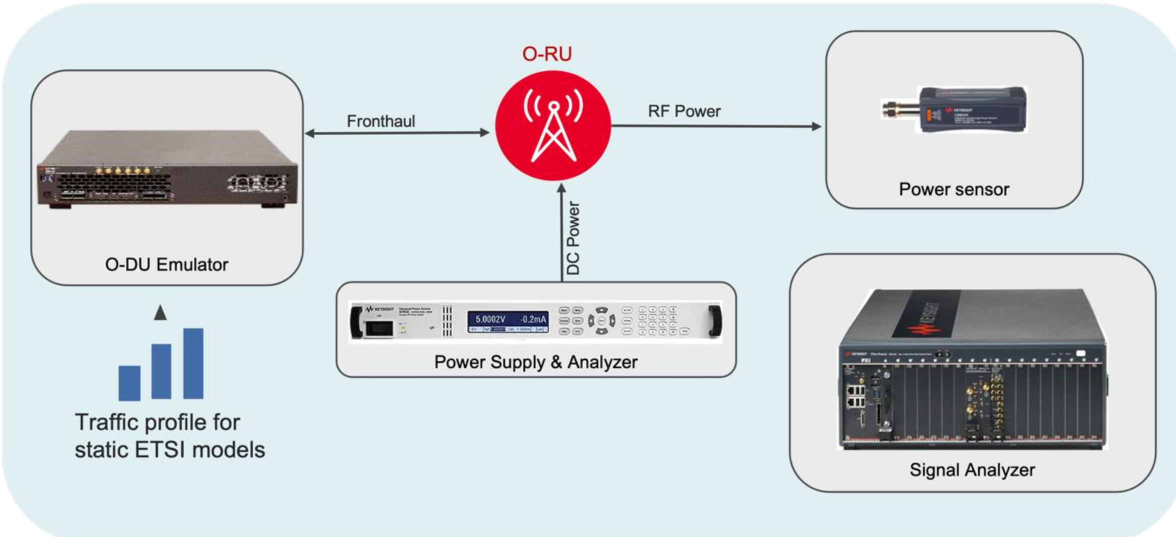
Energy savings were evaluated in three traffic conditions: Busy-hour, Meduim, and Low by tuning the P-state to reduce energy consumption while maintaining the end-user performance. Energy savings of up to 20% could be achieved under Medium and Low traffic conditions. Even during periods of High traffic conditions, energy savings was observed of up to 11%.

Traffic	**Busy-Hour**		**Medium**		**Low**	
	Baseline	Scenario 1	Baseline	Scenario 2	Baseline	Scenario 3
C-state	C0	Parameter Optimization	C0	Parameter Optimization	C0	Parameter Optimization
Uncore	2400 MHz		2400 MHz		2400 MHz	
P-state	2500 MHz		2500 MHz		2500 MHz	
Energy Saving		=< 11%		=< 20%		=< 20%

Test Set-up

Test set-up

O-RU



Required equipment

Model	Function
O-DU Emulator (S5040A) 	The S5040A is used to perform the functions of O-DU emulation and O-RU control via M-Plane. The O-DU emulator also provides 10 MHz frame trigger to the power sensor. PathWave Signal Studio (LTE and 5G-NR) and Open RAN studio licenses must be included to generate the required traffic waveforms and messaging.
Power Sensor (U2063XA or L2063XA) 	The power sensor makes accurate and gated power measurements during the allocated downlink slots of the TDD waveform. U stands for USB and L stands for LAN. The LAN version uses power supply over Ethernet (POE), and so it requires a POE switch
DC Power Supply & Analyzer 	The power supply provides -48V DC supply to the O-RU. It also measures supplied voltage & current, computes instantaneous and accumulated power consumption over time. Supported Power Supplies: RP7900 series, N7900 series & N6900 series

Optional equipment

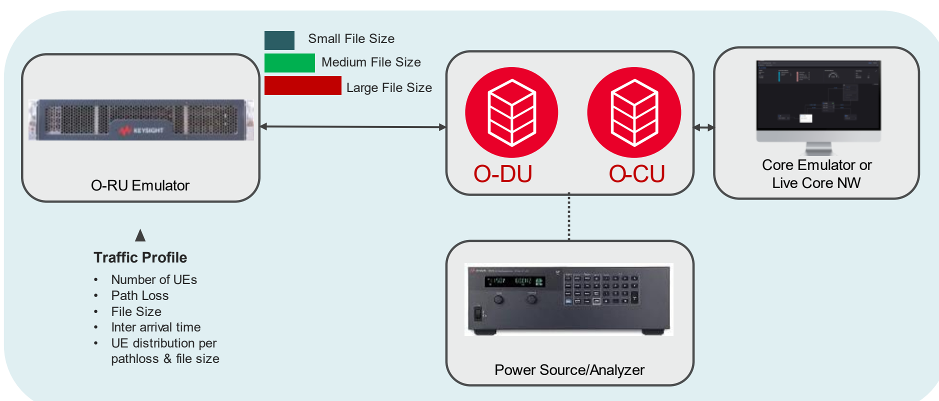
Model	Function
USB 3.0 Powered Hub	Used to power multiple USB RF power sensors
Power over Ethernet (POE) LAN Switch	Used for L2063X power sensor
TTL Fanout Buffer	Used to fan trigger out to multiple power sensors being used to measure a TDD waveform

Software licenses

Keysight offers a comprehensive coverage of the tests. Software licenses are configured based on actual requirements. Please contact Keysight for details.

O-DU/O-CU

Test set-up:



The hardware set-up for E-plane ETSI Test Suite and Design Test Suite for O-DU/O-CU is identical as shown above.

Required equipment

Model	Function
RuSIM: O-RU Emulator P8822S Hardware & software licenses configured to match requirements.  	The RuSIM emulates stateful UE traffic and measurements. RuSIM must be dimensioned to match load testing scenarios
CoreSIM: Core Network Emulator P8850S Server and software licenses configured to match requirements.	CoreSIM terminates the calls from RuSIM for stateful O-DU/O-CU testing. CoreSIM must be dimensioned to match load testing scenarios. Live core network can also be used if the user has access to it.
AC Power Source/Analyzer 	Power Analyzer measures power consumption of the server. Power (Energy) consumption can be measured using: 1. Redfish statistics or 2. Power Analyzer If redfish statistics are available, an external Power Analyzer is *not required*. Supported Power Sources/Analyzers: 6800 series, AC6800 series & PA220XA series

Software licenses

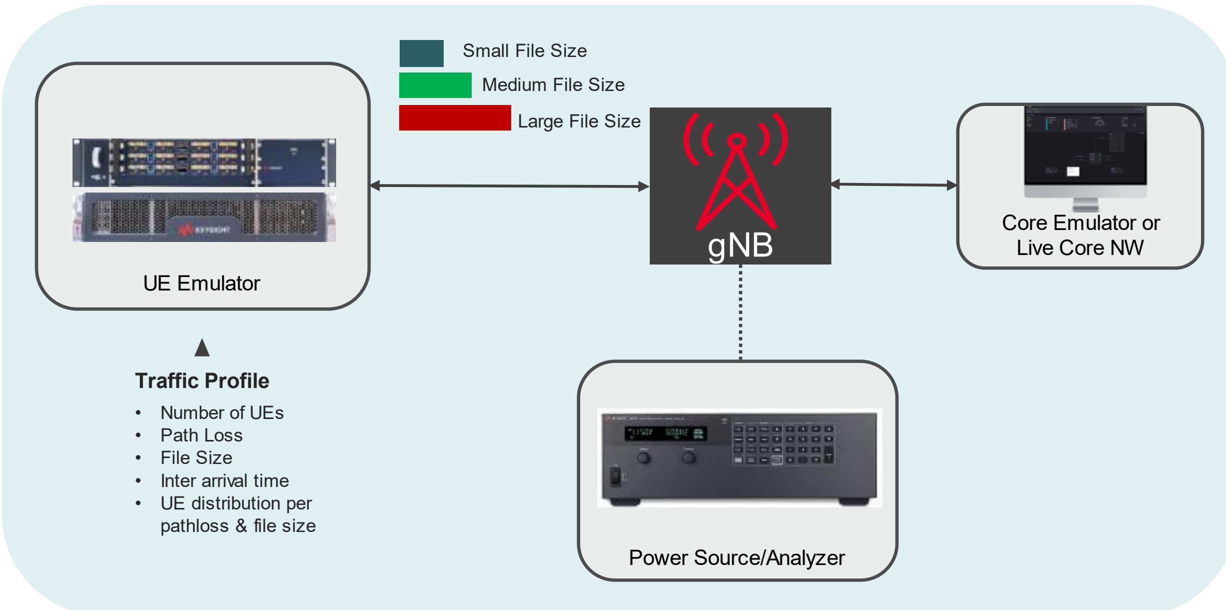
Keysight offers a comprehensive coverage of the tests. Software licenses are configured based on actual requirements. Please contact Keysight for details.

Additional information

Parameters	Values
Technology	5G NR (SA & NSA) FDD & TDD, LTE
Server Type	Intel-based, ARM-based

gNodeB

Test set-up



Required equipment

Model	Function
UeSIM: UE Emulator P8800S Hardware & software licenses configured to match requirements. 	The UeSIM emulates stateful UE traffic and measurements. UeSIM must be dimensioned to match load testing scenarios
CoreSIM: Core Network Emulator P8850S Server and software licenses configured to match requirements.	CoreSIM terminates the calls from UeSIM for stateful O-DU/O-CU testing. CoreSIM must be dimensioned to match load testing scenarios. Live core network can also be used if the user has access to it.
AC Power Source/Analyzer 	Power Analyzer measures power consumption of the server. Power (Energy) consumption can be measured using: 3. Redfish statistics or 4. Power Analyzer If redfish statistics are available, an external Power Analyzer is *not required*. Supported Power Analyzers: 6800 series, AC6800 & PA220XA series

Software licenses

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Additional Information

Parameters	Values
Technology Supported	5G NR (SA & NSA) FDD & TDD, LTE
Server Type	Intel-based, ARM-based

For more information

P8800S UeSIM UE Emulation RAN Solutions UeSIM UE Emulator

P8822S RuSIM — UE/O-RU Emulation Over the O-RAN Fronthaul RuSIM O-RU Emulator

P8850S CoreSIM — Core Simulation RAN Solutions CoreSIM Core Network Emulator

U5040BSCB Open RAN Studio for O-RU Testing and Validation Open RAN Studio

Power Supplies RP7900 Series, N6900 Series, N7900 Series

Power Analyzers 6800 Series, AC6800 Series, PA220XA series

Power Sensor - U2063XA 10 MHz to 33 GHz USB Wide Dynamic Range Average & Peak Power Sensor U2063XA

Conclusion

Energy Consumption, Energy Efficiency, and Energy Savings are increasingly important concerns in cellular networks.

Keysight's E-Plane Test Suites are designed to solve challenges of measuring the EC, EE, and ES in Radio Access Networks at various stages of disaggregation and virtualization such as RAN, vRAN and O-RAN.

They also provide Test Suites for characterizing the E-Plane performance of O-DU/O-CU and gNodeB under changing CPU functions, node scaling, frequencies, latencies, and user experienced throughput.

The E-Plane Test Suites leverage the equipment and software set-up used for O-RAN conformance & performance tests to provide a unified framework for Protocol, RF, and E-Plane domain testing.