

Virtualized, Disaggregated 3GPP 5G RAN and Small Cells

Prasad Bhandaru

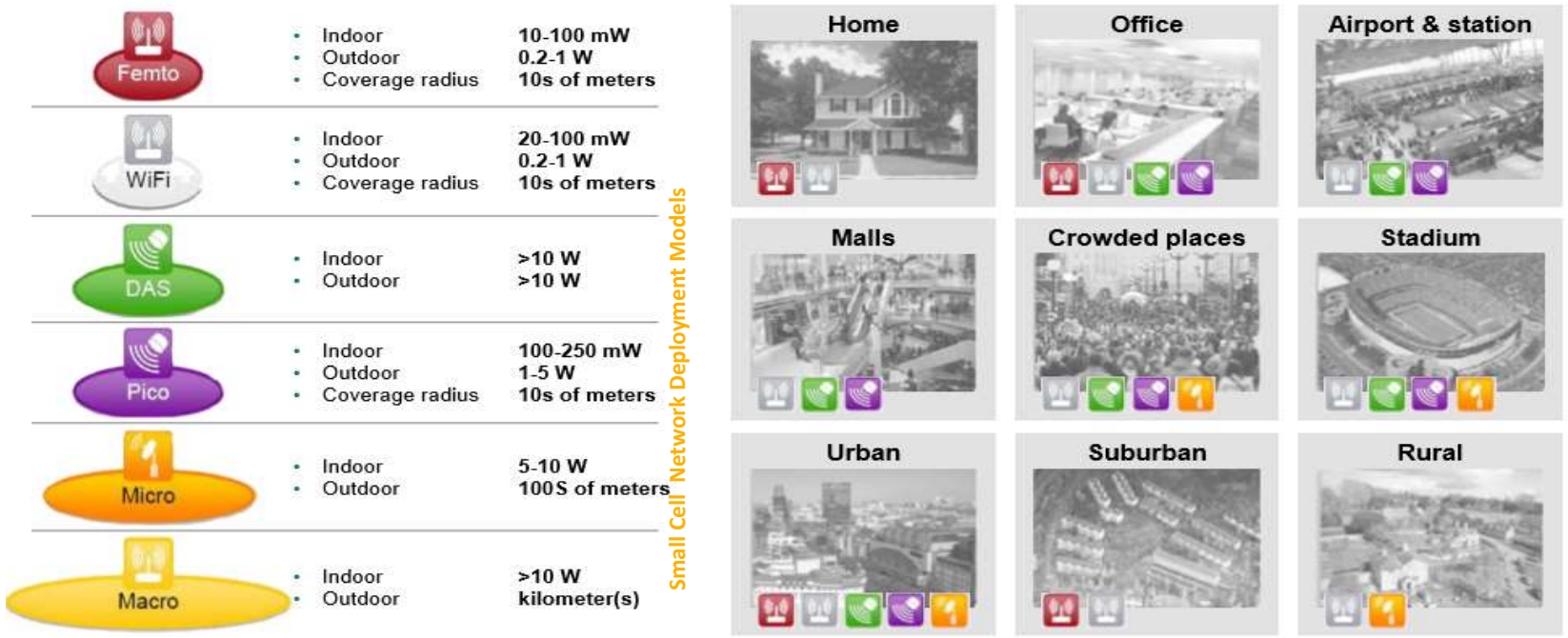
Wireless Program Manager

Prasad.Bhandaru@cyient.com

M: 908-489-3942

Cyient Inc

5G needs Ultra Dense Networks



- Thruput per square mile increases to the 3rd power frequency while number of sites increases to the frequency squared.
- Everything else being equal your capital cost per bit decreases by a factor of 10

5G UWB in 13 NFL stadiums

https://youtu.be/LfLikZt9Oz0



"Unlike LTE and Sub-6GHz, mmWave often can't penetrate hard surfaces like concrete. Its range is also minimal. Those disadvantages are what makes a stadium deployment so appealing to carriers that want to sell consumers on 5G. Open-air sports stadiums are one of the few places where a mmWave deployment makes sense since there's enough density to justify building out all the small cells that are required to blanket even a small area with 5G coverage".

VzW

5G components and architecture

New spectrum	High frequency spectrum above 6 Ghz and new spectrum between 3.4 and 6 Ghz. mmWave spectrum to be used for fixed wireless, mobile access and transport or a capacity layer for LTE networks
Flexible and programmable networks	SDN, NFV and slicing will enable flexibility, scalability and configurability of networks
Multi-connectivity	5G to work with LTE, other RAT
Virtualized/cloud RAN and core	LTE RAN, 5G RAN and core will be virtualized/cloudified, with a combination of centralized and distributed cloud
Massive MIMO and beamforming	applied to enhance capacity and coverage, reduce interference
HetNet and densification	More nodes and more small cells in 5G than in previous generations

Sample 5G RAN Requirements

5G RAN Vision

- All network functions should be software defined, running on COTS
- Complete separation of user plane and control plane, and be optimized for cloud native architecture and services
- Network slicing to support business demands for an independent "network slice as a service"
- Multiple-access Edge Computing (MEC) to support Ultra Reliable Low Latency Communication (URLLC) services with open API to facilitate new app and service introduction
- Support of Fixed Mobile Convergence (FMC) is mandatory; aiming at access agnostic client experiences
- 5G RAN and Core should be fully automated ("zero-touch") from commissioning to operation to greatly reduce OPEX and increase efficiency

5G RAN Strategy

- The radio air interface shall support smooth migration from 4G LTE to 5G NR through software upgrade, no HW swap should be required
- Superior air interface spectral efficiency to reduce the cost per GB and increase air interface capacity
- Support of new spectrum with larger bandwidth, i.e. 10x more
- Superior air interface design flexibility to efficiently support various vertical applications (e.g. low latency with high bandwidth, reliable connectivity, extreme low latency, high latency with small bandwidth, etc.)
- Support of massive IoT, i.e. support of millions of devices with very different traffic patterns

Potential Roadmap

- CBRS, 600MHz and C-band 5G on macro layer and mmWave as a capacity layer
- LTE-A Pro will continue to evolve for both capacity and coverage in the coming years; re-farming LTE to NR could be accelerated depending on ecosystem adoption
- Aggregate NR with LTE to have superior data rates beyond LTE-A Pro or NR is desirable
- Capability to pool fixed and mobile resources, for efficiency and capacity is desirable
- A security model that ensures the authenticity of all RAN elements and protects the network from security attacks originating at the UE

Few Applications

- eMBB and/or WTTx, Network Slicing, eMBB, URLLC, AR/VR

Source: Various CEO's from Rogers, Verizon etc

ONF CONNECT

How to Virtualize

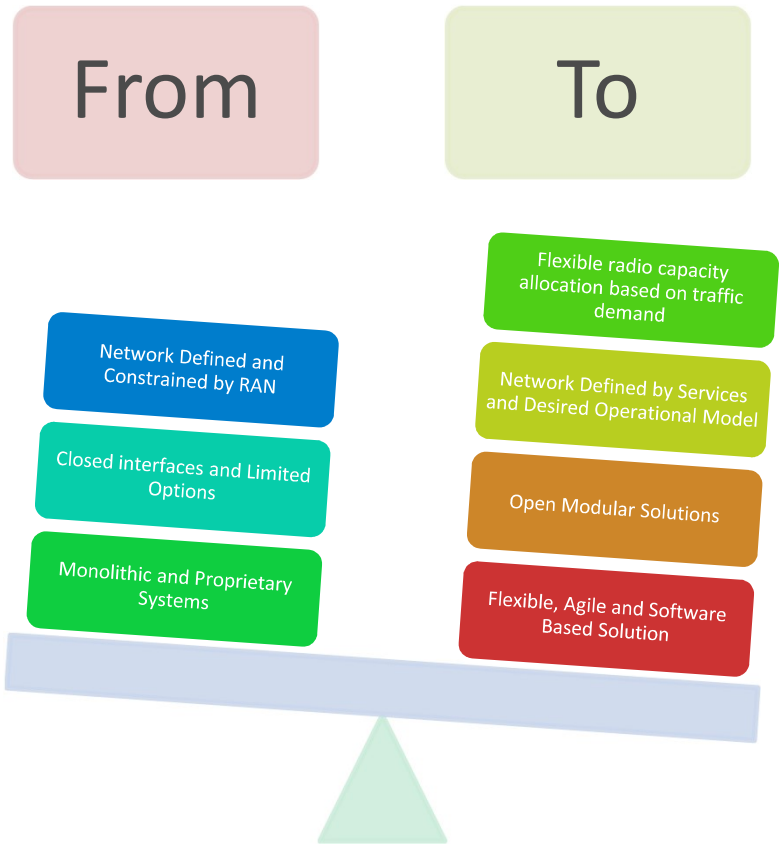
Monolithic BS's is decomposed into

- Distributed radio elements with much smaller footprints and
- Remote pools of baseband units that centralize the remaining RAN functions. Disaggregating into Radio Unit (RU), Distributed Unit (DU) and Centralized Unit (CU)

Goal is to virtualize latency and jitter-insensitive RAN baseband functions (non-real-time functions). Question is::

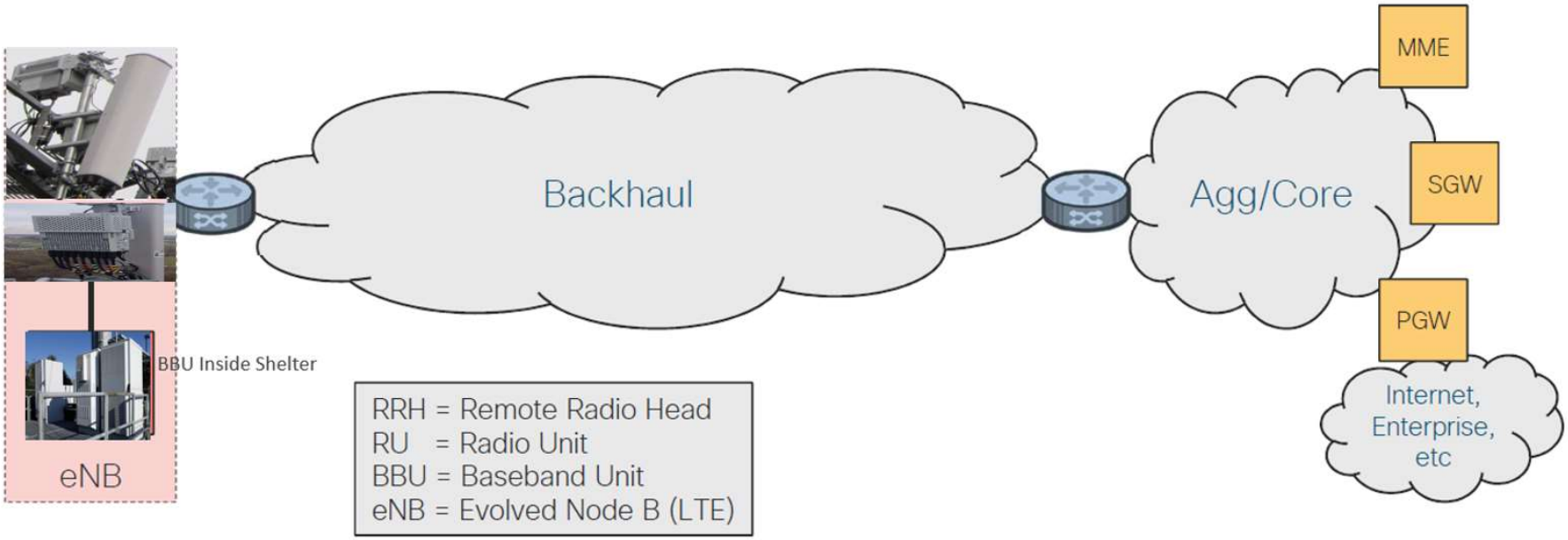
- How to virtualize RAN systems implement latency and jitter-sensitive (real-time) functions.
  - Different options exist including full virtualization or using hardware accelerators
- Location of the RAN functions which is determined by the service functional requirements and the deployment economics specifically the cost of the fronthaul that connects these functions.

5G needs Software Defined Mobile Networks

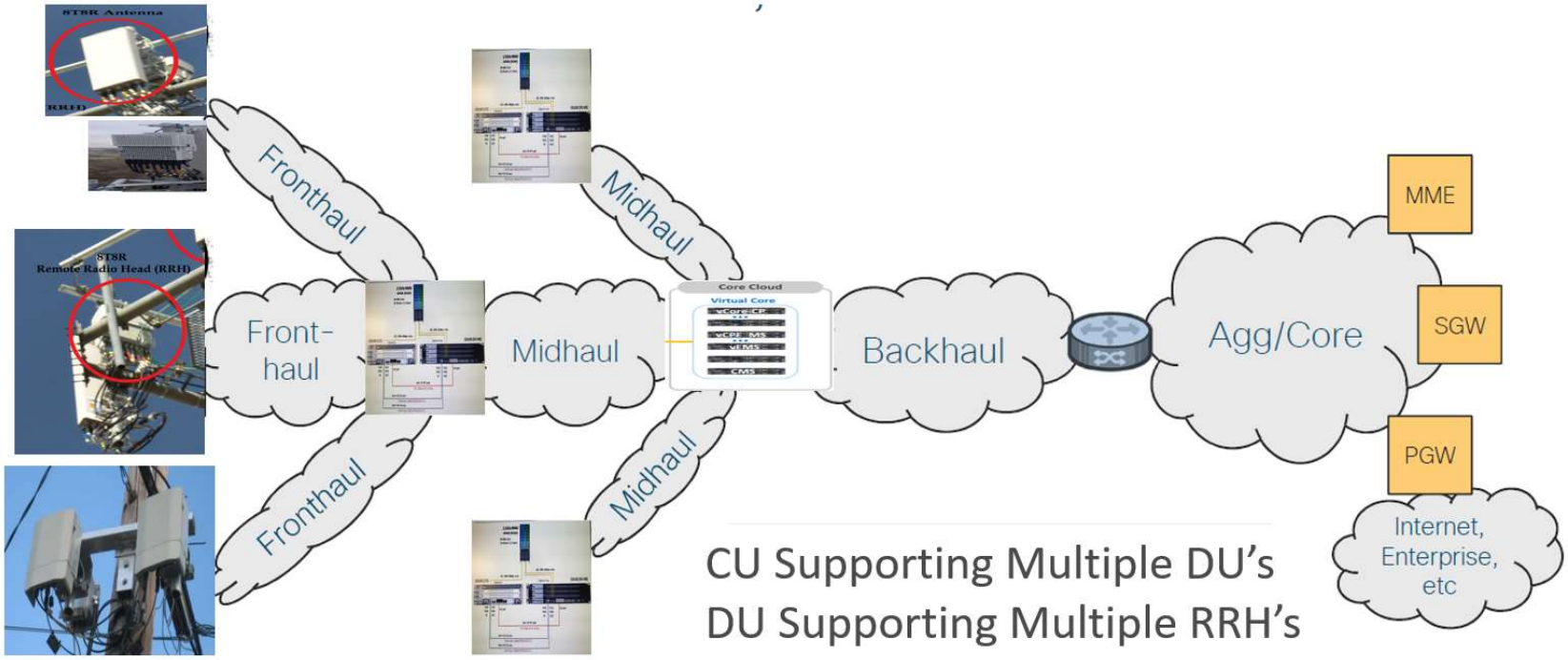


- Disaggregation simplifies SW and HW
- Rapidly Deploy New Capabilities and Services
- Infrastructure and Location agnostic
- Easier to Stitch together complex service chains
- Simpler to standardize Ops Tooling

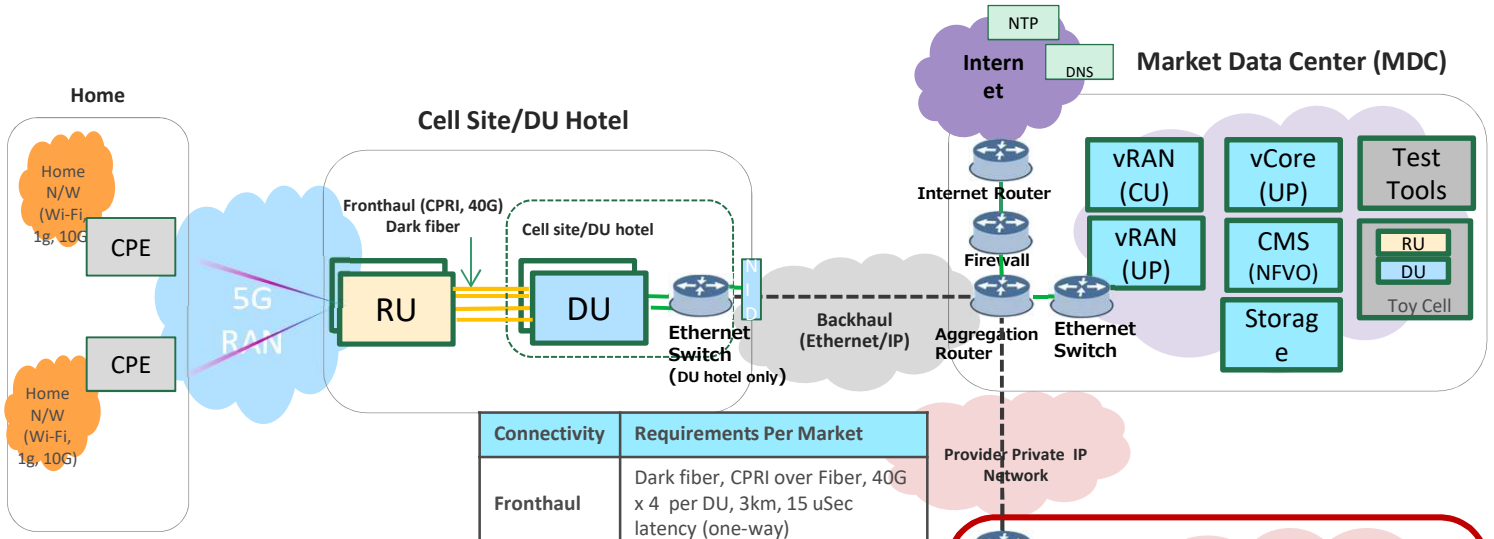
Traditional Distributed RAN Architecture



vRAN Architecture



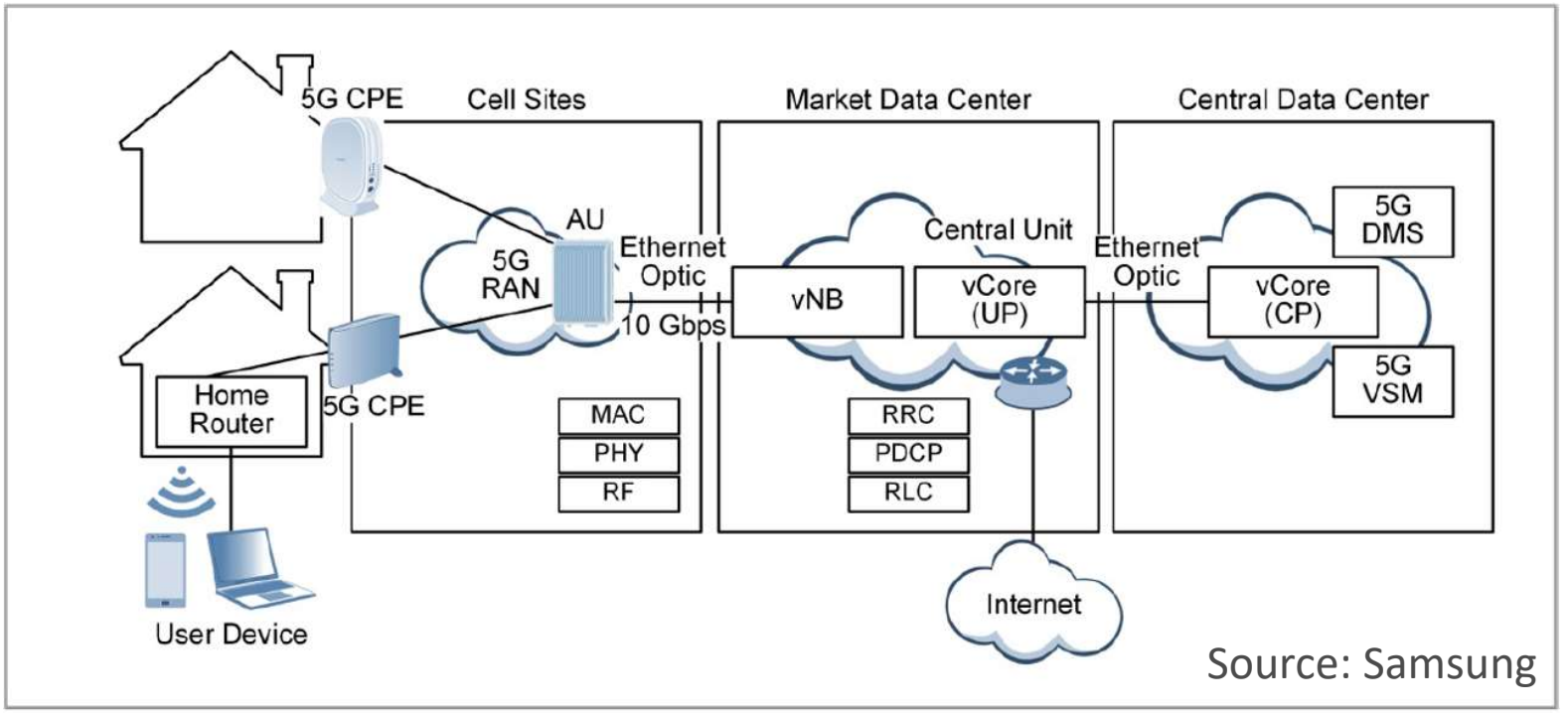
5G Network Architecture



Link	Requirements	Connectivity
Front haul	CPRI over Fiber, 40G x 4 per DU, (40Gx2 per RU), 3km, 15 uSec latency (one-way)	Dark fiber, with **two** dual stranded fiber cable per RU, QSFP (standard) connector at DU and RU.
Backhaul	Fiber/Ethernet/IP, 0.5 msec one-way latency (100km max distance over dark fiber), up to 10Gbps capacity to each site based on the user traffic estimates	End to end Ethernet connectivity, with a demarcation NID at the site with at least one 10G SFP+

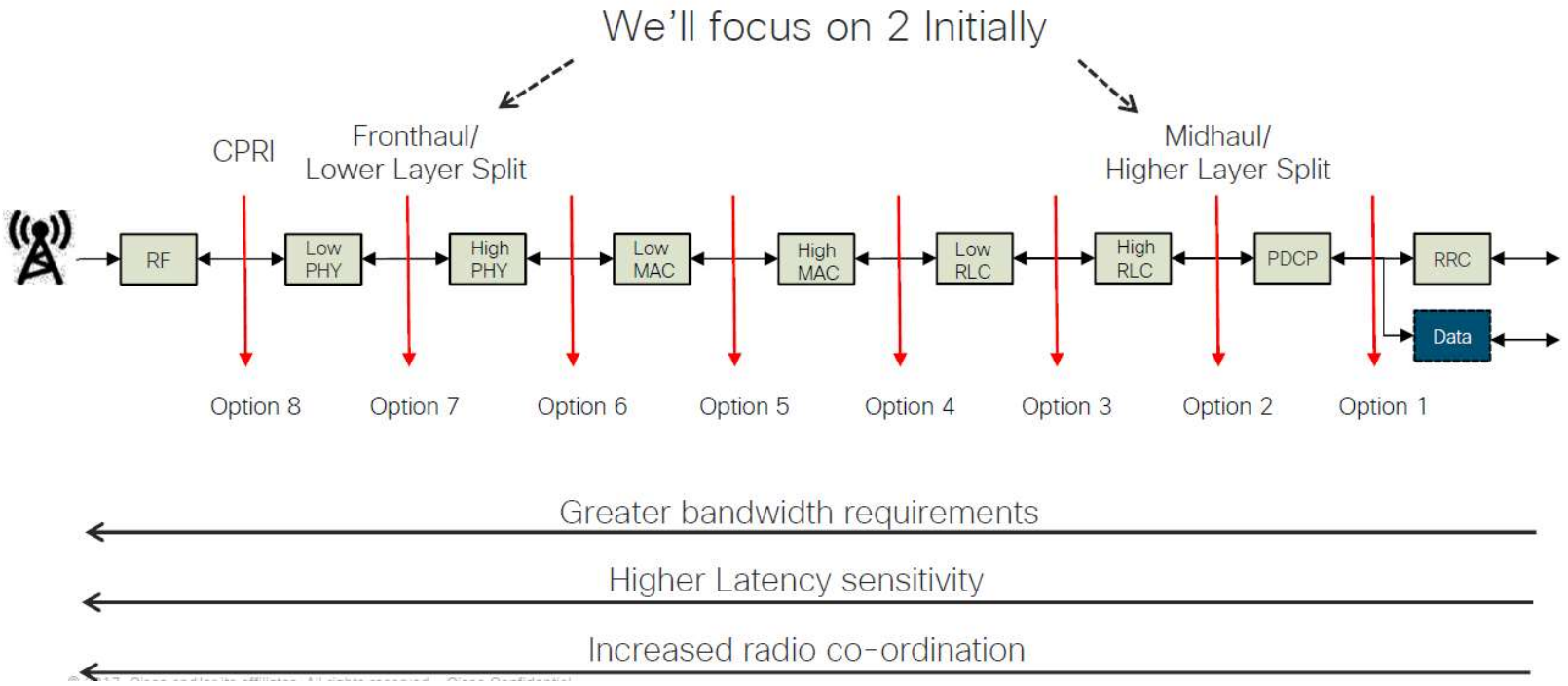
Connectivity	Requirements Per Market
Fronthaul	Dark fiber, CPRI over Fiber, 40G x 4 per DU, 3km, 15 uSec latency (one-way)
Backhaul	Fiber/Ethernet/IP, 100km, 0.5 msec latency (one way)
CPEs	240 ~ 260 CPEs per market (initial analysis of each market)
Core User Plane Throughput	~16 Gbps (UL + DL) per market
Core Control Plane Throughput	~4.5K Transactions/Second @ 110 Bytes/Transaction (~5Mbps) per market Assume similar transaction rate between Control and User Plane

5g Architecture



Source: Samsung

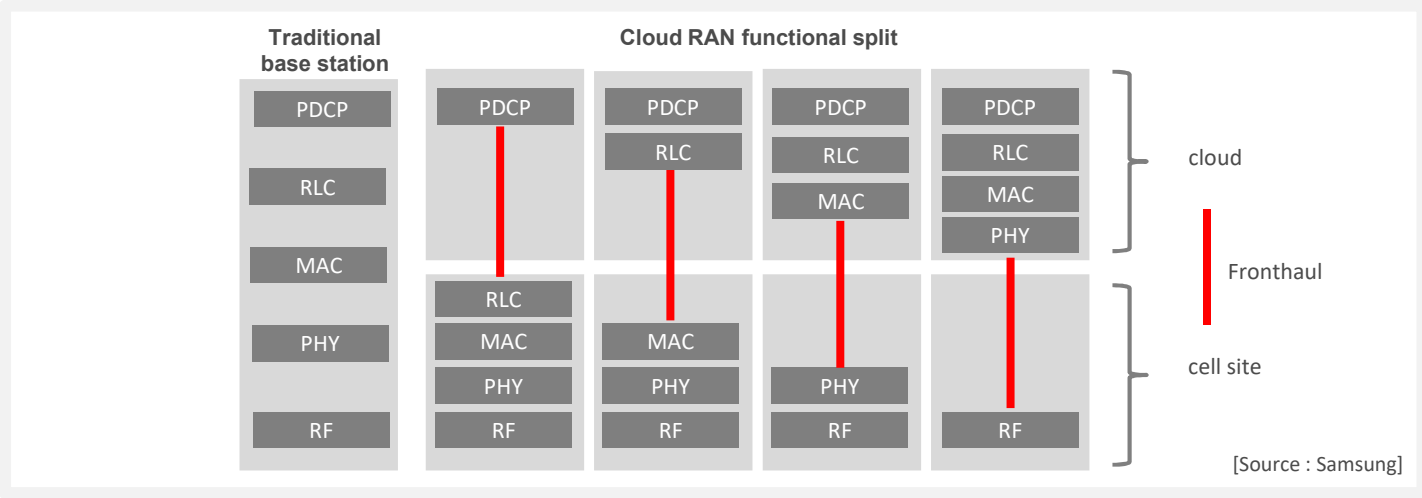
There are a lot of Split Options



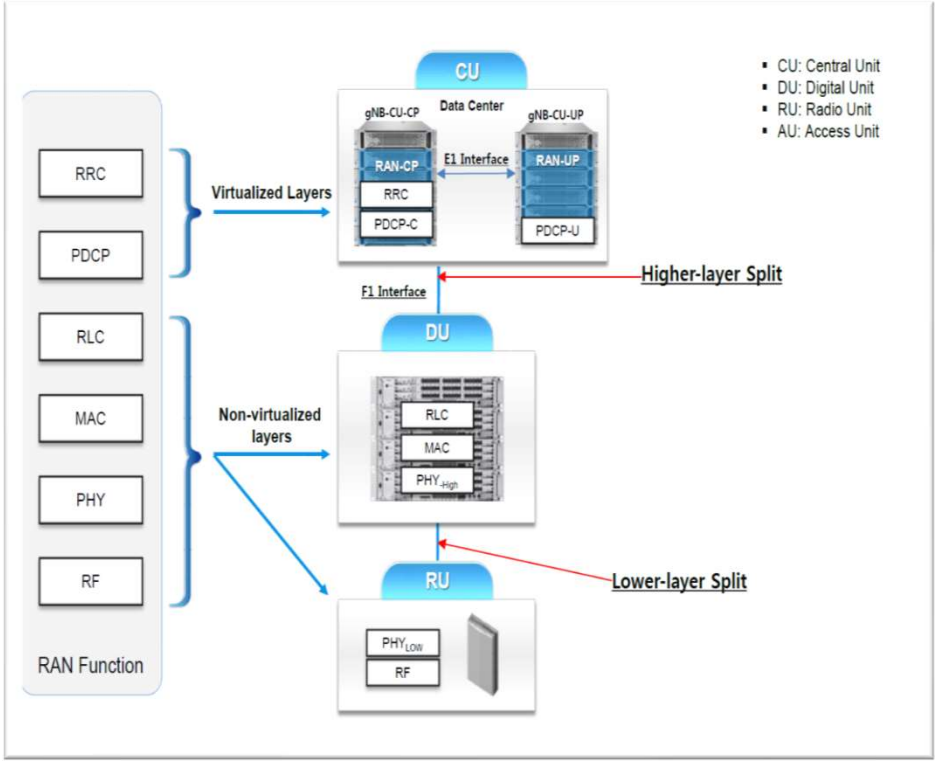
Virtualized/cloud RAN functional splits

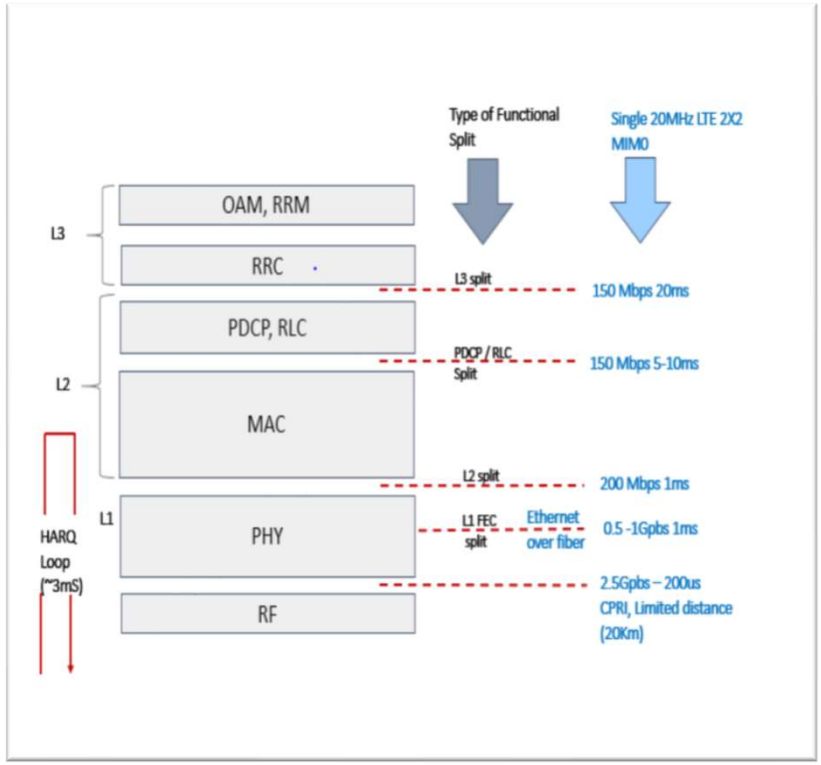
- **vRAN functional split** : the layer of virtualization may differ according to the requirements and fronthaul availability
- **C-RAN and D-RAN coexist** : 5G will take advantage of both. A more distributed architecture reduces backhaul capacity need, ensure performance while a more centralized architecture takes advantage of pooling, scalability and lower cost
- **Integrated virtualized RAN** : 4G+5G virtualized RAN can be supported by a common platform

	Ericsson	Nokia	Huawei
Solution	5G RAN virtualization Plug-in Virtualized functions on HDS 8,000 Elastic RAN	Cloud RAN Real-time BB on Airscale DU Non real-time BB on AirFrame cloud server	CloudRAN and CloudAir Non real-time function on Mobile Cloud Engine
Functional split	Various splits including : - PDCP-RLC - MAC-PHY - Split MAC	Various splits including : - PDCP-RLC - MAC-PHY	Various splits

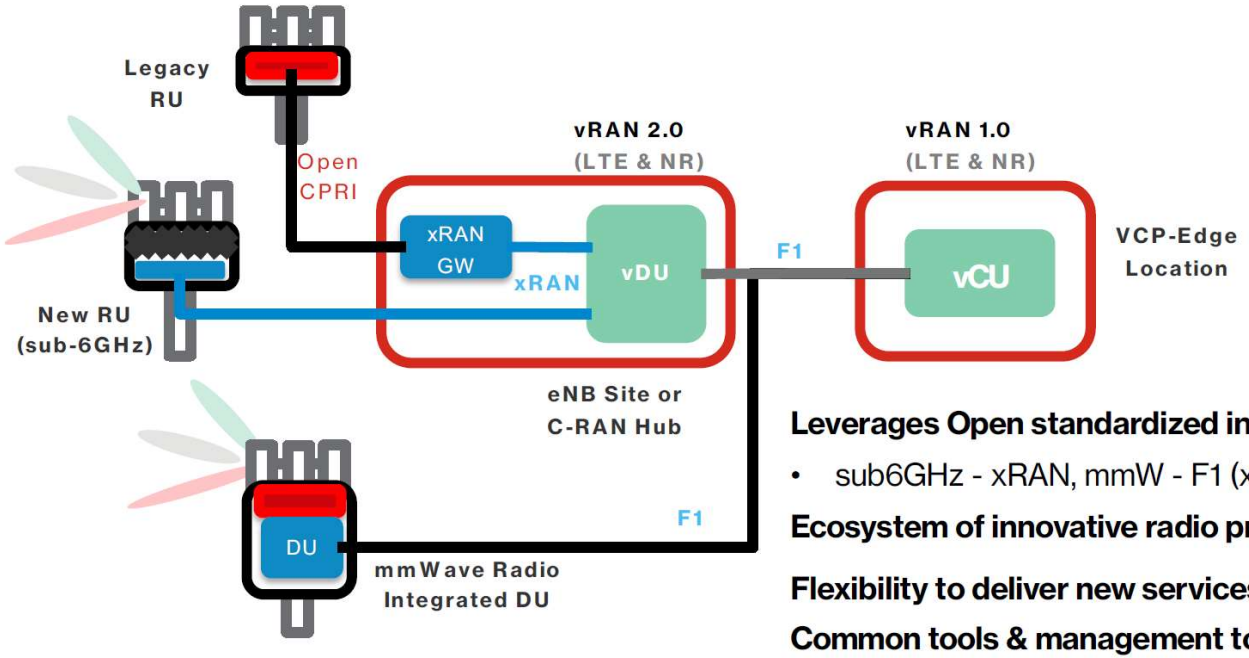


CU-DU Separation





Putting It together



Leverages Open standardized interfaces

- sub6GHz - xRAN, mmW - F1 (xRAN an option)

Ecosystem of innovative radio products for various use cases

Flexibility to deliver new services based on virtualized BBU

Common tools & management to minimize integration effort



5G FWADeployment

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5G FWA RAN Deployment in an Urban Area



Maximum UE per Cell	16
Maximum number of bearer per UE	4
Maximum number of bearer per Cell	64

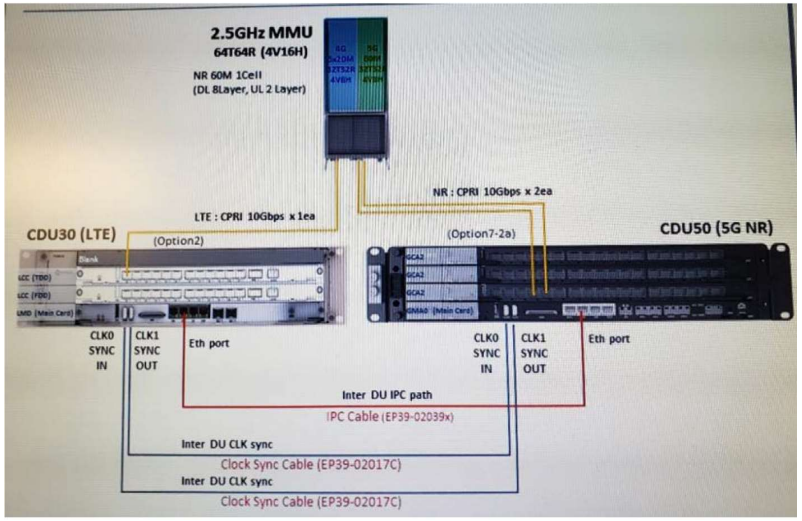
C&I

gNB Integration Overview

- Tenant Setup
  - Create Host Aggregators
- VIM Registration
- VM SW loading
  - VM image download from Samsung
  - VNFD and YAML files
- Pre-Requisite: VSM Integration complete
  gNB Instantiation
  - Instantiate gNB using CMO
  - VM Post Checks
- gNB Create
  - gNB Create on VSM
  - gNB Post checks

DU C&I Flow

- ENDC Configuration
- DU Commisioning
- DU grow
- Cell Grow
- DU-Post checks
- Post check cell/Radio status

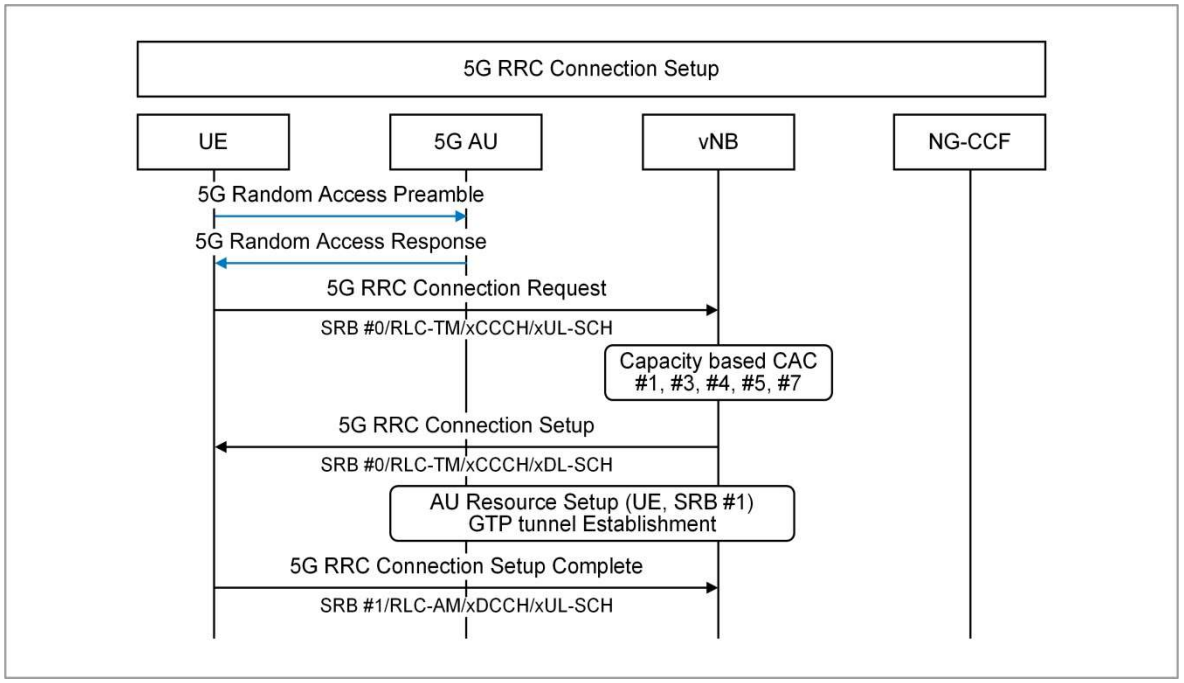


Source: Samsung

Sample AUTP

Category	Test Title
Connectivity	Verfiy AU access from VSM
AU Plug & Play	Verify AU plug & Play procedure and AU access from VSM
Sysytem Operation	Verify cell status
	Verify Radio status
	Verify current alarms on vNB
	Verify current alarm on AU
	Retrieve current AU SW
	Test AU transmit status
Call processing	Verify attach call flow and Ping test for 4CC & 6CC
	Verify detach call flow and ping test for 4CC & 6CC
	Verify DL peak throughput 4CC with indoor CPE-Indoor CPE/ Outdoor CPE
	Verify UL peak throughput 4cc with Indoor CPE-Indoor CPE /Outdoor CPE
	Verify DL peak throughput 6CC with Indoor CPE-Indoor CPE / Outdoor CPE
	Verify UL peak throughput 6cc with Indoor CPE-Indoor CPE / Outdoor CPE
	Verify Single user internet access/ speed test with lab top connected on 1G port
Stability	Verify 2 Hour Stability Performance

Capacity-based CAC during at RRC Connection Setup Procedure

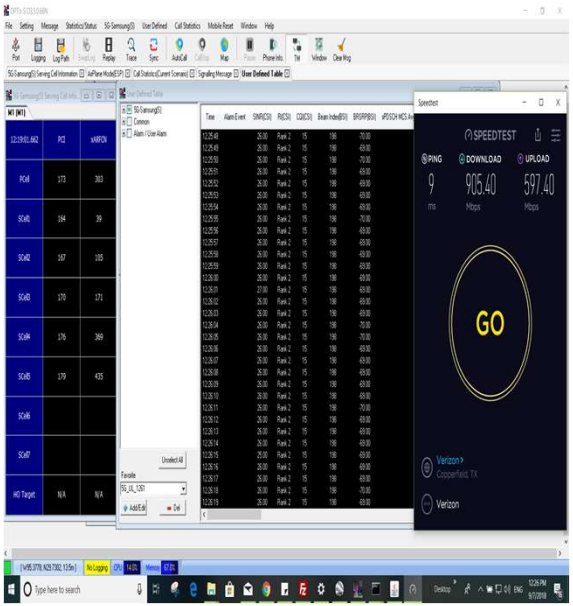


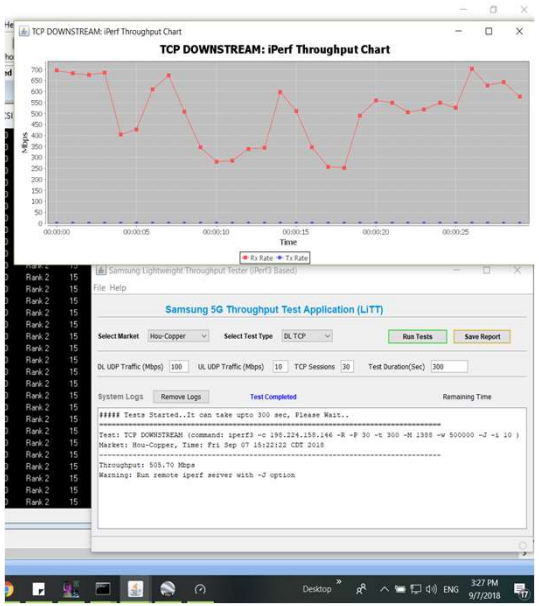


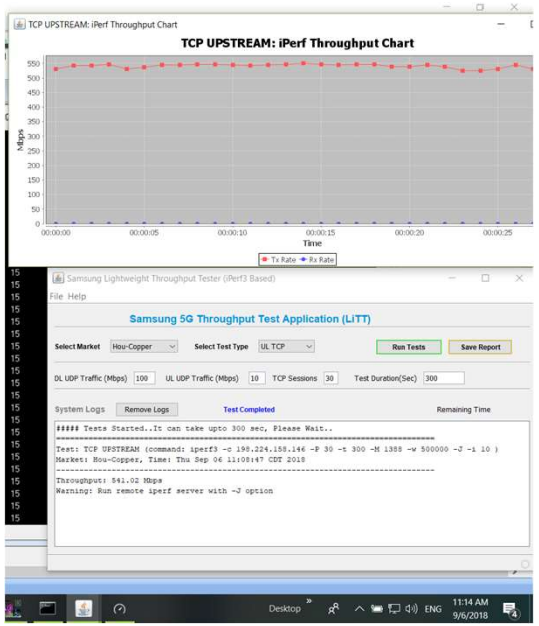
Field Testing

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AUTP Field Measurements







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mmWave performance in Tower mounted Scenario



Morphology	Bandwidth	Channel Condition	Distance	DL Throughput	UL Throughput
Urban	800	LOS	380m	900Mbps	597Mbps

Trial	KPI	Results
E2E Field Test	Peak CPE Throughput	1.1Gbps
	Average CPE Throughput	736Mbps
	Average Latency (Speed Test)	25msec
	LOS Maximum Coverage and Cell Edge Throughput	981Mbps@380meters
CPE ATP Performance (Installation Test in customer home)	Peak Throughput Burst(Best CPE)	DL: 1.8Gbps UL: 328Mbps
	Peak Throughput Burst (Avg of CPEs)	DL: 991Mbps UL: 158Mbps
	Average Throughput (Best CPE)	DL: 934Mbps UL: 311Mbps
	Average Throughput (Avg of CPEs)	DL: 627Mbps UL: 122Mbps
End User Performance *(Limited by End user application usage and by Wi-Fi connectivity)*	Peak Throughput Burst (Best CPE)	DL: 1077Mbps UL: 303Mbps
	Peak Throughput Burst(Average of CPEs)	DL: 119Mbps UL: 28Mbps
	Average Busy Hour Utilization (Best CPE	DL: 178Mbps UL: 67Mbps
	Average Busy Hour Utilization (Avg of CPEs)	DL: 5Mbps UL: 0.5Mbps
	Average Effective Throughput (Utilized TTIs)	DL: 76Mbps UL: 13Mbps
	Average Weekly Tonnage Performance (UHD TV)	49GB


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