Virtual RAN (vRAN) Over DOCSIS, DOCSIS as a Midhaul

A Technical Paper prepared for SCTE by

Ramneek Bali
Principal Engineer
Charter Communications
Ramneek.bali@charter.com

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1. Introduction

The objective of this paper is to present real-world results using commercial solutions that integrate Midhaul interface (F1) over DOCSIS and performance under varying traffic demands and user profiles in RAN and DOCSIS networks. The interface between virtualized distributed unit (vDU) and virtualized central unit (vCU) is called F1 or midhaul.

Virtual Radio Access Network (vRAN) enables the move to more disaggregated and virtualized architecture for deploying 5G networks. Three important elements, which are fully disaggregated in RAN, are the Centralized Unit (CU), the Distributed Unit (DU) and the Radio Unit (RU). Building elements of RAN have further been virtualized, vDU and vCU, and can be deployed on over-the-shelf hardware. To see the benefits of the disaggregated vDU and vCU deployment model, vDU with RU can be deployed at a site and vCU can be centralized at a data center or far-edge location.

Virtual Centralized Unit (vCU) provides non-real-time processing and access control. It manages higher layer protocols including Radio Resource Control (RRC) from the control plane, and Service Data Adaptation Protocol (SDAP) and Packed Data Convergence Protocol (PDCP) from the user plane. The vCU is connected between the 5G core network and the vDU. One vCU can be connected to multiple vDUs.

Virtual Distributed Unit (vDU) provides real-time processing and coordinates lower layer protocols including Physical Layer (PHY), Radio Link Control (RLC) and Media Access Control (MAC). Virtualization shifts the vCU and vDU from dedicated hardware to software components, allowing for flexible scaling, as well as rapid and continuous evolution. This virtualization allows the networks to easily meet the evolving demands of new and existing services with minimal impact on the deployment and operation costs. With vDU, all the baseband functions of real-time RLC/MAC/PHY layers are executed over the commercial-off-the-shelf (COTS) server.

Remote Radio Unit (RRU) provides the physical layer transmission and reception, supporting technologies such as Multiple Input Multiple Output (MIMO).

vRAN offers the flexibility of varied deployment options based on the latency requirements. The lowest latency is achieved by deploying the vDU and vCU at the edge cloud, along with the core in the mobile edge compute (MEC)server. Consequently, the user plane is now located nearest to the service available cell and with the core user plane terminated at the edge cloud itself.

A key asset in the cable industry is the hybrid fiber coax (HFC) network. The vRAN architecture split depends on the throughput and latency performance of the HFC network. These requirements will decide which interface (fronthaul, mid (haul or backhaul) is best suited to deploy over DOCSIS. Fronthaul has the most stringent bitrate and latency constraints and backhaul has the least.

Studies and vendor requirements have shown that the enhanced Common Public Radio Interface (eCPRI) based fronthaul transport needs significantly more bandwidth, overhead and one-way latency in the neighborhood of 100 microseconds between the RU and vDU. Hence, front haul is preferred to be on fiber exclusively, while mid-haul and backhaul can be supported by a transport network with 10-100ms latency. These limitations and cost considerations of deploying fiber makes it easier to deploy RU and vDU at cell site location and vCU/core at centralized location.

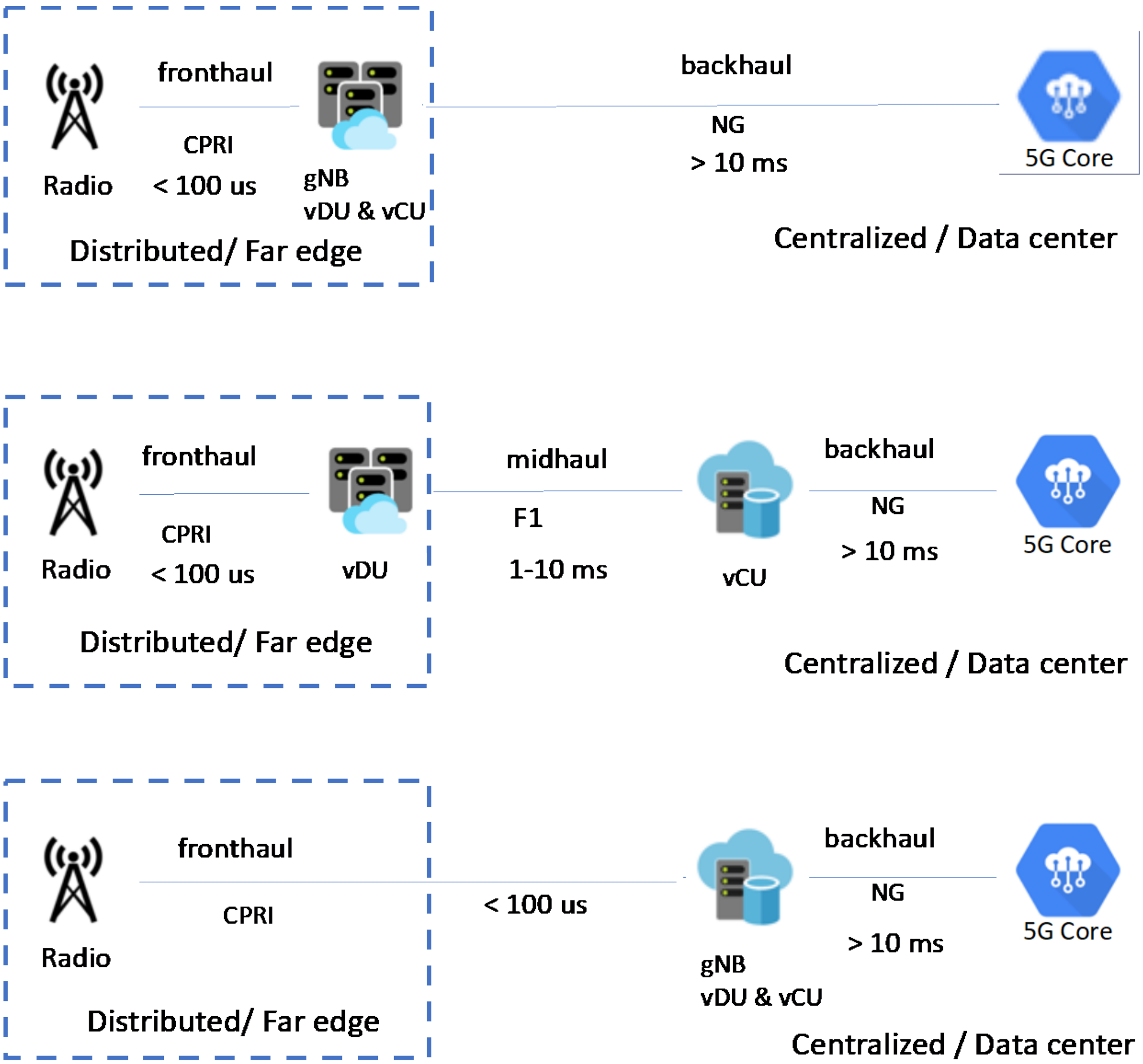

Figure 1 – vRAN deployment options

The interface between vDU and vCU is called F1 or midhaul and has a latency requirement of around 10ms. DOCSIS can play a key role in enabling disaggregated deployments while maintaining the key performance metrics. The latency performance of DOCSIS is best suited for this type of deployment with vDU at the edge and vCU centralized, or at the edge. For now, fiber is required for any fronthaul support and, depending on the availability of the fiber, vDU can be positioned either at the edge or centralized location.

Improvements in new DOCSIS technologies, such as Low Latency Xhaul (LLX), Low Latency DOCSIS (LLD), Active Queue Management (AQM), high split and Low Latency, Low Loss, Scalable Throughput (L4S) will be required to reduce latency to sub 1ms level, making HFC virtually indistinguishable from dedicated fiber for 5G and mid/fronthaul purposes.

2. Lab Setup

Complete end-to-end vRAN lab was built to validate all the vRAN over DOCSIS, which included a 5G SA virtual core, vRAN, UE simulator and full DOCSIS system. vRAN was deployed on open platforms over COTS hardware and built using open platforms and common over-the-shelf hardware. Once the platform was built, RAN application from various vendors was deployed successfully on it.

The study was done to understand the hardware requirements, software deployments and integration effort required between different vendors. This platform was also used to study the RAN and DOCSIS performance under varying RAN and DOCSIS load.

The figure below shows the lab layout.

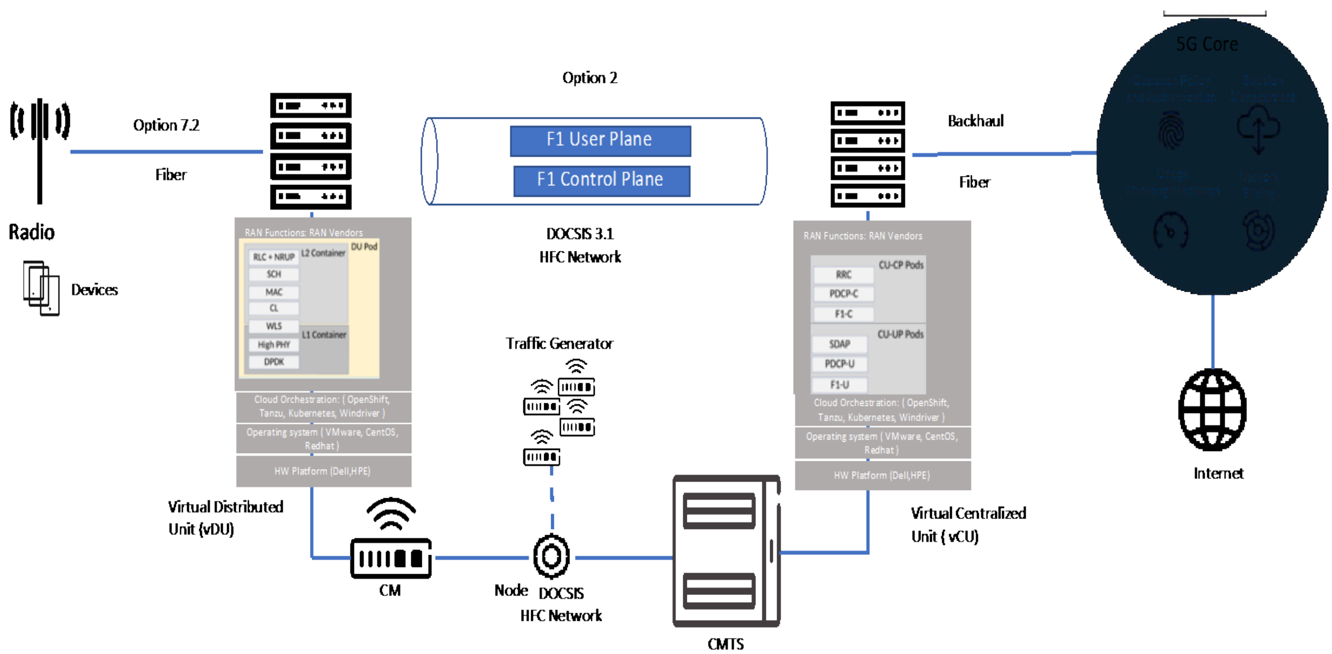

Figure 2 – vRAN Lab Setup

3. Results Summary

vRAN system performance was measured for different key areas over DOCSIS for multi-UE, different radio conditions, mobility and varying traffic load.

The figures below show the results for multi-UE under varying DOCSIS load and different DOCSIS configurations.

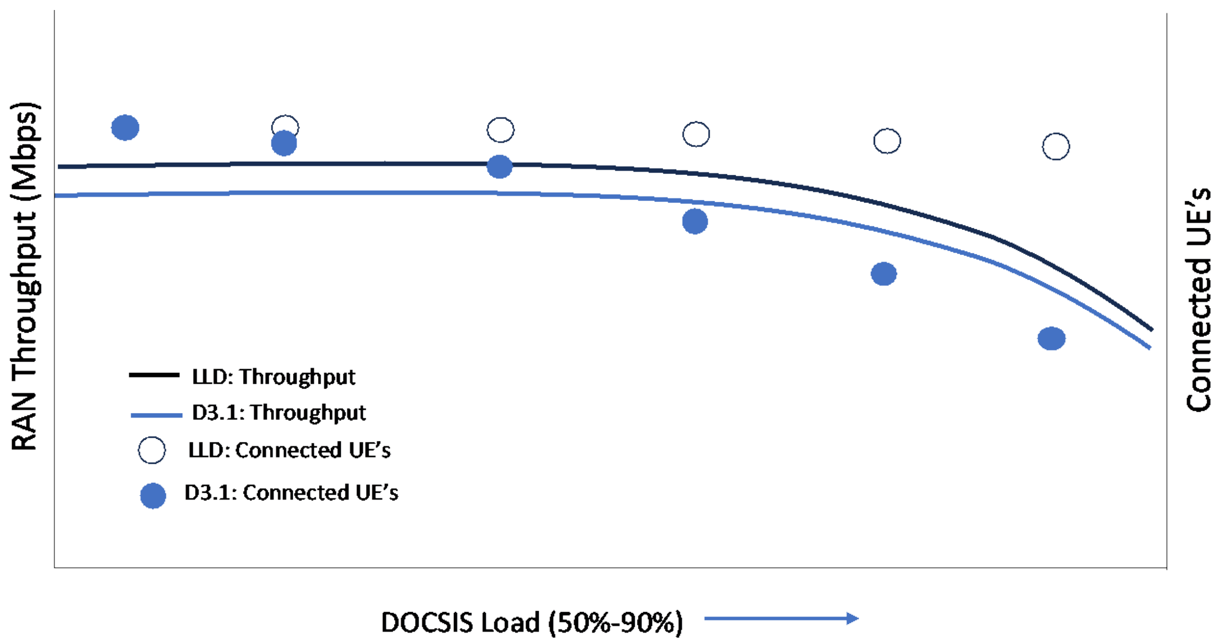

Figure 3 – vRAN Performance Under Varying DOCSIS Load

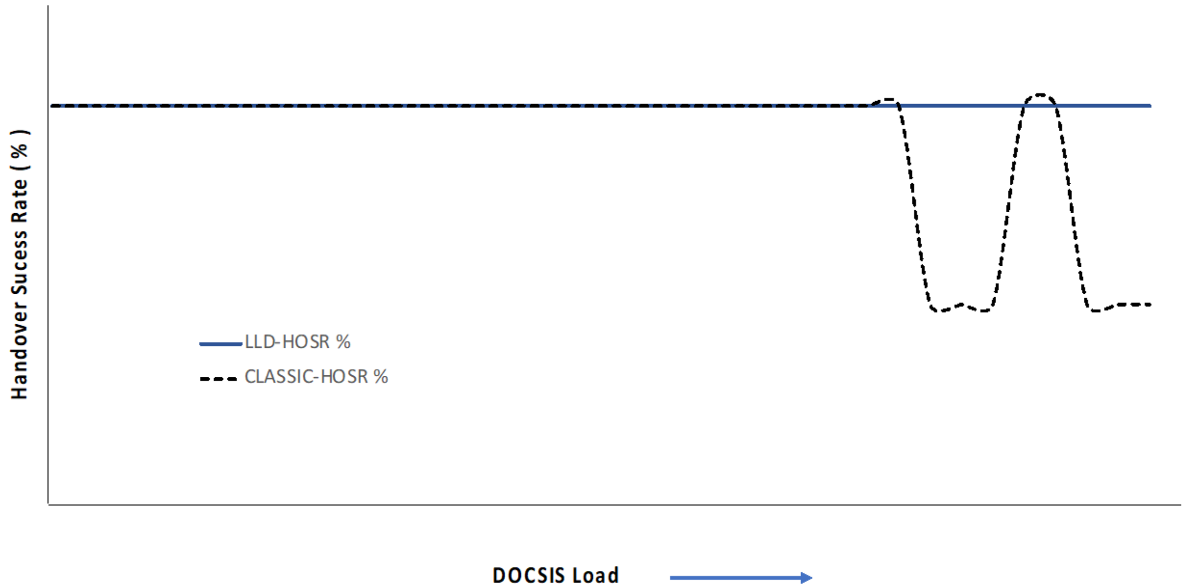

Figure 4 – Mobility vRAN Performance Under Varying DOCSIS Load

Key Observations

- RAN performance is limited by DOCSIS load. At higher DOCSIS load, RAN throughput degrades by more than 100%.
- Increase in latency triggered by DOCSIS load and RAN throughput will mutually degrade both DOCSIS and RAN performance.
- In DOCSIS 3.1, maximum number of simultaneously active UEs per small cell reduces with increasing DOCSIS load as compared to LLD. Contention is observed at CMTS, despite optimized user packet dataflow at CM.
- At high DOCSIS load, able to connect almost all the UEs in LLD as compared to reduction in the simultaneous call establishment for DOCSIS 3.1.
- Signaling traffic (SCTP) being routed via LLD service flow and user traffic is still on default service flow.
- LLD maintains a 100% handover success rate at higher loads as compared to classic DOCSIS, driven primarily by the higher priority given to signaling in LLD.

4. Conclusion

DOCSIS can play a key role in enabling disaggregated deployments while maintaining the key performance metrics. The latency performance of DOCSIS is best suited for this type of deployment with vDU at the edge and vCU centralized, or at the edge. Improvements in new DOCSIS technologies, such as Low Latency Xhaul (LLX), Low Latency DOCSIS (LLD), Active Queue Management (AQM), high split and Low Latency, Low Loss, Scalable Throughput (L4S) will be required to reduce latency to sub 1ms level, making HFC virtually indistinguishable from dedicated fiber for 5G and mid/fronthaul purposes.

Abbreviations

vDU	Virtual Distributed Unit
vCU	Virtual Centralized unit
RU	Radio Unit
MEC	Mobile edge compute
HD	high definition
Hz	hertz
K	kelvin
SCTE	Society of Cable Telecommunications Engineers