Achieving Significant Space, Energy, And Cost Reductions With Future Virtualized Distributed Access RPD And RMD Architectures For MSOs

A Technical Paper prepared for SCTE•ISBE by

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Introduction

Cable access networks are on the cusp of a major transformation driven by an insatiable consumer appetite for multimedia and Over the Top (OTT) content, social media, learning and communication. This hunger is enabled by the digitization of everything and the automation of the world around us, both of which are enhancing human experiences and forever changing our lives. Satisfying this appetite cost-effectively requires a foundational transformation in cable access network architecture to provide the capacity and performance needed to satisfy these enhanced human experiences and needs.

The use of Distributed Access Architectures (DAA[1]) will transform cable networks to a degree that has not been seen since the late 1980s and early 1990s when fiber began to play a prominent role in Hybrid-Fiber Coax (HFC) networks. Today's asymmetrical multi-Mbps capacity HFC networks will shift over time to a hyper-scaled symmetrical multi-Gbps capacity HFC network. DAA will deliver these speeds with space and energy savings when compared to today's network architectures.

However, this shift will impact cable edge facility[2] space requirements, and edge facility and Outside Plant (OSP) energy requirements. This paper presents an analysis of an exemplary edge facility and its associated OSP. It compares the space utilization and energy consumption of three DAA architectures to the conventional I-CCAP (Integrated-Converged Cable Access Platform) architecture. We demonstrate that when migrating from n+6 to n+3, a virtualized Cable Modem Termination System (vCMTS) Remote MACPHY[3] Device (RMD) based architecture provides the greatest savings in edge facility space (66%) and energy consumption (86%) over I-CCAP. Migrating to DAA increases OSP energy needs in all architectures, however, there is a variance of just 5% among the DAA alternatives at n+3.

The Shift to DAA

Bell Labs' Future X[4] Massive Scale Access vision is driven by new technological capabilities and critical digital network needs that will deliver a cost/capacity/bandwidth value transformation to MSOs and consumers. In summary, these capabilities and needs are:

- Seemingly infinite hyper-capacity at 100x growth over the next decade.
- Unlimited on-demand capacity for any application or service.
- Tera-hyper-scaling of networks to support trillions of connected systems, devices, processes, objects and automata.

MSOs need to meet these digital network needs with a network that delivers increased capacity, greater flexibility and reduced complexity, with increased efficiency and reusability – all at a reduced cost. DAA is a critical part of the Bell Labs vision and will enable several major cable access architecture shifts:

- Capacity expansion - DOCSIS® 3.1 increases capacity through improved spectral efficiency, increased Upstream (US) spectrum (and capacity), increased aggregate US/Downstream (DS) spectrum to 1.2 GHz, and many other means. Moving fiber deeper through physical node splitting and node relocation enables spectrum reuse and higher average bandwidth per consumer. Full Duplex (FDX) DOCSIS, currently under definition, will provide symmetrical multi-Gbps data

[1] Defined later in this paper
[2] Also, may be known as a hub
[3] Media Access Control/Physical Layer, also referred to as MAC/PHY or MAC-PHY
[4] The Future X Network, A Bell Labs Perspective, 2016, M. Weldon and all, CRC Press – Taylor & Francis Group

speeds on existing coax. Longer-term, fiber can be extended to the last coax drop tap, to within tens of meters of about four to six consumers, exploiting spectrum above 1.2 GHz to reach up to 30 or 40 Gbps. DAA architectures will help enable this transformation to FDX.
- Energy consumption reduction and space reduction - Edge facility energy and total energy (i.e., edge facility and OSP combined) improves as devices become more efficient and as functionality (e.g., MACPHY) is moved from the edge facility to the OSP.
- OSP modernization - DAA will trigger a shift from analog fiber to digital fiber, providing a multitude of advantages including: use of higher-order QAM modulation, reducing maintenance costs, and traversing longer distances.

DAA Architectures

I-CCAP is the baseline centralized architecture being deployed today, with integrated Media Access Control (MAC) and Physical (PHY) layer functions located at the cable edge facility and connected to a remote fiber node via analog fiber. Three primary distributed architectures (DAA) have been defined by vendors, MSOs, and CableLabs®:

- CCAP Core Remote PHY Device (RPD) - A non-virtualized CCAP core containing the DOCSIS® 3.1 MAC function with the PHY function in a remote node connected to the edge facility via digital fiber.
- vCMTS RPD - A vCMTS function running the DOCSIS 3.1[5] MAC on an off-the-shelf server in an edge facility or centralized location with the PHY function in a remote node connected to the edge facility via digital fiber.
- vCMTS RMD - A vCMTS running DOCSIS 3.1 MAC and PHY functions in a remote node connected to an edge facility via digital fiber.

[5] Could also be DOCSIS 3.0, however DOCSIS 3.1 is the current technology

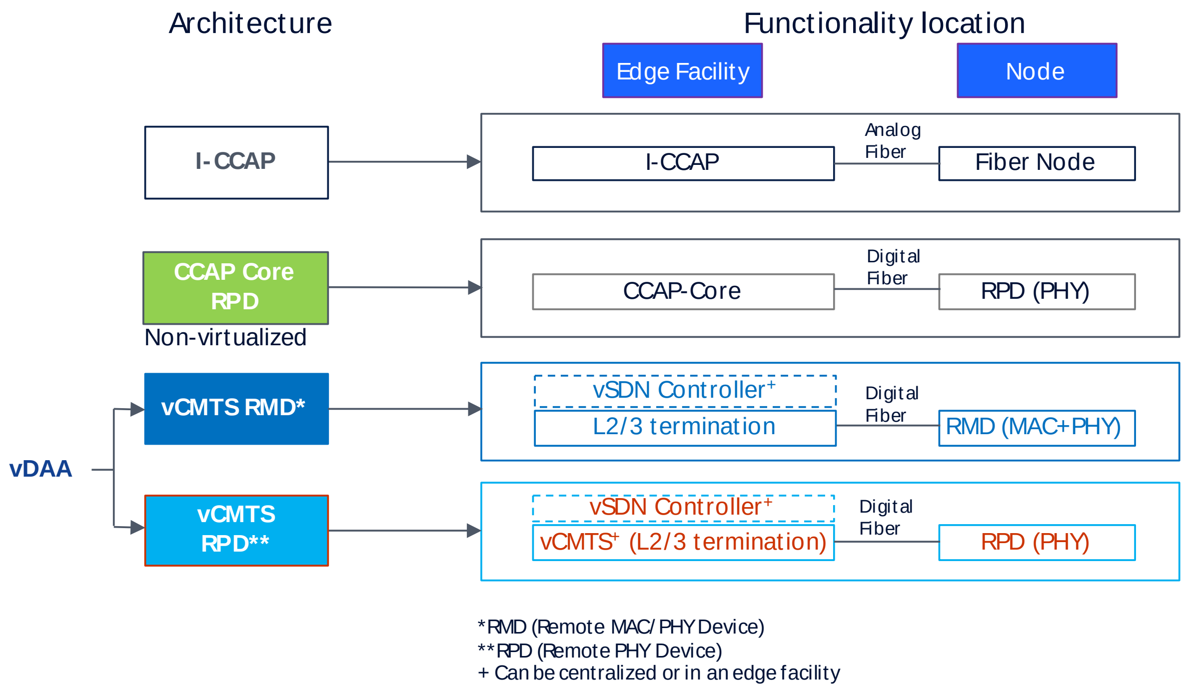

Figure 1 - CCAP and DAA Architectures

Benefits of DAA

Bell Labs Consulting modelled the CCAP Core RPD, vCMTS RPD, and vCMTS RMD based architectures to compare them to the I-CCAP based architecture for space utilization and energy consumption. To provide a holistic view, Total Cost of Ownership (TCO) modelling analysis included equipment required to deploy each of the DAA architectures and the I-CCAP architecture from the edge facility out to the node, including off-the-shelf servers, switches, routers, video equipment and racks. To keep the comparison between these architectures consistent, the modeling was performed on an exemplary edge facility supporting 50,000 households passed and a representative OSP topology. Significant differences exist in how these architectures compare across space utilization and energy consumption. Figure 2 illustrates the equipment in a standard datacenter rack that support a vCMTS RMD solution.

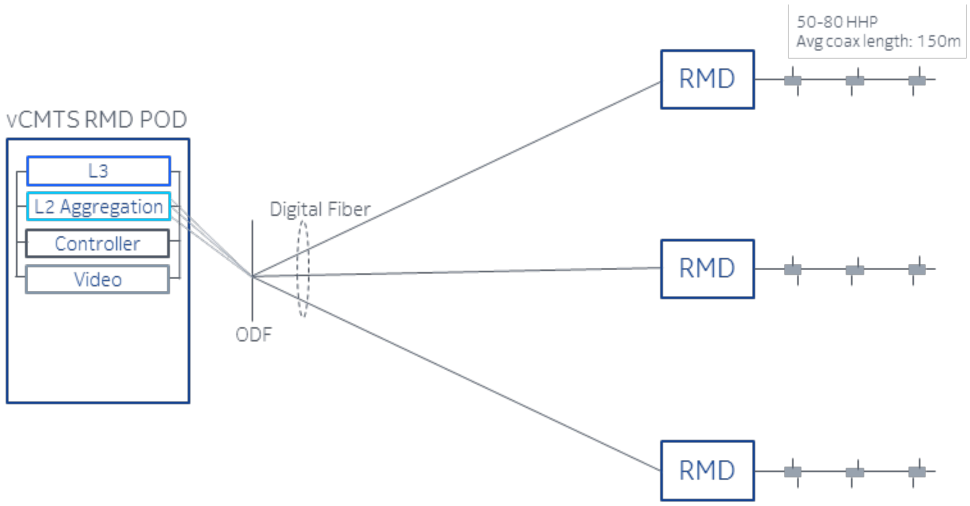

Figure 2 - Realization of vCMTS RMD

Figure 3 illustrates the equipment needed in a standard data center rack for a vCMTS RPD solution realization. A leaf-spine architecture is used to interconnect multiple Commercial Off-The-Shelf (COTS) servers with essential vCMTS terminating components.

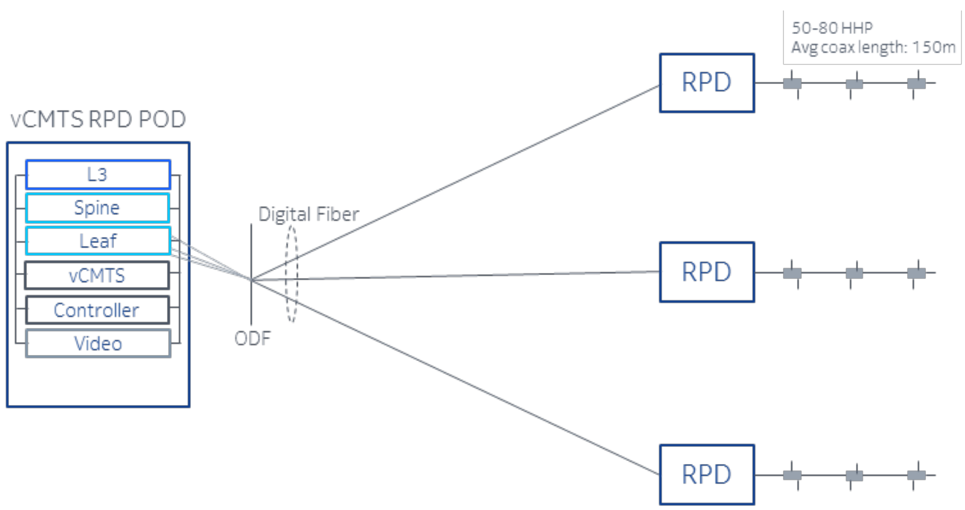

Figure 3- Realization of vCMTS RPD

Key modeling assumptions

Several hundred assumptions are included in the models. Assumptions that have the greatest impact on the analysis results are listed here.

Assumptions common amongst all architectures:

- 50K HHP coverage by edge facility
- 30K consumers served/edge facility
- 42 Rack Unit (RU) rack size
- 10 KW per rack limit

- 2 service groups per node

I-CCAP specific assumptions:

- 16 RU chassis with a density of 96 service groups

CCAP Core RPD specific assumptions:

- 16 RU chassis with a density of 192 service groups

Assumptions common to all vCMTS architectures:

- 600 watts, 1RU COTS compute server trays
- Video servers of similar capability

vCMTS specific RPD assumptions:

- 32 service groups per server tray
- 20 server trays per POD hosting vCMTS function – no redundancy

Controller assumptions:

- 500 service groups per server tray for controller (1+1 configuration[6])

1. Space utilization analysis results

Edge facility space requirements increase to accommodate additional equipment required as the number of service groups grows and as the OSP architecture correspondingly evolves from N+6 to N+0. The following table illustrates this growth to N+3, using N+6 with 96 SGs (i.e., 48 nodes) as the baseline.

Table 1 - Space Increase at Edge Facility

N+6 - Baseline Architecture	N+3 - Edge Facility Space Increase (over N+6)
I-CCAP	3x
CCAP Core RPD	3x
vCMTS RPD	3x
vCMTS RMD	2x

Remote placement of vCMTS RMD MAC and PHY functions in the OSP provide significant edge facility space utilization (rack unit) savings over I-CCAP and all other DAA approaches.

As seen in Figure 4, the gradual rise of the vCMTS RMD plot reflects its ability to scale more efficiently than other DAA solutions.

[6] One active, one standby

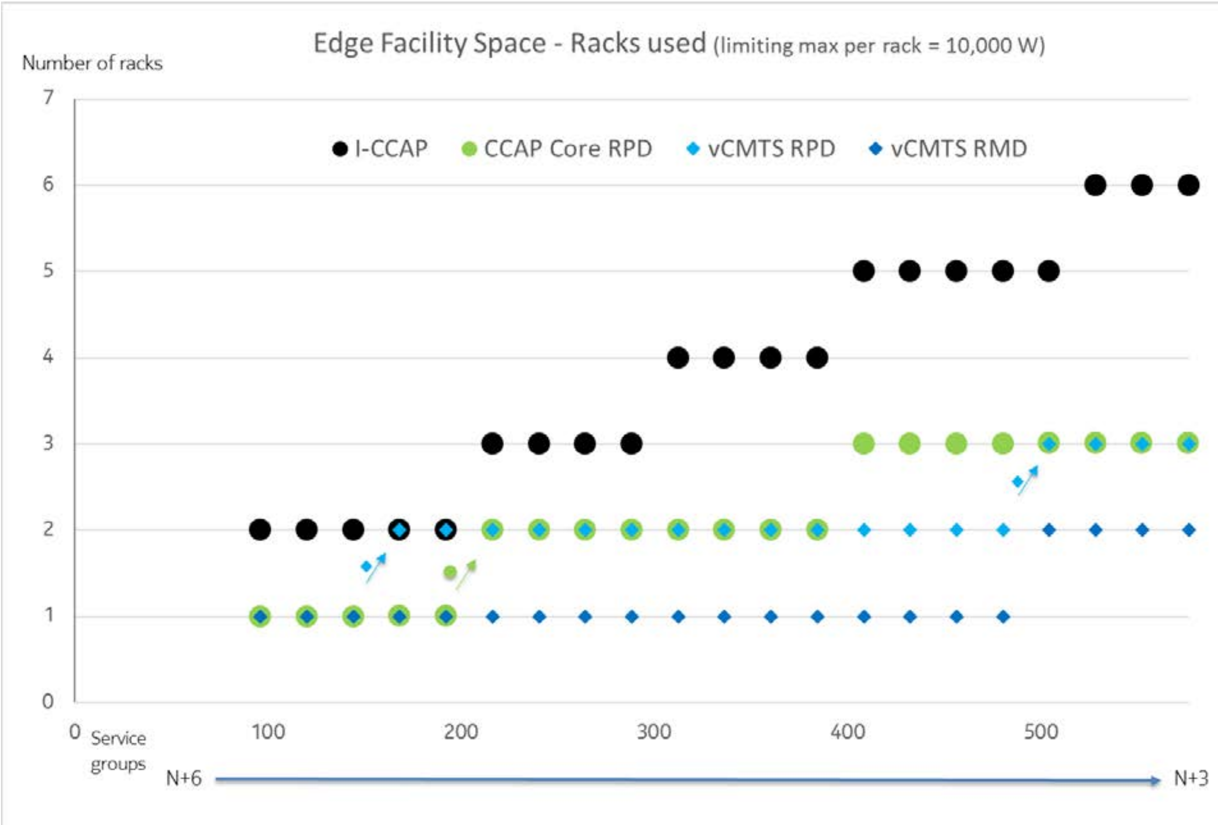

Figure 4 - Edge Facility Space Modeling Results

2. Energy analysis results

2.1. Edge Facility

Edge facility energy usage increases as the number of service groups grows and as the OSP architecture correspondingly evolves from N+6 to N+0. The following table illustrates this growth to N+3, using N+6 with 96 SGs as the baseline.

Table 2 - Edge Facility Energy Increase

N+6 - Baseline Architecture	N+3 - Edge Facility Energy Increase (over N+6)
I-CCAP	5.2X
CCAP Core RPD	4.5X
vCMTS RPD	2.8X
vCMTS RMD	1.8X

Figure 5 illustrates this growth in edge facility energy consumption showing estimated edge facility equipment energy usage (in watts) for the four architectures. Since heating, ventilation and air conditioning would account for a constant multiple based on Power Usage Effectiveness (PUE), it is not shown in the calculations below.

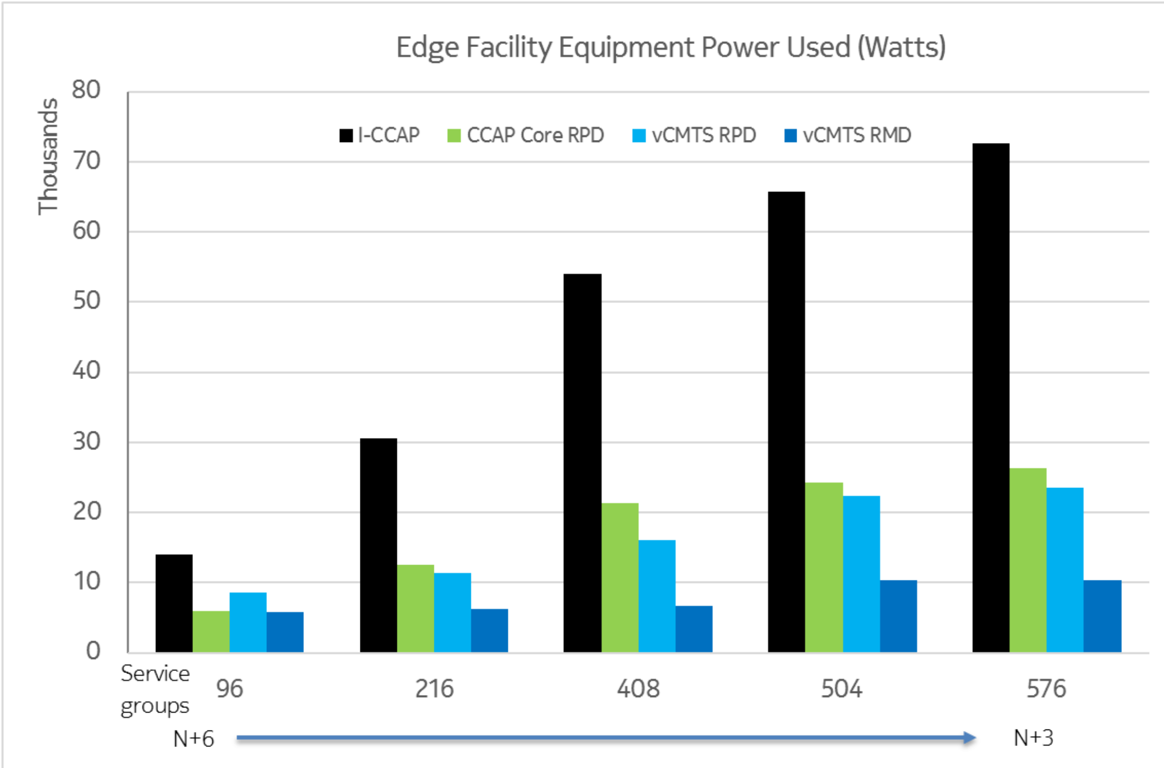

Figure 5 - Edge Facility Energy Modeling Results

All DAA architectures consume less edge facility energy than I-CCAP due to the distribution of key functions into the OSP. Requiring only a controller function at the edge facility and distributing both the MAC and PHY functions to remote nodes, vCMTS RMD reduces energy consumption in the edge facility more than any of the other architectures.

2.2. Outside Plant

OSP energy usage also increases as the number of service groups grows and as the OSP architecture correspondingly evolves from N+6 to smaller N+x. The following figure illustrates this growth as the OSP evolves from N+6 to N+3. It is normalized to RPD at n+3.

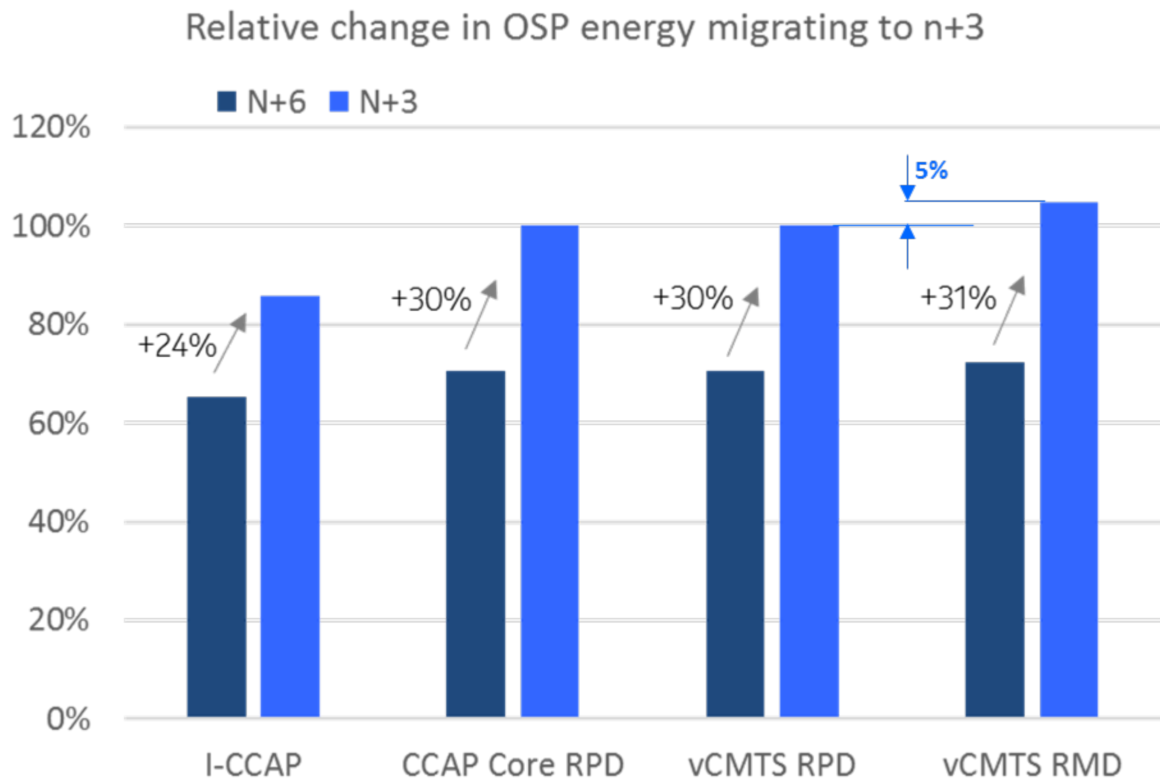

Figure 6 - OSP Energy Growth for Each Architecture Comparing N+6 to N+3

A vCMTS RMD-based OSP consumes about 5% more energy than an RPD-based OSP at n+3, due to the MAC and the PHY being collocated. However, the vCMTS RMD solution offers significant savings in the energy consumed at the edge facility as shown in Figure 5 which makes it attractive from an OpEx perspective.

Conclusion

Both vCMTS RPD and vCMTS RMD solutions reduce edge facility space and energy consumption when compared to I-CCAP and CCAP Core RPD solutions. vCMTS RMD provides the greatest savings in edge facility space (66%) and energy consumption (86%) compared to I-CCAP at n+3. vCMTS RMD consumes slightly more OSP energy (about 5%) than the RPD alternatives. Although, these space and energy savings are an interplay of many factors, the results herein are representative of the typical needs and benefits for larger cable edge facilities.

Abbreviations

CMTS	cable modem termination system
COTS	common off the shelf
DAA	distributed access architecture
DOCSIS	data over cable system interface specification
FEC	forward error correction

HFC	hybrid fiber-coax
HHP	households passed
I-CCAP	Integrated-common cable access platform
ISBE	International Society of Broadband Experts
MAC	media access control (layer)
Mbps	megabits per second
MSO	multiple system operator
OSP	outside plant
OTT	over the top
PHY	physical (layer)
PUE	power usage effectiveness
RMD	remote mac and phy device
RPD	remote phy device
RU	rack unit
SCTE	Society of Cable Telecommunications Engineers
TCO	total cost of ownership
vCMTS	virtualized cable modem termination system

Bibliography & References

The Future X Network, A Bell Labs Perspective, 2016, M. Weldon and all