Increasing the performance of broadband cable networks

Virtual CMTS – Head in the Cloud

Remote PHY and Remote MACPHY technologies can move functions of the CMTS to the optical nodes and bring more bandwidth to the customers. The physical CMTS becomes a virtual CMTS, which also brings numerous advantages for the network operators. By Dr. Alex Adams

Mothers' Day is being celebrated on the second Sunday in May every year, when we traditionally honor that special lady who gave us life, put us on the planet and taught us the ropes during the first years of life on it. Under normal circumstances motherly care can hardly be avoided, our mothers strive to take care of us our entire lives. Broadband communications networks generally are far removed from such family affairs, however, the relationship of a CMTS – that is short for "Cable Modem Termination System" – to its cable modems can under certain circumstances be regarded as parental, maybe even outright motherly. That is why in the remainder of this article the CMTS will be referred to in the female gender.

CMTS as head of the network

The CMTS is the head of the "Cable Family". With very few exceptions, nothing happens and occurs within an HFC-network that was not instructed or approved to by the CMTS. She is the boss of the network. The cable modems can only execute her orders or place a request with her. Downstream signals are generally sent down the network as broadcast signals and the individual cable modems are told which frequencies the requested information will be arriving on. Every modem can then isolate the traffic that is destined to it from the broadcast signal. This situation may be compared to my sister giving general instructions to her four boys. Every son filters the information concerning him out of the motherly downstream. Should questions arise from amidst the young gentlemen, these need to be taken care of sequentially, one by one. Hence each son needs to wait his turn to talk to his mother. The upstream of an HFC-network is also divided into timeslots, a setup named a time-division-multiplexing-system. Therefore, the comparison of a CMTS and her cable modems to a mother with thousands of children is not all too farfetched.

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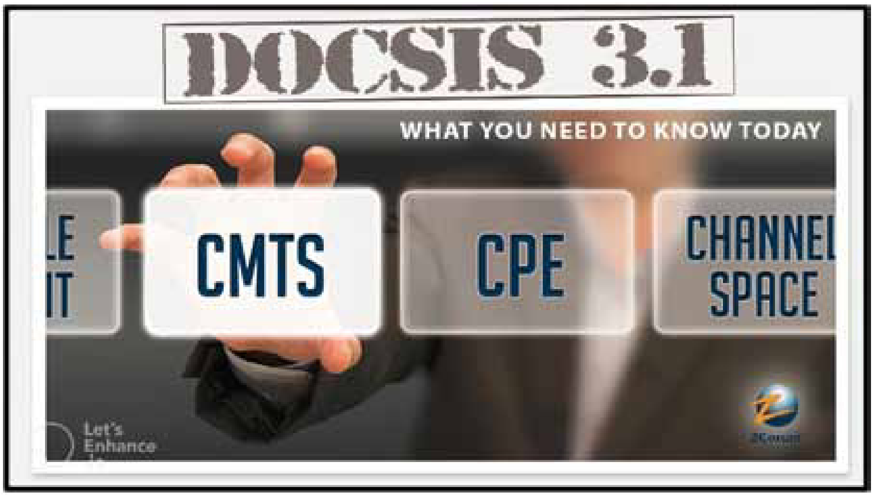
Figure 1: Head in the clouds - the CMTS is moved to the cloud and virtualised

CCAP improves performance and quality

Traditionally, a CMTS is part of a so called "Converged Cable Access Platform (CCAP)". The functions that have been converged upon this platform are the transmission of data signals as well as video- and voice-signals. A CCAP combines the functions of a Cable Modem Termination System (CMTS) for transmitting data and of so-called Edge Quadrature Amplitude Modulators (EdgeQAM) for the transmission of audio- and video-data. The combination of these elements allows for a more efficient utilization of the network, and it reduces the physical mounting-space required in a headend. The use of CCAP-equipment put network operators in a position to deliver ever higher data rates and service quality to their customers in the past years. CCAP-systems deliver high-speed internet, voice-over-IP telephony, digital video services, DOCSIS-applications, and IPTV (Internet Protocol Television). Hence, a CCAP is a powerful and specialized computer, directing network operations from a central position such as a headend or a hub.

Decentralization through Remote PHY

The introduction of DOCSIS 3.1-technology into HFC-networks often goes hand in hand with the simultaneous introduction of RemotePHY-technology to further optimize CMTS-systems and functionality. RemotePHY-systems decentralize many functions of a CMTS within the network and move them into the optical nodes, while keeping a core-CMTS module in the headend. This approach in a way "smears" the functions of the CMTS across the entire footprint. This means that a considerable amount of management messages for the purpose of organizing and executing data transport are now exchanged between cable modems and optical node, instead of going from the cable modem all the way back to a central CMTS in a headend. This results amongst others in significantly shorter latency.



Source: SCTE, a subsidiary of CableLabs

Figure 2: In parallel with the introduction of DOCSIS 3.1 technology in HFC networks, CMTS systems were further optimized by remote PHY

Two layers

The physical layer is "Layer 1" of the Open-System-Interconnect-Model (OSI-model). In the cable industry we love abbreviations, which is why the PHY-layer very quickly becomes just "The PHY". Additionally, in RemoteMAC-PHY-systems, functions of the OSI-Model's "Layer 2" are being placed into the optical nodes as well. This layer is officially called the "Data Link Layer". However, the cable industry likes to refer to it as the "DOCSIS MAC", which actually constitutes merely a subgroup of the Data Link Layer in broadband cable. Figure 3 depicts the OSI-model specialized for the broadband industry.

The PHY-layer contains upstream and downstream "Physical Media Dependent (PMD)", performing the modulation with the transmission frequency and the consequent transmission of the signal across the cable. In the "Downstream Transmission Convergence Layer (DS TC)", downstream data is assigned to modulation profiles, depending on the transmission frequency and conditions of the network connection to the individual modems. Hence, the PHY-layer is the one where the physical labor of data modulation and transmission is being performed.

On the other hand, the Data Link layer consists of DOCSIS Media Access Control (MAC), Link Security und 802.2 Logical Link Control. Both Logical Link Control and Security are somewhat self-descriptive, they serve the purpose of control and security of the links, of framing and encapsulation, flow- and error control, addressing as well as connection establishment and termination. As mentioned before, the entire Data Link layer sometimes gets referred to as the DOCSIS MAC. However, Figure 3 shows that to be not completely accurate, as it often is with nicknames. The Data Link layer -- and especially the DOCSIS MAC within it -- are crucially important for the logistic organization of data transport across the network. For this purpose, so-called MAC management messages (MMMs) are being exchanged between CMTS and cable modems on the DOCSIS MAC. These MMMs are not very large strings of information – about one or two kilobytes in size – yet without them data transport is impossible across the network. In DOCSIS 3.1-networks, cable modems receive the MMMs from the subcarriers of the PHY-link channel (PLC) within the downstream OFDM-channel. The PLC uses very robust modulation orders to protect the MMMs on their way across the network.

For a more tangible description of the PHY- and Data-Link layers' roles in data transport, consider the transfer of an overseas shipping container on a truck from the port of Hamburg to Munich across the highway. While truck, container and the trip across the Autobahn would be standing for functions of the Physical Layer (OSI Layer 1), the MAC management messages on the Data-Link layer would be represented by the logistic preparation of the transport before and during the truck-roll in the analogy. Just as the truck driver will not randomly pick up any container in port and start hauling it into a somewhat southerly direction, the transport will be planned by a logistics company ahead of time for utmost efficiency. Amongst others, a driver needs to be assigned with the proper license, papers need to be prepared, the route needs planning and toll-fares need to get calculated, contact persons at the port and at the destination need to be arranged for, etc. It could be put this way: Without DOCSIS MAC, the system has no plan!

Central computer in the headend becomes superfluous

Remote PHY- and MAC/PHY-systems have replaced the central CMTS at the headend with a skinned down core-CMTS as an interface to the superordinate internet service provider as well as a large number of "satellites" of the CMTS within the optical nodes out in the network taking care of PHY-functions (Remote PHY-System). On top of many advantages of such a setup – like the use of digital optical links and reduced latency – the need for a powerful central computer in the headend ceases to apply. Instead, there is need for a lot of comparatively less powerful computers in headend and optical nodes. These computers do not have to be specially designed for the broadband industry like central CMTS-systems are, CMTS-functions can be implemented using generic server- and cloud-systems off the shelf. Physical CMTS turns into virtual CMTS (vCMTS).

More cost efficiency and flexibility

Virtual cable modem termination systems sport some additional beneficial features. Other than her technologically older sister, a virtual CMTS does not consist of a central and specially designed super-computer. More so, a vCMTS is a software-based solution hosted on virtualized servers. A vCMTS emulates the functions of a physical CMTS, meaning it imitates them using software to manage and route data traffic between the cable modems and the superordinate network provider.

Decoupling of CMTS-functions from special hardware necessities bears the advantage that system scaling does not go hand-in-hand with costly exchange of hardware but can be done solely by the use of software. That is not only a more cost-efficient approach, it also is achievable in a more favorable timeframe than could be done with a central and physical CMTS-system. Additionally, vCMTS-systems hold economic and technical advantages for big as well as small network operators and pose high flexibility, e.g., when network capacity is to be increased without laying new infrastructure.

Easier network management and greater reliability

Virtual CMTS can be incorporated into a cloud-environments, ensuring an easier system scalability, and granting the HFC-network operator a better overall flexibility. Virtual and decentralized CMTS are easily scalable using software applications and can be applied to those sections within the network where this scalability is needed or when customer demand is changing quickly. In this fashion, network operators may add or drop capacity dynamically without having to field new equipment.

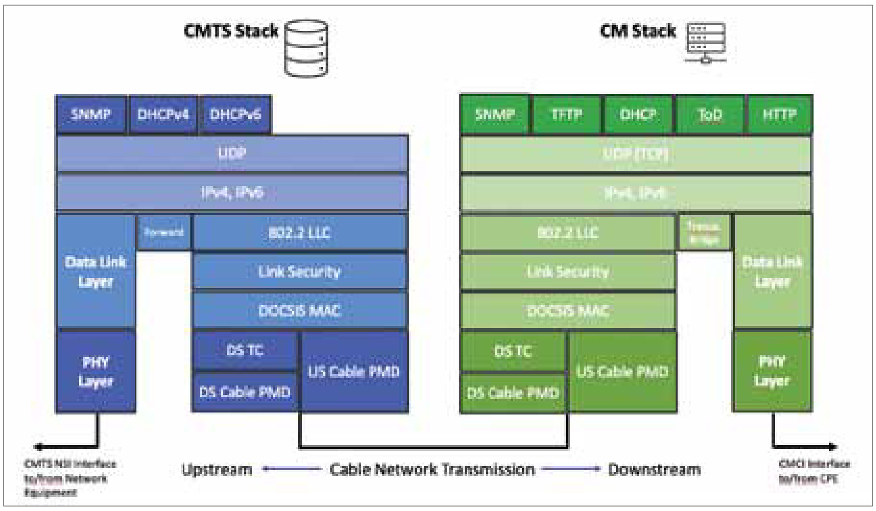


Figure 3: OSI-Stack for HFC-Networks

Ensuring connectivity in the future

Further, another important aspect of virtualizing the overall CMTS-structure of the network is the delectable development of costs in acquisition and operation coming with this approach (e.g., power consumption, maintenance). Traditional central and physical CMTS require a substantial monetary investment into the technical infrastructure, since it is a machine designed especially and precisely for this purpose, as was explained above. Traditional physical CMTS do sport their price in acquisition, maintenance, and upgrade. Virtual CMTS-systems on the other hand can be placed on generic servers that can be purchased in any computer store. These systems are usually not purpose-built super-computers but rather programmable generalist, and as such they are a lot less pricy. Figure 4 depicts such equipment exemplary, as well as software elements to be run on it. Further, network operators will be able to project future technological advances as well as future transmission standards upon their networks by upgrading vCMTS-systems, thus easing their support of the latest industry standards.

Changing the network architecture toward the employment of virtualized CMTS-functionality results in simplified network management approaches, for vCMTS-solutions exhibit central management interfaces, allowing for a holistic view of network infrastructure and its functionality. This poses a significant improvement in network man-

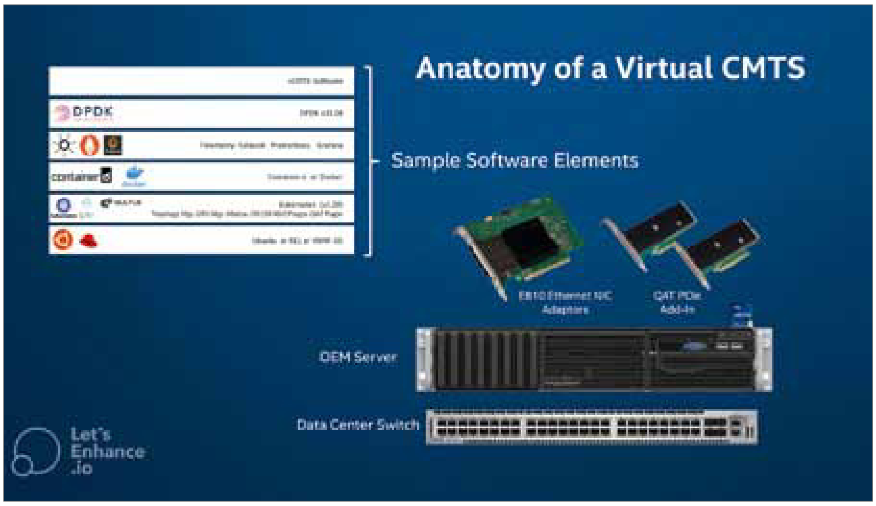


Figure 4: Anatomy of a virtual CMTS

ageability and opens new possibilities in monitoring CMTS-functions in live networks, in troubleshooting processes, in configuration, and in the overall administration of the network. Moreover, network redundancy and availability may be improved upon by means of virtualization. The incorporation of redundant virtual equipment into network design and the establishment of failover-processes help to reduce network down-times to a minimum, resulting in higher network reliability in return.
Currently, virtual CMTS-structures are becoming ever more attractive, since the COVID-pandemic has pushed the demand for high-speed internet even further. For a significant proportion of the population, the internet is a necessary tool to perform their daily work. After the years of the pandemic, it has remained customary in a widespread fashion to keep one or two days of home-office work in the weekly schedule. Furthermore, the internet rules a lot more than our working lives, it has become a factor in about every aspect of life – a fact we quickly realize when involuntarily removed from our smart phones for a few days. We use it for work and play, for entertainment, for education, for training and professional development, for health issues, for shopping and for taking care of administrative issues, to name just a few examples. Every aspect of life generates its own data, for every person, every day, and a lot more on top of that. Network operators need to ensure their ability to keep offering an effective, capable and flexible infrastructure as we move toward the future, ensuring the needed connectivity in the face of an ever-growing avalanche of data.
Today, virtual approaches already offer flexible and cost-efficient solutions without the necessity of deploying added physical infrastructure. After all, a steadfast principle of practically all mothers is expressed in the attitude that existing equipment should be used first before investing money into new one. Were a CMTS more human, I am sure she would concur. ■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Dr.-Ing. Alexander C. Adams

Dr. Alex Adams is Chief Science Officer of the Netzkontor Group and managing director of Adams Network Engineering. Alex has 22 years of working experience in the German and international broadband cable industry. He is instructor of the SCTE, a subsidiary of CableLabs and he is her European representative. Further, Alex is an Associate Professor at the Jade University in Wilhelmshaven/Oldenburg, Germany. Alex holds Bachelor- as well as a Master-of-Science degrees from the University of Hawai'i and a doctorate degree from the Technical University of Darmstadt, Germany.