ENHANCING DOCSIS SERVICES THROUGH NETWORK FUNCTIONS VIRTUALIZATION

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Abstract

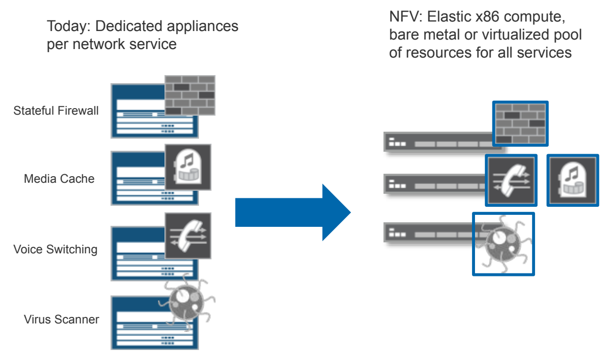
The DOCSIS system does not directly define a service offered to a subscriber. The use of classifiers, service-flows and the like define the parameters around a service – typically IP high-speed-data, L3VPN, or L2VPN but does not make any attempt to define, or enhance, the actual service delivered over DOCSIS. This paper will examine the role that Network Functions Virtualization (NFV), an effort within the Software Defined Networking (SDN) community, can play as an enhancement to data services delivered via DOCSIS. We will examine benefits of NFV, propose an integration scheme of NFV and DOCSIS, and explore some potential use cases of this enhanced DOCSIS services architecture. This integration can increase network efficiency, enable new revenue opportunities, and permit rapid service innovation.

NFV OVERVIEW

Network Functions Virtualization is an effort originally proposed by the European Telecommunications Standard Institute (ETSI), a group of service providers and operators at the SDN and OpenFlow World Congress in 2012. [1]. The objective of NFV is to leverage modern generic computation and software virtualization systems to enable a new platform upon which to build high-touch network services and revenue models. The number of proprietary hardware appliances is reduced, with an increase of standard x86-style compute platforms and software implemented on data and control plane packet processing.

The benefits of NFV are, but are not limited to:

- Reduction in equipment costs and power through economies of scale
- Increased innovation velocity through software development
- Elastic scaling of a services-plane within a network
- Open and robust services innovation



BENEFITS OF DOCSIS WITH NFV

Network Functions Virtualization presents an innovation opportunity for cable operators. Previous models of network service architecture required large, centralized service data centers (i.e. voice switching) or highly distributed, purpose built appliances (i.e. video caching), both with economic and operational challenges. To maintain large central data centers in cable environments requires service rates and take-up percentages to justify the build and operating costs. Distributed appliances have similar challenges, in that they must offset enough capex from "business as usual" – simply deploying more bandwidth – to become feasible.

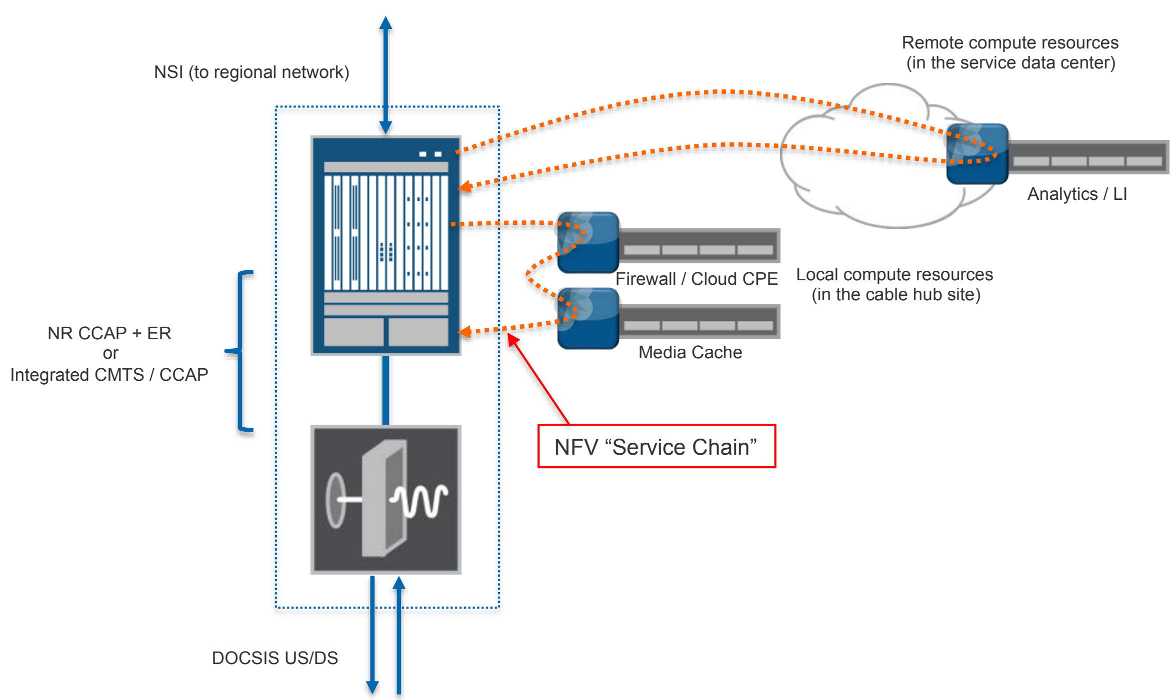
The virtualized aspect of NFV permits one investment, in generic x86 computing resources, to be leveraged enabling many services. Where previous network services were instantiated on dedicated, standalone appliances – each with their own vendor, support, operational model and depreciation schedule – now one investment can be made to support all services. Services themselves run as virtual machines in an x86 compute environment. Individual services can scale just as in a modern data center, through the allocation of virtualized memory, CPU, storage and network policy, as well as horizontally by adding additional load-balanced virtual machines.

The generic nature of this new services infrastructure enables us to propose an integration of DOCSIS and NFV, such that the cable operator can enable services on a per-service flow, per-cable modem or per-VPN nature. These services would be provisioned using the standard DOCSIS tools and existing TFTP and DHCP mechanisms of standard cable modem registration.

NFV AND DOCSIS INTEGRATION

The figure illustrates a potential deployment scenario in a typical cable hub site with local and remote x86 service elements. The "ER" in the figure is the CCAP "Edge Router." In an Non-Routing (NR) CCAP architecture, the ER manages IP sessions, IP routing, IP/MPLS servces and implements NFV, while the CCAP handles specific MAC and PHY interfaces for DOCSIS. In an Integrated-CCAP or traditional CMTS architecture, all of this hardware and software functionality must be built in to a single chassis. Either architecture is capable of integrating NFV with DOCSIS. The differences between NR-CCAP and Integrated-CMTS/CCAP architectures are beyond the scope of this paper.

In this example, three services have been virtualized: Analytics and Lawful



Intercept, Firewall and Cloud CPE, and a Media Cache. The Lawful Intercept function has been virtualized in a centralized manner, the other services are local to the hub site. The architecture permits this flexibility – some services may have a very low usage rate where economies of scale will find the optimal placement to be in a central location. Policy may also dictate a centralized location, such as data security or integrity.

Services that are part of the data plane and potentially latency sensitive should be placed in the cable hub site. This is for performance optimization as well as to restrict the "tromboning" effect of traffic flows to local, short reach interfaces and avoid metro or long-haul optical networks.

All of these services are implemented on standard x86 computing environments. As the network grows and changes, simply rearranging software elements can shift where these services are implemented. No service is permanently fixed to a particular location or resource in the network. The operator is able to adapt this system to their particular use case, load or traffic pattern, or policy requirements.

The combination of services enabled for a flow of data is called a "service chain." The service chain may contain one or more elements to perform actions upon the data flow, and they can be positioned local to the hub site or remotely across the IP/MPLS metro network.

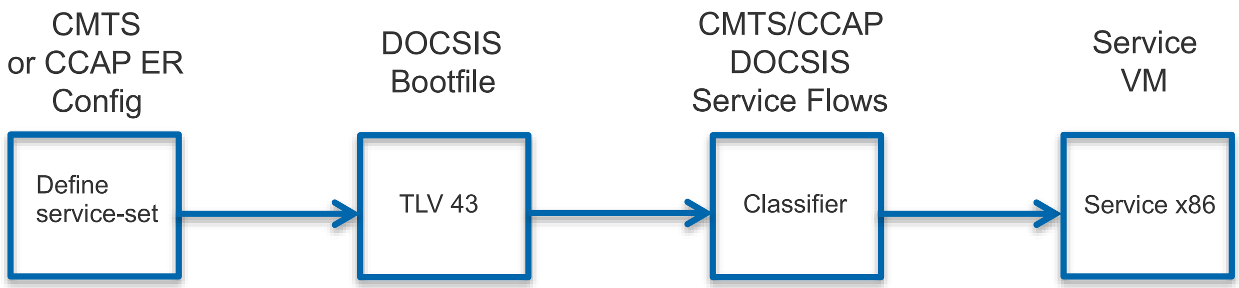
A flow of traffic may be routed through a Lawful Intercept and Media Cache. Another flow could go through only the Cloud CPE. The construct of the service chains are entirely arbitrary and up to the discretion of the cable operator. The x86 compute devices and their resident NFV service functions are connected to the network using standard Ethernet and/or MPLS VPN implementations, depending on the proximity of the services defined in the service chain to the Edge Router.

The particular services deployed in a service chain is up to the operator. A typical cable operator may pre-define several service chains for given service levels to subscribers.

Chain	Flow	Description
Set A	Internet > Subscriber	Today's status quo, HSD service
Set B	Internet > Cache > Subscriber	An HSD subscriber with video cache selectively enabled before the downstream
Set C	Internet > LI > Cache > Subscriber	HSD subscriber, data shipped off to remote LI collection before being routed to local cache then on to the downstream
Set D	Internet > Cloud CPE > Cache > Subscriber	Subscriber traffic bounces through two service elements before being routed downstream

PROVISIONING NFV AND DOCSIS

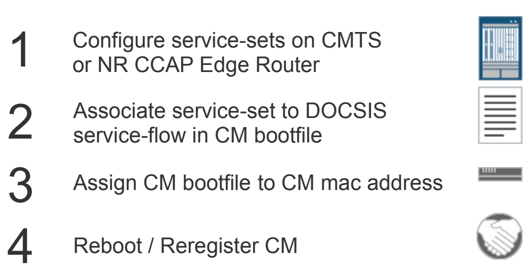
Service sets will be pre-defined once in the configuration of the CMTS/CCAP or the ER of an NR-CCAP system. These service sets need only be configured once. One instance of a service-set can be applied to multiple simultaneous DOCSIS service flows.



This paper proposes a new Type-length-value (TLV) in the DOCSIS boot file to associate a specific DOCSIS service-flow with a specific NFV service chain. We initially propose a VendorSpecific TLV but this is envisioned to become part of an enhanced, standards based DOCSIS service definition mechanism.

Once in place, when the cable modem registers to the CMTS or NR CCAP, the specific service-flows defined in the DOCSIS boot file will be associated with NFV service-sets, and the data classified in those service-flows will be subject to the actions defined in the service-set.

The use of DOCSIS Service Class Names could also be used to abstract the NFV portion of the ER confirguration from the cable modem boot file's specific DOCSIS service-flows, depending on operator implementation and potential operator billing preferences. This would also permit more granular definition of the DOCSIS to NFV relationship in the running config of the ER or Integrated system. [2]



Future architectures may be able to dynamically associate DOCSIS service flows to NFV service-sets without rebooting the cable modem, through the use of SNMP, PCMM or similar centralized signaling mechanisms.

The use of a VendorSpecific TLV ensures that if a CM registers to a legacy CMTS that does not have NFV support that the TLV is subsequently ignored. The CM will be allowed to come online, but there will be no benefits of the NFV infrastructure. [3]

SERVICE CHAIN CONFIGURATION

It is envisioned that the service-chains are configured universally across a cable operator's network to permit cable modem mobility, i.e. a cable modem is not tied to a particular CMTS or hub site. The service chains themselves need not operate identically – in one hub site an LI function could be local, in another it could be remote, but from the perspective of DOCSIS the operation is identical.

The NR-CCAP ER or CMTS will know the service-set, and location of the service instances, based on the running config of the system. A system in a smaller hub site may be configured to tunnel certain NFV flows back to a central location, while a system in a large hub site may locate services locally. Where services are instansiated depends upon the network topology, service requirements and other critera defined by the operator.

The service-chain "Set C" from the previous examples, represented on a NR-CCAP ER or an integrated CMTS/CCAP, could be configured as follows. This is a representative XML schema:

```
<rpc-reply
xmlns:junos="http://xml.juniper.net/junos/13.3
X-cable/junos">
  <version>13.3X-cable [slt-builder]</version>
    <services>
      <service-set Set-C>
        <docsis-flow-id 101>
           <chain>
             <service-instance>
              <target>LI-DataCenter-HQ</target>
             </service-instance>
             <service-instance>
              <target>Cache-HTTP-Local</target>
             </service-instance>
             <service-instance>
               <end/>
             </service-instance>
            </chain>
          </docsis-flow-id>
        </service-set>
      <service-target>
        <name>LI-DataCenter-HQ</name>
          <location>remote</location>
           <access-via>
             <pwe3>
               <remote>
                <host>69.252.101.5</host>
                 <vc-id>500</vc-id>
               </remote>
             </pwe3>
           </access-via>
      </service-target>
      <service-target>
       <name>Cache-HTTP-Local</name>
           <location>local</location>
            <access-via>
             <ethernet>
               <local>
                 <interface>xe-5/3/2</host>
                 <vlan-id>6</vlan-id>
               </local>
             </ethernet>
           </access-via>
        </service-target>
      </services>
```

This configuration defines:

- The DOCSIS service flow reference, in this case, the value 101. This value is also present in the DOCSIS boot file, and is the linkage between DOCSIS and the NFV chain,
- The service-chain, through a series of service-instance statements,
- The target elements of the service chain, one remote (LI-DataCenter-HQ) and one local (Cache-HTTP-Local) and the respective access methods to each chain element.

DOCSIS CONFIGURATION

The following is an example portion from a DOCSIS boot modem configuration.

```
DsPacketClass
{
      ClassifierRef 101;
      ServiceFlowRef 101;
      ActivationState 1;
      IpPacketClassifier
      {
            IpProto 6;
            DstPortStart 80;
            DstPortEnd 80;
      }
      GenericTLV TlvCode 43 TlvLength
8 TlvValue 0x0803ffffff010100

}
DsServiceFlow
{
      DsServiceFlowRef 101;
      QosParamSetType 7;
      TrafficPriority 4;
      MaxRateSustained 5000000;
}
```

This configuration file uses a DOCSIS Downstream Packet Classifier to select all TCP traffic on port 80 and push it to NFV service chain 101. This traffic is associated with Service Flow 101, and rate limited to 50 Mb/s.

The operator can choose any combination of service flows, rate limits, TOS markings or packet classifiers when choosing which traffic will, or will not, be subject to NFV functionality.

CONCLUSION

Network Functions Virtuzliation represents a potential new area of innovation in cable high speed data services. Service chains can be constructed by the operator to increase network efficiency, enable new revenue opportunities, or any combination thereof. The concepts presented in this paper illustrate a linkage between DOCSIS and the SDN community through software and services innovation. As the NFV and SDN communities mature, cable operators will be ready to take advantage of a next generation, revenue enhancing services-plane by following the concepts in this paper.

REFERENCES

[1] Chiosi, Margaret, et. al, (2012). *Network Functions Virtualisation, An Introduction, Benefits, Enablers, Challenges & Call for Action*, SDN and OpenFlow World Congress, Darmstadt-Germany

[2] Cablelabs, et. al, (2003). *Data-Over-Cable Service Interface Specifications, DOCSIS 1.1, Operations Support System Interface Specification, SP-OSSI-v1.1*, Cable Television Laboratories, Inc, Loiusville, CO.

[3] Cablelabs, et. al, (2007). *Data-Over-Cable Service Interface Specifications, DOCSIS 3.0, MAC and Upper Layer Protocols Interface Specification, CM-SP-MULPIv3.0*, Cable Television Laboratories, Inc, Loiusville, CO.

CONTRIBUTORS

Stuart Mackie and Ken Gray, of Juniper Networks, contributed to this paper.