Empower Rural Iowa Broadband Grant Program

Date: July 28, 2021
Applicant: Cox Omaha, LLC

PE Certification:

The detailed technical submission that follows was developed from contributions from a number of Cox engineers. The qualifications of these contributors are provided in Exhibit A. Based upon these contributions, I certify that the network as designed is capable of delivering, to at least 95% of the required number of locations in each relevant state, voice and broadband service that meets the requisite performance requirements.

/s/
Guy McCormick
SVP, Engineering
Cox Communications, Inc.

Contributing Engineers

Deependra Malla is a Lead IP Design Engineer at Cox Communications with 15 years of experience in the networking industry. He specializes in planning, design, implementation and troubleshooting of complex networks in a service provider environment with multi-vendor platforms running advanced protocols (BGP, ISIS, OSPF, MPLS). He successfully lead the deployment of metro hub aggregation routers in all Cox markets, and also led the Cox backbone and metro network teams to formulate network standards and implement compliance throughout the Cox network. He designed, tested and helped implement Cox's Converged Interconnect Network (CIN) to aggregate Cox's residential (R-PHY DOCSIS) network. He has also performed large-scale network migrations and mergers of networks running BGP, ISIS, OSPF, L3VPN.

Deependra holds MS in Electrical Engineering from Wichita State University and MBA from Washington State University. He is a Cisco Certified Internetwork Expert in Routing and Switching (CCIE #42229).

Mark Goodwin is a Lead IP Design Engineer with 20+ years of experience in building Service Provider networks with interests in emerging technologies.

Mark plays a leading role in the growth and evolution of the Cox Communications IP network. His recent design contributions include BGP resource public key infrastructure (BGP RPKI), Mapping of address and port translation (MAP-T), and interconnectivity design for edge compute platforms. These projects provide greater security, scale, and service delivery for the Cox IP infrastructure. Mark has also provided design solutions for video delivery over the IP infrastructure using MPLS Multicast VPN (MVPN) and served as a lead role in the planning of a redesign of the Cox nationwide IP Backbone for greater efficiency. Mark also served as a lead role for network standardization practices in the creation and management of an IP playbook which highlights best operational practices for network operations. For internal IP route and traffic flow management Mark made significant contributions to developing BGP community guidelines. These practices significantly improved operational efficiency. Mark's demonstrated expertise in network design, network implementation, vendor management, and routing protocols has enabled meaningful contributions to the Cox Communications High Speed IP network.

Mark holds a Bachelor of Science degree in telecommunications from DeVry University. He also holds a Juniper Networks Certified Internet Expert (JNCIE) certificate from Juniper Networks and has served as a keynote speaker and contributor for industry conferences.

1. ***Overall Network Design*.** ***A long-form applicant, regardless of the technology (or technologies) it proposes to use, is expected to:***

    a) ***Describe the proposed last mile architecture(s), design, and technologies.***

In currently served areas near the RDOF awarded areas, Cox utilizes both HFC and Fiber to the Home (FTTH) last mile network architectures to provide voice and broadband services and both architectures would be evaluated in servicing new deployments to RDOF supported areas. Schematic diagrams of these two architectures depicting the major system components are attached. The HFC network architecture will utilize Packet Cable 2.0 to provide Voice Services, while utilizing DOCSIS 3.1 to provide broadband services. FTTH Architected services will leverage Gigabit-capable Passive Optical Network (GPON) or 10G-Ethernet Passive Optical Network (XGS-PON) to deliver broadband internet access while voice service will be delivered using Session Initiation Protocol (SIP) and Media Gateway Control Protocol (MGCP). All the standard industry wireline technologies proposed by Cox for these service offerings are currently in production today, serving Cox customers.

Last Mile HFC Architecture

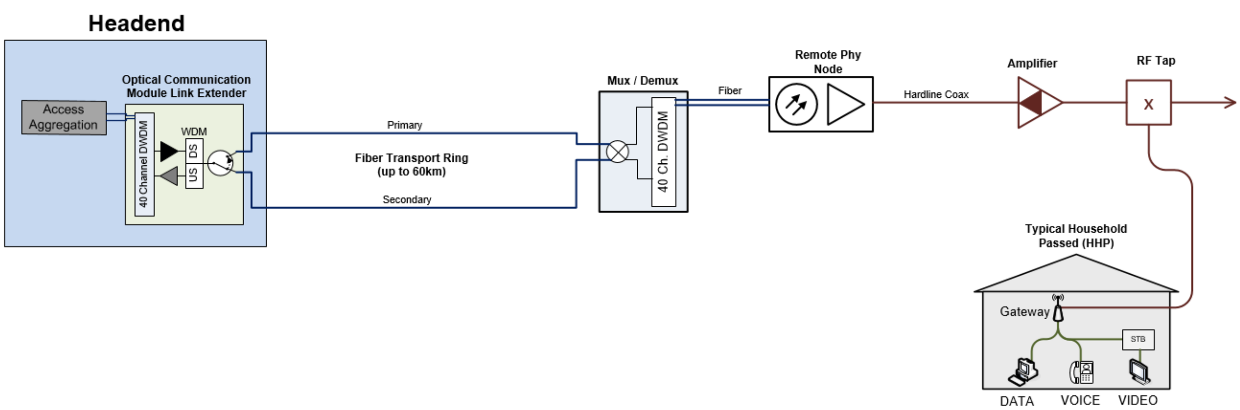


Fig 1. Last Mile HFC Architecture

Last Mile HFC Architecture: Last mile Hybrid Fiber Coax (HFC) networks serve residential customers via a combination of optical fiber transport and Radio Frequency (RF) distribution. The fiber transport consists of an Optical Communication Module Link extender (OCML) and Mux / Demux (MDM) system. The OCML contains integrated pre & post optical amplification, gain control and optical switching used in combination with a pair of 40 channel Dense Wave Division Multiplexing (DWDM) filters in each the OCML and MDM to allow for transport of up to twenty 10 GigE optical links, redundantly across fiber distances up to 60 km. The rack-mounted ATX CP-DLX40 OCML and field-hardened passive ATX HDM-20E-2MDM-NN9 is an example of a common OCML/MDM system used in Cox networks today.

The Remote Phy (R-Phy) Node serves as the demarcation between the 10 GigE optical and RF domains. They are deployed centrally located within geographic serving areas and can generate RF sources up to 1.2GHz. Cox will deploy the Cisco GS7000 1218-MHz 4-Port R-Phy node or equivalent version. The node is the RF launching point into the coaxial cable distribution network consisting of cascades of amplifiers, splitters and tap devices for managing RF signal levels. RF distribution networks are custom designed and calculated for each serving area. An example of a commonly deployed amplifier is the CommScope MB120 1.2GHz amplifier or equivalent version. RF taps are the tie point for the customer coax drops feeding an in-home gateway device to deliver data, voice, and video services.

Last Mile Fiber-to-the-Home Architecture

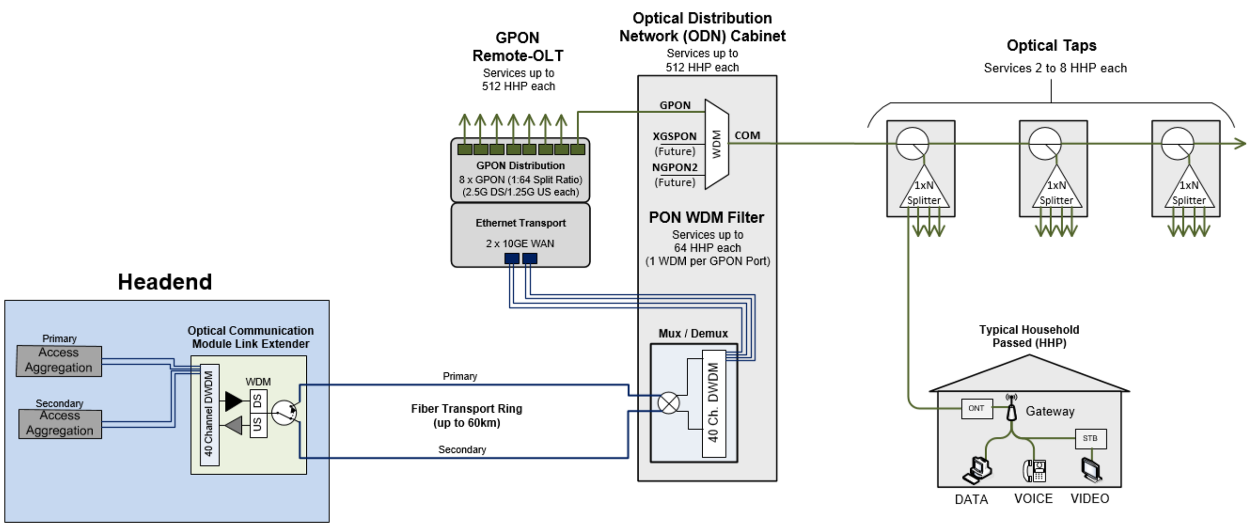


Fig 2. Last Mile Fiber-to-the-Home Architecture

Last Mile FTTH Architecture: Last mile FTTH (Fiber-to-the-Home) networks serve residential customers via entirely fiber-based optical transport and distribution networks. The fiber transport leverages the same Optical Communication Module Link extender (OCML) and Mux / Demux (MDM) system as the HFC architecture. The OCML contains integrated pre & post optical amplification, gain control and optical switching used in combination with a pair of 40 channel DWDM filters in each the OCML and MDM to allow for transport of up to twenty 10 GigE optical links, redundantly across fiber distances up to 60 km. The rack-mounted ATX CP-DLX40 OCML and field-hardened passive ATX HDM-20E-2MDM-NN9 is an example of a common OCML/MDM system used in Cox networks today.

FTTH networks leverage a point-to-multipoint protocol called PON (Passive Optical Network) for distribution via passive optical splitters. The Remote Optical Line Terminal (OLT) serves as the demarcation between the 10 GigE transport and PON (Passive Optical Network) distribution networks. The Remote-OLT is field hardened and passively cooled, they are deployed centrally located within geographic serving areas of up to 512 Households Passed (HHP). PON distribution will leverage Gigabit-capable Passive Optical Network (GPON) or 10G-Ethernet Passive Optical Network (XGS-PON) technologies. The Nokia 7360 ISAM SF-8 is typically used for GPON deployments while the Calix E3-2 platform is typically used for XGS-PON deployments.

PON distribution ports will feed into an Optical Distribution Network (ODN) cabinet containing Wave Division Multiplexing (WDM) devices. Each PON port will feed through a PON WDM filter enabling an upgrade path and injection point for future-state PON technologies such as Next Generation Passive Optical Network 2 (NGPON2) capable of symmetrical data speeds up to 80Gbps. As PON signals exit the ODN cabinet each port will feed into a series of passive Optical Tap devices limited to 64 HHP per OLT port. The tap system, like HFC, is a controlled approach to managing signal levels with a combination of unbalanced and balanced splitters custom designed and calculated for each serving area enabling up to

20km of reach. Optical taps are the tie point for the customer fiber drops feeding an in-home Optical Network Termination (ONT) and gateway devices to deliver data, voice, and video services.

b) Describe the proposed middle mile/backhaul topology, architecture, design, and technologies.

Middle Mile Architecture, Design and Technologies

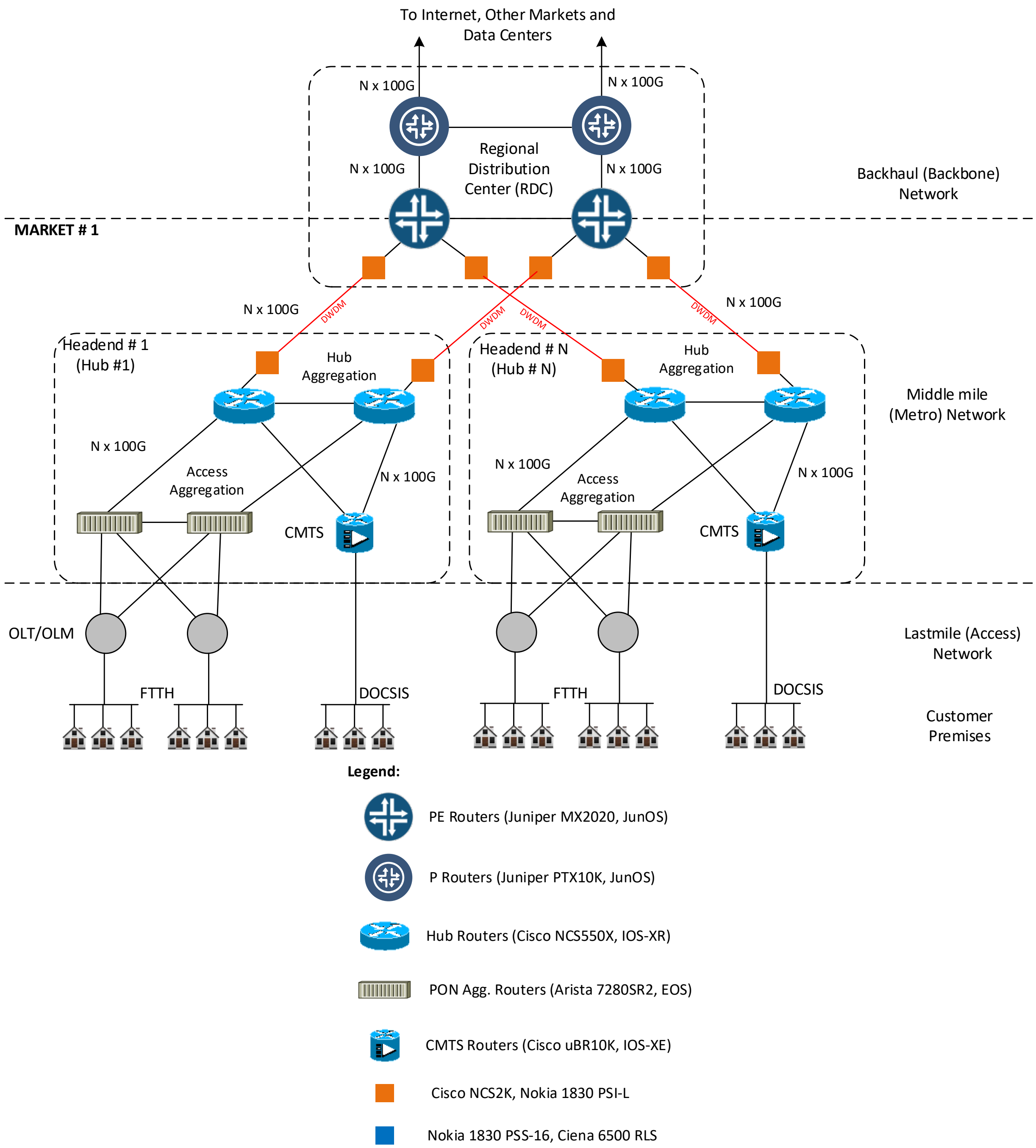


Fig 3. Cox Communications Middle mile (Metro) Network Topology

Topology and Architecture: Middle mile (Residential Metro) networks serve Cox's residential markets. Each market consists of several Hub sites (also known as Headends) serving specific geographic areas in that market. Cox's middle mile network is designed based on a Hierarchical Hub and Spoke topology. At the top level, each market has a Regional Distribution Center (RDC) aggregating each hub (headend) location. At Hub level, Hub routers aggregate several services and access level devices in that particular hub site. Each hub site consists of several GPON aggregation routers, Cable Modem Termination System (CMTS) and service aggregation routers.

Design and Technologies: Cox's middle mile (Metro) network devices are interconnected with fiber point-to-point links running Ethernet technology. The Middle mile network is optimized for 100Gbps speed and consists of Nx100G link bundles (aggregate ether bundles) running Link Aggregation Control Protocol (IEEE 802.11ad). Each market is served by dual regional distribution routers for redundancy purposes. Similarly, at each hub site, we have dual hub routers aggregating GPON aggregation routers, CMTSs and service routers. Failure of any one device or any one uplink will shift the entire traffic to other surviving routers or link. From the capacity planning perspective, northbound links are designed to carry entire traffic from that particular facility in case of one northbound link fails or one router fails. During steady state, each pair of regional distribution routers or hub routers share almost equal traffic load to and from customers.

Middle mile network devices run Intermediate System – to – Intermediate System (ISIS) Level -1 protocol as Interior Gateway Protocol (IGP). IS-IS carries Network Layer Reachability Information (NLRI) for infrastructure prefixes (loopbacks and P2P links). Hierarchical internal Border Gateway Protocol (iBGP) is used to carry NLRI for customer/residential prefixes. Regional Distribution Routers are Tier-1 BGP route reflectors whereas Hub routers are Route Reflector Clients. Similarly, Hub routers also act as Tier-2 BGP route reflectors. GPON/OLT aggregation routers, CMTS and service routers are Route Reflector Clients. Protocols running on these routers are tuned to allow for fast convergence in case of node and link failure and restoration.

All middle mile network devices are dual stack enabled routers i.e., both Internet Protocol Version 4 (IPv4) and Version 6 (IPv6) are enabled on these routers. Label Distribution Protocol (LDP) is used as Multiprotocol Label Switching (MPLS) label distribution. In the middle mile network, all BGP customer traffic is label switched. LDP is also used to provide VPLS or EoMPLS services to customers.

Cox's middle mile network is a converged network i.e., it carries voice, video, and data traffic over same connection. To achieve desirable network performance, quality of service (QoS) is enabled on each router and each link. Cox classifies and marks all incoming traffic with appropriate DSCP code points at the edge of the middle mile network and utilizes appropriate egress queuing and scheduling to provide priority to various traffic types. In the MPLS enabled links, egress queuing and scheduling takes place based on the 3-bit EXP field of the MPLS header that gets copied from DSCP code points.

Cox's middle mile network consists of the latest hardware and technologies. Regional distribution routers are Juniper MX2020 and Juniper PTX10K routers running Juniper Operating System (JunOS).
Hub routers are Cisco NCS 5502, 5504 or 5508 routers running Cisco IOS-XR. GPON/PON aggregation routers are Arista 7280SR2 routers running EOS images. Similarly, Cable Modem Termination Routers are Cisco uBR10Ks and cBR-8s running Cisco IOS/IOS-XE software.

Application servers like Dynamic Host Configuration Protocol (DHCP), Network Time Protocol (NTP), Domain Name System (DNS) are connected to the switching network at Regional Distribution Center. These services are an integral part of middle mile network and provide services to corresponding markets.

For connectivity from the RDCs to the hubs, Dense Wavelength Division Multiplexing (DWDM) is used. Cox utilizes a Colorless-Directionless-Contentionless with Flexible grid (CDC-F) Reconfigurable Optical Add-Drop Multiplexer (ROADM) architecture. Current deployments are either 96-channel CDC-F Cisco NCS2K optimized for 200G waves, or Nokia 1830 PSI-L Open Line System (OLS) which allows up to 800G wavelengths and is C+L band capable.

Configuration Guidelines: Cox developed a Metro IP Playbook to document and enforce standard network topology, protocols, and configuration standards to all middle mile network devices. The Metro IP Playbook outlines the configurations and configuration guidelines for device turn up, maintenance and troubleshooting. To minimize any human issues on configuration and enforce configuration standards, Cox utilizes configuration generators to generate middle mile network device configurations.

Future Roadmap: Cox is constantly evolving its network and platforms to outpace capacity demands and provide a great customer experience. Most areas of the middle mile (metro) network are optimized for 100G density. The Cisco NCS5K hub routers support high-density 36x100G line cards, and due to their modular design, will scale to future line cards with 400G support. The Juniper MX2020 is a 20-slot chassis that will today accommodate a total capacity of up to 32 Terabits using 16x100G per slot line rate with the Modular Port Concentrator (MPC) 9E line card. In the future it will scale to 80 Terabits with 40x100G per slot line rate or 160x400G per slot using the MPC 11E line card. The Juniper PTX10K today will accommodate a total capacity of 24 Terabits per chassis across 8 slots using the PTX10K-LC1101 line card which supports 30x100G. Future line cards will be optimized for 400G density.

Backhaul Architecture, Design and Technologies

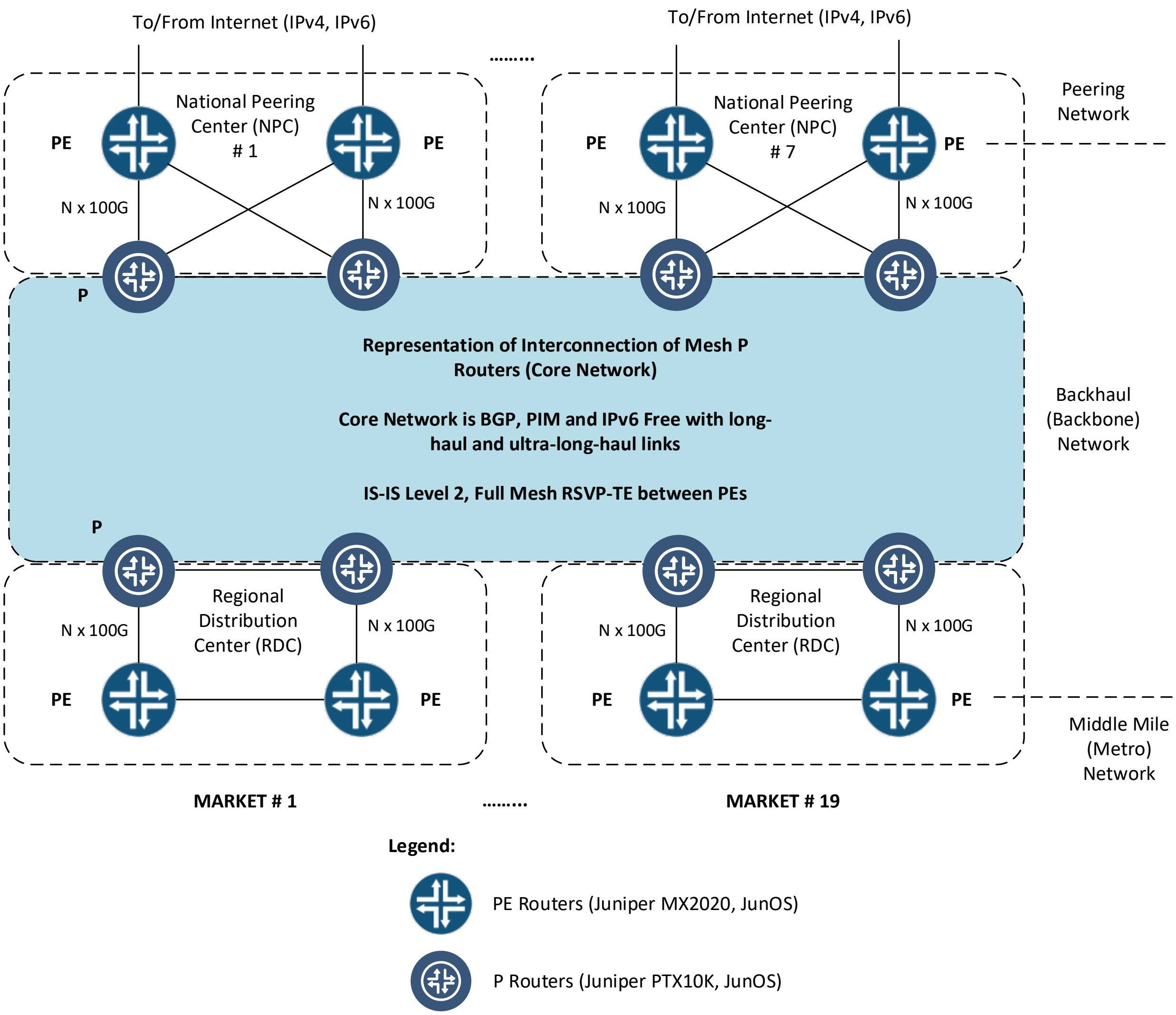


Fig. 4 Cox Communications Backhaul (Backbone) Network

Topology and Architecture: The backhaul (backbone) network connects all 19 markets and 8 national peering centers (NPCs) together with the help of long-haul and ultra-long-haul connections. Each market consists one or two regional distribution centers (RDCs) that serves as the Internet Backbone Gateway for that market. As shown in Fig. 2, each RDC and NPC consists of two P routers and two PE routers connected in a square topology. P routers at RDCs and NPCs “interconnect” with each other to form an inner core layer backhaul network.

Design and Technologies: The backbone inner core layer is the interconnection of P routers in a Mesh topology. The backbone core network routers (P routers) are connected with fiber point-to-point links running Ethernet technology. The network is optimized for 100Gbps speed and consists of Nx100G link bundles (aggregate ether bundles) running Link Aggregation Control Protocol (IEEE 802.11ad). Each RDC consists of dual regional distribution routers (PE routers) and dual backbone core routers (P routers) for redundancy purposes. Failure of any one device or any one uplink will shift all traffic to other surviving routers or links. From the capacity planning perspective, northbound links between regional distribution routers and backbone core routers are designed to carry the entire load of traffic from that market in case of one northbound link fails or one router fails. During steady state, each pair of regional distribution routers share almost equal traffic load to and from customers for that market.

Cox's backhaul network is designed based on "Lean Core" architecture concept to achieve extremely efficient traffic switching to reduce traffic latency. The inner core layer of network (P routers layer) is BGP, PIM and IPv6 free layer. Traffic switching in this layer happens through label switching. Backbone network devices run Intermediate System – to – Intermediate System (ISIS) Level -2 protocol as Interior Gateway Protocol (IGP). IS-IS carries Network Layer Reachability Information (NLRI) for infrastructure prefixes (loopbacks and P2P links). Full mesh Internal Border Gateway Protocol (iBGP) is configured between PE routers only and is used to carry BGP NLRI for customer/residential prefixes and Internet prefixes. Regional distribution routers at each market receive full Internet table via BGP for both IPv4 and IPv6 and are Internet Gateways for that market. Protocols running on these routers are tuned to allow for fast convergence in case of node and link failure and restoration.

In the backhaul network, only backbone PE devices are dual stack enabled routers i.e., both Internet Protocol Version 4 (IPv4) and Version 6 (IPv6) are enabled on these routers. The backhaul (backbone) portion of the distribution network utilizes the Resource Reservation Protocol for Traffic Engineering (RSVP-TE) to label switch customer traffic. Link protection is enabled on each router to gracefully shift customer traffic within 50ms in the event of fiber cuts or link failures. The backhaul network is optimized to efficiently use bandwidth by using TE++ and auto-bandwidth features.

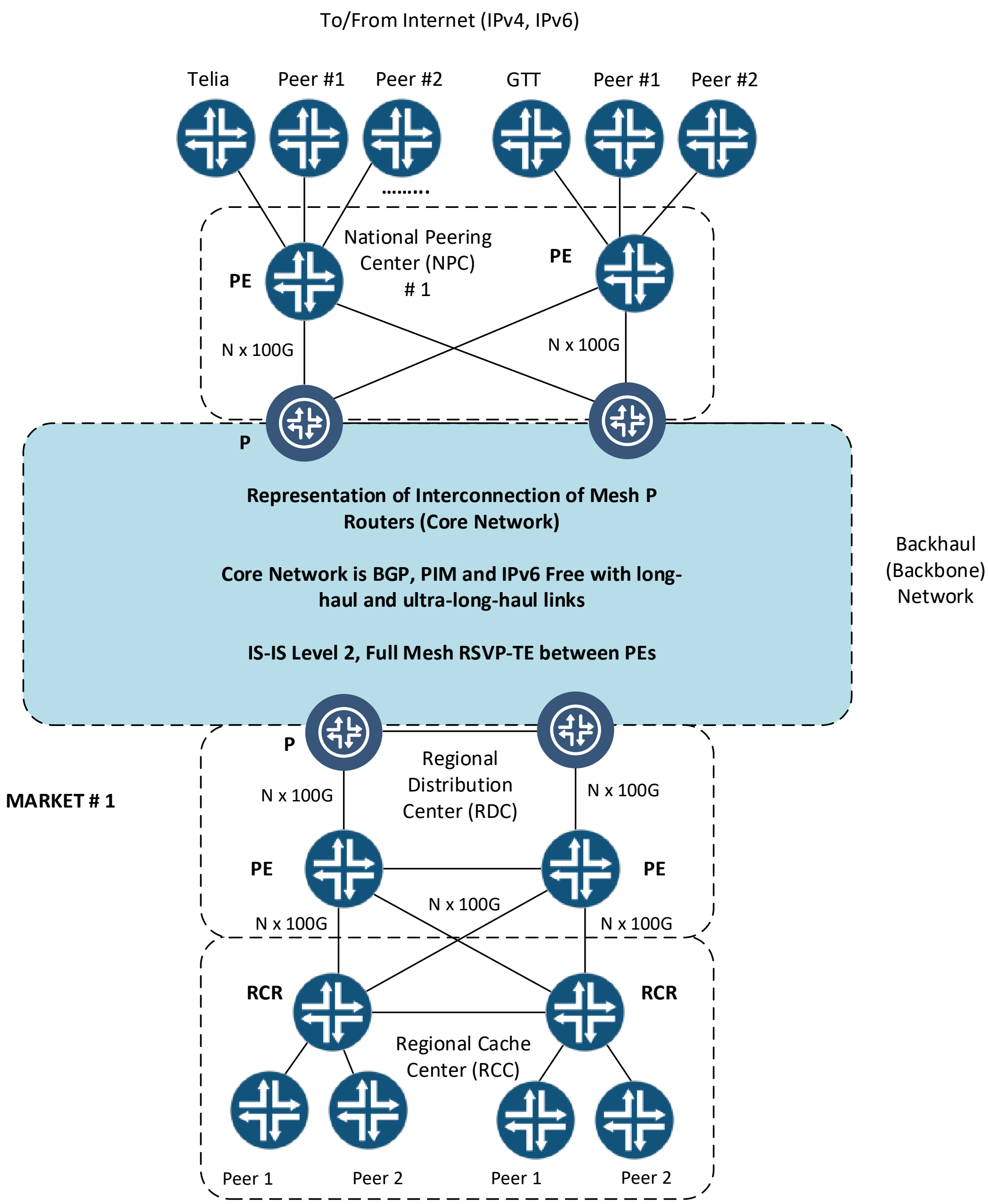
Cox's backhaul network is a converged network i.e., it carries voice, video, and data traffic over the same connections. To achieve desirable network performance, quality of service (QoS) is enabled on each router and each link. Cox marks all incoming traffic with appropriate IPP code points and utilizes appropriate egress queuing and scheduling algorithms to provide priority to various traffic types. In the MPLS enabled links, egress queuing and scheduling takes place based on the 3-bit EXP field of the MPLS header that gets copied from IPP code points.
Cox backhaul network consists of the latest hardware technologies. Regional distribution routers (PEs) are Juniper MX2020 and backbone routers (Ps) are Juniper PTX10K routers running Juniper Operating System (JunOS).

For long-haul connectivity between all RDCs, National Peering Centers (NPCs), and Data Centers, Dense Wavelength Division Multiplexing (DWDM) is used. Cox utilizes a Colorless-Directionless-Contentionless with Flexible grid (CDC-F) Reconfigurable Optical Add-Drop Multiplexer (ROADM) architecture. Currently our nation-wide optical network consists of a CDC-F Nokia 1830 PSS-16 deployment optimized for 200G wavelengths, with C+L band capability. In 2021 we'll begin deploying a Ciena 6500 RLS network with C+L band capability, with the ability to utilize 800G wavelengths. Source-based restoration (SBR) is used to re-route circuits at the optical layer during fiber impairments.

Configuration Guidelines: Cox developed a Backbone IP Playbook to document and enforce standard network topology, protocols, and configuration standards to all backhaul network devices. The Backbone IP Playbook outlines the configurations and configuration guidelines for device turn up, maintenance and troubleshooting. To minimize any human issues on configuration and enforce configuration standards, Cox utilizes automation tools such as Ansible to generate backbone network device configurations.

Future Roadmap: Cox is constantly evolving its network and platforms to outpace capacity demands and provide a great customer experience. All areas of the backhaul (backbone) network are optimized for 100G density. The Juniper MX2020 is a 20-slot chassis that will today accommodate a total capacity of up to 32 Terabits using 16x100G per slot line rate with the Modular Port Concentrator (MPC) 9E line card. In the future it will scale to 80 Terabits with 40x100G per slot line rate or 160x400G per slot using the MPC 11E line card. The Juniper PTX10K today will accommodate a total capacity of 24 Terabits per chassis across 8 slots using the PTX10K-LC1101 line card which supports 30x100G. Future line cards will be optimized for 400G density. In 2022/2023, Cox will begin deploying routers with 400G capability as well as Segment Routing (SR).

c) ***Describe the proposed interconnection architecture, design, and technologies solution to connect to the Internet. This will include the likely service providers, link data-rate/size, locations, dual-homing, and multi-homing characteristics.***



Overview: The interconnection architecture for the Cox network connection to the Internet includes two separate facility designs. These are a National Peering Center (NPC) design and a Regional Cache Center (RCC) design. Logically each of these facilities are at the edge of the Cox network and represent the main ingress / egress connection points for the global Internet. Details and technologies for each design are noted in the following paragraphs.

National Peering Center Design: The Cox network deploys National Peering Centers (NPCs) in eight locations across the U.S. These locations include Los Angeles, San Jose, Dallas, Kansas City, Chicago, Atlanta, Ashburn, and New York. The physical design and topology are standardized across all locations. The key design requirements include redundancy, resiliency, reliability, and scalability. These criteria are baked into both the physical and logical layers of the NPC design.

Each NPC location includes an established four router design. This includes two Juniper MX2020 routers running JunOS software in the distribution layer serving as MPLS PE routers. These participate in the network's MPLS full RSVP-TE mesh. Also included are two Juniper PTX10K routers with JunOS software and these are in the core layer providing MPLS P router functionality. They carry Nx100GE backbone circuits and act as transit LSRs. The PE routers and P routers are all interconnected using Nx100GE circuits. Collectively they are referred to as backbone peering nodes and are interconnected to the Cox core network to via long haul fiber circuits.

The routing details include ISIS L1/L2 as the IGP for internal link and loopback reachability. External BGP is used to connect to carrier neutral providers and transit providers. Internal BGP is used to carry customer, service, and provider routing traffic. MPLS RSVP-TE is used for traffic engineering capabilities for bandwidth management and optimization. Specifically, Auto-Bandwidth is enabled across the core network to allow for adjustment of bandwidth allocation based on the volume of traffic traversing the LSPs. In steady state traffic delivery from NPCs to PE nodes will follow the IGP shortest path based on delay-based metrics.

The MX2020 pair serving the role of PE routers will terminate IP transit and settlement free peering connections using external BGP. Telia Carrier and GTT Communications, Inc are the current preferred transit providers for the Cox network. Both providers offer global tier 1 connectivity and competitive transit rates. Having two providers provide high transit reliability in the event of issues with one of the providers. To ensure for redundancy, the Telia Carrier and GTT Communications connections are split between the two PE routers at all NPC locations. The MPLS PE nodes also participate in the core network's full iBGP mesh. As the BGP full table is learned from Telia and GTT it is advertised to all other PE nodes in the distribution layer. Reachability to the global internet via Telia/GTT from any of the Cox RDCs or PE nodes is designed to follow the geographically shortest route to the nearest NPC. This is accomplished using delay based IGP metrics for the internal core network. For ingress traffic from the internet, static LSP metrics are used determine which RDCs are served by which NPC. This is accomplished by copying the static LSP metric to the BGP MED value.

Cox connects to settlement-free peers to offset the cost of exchanging transit traffic. This provides significant cost savings for peers who exchange large amounts of traffic with the Cox network. As a result, most of the ingress traffic to the Cox network is through settlement free peering connections. The routing mechanisms used to accomplish this include manipulating the BGP MED to influence providers' ingress traffic and local preference values to influence the network's egress traffic. The aggregation of transit and peering traffic at NPCs is delivered to Cox markets or RDCs over the MPLS network using LSPs. As described earlier, the design intent is for NPCs to be the preferred choice for their geographically closest markets with the adjacent NPCs serving as backup facilities.

The NPC architecture utilizing Juniper MX2020 and PTX10K routers serving as MPLS PE and P nodes, respectively, represent a scalable design solution that will accommodate IP traffic growth for up to 10 years. The MX2020 is a 20-slot chassis that will today accommodate a total capacity of up to 32 Terabits using 16x100GE per slot line rate with the Modular Port Concentrator (MPC) 9E line card. In the future it will scale to 80 Terabits with 40x100GE per slot line rate or 160x400GE per slot throughput using the MPC 11E line card. This provides significant headroom for growth.

The PTX10K today will accommodate a total capacity of 24 Terabits per chassis across 8 slots using the PTX10K-LC1101 line card which supports 30x100GE port connections.

Cox guidelines for router architecture include N+1 fabric redundancy, control plane redundancy, N+N power feed redundancy, and N+1 power supply redundancy.

Cox guidelines for NPC facilities include adequate power and cooling for all routing and switching equipment. 1+1 power and N+1 cooling redundancy is required. All equipment should be connected to diverse A and B power sources.

Regional Caching Center Design: The Cox network deploys five Regional Caching Centers (RCC) across the U.S. The locations include Hampton Roads, Las Vegas, Phoenix, San Diego, and Boston. The purpose of these facilities is to terminate content delivery network (CDN) providers with CDN cache nodes specifically dedicated to the Cox network. The RCC facilities are located within Cox markets which eliminate long haul traffic for both the content providers and the Cox network. This is advantageous as this traffic type is high bandwidth video from providers such as Netflix and Amazon which represents a substantial amount of our peak traffic.

The key requirements for design in these facilities include reliability, resiliency, and redundancy. Cox requires any 3rd party data center to follow guidelines of design guidelines for adequate power and cooling of Cox equipment. 1+1 power and N+1 redundancy is a requirement. All Cox equipment should be connected to diverse A and B power sources.

The RCCs will utilize redundant diverse fiber connections from the 3rd party datacenters into the local Cox RDCs. This fiber can be Cox-owned or leased from another provider but must use diverse entrances and paths for all fiber segments. The RCC network connectivity must be fully redundant to each Cox RDC PE node. All logical transport circuits between locations should be provisioned as unprotected.

Cox places IP routers in the RCC location for terminating IP traffic from the content providers using E-BGP. It also serves as another point to statistically multiplex traffic between the RCC and RDC, reducing the number of logical circuits needed on the transport network. The Cox network uses a pair of Cisco NCS 5504 series routers for the RCC locations. These routers support high-density 100GE ports and due to their modular design, will scale to future linecards with 400GE support. To differentiate their roles, these routers are referred to as Regional Cache Routers (RCRs). The RCRs are redundant to provide for high reliability. They are not a part of the MPLS full RSVP-TE mesh as they are intended to only serve content to their local market. This is accomplished by using the ISIS L1 IGP protocol for link and loopback connectivity. Also, iBGP is used between the RCCs and the RDCs to route provider cache traffic. The RCCs only receive local iBGP routing information from their connected RDCs and not from the global Cox network.

Connectivity between the RCC site and the RDC(s) utilizes a cross design where each RCR router has an equal amount of bandwidth to each RDC PE node. This provides superior reliability and reductions in interconnect capacity. The local interconnect capacity will be equal to the amount of one of the upstream links. Where Nx100G is utilized the circuit capacity must be rounded up to the nearest Nx100G. Traffic exchange between the RCCs and RDC sites are engineered using BGP local preference values. Any cache traffic not available from the local RCC can be obtained from the geographically closest NPC.

d) Describe the proposed architecture that will be used to provide voice service.[1] Describe whether the proposed voice services will: 1) be internally provided, 2) use a managed voice service provider, 3) use a voice over the top service, or 4) use another type of voice service.[2]

Cox Residential Voice Service Solution Detail:

Cox Residential intends to utilize currently deployed voice service platforms, vendors, and MVSP solutions to provide voice service for RDOF.

Cox Residential voice service is comprised of PacketCable 2.0-based embedded digital voice adapters (eDVAs) and multi-media voice adapters (MTAs) as Customer Premises Equipment (CPE). The eDVAs have MTA and cable modem (CM) functions in the same device. Cox also has an eDVA which can have the DOCSIS interface disabled and a second Ethernet port activated as a WAN port to allow data services and utilize the MTA portion for voice service over Cox's PON networks. The CPE vendors include Arris/Commscope, Ubee, and Technicolor. The CPE interface to Session Border Controllers (SBCs), via SIP for signaling and RTP for media/audio. Cox Residential CPE provide some voice features directly (i.e., call waiting, 3 way calling, and caller ID display).

The SBCs are internally designed and operated Metaswitch Networks/Microsoft Perimeta platforms, and function as IMS P-CSCFs, which interface to a Managed Voice Service Provider's (MVSP) IMS core network for many features and services, including interconnection to the Public Switched Telephone Network (PSTN) via SIP, RTP, SS7, and TDM. The MVSP's IMS core network, including the HSS, TAS, and x-CSCF, is from Ericsson; The BGCF is from NetNumber. The MVSP's vendor for MGCF and MGW is Alcatel-Lucent/ALU. SBCs are Oracle and Ribbon. Interconnections between Cox and the MVSP are across private physical connections in four geographically separated co-lo/meet-me points in Los Angeles CA, Chicago

---

[1] If the long-form applicant obtains these or other voice service functions as services from another provider or providers (for example, an over-the-top VoIP provider, or an incumbent or competitive local exchange carrier), the description should so indicate. Voice solutions are a collection of integrated sub-systems dependent on selected architecture and design implementation. These architectures can include items such as: SIP, H.323, and MGCP; internal trunking, e.g., SIP trunks; quality of service protocols and use; connectivity to the PSTN and other VoIP providers; associated internal traffic-engineering to support voice quality; and more. If the applicant is using a hosted or Managed Service Provider (MSP) for its voice solution it must provide and sufficiently describe its infrastructure support. Such network infrastructure support solutions may include Quality of Service (QoS), voice paths setup by traffic-engineering protocols, trunking, and other methods, e.g., when using a voice MSP (Managed Service Provider).

[2] *See Rural Digital Opportunity Fund Phase I Auction Scheduled for October 29, 2020; Notice and Filing Requirements and Other Procedures for Auction 904*, AU Docket No. 20-34 et al., Public Notice, 35 FCC Rcd 6077, 6127-29, paras. 135-39 (2020) (*Auction 904 Procedures Public Notice*). (describing how an ETC must offer qualifying voice service using its own facilities, at least in part).

IL, Ashburn VA, and Atlanta GA. The Cox Residential SBCs are located in four geographically separated data centers; The data centers are in Phoenix-area AZ, Omaha NE, Providence RI, and Atlanta-area GA.

Cox Residential voice services has optional access to voicemail provided by an internally designed and operated, and geo-diverse voicemail platforms. The voicemail platforms are located in Phoenix-area AZ and Atlanta-area GA.

Cox Residential's Managed Voice Service Provider owns and operates an IMS, and PSTN and carrier interconnection. The IMS network is comprised of 8 IMS cores distributed across 4 major geographically separated locations within the continental US. All IMS cores share a single logical HSS which has subscriber data synchronized across the core locations. PSTN and carrier interconnection is performed through media/trunking gateways with diverse connectivity to carriers, as well as through NNI SBCs which are geographically distributed within the continental US and have diverse connectivity to carriers.

Cox Residential Voice Service Capacity:

Cox Residential's SBC's primary capacity driver is registered users/endpoints. The SBCs are sized to handle 450K registered users based on Cox's typical residential customer's call patterns, call volume, and ancillary signaling (e.g., subscribe, notify); All residential SBC signaling servers are currently at least 20% below the peak capacity value, with the average being roughly 50%. The primary/backup SBC association for Cox customers is designed to ensure that during each data center's failure scenario, the distribution of affected users is spread across the remaining SBCs without crossing the maximum registered user capacity.

Cox's MVSP is committed to capacity on the IMS core and support networks for Cox's capacity needs. Cox has provided residential service with the MVSP for 3 years, and capacity in the IMS core and support networks has not been an issue. PSTN capacity, through TDM and SIP interconnections, is managed actively by the MVSP.

Cox Residential Voice Service Resiliency and Redundancy:

The entire voice core solution, including the Cox SBCs and the MVSP's IMS core functions, has sufficient capacity to gracefully adjust to a complete data center outage scenario.

All endpoints will recover for inbound calls within 1 hour due to eDVA registration intervals (1 hour expires timer value); Outbound calls for endpoints whose re-registration timer has not popped will re-register upon determination the SIP Invite request is not responsed to by the SBC to which the eDVA was last registered.

Cox Residential CPE to SBC associations are geo-diverse and geo-redundant, with each CPE having a primary SBC and at least one backup SBC in a different geographic facility. Determination of primary and backup SBC(s) is primarily performed through provisioning of FQDNs, with DNS being used to determine the IP addresses of the SBCs. Registering CPE are configured to perform SIP registration at various times, but always within 1 hour, with configuration to automatically register to a backup SBC if the primary SBC is not responding to registration requests or not responding to call initiation request (SIP Invites). Cox Business supports non-registering SIP trunking customers, and those customer's CPE associates to a minimum of two geographically separated SBCs.

Cox Residential Regulatory Compliance:

Cox Residential's MVSP provides STIR/SHAKEN functionality through a solution they designed, developed, and operate. Cox's MVSP enables NoMoRobo service for Cox Residential subscribers. Cox Residential voice service complies with all applicable state and federal regulations, including CALEA.

Cox Business Voice Service Overview:

Cox Residential intends to utilize currently deployed voice service platforms, vendors, and MVSP solutions to provide voice service for RDOF.

Cox Business voice services, for the proposed solution, are comprised of SIP CPE, including embedded Multimedia Terminal Adapters (eMTAs), Integrated Access Devices (IADs), gateways, and edge/enterprise SBCs, providing FXS (Foreign Exchange Service; e.g., phone) line, SIP trunk, PRI trunk, and IP Phone capabilities, and which interface to user-to-network interface (UNI) SBCs to provide and enforce security controls and policies. Cox Business voice services also support SIP soft clients, which may be provided as part of the service for some product offerings.

Cox Business does offer voice services over the DOCSIS network, but also over Cox's metroE networks and various PON networks, and over the Internet where customers may have DSL, PON, RAN, or other access networks.

UNI SBCs interface to the voice applications servers, all of which are internally designed and operated, and which interface to the intermediate Voice Network Providers (IVNPs) through network-to-network interface (NNI) SBCs to exchange calls with the PSTN and other carriers; The NNI SBCs also provide invocation of Cox's STIR/SHAKEN Authentication and Verification services.

Cox Business' voice application servers are internally designed and operated, and are virtualized in two geographically separated locations, and are geo-redundant, including maintaining SIP registration state. Cox Business' virtualization platform is currently VMWare-based. Cox Business' voice feature servers (called the 'AS' in Broadworks terminology) are deployed in an active/active model with one active side being the primary server and the other active side being a secondary server, with synchronization of registration state between the two servers. The voice feature servers provide most of Cox Business' features and functionality, and CPE management responsibility. The voice network/routing server (called the 'NS' in Broadworks terminology) and the media servers operates in a transaction-based active/active model. Data is synchronized between network/routing servers, and separately between media servers in an on-going manner.

Cox Business's proposed solution utilizes multiple IVNPs for PSTN access, with all exchange being performed between Cox NNIs SBCs and IVNP NNI SBCs. All interconnections are across private physical connections in four geographically separated co-lo/meet-me points in the continental US.

Cox Business voice services has optional access to voicemail provided by an internally designed and operated, and geo-diverse voicemail platforms. The voicemail platforms are located in Phoenix-area AZ and Atlanta-area GA.

Cox Business Voice Service Capacity:

As a close estimate for capacity, each UNI SBC HA pair can handle is 300K registered users, but that value varies depending on the services provisioned for the users on an individual UNI SBC HA pair. Cox Business' voice network capacity is impacted by many factors, including registered users, customer type/services (e.g., subscribe / notify activity for IP Phones drives a lot of transactions), and transcoding needs (e.g., T.38 and SD/HD voice codecs). In addition to typical capacity monitoring and management best practices, Cox Engineering works closely with Cox Business to plan for changes in sales/market targets, as well as product offerings, which could affect existing capacity.

Cox Business' voice application servers are scaled horizontally, based on ongoing virtual server utilization metrics. As an application server is nearing 70% utilization, Cox begins the effort to add an additional application server to handle new growth or customer usage pattern changes.

Cox Engineering plans interconnection capacity with its IVNPs to ensure PSTN capacity, through TDM and SIP interconnections, is sufficient for as Cox's Business' needs and usage changes.

Cox Business Voice Service Resiliency and Redundancy:

The entire voice core solution, including the UNI and NNI SBCs and the voice application servers, has sufficient capacity to gracefully adjust to a complete data center outage scenario.

Cox Business CPE to SBC associations are geo-diverse and geo-redundant, with each CPE having a primary SBC and at least one backup SBC in a different geographic facility. Determination of primary and backup SBC(s) is primarily performed through provisioning of FQDNs, with DNS being used to determine the IP addresses of the SBCs. Registering CPE are configured to perform SIP registration at various times, but always within 1 hour, with configuration to automatically register to a backup SBC if the primary SBC is not responding to registration requests or not responding to call initiation request (SIP Invites). Cox Business supports non-registering SIP trunking customers, and those customer's CPE associates to a minimum of two geographically separated SBCs.

Cox Business Regulatory Compliance:

Cox Business voice service complies with all applicable state and federal regulations, including CALEA. Cox Business provides STIR/SHAKEN and CALEA through a hosted service provided by Neustar.

Cox Residential and Cox Business Voice QoS:

Cox Residential and Cox Business access/UNI SBCs are the Policy Decision Point (PDP) for Dynamic Quality of Service (DQoS) on the DOCSIS access network to provide guaranteed bandwidth for voice call media/audio; The SBCs request bandwidth for RTP on a per-call basis to the top tier Policy Servers via Diameter protocol. Top tier Policy Servers request RTP bandwidth to local Policy Servers via Diameter protocol. Local Policy Servers request RTP bandwidth to Converged Cable Access Platform (CCAP) devices (the Policy Enforcement Points (PEPs)) via Common Open Policy Server (COPS) protocol. Cox's Policy Server are from Oracle. The CCAP devices will perform DOCSIS-level configuration of the CM CPE, as well as the CCAP device, to provide dedicated transmission timeslots (unsolicited grants) for the RTP traffic. Cox's CCAP vendor is Cisco.

Cox's Residential and Cox Business voice signaling and media packets are prioritized on the backbone network through DiffServ bit setting; decimal 40 for SIP, and decimal 46 for RTP. When 802.1p is safely supported by network devices, Class of Service 5 is used for SIP, and Class of Service 6 is used for RTP.

Cox Residential and Cox Business Voice Packet Monitoring:

Cox uses Empirix's Hammer XMS solution to perform network-wide, independent monitoring of voice signaling and media packets; Media is only captured with customer consent and for only as long as necessary for troubleshooting purposes. Cox enables packet capture with optical taps placed on uplinks/connections between layer 2 switches and layer 3 routers in Cox data centers, and on the 'inside' and 'outside' of Cox's peering routers for interconnections with its MVSP and Intermediate Voice Network Providers. Signaling traces can be exported from Empirix in HTML or pcap formats.

Cox's SBCs have a vendor provided solution for call tracing and internal debug, based on the packets that flow through those devices. The solution is called Service Assurance Server (SAS). Cox's SBC vendor is Metaswitch Network/Microsoft.

Forward Looking Statement on Voice Network Architecture:

Cox has been virtualizing voice services since 2014, and Cox will be virtualizing all voice service applications, including SBCs (access, UNI, and NNI) and voicemail servers, over the next 10 years, with a target of completion in 5 -7 years. Cox Business UNI SBCs are likely to be installed in virtualization infrastructure in Cox Regional Data Centers in Orange County CA, San Diego CA, Las Vegas NV, Phoenix AZ, Omaha NE, Oklahoma City OK, Wichita KS, Providence RI, Hampton Roads VA, Fairfax VA, New Orleans LA, and Atlanta GA, whereas today the physical UNI SBCs are at Cox's two national technology centers which are in Phoenix-area AZ and Atlanta-area GA.

Cox's Policy Server network is being virtualized in 2021. The virtualization will keep the same topology; however, the "local policy servers" will be located on virtual infrastructure in Cox's two national technology centers.

Cox Residential's MVSP's IMS core is in the process of being further virtualized.

e) Describe the network's scalability to support customer growth and network data usage growth to account for: 1) ever increasing application requirements, 2) increasing quality demands, and 3) lower response/latency demands for ever increasing usage of highly interactive applications.

f) Describe the design and features that it proposes to implement that will: improve reliability (such as redundancy) for equipment, links and software; dual homing; and multi-homing connectivity.

Last Mile Network Reliability: The optical transport of both HFC and FTTH architectures consists of an Optical Communication Module Link extender (OCML) and Mux / Demux (MDM) system to support path redundancy. The OCML contains integrated pre & post optical amplification, gain control and optical switching used in combination with a pair of 40 channel Dense Wave Division Multiplexing (DWDM) filters in each the OCML and MDM to allow for transport of up to twenty 10 GigE optical links, redundantly across fiber distances up to 60 km.

Middle Mile Network Reliability: Cox utilizes efficient hierarchical hub and spoke topology at the middle mile network. At the bottom layer of the middle mile network, Cox utilizes chassis redundancy, line card redundancy and route processor redundancy. Bottom layer routers are dual homed to upstream hub routers. Hub layer and regional distribution layers also have chassis redundancy, line card redundancy and route processor redundancy to improve network reliability. Both hub routers have dual egress path to regional distribution routers. At all levels of the middle mile network, Cox utilizes Link Aggregation Control Protocol (LACP, 802.11ad) to bundle multiple 100Gbps links to create a single layer 3 point-to-point connection.

Backhaul/Core Network Reliability: Cox's backhaul network is a mesh of provider (P) routers that connects all 19 markets and 8 national peering centers. At each regional distribution center, the provider edge (PE) routers uplinks to P routers. All PE routers have dual egress/ingress path to P routers. Similarly, both P and PE routers at each regional and national peering center have chassis, line cards and route processor redundancy for increased reliability. The inner core layer (P routers) of backhaul network is interconnected via long-haul and ultra-long-haul links which averages degree of 3.44 i.e., in average there are more than 3 links (multi-home) per P router connecting to other P routers. In backhaul network, Cox utilizes link aggregation control protocols (LACP, 802.11ad) to bundle multiple 100Gbps links to create a single layer 3 point-to-point connection. Cox utilizes Label Switching Paths (LSPs) path splitting to create multiple 10Gbps LSPs to efficiently utilize link bandwidth and improve network path availability as it is easy to find resources and move lean LSPs across the network. Cox also utilizes link protection to protect the primary LSP path with bypass LSP ensuring 50ms traffic failover. This helps in improving network reliability as well as availability.

Long haul Fiber Redundancy: From a physical fiber standpoint, all Cox markets have at least three diverse fiber paths into the market, allowing the market to withstand a double fiber cut or long-haul equipment failure and still pass customer traffic. This architecture is known as "Triversity."

g) Describe network infrastructure ownership. Indicate which parts of the network will use the long-form applicant's or another party's existing network facilities, including both non-wireless and wireless facilities extending from the network to customers' locations. For non-wireless facilities that do not yet exist, the description should indicate whether the new facilities will be aerial, buried, or underground. This includes leased lines, transit services, rented tower space for radios, etc.

Last mile HFC and FTTH access networks contain a combination of Outside Plant (OSP) fiber cables and hardline coaxial cables. The Cox network is made up of over than 61,000 miles of aerial and 78,000 miles of underground plant, which we have a long history building and maintaining. Many of the new service areas are within or neighboring the Cox footprint and will leverage as much existing Cox infrastructure as feasible. Cox will partner with local municipals to build new aerial and underground plant in an agreeable manner to both parties.

h) Provide technical information about the design methods, "rules of thumb," and engineering assumptions used to size the capacity of the network's nodes (or gateways), links and wireless

base stations. These are often expressed as ratios, such as "oversubscription ratio" applied in the middle-mile/backhaul and interconnection network levels that funnel the consumer traffic to the Internet. The information provided should demonstrate how the required performance for the relevant performance tier will be achieved during periods of peak usage, downstream and upstream speed, and latency assuming a 70% subscription rate by the final service milestone. For example, the diagram below shows the various oversubscription ratios, link media (wired, wireless, etc.), redundancy and multi-homing in a visual format. It can also be described in text with no need for a diagram. Regardless, we do expect sufficient technical detail rather than a simplistic approach. We expect several ratios as shown and not a simple statement that the network "will use a 20:1 ratio" since ratios are generally different at different levels and locations.

The IXP/peering center links are designed to operate below 70% utilization at 95th percentile. All peering/transit links are forecasted using multi-linear regression models and capacity augments are initiated before the 70% threshold is breached.

For the internet connection points (core) and middle-mile/backhaul (distribution), capacity is forecasted using multi-linear regression models for a rolling 10-year period. Cox also runs models that simulate fiber and hardware failures and adds enough capacity on the redundant paths to handle the full load of traffic. All links in these segments of the network are designed stay below 70% utilization at 95th percentile. Typically, capacity is added 6 months to a year in advance of the forecasted usage, in order to accommodate unanticipated spikes or shifts in traffic patterns.

All Cox markets have at least three diverse fiber paths into the market, allowing the market to withstand a double fiber cut or long-haul equipment failure and still pass customer traffic. This architecture is known as "Triversity."

i) Finally, describe how the long-form applicant's design will meet the peak period end-to-end performance requirements for the path from the consumer premises to the Internet. This requires that the applicant detail consumer path use case(s) that the long-form applicant will use to move traffic to and from the consumer premises to the Internet.

---

2. <u>Network Management and On-going Operations</u>. The applicant's detailed description should:

a) Describe the applicant's plans for monitoring network usage/capacity, performance, congestion, and other parameters.[3]

Our team(s) will introduce device level monitoring that will enable COX to validate faults within the network and associated application system(s).

[3] Network management systems are a mix of personnel, organizations, software, equipment, and processes. These resources are organized along generally accepted frameworks such as FCAP, ITIL or SIEM.

Backhaul/Backbone (P and PE layers)

Cox's backbone packet layer is composed of core (P) and core-edge (PE) layers. The core-edge is service-aware and serves as an aggregation point with massive data plane capacity while core nodes serve as fast Multiprotocol Label Switch (MPLS) switches. All the traffic is MPLS-switched via Resource Reservation Protocol with Traffic Engineering (RSVP-TE) Label Switched Path Point-to-Point (P2P) and Point-to-Multipoint (P2MP) for unicast and multicast, respectively.

The core-edge layer is fully meshed via RSVP-TE with per class of service LSP with data plane per hop behavior to meet our stringent Differentiated Services. The network was designed since its inception to be service agnostic and carries voice, linear video, Internet, and MPLS-based Virtual Private Lan Services (VPN) with their prescribed quality of experience.

The Constraint Shortest Path (CSPF) computation is guided via parameters such as Shared Risk Link Group (SRLG), reservable bandwidth, and delay so that the primary and backup LSPS are failure-disjoint while meeting delay and traffic engineering objective function. The link metrics are based on propagation delay, so the geodesic shortest paths for all traffic is guaranteed.

We utilize two-phase approach for multi-layer network protection where we combine local protection based on MPLS Fast Reroute followed by global shared mesh MPLS-based restoration. The local protection process is fast since the bypass protection is compute and failure independent. Once the location protection is initiated, all the core-edge nodes that are impacted by the fiber cut, will start the global shared mesh restoration process to optimize resources further by running discrete optimization algorithm while invoking make-before-break to move traffic to the most optimal paths by guaranteeing shortest Geodesic distance.

Our Backbone has been designed from the beginning with **on node programmability** using online supervised machine learning where each core-edge node autonomically measures, using Auto-Bandwidth and per class of service LSP, to predict and signal the right amount of bandwidth per LSP without human intervention. We will be adding more capabilities so that each core-edge Label Switch Router (LSR) will autonomically split and merge LSPs based on traffic profile.

Cox's multi-layer network is built based on the best technological innovation and trend for both packet and transport. The transport layer is composed of 29K miles of fiber, empowered by Colorless, Directionless, and Contentionless Reconfigurable Optical Add Drop Multiplexer equipped with Flexible grid **(CDC-F ROADM)**.

Our network is highly available and survivable because the physical topology average degree of connectivity is **3.67,** so our network will remain connected for any failure combination of cuts of size 2. The spare capacity is being kept in the packet layer since the packet layer protection is failure domain independent, so that it protects against both failures in the packet and transport domain.

Shared Risk Link Groups (SRLG) are computed and propagated to the packet layer, so the path computation protocol is SRLG-aware. The fiber links propagation delays are propagated up to the packet layer so that network link metrics are delay-aware, and the Interior Gateway Protocol (IS-IS) makes use of it.

The transponders are software driven and equipped with many modulation profiles to maximize reach versus bandwidth. The achievable bandwidth per fiber link is about 19 Tbps in the C-band for our 1st optical backbone (Nokia), and 33 Tbps for our 2nd (Ciena). The transport network will double its capacity once we enable the L-band. We have seen very encouraging lab verification and validation results to make this transition in the next few years.

On average, a given fiber link of 1000 miles of fiber will experience two cuts per year. A network with 30K miles of fiber, on average will experience one cut every 6 days. Based on our fiber footprint, approximately 5% of the time there will be at least one failed demand without any protection, but our integrated multilayer network dimensioning will add the required spare capacity to mitigate that risk.

We utilize integrated network modeling and simulation tool with accurate traffic demand matrix and forecast for a given planning period for packet layer and transport layer. We add to our multilayer network model shared risk link group, operational routes, and policies to compute the working capacity. After that, we iterate a single link fiber cut across all fibers to compute the spare capacity. Our network dimensioning criteria states that no single link can exceed 75 percent utilization during steady state or failure states.

We also use active measurements to baseline our network using probing to measure site to site traffic demands, latency, and packet loss. The network is also enabled with passive measurements such as streaming telemetry to gather more information about network devices.

Network analytics is a major entity in our overall system architecture. In using Machine learning, we are trying to find some hidden patterns in data to optimize a given resource, to maximize customer experience, and to predict a failure of a given resource and take proactive steps to minimize the impact of that event.

Mid-mile

The methodologies and procedure that we described for our Core/Interconnections also apply to Mid-mile network domain.

The Mid-mile network is configured with active probing based on Y.1731 for Delay Measurement Message, Delay Measurement Reply, Synthetic Loss Message, Synthetic Loss Reply. The differentiated services with service level objectives such as latency, jitter, and packet loss are measured using the active probes described above. Our customers have access to the dashboard to validate their Diff Serv dynamically to report any drift between intend service states and the operational service state.

The network dimension, capacity planning, MPLS Traffic engineering, and Differentiated service are the same as Core/Internet-connections.

Last Mile Access Network

Cox has various monitoring application systems to monitor our network status including network utilization, capacity, and congestion of each link. Access network utilization can be monitored in real time through SNMP protocol. It is reported in a weekly basis so that we can keep track of the trend and plan for adding capacity when the link utilization exceeds a predefined threshold. The telemetry database is deployed in a big data system in Hadoop framework. We have an automated topology monitoring tool which represents the access network topology to identify a node capacity and connection of each network entities with geographic details.

We develop Network Planning Automation tool which forecasts node level traffic load with machine learning and integrates it with the network topology data and technology evolution projection so that we can optimize our access network capacity planning ahead of time.

Cox has customer's device level monitoring tool which represents physical link health including Tx/Rx(Transmit/Receive) signal level, MER(Modulation Error Ratio) and BER(Bit Error Rate). It allows us to monitor last mile performance.

Cox has big analytics teams to keep developing numerous monitoring tools and analyze the tremendous amount of telemetry data to provide best services to our customers.

b) Describe how the applicant will maintain the performance and quality of the service for the duration of the 10-year support term.[4]

Cox operates over 150k miles of broadband network serving over 6 million customers across America. Ensuring a positive customer experience, services delivered based on what customers subscribed for, is what Cox has done and does its our core business. To support ongoing quality and performance of Cox's network proactive management and monitoring is operationalized to the customer level. This includes a portfolio of capabilities provided by tools, technology, processes and a highly skilled and continuously trained workforce.

Cox utilizes state of the art tools that provide proactive/reactive monitoring to identify performance and quality anomalies within its network and supporting platforms. The tools are tuned to thresholds that are based on engineering and operational specifications as prescribed by Federal, industry and company requirements.

Investing in technologies that support a highly available, reliable and scalable network are 1 of 2 Cox's pillars – People and Network. It's billions in investments are core to the level of service that Cox customer's experience. The expansion into any RDOF opportunity will be serviced by those same network technologies that deliver Cox's services today.

Cox's operation incorporates processes built on ITIL, Six Sigma and other industry practices to support the customer journey from the Fulfillment to Assurance phases. These processes continue to be optimized with Net Promoter Score being the measuring stick to ensure customer expectations are delivered on.

A highly skilled and trained workforce is only realized when the culture supports it. Cox's culture is founded on the employee and has been in place for 120 years. Training is key component of that focus that ensures the workforce is equipped to maintain/sustain network performance and quality metrics.

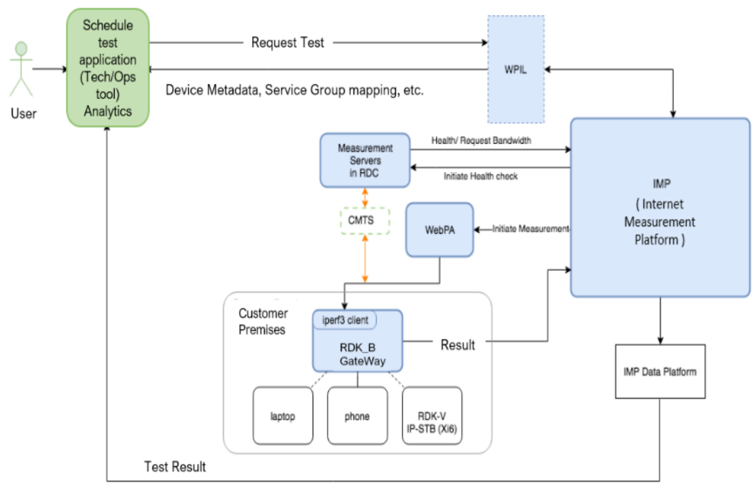
c) Describe who will provide these services. Will the applicant: 1) use existing internal organizations, 2) use contracted management service providers, 3) create new internal organizations, or 4) engage new contractors?

[4] Widely used network level performance management techniques include traffic-engineering, Quality of Service, over-building/scalability, redundancy, load-balancing, equipment that easily allows upgrades and a variety of other techniques. Relevant information can include oversubscription ratios at all network levels, assumptions, specific calculations, and most importantly PEAK period impact. Lastly, the answer must provide and sufficiently describe the rules of thumb and effective corrective actions as requested for all three levels of the network (last-mile, middle-mile, and core/Internet-connections.

This will be a hybrid approach. COX has tenured technical engineers who are very familiar with our network. Additionally, when required, we utilize specialized contracted management services to augment our Fulfillment and Service Assurance teams.

d) Describe how the applicant will comply with Commission performance measures for speed and latency.[5] The description should include whether the applicant plans to use the Measuring Broadband America (MBA) system, off-the-shelf testing mechanisms such as existing network management systems and network management tools, or provider-developed self-testing mechanisms.

Cox plans to comply with Commission performance measures for speed and latency by using an in-device diagnostic testing system for Panoramic Wifi devices that will be deployed in 2021. This test will allow Cox to measure hardwired speed performance and latency performance to Panoramic Wifi devices.



Point-to-point speed test will be executed between partner network server and customer's gateway. The Internet Measurement Platform (IMP) API gives customer Gateway devices the ability to measure Internet speeds and other Internet-based measurements over the default high-speed data service flow. IMP directly queries the customer's Internet Gateway to provide the measurement. The platform utilizes open-source networking tools, such as iperf3 and netperf, to collect data.

Cox has the ability to run scheduled polling to applicable devices to capture performance measures and will be able to report the results to the Commission as needed.

---

3. <u>Network Diagram</u>. The network diagram must be certified by a professional engineer and should:

a) Identify all wireline and wireless segments of the proposed networks. This should include applicable middle-mile/backhaul and interconnection network infrastructure. These are also commonly referred to as "links" between the nodes. These descriptions should indicate the media/link technology, data-rate/speed, and topology if point-to-point, ring, etc.

[5] *See generally Connect America Fund*, Order, 33 FCC Rcd 6509 (WCB/WTB/OET 2018) (CAF Performance Measures Order). Further modifications were made to the performance measures requirements in subsequent reconsideration orders. *See Connect America Fund*, Order on Reconsideration, 34 FCC Rcd 8081 (WCB/WTB/OET 2019) (CAF Performance Measures First Reconsideration Order); *Connect America Fund*, Order on Reconsideration, 34 FCC Rcd 10109 (2019) (CAF Performance Measures Second Reconsideration Order) (describing the methodologies for the Commission's performance measures).

b) ***Uniquely identify (i) major network nodes including their manufacturer and model, as well as their functions, locations, and throughput/capacity; (ii) access nodes or gateways, including their technology, manufacturer and model, location, and throughput/capacity; and (iii) major inter-nodal links (not last mile),[6] and their throughput/capacity.***

c) ***Indicate how many locations/consumers will be offered service from each access node or from each gateway, and which performance tier or tiers will be supported at each access node.***

d) ***Indicate what parts of the network will be new deployment and what parts will use existing network facilities.***

e) ***Identify specialized nodes used in providing voice service, such as SIP servers, PSTN gateways or voice OTT providers.***

f) ***Explain how nodes or gateways are connected to the Internet backbone and Public Switched Telephone Network. Show redundancy, dual- or multi-homing configurations.***

[6] Include links that connect access nodes to the network core, among other major inter-nodal links. Each inter-nodal link should be identified by specifying the nodes at the ends of the link.

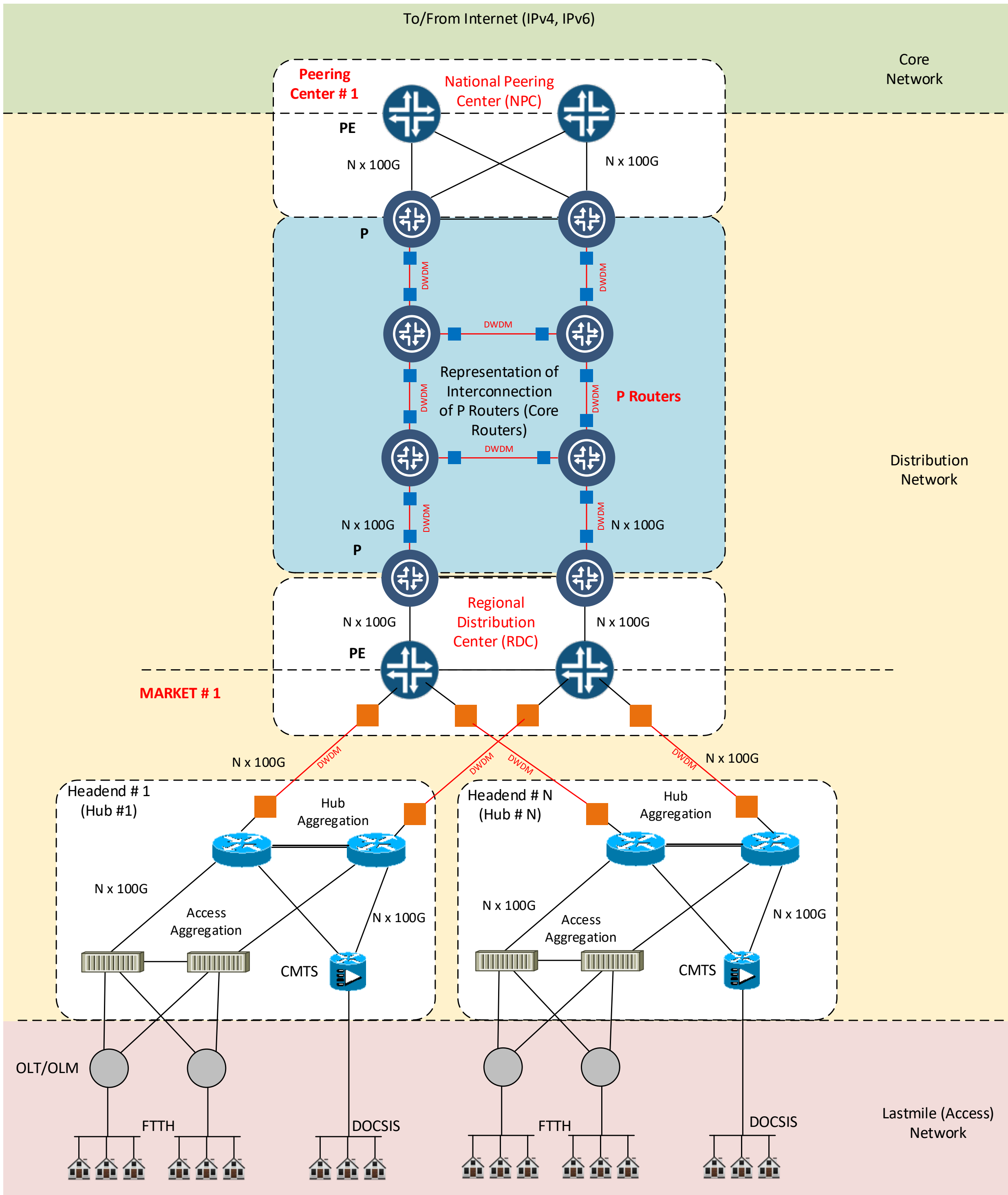
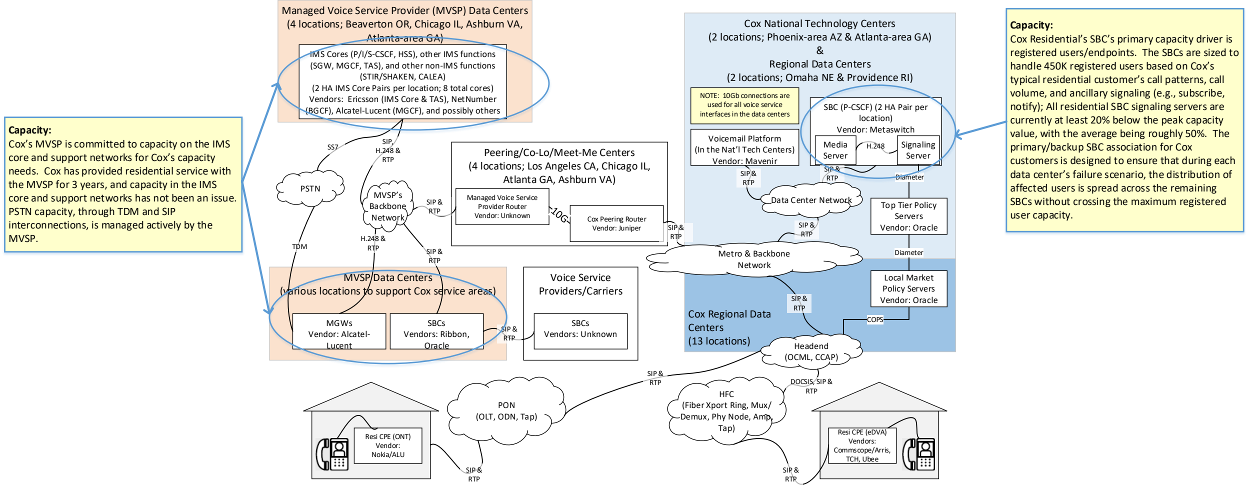


Fig. Cox Communication End – to – end Network Topology showing various layers (legend and node locations shown below)

Node Locations:	**Legend:**
Peering Centers: • San Jose • Los Angeles • Dallas • Kansas City • Chicago • Marietta • Ashburn • New York Regional Distribution Centers (Markets) • Orange County • San Diego • Las Vegas • Arizona • Omaha • Oklahoma • Tulsa • Wichita • Johnson • Baton Rouge • Louisiana • Pensacola • Gainesville • Macon • Merrifield • Roanoke • Hampton Road/Virginia Beach • Cleveland • Providence	**Legend:** PE Routers (Juniper MX2020, JunOS) P Routers (Juniper PTX10K, JunOS) Hub Routers (Cisco NCS550X, IOS-XR) PON Agg. Routers (Arista 7280SR2, EOS) CMTS Routers (Cisco uBR10K, IOS-XE) Cisco NCS2K, Nokia 1830 PSI-L Nokia 1830 PSS-16, Ciena 6500 RLS

Cox Residential Voice Service Network Diagram



Cox Business Voice Service Network Diagram