CITY OF CHESAPEAKE

C-NGN Fiber Master Plan

Magellan ADVISORS

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C-NGN FIBER MASTER PLAN

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Executive Summary

To further establish itself as an exceptional place to live, learn, work, farm, and play Chesapeake needs to increase access to affordable, high-speed fiber-optic broadband services. Investing in enhanced broadband services will enable Chesapeake to better serve its citizens, businesses, and visitors; take advantage of the Transoceanic Cable Landing and Southside Network Authority Regional Connectivity Ring (SNA-RCR), and will be a catalyst for private investment in competitive residential and commercial broadband services, and community and economic development citywide.

The City of Chesapeake hired Magellan Advisors in September 2019 to develop a Broadband Master Plan. The company was asked to clearly define the gap between where Chesapeake is and where the City wants to be. There was extensive data gathering of the current state of Broadband Services in Chesapeake and the region. We conducted 20+ work sessions with City, Library, School personnel, and external stakeholder groups, involving more than 240 people in the process. Along the way, we learned that Chesapeake is generally underserved with relatively few providers, limited competition, and significant "Digital Deserts." The City pays a lot for limited broadband services and has significant unmet needs. The City has the opportunity to substantially simplify and consolidate WAN services resulting in lower costs without encroaching on City, School, and Library network autonomy. The City will be able to ensure its network is financially and operationally sustainable and resilient.

Together, we identified the best ways to address these needs and opportunities. The final plan, described in this report, provides a business model, high-level design, and implementation approach for an optimal technical architecture. It provides a detailed business case analysis, including financial projections, and a roadmap for execution. The plan is for the City of Chesapeake to become an *Infrastructure-only Government Service Provider*. Under this business model, the City finances, builds, owns, and operates the C-NGN to support its own operations, and leases excess capacity to drive community and economic development.

The plan calls for 172 miles of underground construction to create a City-owned and Department of IT (DIT) operated high-speed optical transport ring. To be constructed in three phases, the C-NGN will consist of four interconnected core sites with sub-second service failover in case of fiber cuts. It will connect 207+ sites, including redundant connections to key facilities, and 32 wireless gateways serving 70,000+ wireless endpoints, 260+ Utility assets, and 15 Safety/Traffic cameras and signs. The City will have 15 more facilities connected and forty times more

bandwidth on average than it does currently. The C-NGN will reach across the entire City, plug into private data center services, interconnect with adjacent city networks and the SNA-RCR, and provide shared, redundant, high-capacity Internet access. The network will support future Smart City initiatives and enable Chesapeake to connect additional assets and locations for a nominal cost. Not only does C-NGN provide more bandwidth, more connections, cost savings, and a hedge against cost increases over time, it will be a valuable asset for the City.

The C-NGN will cost $32.58 million to design, construct, deploy, and migrate sites to it. The largest cost will be $26.84 million to design and construct fiber backbone and lateral routes, which may be reduced by co-building with private partners, route optimization, value engineering, and other means. There will be $2.75 million in network and data center equipment, including wireless overlay, and $2.63 million for construction/project management, facilities, and tools. Focused marketing along with policy changes will foster private investment in advanced communications services, improve revenue-generating opportunities, and reduce construction costs.

As the C-NGN is turned up, there will be an immediate 22% reduction in 1 Gbps circuit costs and a 33% reduction in 10 Gbps Circuit costs, with future rate reductions planned. The City will tap new revenue opportunities by leasing conduit, dark fiber, tower attachments, and wireless network capacity. The C-NGN will decrease the Chesapeake's contracted network service costs from $1.38 million to $243,454 by Year 5. This will be offset by $1.52 million in new operating costs for personnel, hardware and software maintenance, and data center collocation and related services.

Magellan Advisors created a conceptual design for the C-NGN, which is the basis for the projections, above. The next step is to build the C-NGN. This involves low-level design and value engineering, bidding construction through a competitive solicitation, and construction management and procurement of remaining C-NGN components (equipment, services, etc.). Concurrently, the City needs to plan C-NGN operations. As the network is being built it will be necessary to begin staffing for network engineering and management, contract administration, and marketing. The proposed roadmap has the initial C-NGN network services coming online as early as Q1/Q2 of 2022.

The selected approach is fiscally responsible and maximizes returns on taxpayer investment. The City lowers its long-term operating costs and gains valuable real assets. Because the City will own its infrastructure, it can deploy new services and connect additional locations at low marginal costs. By approaching the C-NGN as a

municipal capital improvement, Chesapeake builds lasting value for taxpayers that can yield additional benefits.

The C-NGN puts Chesapeake in charge of its own destiny. In addition to providing long-term operational efficiencies and giving the city the flexibility it needs to adapt quickly to changing conditions and new technologies to provide enhanced government services, the C-NGN provides the potential for significant top-line benefits including revenue generation through leasing excess capacity and an expansion of the tax base through new economic development opportunities made possible by the C-NGN. With the C-NGN, the City can attract new investment by more companies, particularly internet service providers and other tech-intensive firms, which can grow the tax base. The C-NGN positions Chesapeake especially well for advanced manufacturing, computer simulation, data centers, logistics, robotics, and related industries. Skilled workers and technical talent require abundant, cheap bandwidth and ubiquitous access to do their work, more now than ever and they expect it in the communities within which they choose to locate.

A. Introduction

The City of Chesapeake is planning a fiber and wireless Chesapeake Next Generation Network (C-NGN) to enhance municipal operations, promote economic development, and encourage broadband offerings by the private sector. The City provides the full range of local government services for a population of over 235,410 covering 351 square miles in the South Hampton Roads region of Virginia. Chesapeake's leaders recognize that the City needs world-class connectivity to operate and serve citizens and visitors effectively. Large areas of Chesapeake are prime for business investment and residential growth, which will require additional public infrastructure and services. The C-NGN will provide cost-effective, enhanced services to local government over City-owned infrastructure, and that infrastructure will be available for private companies to use in offering new services to the community and to expand broadband and cellular services.

Magellan Advisors met with and interviewed officials with various City departments, the Schools and Libraries, to determine what connectivity they have and need. We studied comparable communities and industry trends and gathered information from Chesapeake's regional partners and telecommunications companies operating in the area. We also analyzed IT records, focusing on the current network architecture, connections, and costs. This analysis uncovered multiple gaps in network infrastructure and services due to a number of issues, all of which are detailed in Appendix 1, under a separate cover.

Currently, Chesapeake spends over $1.2 million per year for connectivity to City facilities, including Schools and Libraries, mobile units, and remote sites. The true cost is closer to $2 million per year when you include subsidies such as the Federal E-Rate program. Most of the current connections fall far short of the City's requirements, as summarized below. In comparison, the City of Portsmouth, which is immediately north of Chesapeake, is building a network that will provide a minimum of 1 Gbps, and up to 10 Gbps, to all City, Library, and School sites by 2021. And, they will get it for a fixed cost that will not be subject to third-party price increases.

1. Project Vision, Goals, and Objectives

The goals for the C-NGN are economical connectivity for all public sector sites—particularly City facilities, Libraries, and Schools—and private investment in ubiquitous competitive broadband options for the community. Specifically, C-NGN will:

- Provide affordable, broadband services to all City, School, and Library facilities
- Leverage the Subsea Cables and Regional Connectivity Ring (SNA-RCR)
- Ensure network financial and operational sustainability and resiliency
- Make Chesapeake an exceptional place to live, learn, work, farm, and play by:
    - Better serving citizens, businesses, and visitors
    - Creating a catalyst for private investment in broadband services to all citizens and businesses city-wide (more competition)
    - Creating a catalyst for community and economic development

The overall purpose is to position the City for sustainable, technology-based economic development, capitalizing on the City's abundant developable properties, geographic position, and proximity to trans-Atlantic cable landings, and support improvements in municipal operations, services, and overall quality of life. Great business and residential connectivity, along with smart public technology use, are essential for this purpose. Chesapeake simply cannot attract investment and grow sustainably without it.

The vision of the C-NGN is to cost-effectively interconnect City assets and facilities to support improved municipal operations, provide a foundation for Smart City initiatives, and foster private broadband investment so all citizens and organizations have the access they need to prosper in Chesapeake, which may have been best stated as:

> "Chesapeake's broadband network will enhance education, improve public safety response, expand healthcare, and spur economic development and that's just for starters. For Chesapeake to compete and lead in this region and in this country, we need the most modern infrastructure to make doing business easy, fast and efficient."
>
> – *Susan Vitale – Chesapeake City Council Member*

The City of Chesapeake has three "Strategic Anchors" or guiding principles that serve as fundamental benchmarks for the C-NGN. The first is, "We help make Chesapeake an exceptional place to live, learn, work, farm, and play." The C-NGN enables this by providing the necessary connectivity for these activities. The COVID-19 pandemic has increased these needs. The C-NGN makes it possible to "provide outstanding service to Council, our community, our customers and each other," which is the second Strategic Anchor, in today's digital world. The last, fundamental Strategic Anchor is "We will be fiscally responsible and sustainable," which the C-NGN achieves by lowering the long-term operating costs of the City's networks and as a valuable real public asset that creates new, exciting opportunities for the community, its businesses and residents.

With the C-NGN, Chesapeake's new network connectivity standard is for City facilities to be connected via diversely-routed fiber at a minimum speed of 1 Gbps. Key sites are to have physically redundant connections and all sites are to have shared redundant dedicated internet connections via multiple providers. Municipal assets, particularly for Public Safety, Traffic Management, and Utilities, will be connected to data networks. A range of wireless connectivity options must be available for connecting numerous small devices such as cameras, controls, and meters. These requirements will provide the City with a great deal of capacity, flexibility, and reliability to operate online.

Due to Chesapeake's characteristics, discussed below, the City requires a large and reasonably complex network. There were several options Chesapeake considered to get the required connectivity. The City could lease connections from private providers as it does today or build and own its own network. It will cost tens of millions of dollars to construct but it will cost much more over a 20-year term to rent. And renting connectivity doesn't provide the control required or result in ownership of real assets. Therefore, to get as much benefit from its network investments as possible while keeping the Total Cost of Ownership (TCO) down, the City has opted to build, own, and operate its network infrastructure.

The infrastructure will be funded as a capital project by the City. Construction and operations will be paid for by internal chargebacks, federal and state grants, lease revenue, and private investments. Deployment costs are to be minimized by opportunistically combining construction with other capital projects and developments, joint building with private providers, and value engineering. The network will be operated by a mix of City personnel, contractors, and private partners.

The City of Chesapeake is allowed by law to construct and operate a network for its own purposes, to achieve the primary goal for the C-NGN. While it is not allowed to

provide retail broadband services that would directly achieve the second goal of ubiquitous competitive access, the City can allow private companies to use the C-NGN, by leasing excess capacity, for this purpose. These general roles—directly providing services to local government and providing infrastructure for service providers—are the means by which the C-NGN will generate return on taxpayers' investments and strengthen the City's Strategic Anchors. The C-NGN will reduce overall costs, improve public services, and generate revenue from public assets. It will also be a flexible platform for current unforeseeable innovations that would further enable operational improvements and fuel economic development.

By working together to build a common digital infrastructure, Chesapeake leaders will get the connectivity their community needs for decades to come. The C-NGN will be a valuable real asset for the community. It will create economic opportunities by catalyzing private investment by tech-oriented companies and making it possible to undertake bold technology initiatives. Because of Chesapeake's investment and willingness to lease excess capacity, it becomes cheaper for private companies to enter the market, making it possible for them to provide broadband options in under-served areas.

This document summarizes the City's connectivity requirements and related issues in this section before describing the C-NGN architecture, business model, construction, financing, operations, and supporting policies. Additional details on all of these topics are provided in appendices. Lastly, we offer recommendations and specify the next steps for building the C-NGN. Our goal is for this document to serve as a roadmap for getting the necessary components and creating a true next-generation network for the City of Chesapeake.

2. Connectivity Requirements

Connectivity requirements are based largely on business functions, including applications and locations for those functions. Magellan Advisors worked with City personnel to determine the current and future needs of the City overall, the Libraries and other departments, and the Schools. The City of Chesapeake's public sector network infrastructure and services consist of three organizations with separate IT departments: The City of Chesapeake's DIT, the Chesapeake Public Library system, and the Chesapeake Public Schools. All three agencies are formally funded through the City but are functionally and operationally separate in their IT strategies and network management. This section summarizes information systems currently used for various business functions within the City, focusing on connectivity requirements.

City Operations

The City of Chesapeake has the equivalent of 32 departments, including its constitutional offices, courts, and judicial offices, customer service center, and libraries, in 123 offices or other facilities. These departments cover the full range of local government functions, with most agencies reporting to the City Manager. The City provides technology support, including connectivity, to these offices with a mix of state and local funding. Some agencies receive most of their network and technology support through the State. In these cases, the City often augments state support with City resources. The Libraries have distinct requirements and network resources which we consider separately below.

Most basic business functions, such as accounting, document and file sharing, timekeeping, are on internal Microsoft Server infrastructure, including Peoplesoft for financials, Munis for human resources, Accela for development and permits. Revenue and tax applications are hosted on IBM Z12 mainframe in Boston (MA) with a back-up site in Chattanooga (TN). Chesapeake uses a variety of software-as-a-service (SaaS) products, particularly for departments as noted below, but also generally for content archiving and management, mass notification, and surveys. During plan development, the City was in the process of migrating to Mitel voice over internet protocol (VoIP) services. They were also investigating enterprise solutions to enhance physical security with security cameras and access control. Both VoIP and enterprise security cameras and access control are network dependent applications and these projects influenced the ultimate C-NGN network design.

Libraries

Chesapeake has eight (8) library locations that lend books, host classes, and provide research and related services. The Library contracts its wide-area network Metro Ethernet connections and Multi-Protocol Label Switching (MPLS) from Cox. The library manages an independent web site (http://www.infopeake.org/) with significant online information resources and provides public WiFi with internet access and internet-connected computers. They were planning to move to an integrated, cloud-based library management system at the time of this research.

Schools

There are 47 Chesapeake Public Schools (CPS), distributed throughout the City, with two administrative buildings at 304 and 312 Cedar Street on the municipal campus, a historic school building, and a vocational center at 2104 Steppingstone Square. The Schools' data center, which is about five years old, is located in the Educational Services Center, at 369 Battlefield Boulevard. They also have a "cold" disaster

recovery site at a school in the Western Branch area. Generally, the schools anticipate an ever-increasing need for bandwidth and storage, more video, and more IoT. While the COVID-19 pandemic has forced schools to send students and teachers home, it has also pushed them to do more online, pushing connectivity requirements out into the community.

Many of the Schools' administrative systems are on local servers, including a financial system hosted by the City and systems provided by the state. Most of their assessment, certification, and testing tools are cloud-based, as are some administrative systems. Some testing and a lot of curriculum content are provided by the state via secure portals. They plan to move everything to the cloud eventually, including a new learning management system and student information system. The Schools are transitioning to G-Suite for all faculty, staff, and students, building on their one-to-one deployment of Chromebooks. They are expanding access control, moving from analog to IP video cameras, and maintain a separate door access control system. CPS is piloting ID badges for students.

Community Stakeholders

The planning process included engaging local business and community stakeholders. Magellan Advisors conducted extensive data-gathering of the current state of broadband services in Chesapeake and the region. The consultants conducted over 20 work sessions with City, Library, and School personnel and external stakeholder groups involving more than 240 people. Stakeholders engagement were from small business, major employers, agriculture, tourism, regional development, and telecommunications industry providers. The complete list of stakeholders engaged is included in Appendix 1: Under Separate Cover.

3. Public Assets to be Connected

At the onset of this project, Magellan Advisors identified 146 City, Library, and School sites requiring connectivity. In addition, Chesapeake has 344 water and wastewater assets and 239 traffic-related assets including bridge minders, cameras, signals, signs, and toll collection related devices. Most of these are to be connected by the C-NGN. The City owns over 800 streetlights, primarily at public facilities and parking areas, and has access to the other 25,000 light poles through Dominion Power, which may need to be connected and could be used to deploy network assets.

Technology trends are for even more things to be connected. The universe of possible connections will inevitably expand and the value of those connections for operations and to citizens will likely increase. The C-NGN design anticipates growth and can be easily adapted and expanded to meet changing needs. City facilities and

other assets to be connected by the C-NGN are described in detail in the Network Architecture section below.

4. Objectives

In consultation with City leadership, technology staff, and key stakeholders, Magellan Advisors has identified the following set of goals and objectives that align with the City's overall Strategic Anchors. We recommend that C-NGN leadership develop metrics in support of these objectives:

A. Goal 1: Provide affordable broadband services to all City, School, and Library facilities.

   Objective A.1: Deploy fiber and wireless connections to all sites identified in the C-NGN design.

   Objective A.2: Promote utilization of the C-NGN for civic/municipal purposes.

   Objective A.3: Support current and future Smart City needs

B. Goal 2: Leverage the Subsea Cables and the Southside Network Authority's, Regional Connectivity Ring (SNA-RCR)

   Objective B.1: Provide resilient connections to the SNA-RCR and the Subsea Cable Landing meet point

   Objective B.2: Interconnect directly to one or more regional private data center providers to place the C-NGN "on-net", providing direct access to wholesale providers and content ecosystems, decreasing Internet access and other third-part IP service costs, and providing access to new cloud services and disaster recovery options.

C. Goal 3: Ensure network financial and operational sustainability and resiliency, and

   Objective C.1: Deploy the C-NGN as cost-effectively as possible through value engineering and leveraging "one-dig" and co-build opportunities

   Objective C.2: Provide cheaper rates than current private sector rates and decrease rates over time

   Objective C.3: Provide improved network resiliency with increased redundant connections and sub-second service failover on fiber cuts

D. Goal 4: Make Chesapeake an exceptional place to live, learn, work, farm, and play by 1) Better serving citizens, businesses, and visitors; 2) creating a catalyst for private investment in broadband services to all citizens and

businesses city-wide, creating competition; and 3) creating a catalyst for community and economic development.

Objective D.1: Ensure network routes support city service needs, promote broad geographic coverage, and intersect with key economic development areas

Objective D.2: Attract private providers to lease network assets and provide services, especially in under-served areas.

Objective D.3: Promote the use of the C-NGN for commercial, industrial, educational, healthcare, and recreational purposes

B. The C-NGN Business Model and Business Case Overview

Based on Magellan's recommendation, the City of Chesapeake has chosen the *Infrastructure-Only/Government Services Provider* business model for the C-NGN. The City will construct, finance, own, and operate the network as a City enterprise fund. The City will use a portion of the C-NGN infrastructure to provide WAN connectivity to its departments and other public agencies. Unused portions of the infrastructure will be leased to private companies for providing services to the community. Private companies may jointly build network infrastructure with the City, which would defray the City's costs.

From a total cost of ownership perspective, this approach is more cost-effective than continuing to lease services. The potential to generate revenue from leasing excess network capacity makes the business case even more compelling. The C-NGN will connect more sites and provide greater bandwidth at a lower cost than comparable private services. Additionally, the wireless overlay will allow the City to economically deploy new, cost-saving services, and city ownership and control of the network assets allows the City to capitalize on the C-NGN for economic development purposes giving the city the needed flexibility to adapt to evolving needs.

As an Enterprise Fund within the IT Department, City Departments, Schools, and Libraries, and other public entities will pay for the C-NGN services they consume generating "revenue" for the C-NGN. The C-NGN will generate additional revenue by leasing excess capacity. Any externally generated revenue will be returned to C-NGN to lower the overall costs of the network and rates charged. This will require that the IT Department develop a robust, transparent chargeback mechanism.

The C-NGN business case is based on avoiding costs from recurring service fees for the five existing WANs, connecting more facilities and other municipal assets (e.g., traffic signals and water pumps), substantially increasing bandwidth, and improving network reliability. We believe these "bottom line" benefits, balanced with cost considerations mentioned above, justify the investment in the fiber backbone. Magellan projects the City will recover its costs and have $27M in cash-on-hand from the investment after 30 years. This business case and associated financials are described in the Financing and Operations section.

The fiber backbone and wireless overlay serve different purposes for the City. Therefore, we analyze them separately. The case for the wireless overlay is based on cost avoidance for new functions, planned remote water meter reading, and current functions, such as SCADA and Telemetry, and Intelligent Transportation.

> The C-NGN requires public investment but gives the City ownership of the network, allows maximum control over its services, and generates a better long-term ROI.

The C-NGN will enable the City of Chesapeake to (a) avoid recurring fees for connections, (b) connect more sites at higher speeds, (c) more flexibly respond to evolving needs and opportunities, and (d) be a valuable real asset the City can leverage for other purposes.

Under the business model for the C-NGN, the City meets its telecommunications and network infrastructure requirements by building out an underground conduit and fiber-optic backbone/lateral network to serve the needs of the City, illustrated in Figure 1. This is done as a Capital Improvement Project. The C-NGN becomes community infrastructure, just like water, sewer, and other City assets deployed through the public rights-of-way.

Figure 1: Conceptual Network Map

Under this model, the City deploys capital assets over a construction period of 36 months or longer (3 years has been modeled), transitioning away from the service provider's managed services in a phased manner. At the same time, funds that were going to monthly recurring costs are reallocated to C-NGN. The City builds and owns underground digital infrastructure to serve local public sector needs for at least the next 30 years, thereby permanently eliminating the recurring costs associated with procuring third-party network services. The City will be able to expand the network to support future community initiatives, including Smart City projects, at low incremental costs, versus incurring additional monthly recurring operating costs for connectivity from the managed service provider.

C. Network Architecture, Design, and Construction

The C-NGN architecture provides carrier-grade service levels, at both the core distribution and wireless components of the network. At the Core, a high-speed, high-count fiber-optic backbone architected with 100+ Gbps DWDM (Dense Wavelength Division Multiplexing) transport equipment will interconnect major City facilities and network shelters each acting as a network PoP (Point of Presence). Within these C-NGN PoPs, network aggregation equipment will interconnect the 207 City, Library, School, and CIBH sites identified to date.

The C-NGN includes a total of 663,836 feet (126 miles) of fiber-optic backbone buildout and 242,880 feet (46 miles) of fiber-optic lateral extensions for a total underground build of 172 miles delivering a minimum 1 Gbps network connection, with major facilities being connected at 10 Gbps or more. The network will connect dozens of additional facilities, including public safety radio towers, traffic cabinets, and public utility components. The C-NGN will be able to scale to multi-hundred Gbps in the Core, and 100 Gbps+ in the aggregate distribution networks in the future.

In addition to the design and construction of horizontal underground conduit and fiber, the City will also procure architectural and construction services for data center facilities/PoPs, as well as substantial network equipment and data center components. The C-NGN will be deployed in an established network environment with an installed base of Cisco equipment, staff expertise, and contracted resources. For this reason, Cisco is being specified as the equipment manufacturer and should be included in procurement solicitations and professional services should be limited to qualified value-added resellers (VAR's).

The City's existing wireless networks for public safety, traffic management, utility SCADA, on the other hand, were procured as a vertically integrated solution, which the C-NGN wireless overlay networks replace as greenfield deployments. With the C-NGN approach to developing a set of ubiquitous wireless overlay networks, procurement can be based solely on specifications for each network type with proposed solutions being evaluated against a set of selection criteria included in the procurement package. This will allow the City to consider the best of breed solutions for the network overlays and provide a set of specifications from the selected vendor to be included in all future wireless application procurements.

Additionally, the C-NGN architecture calls for the C-NGN to be physically tied into at least one regional data center. This will most likely happen through an intracity network interconnect, i.e., Chesapeake to Portsmouth, Chesapeake to Norfolk, Chesapeake to Virginia Beach, Chesapeake to Suffolk. An interconnection and fiber sharing agreement will be required to support this – at least until the SNA-RCR is in place and operational.

Once connected, the C-NGN should establish a physical presence in a facility through the lease of a rack or cage and should plan for new cross-connects into wholesale Internet Providers, Azure Express Routes, and other key services/content offerings. These network interconnects and third-party service offerings can then be incorporated into and distributed across the C-NGN and delivered to the edge of each agency network.

Based on the Needs Assessment and leading industry best practices, this is the optimal technical architecture and high-level systems design for the C-NGN. This architecture and high-level systems design meets or exceeds the requirements and goals identified through the planning process, including:

- Resiliency and fault tolerance
- Bandwidths capable of far exceeding requirements
- Designed to connect hundreds of sites initially, scalable to thousands of connections
- Supporting separate City, School, and Library networks leveraging common infrastructure

As depicted below in Figure 2, the fiber backbone is ringed across the City of Chesapeake, interconnecting four (4) Core C-NGN Aggregation/Transport nodes located at Priority 1 (P1) City facilities, using End to End Carrier Ethernet and Optical Transport services. Every additional site connected will be configured with a single, non-redundant connection, or with dual, redundant connections.

While the basic function of the C-NGN is to connect sites/facilities and assets throughout the community, the vision of the C-NGN is for it to function as a new digital network platform that creates an IP/Smart Connected City ecosystem for its users. This includes on-net interconnections to third party infrastructure including the future SNA-RCR, surrounding municipal fiber networks, and a range of regional data center/colocation assets and private operators.

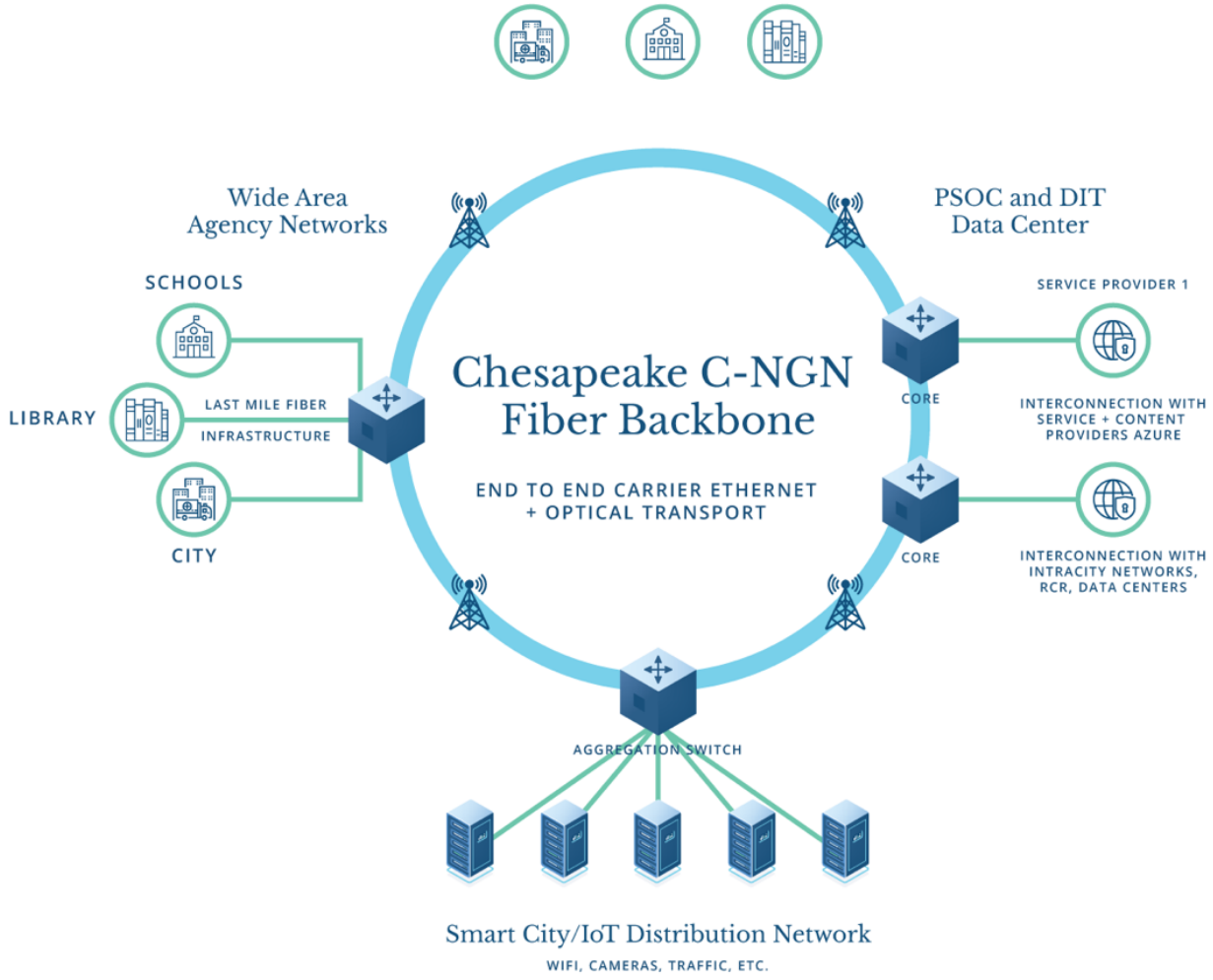

Figure 2: Vision of the C-NGN

The primary role of the C-NGN is to offer network services to the City, Schools, and Libraries. It is also designed with an eye to the future. The C-NGN platform will be able to support connections to other third-party networks, connect traffic cabinets and utility assets across the City, and enable future smart city applications. In short, the C-NGN functional requirements mirror that of the WAN services provided today through the incumbent provider's network, but with more and cheaper bandwidth, greater control over the network, and a valuable real infrastructure asset for Chesapeake.

1. Fiber Backbone Network

The C-NGN fiber-optic backbone network is designed to connect 207 public Chesapeake sites, as well as interconnections into the SNA-RCR, and surrounding city networks. The C-NGN will be extended through surrounding cities to connect to one of many commercial data centers located in the region. The C-NGN fiber-optic network requirements are summarized as follows:

- Constructed to replace leased services to current sites, connecting 207 sites at its inception, and be able to scale to thousands of connections
- Highly resilient fiber ring architecture with four (4) hub sites
- High-count backbone cable with excess capacity planned for future growth
- Interconnected regionally to peer networks and commercial data center assets
- 100% underground construction for security and protection
- Ability to serve critical facilities with diverse geo-redundant fiber feeds

The C-NGN will be constructed underground in a conduit bank, routed through many primary and secondary transit corridors across Chesapeake. The underground fiber infrastructure is routed to most efficiently interconnect core Chesapeake sites and facilities, and where possible, through other areas of interest which could benefit from improved connectivity, such as major transit corridors, commercial areas, traditionally underserved areas, and economic development sites.

Backbone Routes

The C-NGN backbone network will traverse 126 miles of City roadway infrastructure and conduit routes, passing 207 facilities and other key areas of the community. Table 1 below provides a breakdown of the backbone distances and sites connected by the phase of deployment that has been outlined within this plan.

Table 1: C-NGN – Backbone Distances by Phase

Phase	Backbone Footage	Sites Connected
1	284,259 (54 miles)	133
2	244,142 (46 miles)	65
3	135,445 (26 miles)	9
Total	663,846 (126 miles)	207

There are four (4) distributed locations around the backbone ring that serve as hubs for the C-NGN core network and site connections. These 4 sites are designated as Priority 1 (P1) hubs and are designed to be highly redundant by incorporating diverse fiber routes and redundant electronics to form the high-speed transport network connecting the C-NGN sites and services. The P1 sites include the Public Safety Operations Center (PSOC), the Department of Information Technology building, new Fire Station 7, and Police Precinct 4.

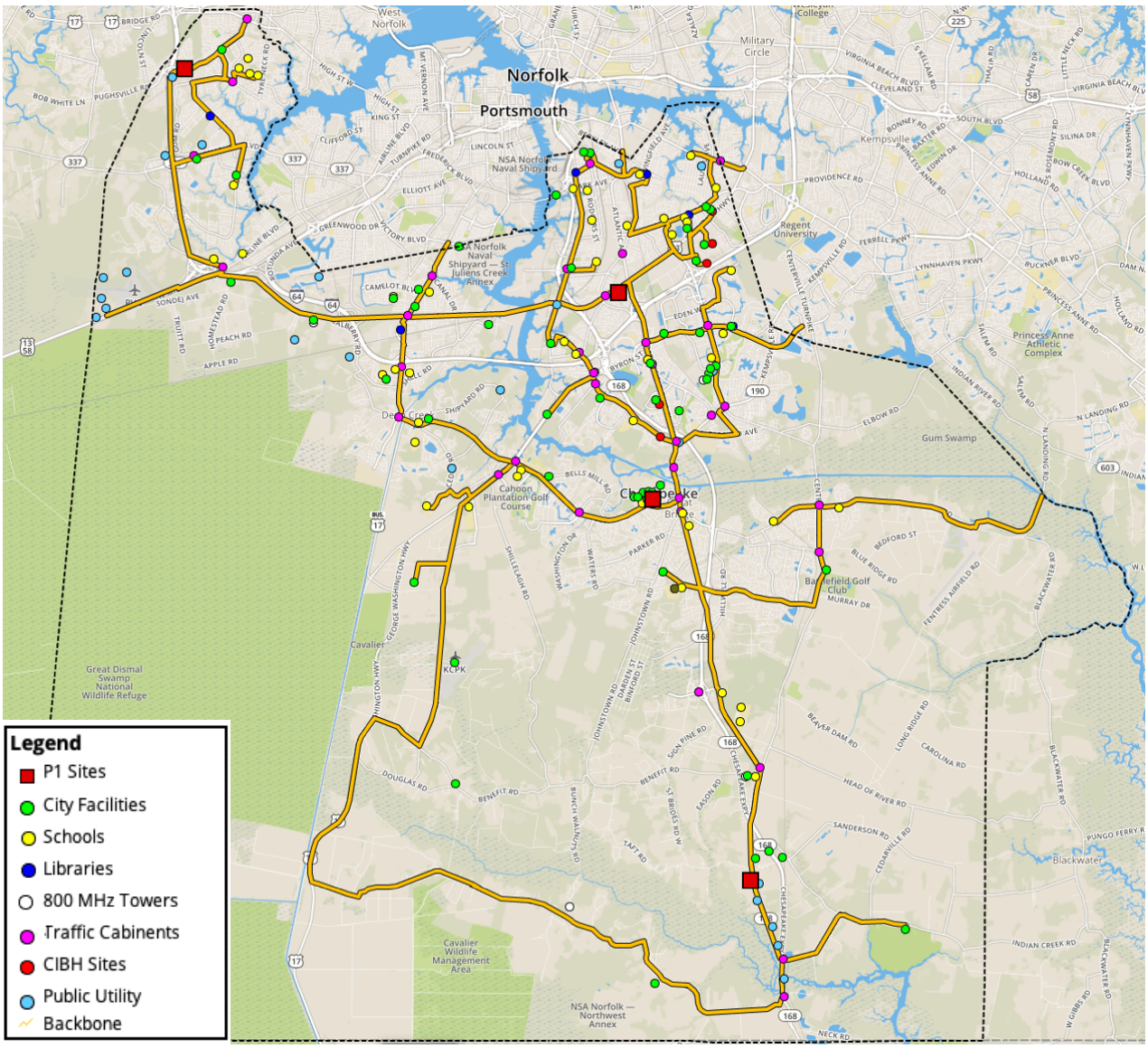

Figure 3: Backbone Routing and Site Connections

The backbone of a broadband network is designed to form multiple physical rings, , as illustrated in Figure 3, passing all the sites targeted for connection to the network. These sites may consist of buildings, areas of future development, third-party networks, commercial data centers, and other locations deemed strategic to

the C-NGN. The physical fiber rings allow for network redundancy through the use of standards-based protocols and technologies, thereby preventing single-points of failure in the event of a fiber cut. In addition, excess capacity (extra fiber strands) in the backbone cable will be available for use by private sector providers to expand their services footprint into new areas of the City where the C-NGN will be deployed. The C-NGN has been specified with an initial 432-count cable to allow sufficient fiber assignments to the various functions initially served plus projected future growth.

Site Connections

Sites will connect to the backbone at each of the P1 hubs via lateral fiber segments, constituting an additional 46 miles of construction. As outlined in Table 2 below and shown in the maps in Figures 3 and 4, the C-NGN will connect four (4) P1 hubs, seventy-three (73) city department sites, fifty-one (51) schools, seven (7) libraries, six (6) 800 MHz microwave towers, thirty-five (35) traffic cabinets, seven (7) CIBH sites, and twenty-four (24) public utility facilities at its inception.

There are three types of site connections to the C-NGN based on the redundancy requirements of the site. Thirty-three (33) Priority 2 (P2) sites will be connected by two diversely routed laterals with separate building entrances to prevent a single point of failure with a fiber cut. One hundred seventy (170) Priority 3 (P3) sites will be connected by a single lateral at a lower cost. Priority 4 (P4) sites will connect to a campus hub site, which in turn will have a P2 or P3 connection to the backbone. This will make use of existing city conduit and fiber to reduce C-NGN lateral and equipment costs.

Table 2: Chesapeake Sites Planned for Connectivity to the C-NGN by Phase

Site Agency/Use	Phase 1	Phase 2	Phase 3	Total
P1 Hubs*[1]	2	2	0	**4**
City Facilities	54	15	4	**73**
Schools	32	17	2	**51**
Libraries	6	1	0	**7**
800 MHz Towers[1]	3	2	1	**6**
Traffic Cabinets	22	12	1	**35**
CIBH Sites	7	0	0	**7**
Public Utility	7	16	1	**24**
Total	**133**	**65**	**9**	**207**

[1] P1 hub sites also contain four (4) city offices that will be configured as P2 sites.

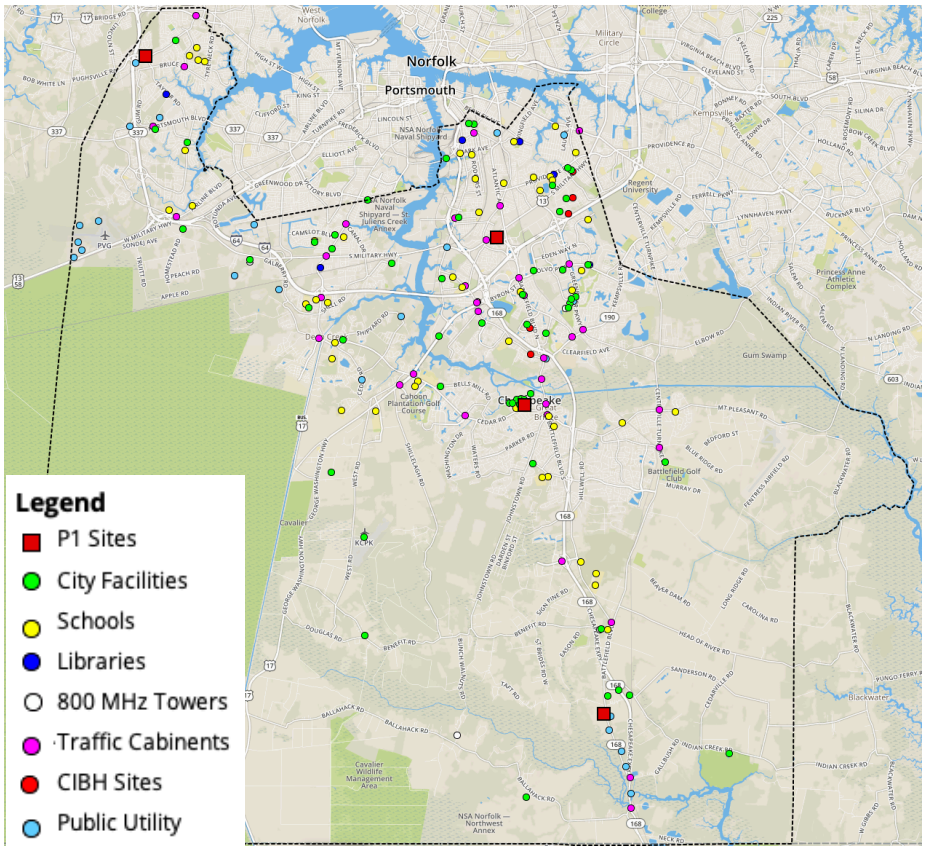

Figure 4: C-NGN Proposed Connections

Fiber Network Interconnects

The C-NGN will be designed to interconnect with the adjacent municipal networks including Norfolk, Portsmouth, Suffolk, and Virginia Beach. As depicted in Figure 5, all four currently have viable routes to connect with the C-NGN for joint access to the digital assets available within each community. These interconnects are planned to take place in a splice vault or future prefab structure at yet to be determined locations. These interconnects will require coordination with each City and will require a fiber sharing or swap agreement.

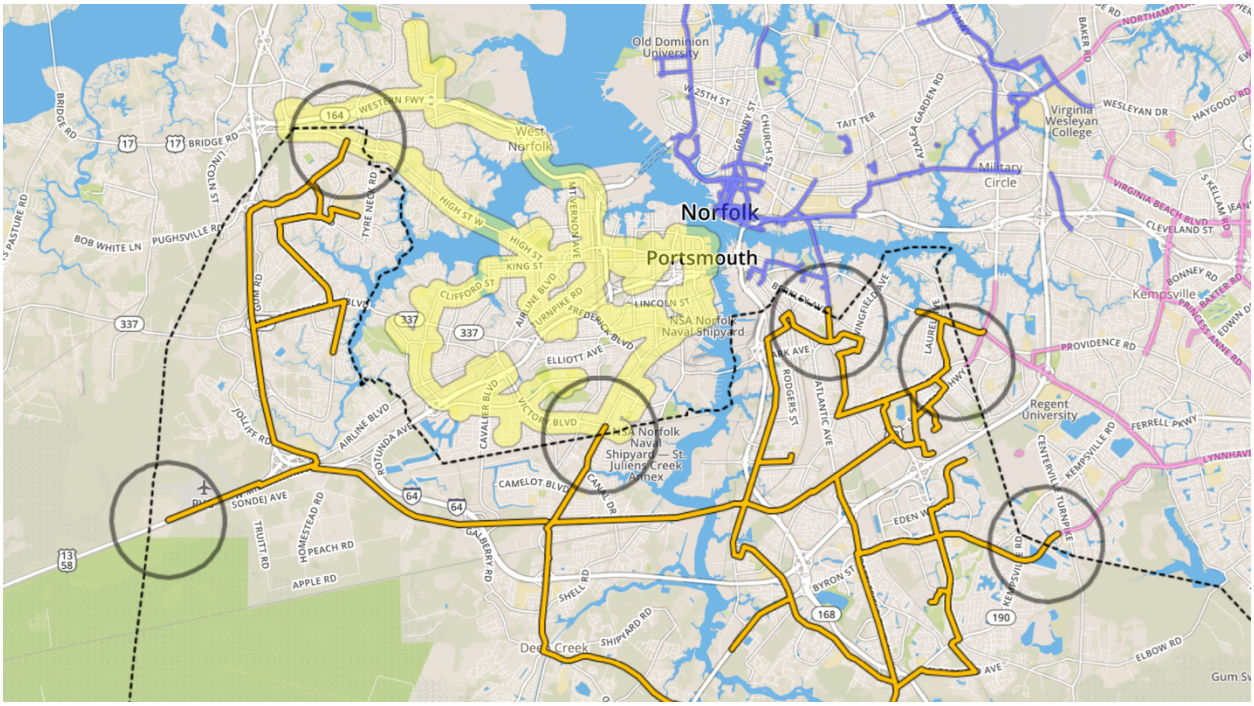

Figure 5: Peer Municipal Networks for Potential Interconnect

Regional Data Center Interconnect Options

A short-term goal of the C-NGN is to interconnect directly to a data center located in the region. There are 46 data centers located in the region, as illustrated in Figure 6, ten of which are carrier-neutral facilities not owned by a network services provider. Direct connection to one or more of these data centers will give C-NGN on-net access to wholesale providers and content ecosystems. It will facilitate a significant decrease in Internet access and other third-party IP services costs for the C-NGN and will also introduce options for new Disaster Recovery and Cloud services.

Initially, the C-NGN can use the following methods to connect:

- Private build to a data center across adjacent city boundaries
- Negotiate fiber sharing agreement with Norfolk and/or Virginia Beach, then construct entrance fiber from their nearest route into the data center
- Lease dark fiber or lit services from a regional service provider

The C-NGN would be best served by identifying the most cost-effective option. Furthermore, commercial data center connectivity should be discussed within the SNA-RCR authority, considering fiber routes, collocation, fiber entrance, and dark/lit service models to facilitate access into the regional data centers. The following regional data centers are candidates for C-NGN collocation:

- EdgeConneX: 3800 Village Avenue, Suite C, Norfolk, Virginia

- Globalinx Virginia Beach: 1632 Corporate Landing Parkway, Virginia Beach, VA
- PointOne NAP of Virginia Beach: 1893 Corporate Landing Parkway, Virginia Beach, VA
- Digital Realty ACC9: 21745 Sir Timothy Drive, Virginia Beach VA
- QTS Richmond Data Center: 6000 Technology Boulevard, Sandston, VA
- Flexential Richmond Data Center: 8851 Park Central Dr, Richmond, VA

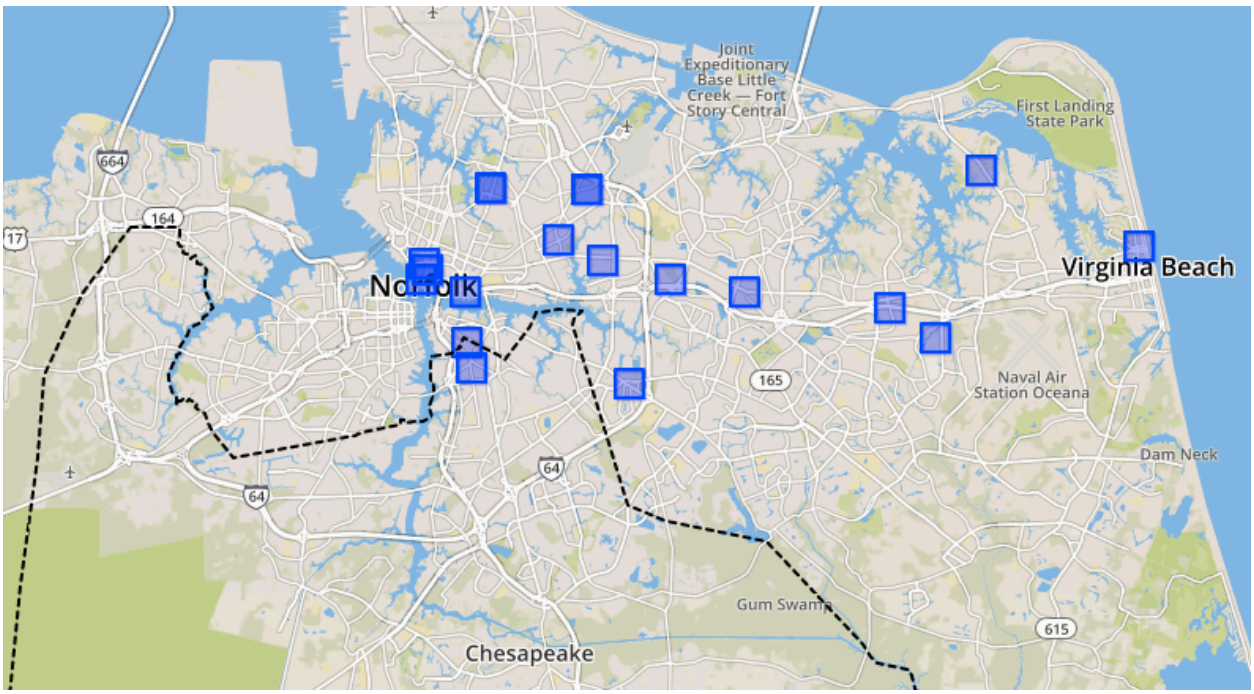

Figure 6: Regional Data Centers for Potential Interconnect to the C-NGN

2. Wireless Overlay Network

The C-NGN wireless overlay is designed to flexibly connect remote devices by supporting a range of bandwidths and communication protocols. The overarching requirement is secure, reliable access at locations with no wired network infrastructure. To meet these requirements, the wireless overlay uses multiple radio frequency bands and related technologies, each with different capacities and propagation profiles. The wireless technologies and their characteristics are summarized in Table 3.

Table 3: Wireless overlay technologies compared

	700 MHZ	LoRaWAN	4.9 GHZ
Pros	Licensed spectrum, higher transmit power	Best battery life, low-cost endpoints, security	Licensed spectrum; devices may also support other bands such as Wi-Fi
Cons	Upfront cost, more limited device availability, standard LMR type form factor	Unlicensed spectrum, noise/Interference	Limited to public safety and related uses; FCC may open use to other licensees
Use Cases	PtMP, mobility	PtP, PtMP	PtP, PtMP. Mobility
Coverage	Wide area	Wide area	Wide area
Data	10 kbps – 1Mbps	0.3 kbps to 50 kbps.	Up to 1.3 Gbps

LoRaWAN at 902-928 MHz will be used for smart meter/sensor and Internet of Things (IoT) applications. The 700 MHz block A spectrum will be used for real-time supervisory control and data (SCADA) and telemetry applications. 4.9 GHz is planned for high bandwidth endpoints such as video cameras that can't be served cost-effectively by fiber.[2]

Each of these will be physically separate networks, using different antenna and gateways at shared fiber-connected tower sites around Chesapeake. The fiber backbone will be used to connect the various wireless gateways to the City's WAN, and the gateways will have the capacity for additional applications and devices.

The C-NGN design will easily accommodate additional gateway sites or other wireless technologies as requirements evolve over time to supplement the proposed overlay networks. This will provide the City flexibility in supporting future application needs and avoid being locked into a single source/vendor solution.

The City should work with potential vendors to develop small-scale proof of concept pilots for each of the proposed wireless overlays to allow assessment of the technology performance within the urban/suburban/rural nature of the City and its proximity to both other large independent cities in the Hampton Roads Region and Naval Station Norfolk.

[2] Emerging access services, specifically Citizens Broadband Radio Service, should be monitored as possible alternatives. See Appendix 2 for additional information.

Licensing for the 4.9 GHz sites should move forward as soon as possible to take advantage of the current, less stringent filing requirements. The City should also open discussions with the spectrum broker for the Upper 700 MHz A block spectrum to secure rights to this spectrum, should the City decide to move forward with this band as well.

3. Build Plan

The C-NGN could be constructed in 36 months, with an additional 6-month project and contract closeout period. A timeline for design and construction is included as Figure 7. The network routes (see Figures 1 and 3) are primarily through the Chesapeake public right-of-way; however, the design calls for several railroad and subaqueous crossings which may significantly impact construction timelines.

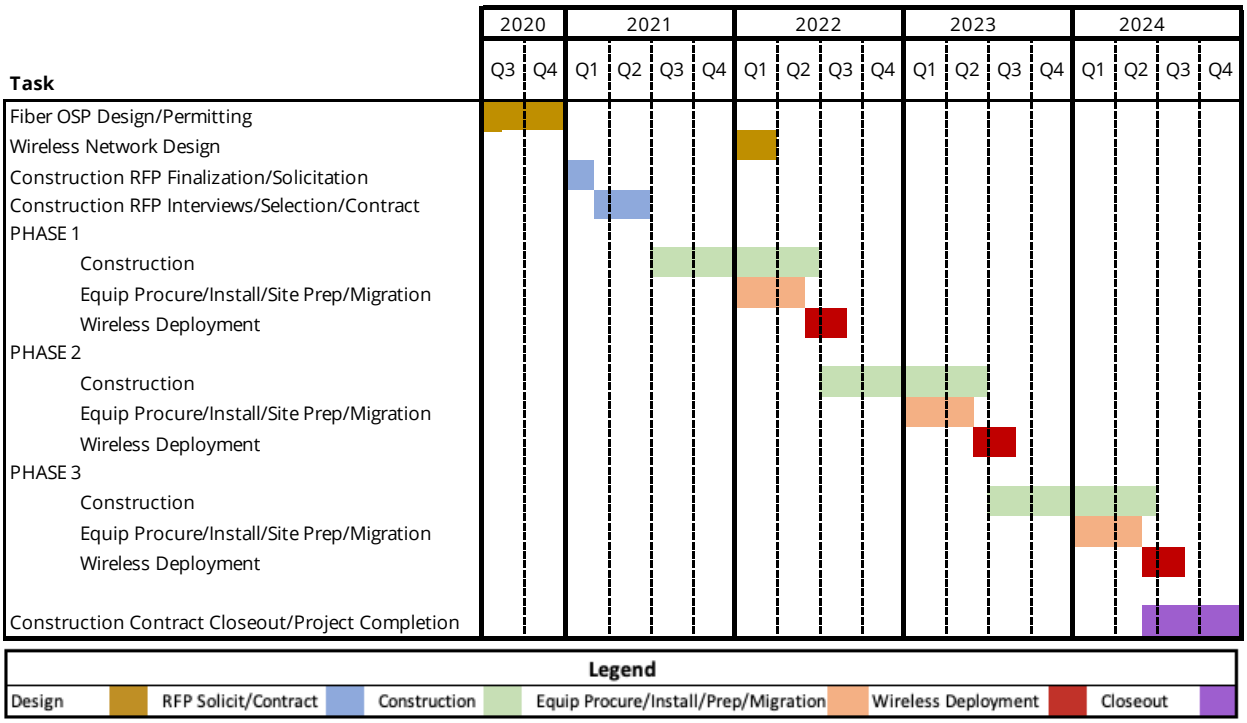

Figure 7: Design and construction timeline for the C-NGN

During this planning process, a high-level system design (HLD) was completed to support the C-NGN design and capital cost estimates. The fiber-optic outside plant (OSP) HLD layouts include preliminary route selection, Bills of Materials (BOMs), and other key supporting files, which are prepared to streamline the full design/engineering required to develop construction-ready design documents otherwise known as low-level design. All fiber-optic network segments, as well as

terminating facilities (buildings, cabinets, etc.) must be accounted for within the HLD to ensure end-to-end connectivity.

For the optical transport, wide area network, and wireless overlay, HLD includes the development of functional specifications, architecture descriptions, network requirements, and RF coverage which is used to create rough order of magnitude pricing for capital and operating cost modeling. Equipment specifications based on the City's installed base of Cisco equipment are also included. This information will be further refined in the future to create requests for proposals (RFP) that manufacturers and integrators use to develop actual design packages, bills of material, and proposals for deployment of their systems.

As previously stated, the C-NGN as designed includes 172 miles of underground construction. As depicted in the timeline, the build plan includes 8-10 months of design, engineering, and permitting, 36 months of construction activity, and 6 months of project closeout for a total project timeline of at least 50 months. Total costs of the C-NGN fiber-optic backbone and laterals are further summarized by Phase in Table 4.

Table 3: Fiber-optic Cost Summaries

Backbone and Lateral	Phase 1	Phase 2	Phase 3	Totals
Backbone	$8,283,317	$7,114,306	$3,946,872	**$19,344,495**
City Facilities	$1,360,492	$421,777	$284,146	**$2,066,415**
Schools	$977,563	$781,370	$130,339	**$1,889,272**
Libraries	$157,546	$38,530	$0	**$196,076**
Public Safety Radio Towers	$121,292	$18,550	$41,700	**$181,543**
Traffic Cabinets	$201,404	$126,899	$2,701	**$331,004**
CIBH Sites	$132,328	$0	$0	**$132,328**
Public Utilities	$417,273	$979,110	$61,590	**$1,457,973**
Total	**$11,651,215**	**$9,480,544**	**$4,467,348**	**$25,599,107**

The LoRaWAN, 4.9 GHz, and 700 MHz wireless overlay networks do not require any new tower infrastructure, only slight modifications to existing towers/structures.

Sub-50-foot tall standalone concrete poles may be considered to provide better in-fill coverage. The wireless overlay deployment will follow the build plan for the fiber backbone, described in the previous section. As each phase of construction is completed, wireless overlay components will be procured, installed, and connected, along with other required network components, shortly after the fiber has landed and transport services are activated at each wireless site.

D. Policies and Regulations

Policy and regulations are essential to C-NGN's goals; for ensuring network assets are deployed consistently, correctly, and economically by all, including the City as well as private companies. The Commonwealth of Virginia and the Federal government limit what the City can do directly or can require of private parties using public assets. Therefore, policies and regulations must be carefully crafted to avoid conflict with those policies and to achieve the C-NGN goals. Refer to Appendix 3 (under a separate cover) for details on policies to foster investment in C-NGN and other communications infrastructure.

1. Network Design and Construction Standards

The City of Chesapeake has a *Public Facilities Manual* (PFM) that layouts out design criteria, standards, and technical specifications for the whole array of public facilities, including any privately-owned assets on public property or rights-of-way. Magellan Advisors worked with the Public Works Department and other internal City stakeholders to update the PFM with information related to placing conduit, fiber, small cell/wireless, and other network assets in the public right-of-way. These should be applied to the C-NGN as well as private assets. The City may want to include standards for other assets such as smart poles.

2. Dig Once

"Dig Once" refers to policies that minimize construction in the public right of way while supporting improvements. In Chesapeake, the City provides all utility and similar companies a 90-day notice of construction. The companies can then add to the construction at their own expense. After that, there is a one-year moratorium on any other construction in that area. With C-NGN, the City will formalize this policy, coordinate various parties' activities, and allow for more time before construction while also potentially increasing the moratorium to up to five.

3. Small Cells

As mobile data and phone services evolve to provide faster speeds and better connections in densely populated areas, the companies that provide those services are deploying more, smaller antenna sites, which are commonly called "cells." The City should expect more applications for small cell permits, especially as providers roll out 5G cellular services. Review the Zoning Code to ensure it accommodates these changes in both the amount and substance of permit requests. The City should consider expanding the Master Licensing Agreements (MLA) to include City poles and other structures. It may also be necessary to modify permitting fees and processes.

E. Financing and Operations

The C-NGN will be financed and constructed as a capital asset, part of the City's Capital Improvement Plan, and operated as a Division of the Department of IT. Portions of the network will be used for internal purposes, with chargebacks to the appropriate departments and users. Other portions of the network may be leased to or otherwise used by private companies to provide network services. This section provides some details about these plans and contrasts the build-own-operate approach to managed services and other Public-Private Partnership (P3) approaches. See section Alternative Analysis below, for an analysis of this alternative. Additional details are included in Appendix 4 under a separate cover.

1. Capital Investment

The C-NGN requires a substantial initial capital investment: $32.58 million over 50 months to design, construct, deploy the C-NGN, and migrate sites to it. This includes $26.84 million to design, and construct fiber backbone and lateral routes, $2.75 million in network and data center equipment as well as wireless overlay technologies, and $2.63 million for construction/project management, facilities, and tools, with a 10% construction contingency budget.

The City plans to reduce construction costs through route optimization and value engineering during the low-level design engineering process. Some of those opportunities include:

- Identify new and in-process Dig-Once opportunities
- Identify the condition and usability of existing and planned assets (conduits, fiber, provider strands)
- Reconfiguration of existing campus conduit and fiber connections

- Incorporate a redesigned SNA-RCR route through the City of Chesapeake, reducing the SNA-RCR footprint in the City, and sharing the same trench as the C-NGN where possible
- Explore partnerships with Dominion Energy, VDOT and others for potential co-investment in key routes

The key metric to assess the C-NGN is total cost of ownership (TCO), the aggregate long-term expenditures for a system, or a set of features and functionality. The up-front capital investment of the C-NGN and its long-term operating costs will result in a substantially lower TCO as compared to Managed Services options.

2. Operating Cost

The C-NGN business model will reduce the City's third-party network service costs more than 80% by Year 5. However, new operating costs totaling $1.52 million in Year 5 will be incurred. These new C-NGN operating costs include dedicated staffing, network and software maintenance contracts, colocation costs, and other normal operational expenses.

The construction plan will allow the disconnection of managed services after each phase is complete. This phased migration tied to the construction schedule will allow the City to maximize its savings potential by eliminating recurring service costs as soon as possible. Table 5 details the estimated cost reduction per construction phase. The "Unassigned" costs are not tied to a construction phase, rather they consist of services associated with sites that are planned to be moved or decommissioned.

Table 4: Phased Annual Cost Reduction

Phase	Estimated Annual Cost Reduction
Phase 1	$839,146
Phase 2	$336,900
Phase 3	$39,576
Unassigned	$55,800
Total	**$1,271,421**

The City will also incur debt service over this term, which will increase its overall spend on the C-NGN, however, annual debt service spending will decrease at the first 7, 10- and 20-year increments after deployment, with the ability to retire debt service earlier given the opportunity. Any capital contributions, third-party capital

investments, grants, or network cost reductions which can limit the City's borrowings will reduce the debt service annual costs and will have a direct impact on the service rates offered through the C-NGN.

3. Operational Impact

A dedicated staff is necessary for the City to build, operate, and own the C-NGN. City DIT requires an additional 6.5 FTE for operations of the Fiber C-NGN, and an additional 1 FTE Wireless Engineer to support the Wireless Overlay components at an annual cost of $665,000 by Year 4 when all positions are filled. This staffing requirement can be evaluated over time and is planned to be reduced by Year 8. The C-NGN Operations Team will operate back-office network management systems and is responsible for tracking all infrastructure assets in a fiber management system (FMS) used to track the physical cable plant and associated assets.

> Building, owning, and operating the C-NGN give the City the greatest level of communications independence and maximum flexibility for addressing evolving requirements with minimal new costs.

Operationally, as designed, the five WANs continue autonomous operations and support of their existing LANs as they do today. They receive their transport and Internet services from the C-NGN and place WAN service calls to the C-NGN network operations staff instead of a commercial service provider. In turn, the City's current workload managing external service providers shifts to managing the selected fiber and wireless O&M contractors and vendors. The C-NGN Operations Team has to meet strict SLAs for services and must be equipped with the required knowledge and tools. Additionally, underground locates, software and network maintenance contracts, and other SG&A expenses are covered by the City.

Bandwidth Deployed

In addition to meeting Chesapeake's requirements for at least 1 Gbps to all sites, the C-NGN will support 10 Gbps from day one, allow for multi-10 Gbps connections, and will be able to support 100 Gbps services when necessary. The C-NGN provides 40 times more bandwidth to the average City site, as well as diverse, redundant connections to key facilities. The C-NGN circuits proposed chargeback pricing is very competitively priced to current contracted services on a cost-per-Mbps basis

as shown in Table 6. In fact, a 1 Gbps C-NGN transport circuit is 22% less costly than currently contracted 1 Gbps services, while 10 Gbps circuits are 33% less.

Table 5: Bandwidth Cost per Mbps

Description	Bandwidth (Mbps)	Cost[3]	Cost Per Mb
Local Provider (2020 rate)	20	$670	$33.50
	100	$1,190	$11.90
	1,000	$1,275	$1.28
	10,000	$2,975	$0.30
C-NGN Fiber	1,000	$1,000	$1.00
	10,000	$2,000	$0.20

Control of Assets

The C-NGN will be owned and managed by the City of Chesapeake, with direct local decision-making authority by the City Council, and its appointed City leadership and operating staff. The City and its partnering agencies will be able to determine when, where, and how the network is expanded and at what rates. It will form the basis of the City's Smart City connectivity solution, supporting key community initiatives while controlling long-term telecommunications contracts and costs.

Support for Other Initiatives

The five agency WANs and regional interconnects will be fully available without the constraint of a managed service vendor's capabilities or willingness to extend service. The decision on when and how to extend the network solely rests on the cost to connect to the network. Further, the City and its partners would be able to support other regional partnerships, enable greater governmental collaboration, and support upcoming Smart City initiatives without the concern for additional long-term connectivity costs.

Additionally, as opportunities arise to deploy Smart City initiatives or other sensor style devices, the C-NGN will be ready to connect any device that a City department

[3] Local Provider Costs outlined in this table were sourced from current contracts and invoices of the City and Schools.

may require and will do so at significant cost savings to traditional recurring-cost telecommunications service options. For the City Public Utility Department's AMI project, the C-NGN LoRaWAN service will save the Utility hundreds of thousands of dollars in connectivity charges per year that would otherwise be paid to a commercial carrier.[4]

Using LoRaWAN for AMI not only saves money for the Utility, it can also yield top-line benefits. New revenue from applications such as AMI—even if it is internally generated—can fund network operations, expansion, and other improvements. Other top-line benefits will come from supporting other activities and applications. For example, the LoRaWAN used for AMI might also be used for building automation, energy management, environmental monitoring, and even for industries like agriculture and distribution.

The C-NGN will create numerous opportunities for improved outcomes and top-line benefits, such as tech-based economic development, telemedicine, rural broadband initiatives, remote education, and telework. Indeed, the bulk of return on the C-NGN could come from the growth in revenue and other top-line benefits rather than the bottom-line cost savings, efficiency gains, and reduced resource requirements that are the basis for the business case detailed in this document.

4. 30-Year Total Cost of Ownership

A 30-year Total Cost of Ownership (TCO) model for a City-owned and operated network includes all capital and operating expenses (CAPEX / OPEX) over the term. As we can only model known CAPEX costs, these models do not reflect future network expansions or their cost estimates beyond what has been identified in this plan, however a Capital Expansion fund has been incorporated into the C-NGN's financial plan. The C-NGN will grow as new municipal or community projects requiring network connectivity are identified. CAPEX spending will then increase through annual project-based budget appropriations while OPEX costs grow incrementally as expansion occurs.

As the City builds the C-NGN, it funds $32.5 million in construction costs over 36 months. The City's total annual spending including debt service on the C-NGN grows from about $1.8 million in 2023 to $3.74 million in 2027. The C-NGN will maintain these annual cost structures until approximately year 23 or 24 when key debt service amounts are retired. As outlined in the Detailed C-NGN Financial

[4] Without City-own LoRaWAN, the Utility Department would need to purchase connectivity for all water meters at the cost of approximately $9 per month each.

section below, the C-NGN has several revenue sources including internal service chargebacks from the five WANs and third-party external revenues to offset these costs. The City will also acquire less expensive Dedicated Internet Access (DIA) service through regional data center interconnects, thereby significantly reducing its remaining network service costs.

As reflected in Figure 8 below, the C-NGN spend increases dramatically through the Year 2027 as indicated by the green trendline as compared to the Managed Service Baseline spend in red. This is due to the capital and operating costs of the C-NGN including debt service at launch. At 7, 10, and 20-year intervals the total annual spending decreases until the Year 2044 when debt service is fully retired. At this point, the annual cost of the C-NGN is less than 40% of what the City would pay for equivalent managed services. With the build-own approach, any direct or indirect cost reductions, incremental revenues, or additional funding contributions will only serve to improve the cumulative 30-Year TCO.

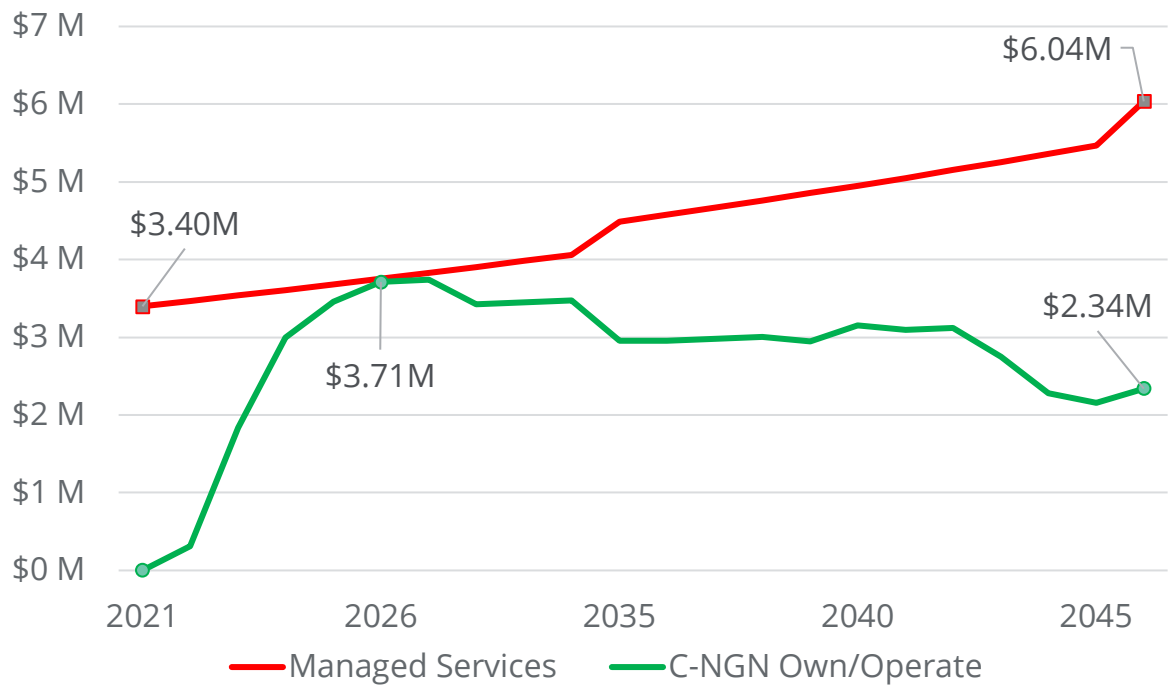

Figure 8: C-NGN 30-year Annual Spend

The estimated spend for each of the five WANs and selected departments is outlined below in Table 7. The C-NGN will both create a structure to retain broadband service dollars within the City and provide a clear and consistent method for the City to chargeback costs to its operating departments where one does not exist today. A chargeback method for the C-NGN services will be structured on a per circuit basis to reflect actual use by all five WANs as

summarized more fully in later sections. Wireless services would be billed per endpoint device connected to each wireless overlay.

These projections include only fiber-based transport and DIA services at the Year 1 proposed C-NGN rates and do not reflect any future rate decreases that may be implemented as debt service is retired. The detailed financial model for the C-NGN incorporates a 10% reduction of rates starting in Year 10, and every 5 years after. After debt retirement, the C-NGN can incorporate its free cash into buying down service rates, funding additional network expansions[5], or offering support of other related technology initiatives as needed.

Table 6: Day One Connectivity Spending to meet City Requirements Compared

Agency/Department	C-NGN Spend	Managed Services Spend	C-NGN Savings
City	$2,013,600	$2,632,800	$619,200
Utilities	$204,000	$260,100	$56,100
Police	$360,000	$459,000	$99,000
Fire	$240,000	$306,000	$66,000
Traffic	$444,000	$566,100	$122,100
School	$350,400	$446,040	$95,640
Library	$96,000	$125,400	$29,400
CIBH	$150,000[6]	$195,000	$45,000
Total	$2,610,000	$3,399,240	**$789,240**

[5] The financial model for C-NGN includes putting $150,000 per year into a Capital Expansion Fund.

[6] It may be possible to reduce CIBH costs by consolidating circuits from 11 to 9 during design.

5. Wireless Overlay Summary

City leadership wanted the C-NGN to serve as a foundation for current and future Smart City initiatives. As previously documented, Chesapeake is deeply engaged in implementing Smart City applications. The City has an intelligent transportation program that uses various wireless solutions, Fleet and Public Safety agencies have an extensive list of applications that depend on wireless technology, and Public Utilities uses wireless technology to support utility telemetry. Other Smart City applications are being planned. The City, for example, intends to deploy Advanced Metering Infrastructure (AMI), enhanced SCADA controls, and environmental monitoring sensors. The proposed C-NGN Wireless Overlay will create a platform for the city to cost-effectively deploy these applications and others as they emerge.

> The City's deployment of a multi-technology Wireless Overlay will extend its connections into key areas of the City and will provide broad wireless coverage across the City to further its goals.

The C-NGN's multi-technology Wireless Overlay will support wireless connectivity for multiple applications across the City and will be charged back to City departments on a cost-recovery basis as they seek to implement Smart City applications.

The alternative is to purchase "turn-key" solutions where the vendor defines the technical architecture and provides both the connectivity and the solution. The result is a large, complicated set of disparate technical solutions, all charging their own recurring network access fees. This creates inefficiencies and silos and increases the City's communications costs further due to the duplication of services.

Table 7: C-NGN Wireless Overlay Cost Estimates CAPEX, TCO and MRC

Wireless Service	Day 1 Devices	Deployment CAPEX	10-Year TCO	Calculated Service MRC
LoRa	70,000 (Utility Meters)	$223,500 (14 Gateways[7])	$1,249,064 (Includes R&R[8])	$0.15
700 Mhz	260 (Pump/Lift Stations)	$398,000 (18 Gateways)	$1,862,531 (Includes R&R)	$59.70
4.9 Ghz	15 (Cameras, Signs)	$142,500 (7 Gateways)	$695,844 (Includes R&R)	$386.58

As with the fiber backbone, the C-NGN Wireless Overlay will give the City more control over the technical architecture and how and where it deploys devices at substantial cost savings over traditional carrier services.

Also, like the fiber component of the C-NGN, the Wireless Overlay has a fixed cost for the infrastructure deployment, shown in Table 8. These fixed costs include the technology platform, fiber back-haul, and communications back-end gateway infrastructure necessary to support Smart City applications. Once the initial investment is made, applications and devices can be added to the C-NGN Wireless Overlay as the need arises. As more devices are added, the cost per device, per technology is reduced.

Appendix 4 (under a separate cover) includes detailed cost breakdowns and initial rates for the three wireless technologies that will be used to provide the C-NGN Wireless Overlay. Initial rates are based on current identified use cases. As applications and endpoint devices increase, these rates will continue to decline.

6. Alternative Analysis

The alternative to building, owning, and operating the C-NGN is for the City of Chesapeake to procure managed services—under which a private company provides C-NGN as a service without the City owning any of the infrastructure—either outright or as part of a Public-Private Partnership (P3). This alternative would require less up-front capital investment but would involve much higher operating costs while not allowing the City to own, control, and capitalize on the

[7] Two additional LoRa gateways may be needed for full coverage.

[8] Renewal and replacement

infrastructure. This would limit the City's ability to add sites and deploy needed applications over the network and would result in a higher long-run total cost for the required connectivity. A managed services approach requires capital from the City for lateral extensions to connect new sites and for redundancy to critical sites in some cases. A provider may charge up-front for all construction costs.

An alternative P3 arrangement could involve a private company building a privately-owned network or managing City-owned assets and may end up functioning much like managed services. Providers will likely charge a percentage of construction costs based on factors including monthly service fees, the contract term, and how many other customers they can acquire along the route. The provider amortizes their costs across multiple sites if possible, but the City may have to identify those additional customers/sites or bear the whole cost of construction.

Consequently, under any approach, the City pays for some portion of construction to extend network facilities where none exists today. In areas such as South Chesapeake, where providers face significant investment in access or distribution facilities, the City may incur substantial upfront costs to get the required network services and support economic development. Services would be priced on an individual case basis (ICB) involving non-recurring and/or monthly recurring costs over the agreement term. Generally, the TCO for a P3 is likely to be higher than for the build-own-operate approach.

Managed services that meet the City's requirements will cost $3.68 million by Year 5. In total, the City, Libraries, and Schools would spend as much as $138 million over the next 30 years, after E-Rate discounts, on managed services. This does not take into account other internal operating costs such as staff or network management services. It is just the service provider contract spend. A competitive solicitation is likely to result in lower managed services costs but would create administrative costs and delays. This approach would not give the City control over the network or ownership of any infrastructure assets.

The managed services approach provides the City with no control of any WAN assets. All infrastructure is owned and managed exclusively by the providers. Furthermore, any cost to extend their infrastructure or provide site redundancy for the City would ultimately pay for the vendor's capital improvement of their private network. While the City may fund fiber extensions under this scenario, it does not own any resulting assets.

Under the managed services approach, City, Library, School, and/or regional initiatives are constrained by providers' ability, costs, and willingness to support the particular connections or service. Furthermore, every new connection deployed will

add to network operating costs. A P3 may be structured to include support for other initiatives, but it would need to be spelled out in some detail, which might be difficult given the emergent nature of these opportunities.

F. Financial Analysis

Under the selected *Infrastructure-Only Government Service Provider* model, presented below in Figure 9, the City would invest $32.58 million in infrastructure, and budget for annual Operating Costs, and Debt Service as previously detailed. Under this model, the City will spend $82.4 million over the same 30-year period but would end with nearly $27 million cash on hand in the form of funded reserves and free cash-flow. This is a true investment that will give taxpayers ownership of valuable local infrastructure assets.

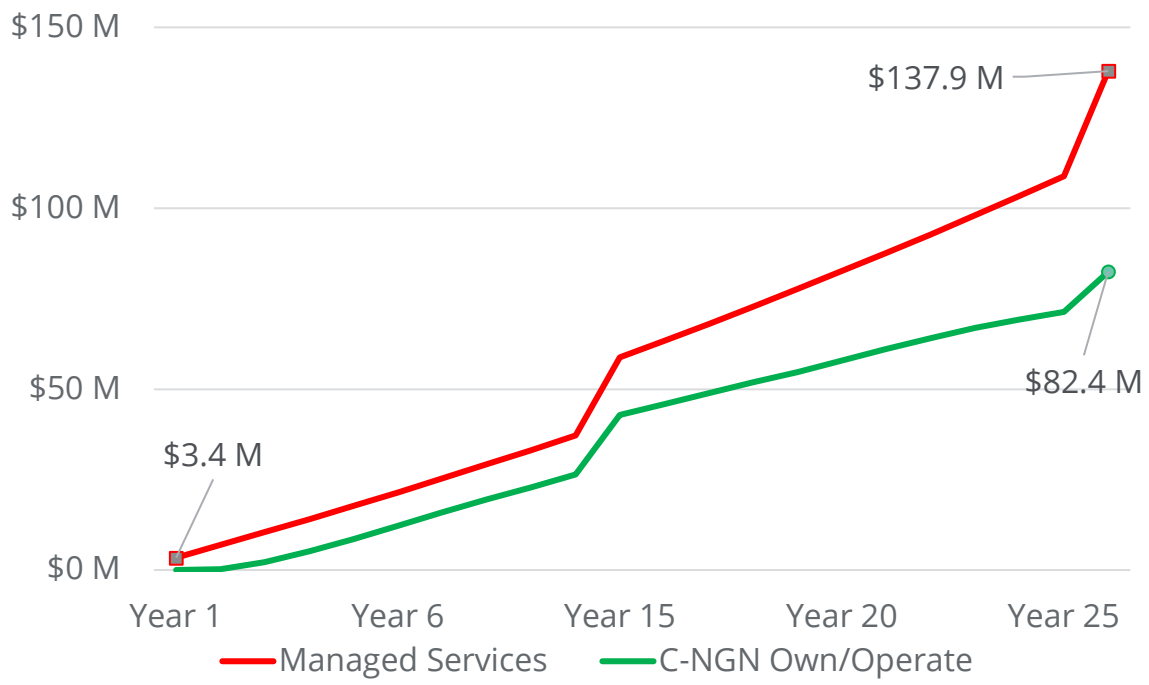

Figure 9: Managed vs. Owned Cumulative Spend

Progressive municipalities that deal with and understand underground utilities have opted to install publicly owned conduit and fiber-optic systems as a way to control their telecommunications costs and to increase the features and functionality of their networks. These networks are used to enable smart utilities, intelligent traffic systems, and to enable greater digital collaboration amongst public agencies. If the C-NGN is structured as a City enterprise fund, as we recommend, it will become a revenue center rather than a cost center as network

services are currently.

Under the selected approach, the City can increase ROI by adding applications to the network. Since the City will have total control over network assets, only small marginal costs are generated by additional uses. The Wireless Overlay greatly expands the possible use cases for the C-NGN because it accommodates remote, small-scale, and temporary sites. Connecting additional sites to the C-NGN will further reduce or defer costs, increase the ROI, and reduce the payback period. The Wireless Overlay could multiply this effect by replacing for-fee connections to mobile users and avoiding costs for additional connected devices in the future.

As an infrastructure deployment project, the C-NGN construction costs can be reduced by leveraging existing compatible Capital Projects, several of which have been identified so far. The City can tap special funds for the C-NGN where it runs through special districts and economic development zones. Finally, there are several opportunities to defer costs for existing City systems that are at the end of their useful life by migrating those systems to the C-NGN. Specifically, replacing the Public Safety Microwave upgrades planned for 2025 with the C-NGN would save Chesapeake $1.5 million. Under the selected approach, the City has much more control over how the C-NGN is deployed, under what cost structures, and from what funding buckets.

The C-NGN when structured as a self-supporting network entity, will have to balance its ability to provide a high-quality resilient network service with generating enough revenue to ensure an operational and financially sustainable enterprise. While the City, Libraries, and Schools will pay more for the C-NGN than they currently pay, they will get faster speeds to more locations, with significantly better resiliency, and they will be paying less than they would otherwise pay if they received comparable services from their current service provider. With the C-NGN, the City's minimum network connection will be 1 Gbps and 10 Gbps, with future capabilities to scale as the City and its partners deem necessary. The network will also increase Chesapeake's capabilities to achieve major City goals.

1. Services and Pricing

The C-NGN primary service offering is point-to-point Wide Area Network connectivity, providing transport bandwidth to sites and services across the community. Transport services will be provisioned initially at 1 Gbps minimum, and 10 Gbps offerings, with an eye to higher bandwidth circuits if required. Multiple Gbps DIA circuits and Wireless services are also available. All fiber services will be provisioned using Active Ethernet, dedicated bandwidth, and will include strict Service Level Agreements (SLA).

Transport Services

Transport services are priced by the circuit and do not include any mileage or distance fees. Circuits are provisioned anywhere within the network's service area. There are currently no non-recurring costs or install fees planned within the initial sites planned for deployment. Table 9 summarizes Transport Circuit Pricing. Further network extensions should be evaluated on a case by case basis and install fees should be charged when necessary. This model assumes that future City capital projects, like building a Fire Station, include the capital expense for the fiber extension as part of the capital project budget.

Table 8: Transport Circuit Pricing

Circuit Bandwidth	MRC	NRC[9]	Current Provider Rate
1 Gbps	$1,000	$0 initially	$1,275
10 Gbps	$2,000	$0 initially	$2,950

Dedicated Internet Access Services

Dedicated Internet Access (DIA) services are also planned within the C-NGN deployment, consolidating the various IP contracts into a consolidated C-NGN IP Edge. Table 10 compares NGN proposed MRCs against current provider rates. These services are planned to be managed centrally, with individual DIA circuits being provisioned downstream to each department, Schools, or Library. Each would take the DIA handoff, just as it does today with its Internet Service Provider, and would manage its own firewalls, IP address blocks, and other security requirements. DIA is only planned for the City, Schools, Library, and CIBH, and we have not identified any other organizations or third-party customers for this service.

[9] Non-recurring costs including installation fees, circuit activation, etc.

Table 9: Dedicated Internet Access Circuit Pricing

Circuit Bandwidth	MRC	NRC	Current Provider Rate
1 Gbps	$2,500	$0 Initially	$3,500
2 Gbps	$2,900	$0 initially	$6,000
5 Gbps	$6,000	$0 initially	$7,150
10 Gbps	$10,500	$0 initially	N/A

Wireless Services

The City's Wireless Overlay will have three distinct technology platforms capable of providing remote connectivity to network components that may need low data rate solutions, while others are geared toward supporting critical utility infrastructure. The City's Department of IT already supports the City's public safety 800 MHz Open Sky radio, 700 MHz P25 radio systems, and Microwave backhaul systems. The proposed LoRaWAN, 700 MHz, and 4.9 GHz offerings is complementary to its existing wireless solutions and will be managed with the same level of criticality. The rates for Wireless Services are outlined in Table 11.

Table 10: Dedicated Internet Access Circuit Pricing

Wireless Technology	MRC (per device/endpoint)
LoRaWAN	$0.15
700 MHz	$59.70
4.9 GHz Point to Point	$386.58

Dark Fiber Leasing

The City will lease excess dark fiber strands and conduit paths to service providers. Cities differ in their policies and pricing for dark fiber access. Sample lease rates from other Municipal organizations have been detailed in Appendix 4 under a separate cover. For the C-NGN, we recommend the City establish a rate in the range of $100-$125/strand mile, however, market rates can increase over time as the region becomes more connected, and new data centers and cable landings are more accessible and available. Strand mile rates like any rates for service should have periodic review and updating. The financial analysis assumes dark fiber leasing rates of $125 per strand route mile as noted in Table 12.

Table 11: Dark Fiber Leasing

Dark Fiber Lease	MRC
Per Strand Route Mile	$125.00

Tower Attachments

The City already has a legacy Tower attachment lease agreement and rate structure for the cell/mobile carrier industry to deploy cell tower infrastructure. The City will take the same approach with Wireless broadband providers, or WISPs, allowing the City to provide both dark fiber connectivity and tower attachments to support the deployment of wireless broadband services throughout the community. The City should update its tower attachment pricing model taking into consideration the new wireless and backhaul options available.

Opportunities for Top-line Benefits

Opportunities for direct top-line benefits in the form of new revenue from leasing network assets are incorporated into the business model, as described above. Opportunities for indirect top-line benefits involve leveraging the C-NGN to attract investment that meets community needs and expands the City's tax base. These benefits are potentially much larger than those from cost avoidance and recovery. The C-NGN will not intrinsically enable these benefits as it does bottom-line benefits and revenue from asset leases. Additional investment, programs, and resources will be needed to achieve them, therefore they were not included in the C-NGN business case.

Economic Development

Expanding and relocating businesses, particularly in hosting, software, and other technology-intensive sectors, require fiber-fed sites. Chesapeake has numerous sites for economic development, but they have limited or no connectivity. C-NGN could enable any site to be connected by practically any provider, not just those with local infrastructure. This would be a distinct competitive advantage for Chesapeake as a business location, especially with the trans-Atlantic cable landing so close.

Beyond traditional economic development, the C-NGN positions Chesapeake for innovation-based development. There is a multitude of diverse existing and startup companies working to solve critical problems with technology. Most of these companies need massive amounts of bandwidth. The C-NGN enables the City to cultivate innovative solutions in areas such as advanced manufacturing, data analytics, distribution and logistics, healthcare, retail, and transportation. Industries

often cluster in regions, driving additional needs for local connectivity. Shipbuilding and shipping are prime examples in the Hampton Roads region. The City could attract innovative, high-growth companies in these sectors by enabling them to tap into these clusters without having to be physically at ports and shipyards.

Community Benefits

There are many potential benefits to the Chesapeake community from the C-NGN beyond cost savings and service improvements for municipal operations. Use of the infrastructure by a private company to provide broadband internet access is possibly the most important one, since it addresses one of the C-NGN's overall goals and one of the City's Strategic Anchors.

Expanded broadband is necessary for online learning, remote work, and telehealth. The COVID-19 crisis has forced businesses, hospitals, and schools to go virtual, which has numerous benefits beyond reducing infection risks. Businesses and workers can be more productive and responsive by working online. People can live in Chesapeake and work almost anywhere. Local businesses can reduce overhead while being more attractive to talented workers. Local institutions get the same benefits along with improved access for disabled, elderly, and low-income persons. While these benefits don't directly generate revenue—financial return on the taxpayers' investment—they directly address the City's primary Strategic Anchor: to make Chesapeake a great place to live, learn, work, farm, and play.

Key Issues for Top-line Benefits

Fully tapping opportunities for top-line benefits could radically strengthen the C-NGN's business case. Indeed, as pointed out elsewhere, the possible top-line benefits are much greater than the C-NGN's bottom-line benefits. And, the City will likely need to make additional, complementary investments to realize the network's potential.

The City of Chesapeake should seek out private investments that parallel its investment in the C-NGN. The investment can come from major corporations, real estate developers, startup companies, and a range of other entities. It also has to come from community members learning new skills, starting their own companies, and working with new technologies. In other jurisdictions where this was done, collaboration with higher education, entrepreneur support organizations, and technology leaders was a key success factor.

The general goal should be to get as much external investment for as little additional City investment as possible. Marginal spending increases for the C-NGN or other programs to use the network could lead to substantial growth in the local

economy, education, wellness, and workforce. If the City of Chesapeake achieved this goal, not only would it realize huge returns for its taxpayers, it would become a model for other communities. The C-NGN team will need to develop close collaborative relationships with internal and regional economic development and community development teams, with the greater business community, and with large-scale stakeholders, including the Commonwealth of Virginia and various federal government agencies.

2. Capital Plan

The C-NGN Capital Plan includes Fiber Design, Engineering and Permitting, Fiber OSP Construction, Construction Contingencies, Facilities, Equipment, Servers and Software, and Project Management, Construction Management, and Inspections, as well as the Wireless Overlay infrastructure to initially stand up the planned wireless technologies. The total capital plan (See Table 13) is estimated at $39.9 million, which includes approximately $6.9 million in equipment renewal and replacement at regular 7 and 10-year intervals for both fiber and wireless networks.

Table 12: Capital Plan

Capital Plan

		Initial Deployment	Renewal and Replacement	Overall Totals
Est total mileage	172.25			
Full Network Design/Permitting	1-Design	$ 1,282,320		$ 1,282,320
OSP Construction Costs				
172.25-Mile Fiber OSP Construction	1-Labor	$17,475,567		$ 17,475,567
	1-Material	$ 5,760,181		$ 5,760,181
	1-Contingency-10	$ 2,323,576		$ 2,323,576
OSP Construction Costs		$25,559,323		$ 25,559,323
Premises Connected (Drops)		$ 402,583	$1,207,749	$ 1,610,332
Network Equipment/Refresh/Systems/Project Mgmt				
Transport Equipment Ring (4 sites) [4]		$ 242,372	$ 484,744	$ 727,116
Core and Aggregation Equipment (4 sites) [4]		$ 923,304	$1,846,608	$ 2,769,912
Edge Routing (2 routers) [2]		$ 207,694	$ 415,388	$ 623,082
Security (Distributed Denial-of-Service Appliance) [1]		$ 42,129	$ 84,258	$ 126,387
Spares (Equipment Spares) [1]		$ 25,000	$ 50,000	$ 75,000
Professional Services (install/config) (18% of equipment costs) [1]		$ 254,790	$ 509,580	$ 764,370
Systems:				
Fiber Management () [1]		$ 100,000		$ 100,000
Backoffice Software (Network Mgmt/CRM/Ordering/Provisioning/Billing/etc) [1]		$ 150,000		$ 150,000
Inside Plant (Racks/cabinets/ladders/raceways/UPS for sites) [203]		$ 152,250		$ 152,250
Contingency (Ntwk Equip/Selected Software/In-Plant; P2/P3 CPE)		$ 250,012	$ 339,058	$ 589,070
Project Turnkey Management		$ 714,000		$ 714,000
Project Construction Management/Inspections		$ 1,050,000		$ 1,050,000
Total Network Equipment/Refresh/Systems/Project Mgmt Costs		$ 4,111,551	$3,729,636	$ 7,841,187
Building Improvements				
Data Center (New) [1]		$ 500,000		$ 500,000
Prefab Shelters (P1 Sites) [1]		$ 250,000		$ 250,000
Total Building Improvements Costs		$ 750,000		$ 750,000
General Equipment/Other CapEx				
Vehicles (Maintenance) [2]		$ 105,000	$ 210,000	$ 315,000
Tools: Field () [1]		$ 7,000	$ 14,000	$ 21,000
General Equipment/Other Costs		$ 112,000	$ 224,000	$ 336,000
Wireless Cap-Ex (LoRam 700MHz, 4.9GHz)		$ 764,001	$1,764,842	$ 2,528,843
Total Capital		$32,981,778	$6,926,227	$ 39,908,006

Operating Cost Assumptions

The C-NGN's Operating Costs will be structured very much like the City's current IT Department and will include staffing, wholesale Internet and network interconnects, colocation fees, fiber O&M, locate services, utilities, and professional/consulting services, as well as equipment and software maintenance. Typical overhead, training, travel, and other expected expenses are included in the General SG&A calculated at 10% of total OPEX. Tables 14 and 15 provide the Cost of Services and Staffing Plan respectively.

Table 13: Cost of Services

Cost of Services				
Annual IP and Interconnect Services	Annual	$204,000	-	
Colocation Fees @ Data Center	Annual	$30,000	-	
Annual OSP O&M Costs (Additional)	Annual	$161,760	-	
OSP Locates Services	Annual	-	-	
Annual NMS, DDoS, FMS, and Equip Maint	Annual	$182,915	2%	
Professional/Consulting/Level 3 Support	Annual	$75,000	2%	
Wireless Overlay OPEX	Annual	$20,000	1%	
Sales, General, & Administrative Expenses				
General SG&A (10% of highlight O&M + staff)	10% OPEX	10%	-	
Depreciation		Lifetime		
Premise Site Equipment	Calculated	7		
Network & General Equipment	Calculated	10		
Infrastructure (Towers, Fiber, Facilities)	Calculated	20		
Financial Assumptions				
Fund Type	Type	Percentage	Flat Amt	Beg. Year
Operating Reserve Fund	2-% OPEX	1%		1
Renewal & Replacement Fund	1-Flat Rate		$225,000	4
Capital Expansion Fund	1-Flat Rate		$150,000	5

3. Staffing Plan

7.5 FTE's will be required by the end of the full deployment in Year 4. This team will be led by a Broadband Manager, reporting to the City's CIO. Initially, there are 4 Engineering positions, but the City believes 2 of those positions can be reduced once the network is stood up, fully operational, and the operation is mature. A Junior Wireless Engineer has been added to support the Wireless Overlay.

Table 14: Staffing Plan

Position	Initial Staff (2021)	Year 5 Staffing (projected)	Year 10 Staffing (projected)
Broadband Manager	.50	1	1
Admin Assistant I	.50	.50	.50
Network Engineer	.50	1	1
InfoSec Analyst	0	1	0
Network Technician	0	1	0
OSP GIS Technician	.50	1	1
Utility Locator		1	1
Junior Wireless Engineer	.50	1	1
Total	2.5	7.5	5.5

4. Borrowing/Debt Service and City Contributions

The City of Chesapeake will have to fund the capital investment required to construct, deploy, and operate the C-NGN initially. The Master Plan assumes the effort will be debt-financed using taxable bonds and will leverage other sources to lower the debt load. Magellan has modeled 3.5% at 20-years, 10-years, and 7-years for various levels of debt service.

While nearly $33 million is required to build and deploy the network through the first 5 years of this Plan, $22 million is planned to be funded through debt service, as an estimated $11.77 million has been identified locally, as possible contributions to the network investment. Table 16 below identified the total capital requirements for the C-NGN, the amount to be financed, as well as a breakdown of possible contributions, including:

- City IT/CIP Budgets - $2,290,815 (2021 – 2025)
- Grant Funding CARES - $1,984,949 (2021)
- Public Safety Microwave Replacement Project - $1,500,000 (2024)
- TIF/Economic Development Funding - $3,500,000 (2022)
- Public Utilities - $2,492,871 (2022 – 2023)

Table 15: Borrowing Summary and City Contributions

Total to be Financed	Year # Totals	1 2021	2 2022	3 2023	4 2024	5 2025
20 Yr- Plant & Facilities	$26,841,643	$3,465,764	$10,986,663	$8,415,316	$3,973,900	
10 Yr-Network Equipment & Buildings	$5,737,552		$1,660,667	$2,090,524	$1,734,361	$252,000
7 Yr-Premise Site Equipment	$402,583			$273,943	$128,640	
Totals	**$32,981,778**					
Contributions						
City/CIP	$2,290,815	$1,380,815	$360,000	$300,000	$250,000	
Grant Funding	$1,984,949	$1,984,949				
Public Safety	$1,500,000				$1,500,000	
Schools/Library						
TIF/Economic Development	$3,500,000		$3,500,000			
Traffic						
Utility	$2,492,871		$1,492,871	$1,000,000		
Total Contribution	$11,768,635	$3,365,764	$5,352,871	$1,300,000	$1,750,000	
1 Yr-Working Capital	$910,000		$360,000	$300,000		$250,000
Totals	**$22,123,144**	**$100,000**	**$764,459**	**$9,779,784**	**$4,086,901**	**$502,000**

5. Revenues

Revenues are derived from service charges for transport, wireless, and DIA connectivity provided across the C-NGN. As indicated below, DIA services grow to approximately $303,600 by 2023/2024 and remain steady as there has not been any growth defined in the model. Transport services are the predominant revenue source for the C-NGN, growing to just over $3.7 million by 2025. Wireless services revenue grows to $381,900 by 2024/2025.

As indicated below in Table 17, total C-NGN revenues will grow to $4.4 million by 2025/2026 and will grow little each year beyond this point unless a large number of sites or new services are deployed, beyond what has been modeled.

Table 16: C-NGN Revenues

	2020-2021	2021-2022	2022-2023	2023-2024	2024-2025	2025-2026	2026-2027	2027-2028	2028-2029	2029-2030
YEAR	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
WIRELESS SERVICE REVENUES										
W-LORA (99.6%)			$41,580	$83,160	$126,000	$126,000	$126,000	$126,000	$126,000	$126,000
W-700 MHZ (0.4%)			$61,610	$123,221	$186,264	$186,264	$186,264	$186,264	$186,264	$186,264
W-4.9 GHZ (0.0%)			$23,195	$46,390	$69,584	$69,584	$69,584	$69,584	$69,584	$69,584
SUBTOTAL WIRELESS SERVICE REVENUES			$126,385	$252,770	$381,848	$381,848	$381,848	$381,848	$381,848	$381,848
INTERNET SERVICE REVENUES										
I-INTERNET 1G DIA (43.0%)			$45,000	$90,000	$90,000	$90,000	$90,000	$90,000	$90,000	$90,000
I-INTERNET 2G DIA (29.0%)			$34,800	$69,600	$69,600	$69,600	$69,600	$69,600	$69,600	$69,600
I-INTERNET 1G DIA (29.0%)			$72,000	$144,000	$144,000	$144,000	$144,000	$144,000	$144,000	$144,000
SUBTOTAL INTERNET SERVICE REVENUES			$151,800	$303,600	$303,600	$303,600	$303,600	$303,600	$303,600	$303,600
TRANSPORT & DEDICATED REVENUES										
I 1GX1G TRANSPORT (PRE Y5) (98.4%)			$1,440,000	$2,886,000	$2,898,000					
I 10GX10G TRANSPORT (PRE Y5) (1.6%)			$48,000	$96,000	$96,000					
I 1GX1G (POST Y4) (75.0%)						$2,323,000	$2,232,000	$2,238,000	$2,250,000	$2,041,200
I 10GX10G TRANSPORT (POST Y4) (25%)										
SUBTOTAL TRANSPORT & DEDICATED REVENUES			$1,488,000	$2,982,000	$2,994,000	$3,720,000	$3,720,000	$3,726,000	$3,750,000	$3,402,000
TOTAL REVENUE (SERVICE+INSTALL+EQUIP)			**$1,766,185**	**$3,538,370**	**$3,679,448**	**$4,405,448**	**$4,405,448**	**$4,411,448**	**$4,435,448**	**$4,087,448**

Third-Party Revenue Opportunities

The C-NGN will also have the opportunity to generate new third-party revenues from leasing excess conduit, excess fiber strands, and tower attachments. This portion of the C-NGN business case is more speculative, because it is relatively uncertain, and requires relationship building across the community and region. The Master Plan assumes that the C-NGN will start generating third-party/external revenues by Year 6 at a rate of $250,000 annually, and by Year 10 that revenue will grow to $500,000. We feel this is a conservative assumption. Revenues could be increased greatly by actively marketing C-NGN's excess capacity.

6. Pro Forma

The included Pro Forma (Table 18) indicates profitability and cash flows for the 20-year and 30-year durations included in these projections. Revenues Peak for the C-NGN around Year 6 at $4.7 million under the current assumptions. Projections show Positive Net Income by Year 6, and the C-NGN covers its debt service, funds reserves for Renewal and Replacement, and Capital Expansion. At current projections, with current rate structures, and rate decreases throughout the term, the C-NGN has 20-Year Cumulative Free Cash Flows of $11.9 million, and 30-Year of Free Cash Flows of $23.2 million. If the C-NGN grows its connections, the City should expect revenues to grow, as well as free cash.

Table 17: 20-Year Pro Forma

Pro Forma — Fiscal (July-June) — *Proprietary and Confidential Information*

Total Network-Buried	2020-2021	2021-2022	2022-2023	2023-2024	2024-2025	2025-2026	2026-2027	2027-2028	2028-2029	2029-2030	2034-2035	2039-2040	2044-2045	2049-2050
Year #	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*15*	*20*	*25*	*30*
Service Revenues														
**Third Party/External (Manual Override)						$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 500,000	$ 500,000	$ 500,000	$ 500,000
Wireless	$ -	$ -	$ 126,385	$ 252,770	$ 381,848	$ 381,848	$ 381,848	$ 381,848	$ 381,848	$ 381,848	$ 381,848	$ 381,848	$ 381,848	$ 381,848
Internet	$ -	$ -	$ 151,800	$ 303,600	$ 303,600	$ 303,600	$ 303,600	$ 303,600	$ 303,600	$ 303,600	$ 303,600	$ 303,600	$ 303,600	$ 303,600
Community Transport	$ -	$ -	$ 1,488,000	$ 2,982,000	$ 2,994,000	$ 3,720,000	$ 3,720,000	$ 3,726,000	$ 3,750,000	$ 3,402,000	$ 3,154,140	$ 2,891,214	$ 2,676,888	$ 2,462,343
Subtotal: Service Revenues	$ -	$ -	$ 1,766,185	$ 3,538,370	$ 3,679,448	$ 4,655,448	$ 4,655,448	$ 4,661,448	$ 4,685,448	$ 4,337,448	$ 4,339,588	$ 4,076,662	$ 3,862,336	$ 3,647,792
Cost of Services														
Direct Staffing	$ -	$ 162,787	$ 579,441	$ 664,891	$ 679,746	$ 695,046	$ 710,806	$ 413,420	$ 420,731	$ 428,260	$ 469,439	$ 517,176	$ 572,516	$ 636,670
1-Annual IP and Interconnect Services	$ -	$ -	$ 102,000	$ 204,000	$ 204,000	$ 204,000	$ 204,000	$ 204,000	$ 204,000	$ 204,000	$ 204,000	$ 204,000	$ 204,000	$ 204,000
2-Colocation Fees @ Data Center	$ -	$ -	$ 15,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000	$ 30,000
3-Annual OSP O&M Costs (Additional)	$ -	$ -	$ -	$ 161,760	$ 161,760	$ 161,760	$ 161,760	$ 161,760	$ 161,760	$ 161,760	$ 161,760	$ 161,760	$ 161,760	$ 161,760
4-OSP Locate Services	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
5-Annual NMS, DDoS, FMS, and Equipment Maint	$ -	$ -	$ -		$ -	$ 182,915	$ 186,573	$ 190,305	$ 194,111	$ 197,993	$ 218,600	$ 241,352	$ 266,472	$ 294,207
6-Professional/Consulting/Level 3 Support	$ -	$ -	$ -	$ -	$ 75,000	$ 76,500	$ 78,030	$ 79,591	$ 81,182	$ 82,806	$ 91,425	$ 100,940	$ 111,446	$ 123,045
7-Utilities	$ -	$ -	$ 20,000	$ 20,200	$ 20,402	$ 20,606	$ 20,812	$ 21,020	$ 21,230	$ 21,443	$ 22,537	$ 23,686	$ 24,894	$ 26,164
8-Wireless Overlay Op-Ex	$ -	$ -	$ 272,445	$ 272,445	$ 272,445	$ 272,445	$ 272,445	$ 272,445	$ 272,445	$ 272,445	$ 272,445	$ 272,445	$ 272,445	$ 272,445
Subtotal: Cost of Services	$ -	$ 162,787	$ 988,886	$ 1,353,296	$ 1,443,353	$ 1,643,272	$ 1,664,426	$ 1,372,541	$ 1,385,459	$ 1,398,707	$ 1,470,206	$ 1,643,272	$ 1,643,533	$ 1,748,291
GROSS PROFIT	$ -	$ (162,787)	$ 777,299	$ 2,185,074	$ 2,236,095	$ 3,012,176	$ 2,991,022	$ 3,288,907	$ 3,299,989	$ 2,938,741	$ 2,869,382	$ 2,433,390	$ 2,218,803	$ 1,899,501
Sales, General & Administrative Expenses														
Indirect Staffing	$ -	$ 111,845	$ 191,184	$ 196,920	$ 202,827	$ 208,912	$ 215,180	$ 221,635	$ 228,283	$ 235,132	$ 272,583	$ 315,998	$ 366,329	$ 424,675
1-General SG&A (10% of highlight O&M+Staff)	$ -	$ 27,463	$ 79,063	$ 104,377	$ 113,974	$ 134,574	$ 137,316	$ 108,773	$ 110,730	$ 112,739	$ 123,634	$ 136,091	$ 150,342	$ 166,652
total: Sales, General & Administrative Expenses	$ -	$ 139,308	$ 270,247	$ 301,297	$ 316,801	$ 343,486	$ 352,496	$ 330,408	$ 339,013	$ 347,871	$ 396,217	$ 452,089	$ 516,671	$ 591,327
EBIT	$ -	$ (302,095)	$ 507,052	$ 1,883,777	$ 1,919,294	$ 2,668,690	$ 2,638,526	$ 2,958,499	$ 2,960,976	$ 2,590,870	$ 2,473,165	$ 1,981,301	$ 1,702,132	$ 1,308,174
	$ -													
Depreciation & Amortization														
Depreciation	$ -	$ -	$ 888,688	$ 1,557,641	$ 1,948,149	$ 1,973,349	$ 1,973,349	$ 1,973,349	$ 1,973,349	$ 1,973,349	$ 1,706,516	$ 1,681,316	$ 18,377	$ -
Amortization	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Subtotal: Depreciation & Amortization	$ -	$ -	$ 888,688	$ 1,557,641	$ 1,948,149	$ 1,973,349	$ 1,973,349	$ 1,973,349	$ 1,973,349	$ 1,973,349	$ 1,706,516	$ 1,681,316	$ 18,377	$ -
EBITDA	$ -	$ (302,095)	$ (381,636)	$ 326,136	$ (28,855)	$ 695,341	$ 665,177	$ 985,150	$ 987,627	$ 617,521	$ 766,649	$ 299,985	$ 1,683,755	$ 1,308,174
Interest														
Borrowings	$ -	$ 3,500	$ 258,682	$ 578,420	$ 692,708	$ 663,264	$ 622,908	$ 581,140	$ 537,910	$ 493,167	$ 276,752	$ 128,426	$ -	$ -
Subtotal: Interest Expenses	$ -	$ 3,500	$ 258,682	$ 578,420	$ 692,708	$ 663,264	$ 622,908	$ 581,140	$ 537,910	$ 493,167	$ 276,752	$ 128,426	$ -	$ -
NET INCOME	$ -	$ (305,595)	$ (640,318)	$ (252,283)	$ (721,563)	$ 32,078	$ 42,269	$ 404,010	$ 449,717	$ 124,355	$ 489,897	$ 171,559	$ 1,683,755	$ 1,308,174
Debt Principal Payments														
Borrowings	$ -	$ 3,536	$ 344,434	$ 821,508	$ 1,093,275	$ 1,153,021	$ 1,193,377	$ 1,235,145	$ 1,278,375	$ 1,323,118	$ 814,102	$ 932,127	$ -	$ -
Subtotal: Principal Payments	$ -	$ 3,536	$ 344,434	$ 821,508	$ 1,093,275	$ 1,153,021	$ 1,193,377	$ 1,235,145	$ 1,278,375	$ 1,323,118	$ 814,102	$ 932,127	$ -	$ -
Reserve Fund Requirements														
Operating Reserve Fund (max 2 mo of yearly Op-E	$ -	$ 50,349	$ 159,506	$ 65,910	$ 17,594	$ 37,767	$ 5,027	$ -	$ -	$ -	$ -	$ 12,676	$ 5,511	$ 6,309
Renewal & Replacement Fund	$ -	$ -	$ -	$ 225,000	$ 225,000	$ 225,000	$ 225,000	$ 225,000	$ 225,000	$ 225,000	$ 225,000	$ 225,000	$ 225,000	$ 225,000
Capital Expansion Fund	$ -	$ -	$ -	$ -	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000
Less Use of Reserves for CapEx Post Borrow Y	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 273,943	$ -	$ -	$ 128,640	$ -	
Subtotal: Annual Reserve Fund Requirements	$ -	$ 50,349	$ 159,506	$ 290,910	$ 392,594	$ 412,767	$ 380,027	$ 375,000	$ 375,000	$ 101,057	$ 375,000	$ 387,676	$ 251,871	$ 381,309
Subtotal: Cumulative Reserves	$ -	$ 50,349	$ 209,856	$ 500,766	$ 893,359	$ 1,306,126	$ 1,686,154	$ 2,061,154	$ 2,436,154	$ 2,537,211	$ 1,466,749	$ 2,951,842	$ 1,533,807	$ 3,438,709
Capital Spending														
Capital Budget	$ 3,465,764	$ 12,647,330	$ 10,779,784	$ 5,836,901	$ 252,000	$ -	$ -	$ -	$ -	$ 273,943	$ -	$ -	$ 128,640	$ -
Other														
Subtotal: Capital Spending	$ 3,465,764	$ 12,647,330	$ 10,779,784	$ 5,836,901	$ 252,000	$ -	$ -	$ -	$ -	$ 273,943	$ -	$ -	$ 128,640	$ -
TOTAL NON-OPERATING, CAPEX AND RESERVES	$ 3,465,764	$ 12,701,215	$ 11,283,724	$ 6,949,318	$ 1,737,869	$ 1,565,788	$ 1,573,404	$ 1,610,145	$ 1,653,375	$ 1,698,118	$ 1,189,102	$ 1,319,802	$ 380,511	$ 381,309
Cash Flow														
Beginning of Year	$ -	$ -	$ 520	$ 44,949	$ 237,889	$ 228,606	$ 668,245	$ 1,110,459	$ 1,877,674	$ 2,647,366	$ 6,300,789	$ 11,404,299	$ 15,689,035	$ 22,309,449
Add: Net Income	$ -	$ (305,595)	$ (640,318)	$ (252,283)	$ (721,563)	$ 32,078	$ 42,269	$ 404,010	$ 449,717	$ 124,355	$ 489,897	$ 171,559	$ 1,683,755	$ 1,308,174
Add: Depreciation	$ -	$ -	$ 888,688	$ 1,557,641	$ 1,948,149	$ 1,973,349	$ 1,973,349	$ 1,973,349	$ 1,973,349	$ 1,973,349	$ 1,706,516	$ 1,681,316	$ 18,377	$ -
Add: New Funding	$ 3,465,764	$ 12,647,330	$ 10,779,784	$ 5,836,901	$ 252,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Less: Non-Operating, CAPEX and RESERVES	$ 3,465,764	$ 12,701,215	$ 11,283,724	$ 6,949,318	$ 1,737,869	$ 1,565,788	$ 1,573,404	$ 1,610,145	$ 1,653,375	$ 1,698,118	$ 1,189,102	$ 1,319,802	$ 380,511	$ 381,309
End of Year Cash Flow - Pre Working Capital	$ -	$ (359,480)	$ (255,051)	$ 237,889	$ (21,394)	$ 668,245	$ 1,110,459	$ 1,877,674	$ 2,647,366	$ 3,046,952	$ 7,308,101	$ 11,937,372	$ 17,010,657	$ 23,236,314
Add: Addl Working Capital		$ 360,000	$ 300,000		$ 250,000									
Less: Working Capital Principal/Interest	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
End of Year Cash Flow Final	$ -	$ 520	$ 44,949	$ 237,889	$ 228,606	$ 668,245	$ 1,110,459	$ 1,877,674	$ 2,647,366	$ 3,046,952	$ 7,308,101	$ 11,937,372	$ 17,010,657	$ 23,236,314

End of Year Cash Flow Final 30 Yr Total	$ 23,236,314
End of Year Cash Flow Final 20 Yr Total	$ 11,937,372

G. Conclusion

The C-NGN will provide the City of Chesapeake with economical, high-capacity, high-reliability connections over which it has complete control, including the ability to leverage the network to attract investment that will lead to ubiquitous, competitive broadband options for the community. The City has concluded that an *Infrastructure-Only Government Services Provider* model for the C-NGN, which involves the City building, owning, and operating the network is the most cost-effective option and best serves the needs of the citizens.

This model has a strong bottom-line business case. It has greater flexibility and lower long-term costs than other options for meeting the City's connectivity needs and enables the City to generate revenue from leasing excess capacity and acting as an E-Rate service provider to the Libraries and Schools. Magellan Advisors believes that the C-NGN provides significant opportunities for revenue generation and that the investment in the C-NGN will produce long-term tax growth by driving economic development. While we believe this growth is likely, it is difficult to quantify so we have not included it in our business case.

The City of Chesapeake will reduce its long-term operating costs for municipal network operations by tens of millions of dollars over the projected 30-year period with the C-NGN. As outlined in this Plan, once deployed, the C-NGN is delivering 1 Gbps and 10 Gbps circuits at $1,000 and $2,000 respectively, a decrease of approximately 22% to 34% ($1,275, $2,950) from rates experienced today in current contracts.

All City departments, the Libraries, Schools, and public entities will pay their fair share of the services they consume. The City will pursue discounts, grants, and other funding to reduce both capital deployment costs and monthly recurring charges. The City will deploy the C-NGN as cost-effectively as possible, capitalizing on other infrastructure projects and removing profit motives from the services procured.

The C-NGN will support additional future community initiatives that deal with mobility, utility automation, and Smart City applications. It will enable healthcare, education, digital inclusion, broadband expansion, and local government regional collaboration. Excess capacity can be leased to private companies for expanding service options to the community and generating new revenue for the City.

The City of Chesapeake will need additional and faster network connections every year. The increase in requirements will not slow down as long as more devices,

more people, and more components are connected and communicating. With the C-NGN, the City can control its costs, support broad community-based initiatives, and supply new assets for the wholesale telecommunications market. Without the C-NGN, the City will continue to be obligated to its providers and the greater telecom industry and will be required to continue paying ever-increasing annual costs. This plan is a long-term approach to turning communications services and their monthly recurring fees into an investment in critical local public infrastructure that will result in:

- Affordable, broadband services to all City, School, and Library facilities
- Leveraging the Subsea Cables and Regional Connectivity Ring (SNA-RCR)
- Ensuring network financial and operational sustainability and resiliency
- Making Chesapeake an exceptional place to live, learn, work, farm, and play by:
    - Better serving citizens, businesses, and visitors
    - Creating a catalyst for private investment in broadband services to all citizens and businesses city-wide (more competition)
    - Creating a catalyst for community and economic development

1. Recommendations and Next Steps

A number of recommendations are made throughout this document. These recommendations are summarized below:

Business Model

- Operate the C-NGN as an Infrastructure-Only/Government Services Provider for its departments and other local public agencies, structured as a City Enterprise or Internal Services Fund.
- Create a rate structure to recover costs of the C-NGN connections, internet access, transport service, wireless overlay, and other network components from the City departments that use them.
- Apply to become an E-Rate provider through the Universal Service Administration Company (USAC) and compete for School and Library WAN services.
- Monetize the C-NGN by leasing excess capacity of passive network assets including fiber-optic cable strands and unused conduit.
- Actively develop possibilities for top-line growth from the C-NGN, develop a detailed business case, and revise its approach accordingly.

Fiber Construction and Network Deployment

- Identify equipment with sub-GigE network interfaces and unprotected or cascaded switch uplinks and develop plans for reconfiguration and replacement.
- Standardize on Cisco as the backbone equipment manufacturer for procurement solicitations and professional services should be limited to qualified value-added resellers (VAR's).
- Require integrated hardware/professional services, a detailed scope of work, and a set of qualifications for value-added resellers (VAR) to ensure a successful turn-key solution.
- Include provisions in the Construction RFP that allow bidders to offer "innovative solutions" that would decrease the City's upfront capital investment.
- Establish a physical presence in an existing regional data center through the lease of a rack or cage and should plan for new cross-connects into wholesale Internet Providers, Azure Express Routes, and other key service/content offerings, including options for new Disaster Recovery and Cloud services.
- Reuse private IP addressing in the C-NGN architecture, which are currently used for Cox L3 MPLS connections, to minimize configuration changes for attached LANs.
- Aggregate all underground locate needs, including its utility infrastructure into one master locate contract or internal locate group to reduce these costs.

Wireless

- Open discussions about acquiring license for the 700 MHz A block spectrum.
- Move forward with licensing the required 4.9 GHz spectrum as soon as possible to take advantage of the current, less stringent filing requirements.
- Develop small-scale proof-of-concept projects for deploying more applications and expanding the wireless overlay networks.
- Monitor emerging access services, specifically Citizens Broadband Radio Service, as possible alternatives or supplements to the wireless overlay.

Operations and Policy

Construction and Expansion

- Apply design and construction standards to the C-NGN and similar infrastructure via permitting and planning processes.
- Expand the existing Infrastructure coordination, capital projects coordination and development/permit review processes to include the C-NGN.

Financing and Staffing

- The Operations Team must be dedicated staff and resources to the C-NGN and should not be other full-time staff with new "additional responsibilities."
- Develop department and enterprise fund chargebacks for fiber and wireless services, as well as IT services, in general, so that departments pay for the services they consume.
- Future Capital Projects that require the extension of the C-NGN for network services should include expansion funds within the specific CIP project.
- Include the funding of Reserve Accounts for Operations, Network Expansion, and Network Renewal and Replacement.
- In addition to reserve accounts, the C-NGN should receive regular capital infusions to opportunistically take advantage of dig once and joint trench opportunities.

Marketing and Revenue

- Establish a program to market excess network capacity and other assets.
- City Council should adopt a transparent and non-discriminatory rate structure using a cost per fiber strand mile model for all lease agreements.
- Market dark fiber to providers, including cellular providers with which the City does have existing relationships with.
- Market both dark fiber and tower attachments to support the deployment of wireless broadband services throughout the community.
- Work closely with Economic Development to actively promote the C-NGN and drive private investment.

Policy

- Establish the C-NGN Governance structure with cross-functional participation and public engagement.

- Evaluate and modify tower attachment policies and rate schedule to account for new fiber connections to towers and promote the deployment of wireless broadband services throughout the community.
    - Consider including use of City-owned assets in the Master Licensing Agreements (MLAs) for network service providers, particularly cellular.
    - It may also be necessary to modify permitting fees and processes.
- Periodically evaluate city policies and practices to maximize the value of the C-NGN
    - Design and construction standards for fiber, towers, small cell, smart poles, streetlights, etc.
    - Planning and permitting processes.
    - Internal and external "Dig Once" and joint trenching.
    - Franchise agreements and easements.
    - Master Licensing Agreements (MLAs) for network service providers to allow attachments to selected City-owned structures.

Technical

- The network must be operated and supported to carrier grade specifications as this platform will now provide critical network services to all sites connected.
- The C-NGN should acquire appropriate tools to test fiber integrity, including an optical power meter to measure optical power levels and an optical time domain reflectometer (OTDR) to measure fiber continuity and identify the location of fiber micro-bends and breaks.
- Chesapeake should advocate for commercial data center connectivity within the SNA-RCR to facilitate access into the regional data centers and the subsea cable landing.

2. Conclusion Summary

The C-NGN will enable Chesapeake to connect more sites at higher speeds and lower total costs. Operational improvements will build on flexible connectivity as the City will no longer be constrained by costs and lack of control over this critical infrastructure. The network will provide a foundation for new partnerships that bring additional services, more investment in the City's infrastructure, and competitive broadband options for the community. Combined with Chesapeake's geographic location and abundant development opportunities, the C-NGN will give the City an economic edge and put it in a leadership role for the region and the country.

CITY OF CHESAPEAKE

C-NGN Fiber Master Plan

Appendices Under Separate Cover

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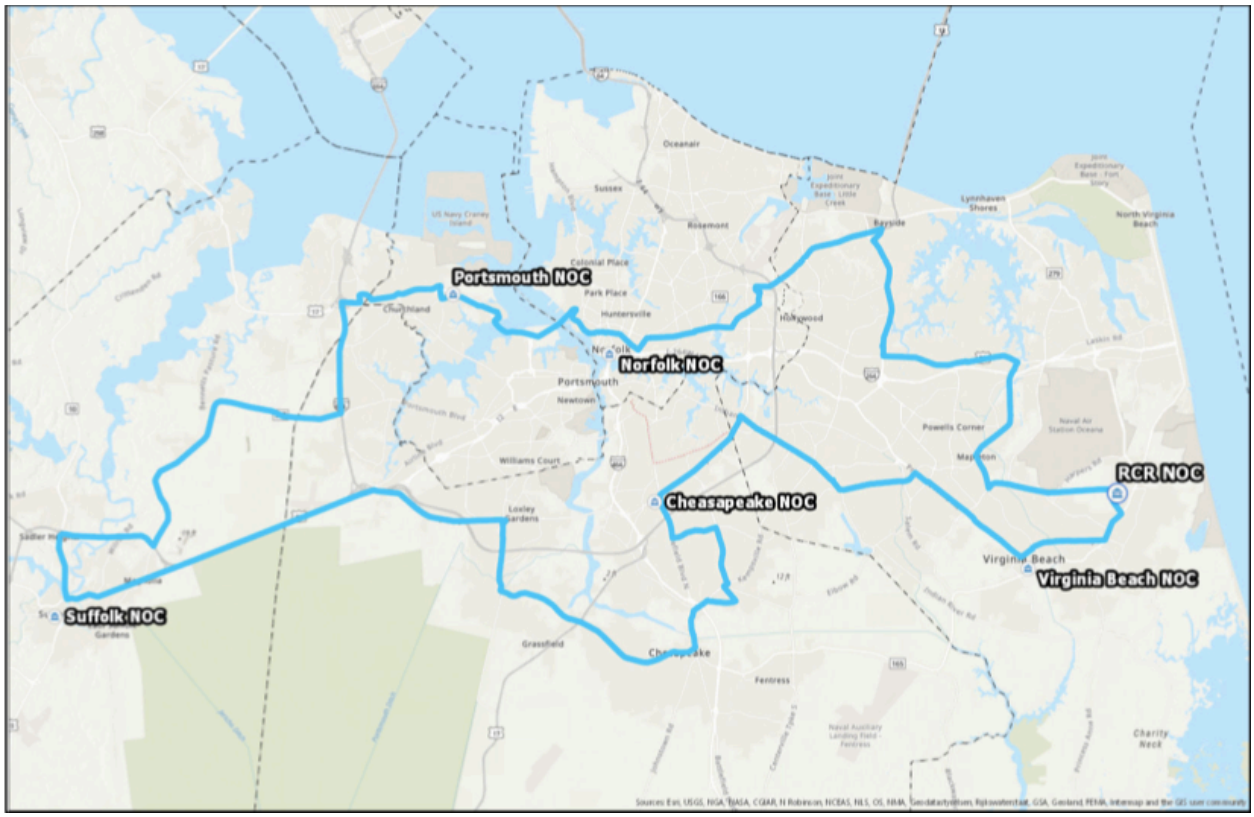
Appendix 1 – Telecommunications Infrastructure and Services Assessment & Gap Analysis

A. Broadband Infrastructure-Related Activities Occurring within the Region

Magellan researched key regional projects and interviewed regional stakeholders to fully understand the impact any regional broadband and transoceanic fiber deployments will have for the C-NGN.

1. Hampton Roads Regional Connectivity Ring (RCR) and the Southside Network Authority

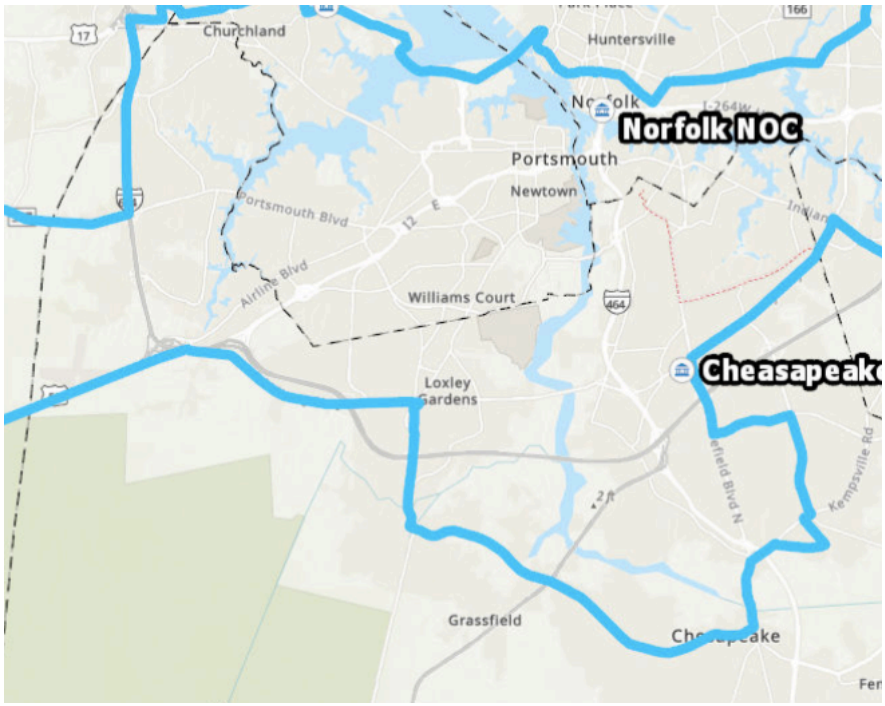
The Hampton Roads Regional Broadband Initiative proposes the creation of a fully integrated regional fiber-optic network that connects employment areas, higher education facilities, research institutions, and municipal facilities throughout the region. This regional broadband network will allow the Hampton Roads cities of Chesapeake, Norfolk, Portsmouth, Suffolk, and Virginia Beach to interconnect and to continue to develop as a nationally connected 21st-century region and international information gateway that will provide the necessary infrastructure to support job creation centered around a number of emerging industry clusters. The Hampton Roads area, anchored through Virginia Beach, is now a digital port and a key asset driving the region toward becoming a "Terabit Region." The transatlantic cables landing in Virginia Beach are bringing vast investments to the region, including the launch of new companies, data center facilities, and the investment of more digital infrastructure.



App 1 Figure 1: Hampton Roads Regional Connectivity Ring (RCR) Proposed Routing

The Regional Connectivity Ring (RCR), illustrated in App 1 Figure 1, interconnects each of the five Southside communities and will be owned and operated through the Southside Network Authority formed in 2019 through the adoption of concurrent resolutions adopting formal Articles of Incorporation pursuant to the Wireless Service Authorities Act. Plans call for the Authority to construct the conduit and dark fiber segments that traverse each municipality, with specific fiber strands dedicated to each City and participating entity throughout the RCR.

The regional network is slated to come through the City of Chesapeake in two locations and could be terminated into one or possibly two City sites where network traffic can be handed off to the RCR. The RCR route from Virginia Beach runs along Military Road and traverses many local roads and highways in Chesapeake as it routes its way into Suffolk to the West. There's also a small portion of the network that comes West from Suffolk, briefly cutting through Chesapeake in its northwest corner, routing to the north back into Suffolk before it moves into Portsmouth. (See App 1 Figure 2.) It would be most economical for the C-NGN and RCR to interconnect in these areas.



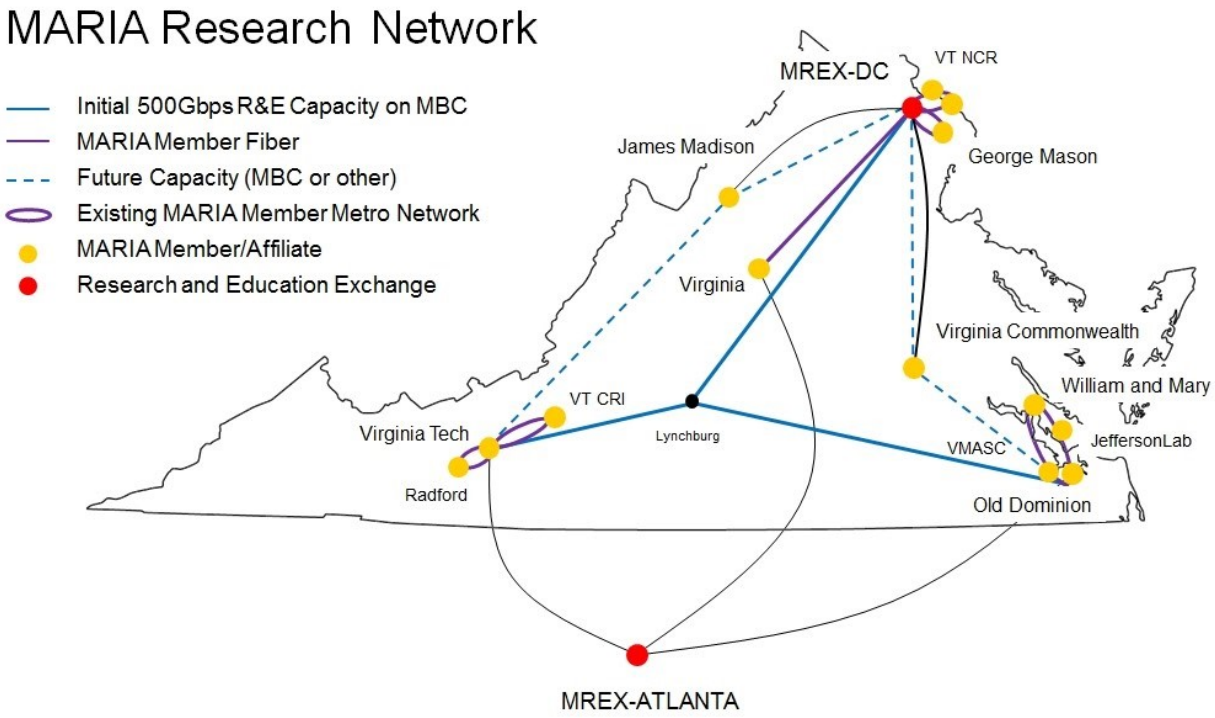
App 1 Figure 2: RCR Routing through Chesapeake

For the City of Chesapeake, the RCR represents ownership in a new middle-mile fiber-optic backbone that will not only connect the City to its peer municipalities throughout the region but will place the City "on-net" to some of the fastest networks and most advanced data centers in the world. This will introduce a new range of service providers and services the City can integrate into its IT systems and enhance the services it delivers to its end users. The outcomes from these types of interconnections include more bandwidth at cheaper costs, direct access to Azure ExpressRoutes[1] for Cloud computing, and transport services in and around the region, and across the United States.

[1] An ExpressRoute is a Microsoft service for private connections between Azure datacenters and infrastructure on customer premises or in a third party data center. ExpressRoute connections don't go over the public Internet so are positioned as more reliable, faster, and lower latency than many Internet connections.

2. ODU's E-LITE and Mid-Atlantic Research Infrastructure Alliance Network (MARIA Network)

ODU's E-LITE network allows the University and partners to share connectivity and costs to the state and national research and education networks. E-LITE is essentially a fiber network around Hampton Roads provided by Cox using DWDM, with Internet2 peering in Ashburn, VA, and Atlanta, GA.



App 1 Figure 3: MARIA Research Network Map

App 1 Figure 3 is a conceptual diagram of the Mid-Atlantic Research Infrastructure Alliance (MARIA) Research Network.[2] Operated by ODU, this network connects the College of William and Mary, Thomas Jefferson National Accelerator Facility, NASA Langley Research Center, six National Oceanographic and Atmospheric Agency (NOAA) facilities, and the Joint Forces Command (JFCOM) together and with other organizations across Virginia and the country. ODU acquired multiple (20) strands of dark fiber from Virginia Beach to Petersburg and through Suffolk to Emporia as part of a grant with the Mid-Atlantic Broadband Coalition (MBC). MARIA also has a

[2] For additional information see https://www.marialliance.net/about/.

10-year IRU on fiber from Cox for VMASC that runs through Chesapeake to the Norfolk campus.

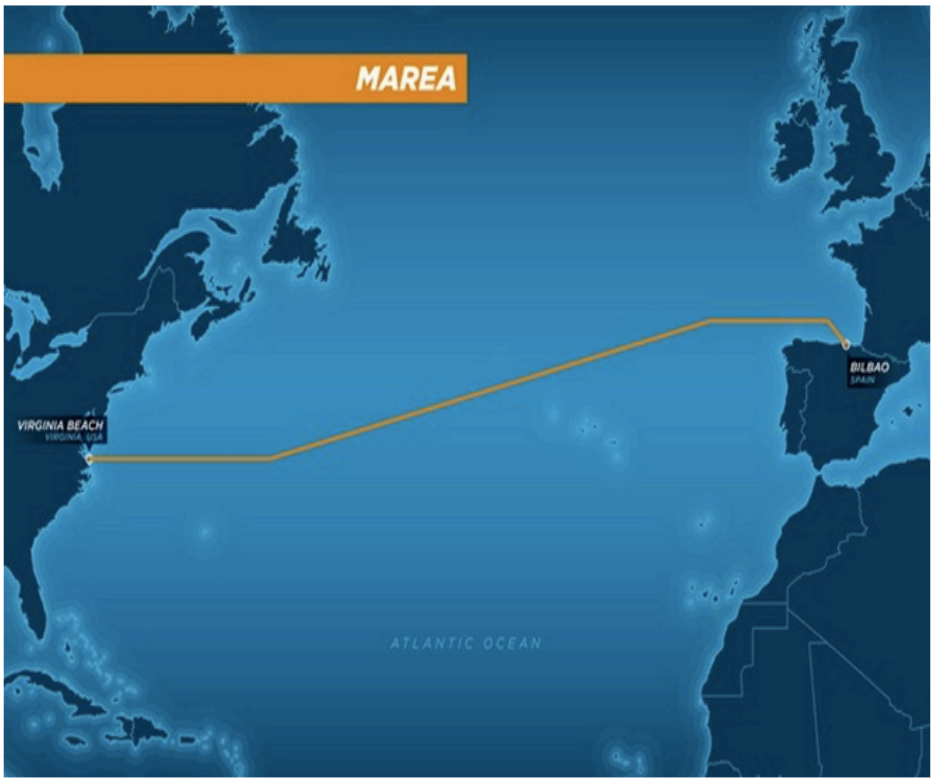
MARIA doesn't plan to manage and maintain fiber in the public right-of-way because it doesn't have that capacity, but it does own actual infrastructure, promotes its use, and provides high-performance computing resources. It plans to expand to all higher educational institutions in Hampton Roads and is scaling at 100 Gbps, with 400 Gbps connections to multiple institutions. MARIA's vision is to be a complete compute/data facilitator for researchers and has participated in the regional broadband discussion to that end.

3. Transoceanic Cable Landing Projects

Virginia Beach is now a hot site for submarine fiber-optic cable landing stations, hosting MAREA, BRUSA, SAEx1, and Dunant submarine cable systems. Microsoft and Facebook are partnering with Telxius and landed their 160 Tbps MAREA cable system at the Virginia Beach Cable Landing Station (CLS) site at 1900 Corporate Landing Parkway in Virginia Beach. Talxius also lands its private cable BRUSA at the Virginia Beach Cable Landing Station, while ACA International LLC, the landing party in the US for the South Atlantic Express (SAEx1), bought 10 acres in the Corporate Landing Business Park to build a cable landing station and data center. Google has announced plans to land its second private and non-telecom Dunant submarine cable in Virginia Beach. Seaborn Networks plans to extend its Seabras-1 cable system with a branch to Virginia Beach.

MAREA

MAREA is a new 6,600km submarine cable system that traverses the Atlantic, as shown in App 1 Figure 4, connecting the United States to southern Europe, Africa, the Middle East, and Asia. MAREA consists of eight fiber pairs and a design capacity of 160 Tbps. Facebook and Microsoft jointly developed MAREA as the first Open Cable System in the world. Telxius joined in later as the third-party of the MAREA consortium and operates and manages the MAREA cable system. MAREA has been in service since April 2018.



App 1 Figure 4: MAREA Network Map

BRUSA

BRUSA, a new submarine cable nearly 11,000km in length linking Rio de Janeiro and Fortaleza, Brazil, with San Juan Puerto Rico, and Virginia Beach, consisting of 8 fiber pairs, with an initial design capacity of 135 x 100 Gbps per fiber pair, and ROADM technology. BRUSA is a private cable built and operated by Telefonica. The BRUSA cable system was launched for commercial service in August 2018. Like the MAREA cable system, the BRUSA is landed in Virginia Beach cable landing station and extends the backhaul capacity into Equinix DC2 and other data centers.

4. Data Centers

The MAREA and BRUSA subsea cable projects have given rise to a new data center sector in Virginia Beach, which is of great benefit to the Hampton Roads region in general. In addition, the northern Virginia area between Richmond and Ashburn has been a major hub for data center services and fiber route convergence for several years. The proximity of these sub-sea landings to the regional data centers provides a significant competitive advantage in attracting software and platform service providers (SaaS/PaaS) to establish points of presence within the Hampton Roads region. These types of service providers typically require direct low-latency optical access to major IP and cloud service interexchanges such as this. The

relatively short distances between data center add/drop nodes require less amplification and fewer optical-electrical-optical (OEO) conversions, thereby reducing round-trip packet delay and jitter. All of these developments provide a rich set of connectivity options to the City for competitive low-cost access to IP transit, collocation, and cloud services. Points of interconnection to dark fiber and lit service providers will be identified and considered in the high-level network design to facilitate local access to the provider networks and their various tenant data centers.

EdgeConneX operates a carrier-neutral data center at 3800 Village Avenue, Suite C, Norfolk, Virginia 23502. The 100,100 sqft facility has 5,100 sqft of raised floor colocation space. It is located three miles from the Norfolk International Airport and four miles from downtown. The EDC in Norfolk can support 20+kW per rack or cabinet and 600 watts per square foot. Site certifications include SOC 2 Type 2 and Open-IX. The site provides IP transit, cloud service access, remote hands, and collocation design, build, implementation, and maintenance. Network and cable operator partners include COX, Segra, XO Communications, Cogent, Level 3/CenturyLink, and Windstream.

Globalinx Virginia Beach is located in the Corporate Landing Business Park in Virginia Beach, with the Globalinx Subsea Carrier Neutral Hotel serving as an interconnection point between subsea and terrestrial fiber networks. It provides direct access to the MAREA and BRUSA Subsea Cables, linking Virginia Beach directly to Spain, Puerto Rico, and Brazil. Virginia Beach is becoming an alternative subsea cable termination point for diversity to the existing subsea cable landing stations in Long Island and New Jersey. The data center is rated Tier III with a power capacity of 15kW per collocation cabinet. It is served by a 34.5 kV three-phase primary underground distribution feeder with a nearby 115 kV transmission line. Nearby and collocated network providers include Level 3, Windstream, Segra, Mid-Atlantic Broadband, and Metro Fiber Networks.

Digital Realty is located at 21745 Sir Timothy Drive, Virginia Beach VA, and contains 326,000 sqft of gross space with 34.5 million megawatts of power capacity. Site certifications include PCI-DSS, SOC 2, NIST 800-53, FISMA. The site provides cloud service access and serves as a neutral collocation facility for carriers.

QTS Richmond Data Center is located at 6000 Technology Boulevard, Sandston, VA. The data center contains a total area of 1.3 million sqft, including 600,000 sqft of collocation space and 110 megawatts of redundant power capacity. The site provides cloud service access and serves as a

neutral collocation facility for carriers. The MAREA and BRUSA cables terminate in Richmond, VA making it an emerging interconnection hub delivering the lowest latency connectivity and highest capacity from new subsea cables.

Flexential Richmond Data Center is located at 8851 Park Central Dr, Richmond, VA 23227. It contains a total of 30,000 sqft, including 10,500 sqft in raised floor space for collocation and redundant UPS power. The facility currently houses 80 on-net carriers. Certifications for this location include HIPAA, HITECH, PCI-DSS, SSAE-16 Type 1, SOC 2 Type 2, SOC 3, ISO 27001, EU-US, SOC 1 Type 2, NIST 800-53, SSAE-18.

PointOne NAP of Virginia Beach is located at 1893 Corporate Landing Parkway Virginia Beach, VA 23454. It contains two 20,000 sqft facilities totaling 9.6 MW of critical power load. This data is located across the street from MAREA and BRUSA subsea cables, with diverse connectivity to them via 2 x 432 fiber conduit routes.

B. Assets, Capacity, Products, and Services Offered within or Adjacent to the City

This sub-section identifies the services that are available in Chesapeake, including providers, service level, pricing, and access type. It documents privately-owned networks in the area in a comprehensive GIS-based broadband map and identifies costs for internet access to community institutions and local businesses. Magellan researched the state of broadband and fiber networks in the City as related to the Fiber Master Plan, specifically reviewing fiber enterprise providers. Through this assessment process, we identified the existence of several network operators offering IP access, transport, and dark fiber products throughout the market.[3] This sub-section provides details on these services, including relevant network infrastructure, as well as mass-market broadband services from incumbent cable and telephone companies.

Fiber-optic broadband services are available in some areas of the City through multiple providers. In many cases, fiber-optic routes are not available to retail subscribers because of their use as backhaul or within a metro ring fiber. Private companies own the fiber-based broadband facilities in the City. These companies

[3] Dark fiber refers to unused fiber-optic cable. Companies that own fiber-optic cable may "over build" the network capacity to avoid the cost of future expansion.

include the incumbent cable TV MSO[4], the regional incumbent local exchange carrier (ILEC), regional competitive local exchange carriers (CLEC), and Tier 1[5]/Tier 2[6] global telecommunications providers.

Two companies predominately provide broadband in the area: Cox Communications[7] and Verizon[8]. Cox provides broadband over a hybrid fiber-coaxial network infrastructure. Verizon provides broadband over fiber for its Fios broadband service, and it's "High Speed" service uses twisted-pair copper wire as the access medium for the "last 100 feet" that connects subscribers to providers' network.

App 1 Figure 5 comes from the FCC and suggests that the area has multiple providers. Most of the area appears to have three or more providers. Only Cox and Verizon are openly offering commercial and/or residential retail broadband services. Megapath, Mediacom, Centurylink, gtt, Crown Castle, and Windstream nominally offer services in small pockets of Chesapeake. Some key spots have no or only one company providing services to them. And, as discussed below, some "broadband" service offerings do not meet the speed standards for broadband.[9] The digital deserts are a key driver for the implementation of a C-NGN.

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[4] MSO - multiple service operator, or an operator of multiple cable or satellite television systems

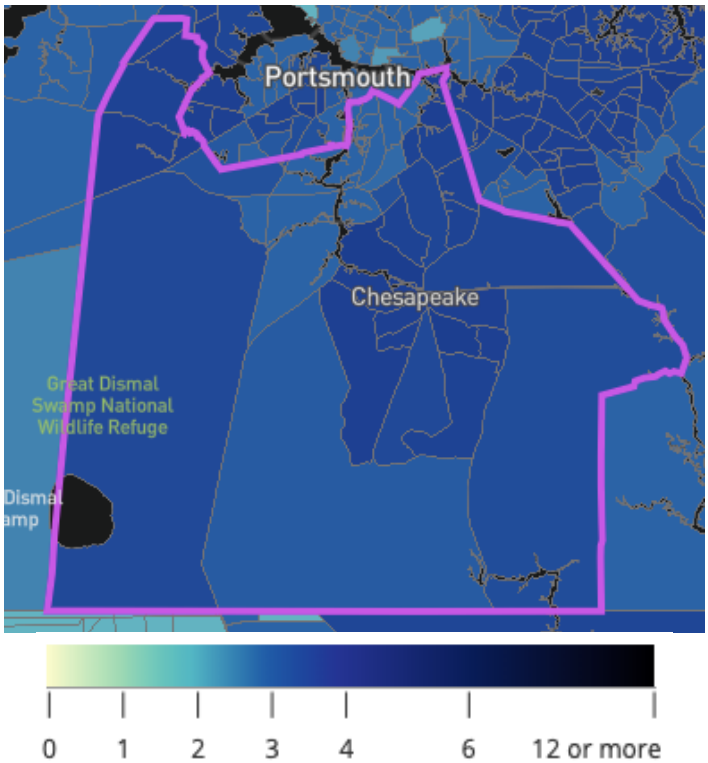
[5] Tier 1 - a carrier that owns a significant portion of the network infrastructure and is able to offer competitive service level agreements.

[6] Tier 2 – a carrier that engages in peering with other operators or purchases IP transit to reach some portions of the network.

[7] https://www.cox.com/

[8] https://www.verizon.com/

[9] The Federal Communications Commission defines broadband as having minimum 25 Mbps download, from the internet to the subscriber's device, and 3 Mbps upload speeds. See https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2018-broadband-deployment-report



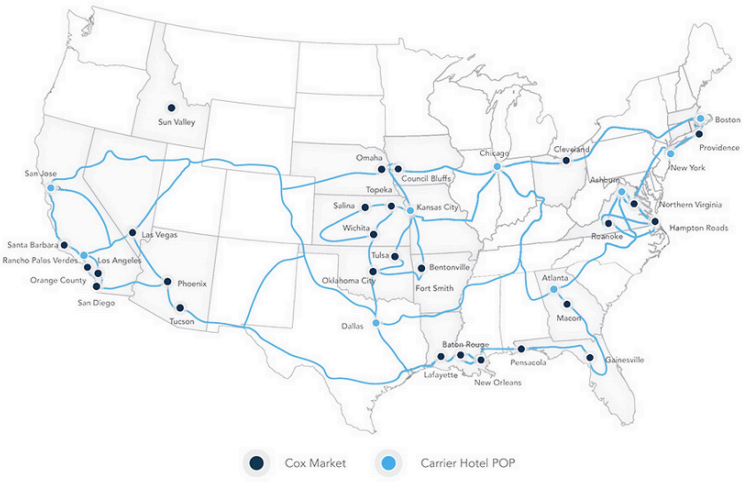
App 1 Figure 5: Number of providers in the Chesapeake area[10]

1. Network Service Providers

Cox Communications

Cox is a former cable television multi-system operator that added internet access and then evolved into a full-service telecommunications company. It is a subsidiary of Cox Enterprises, a privately held company headquartered in Atlanta, GA. Today Cox operates a nationwide fiber-optic backbone (See App 1 Figure 6), and provides local services in nearly thirty markets, interconnecting

[10] Source: Federal Communications Commission, Fixed Broadband Deployment, https://broadbandmap.fcc.gov/#/area-summary?version=jun2019&type=county&geoid=51550&tech=acfosw&speed=25_3&vlat=36.70864606744732&vlon=-76.2785245&vzoom=8.478222254083972



App 1 Figure 1: Cox Communications backbone network

through eight Tier 1 internet interconnection points (see App 1 Table 1). Cox covers approximately 91%[11] of the City of Chesapeake with speeds topping out at 300 Mbps.

Cox's business broadband service ranges from 120 megabits per second (Mbps) total throughput[12] (100 Mbps down and 20 Mbps up) for $79.99 per month to 330 Mbps of throughput for $104.99 per month. Discounts up to 31% are available with a two- or three-year contract for 100 or 200 megabit download service. No discounts are offered for the 300 megabit download service. Business subscribers pay Cox about $1.60 or more per Mbps per month. Cox's average commercial offering is about 220 Mbps for $330 per month ($104.99 with the discount) per month. Enterprise solutions are available on a case-by-case basis through consultation with sales. Cox's generally advertised rates in November 2019 are as follows:

App 1 Table 1: COX Business Advertised Rates

Address	Packages	Speeds	Price per month
1416 Kellan Dr. B 23320	COX Business Internet 100- 1 yr contract	100/20M	$290/m
		100/20M	$79.99/m
	COX Business Internet 100 – 2 or 3 yr contract	200/20M	$330/m
		200/20M	$104.99/m
	COX Business 200 – 1 yr contract	300/30M	$144.99/m

[11] According to www.broadbandnow.com

[12] Throughput: the amount of data that enters and goes through the system (download plus upload speeds)

Address	Packages	Speeds	Price per month
	COX Business 200 – 2 or 3 yr contract COX Business 300 - 2 or 3 yr contract (no 1 yr offer)		
1103 S Military Hwy 23320	Same as Above		
501 Discovery Dr 23320	Same as Above		
4868 Bridge Dr 23321	Same as Above		
2434 Gum Rd 23321	Same as Above		
237 Hanbury Rd E Ste 17 23322	Same as Above		
3970 Cornland Rd 23322	Service Not Available	NA	$75,000 to connect

In August of 2019, a resident in the southern portion of Chesapeake (the Cornland Road area) contacted the City Attorney's office to discuss Cox's inability to provide service to that area. The southern portion of Chesapeake is rural agriculture with a low population density compared to the more urban north. Twelve families in that area banded together to get a quote from Cox on getting cable built to their homes. Cox quoted the families $75,318.96, or roughly $6,300 per household to get service to them. The resident who was spearheading this campaign began inquiring to the City about grant opportunities that they might look into, as they would not be able to afford the $6,300 per family.

This anecdote shows the pent-up demand and tremendous barriers to broadband in the area. Research suggests[13] that bringing high-speed broadband to these homes and potential businesses could stimulate the economy in the southern area of Chesapeake. The City cannot provide retail services to these homes and businesses directly but desires to encourage broadband expansion and competition within the service provider community to support economic

[13] As examples, see https://muninetworks.org/content/municipal-networks-and-economic-development, https://www.sciencedirect.com/science/article/pii/S0743016717312615, and https://sngroup.com/broadband-for-your-community-vitality/"

development for the rural areas of Chesapeake. Indeed, we expect it to be essential for development in the area.

Verizon

Formed out of the "Baby Bell" telephone companies and early cellular telephone companies, Verizon is one of the few remaining traditional local exchange carriers. Although primarily known for Verizon Wireless, the company provides a full range of telecommunications services, including broadband. An early entrant into fiber-based broadband with its FiOS service, Verizon sold much of its local wireline network a decade ago. It continues to provide local wireline services throughout the mid-Atlantic states, separate from its nationwide Wireless division. Verizon owns global fiber-optic network assets, most recently acquiring enterprise network operator XO Communications, and major internet assets including AOL and Yahoo! It is headquartered in New York City.

Verizon provides two types of broadband in the area: slower digital subscriber line (DSL) service that runs over telephone wires and FiOS fiber-optic service. Verizon DSL services cover 100% of the City, with the fastest speeds reported being 15 Mbps; conversely, Verizon FiOS covers approximately 87%[14] of the City with the fastest speeds offered at 940 Mbps. The average FiOS offering is practically a gigabit per second (940 Mbps) with prices starting at a monthly price of $214.99. This is by far the most economical service because it only costs about $0.12 per month for a Mbps of throughput, about a one-tenth of the monthly cost for a Mbps from Cox.

Verizon "High Speed Internet" service, on the other hand, has the slowest speed, from 1 Mbps to 3 Mbps, which means this service does not meet the FCC's technical definition of broadband. The fastest offered upload speed is 3 Mbps. This service also has the highest per Mbps cost at $14.33 per Mbps per month for business service. Verizon's generally advertised business packages in November 2019 are detailed in App 1 Table 2.

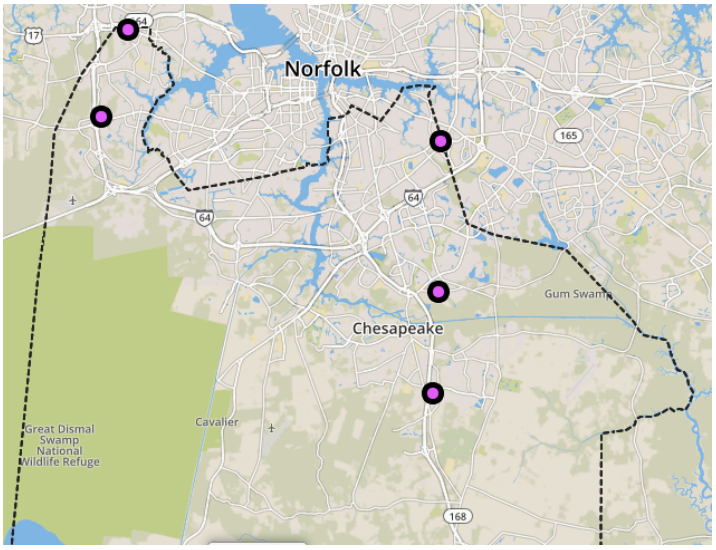
[14] According to www.broadbandnow.com

App 1 Table 2: Verizon Advertised Rates

Address	Package	Speed	Prices
1416 Kellan Dr. B 23320	Phone Only No Internet	NA	NA
1103 S Military Hwy 23320	Fios Business Internet - 2 year agreement.	75/75M	$79.99/mo. + taxes, and Router fee
501 Discovery Dr. 23320	Fios Business Internet - 2 year agreement.	150/150M	$109.99/mo. + taxes
4868 Bridge Rd 23321	Fios Business Internet - 2 year agreement	300/300M	$184.99/mo. + taxes
	Fios Business Internet - 2 year agreement	500/500M	$214.99/mo. + taxes
	Fios Business Internet Gigabit Connection - 2 year agreement	940/880M	$214.99/mo. + taxes
2434 Gum Rd 23321	No Service Available	NA	NA
237 Hanbury Rd E Ste 12 23321	Fios Business Internet - 2 year agreement.	75/75M	$79.99/mo. + taxes, and Router fee
	Fios Business Internet - 2 year agreement.	150/150M	$109.99/mo. + taxes
	Fios Business Internet - 2 year agreement	300/300M	$184.99/mo. + taxes
	Fios Business Internet - 2 year agreement	500/500M	$214.99/mo. + taxes
	Fios Business Internet Gigabit Connection - 2 year agreement	940/880M	$214.99/mo. + taxes
3970 Cornland Road 23322	Phone Service Only	NA	NA

2. Other Retail Providers

There are a number of retail business and enterprise providers that nominally offer services in Chesapeake. These include Fusion, Mediacom, CenturyLink, gtt, and Crown Castle. However, each of these providers have 10% or less of the market in Chesapeake. When Magellan conducted the market study, Fusion provided services to each of the five (5) addresses inquired for (detailed in App 1 Table 3 below), some with fiber services. Magellan did not search for pricing for any other provider as the majority of the companies' share of the market was well below 10%.



App 1 Figure 2: Map of Five(5) Addresses Researched

App 1 Table 3: Fusion Advertised Rates

Address	Package	Speed	Prices
1103 S Military Hwy 23320	Broadband Business Fiber, Standard Ethernet	150/150M	$169/m
	Broadband Business Fiber, Standard Ethernet	300/300M	$109.99/mo. + taxes
	Broadband Business Fiber, Standard Ethernet	300/300M	$184.99/mo. + taxes
	Fios Business Internet - 2 year agreement	500/500M	$214.99/mo. + taxes

Address	Package	Speed	Prices
	100 Mb Ethernet, Hi Cap Ethernet	100/100M	$2,346 12m contract $2,277 24m contract $2,253 36m contract
	200 Mb Ethernet, Hi Cap Ethernet	200/200M	$2,716 12m contract $2,647 24m contract $2,623 36m contract
501 Discovery Dr. 23320	100 Mb Ethernet, Hi Cap Ethernet	100/100M	$2,346 12m contract $2,277 24m contract $2,253 36m contract
	200 Mb Ethernet, Hi Cap Ethernet	200/200M	$2,716 12m contract $2,647 24m contract $2,623 36m contract
	T1 1.5 (ESA)	1.5/1.5M	$711.00 12 m contract $624.00 24 m contract $595.00 36 m contract

Address	Package	Speed	Prices
3587 Forest Haven Ln 23321	Dedicated ADSL	6M/768K	$80/m for 12/24/36 m contracts
	Broadband Business Fiber 25/25 Static	25/25M	$85/m for 12/24/36 m contracts
	Broadband Business Fiber 50/50 Static		$97/m for 12/24/36 m contracts
	Broadband Business Fiber 75/75 Static	75/75M	$119/m for 12/24/36 m contracts
	Broadband Business Fiber 150/150 Static	150/150M	$169/m for 12/24/36 m contracts
	Broadband Business Fiber 300/300 Static	300/300M	$299/m for 12/24/36 m contracts
2434 Gum Rd 23321	Business Cable 100/20 Static	100/20M	$430 12/24/36 m contract
	Business Cable 200/20 Static	200/20M	$640 12/24/36 m contract
	Business Cable 300/20 Static	300/30M	$750 12/24/36 m contract
	100 Mb Ethernet (ESA)	100/100M	$2,346 12m contract $2,277 24m contract $2,253 36m contract
	200 Mb Ethernet (ESA)	200/200M	$2,757 12m contract

Address	Package	Speed	Prices
			$2,687 24m contract $2,664 36m contract
	T1 1.5	1.5/1.5M	$741 12/24/36m contract
237 Hanbury Rd E 23322	Business Cable 100/20 Static	100/20M	$430 12/24/36 m contract
	Business Cable 200/20 Static	200/20M	$640 12/24/36 m contract
	Business Cable 300/20 Static	300/30M	$750 12/24/36 m contract
	100 Mb Ethernet (ESA)	100/100M	$2,346 12m contract $2,277 24m contract $2,253 36m contract
	200 Mb Ethernet (ESA)	200/200M	$2,757 12m contract $2,687 24m contract $2,664 36m contract

**(to determine exactly where these providers offer services, we randomly chose geographically diverse locations)

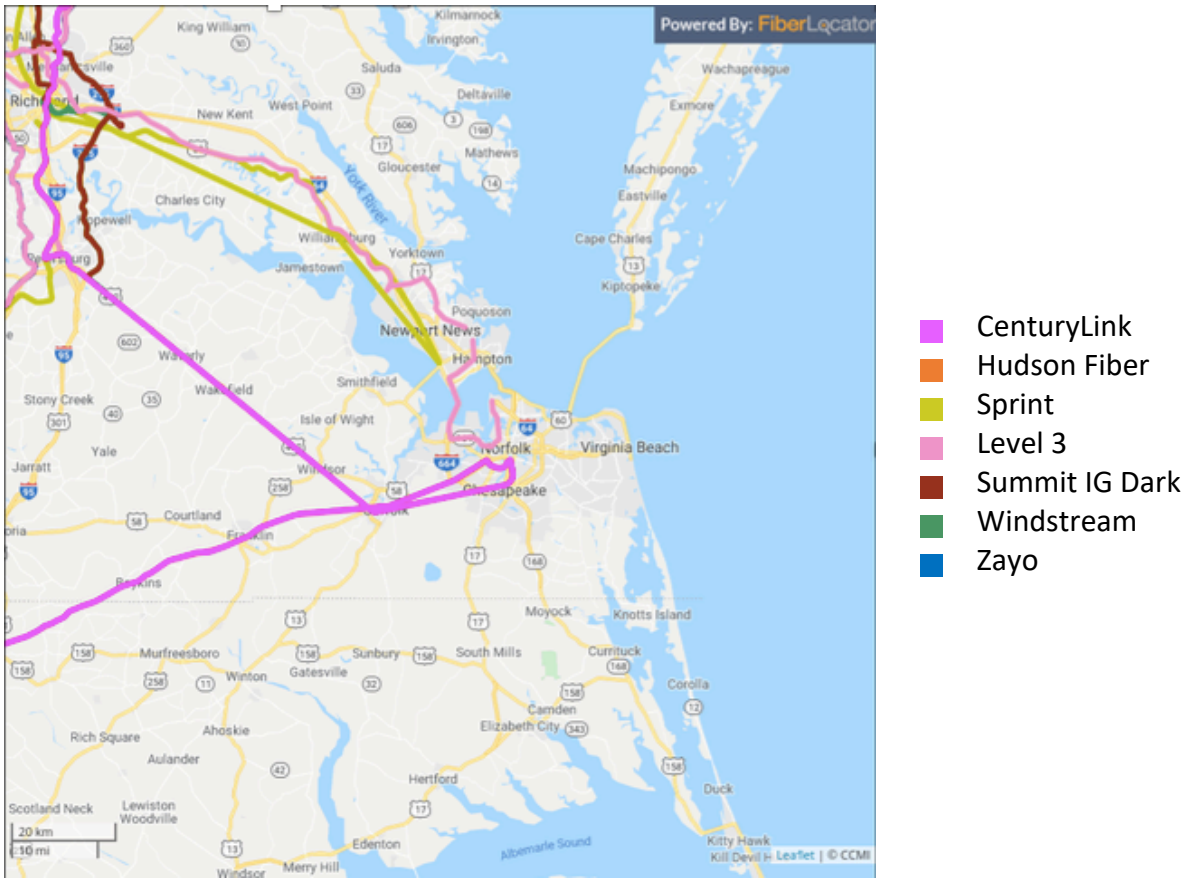
3. Other Providers and Network assets

There are multiple companies with network assets in and around Hampton Roads. These include regional "middle-mile" networks that connect local networks, as well as national and international "long-haul" networks that pass through the area. Several of these providers are regionally focused. Some provide IP transport and enterprise network services and some lease dark fiber that users must light and

manage. There are also a number of wireless service providers and data center operators.

Middle-mile and long-haul networks

As shown in App 1 Figure 7, CenturyLink[15] has long-haul networks passing through the area, in addition to Cox and Verizon's "backhaul" connection from their local networks to their core "backbone" network. These are major local wireline and wireless service companies, although they do not provide retail broadband.



App 1 Figure 6: Long-haul network routes in the Hampton Roads region

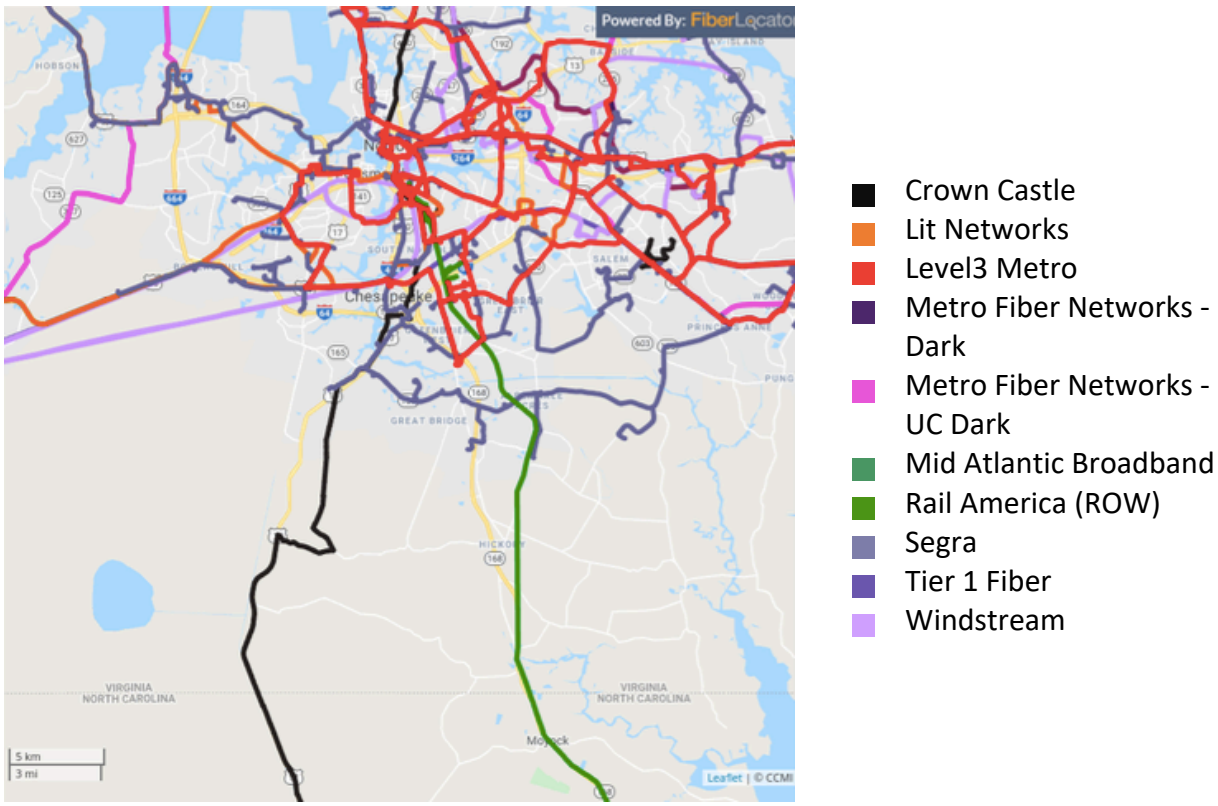
Middle-mile networks, mapped in App 1 Figure 8[16], interconnect metropolitan areas, sites within them, and, in some cases, rural areas. CenturyLink/Level3 and Windstream[17] are full-range network service providers, like Cox and Verizon, but do

[15] http://www.centurylink.com/

[16] Source: FiberLocator, https://www.fiberlocator.com/

[17] https://www.windstream.com/

not provide retail broadband in the area. Crown Castle[18] is similar but does not provide any broadband. LIT Networks[19] and Mid-Atlantic Broadband[20] are both regional partnerships of multiple independent local broadband providers and both networks reach into rural areas across the southeast. Mid-Atlantic has an explicit economic development mission. Metro Fiber Networks[21] is a subsidiary of a national tech company. Note that Metro Fiber has two essentially separate networks in the area.



App 1 Figure 7: Metro and middle-mile network routes in the Hampton Roads region

[18] http://www.crowncastle.com/

[19] https://www.litnetworks.com/

[20] https://mbc-va.com/

[21] https://metrofibernetworks.com/

Cellular wireless services

Cellular services use licensed spectrum that is ideal for mobile connectivity. Antenna are mounted on towers and are contained in subscriber devices. As subscribers move, their wireless signals hand-off from one cell to the next. Some of the spectrum is used for voice, some for data and internet access. Speeds are nominally as fast as 12 Mbps (from Verizon) but speeds depend on numerous factors, including distance between antenna, number of subscribers in the cell, and weather. Services rarely achieve even a quarter of their nominal speed for sustained periods. And, of course, cellular data services come with data caps.

Regardless, cellular is how many people access the internet, and it's faster than most of Verizon's "High Speed" wired internet access service. For example, AT&T's $30 service nominally costs $3 per Mbps of throughput per month, with a 10 Gb cap, while Verizon's $150 service is $12.50 per Mbps per month for a 40 Gb cap, although Verizon also offers more economical services. Sprint and T-Mobile services costs and data allowances fall between AT&T and Verizon. On average, cellular internet costs a total of $73.50 per month for 10 Mbps of throughput with a 20 Gb data allowance.

VITA Contract

As municipal entities, the City, Schools, and Libraries have access to the VITA computing and telecommunication services contracts. Chesapeake DIT, Libraries, and Public Schools currently purchase broadband services from Cox Business and Segra, both being approved VITA contractual providers. Other approved service providers are available based on zip code, although Cox currently has the broadest availability of high-speed connectivity. App 1 Table 4 provides examples of the VITA fiber-based contract service tiers and pricing on services similar to those currently purchased by the City.

App 1 Table 4: VITA Pricing for Fiber to the Premise Tiers 11 and 16 (Internet)

Package	Speeds	Price
Segra- 3 yr term	1 Gbps / 1 Gbps	$4,090/m
Cox - 3 yr term	1 Gbps / 1 Gbps	$3,500/m
Segra - 3 yr term	10 Gbps / 10 Gbps	$29,400/m
Cox - 3 yr term	10 Gbps / 10 Gbps	$17,500/m

4. Broadband Infrastructure Activities

There is a tremendous amount of broadband infrastructure activity taking place throughout the Hampton Roads region. The municipalities of Virginia Beach and Norfolk have substantial municipal fiber networks in place, while Portsmouth is in the midst of a 65+ mile backbone buildout. These municipal networks connect each city's facilities, schools, other community anchors/partners, and areas of interest like economic development zones. These local public investments are soon to be further enhanced through the deployment of the Hampton Roads Regional Connectivity Ring (RCR), connecting each South Hampton Roads city to one another, and beyond to regional data centers, national/international networks, and the new Digital Port taking shape in Virginia Beach. This interconnection is a huge boost to each City and should drastically change the economy of the region.

Private providers are investing in infrastructure to access the Digital Port. While these networks may pass through the area, it is unlikely the companies will have local access points without burgeoning local demand for their services. Chesapeake has multiple relatively large tracts of land that could accommodate data centers and other facilities requiring high-capacity, low-latency connections but providers generally do not deploy infrastructure to meet nonexistent needs. The providers want superhighways to get through the area, but they won't want offramps until there are customers ready to buy big pipes. If and when more big data users emerge or move to the area, providers will deploy access infrastructure. The City of Chesapeake can invest in infrastructure ahead of demand and then capitalize on growth by leasing capacity to providers or end-users. Otherwise, the City can expect local infrastructure development only after the local demand for connectivity increases.

C. Stakeholder Engagement

Magellan Advisors conducted extensive information gathering, including interviewing numerous City officials and multiple external stakeholders in researching network infrastructure and services. The stakeholders engaged in this process included:

- Chesapeake Alliance
- Chesapeake Public Schools
- Chesapeake Regional Healthcare
- City of Chesapeake
  - Agriculture Department
  - Chesapeake Integrated Behavioral Healthcare (CIBH)
  - City Attorney
  - City Council
  - City Manager
  - Development and Permits
  - Economic Development
  - Fire Department
  - Health Department

    - Information Technology Department
    - Libraries and Research Services
    - Parks, Recreation, and Tourism Department
    - Police Department
    - Public Utilities Department
        - Chesapeake Water
    - Public Works Department
        - Traffic Engineering and Management
    - Purchasing and Procurement
    - Sheriff's Office
- Hampton Roads Chamber of Commerce
- Hampton Roads Planning District Commission
- Local agricultural producers (via Agricultural Department)
- Network Service Providers
    - AT&T
    - Broadband Telecom
    - CAS Severn
    - CenturyLink
    - Cox
    - Crown Castle
    - EX2
    - MBC
    - Metro Fiber
    - Peak1Fiber/Tier1Fiber
    - Segra
    - South Bay Communications
    - Tenebris
    - Verizon

D. Gap Analysis

There are four general gaps with Chesapeake's broadband environment, all of which are rooted in limited infrastructure:

1. *Options for network services are limited.* While Chesapeake's local market is comparable to most other cities, the area has fewer options and higher costs for connectivity than places with direct public investment in broadband. This gap means that Chesapeake and its residents are at a competitive disadvantage. Cox and Verizon have no reason to invest in the area, particularly concerning the other areas they serve. Cities that have better, cheaper, faster broadband generally have it because of local public investment.
2. *City facilities lack adequate broadband connectivity.* While access to high-speed services is available, adequately provisioning city facilities with additional or faster connections is prohibitively expensive. The lack of adequate broadband connectivity at city facilities limits the City's ability to leverage new technologies and improve services. Unless the City solves its connectivity issues, the City services will suffer and fall increasingly behind its peers.
3. *There has been limited investment in network infrastructure, especially* from new market entrants. The upfront capital requirements for new service

providers to enter Chesapeake are high and certainty about market demand is low. The dominant incumbent providers control most private telecommunications assets and are highly motivated to maintain their dominance by limiting access and new competition.

4. *Existing infrastructure and services are geographically uneven across the Chesapeake with underserved and unserved areas.* The northern, more populated, sections of Chesapeake mostly have broadband services with some areas having multiple providers. The less populated, southern portion of the city and areas with lower incomes are either underserved or unserved creating a significant digital divide. This divide leads to disparities in economic growth, education, health care, and quality of life.

Although numerous fiber routes run through the northern portion of the City, there is not a true multi-provider competitive environment for broadband. While significant gaps of service are not apparent in the North, the area would benefit from an increase in competition by bringing more options for service to control or drive down prices and to ensure satisfactory performance and customer service.

The rural nature of Southern Chesapeake is evident in its broadband service gaps. In the Southern Chesapeake region infrastructure is lacking, and services are simply not available. Population density is scarce in the south, so access is impacted by a lack of business case to deploy in these areas.

1. Issues Related to Inter-Exchange Point (IXP) Connections

The City has traditionally procured all internet and private data services from higher-cost incumbent service providers due to the lack of access to alternative service providers and peering collocation in nearby data centers. With the recent fiber and data center activity generated by the subsea cable landings, and the surrounding local fiber builds touching the Chesapeake city limits, the City is well-positioned to benefit from the expanding access opportunities. New network providers such as Segra and Tier 1 Fiber are building facilities in the Hampton Roads region, and new carrier-neutral data centers have located in the cities of Virginia Beach and Norfolk. Options for dark fiber swap/lease with these new providers and the surrounding cities will allow the City low-cost access to IP transit, cloud services, and collocation facilities within the Hampton Roads, greater Richmond, and Ashburn area.

2. Wireless Gap – Silos in the Technologies Being Deployed

The City currently suffers from two critical gaps in wireless service access: siloes of municipal telemetry and control networks and the lack of commercial mobile wireless voice and high-speed data coverage in South Chesapeake. The first gap directly impacts City operations, while the second directly impacts consumers as well. The C-NGN directly addresses the first gap and could be used to address the second, generating revenue from leasing assets for providers to use in the process.

Wireless municipal telemetry and control infrastructure has traditionally been deployed to meet specific departmental needs using vendor-proprietary solutions. This approach has resulted in technology silos with severe limits on opportunities to share the wireless network infrastructure with other applications. Wireless network technology has evolved in ways similar to wired technologies like Ethernet, where a single standardized infrastructure and set of protocols can support a variety of applications. For the City to get a common wireless infrastructure and applications, it will need radio spectrum and standard protocols that support both existing and new applications.

The lack of commercial mobile wireless voice and high-speed data coverage in South Chesapeake presents a particularly difficult gap to fill simply due to the fact mobile radio access networks are prohibitively expensive to deploy for private use. The cost of towers, fiber backhaul, and mobile packet core equipment generally prohibit small municipal deployments..

3. Closing the Gaps

The Master Plan provides a roadmap for closing Chesapeake's network gaps. Existing vendors must be engaged to determine their technology roadmaps and compatible solutions. Changes to existing applications and capital requirements for migration to the new wireless networks will need to be identified and planned. Application research and procurement processes must incorporate the new standards as a requirement for vendor consideration. Opportunities to lease dark fiber to commercial mobile wireless carriers may provide the incentive necessary for them to deploy additional LTE facilities in the South Chesapeake area.

The next phase for C-NGN is a low-level network design that can be deployed by the City and its partners and scaled to thousands of connections. Such an approach addresses multiple gaps very economically by accommodating as many public and private uses as possible and thereby generating the greatest overall benefits at the

lowest aggregate costs. The network design will show how the C-NGN could fill gaps in both the north and south areas of Chesapeake, offering a new, more competitively priced middle-mile and distribution fiber network in all areas of the City, and wireless vertical assets to support a multitude of wireless deployments across Chesapeake.

4. Assessment of Planned Infrastructure Projects

This sub-section assesses the gaps and opportunities that a C-NGN will produce for Chesapeake to address the needs and goals of the City, Schools, and Libraries, enhance economic development, and support the community and its anchors. It considers short, mid, and long-term opportunities and which investments will deliver these returns. This information enables City leadership to understand exactly how their investments can bring returns to the City both through on-balance sheet, financial gains, as well as off-balance sheet, or "positive social outcome" returns, as seen in the examples of similar cities above.

The Chesapeake City network, like most municipal networks, has developed ad hoc overtime with a primary focus on meeting known departmental requirements and operational needs. This mode of growth typically results in longer-term challenges to strategic network development in areas of equipment refresh, documentation accuracy, scaling and reliability, and proactive management.

The DIT is aware of its current challenges and has made good use of capital and operating resources to mitigate the impact of them as much as possible within its legacy operating environment. Staff's concern now is how to continue these efforts in a way that will best dovetail with the strategic C-NGN implementation. In support of their effort, Magellan Advisors interviewed DIT, School and Library staff to assess their respective operations and networks to help clarify these challenges to C-NGN implementation and to recommend "low hanging fruit" opportunities to work toward resolution of the challenges in a way that will dovetail with the C-NGN.

Due to the security requirements of critical municipal infrastructure such as data networks, and the detailed network configurations involved in the challenges and opportunities, this information will be provided in a separate technical memo.

Short-term Opportunities

There are a few "low-hanging fruit" opportunities that can be performed in parallel with the C-NGN development and will provide both immediate and long-term benefits. Unfortunately, these do not directly enhance operations or services but set the stage. The City has multi-year capital funding for network infrastructure upgrades, which if planned and targeted properly, can prepare sites for connection to the future C-NGN implementation by replacing obsolete equipment and reducing high-risk layer 1/2 architectures. This in turn will also prepare the City network for future connection to the C-NGN and regional ring. Equipment with sub-GigE network interfaces and unprotected or cascaded switch uplinks should be targeted for reconfiguration and replacement.

Additionally, DIT can work to get its operational capabilities in order, in preparation for deployment and operations of the C-NGN. There will be several decisions that must be made, and processes and governance established to support the C-NGN and the service level agreements that will be necessary to sustain the network. The City will need to structure, staff, and train an Operations Team to run the C-NGN, before full completion of its deployment. The City will also need to focus on implementing a regulatory and governance framework that is supportive of its own broadband deployment while incentivizing greater private investment. Updating of its policies, municipal code, and other supporting legislation can not only reduce the cost of the City's build but can be advantageous to all providers operating in the region.

Mid-term Opportunities

Mid-term opportunities, over the next one to three years, are primarily related to enhancing services and operations while reducing costs. The general opportunity is to replace relatively costly private services with lower cost, higher performance connections via C-NGN. Any network investment will be phased by geography or type of user. Therefore, the specific opportunities over the mid-term will drive or follow the network as its deployed. For example, a starting point might be providing back-up internet access to a few key sites via dedicated fiber, or it might be upgrading connections to sites around the municipal campus. The mid-term opportunities will be determined by events such as contracts sunsetting or other infrastructure being built. The C-NGN should be planned around those to get early wins while minimizing deployment costs.

The other mid-term opportunity is to engage stakeholders in identifying and pursuing long-term opportunities, which can be done in conjunction with planning short-term opportunities. For example, a discussion with school leaders about

replacing obsolete or non-standard equipment should also address strategic issues such as how to keep students engaged in learning, provide after-hours access for schoolwork, and bring local industry professionals into the classroom. Engagement with additional external public stakeholders can also work to identify other opportunities to expand the C-NGN. All these things can be accomplished via the network if they are planned carefully and the network is integrated into other strategic plans.

Long-term Opportunities

Most opportunities for the C-NGN to enhance operations and services are long-term simply because the network has to exist before it can positively impact users. Generally, the opportunities are to replace expensive hosted software with cloud-based systems, make operations more flexible and resilient, and push actual work and decisions off to users. For example, tax software currently runs on a mainframe. The long-term opportunity is not just to replace that software, it's to make it easier for residents to manage their tax bills and stay up to date, along with other City-related information like utilities and solid waste. The network provides the platform for such enhancements, but it does not directly accomplish them. Smart City initiatives and other IoT components can be deployed throughout the City, where the network exists, further supporting the City's long-term goals as it relates to expanded automation, surveillance, and other telemetry style applications.

Long-term opportunities depend on engaging key decision-makers in discussion about how, where, and why to use the network.

5. Key Issues Limiting Broadband Infrastructure Expansion

There are several issues limiting broadband expansion across the City. Some are external to the City itself; others relate directly to City practices. This sub-section lays out these issues in roughly priority order with the most critical or largest issues first. The disconnect between internal practices and external resources is itself an over-arching issue. The City of Chesapeake, like so many cities, has focused on departmental operations and not considered how those operations align with each other let alone with opportunities and requirements beyond those operations. Our general recommendation is for City leaders to take a more comprehensive, strategic approach to resolve this issue, including rethinking technology spending as an investment that can be leveraged for broader community outcomes.

There are multiple barriers to broadband development in Chesapeake, starting with the fact that there are currently no clear economic reasons for existing providers to invest. To resolve this issue the City could either to (a) pay existing providers to expand their infrastructure and services so they don't have to invest or (b) reduce barriers to entry by providing access to public infrastructure and promoting new investments. Chesapeake is relatively large geographically with extensive infrastructure, natural features, and rural areas that create challenges for deploying network infrastructure. Like any municipality, Chesapeake has limited right-of-way, which could result in conflicts and duplication of efforts in deploying infrastructure. A structured, methodical, and comprehensive approach can overcome challenges for everyone while making optimal use of limited space.

Requirements of stakeholders outside the City, Libraries, and Schools can complicate internal broadband expansion. For example, Chesapeake Public Schools can't fully capitalize on modern online learning resources if all students don't have good access at home. The City, Schools, and Libraries currently spend substantial amounts of money to buy services in an uncoordinated manner. Parallel but separate, siloed "solutions" can undermine more comprehensive, cost-effective approaches. A significant portion of the spending was for legacy systems that are very expensive to maintain. None of this spending was going to building anything of lasting value that community members could use. These issues can be resolved by creating a carrier-class network that can accommodate next-generation solutions for the City and be used by private companies to provide broadband for the community.

One way to resolve these issues is to have a cross-functional team collaborating on and providing oversight for all public technology. This is a fundamental recommendation for technology governance because it identifies additional opportunities for value creation even as it minimizes costs and duplication of efforts. This issue can also be addressed via a practice of accommodating as many applications and services as possible over the C-NGN. Having access to a citywide fiber network would allow Chesapeake to use its own assets to support Smart City technologies, saving countless dollars that might otherwise be paid to third parties and allowing for greater control over Smart City systems.

6. An Inventory and Assessment of Current and Planned Infrastructure Projects

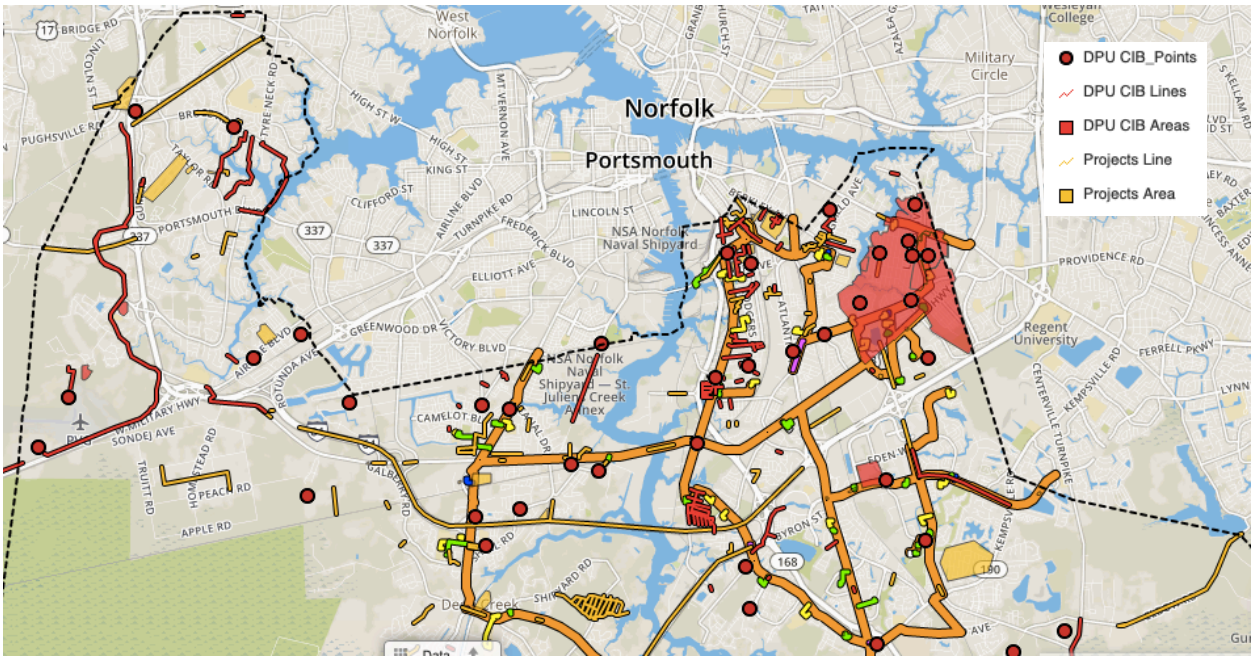
As a local government, the City of Chesapeake has a broad swath of area under its management with tremendous community assets deployed. These assets include water/wastewater assets, extensive street networks, and their associated capital projects, as well as major development opportunities. The development opportunities will provide greenfield deployment options to the City to further its deployment of telecom infrastructure. The City must find ways to capitalize on these projects and opportunities and use joint trench/dig-once efforts to realize significant network deployment cost savings.

Capital projects have been identified throughout the City of Chesapeake, shown in App 1 Figure 9, using its Capital Project GIS data that was made available. The goal is to identify potential projects that may overlap and provide cost savings to the deployment of the C-NGN fiber-optic network. These complimentary projects would need to overlap in funding/construction years and be at a stage where the City's future fiber design standards can be applied to the other project's design. App 1 Table 5 provides a basic analysis of the number of projects and their status.

App 1 Table 5: Chesapeake CIP Projects/Status

	Project Status					
Project Type	*Completed*	*In Design*	*Under Construction*	*Future Project*	*Unfunded*	*Unfunded - Critical*
Stormwater	11	26	9	12	29	4
Transportation	20	26	8	3	0	0

	Project Status								
Project Type	*Complete*	*Construction*	*Design - 100%*	*Design - 90%*	*Design - 75%*	*Design - 60%*	*Design - 30%*	*Future*	*PER*
Sewer	27	3	3	3	0	2	1	4	1
Water	8	3	3	0	1	0	2	2	1
Water/Sewer	1	3	1	0	0	0	0	0	2



App 1 Figure 8: Capital Improvement Projects

The following project types could provide benefit and cost savings to the C-NGN deployment:

- New Road Construction or Widenings
- Underground Utility Extensions (public or private)
- Sidewalk/Multi-Use Path Construction
- Bridge Construction or Significant Rehab
- Utility Subaqueous Crossings
- Private Development Projects
- Public Development Projects or
- State Highway or Transit Projects
- Stormwater Projects
- Private Telecommunications Projects

The City's Public Utilities alone is modifying and upgrading several components of its production and recovery infrastructure. Work was to be done on both the Lake Gaston and Norwest River Water Treatment Plants (WTP), as well as elevated tanks (Cavalier, Western Branch, and Oak Grove) and sewer pump stations. There are numerous plans to renew and upgrade horizontal assets (pipes in the ground), including the following locales:

- 18th Street
- Cedar Road
- Chesapeake Avenue (Guerriere to Ohio)
- Dominion Boulevard and I-64
- Elbyrne Drive
- Greenbrier Parkway
- Indian River Service Area
- Joliff Road
- Liberty Street (500 Block to Collingswood Avenue)
- Military Highway
- Murray Drive and Whittamore Road
- Raleigh Place (Pump Station #7 Basin)

- Volvo Parkway & Executive Boulevard

Public Works has numerous projects in Stormwater and Transportation as well. Stormwater is rehabilitating its system citywide and improving drainage and outfalls all around the City. Transportation is also improving and upgrading streets, sidewalks, intersections, and bridges throughout the City.

More generally, the City of Chesapeake has a full slate of infrastructure projects planned for the near future. All of these will be considered in relation to planned network routes and development phasing to minimize capital requirements and costs.

Appendix 2 – Network Design

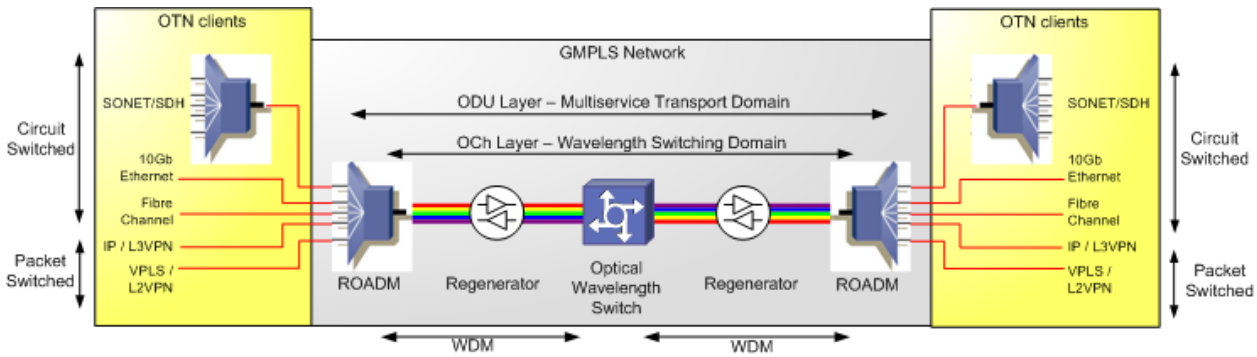
The C-NGN is comprised of a fiber-optic transport network overlaid by wireless access networks, all of which are integrated to provide a range of functions or services. The fiber-optic network consists of a backbone, which traverses the City, and laterals, which connect specific sites to the backbone, including wireless network components located on towers. The City's five current wide area networks (WANs) will operate over the fiber network. The wireless overlay is three physically separate networks operating in 700 MHz, 902-928 MHz, and 4.9 GHz radio spectrum bands, adding a wireless WAN (WWAN) for the City and providing multiple, flexible ways to access the network(s). This document provides technical details of the C-NGN design and construction. For a summary description of the network's architecture, see the C-NGN Master Plan document.

A. C-NGN Fiber Optic Backbone and Laterals

The C-NGN transport requirements gathered from onsite interviews can be summarized as follows:

- High capacity and bandwidth with low end-to-end latency
- Sub-second failover of services from fiber cuts
- Support for multiple 100Gbps services on a single pair of fibers
- Extension of the network to underserved south Chesapeake
- Future support of regional ring and third-party service providers

These requirements indicate an optical transport network (OTN) solution using Wavelength Division Multiplexing (WDM), illustrated in App 2 Figure 1, to carry multiple wavelengths on the same fiber pairs. Reconfigurable optical add/drop multiplexers (ROADM's) insert and remove data streams from individual wavelengths and services. In addition, distances over 100 kilometers can be traversed without the use of optical amplifiers.



App 2 Figure 1: Optical Network Architecture

OTN wavelengths can be protected such that the path they travel will automatically switch in the event of a cable failure to a backup path. This path switching takes place in under 50 milliseconds and is transparent to the payloads being carried by the wavelength. This allows high capacity data and latency-sensitive services to be rerouted without the delay inherent in OSI Layer 3 re-convergence of routing protocols. Optical transport networks (OTN) reside within the Open Standards Interconnect (OSI) reference model at Layer 1 (see App 2 Figure 2).

OSI model				
Layer			Protocol data unit (PDU)	Function[6]
Host layers	7	Application	Data	High-level APIs, including resource sharing, remote file access
	6	Presentation		Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption
	5	Session		Managing communication sessions, i.e., continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes
	4	Transport	Segment, Datagram	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing
Media layers	3	Network	Packet	Structuring and managing a multi-node network, including addressing, routing and traffic control
	2	Data link	Frame	Reliable transmission of data frames between two nodes connected by a physical layer
	1	Physical	Symbol	Transmission and reception of raw bit streams over a physical medium

App 2 Figure 2: OSI Model

1. Design Assumptions

The following design assumptions were derived from the requirements gathered during the onsite meetings and used to develop a technical solution for the OTN:

- Protected optical transport ring supporting multiple wavelengths
- Add/drop of services between C-NGN transport nodes
- Support for add/drop of services with future Regional Connectivity Ring (RCR)
- Support for capacity leasing to third parties

There are several key design considerations and assumptions that are used to develop the C-NGN Fiber OSP (Outside Plant) network, they include:

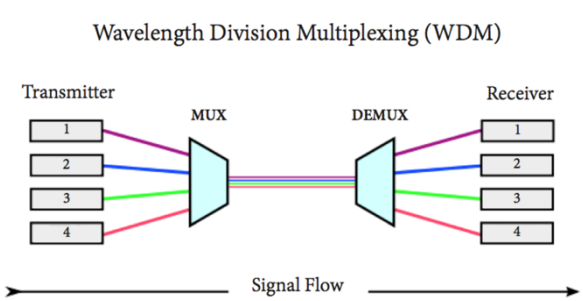
Fiber Backbone Assumptions

- 100% underground deployment of all backbone segments
- 36” buried depth
- (3) 2” conduits HDPE
- 432-count single-mode fiber
- Handhole spacing every 600’
- Handhole sizing is 30” x 48” x 36”
- No rock will be encountered – noted from area experience
- Straight splice every 3,000’
- All splicing will be fusion splicing and tested bi-directionally with OTDR and Power Meter

The planned backbone will incorporate enough fiber capacity from day one to meet the City, Schools, and Libraries' immediate and future site to site connectivity needs, future Smart City initiatives as well as capacity to dedicate to other private sector uses. Excess fiber capacity will be allocated within the current backbone fiber for future third-party opportunities that may develop in time.

Fiber Laterals Assumptions

- 100% underground deployment of all laterals
- 36” buried depth
- (1) 2” conduit HDPE
- 24-count single-mode fiber with exceptions to towers, which is 96-count fiber by site designation
- All new construction into buildings, no existing duct assumed
- All splicing will be fusion splicing and tested bi-directionally with OTDR and Power Meter



App 2 Figure 3: Optical Network Architecture

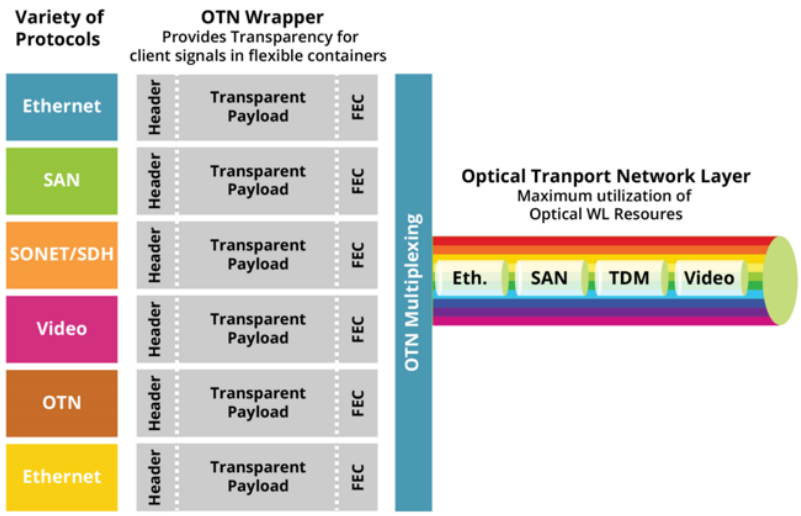
Protected optical transport ring supporting multiple wavelengths

OTN’s such as SONET were originally developed to carry digital time division multiplexed telecom services over high capacity fiber networks. The advent of wave division multiplexing (WDM), illustrated in App 2 Figure 3, allowed

different frequencies of light (ie. wavelengths) to be multiplexed onto a single pair of fibers to increase overall network capacity. This technology has now evolved to support up to 160 wavelengths at over 200 Gbps each, including packet optical interfaces that allow direct multiplexing of layer 2/3 Ethernet packet services over optical wavelengths (IP over DWDM, or IPoDWDM). The WDM system multiplexes each wavelength on or off the fiber network at each transport node and provides sub-second rerouting of wavelengths and their payloads in the event of a fiber cut. An optical filter will multiplex individual wavelengths onto or off the fiber at each transport node.

Add/drop of services between C-NGN transport nodes

ITU G.709 defines a functional framework for service transport, multiplexing, routing, management, supervision, and survivability for OTN's. This allows multiple different service types to be multiplexed, transported, and managed on an individual wavelength. Reconfigurable optical add/drop multiplexers (ROADM's) are used to automate service switching off or onto the network to/from connected equipment, as shown in App 2 Figure 4, significantly reducing the effort required for manual reconfigurations of static optical networks.



App 2 Figure 4: ROADM and Multiplexer Architecture

For the C-NGN, the initial transport needs are relatively simple. A single 100 Gbps wavelength will carry all WAN Ethernet traffic between the aggregation equipment and the edge routers supporting the wide-area network (WAN). Core and aggregation equipment will use IP over DWDM optics (IPoDWDM) to minimize the cost of the transport platform, and bandwidth can be easily upgraded by adding additional IPoDWDM optics. Transponders, muxponders, client interfaces, and ring optics may also be

easily added in the future for support of third-party initiatives without incurring substantial cost out of the gate.

Support for add/drop of services with future Regional Connectivity Ring (RCR)

Although the fiber mileage covered by the RCR will not be fully known until design engineering of the routes is completed, the sheer distance covered and stated use cases for the RCR indicate an OTN will be required. The fiber high-level design (HLD) incorporated the RCR conceptual route through Chesapeake and provided for two P1 sites at the PSOC and Precinct 4 where the RCR equipment will share space with the C-NGN. This will allow future collocation of rack space, power, and equipment for add/drop of services between the RCR and C-NGN. OTN service interfaces can simply be cross-connected using fiber jumpers between patch panels, and services dropped at any of the C-NGN transport nodes.

Support for capacity leasing to third parties

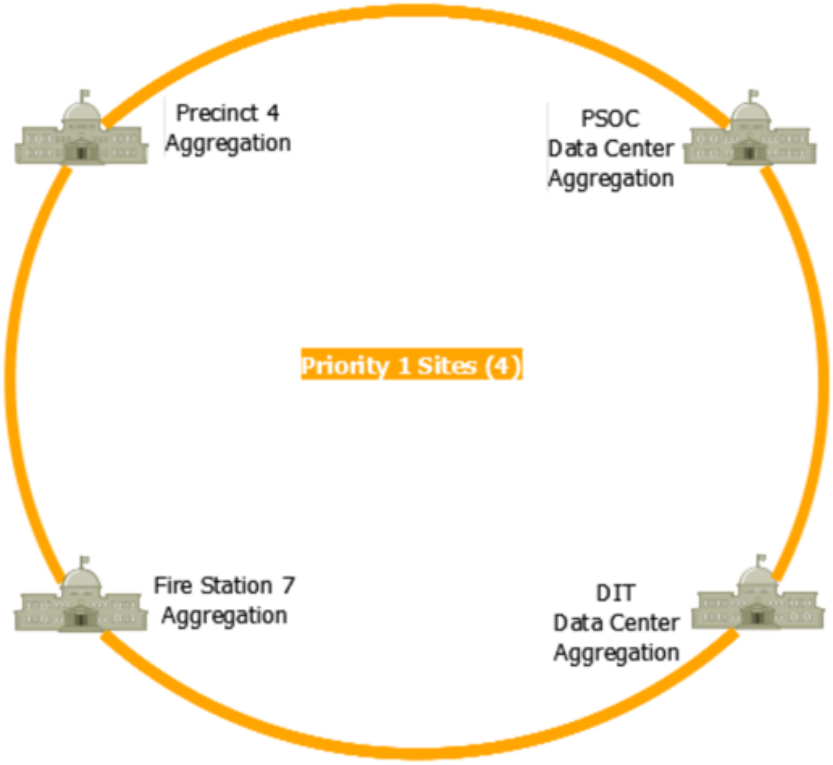
An OTN will support the virtual separation of networks at OSI layer 1, allowing multiple independent transport networks to be created within a single system. The C-NGN transport system must be easily augmented to carry third-party wavelengths or multiplexed higher layer services such as Ethernet circuits by adding ring optics and client interfaces. This functionality will allow the City to provide excess capacity on the C-NGN to any third-party through either dark fiber or wavelength transport, creating an effective and low-maintenance open access system for anyone desiring to use it. It is effective in that C-NGN policy alone can govern fair access to the excess dark or lit capacity. It is low maintenance by nature of dark fiber and layer 1 transport, in that both appear and behave as essentially point to point cable connections. This constrains operational support to fiber break/fix and optical monitoring which must be established for the C-NGN regardless.

2. *Lateral configurations*

Laterals are designed by the Priority designation assigned to them based upon the criticality of a facility. P1, P2, P3, and P4 designations are directly tied to how fiber laterals are deployed to each site. Priority 1 (P1) sites are considered primary network nodes and will be designed for maximum redundancy in both fiber cable connectivity and network equipment functionality. These sites sit directly on the backbone fiber ring and contain termination hardware for a large number of backbone fibers and cross-connect panels to allow both ring and lateral connections to network equipment.

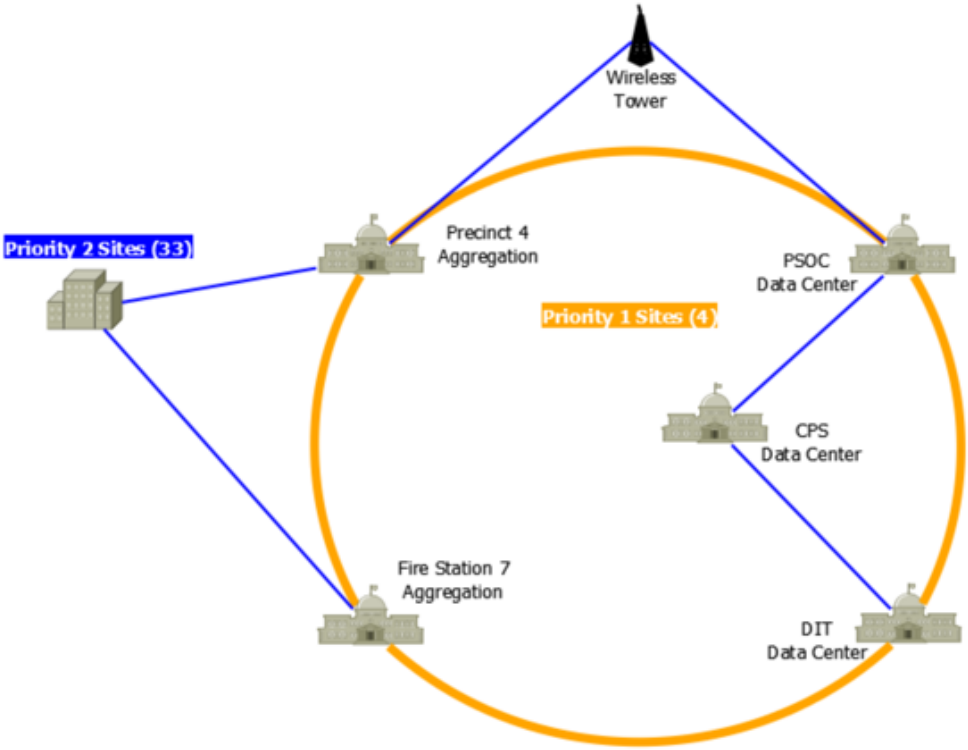
Priority 1 sites consist of primary data centers, network aggregation points, collocation sites, and other high-value and/or highly available location (see App 2 Figure 5). For C-NGN they are:

- Department of Information Technology (on the municipal campus)
- Fire Station 07 / Precinct 06
- Public Safety Operations Center
- Radio Tower at Precinct 4



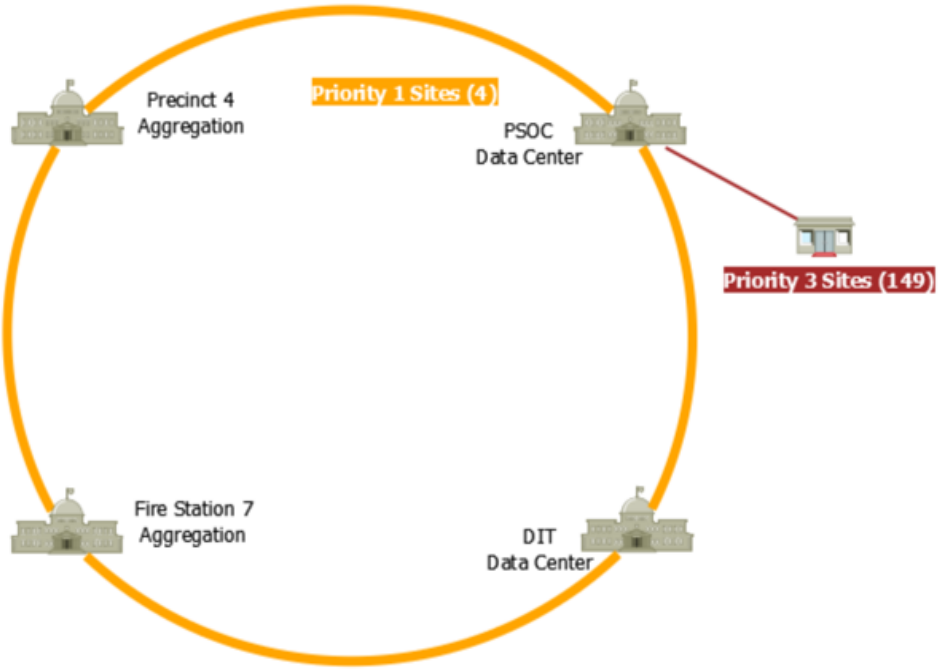
App 2 Figure 5: P1 Site Ring Nodes

Priority 2 (P2) sites are considered redundant network sites and will be designed with two diversely routed lateral connections to separate P1 node sites. See App 2 Figure 6. This eliminates a single point of failure from a cable cut or network hardware failure. In the event of such a failure, network protocols will reroute traffic to the surviving link so that application and Internet service is maintained at the site. P2 sites consist of secondary data centers, critical service sites, and other locations deemed critical to service and network uptime.



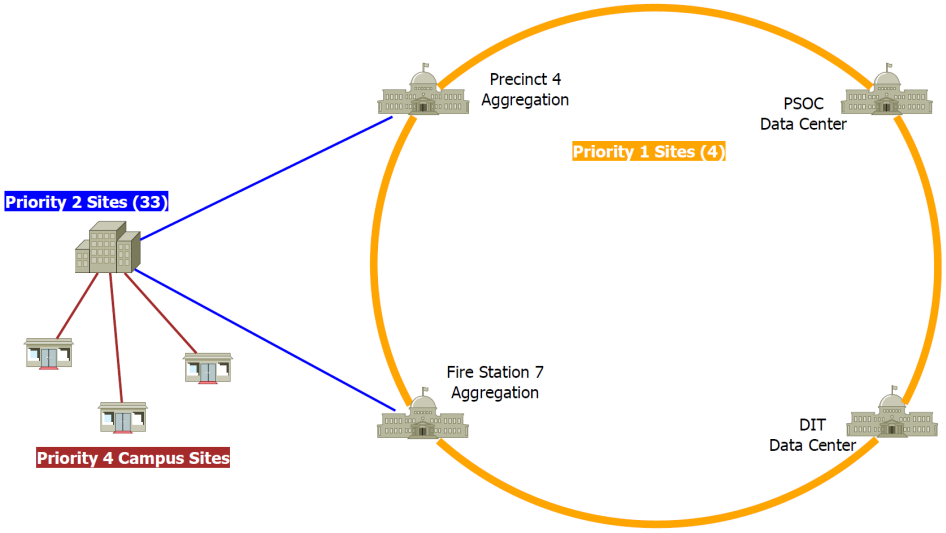
App 2 Figure 6: P2 Site Lateral Connections

Priority 3 (P3) sites, shown in App 2 Figure 7, are considered non-critical to service and network uptime. They are designed with a single fiber lateral cable feeding a single pair of backbone fibers connecting the site to a single Priority 1 aggregation site. In this configuration, a fiber cut or electronics failure at any point between the aggregation site and the P3 site would isolate the P3 site.



App 2 Figure 7: P3 Site Lateral Connections

Priority 4 (P4) sites are shown in App 2 Figure 8 and will be used to connect groups of buildings and structures in a related operational campus. Each P4 site will be homed to a designated P2 or P3 hub site on the campus and connected to a LAN switch. This configuration will provide the required connectivity at each site while reducing the overall C-NGN lateral and equipment costs.



App 2 Figure 8: P4 Sites Campus Connections

3. Wide Area Networks (WANs)

Design Assumptions

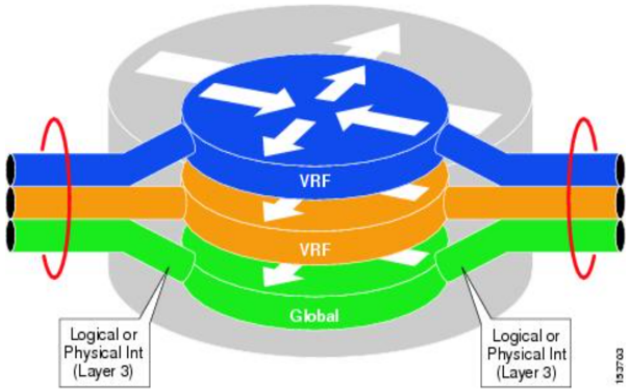
The following design assumptions were derived from the requirements gathered during onsite meetings and used to develop a technical solution for the WAN:

- Carrier-class architecture to replace current leased service
- Fault tolerance for Priority 1 and 2 sites
- Incremental capacity and bandwidth upgrades
- IP and cloud service edge to replace individual WAN leased services
- Existing LAN's will continue to be managed by their respective organizations

These requirements indicate the need for a carrier-class multi-protocol label switched (MPLS) wide area network (WAN) and Layer 3 virtual private network (L3 VPN) overlay to replace the current leased L3 MPLS and direct Internet access (DIA) services from Cox that comprise the five separate WANs. The new WAN will also provide the integration, bandwidth, resiliency, and control desired by the City that is not possible with leased services. Ethernet/MPLS networks reside at OSI Layer 2, while L3 VPN's reside at OSI Layer 3. The OSI model is presented previously in App 2 Figure 2.

Carrier-class architecture to replace current leased service

A L3 MPLS network will provide carrier-class resiliency and traffic isolation so that multiple separate LAN's with differing application requirements can be connected securely over the same IP/Ethernet infrastructure. MPLS provides predictive circuit-switched fault tolerance to packet-based networks such as Ethernet. The underlying protocol uses labels inserted after the Ethernet header to navigate a pre-defined label switched path (LSP) across label switched routers (LSRs). In the event of a link failure, the LSRs can redirect the data flow through alternate LSPs in under 50 milliseconds. This re-routing within LSRs is entirely transparent to upper-layer protocols.



App 2 Figure 9: VRF Implementation

MPLS supports both L2 and L3 virtual private networks (VPN), and L3 VPNs are typically used by commercial service providers to deliver secure Ethernet and IP services to multiple customers. This is the architecture Cox currently uses to provide connectivity and services for the City's separate WAN's. L3 VPN's take the form of virtual routing/forwarding (VRF) instances with Cisco, diagrammed in App 2 Figure 9. IP traffic and routing tables can be completely isolated within a VRF domain. IP routes can be shared between VRF domains through the use of a global VRF or by leaking specific routes if required by the WAN administrator. The independence and security of each separate WAN is strictly maintained through the isolation provided by the virtual networks.

Fault tolerance for Priority 1 and 2 sites

Priority 2 sites as designated by the City must have protection from fiber lateral cuts and network interface failures. This dictates the use of customer premise equipment (CPE) that will support Layer 2 and 3 protocols allowing re-routing of services in the event of facility failures. The CPE will replace existing Cox CPE and will connect to aggregation switch ports at two different P1 sites. This will allow low-cost protocols such as open shortest path first (OSPF) to be used for Layer 3 service re-routing. In addition, CPE supporting MPLS can be deployed in provider edge equipment, effectively extending 50ms failover capabilities to the customer premise.

Incremental capacity and bandwidth upgrades

The current capacity and oversubscription rates of all five WANs and their Internet services are well within commercially acceptable targets. Commercial ISP service is typically maintained at an oversubscription ratio between 10:1 to 50:1, to both manage IP transit costs and ensure good performance of all subscriber services. The five WANs currently have L3 MPLS WAN service bandwidths ranging from 1.5Mbps to 10Gbps. The total provisioned bandwidth across all five WANs is 48.9Gb sharing a combined 13.2Gb aggregation bandwidth, resulting in a low 3.7:1 WAN-to-aggregation oversubscription ratio. By comparison, the C-NGN WAN will be deployed with 207 sites on 1Gb and 10Gb Ethernet links sharing a 100Gb aggregation transport, resulting in an even lower 1.9:1 oversubscription rate of the transport.

For Internet service, the city WANs currently have a combined 13.6Gb of Internet access service shared through a combined 13.2Gb aggregation bandwidth, resulting in a 1:1 aggregation-to-Internet oversubscription, laid out in App 2 Table 1. Unless dedicated bandwidth is required, an oversubscription rate this low using leased services can indicate over-

provisioning and excess cost. By comparison, the C-NGN will be deployed with a total Internet access capacity of 20Gb across two 10GE service ports shared through a 100Gb aggregation transport, resulting in a higher but still very generous 5:1 oversubscription ratio. This will allow one service to carry the full traffic load in the event of circuit failure.

App 2 Table 1: C-NGN Capacity and Oversubscription

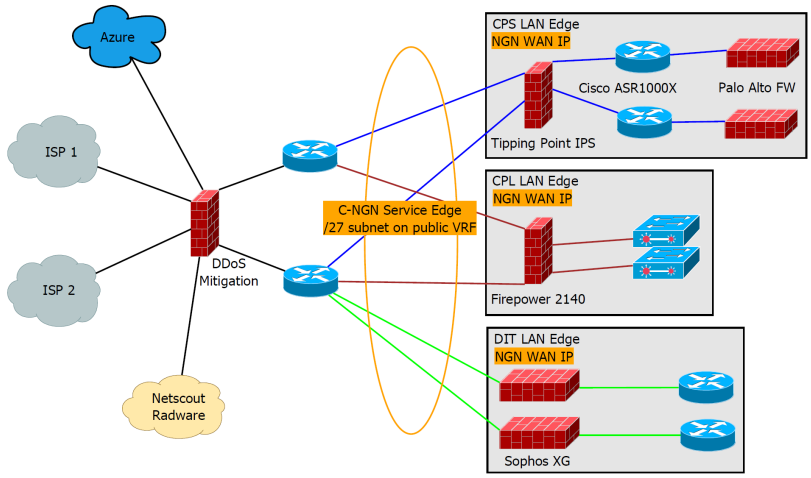
	WAN (MB)	Agg (MB)	WAN:Agg	INET (MB)	Agg:INET
City	1,499	2,000	1:1	2,600	**1:1**
Schools	41,000	10,000	4:1	10,000	**1:1**
Libraries	6,000	1,000	6:1	1,000	**1:1**
CIBH	400	200	2:1	20	**10:1**
Current	**48,899**	**13,200**	**3.7:1**	**13,620**	**1:1**
Projected	**186,000**	**100,000**	**1.9:1**	**20,000**	**5:1**

The C-NGN hardware must support non-blocking throughput for all sites and services, which would initially total 206Gb worse case if all sites and both Internet services were able to connect through a single aggregation switch. Bandwidth and capacity upgrades must be accomplished through the simple addition of new optical interfaces and service configurations to existing hardware. Capacity expansion must be possible through the addition of new hardware chassis and transport wavelengths of the required bandwidth.

IP and cloud service edge to replace individual WAN leased services

The C-NGN will require a public IPv4/IPv6 service edge for advertising C-NGN network routes, cross-connecting with wholesale IP service providers for IP transit, and mitigating malicious attacks from distributed denial of service (DDoS) agents and other similar events. These services are currently provided by Cox and will be incorporated into the C-NGN operations. App 2 Figure 10 is a logical diagram of C-NGN's IP services edge.

Ideally, the edge routers will be collocated within one or more of the local data centers residing in Norfolk and/or VA Beach to gain direct access to low-cost IP transit service providers. If colocation is not possible, transport circuits may be leased on a short term, but any cost savings realized in the Internet service itself will likely be offset by the cost of the transport circuit. Extension of service from the C-NGN fiber routes to the data centers will best be accomplished through dark fiber swaps and/or leases with the adjacent cities.



App 2 Figure 10: C-NGN IP Services Edge

Service connections will be established by placing orders with the Internet service providers of choice for a port and with the data center itself for a cross-connect between the C-NGN and ISP equipment racks. Service costs are typically based on per-megabit commitments, and options to burst above the commitment may also exist. This option can provide great flexibility in managing abnormal traffic events and oversubscription rates by allowing the customer to temporarily exceed the committed rate until upgrades can be performed.

Existing LAN's will continue to be managed by their respective agencies

It was clear from onsite interviews that each of the separate organizational LANs have different missions, business hours, service level requirements, policies, and operational procedures. With this in mind, the C-NGN solution needs to allow for transparent administration of each LAN by their respective organizational staff, while simultaneously providing an integrated transport and IP services WAN to accommodate the overall C-NGN goals. This indicates a solution that essentially replaces the Cox L3 MPLS network with a similar architecture, providing the same connectivity, security, and service levels at a lower cost. The solution that has been developed and recommended to the City will completely fulfill these requirements.

Existing LAN equipment connected to Cox, Segra, or Verizon will need the WAN interface type inventoried to determine if it will support an SFP/SFP+ based optical Ethernet handoff. If not, the interface and/or equipment will need to be planned for an upgrade before the connection to the C-NGN can be made.

The current Cox L3 MPLS architecture uses private IP addressing which should be re-usable if desired in the C-NGN architecture, thereby minimizing configuration changes for the connected LANs.

Furthermore, each LAN firewall and router interface currently connected to Cox and Segra for Internet service will need to be renumbered with a C-NGN public IPv4 address and BGP route advertisements made to match the C-NGN IP edge. Besides these relatively minor changes, which would be required with any change of commercial service provider, the connected LANs should see no significant changes to their internal configurations or operations, and each will remain responsible for the management of routing and switching across their WANS and their local IP edge.

4. Build Plan

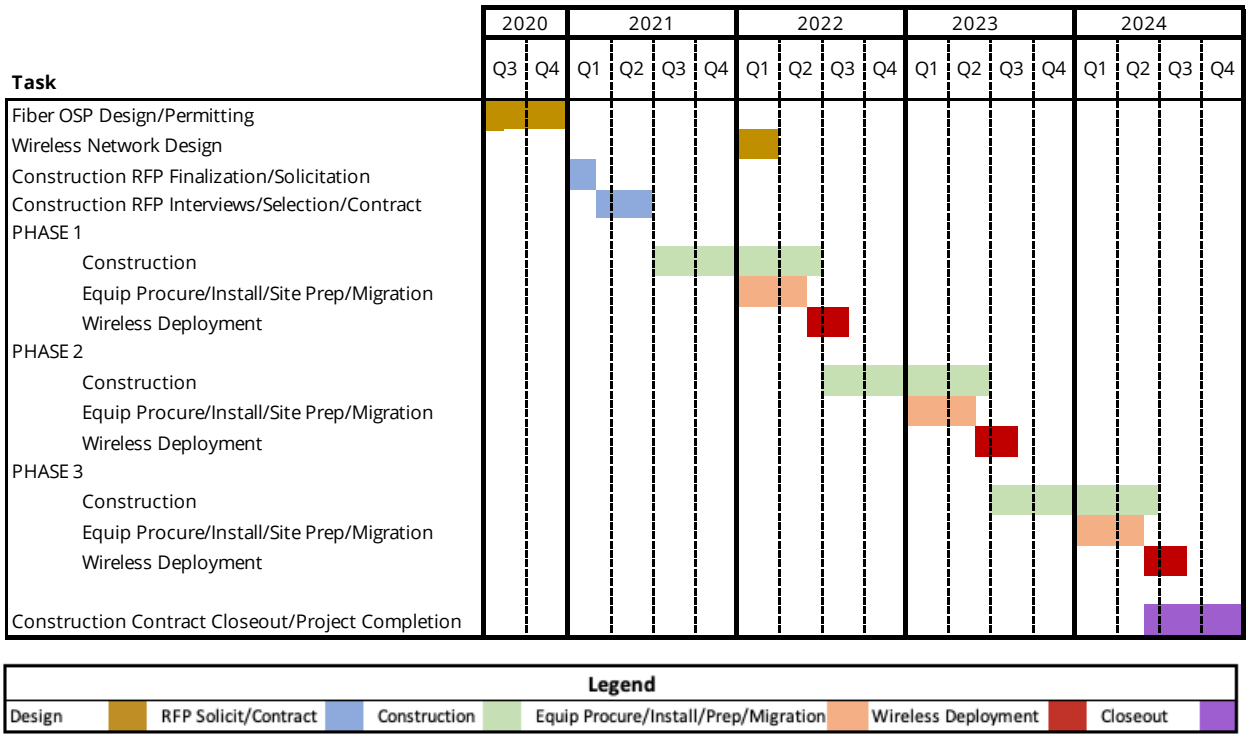
The C-NGN fiber-optic backbone and lateral networks consist of 172 miles of underground construction. A Low-Level Design will require 8-10 months of engineering, while the construction effort is likely to take up to 36 months, with an additional 6 months for closeout of the project and contracts. Permitting can begin in the last several months of design, and alone can take over 6 months due to railway and water crossings, which are plentiful throughout Chesapeake. Magellan recommends that engineering begin as soon as a decision is made to pursue the construction of the C-NGN. This will allow debt funding to be pursued in parallel, with construction to begin as soon as funds are available. The City should plan to identify and secure capital funding during the design process. It would be beneficial to dovetail the design completion and funding commitments before contractor selection and contracts so the network can progress into actual construction.

The build plan outlined below in App 2 Figure 11 has been designed to connect as many sites as early in the deployment as possible, to allow for maximum return on the C-NGN investment. The faster sites are connected, the faster the agencies can reduce their spending on current telecommunications services. As depicted in App 2 Table 2 below, the build plan would commence with design taking place in 2020-2021, Phase 1 Construction (2021-2022) in the City core would connect 133 sites, Phase 2 Construction (2022-2023) in the NW and SW sections would connect another 65 sites, and in Phase 3 Construction (2023-2024) along the SW portion of the City toward William's Farms, would connect the final 9 sites and ring the southern portion of the network.

App 2 Table 2: Proposed Schedule for Deployment including Phasing

Phase	Year	Fiber Mileage	Sites Connected	Summary of Routes
	2020-2021			Design, Engineering and Permitting
1	2021-2022	75mi	133	City Core
2	2022-2023	57mi	65	NW and SE Segments
3	2023-2024	29mi	9	Western N/S Segment closing backbone ring

A proposed schedule for design, construction, and closeout is included here for reference, beginning in Q3 2020 with completion and closeout in late 2024.



App 2 Figure 11: Project Timeline Starting Q4 2020 (design, construction, closeout)

Phase 1/Year 1 Construction

The C-NGN Phase 1/Year 1 Construction effort can connect 133 sites in total. Construction is planned to start in the NE corner of Chesapeake and includes fiber routes along Indian River Rd then South on Sparrow Rd turning East on Providence Rd. The route continues North on Campostella Rd then utilizes Friend Rd, Windy Rd, and Border Rd to form a loop, then crossing Campostella onto Liberty St then North on Seaboard Ave turning SW on 20th St then SE on B St. The route continues SW on Poindexter St before turning South on Bainbridge Blvd crossing S Military Hwy then jogging East on Grant Street, North on Lincoln then SE on Great Bridge Blvd. The route continues down Great Bridge Blvd past Dominion Blvd S then heads South on Battlefield Blvd N crossing the Albemarle and Chesapeake Canal onto Battlefield Blvd S before heading West on Cedar Rd. Heading West on Cedar Rd the Backbone route passes and loops through Chesapeake's City Hall Campus and continues further West crossing back over Dominion Blvd S onto Moses Grandy Trail to then head North on George Washington Hwy N and intersecting two other Backbone segments at S Military Hwy, before crossing into South Portsmouth at Victory Blvd for St. Julians Training facility.

Another major segment of Phase 1 Backbone routes East on S Military Hwy from George Washington Hwy N crossing the Southern Branch Elizabeth River and crossing the previously mentioned route on Bainbridge Blvd and then makes a T intersection at Greenbriar Pkwy. This section of Backbone splits in two different directions to make a small ring using Greenbriar Pkwy, Woodlake Dr, Old Greenbrier Rd, Dunbarton Dr, and previously mentioned Providence. Another small ring is formed adjacent to the previous ring utilizing S Military Hwy, Rokeby Ave, Providence Rd, and Old Greenbriar Rd. The final portion of Phase 1 Backbone heads South on Battlefield Blvd N from S Military Hwy at Providence Junction and continues South to meet other Backbone segments at the intersections of Volvo Pkwy, Great Bridge Drive, and Kempsville Rd. This also forms another ring on the West end of Phase 1 using Kempsville Rd, Clearfield Ave, Greenbriar Pkwy and Volvo Pkwy. 5 Spurs also exist in Phase 1, 4 are possible fiber meet points with neighboring municipalities and one extends the Backbone down Dominion Blvd S for the City's license plate reader and toll shelter sites.

Backbone construction includes 284,259 ft (54 Miles), while Lateral construction includes 131,416 ft (25 Miles). Total Phase 1 construction distances are 415,675 ft (79 Miles). This Phase of the build connects 133 sites, including 54 City facilities, 32 School sites, 6 Library sites, 3 800 Mhz towers, 7 utility sites, 22 Traffic hubs, 7 CIBH sites, and 2 Priority 1 hubs at the DIT and PSOC facilities.

Phase 2/Year 2 Construction

Phase 2 construction would commence in two locations of the City, in the NW section connecting at the intersection of S Military Hwy and George Washington Hwy N. This section of Backbone heads East then jogs North at Bowers Hill onto Jolliff Rd then routes North along the Hampton Roads Beltway and exits at Pughsville Rd. The route continues from Pughsville heading NE on Taylor passing another Backbone segment on Peppercorn and ending at Western Branch Blvd.

A ring is formed in this section of Phase 2, it routes South on Peppercorn, West on Bruce, South on Taylor, and back West on Portsmouth Blvd intersecting the previously mentioned route on the Hampton Roads Beltway. 3 Spurs also exist in this section of Phase 2. The first spur is formed at the intersection of Peppercorn and Bruce Rd and carries over to Bruin Drive then ending on Terry Dr. The second spur routes East on Portsmouth Blvd from Taylor Rd then routes South on Dock Landing Rd stopping in front of E.W. Chittum Elementary. The final spur routes SW on W Military Hwy stopping in front of the Lake Gaston Water Treatment Plant.

The SW section connects to Phase 1 Backbone at Cedar Rd and routes South on Battlefield Blvd S, passing a spur on Hanbury Rd W, Hanbury Rd E, and Etheridge Manor Blvd. This route continues South past Benefit Rd crossing the Chesapeake Expy continuing onto Gallbush Rd to Indian Creek Rd where the route stops in front of Northwest River Park. Another major leg of this section is the spur that starts from Hanbury Rd W and continues East on Etheridge Manor Blvd turning North on Centerville Turnpike S coming to a T intersection at Mt Pleasant Rd. This section of Backbone begins at Butts Road Primary School on Mt Pleasant Rd and routes East past the previous mentioned Backbone segment on Centerville Turnpike S jogging South to SE on Lockheed Ave onto Bellpage Ave then North on Doolittle Ave. The route carries further East NE on Mt Pleasant Road toward Virginia Beach until it stops at the edge of the Albemarle and Chesapeake Canal within Chesapeake.

Backbone construction includes 244,142 ft (46 Miles), while Lateral construction includes 96,031 ft (18 Miles). Total construction distances are 340,173 ft (64 Miles). Phase 2 of the build connects 65 sites, including 15 City sites, 17 School sites, and 1 Library site. 2 800 MHz Towers, 16 utility sites, 12 Traffic hub sites, and 2 Priority 1 hubs at the new Fire Station 7 and Police Precinct 4.

Phase 3/Year 3 Construction

Phase 3 construction would commence along Dominion Blvd S heading SW passing a Backbone spur starting at Scenic Pkwy supplying fiber to Grassfield Elementary. The route then heads South on West Rd passing another Backbone spur on Number Ten Ln and Sentry Dr continuing to Cornland Rd. The route then turns NW on Cornland Rd then South on George Washington Hwy S until heading back East on Ballahack Rd to Old Battlefield Rd where it intersects Phase 2 Backbone at the Chesapeake Expy to close the final fiber ring.

Backbone construction includes 135,445 ft (26 miles), while Lateral construction includes 18,400 ft (3 Miles). Total construction distances are 153,845 ft (29 Miles). Phase 3 of the build connects 9 sites including 4 City sites, 2 School sites, 1 800 Mhz Tower, 1 utility site, and 1 Traffic hub site.

5. Capacity Plans

After analysis of the buffer tube assignment and high-level splicing requirements for all 207 sites to be connected, we have determined that the specified 432-count backbone cable will be under 40% utilized on average across the backbone segments at construction completion. That provides significant excess capacity that can be designated for site growth or monetization through third-party leasing opportunities. It's important to remember there are also two additional 2" conduits available to support future fiber deployment requirements as well.

App 2 Table 3 below depicts the four major network segments which interconnect each of the P1 sites. The fiber capacity requirements outlined in the table, provide an estimate of the required fiber strands by use case. It also shows projections for total strand utilization on each major segment.

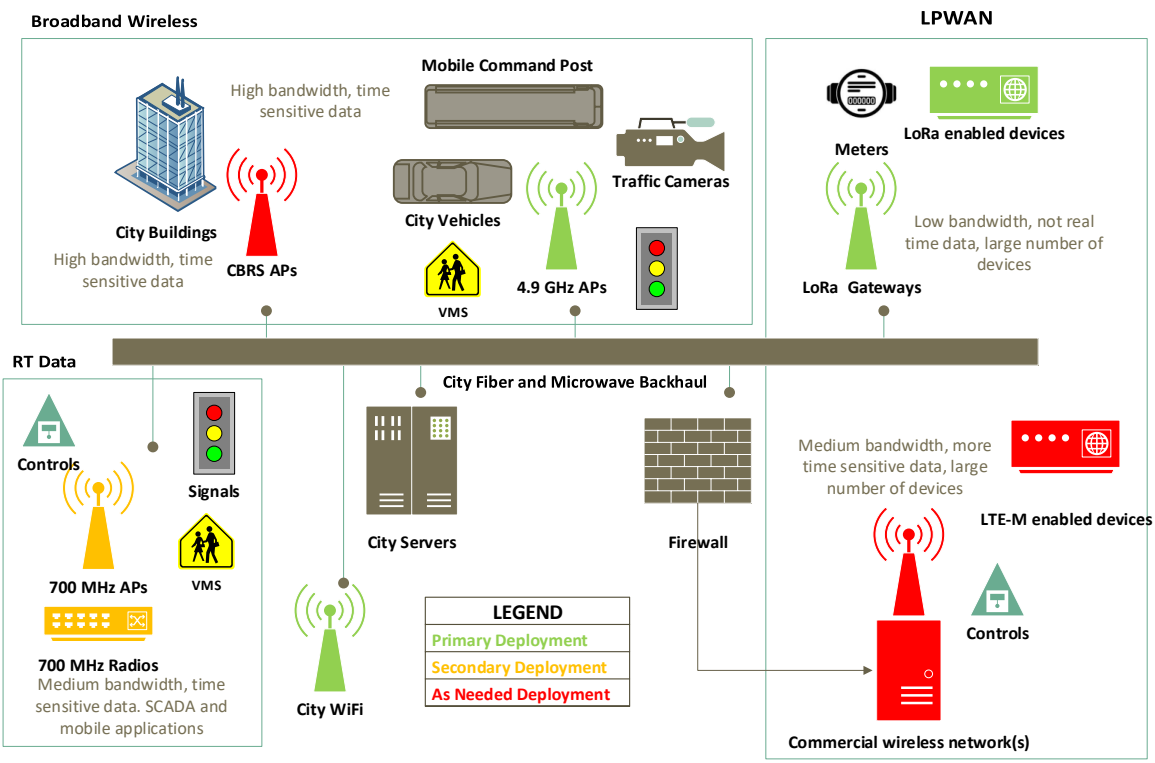
App 2 Table 3: C-NGN – Backbone Fiber Requirements by Use Case– 432-Count Cable

Network Segment	City	Schools	Libraries	Traffic	CIBH	800 Mhz	Total Utilized	Utilization	Excess Capacity
1: PSOC to DoIT	54	26	8	14	12	4	**118**	**27%**	314
2: PSOC to Precinct 4 to DoIT	36	8	2	6	0	2	**54**	**13%**	378
3: DoIT to FS7 (west)	54	24	2	10	0	2	**92**	**21%**	340
4: DoIT to FS7 (east)	36	18	2	10	4	4	**74**	**17%**	358

During the final stages of future design engineering, a fiber allocation table will be constructed to outline fiber assignments by use case. App 2 Table 3 above depicts a potential approach to a C-NGN fiber-optic cable strand allocation plan.

B. Wireless Overlay Networks

The C-NGN is planned to extend to City tower sites and infrastructure to support the deployment of a wireless overlay or wireless wide-area network (WWAN). The WWAN, depicted in App 2 Figure 12 is intended to extend C-NGN connectivity to devices and users across the entire community, providing a standard wireless infrastructure for existing and future applications.



App 2 Figure 12: C-NGN Wireless WAN Conceptual Design

1. Design Assumptions

Unlike traditional wired networks based on IEEE and IETF standard protocols, many wireless networking technologies used within municipal environments have developed as vertically integrated applications within specific operational sectors such as public safety and utilities. In addition, constraints such as licensed/unlicensed spectrum, frequency propagation characteristics, transmit power limits, and lack of protocol standards govern the use cases of various wireless technologies. Federal Engineering (FE) and Magellan reviewed the City's current and future use cases against the various WWAN technologies available and determined the following three are best suited for the C-NGN architecture:

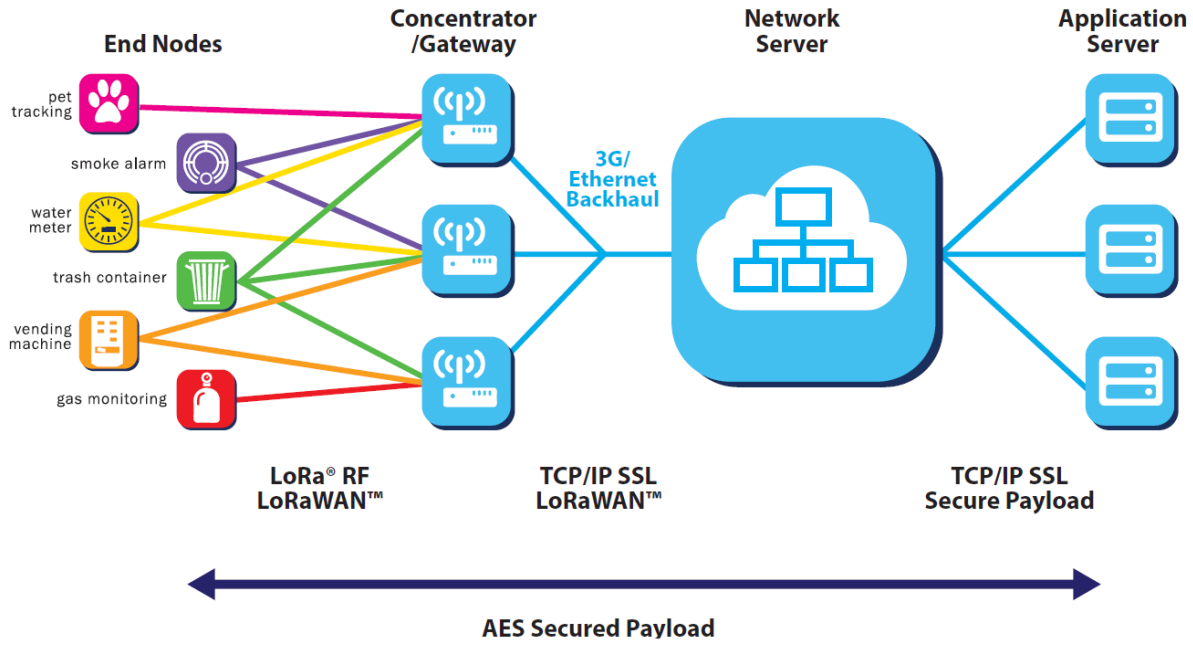
1. LoRaWAN™ at 902-928 MHz for low-bandwidth, wide area, message-based applications
2. 700 MHz Block A spectrum for low-bandwidth, wide area, real time applications
3. 4.9 GHz for high-bandwidth, real time applications as a supplement to fiber connections

Other technologies may be employed over time to supplement each wireless overlay, such as LTE-M to augment LoRaWAN for expanded coverage and Citizens

Broadband Radio Service (CBRS) to augment 4.9GHz for expanded broadband capacity/coverage.

LoRaWAN for Advanced Metering Infrastructure (AMI)

The LoRaWAN is a low power, wide area network (LPWAN) based on LoRa technology. App 2 Figure 13 provides a generic example of a LoRaWAN based network, as provided by the LoRa Alliance.[22] The LoRaWAN supports Internet of Things (IoT) devices that require long battery life, e.g. low battery consumption, and long-range transmission of low to medium speed data, 0.3 kbps to 50 kbps.



App 2 Figure 13: Generic LoRaWAN Example

In the US, LoRaWANs are deployed primarily in the unlicensed Industrial, Scientific and Medical (ISM) radio band from 902-928MHz. This band can be subject to elevated levels of interference given the numerous types of devices and technologies allowed in this band. US deployments must factor this into the design, typically by adding more gateways, using directional antennas, or both.

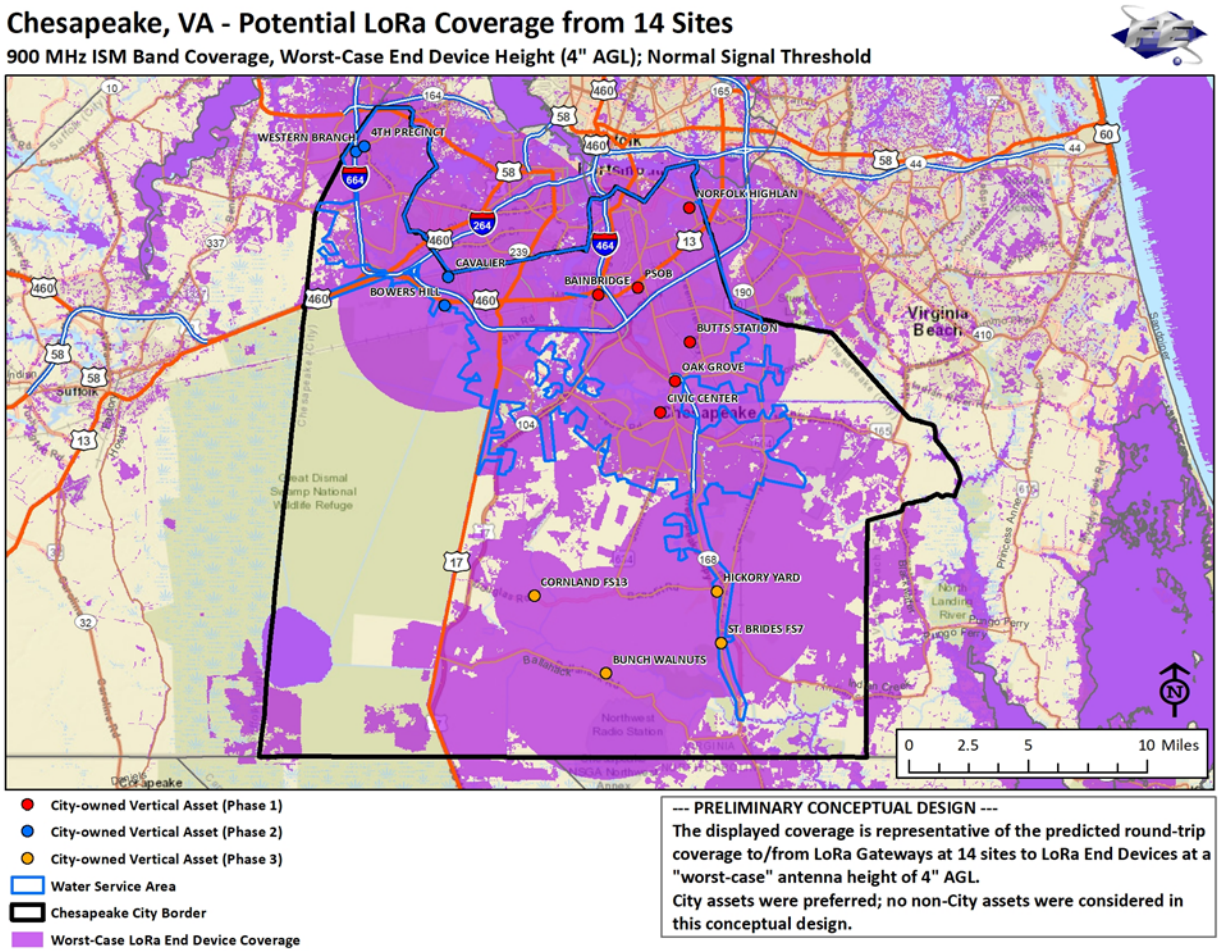
The following use cases (App 2 Table 4) were considered for the LPWAN subsystem in the WWAN conceptual design for the City.

[22] LoRa and LoRaWAN are registered trademarks of the LoRa Alliance. For more information, see https://lora-alliance.org/

App 2 Table 4: LPWAN Use Cases

Department	Use	Wireless Technology	Freq Band	# of Potential Endpoints
Public Utilities	Water Meters (AMI)	LoRa/LoRaWAN	902-928 MHz ISM	70,000

LoRa endpoints would communicate sensor data to strategically located gateways on fourteen City-owned vertical assets. In some cases, endpoints could be retrofitted with LoRa modems, in others, the endpoints could include integrated LoRa devices with the sensors as part of a strategic upgrade plan. For example, older water meters may be replaced with LoRa enabled meters. The City would own and operate the LoRaWAN and be responsible for all the operations and maintenance (O&M) costs associated with it.



App 2 Figure 14: Potential LoRa Coverage: 14 sites

Predicted coverage for the fourteen LoRaWAN gateways is shown in App 2 Figure 14. This prediction is based on endpoints located as close to ground level as possible, to account for use of a puck style antenna on top of the pit for a smart water meter. Standard propagation conditions are also assumed in this design, e.g. no abnormal interference levels that might impact LoRa performance. Due to concerns over contention with other users in the band, the noise floor in the ISM band, and past issues reported in this band by the City, it may be necessary to mitigate these issues by increasing the number of gateways in some areas, on a case by case basis. Two additional gateways with monopoles, for a total of 16 sites, may be required to fill in gaps in the central parts of the city.

700 MHz for SCADA and Telemetry

The 700 MHz A Block spectrum consists of 1 MHz of paired frequencies (2 MHz total) in the Upper 700 MHz band at 757-758 MHz and 787-788 MHz. Originally auctioned by the FCC this spectrum is currently being offered for purchase, with negotiable terms, by the initial auction winners in various geographic areas. Once purchased and licensed by a local entity, this spectrum follows the typical land mobile radio licensing process, e.g. renewable on a 10-year basis at a minimal cost.

The 700 MHz A Block spectrum rules allow for a wide range of technologies and applications, including voice, SCADA, telemetry, and other data applications, in both PtP and PtMP applications, and has the same propagation advantages and characteristics as other public safety land mobile radio bands at 700 and 800 MHz. One vendor is also currently conducting a pilot project to use private LTE in this band.

Transmission protocols in this band are often proprietary, which typically limits the use of equipment to a single vendor, once selected. This is true for most equipment and vendors offering products in the SCADA and telemetry markets. Therefore, procurement specifications for the overlay must require a system with endpoints that provide layer 3 routing and standard Ethernet interfaces so that multiple applications can be deployed concurrently using IP subnets and VLANs.

In addition, the 700 MHz A block spectrum could be segmented into separate channels for use with different use cases/applications if desired, to allow for the use of different manufacturers' equipment for these different use cases/applications. This segmentation would reduce the overall bandwidth and potential throughput for each use case/application but would still result in enough bandwidth and potential throughput for SCADA and telemetry applications.

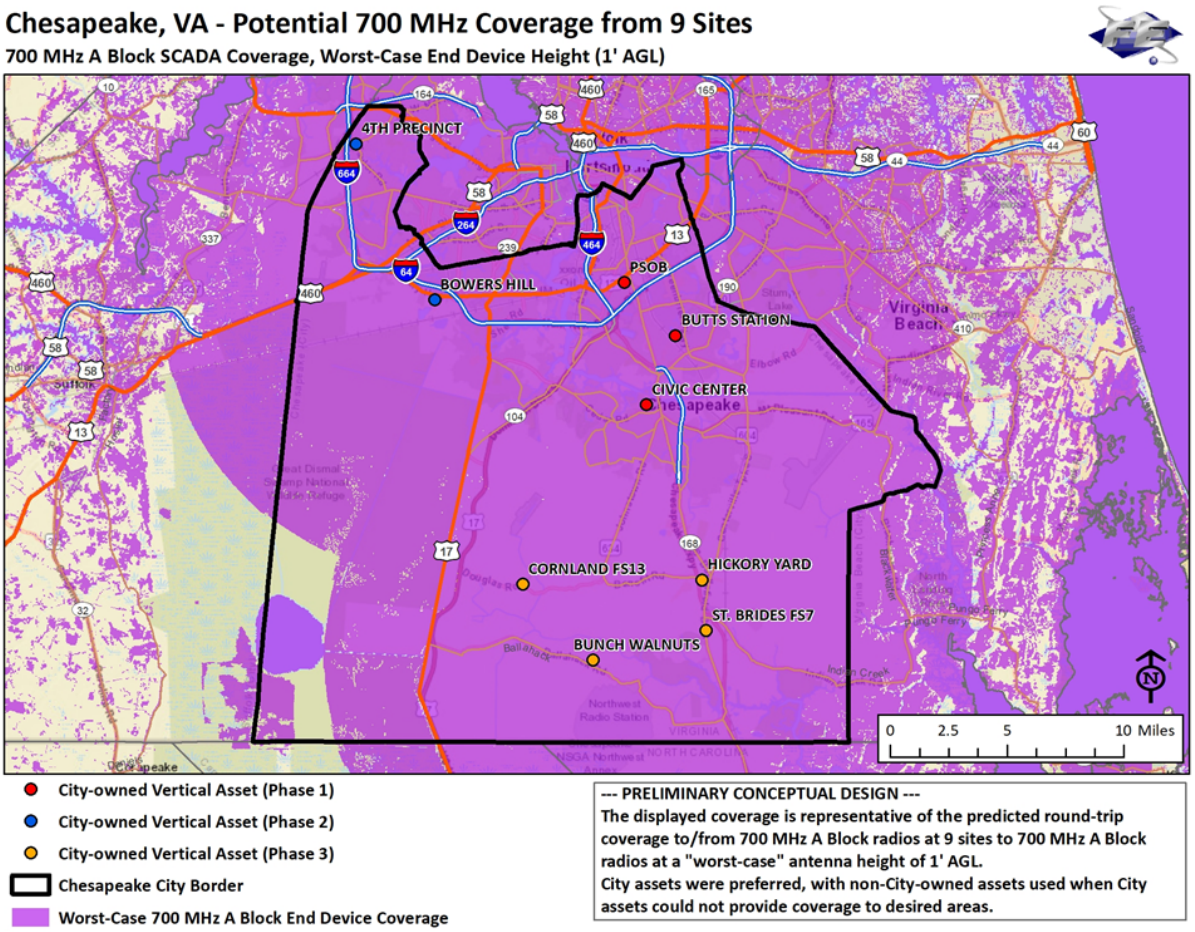
For the SCADA/Telemetry subnetwork of the WWAN, the conceptual design envisions deployment of nine 700 MHz access points connected to the City fiber

and microwave backhaul for the City use cases shown below, which includes the eventual replacement of the Motorola ACE RTUs and Harris SG5300 SCADA radios, which are expected to reach obsolescence in the coming years.

App 2 Table 5: 700 MHz Use Cases

Department	Use	Wireless Technology	Freq Band	# of Potential Endpoints
Public Utilities	Wastewater Lift Stations	SCADA	700 MHz A Block	219
Public Utilities	Monitoring of Water Tanks, Pump Wells, and Water Control Valves	SCADA	700 MHz A Block	41

Predicted coverage for the nine 700 MHz gateways is shown in App 2 Figure 15. This prediction is based on the worst-case use scenario, endpoints with antennas located at ~ 1 foot above ground level, to account for use with water control valves. Coverage for endpoints with higher antennas, such as lift stations, would be better than that shown.



App 2 Figure 15: Potential 700 MHz Coverage from 9 Sites

The predicted coverage percentages for each of the current City use cases/endpoints is depicted below in App 2 Table 6, for the 9-site 700 MHz design. assuming the worst-case coverage scenario.

App 2 Table 6: 700 MHz Coverage

Department	Use	# of Potential Gateway/AP Locations	# of Potential Endpoints	# of Endpoints Covered	Estimated % of Endpoints Covered
Public Utilities	Wastewater Lift Stations	9	219	219	100%
Public Utilities	Monitoring of Water Tanks, Pump Wells, and Water Control Valves	9	41	40	97%

4.9 GHz for Cameras and Signage

In 2002, the Federal Communications Commission (FCC) carved out a 50 MHz slice of the spectrum and dedicated it for use by public safety agencies, which by the FCC's definition includes state or local governmental entities. Since then, there have been some minor modifications to the types of emissions allowed in this band to encourage more use, but overall the band has been underutilized.

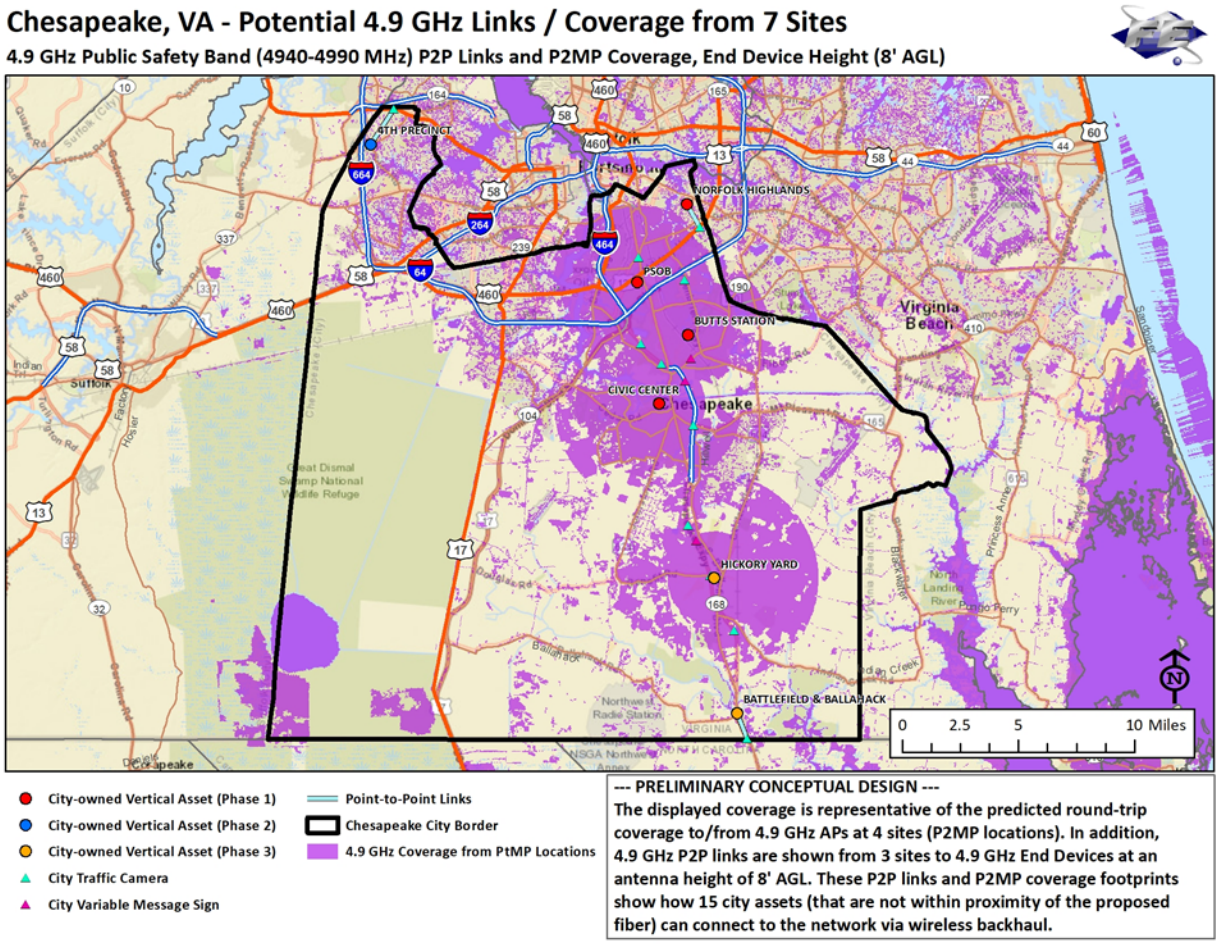
Accordingly, the FCC issued a Notice of Proposed Rule Making (NRPM) and requested comments from public safety and the communications industry. Overwhelmingly, public safety urged the FCC to retain this band for public safety but to further clarify and realign the rules for this band to encourage better use of the spectrum, an approach that the FCC appears to endorse as they are moving to codify these changes in an upcoming rulemaking procedure.

4.9 GHz supports both point to point (PtP) and point to multipoint (PtMP) topologies and is currently being used to support such use cases as air-to-ground communications, real-time video streaming, bomb-squad and other special operations, and point to point transport of critical broadband data. The broadband subnetwork of the WWAN involves deploying seven 4.9 GHz access points connected to the City fiber and microwave backhaul for the City use cases shown below in App 2 Table 7.

App 2 Table 7: 4.9 GHz Use Cases

Department	Use	Wireless Technology	Freq Band	# of Potential Endpoints
Traffic Engineering	Traffic Cameras and Variable Message Signs (not on Fiber)	P2P / P2MP	4.9 GHz (Public safety)	15

Predicted coverage for the forty-eight 4.9 GHz gateways is shown in App 2 Figure 16. This prediction is also based on the worst-case use scenario, endpoints with antennas located at ~ 8 foot above ground level, to account for use with water control valves. Coverage for endpoints with higher antennas would be better than that shown.



App 2 Figure 16: Potential 4.9 GHz coverage: 7 sites

Significantly, 4.9 GHz remains one of the few bands open for licensed use of broadband spectrum, and many manufacturers also permit both licensed 4.9 GHz and unlicensed 5 GHz Wi-Fi operation in the same access point.

Supplemental WWAN Technologies

LTE-M

LTE-M is a subset of the Long-Term Evolution (LTE) standard governed by the 3rd Generation Partnership Project (3GPP) standards organization. LTE-M is also intended to serve the requirements for IoT, e.g. high-coverage, low-cost, and low-power consumption.

In the US, all the major commercial carriers have and are deploying LTE-M solutions and there are multiple sources of LTE-M endpoints, modems, and sensors. While not considered a primary part of the City LPWAN deployment, there may be instances where coverage, interference, or specific use cases require the use of LTE-M devices. One advantage to these types of devices is that the City would rely on the commercial carrier's network to provide connectivity, basically a Network as a Service (NaaS) type model, where the City would not incur O&M costs for the LPWAN, but this is offset somewhat by the recurring airtime costs for the LTE-M endpoints.

Citizen Band Radio Service (CBRS)

The CBRS spectrum (3.5-3.7 GHz) is part of a new FCC initiative to use dynamic spectrum sharing to manage what is an unlicensed spectrum. Under the current FCC plan, there will be tiered sharing of this spectrum between three distinct user groups, as shown below.

Tier 1 – Incumbent Access

Incumbent Access users include authorized federal users, Fixed Satellite Service (space-to-Earth) earth stations, and, briefly, grandfathered wireless broadband licensees. Tier 1 Access users are protected against harmful interference from Priority Access Licensees and General Authorized Access users.

Tier 2 – Priority Access

Priority Access users consist of Priority Access Licenses (PALs) that are expected to be licensed on a county-by-county basis through competitive bidding in the summer of 2020. Each PAL consists of a 10-megahertz channel and will be 10-year renewable licenses, with up to seven PALs licensed in any given county, subject to a four PAL channel aggregate cap for any single licensee. Per the FCC rules, PALs must meet a substantial buildout and performance requirement by the end of the

initial license term and must protect and accept interference from Incumbent Access users, though they do receive protection from General Authorized Access users.

Tier 3 – General Authorized Access (GAA)

GAA users have open, flexible access throughout the 3.5-3.7 GHz band but must not cause harmful interference to Tier 1 or Tier 2 users and must also accept interference from these users. Tier 3 users also have no expectation of interference protection from other Tier 3 users.

Commercial operations in the CBRS spectrum are expected in early 2020, though pilots have been in place for some time. This spectrum frequently referred to as "mid-band", is expected to receive significant interest from commercial wireless carriers, high occupancy building owners, and private industry as both a supplement to current LTE networks and as an option to deploy private LTE networks. On January 27, 2020, the FCC certified four SAS Administrators, CommScope, Federated Wireless, Inc. (Federated), Google, and Sony, Inc. (Sony), which allows full commercial operation in this band to proceed.

Per the FCC, "Access and operations will be managed by an automated frequency coordinator, known as a Spectrum Access System (SAS). When managing spectrum access, SASs may incorporate information from an Environmental Sensing Capability (ESC), a sensor network that detects transmissions from the Department of Defense radar systems and transmits that information to the SAS. Both SASs and ESCs must be approved by the Commission. SASs will coordinate operations between and among users in three tiers of authorization in the 3.5 GHz band: Incumbent Access, Priority Access, and General Authorized Access."

The City's proximity to Naval Station Norfolk, the high degree of interest from commercial interests, as well as the propagation characteristics and rules for this band render it of limited value for wide-area deployment, but it could be used on a supplemental local basis to both expand commercial LTE coverage or private separate City-owned and operated LTE subnetwork for specific facilities with high user counts.

Appendix 3 – Policies and Regulations

Magellan Advisors has applied its knowledge of the federal and state policy environment to review the City's current policies and municipal code provisions regarding communications facilities including placement of fiber-optic cable in public rights-of-way and small cell antennas on City facilities and structures. Specifically, we have considered federal requirements and the balance of federal versus local authority regarding placement of 4G and 5G antennas and related facilities, as well as wireline/fiber facilities. Regarding wireless services, the FCC has imposed an "eligible facilities request" and shot clock rules under the 2012 Spectrum Act and more recently imposed new rules regarding small cell facilities applications that are being challenged by local authorities (and others) in the 9th Circuit Court of Appeals since they greatly limit the discretion of local authorities. Regarding wireline services, i.e., placement of fiber, the FCC has modified pole attachment regulations and established new "one touch make-ready" pole attachment processes.

Similarly, state policy in Virginia has been modified by the General Assembly in 2017 and 2018 to further restrict local authority to review applications for placement of small cell facilities in the public rights-of-way. However, cities are allowed to form or join Wireless Communications Authorities to install communications facilities such as fiber-optic cable and provide communications services. The City has used this provision to join the Southside Network Authority which will ultimately connect the planned C-NGN to the "rest of the world" through the Authority's Regional Connectivity Ring. Our review also encompassed consideration of policies implemented by neighboring cities including Portsmouth, Virginia Beach, Norfolk, Suffolk, and Hampton.

A. Design and Construction Standards and Guidelines

The Department of Development and Permits manages an excellent resource – the Public Facilities Manual[23] which addresses policies, design criteria, standards, and technical specifications for the whole array of public facilities. Some neighboring cities have implemented such standards and guidelines. We recommend Fiber and Small Cell Design Standards and Guidelines as developed for the City be considered for inclusion as an additional chapter in this document. Such Standards and Guidelines generally address:

- The intent and purpose to establish general standards, consistent with all applicable state and federal laws, for the design, aesthetics installation, placement, and co-location of small cell infrastructure
- Definitions
- General requirements to not violate relevant codes and standards, impact public safety or travel or otherwise obstruct the public rights-of-way, and to promote clean, organized, and streamlined infrastructure in an efficient and least intrusive means available to provide wireless services
- Placement preferences for fiber and small cell infrastructure including proximity and eligible poles and structures
- Aesthetic guidelines including concealment of equipment and cables/wires/meters, noise, signage, equipment and placement requirements, finishes and maintenance
- Colocation requirements
- Maximum dimensions of equipment, poles and other structures.

Magellan has provided example standards and guidelines as templates to facilitate the City's review and consideration.

[23] http://www.cityofchesapeake.net/government/city-departments/departments/Department-of-Development-and-Permits/Development-Engineering-and-Construction/pfm.htm

B. "Dig Once" and Joint Trenching

The City has code provisions that support "Dig Once" practices, but they are fairly minimal. Chapter 66 of the City's Municipal Code provides that the Director of Public Works (or designee) shall notify all utility companies and others operating in the City at least 90 days in advance of the actual construction of the intent of the City to pave, surface, or improve a street[24]. The utilities and other recipients of the notice are then obliged to within those 90 days "at their own expense and cost, lay, install, construct and complete new underground pipes, mains, wires, conduits, equipment, and utilities where none are now installed, including house services for each lot abutting a residential street, in advance of the street improvements contemplated by the city."[2]

Finally, the Municipal Code provides for a one-year moratorium period such that "No person shall, within one year from the date of such notice, install new underground pipes, mains, wires, conduits, equipment, and utilities, including house service, and in so doing cut into the street surface or in any manner disrupt the street pavement or hard surface without a reasonable excuse satisfactory to the director of public works or an emergency."[3]

Magellan Advisors recommends further exploration with relevant departments of the City's informal processes for noticing intent to work on streets, and how it may be extended to a fuller Dig Once policy. This more comprehensive policy framework for "Dig Once" would include coordination of work in public rights-of-way when any occupant plans to open the ground for their purposes, regular (e.g., quarterly) mandatory meetings of occupants of the public rights-of-way to share plans and coordinate work, longer advance notice provisions to facilitate longer-term planning by all occupants of the public rights-of-way, and potential extension of the one-year moratorium on street work to a longer-term to protect the streets to three years or five years to further incent participation and cooperation in planning and regular meetings.

C. Wireless Infrastructure and Services

We have reviewed Section 13-600 in the Zoning Code, which pertains to "Communications towers for the operation of radio and other transmitting and receiving facilities" and note that it also includes provisions pertaining to cellular telephone service and "small cell" facilities as well as other types of communications antennas (e.g., microwave, satellite earth station). Our review

[24] Sec. 66-171.

found that small cell deployments are addressed in Section 13-602(B)(6), where wireless communications facility deployment on both City property/public rights of way and private property are addressed. Our observations on Section 13-600 and provisions that could be reviewed include:

- Many provisions pertain to large 3G/4G towers and do not require significant comment
- The definition of "communications small cell facility" allows the installation of refrigerator-sized equipment on support structures such as poles. Many jurisdictions do not allow the installation of equipment this size. Perhaps this can be addressed in Small Cell Design Standards and Guidelines.
- The definition of "existing structure" for the placement of wireless facilities includes water towers, flag poles, and signs. The City should confirm that it is appropriate to install 5G antennas on such structures.
- Subsection 13-602(B)(6) addresses "small cell facilities"
    - The application process includes "a statement signed by a professional engineer licensed in the Commonwealth of Virginia stating that the proposed facilities comply with all applicable Federal Communications Commission regulations, including, without limitation, regulations pertaining to the emission of radio frequency radiation;"
    - Up to 35 permit requests can be submitted on a single application;
    - These applications must be approved or disapproved within 60 days of receipt, with one 30-day extension by the City permitted;
    - Fees are limited to $100 for up to five facilities, plus $50 for each facility over that;
    - Application approved only if:
        - The small cell "shall not have the potential to pose a material interference,"
        - The small cell [installed on public property] "shall be substantially concealed,"
        - "electrical power and battery backup cabinets shall be roof-mounted or otherwise located so as not to be visible from a public street,"
        - Small cells shall only be permitted "in the Chesapeake historic and cultural preservation overlay district if they are not visible from a public right-of-way".

- "The installation, placement, maintenance, or replacement of micro-wireless facilities that are suspended on cables or lines that are strung between existing utility poles shall not require any permit."

We recommend a discussion with the Department of Planning to seek their views regarding any issues or concerns from the implementation of this section of the Code in the 5G small cell environment, and those issues should be considered for any amendments to the Code. Neighboring jurisdictions could serve as one guide for this work. In particular, Virginia Beach has been at the forefront based on citizen concerns over aesthetics and fear of the uncontrolled proliferation of poles and antennas.

The concerns[25] and issues are caused by the fact that small cell antennas and related equipment have short ranges which imply closer spacing in public rights of way, which is made worse by the fact that 3-5 wireless service providers will be seeking access to "the same prime real estate" for antenna placement. Also, it should be noted that the term "small cell" is relative in that some equipment is the size of a household refrigerator on a pole, absent standards prohibiting equipment this large.

At present, the industry preference is not to collocate antennas on the same support structure (e.g., a streetlight pole). The close spacing and multiple service providers mean that the City will need ordinance provisions and internal departmental workflows to deal with potentially large numbers of applications for antenna placement. There are also concerns regarding inspections to ensure that the selected pole can support the weight of the equipment, and also ensure the actual installation does not deviate from the approved plan and permit.[26]

[25] See, "Virginia Beach Leaders have Concerns about 5G Antennas"; by Stacey Parker, The Virginian-Pilot, July 19, 2019.

[26] *Ibid*.

Appendix 4 – Financing and Operations

A. C-NGN Fiber Optic Backbone and Laterals

A 30-year Total Cost of Ownership (TCO) model for a City-owned and operated network includes all capital and operating expenses (CAPEX / OPEX) over the term. As we can only model known CAPEX costs, these models do not reflect future network expansions or their cost estimates beyond what has been identified in this plan. The C-NGN will grow as new municipal or community projects requiring network connectivity are identified. CAPEX spending will then increase through annual project-based budget appropriations while OPEX costs grow incrementally as expansion occurs.

As the City builds the C-NGN, it funds $32.5 million in construction over 36 months for approximately 172 miles of underground conduit and fiber-optic network backbone, campus, and lateral infrastructure. During the buildout period, the City migrates sites to the C-NGN as the network becomes available at that location. Consequently, the City's current operating spending attributed to broadband services decreases from the current total of $1.28 million after E-Rate discounts to $0 by 2024 when all five WAN are migrated to the C-NGN.

The City's total annual spending from the C-NGN including debt service grows from about $1.8 million in 2023 to $3.74 million in 2027. The C-NGN maintains these annual cost structures until approximately years 23/24 when key debt service amounts are retired. As outlined in the Detailed C-NGN Financial section below, the C-NGN has several revenue sources including internal service chargebacks from the five WANs and third-party external revenues to offset these costs. The City will incur less expensive Dedicated Internet Access (DIA) services through regional data center interconnects, thereby significantly reducing its remaining network service costs.

As depicted below in App 4 Table 1, the City spends $82.38 million over the term in addition to the City's initial funding. This spending consists of $32.22 million in capital assets (including a 10% project contingency), $8.65 million in network services, and $46.08 million in operations and maintenance while meeting debt service obligations over the duration.

App 4 Table 1: Selected Approach (Infrastructure-Only Public Service Provider) Total Cost of Ownership

YEAR	COST COMPONENTS			TOTAL ANNUAL OWNED COST			CUMULATIVE SPEND
	CAPITAL	CITY CONTRIBUTIONS	DEBT SERVICE	NETWORK SERVICES	O&M (2%)	TOTAL ANNUAL SPEND	
2021 (YEAR 1)	$3.47M	$3.37M					
2022	$12.39M	$5.35M	$0.01M		$0.30M	$0.31M	$0.31M
2023	$10.53M	$1.30M	$0.57M	$0.23M	$1.03M	$1.83M	$2.14M
2024	$5.58M	$1.50M	$1.34M	$0.24M	$1.42M	$2.99M	$5.13M
2025	$0.25M	$0.25M	$1.69M	$0.24M	$1.52M	$3.45M	$8.58M
2026			$1.72M	$0.25M	$1.74M	$3.71M	$12.29M
2027			$1.72M	$0.25M	$1.76M	$3.74M	$16.03M
2028			$1.72M	$0.26M	$1.44M	$3.43M	$19.46M
2029			$1.72M	$0.26M	$1.46M	$3.45M	$22.91M
2030 (YR 10)			$1.72M	$0.27M	$1.48M	$3.47M	$26.38M
2035 (YR 15)			$1.09M	$0.30M	$1.57M	$2.96M	$42.88M
2040 (YR 20)			$1.06M	$0.33M	$1.77M	$3.16M	$57.92M
2045 (YR 25)				$0.36M	$1.80M	$2.16M	$71.32M

YEAR	COST COMPONENTS			TOTAL ANNUAL OWNED COST			CUMULATIVE SPEND
	CAPITAL	CITY CONTRIBUTIONS	DEBT SERVICE	NETWORK SERVICES	O&M (2%)	TOTAL ANNUAL SPEND	
2050 (YR 30)				$0.40M	$1.94M	$2.34M	$82.38M
TOTALS	$32.22M	$11.77M	$27.63M	$8.65M	$46.08M	$82.38M	

1. Dark Fiber Leasing

Some cities require customers to pay the upfront costs of the fiber construction to reach their facilities and levy a smaller monthly operational charge to manage the fiber connection. Other cities will finance the cost of the fiber construction and charge the customer a higher monthly fee that includes the amortized amount of the fiber construction spread over several years. Sample lease rates from other cities are included in App 4 Table 2.

App 4 Table 2: Municipal Dark Fiber Lease Rates

Municipality/Municipal Utility	State	Monthly Lease Rate
City of Bartow	FL	$125/strand mile
City of Holly Springs	NC	$50/strand mile
City of Lakeland	FL	$100/strand mile
City of Rock Falls	IL	$100/strand mile
Eugene Water & Electric Board	OR	$21/strand mile
Palo Alto Utilities	CA	$336/strand mile
Springfield Utility Board	OR	$16/strand mile

B. C-NGN Wireless Overlay Networks

1. LoRaWan Wireless Overlay

The LoRaWAN Wireless Overlay represents a significant cost saving for the Public Utility AMI application. As shown below in App 4 Table 3, initially deploying 70,000 smart meters will yield the Utility a cost savings of between $294,000 and $504,000 annually eliminating the cost of third-party LTE-M wireless access. As the City deploys more LoRa devices, the savings grow. With 100,000 devices the aggregate savings is $480,000 to $780,000. The additional devices will use the same infrastructure to drive the cost per device down from $0.15 per month to $0.10.

App 4 Table 3: LoRa Costs and Initial Rate Setting

Cost Description	Cost	Other Details
Initial CapEx	$223,500	One Time Deployment Cost
10-Year OpEx on Wireless Assumptions	$136,234	
10-Year Transport/Backhaul	$186,480	1 Gbps Delivered to each tower shared between gateways
10-Year OpEx C-NGN	$291,738	Overhead/Administrative
Infrastructure Renewal and Replacement	$245,850	Initial CapEx + 10%
10-Year Wireless Engineer with OH	$388,762	
Total 10-Year TCO	$1,249,064	Does not include CapEx
Total APs/Gateways	16	
Total Endpoints/Devices	70,000	Assumes City Departments pay for endpoints
Monthly Device Access Fee	$0.15	

App 4 Table 4: LoRa Device Growth and Impact to Costs

Technology	Devices	C-NGN MRC	Commercial MRC	Cost Savings (3rd Party)
LORAWAN	70,000	$0.15	**$0.50 - $0.75 (LTE-M)**	$294k - $504k
	100,000	$0.10	**$0.50 - $0.75 (LTE-M)**	$480k - $780k

2. 700 MHz Wireless Overlay

SCADA is the primary application for the 700 MHz Wireless Overlay to achieve greater reliability and lower costs for the City's water system. C-NGN provides the 18 gateways as well as fiber backbone connections to towers where the gateways are installed. The recommended access fee covers all costs including connections, overhead, and towers. The department will be responsible for deploying the expected 260 network devices to connect to the SCADA components. The level of savings cannot be estimated because this is for an expanded set of devices using a new service—these SCADA components currently communicate over the public safety radio systems, which creates risks for all involved.

The expanded SCADA will enable the Public Utility department to proactively address issues and thereby avoid costs, but we cannot meaningfully estimate the value of that functionality. For example, it could just reduce waste by reducing leakage overproduction, or the SCADA could prevent catastrophic equipment failures. The monthly cost per connection is the cost to deploy and manage the 700 MHz infrastructure spread over all devices; adding devices will lower the monthly cost per connection. While other applications could bolster the business case for 700 MHz, they will need to be assessed carefully to ensure they do not compromise the SCADA system.

App 4 Table 5: 700 Mhz Costs and Initial Rate Setting

Cost Description	Cost	Other Details
Initial CapEx	$398,000	One Time Deployment Cost
10-Year OpEx on Wireless Assumptions	$242,599	
10-Year Transport/Backhaul	$239,760	1 Gbps Delivered to each tower, shared between gateways
10-Year OpEx C-NGN	$442,534	Overhead/Administrative
Infrastructure Renewal and Replacement	$437,800	Initial CapEx + 10%
10-Year Wireless Engineer with OH	$499,837	
Total 10-Year TCO	$1,862,531	Does not include CapEx
Total Aps/Gateways	18	
Total Endpoints/Devices	260	Assumes City Departments pay for endpoints
Monthly Device Access Fee	$59.70	

3. 4.9 GHz Wireless Overlay

The 15 endpoints of the 4.9 GHz Wireless Overlay network are served by three point-to-point gateways (3 endpoints) and four point-to-multipoint gateways (12 endpoints). The initial C-NGN business case for this overlay only covers backhaul of the specified traffic cameras and sign applications, and the recommended monthly recurring cost in the business case includes all associated tower, gateway, and operating components. The traffic department would procure and install the endpoint hardware including the 4.9 GHz client radio, camera, and/or sign separately from the C-NGN budget.

The 4.9 GHz business case can be expanded to provide a large-scale high-speed data overlay by deploying additional gateways and sectorized or omni-directional antennas.[27] Gateways with integrated Wi-Fi are available to support additional use

[27] Riverside CA deployed over 1,300 4.9GHz gateways, providing a complete high-speed overlay of the city

cases (i.e. Cisco Aironet 1500 series). The City can also selectively use the 4.9 GHz network as an alternative lateral solution, where departments would budget and pay for the point-to-point link in the same manner as a fiber link. These deployment models are not analyzed in this business case. In all cases, the DIT will manage the wireless network while the departments using it will manage their endpoint devices and the applications they support.

App 4 Table 6: 4.9 GHz Costs and Initial Rate Setting

Cost Description	Cost	Other Details
Initial CapEx	*$142,500*	*One Time Deployment Cost*
10-Year OpEx on Wireless Assumptions	$86,860	
10-Year Transport/Backhaul	$93,240	1 Gbps Delivered to each tower shared between gateways
10-Year OpEx C-NGN	$164,613	Overhead/Administrative
Infrastructure Renewal and Replacement	$156,750	Initial CapEx + 10%
10-Year Wireless Engineer with OH	$194,381	
Total 10-Year TCO	$695,844	Does not include CapEx
Total APs/Gateways	7	
Total Endpoints/Devices	15	Assumes City Departments pay for endpoints
Monthly Device Access Fee	$386.58	

Glossary

3G – Third Generation	The third generation of mobile broadband technology, used by smartphones, tablets, and other mobile devices to access the web.
4G – Fourth Generation	The fourth generation of mobile broadband technology, used by smartphones, tablets, and other mobile devices to access the web. Also referred to as Long Term Evolution (LTE).
5G – Fifth Generation	The fifth generation of mobile broadband technology, used by smartphones, tablets, and other mobile devices to access the web. It is believed that this technology will significantly increase bandwidth to users, up to 1 Gig.
ADSL – Asymmetric Digital Subscriber Line	DSL service with a larger portion of the capacity devoted to downstream communications, less to upstream. Typically thought of as a residential service.
ADSS – All-Dieletric Self-Supporting	A type of optical fiber cable that contains no conductive metal elements.
AMR/AMI – Automatic Meter Reading/Advanced Metering Infrastructure	Electrical meters that measure more than simple consumption and an associated communication network to report the measurements.
APC – Angled Physical Contact	Fiber connector with an angled ferrule to minimize light reflection and optical return loss. Connecting an APC cable to a UPC jack or vice-versa can damage the connectors.
AS - Autonomous System	A large network or group of networks that has a unified Internet routing policy. Every computer or device that connects to the Internet is connected to an AS.

ASN – Autonomous System Number	A unique number identifying an AS connected to two or more ISP's with its own distinct Internet routing policy.
Bandwidth	The amount of data transmitted in a given amount of time; usually measured in bits per second, kilobits per second (kbps), and Megabits per second (Mbps).
Bit	A single unit of data, either a one or a zero. In the world of broadband, bits are used to refer to the amount of transmitted data. A kilobit (Kb) is approximately 1,000 bits. A Megabit (Mb) is approximately 1,000,000 bits. There are 8 bits in a byte (which is the unit used to measure storage space), therefore a 1 Mbps connection takes about 8 seconds to transfer 1 megabyte of data (about the size of a typical digital camera photo).
BPL – Broadband over Powerline	A technology that provides broadband service over existing electrical power lines.
Broadband	A descriptive term for evolving digital technologies that provide consumers with integrated access to voice, high-speed data service, video-demand services, and interactive delivery services (e.g. DSL, Cable Internet).
CAD – Computer Aided Design	The use of computer systems to assist in the creation, modification, analysis, or optimization of a design.
CAI – Community Anchor Institutions	The National Telecommunications and Information Administration defined CAIs in its SBDD program as "Schools, libraries, medical and healthcare providers, public safety entities, community colleges and other institutions of higher education, and other community support organizations and entities." Universities, colleges, community colleges, K-12 schools, libraries, health care facilities, social service providers, public safety entities, government and municipal offices are all community anchor institutions.

CAP – Competitive Access Provider	(or “Bypass Carrier”) A Company that provides network links between the customer and the Inter-Exchange Carrier or even directly to the Internet Service Provider. CAPs operate private networks independent of Local Exchange Carriers.
CBRS – Citizens Broadband Radio Service	150 MHz of spectrum in the 3.5 GHz band located between 3550 – 3700 MHz. Used sparingly by government and other entities, the band was entified by the FCC as additional spectrum for shared wireless private broadband.
Cellular	A mobile communications system that uses a combination of radio transmission and conventional telephone switching to permit telephone communications to and from mobile users within a specified area.
CLEC – Competitive Local Exchange Carrier	Wireline service provider that is authorized under state and Federal rules to compete with ILECs to provide local telephone service. CLECs provide telephone services in one of three ways or a combination thereof: 1) by building or rebuilding telecommunications facilities of their own, 2) by leasing capacity from another local telephone company (typically an ILEC) and reselling it, and 3) by leasing discrete parts of the ILEC network referred to as UNEs.
CO – Central Office	Voice switching equipment serving telephone lines in a geographic area, usually housed in a small building.
Coaxial Cable	A type of cable that can carry large amounts of bandwidth over long distances. Cable TV and cable modem service both utilize this technology.
CPE – Customer Premise Equipment	Any terminal and associated equipment located at a subscriber's premises and connected with a carrier's telecommunication channel at the demarcation point ("demarc").

CWDM – Coarse Wavelength Division Multiplexing	A technology for multiplexing up to 18 optical wavelengths onto a single fiber strand at a “coarse spacing” of 20 nm apart. Similar to, but less costly than, DWDM where less capacity is required per fiber.
Demarcation Point (“demarc”)	The point at which a service provider’s wide area network connects to a customer's local area network.
DIA – Direct Internet Access	An Internet service delivered to an end user by an ISP where Internet routing is controlled by the ISP.
Dial-Up	A technology that provides customers with access to the Internet over an existing telephone line.
Downstream	Data flowing from the Internet to a computer (Surfing the net, getting E-mail, downloading a file).
DSL – Digital Subscriber Line	The use of a copper telephone line to deliver “always on” broadband Internet service.
DWDM – Dense Wavelength Division Multiplexing	A technology for multiplexing up to 120 optical wavelengths onto a single fiber strand at a “dense spacing” of 0.8 nm apart. Typically used for long distances or high capacity backbones due to its cost premium over CWDM.
E-Rate	A Federal program that provides subsidy for voice and data circuits as well as internal network connections to qualified schools and libraries. The subsidy is based on a percentage designated by the FCC.
EON – Ethernet Optical Network	The use of Ethernet LAN packets running over a fiber network.
FCC – Federal Communications Commission	A Federal regulatory agency that is responsible for regulating interstate and international communications by radio, television, wire, satellite and cable in all 50 states, the District of Rock Falls, and U.S. territories.

FDH – Fiber Distribution Hub	A connection and distribution point for optical fiber cables.
FDP – Fiber Distribution Panel	A rack-mounted panel terminating backbone or distribution fiber to pluggable connectors for cross-connection of other fibers or broadband equipment. Connector profiles are typically SC or LC, and may terminate as UPC or APC.
FMS – Fiber Management System	A fiber management system is software that is the control center for network assets, especially fiber. The system manages connections from outside the fiber rack to the fiber routers. It tracks functions or attributes of the system such as schematic design, physical locations of assets, splice points and more. It can be used to plan, design, build, operate, analyze, and troubleshoot fiber-optic networks.
FTTP – Fiber to the premise (or FTTB – Fiber to the building)	A fiber-optic system that connects directly from the carrier network to the user premises.
GIS – Geographic Information Systems	A system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.
GPON- Gigabit-Capable Passive Optical Network	Supports asymmetric bandwidth of 2.5 Gbps down and 1.2 Gbps up on a single fiber, and can be shared through a passive splitter to serve up to 128 ONT's.
HD – High Definition (Video)	Video of substantially higher resolution than standard definition encompassing 1280x720 pixels for standard HD and 1920x1080 pixels for full HD.
HLD – High-Level Design	A high-level design includes a more accurate depiction of a network after conceptual design, and includes route selection, detailed Bills-of-Material, and engineers estimates to construct.

ICT – Information and Communications Technology	Often used as an extended synonym for information technology (IT), but it is more specific term that stresses the role of unified communications and the integration of telecommunications, computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information.
IEEE – Institute of Electrical Engineers	A professional association headquartered in New York City that is dedicated to advancing technological innovation and excellence.
ILEC – Incumbent Local Exchange Carrier	The traditional wireline telephone service providers within defined geographic areas. Prior to 1996, ILECs operated as monopolies having exclusive right and responsibility for providing local and local toll telephone service within LATAs.
IoT - Internet of Things	A system of networked “things” consisting of mechanical and digital devices with unique functions and identifiers, communicating data to a repository or application without human interaction.
IP Transit	Internet connections between ASN’s allowing Internet routing to be controlled independently by each AS.
IP-VPN – Internet Protocol-Virtual Private Network	A software-defined connection overlaying a shared network offering the security, functionality, and usefulness of a dedicated private network.
ISP – Internet Service Provider	A company providing Internet access to consumers and businesses, acting as a bridge between customer (end-user) and infrastructure owners for dial-up, cable modem and DSL services.

ITS – Intelligent Traffic System	Advanced applications which, without embodying intelligence as such, aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks.
Kbps – Kilobits per second	1,000 bits per second. A measure of how fast data can be transmitted.
LAN – Local Area Network	A geographically localized network consisting of both hardware and software. The network typically links workstations within a single building or campus.
LATA – Local Access and Transport Areas	A geographic area within a divested Regional Bell Operating Company is permitted to offer exchange telecommunications and exchange access service. Calls between LATAs are often thought of as long-distance service. Calls within a LATA (IntraLATA) typically include local and local toll services.
LLD – Low-Level Design	Low-Level Design is the final stage in the development of construction drawings that include actual blueprints, construction details, detailed Bills-of-Material, and final engineer's estimate for construction.
Local Loop	A generic term for the connection between the customer's premises (home, office, etc.) and the provider's serving central office. Historically, this has been a copper wire connection; but in many areas it has transitioned to fiber optic. Also, wireless options are increasingly available for local loop capacity.
LoRaWAN	Long Range, Low Power Wide Area Networking (LPWAN) protocol designed to wirelessly connect battery operated 'things' to the internet, supporting IoT requirements such as bi-directional communication, end-to-end security, mobility and localization services up to 50 Kbps.

MAN – Metropolitan Area Network	A high-speed intra-city network that links multiple locations with a campus, city or LATA. A MAN typically extends as far as 30 miles.
Mbps – Megabits per second	1,000,000 bits per second. A measure of how fast data can be transmitted.
Middle Mile Network	Middle mile is a term most often referring to the network connection between the last mile and greater Internet. For instance, in a rural area, the middle mile would likely connect the town's network to a larger metropolitan area where it interconnects with major carriers.
MPLS – Multiprotocol Label Switching	A feature in carrier-class networks that creates pre-defined data paths using labels that provide sub-second fault recovery for circuit failures. MPLS supports independent and secure layer 2/3 networks shared on the same physical network.
ONT – Optical Network Terminal	Used to terminate the fiber-optic line, demultiplex the signal into its component parts (voice telephone, television, and Internet), and provide power to customer telephones.
OTN – Optical Transport Network	Optical Transport Network is a next-generation, industry-standard protocol that provides an efficient and globally accepted way to multiplex different services onto optical light paths.
Overbuilding	The practice of building excess capacity. In this context, it involves investment in additional infrastructure projects to provide competition.

PON – Passive Optical Network	A Passive Optical Network consists of an optical line terminator located at the Central Office and a set of associated optical network terminals located at the customer's premise. Between them lies the optical distribution network comprised of fibers and passive splitters or couplers. In a PON network, a single piece of fiber can be run from the serving exchange out to a subdivision or office park, and then individual fiber strands to each building or serving equipment can be split from the main fiber using passive splitters / couplers. This allows for an expensive piece of fiber cable from the exchange to the customer to be shared among many customers, thereby dramatically lowering the overall costs of deployment for fiber to the business (FTTB) or fiber to the home (FTTH) applications.
PoP – Point of Presence	A point of presence is a demarcation point, access point, or physical location at which two or more networks or communication devices share a connection.
PPP – Public-Private Partnership	A Public–Private Partnership (PPP) is a government service or private business venture that is funded and operated through a collaborative partnership between a government and one or more private sector organizations. In addition to being referred to as a PPP, they are sometimes called a P3, or P^3.
QOS – Quality of Service	QoS (Quality of Service) refers to a broad collection of networking technologies and techniques. The goal of QoS is to provide guarantees on the ability of a network to deliver predictable results, which are reflected in Service Level Agreements or SLAs. Elements of network performance within the scope of QoS often include availability (uptime), bandwidth (throughput), latency (delay), and error rate. QoS involves prioritization of network traffic.

RF – Radio Frequency	a rate of oscillation in the range of about 3 kHz to 300 GHz, which corresponds to the frequency of radio waves, and the alternating currents which carry radio signals.
Right-of-Way	A legal right of passage over land owned by another. Carriers and service providers must obtain right-of-way to dig trenches or plant poles for cable systems, and to place wireless antennas.
RMS – Resource Management System	A system used to track telecommunications assets.
ROADM – Reconfigurable optical add/drop multiplexers	A network device that can flexibly add or drop data streams from an optical wavelength—a portion of the light spectrum used to carry information.
RUS – Rural Utility Service	A division of the United States Department of Agriculture, it promotes universal service in unserved and underserved areas of the country with grants, loans, and financing. Formerly known as “REA” or the Rural Electrification Administration.
SaaS – Software-as-a-Service	SaaS is a method of software delivery and licensing in which software is accessed online via a subscription, rather than bought and installed on individual computers.
SCADA – Supervisory Control and Data Acquisition	A type of industrial control system (ICS). Industrial control systems are computer-controlled systems that monitor and control industrial processes that exist in the physical world.
SNMP – Simple Network Management Protocol	An Internet-standard protocol for managing devices on IP networks.
SNA-RCR	Southside Network Authority – Regional Connectivity Ring

SONET – Synchronous Optical Network	A family of fiber-optic transmission rates.
Streaming	Streamed data is any information/data delivered from a server to a host where the data represents information that must be delivered in real time. This could be video, audio, graphics, slide shows, web tours, combinations of these, or any other real time application.
Subscribership	Subscribership is how many customers have subscribed for a particular telecommunications service.
Submarine Network	Submarine networking is the process by which data is carried on subsea cables to connect continents. Submarine networks carry 95 percent of the world's intercontinental electronic communications traffic.
Switched Network	A domestic telecommunication network usually accessed by telephone, key telephone systems, private branch exchange trunks, and data arrangements.
TCO – Total Cost of Ownership	The Total cost of ownership of an asset includes its initial costs to construct, as well as the annual operating costs over a specific term.
Universal Service	The idea of providing every home in the United States with basic telephone service.
UPC –Ultra Physical Contact	Fiber connector with a flat ferrule that is less costly than APC connectors. Connecting an APC cable to a UPC jack or vice-versa can damage the connectors.
Upstream	Data flowing from your computer to the Internet (sending E-mail, uploading a file).

UPS – Uninterruptable Power Supply	An electrical apparatus that provides emergency power to a load when the input power source, typically main power, fails.
USAC – Universal Service Administrative Company	An independent American nonprofit corporation designated as the administrator of the Federal Universal Service Fund (USF) by the Federal Communications Commission.
VAR – Value Added Reseller	A VAR is a company that adds features or services to an existing product, then resells it as an integrated product or complete turnkey solution.
Video on Demand	A service that allows users to remotely choose a movie from a digital library whenever they like and be able to pause, fast-forward, and rewind their selection.
VLAN – Virtual Local Area Network	In computer networking, a single layer-2 network may be partitioned to create multiple distinct broadcast domains, which are mutually isolated so that packets can only pass between them via one or more routers; such a domain is referred to as a Virtual Local Area Network, Virtual LAN or VLAN.
VoIP – Voice over Internet Protocol	An application that employs a data network (using a broadband connection) to transmit voice conversations using Internet Protocol.
VPN – Virtual Private Network	A virtual private network (VPN) extends a private network across a public network, such as the Internet. It enables a computer to send and receive data across shared or public networks as if it were directly connected to the private network, while benefitting from the functionality, security and management policies of the private network. This is done by establishing a virtual point-to-point connection through the use of dedicated connections, encryption, or a combination of the two.

WAN – Wide Area Network	A network that covers a broad area (i.e., any telecommunications network that links across metropolitan, regional, or national boundaries) using private or public network transports.
WiFi	WiFi is a popular technology that allows an electronic device to exchange data or connect to the Internet wirelessly using radio waves. The WiFi Alliance defines WiFi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards".
WiMAX	WiMAX is a wireless technology that provides high-throughput broadband connections over long distances. WiMAX can be used for a number of applications, including “last mile” broadband connections, hotspot and cellular backhaul, and high speed enterprise connectivity for businesses.
Wireless	Telephone service transmitted via cellular, PCS, satellite, or other technologies that do not require the telephone to be connected to a land-based line.
Wireless Internet	1) Internet applications and access using mobile devices such as cell phones and palm devices. 2) Broadband Internet service provided via wireless connection, such as satellite or tower transmitters.
Wireline	Service based on infrastructure on or near the ground, such as copper telephone wires or coaxial cable underground or on telephone poles.
WISP – Wireless ISP	An ISP using unlicensed or semi-licensed wireless frequencies and facilities to distribute and deliver retail subscriber Internet services.
XGS-PON- 10Gbs Symetrical Passive Optical Network	Supports symmetric bandwidth of 10Gbps down and up on a single fiber, and can be shared through a passive splitter to serve up to 128 ONT’s.