7. Appendix 1 –SBCM Network Topology Methods

7.1 Introduction to CQLL

SBCM makes use of two long standing models to develop SBCM network topologies: CostQuest LandLine (CQLL) and CostQuest Middle Mile (CQMM).

This appendix provides an overview of how the wireline topology was developed for SBCM. As such, this section includes an overview of the underlying network loop topology platform (i.e., CQLL) as well as a discussion of modeling methods, a summary of key data sources and an overview of results.

Appendix 9 provides a corresponding overview of how wireline middle mile facilities are modeled using the CQMM platform. CQMM output is used by SBCM to build the final comprehensive network topology which is in turn utilized in the development of a Solution Set.

CQLL produces a network topology (including cable lengths, equipment sizes and locations, etc.) for use in the SBCM application. The modeled network includes all work efforts and components to prepare and place the asset / system for productive use within a network designed to provide the desired level of voice and broadband service.

Inputs, as outlined in this Appendix, are based on publicly available data and service area boundaries. Assumptions and engineering rules reflect real-world / current engineering practices, including how these practices are applied within specific terrain.

Finally, the central economic model is a widely accepted, modern approach to network modeling practices used throughout the industry.

CQLL is a next-generation network modeling platform. It models a forward-looking, optimized network based on a current demand analysis of network utilization. The CQLL platform uses a granular approach, adheres to spatial relationships and is based upon realistic implementations of common engineering guidelines.

At its core, the CQLL modeling platform is a "spatial" model. It determines where demand is located and "lays" cable along the actual roads of the service area to reach that demand point. In fact, a cable path can literally be traced from each demand location to the serving Central Office; a path that follows the actual roads in the service area.

CQLL determines the topology for wireline network components, across all categories of plant required to connect a specific service demand group (e.g. all locations or only connected locations) to their serving Central Office – and to provide voice and broadband-capable networks. The model assumes the installation of forward-looking, commercially available telecommunications technologies and uses generally accepted engineering practices and procedures.

7.2 Accurate Bottoms-Up Design

Topologies created by CQLL are grounded in network connections among service demand Just like an engineer, the model tallies the necessary length and type of network facilities, including relevant network components and electronics, based on demand, Central Office locations and service architectures.

7.3 Developing Costs for Voice and Broadband Services

For the SBCM application, CQLL was used to develop a GPON Fiber to the Premise (FTTp) network. More specifically, SBCM 's FTTp topology is a design where the entire network from the Central Office to the demand location is entirely fiber optic facilities. In this design, the demand point is within 5,000 feet of the fiber splitter.

7.4 Network Assets

The logic behind economic network modelling is derived from a realistic, engineering-based understanding of what drives; i.e., causes, investments in the environment (both physical and service demand) in which the network will serve.

As a broad guide, the following discussion provides the increments and drivers of the basic assets in the network modelled within the CQLL framework.

Loop: Wireline loop plant connects demand locations to Central Offices. The basic drivers of loop plant investment, including electronics, include all manner of demand and location. The loop is typically broken into a distribution portion and feeder portion. Distribution runs to demand locations from the Feeder Distribution Interface (FDI) described below while feeder runs to the Central Office from the FDI.

The distribution components, drivers, and nomenclature of the typical loop as modeled in CQLL are described below:

Network Interface Device (NID) – The NID serves as a demarcation point between connected locations and the carrier's distribution plant. In a Fiber to the Premise (FTTp) installation, an Optical Network Terminal and battery are used in place of a conventional copper NID.

Optical Networking Terminal (ONT) – An ONT is used to provide services to connected locations in an FTTP topology. An ONT is hosted by an Optical Line Terminal. The ONT is placed at each connected location.

Customer Premise Equipment (CPE) – CPE can be capitalized equipment that is placed on a customer premise. Its use is driven by a particular service (e.g., a modem for DSL). CPE investment is driven by the count of services, connected locations served, and ultimate ownership of the equipment.

Drop Wire (Drop) – In an FTTp deployment, the Drop is a cable sheath which permanently connects the ONT to the Fiber Service Terminal with fiber optic cable. Essentially, the drop wire provides the connection between the premises and the distribution cable at the street. A drop wire can be buried or aerial and is driven by connected location demand.

Distribution Terminal / Building Terminal (DTBT) – For telecom deployment, the Distribution Terminal (DT) is the point where the drop wires from several connected locations are connected to pairs in a larger cable. This cross-connect (sometimes called a "tap point") can be located at a pole, handhole, buried splice, or pedestal. In some circumstances, the cross-connect or tap point can be a Building Terminal (BT). The BT acts as the demarcation point at a location where it is more effective to simply terminate a distribution cable at the demand location rather than using drop cables and NIDs. For FTTp, the DTs and BTs are replaced by Fiber Service Terminals and are fed by fiber cable.

For reporting purposes, the cross-connect point, whether it is a DT or BT or Fiber Service Terminal is described and tracked as a DTBT within CQLL. It is generically referred to as Node3 in topology structure diagrams.

Distribution Cable (DT-FDI) – The DT-FDI is the loop component that connects the DTBT with the feeder cable at the Feeder Distribution Interface (FDI). For FTTp designs, the distribution cable is fiber.

As the topology is exported to SBCM, SBCM user inputs specify the percentage of distribution cable that is buried, underground or aerial through the entries in the plant mix table. The plant mix table is a portion of an Input Collection.

The major components of the feeder portion of the loop are described below:

Feeder Distribution Interface (FDI) – In copper loop architectures, the FDI is where distribution cables are connected to a feeder cable. The FDI allows any feeder pair to be connected to any distribution pair. (For reporting purposes, a portion of the FDI is assigned to distribution.) For FTTp designs, the FDI is replaced by the Fiber Distribution Hub (FDH) or Primary Flexibility Point (PFP).

Fiber Distribution Hub / FiberSplitter (FDH/PFP) – In an FTTp design, the fiber cable from the OLT in the Central Office or in the field is split at the FDH/PFP into 16 to 32 distribution fibers. These 16 to 32 distribution fibers then connect to ONTs at the premises.

The FDI and FDH/PFP are generically referred to as Node2 in topology structure diagrams.

Optical Line Terminal (OLT) – In an FTTp design, the fiber cable from the PFP terminates on an OLT. This OLT can either be housed in the Central Office or in the field.

Gigabit Ethernet (GbE or GigE) – A term implying the use of Ethernet to carry data at Gigabit speeds over Fiber Optic cable. For example, GigE is generally used to transport data from OLTs to the Central Office.

Feeder Cable (FDI-DLC and DLC-CO) – The feeder cable transports traffic between the FDI/PFP and the Central Office.

Ethernet Switch (eSwitch) – Internet Protocol traffic from each Service Area is routed to an Ethernet switch located in each Central Office.

The OLT and Ethernet Switch are generically referred to as Node0 in topology structure diagrams.

7.4.1 End User Demand Point Data

Within CQLL, the modeling exercise can begin with address-geocoded location data. Address geocoding is a method used to match an address to a location on a physical (real world) road network. Address geocoding is a well-established technique to derive a locational attribute, such as longitude and latitude or linear reference,[35] from an address.

CQLL then augments actual geocoded point data with surrogate locations for demand that cannot be located accurately. These surrogate locations are based upon generally accepted data sources (e.g., Census data), client-specific engineering and optimization rules, and standard industry practices.

In the current SBCM implementation, CQLL uses geocoded information from GeoResults and Census information to derive estimated demand locations. As noted above, the surrogation of points is based upon generally accepted practices and occurs at the finest level of Census geography. That is, the surrogation of data takes place at the Census Block level using the roads and location counts within each Census Block. A technique called "stacking" provides for a relevant representation of demand located in apartment buildings. Care is taken so as not to place locations on specific types of roads such as interstate highways.

7.4.2 Service Areas

Using industry standard engineering rules, road distance and service demand information (e.g., DS0s, pairs, Living Units, etc.), service clusters are formed. A service cluster is a group of demand points which share a common loop network technology. For example, for a broadband network a service area could be described for all demand locations sharing the same DSLAM. Within each cluster, appropriate forward-looking digital equipment and copper and/or fiber cable is placed. Service clusters are used to surrogate: Distribution Areas (DAs), Fiber Serving Areas, Carrier Serving Areas, and Allocation Areas (FSA/CSA/AA).

7.5 Methods - Efficient Road Pathing and Networks

CQLL designs a network to serve demand locations within a service area (e.g., wire center, etc.) based on where they actually reside. The model "lays" cable along the actual roads in the service area to connect locations with their serving Central Office. As this section demonstrates, the network can be seen on a map of the actual roads in a service area. In fact, it will aid the reader in understanding the model if he/she begins to immediately consider *visually* the spatial layout of a road network. The figure below shows the road network for a typical service area.

[35] A linear reference is a method by which location is described in terms of a distance along a feature. A highway mile-marker is a type of linear reference. This is in contrast to a latitude, longitude which is a locational reference in terms of a grid placed upon the Earth's surface.

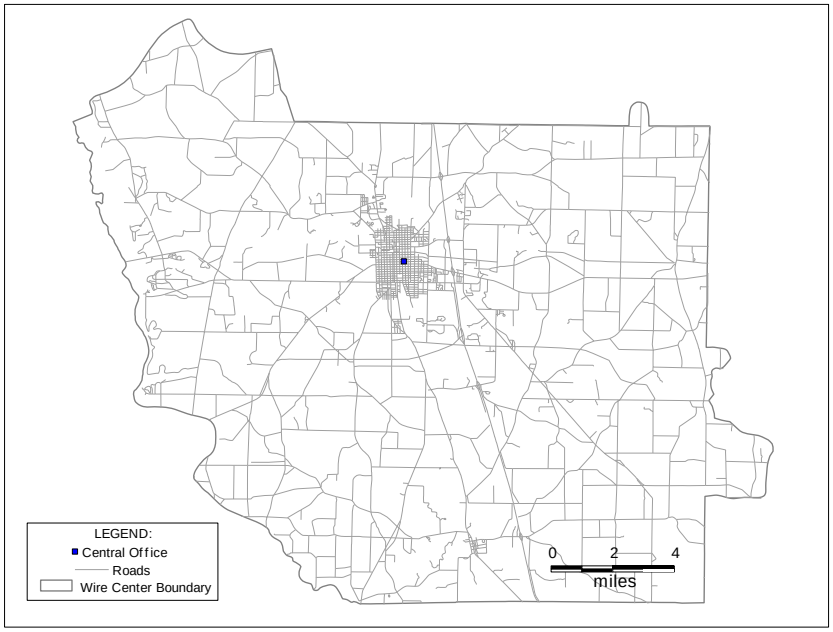


Figure 5 -- Road Network

7.6 Demand Data Preparation

The demand location data (both business and residential) was pulled from public sources. For residential data, GeoResults address data was trued up with Census household counts. For business data, GeoResults address data was used. In each case, counts of locations by address and/or Census Block are provided. Before the location data can be used, it must be located on the earth's surface, along a road path so that the network routing algorithms know where to route. For demand location that is non-address or cannot be geocoded, a random placement algorithm is used to place the demand locations along the roads of the Census Block. Care is taken so as not to use roads that are restricted (e.g., interstate highways).[36] In addition, multifamily and buildings containing residential and business demand are tracked. This allows CQLL to identify the appropriate multi-dwelling equipment rather than replicate single demand unit equipment.

Figure 6, presents a section of the view shown in Figure 7 with demand locations shown as circles. In this example, these circles represent *all* of the service demand points (e.g., both business and residences). The demand and service data are now ready for processing by CQLL.

[36] TIGER road types used by the model include S1200, S1400, S1640 and S1740.

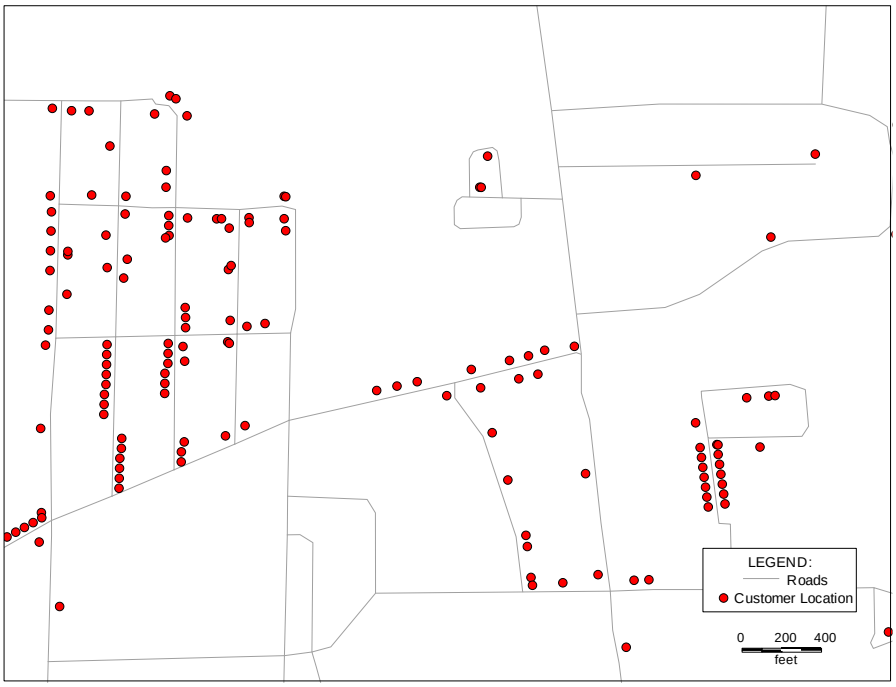


Figure 6 -- Demand Locations

7.7 Efficient Routing

Using the demand locations and the road network, specifically designed and reviewed algorithms determine network routing and placement based upon standard industry engineering rules. As a first step, CQLL uses an Efficient Road Pathing ("ERP") algorithm to develop the optimized routing from the Central Office to all demand locations. Once a full service area ERP is determined, CQLL develops natural clusters by linking demand points that are close together (e.g., neighbors). These neighbor groups are further combined with other nearby demand clusters to form larger clusters ("neighborhoods"). This process continues until the clusters reach the limits of length and/or capacity as specified by the engineering design (e.g., 5kft max length from the fiber splitter). Once all demand locations to be served by a host node are determined, appropriate components such as Feeder Distribution Hubs (FDHs), Fiber Nodes and Feeder Distribution Interfaces (FDIs) are located within each serving area. Once the serving nodes are placed within these "remote" served serving areas, an optimal path is formed to the hosting Node. The path within each serving area then becomes the distribution cable path. This process continues until all portions of the service area have been "clustered".

For those demand locations served by a terminal in the Central Office, a distinct ERP is determined. Once the main Central Office served areas are determined, an ERP is created. These tree paths are then 'walked' to determine points at which Feeder Distribution Interfaces (for copper areas) or Fiber Distribution Hubs (for fiber served areas) terminals are to be placed. These placements are driven by user inputs guiding demand location counts and distance limits.

As a final step in the pathing algorithms, an ERP for feeder plant is determined. That ERP links the nodes outside of the Central Office (e.g. DSLAM or FSH, Node2) to the Central

Office (CO). Figure 7 depicts a distribution network created by the process based on the optimized ERP approach. Figure 8 depicts the same type of information for the feeder network.

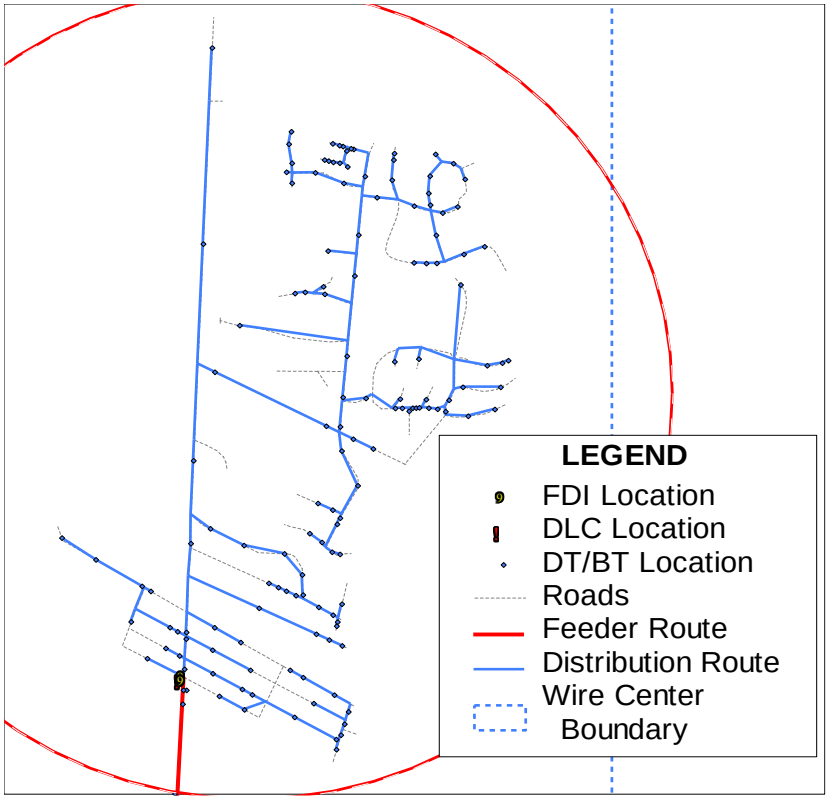


Figure 7—Distribution Plant

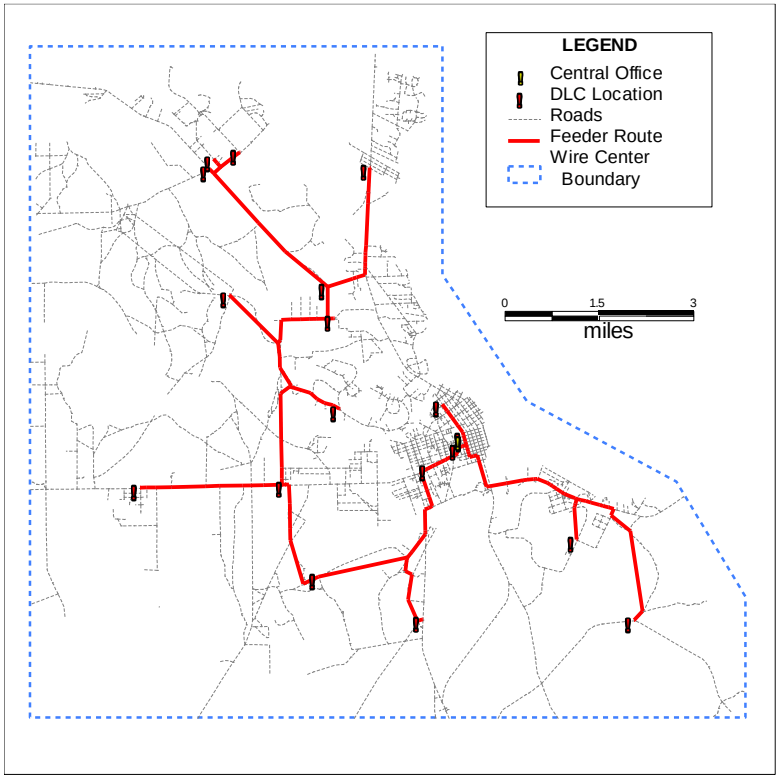


Figure 8 -- Path for Feeder Plant

After the serving areas and optimal routings are determined, engineering rules guide the installation and placement of electronics, such as Fiber Nodes and Central Office Terminals.

Once the spatial layout of the network is determined, CQLL's Configuration Process connects the network components. This entails the determination of cable sizes, identification of service points requiring special engineering, and selection and sizing of Node2 type. Once the network is configured, CQLL summarizes the network topology information to create the source file for the SBCM application. In this summarization, the information about the network build is related to / associated with the relevant Census Block records. As such, each Census Block record captures the size of the main serving terminal (e.g., DSLAM, FDH, etc.), the demand at the Central Office, the length of the feeder and distribution cable and the portion attributable to the Census Block, and other pertinent information relevant to the network build.

SBCM allows an end user to review these two summary files by wire center. These reports are available as Audit reports, Audit Network Design Dist or Audit Network Design Feeder.

7.8 CQLL Network Engineering, Topologies and Node Terminology

CQLL develops investment estimates for wireline loop plant. The loop is the portion of the telecommunications network that extends from the Central Office (CO) to the demand location.

A loop extends from a demand location (a business or housing unit). It can be terminated on specific customer premise equipment, CLEC equipment or any multitude of routers, gateways or specialized equipment necessary to support IP driven services like VoIP.

CQLL designs a network using forward-looking technologies and design principles. To meet the heterogeneous engineering characteristics of today's service providers, CQLL is capable of modeling different wireline topologies. This section describes potential network topologies and lists the Node reference for each. It is helpful to understand the unique Node naming conventions as these descriptions carry forward to audit reports and cost / investment information.

In the SBCM network designs, the references to network topology have been standardized by using the values of Node0 through Node4. Node identifiers are used to help bridge the understanding of functionality across the differing technologies (wireless and various forms of fiber and hybrid fiber solutions) that are used in SBCM. The "nodes" are significant in that they represent the way in which costs are assigned / aggregated to enable comparisons across technologies. A node diagram for FTTp design is provided for reference.

The IP based topology modeled in SBCM is Passive Optical Network (GPON) FTTp (Fiber to the Premise), as depicted below.

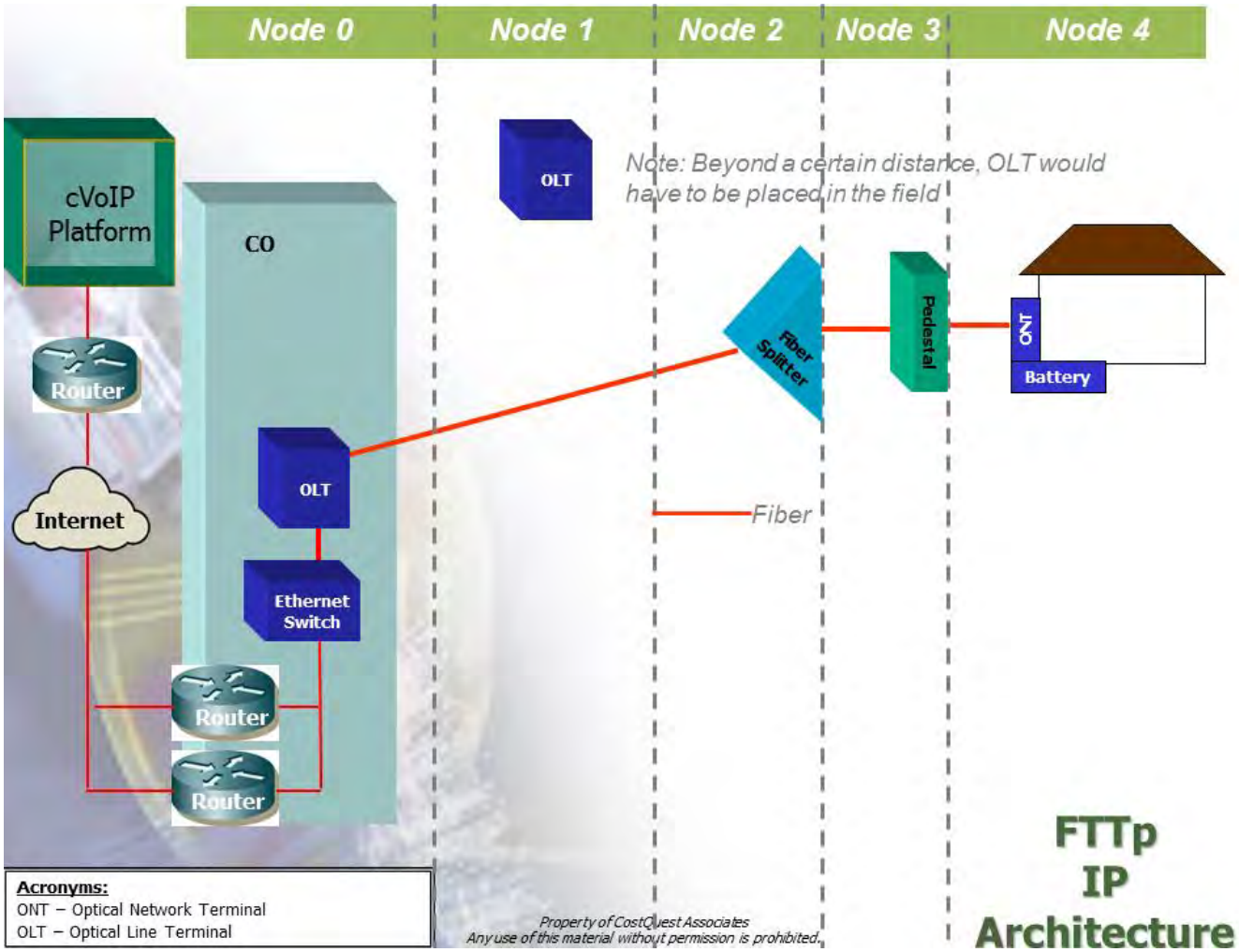


Figure 9--FTTP topology

In this topology an ONT (Optical Network Terminal) is placed at the demand location, along with a battery for backup power. Fiber cable then connects to the Central Office. Along the path, the fiber is concentrated at the PFP (Primary Flexibility Point) or FDH (Fiber Distribution Hub) in a typical 32 to 1 ratio. At the Central Office, the fiber from the PFP or FDH terminates on an OLT (Optical Line Terminal). The traffic is then sent to an Ethernet switch. IP packets are routed to the IP network via a connection to a router. This gateway router can be in the Central Office or can be located at an intermediate office to support multiple Central Offices.

7.9 Key Network Topology Data Sources

Network Topology development requires data inputs and modeling assumptions unique to SBCM's requirements and assumptions. Input data and relevant sources are outlined below.

7.9.1 Service Area Engineering Input data

Public domain and commercially licensed data products provide the foundation for the CQLL model. This included service area boundaries, Central Office locations and demand sources.

- Service Area boundaries and Central Office locations were derived based upon carrier submissions to the FCC through the Study Are Boundary development process and response to the SBCM Service Area public notice.

7.9.2 Demand data

The goal of SBCM was to produce investment for all potential voice and broadband demand locations; CQLL develops a network serving all potential residential and business locations.

Residential demand was based upon GeoResults (3rd Qtr. 2012) data that provided residential and business address data. Residential counts in each Census block were trued up to Housing Unit counts from 2011 Census data. Business demand data was also derived from GeoResults (3rd Qtr 2012).

7.9.3 Supporting Demographic Data

CQLL requires several additional data sources to support road pathing and demographic analysis.

These data sources are described below:

- Roads
  - Source: US Census TIGER
  - Vintage: 2010

- Census Blocks
  - Source: US Census TIGER
  - Vintage: 2010

- Demographic Estimates
  - US Census Housing Unit and Population Estimates
  - Vintage 2011

8. Appendix 2 – SBCM Middle Mile Network Topology Methods

8.1 Introduction to CQMM

In concert with the development of loop topologies using CQLL, the middle mile methodology and approach of SBCM uses components of the CostQuest network modeling platform (CQMM).

The middle mile is that portion of the network that provides a high capacity transport connection from Central Office to Central Office (Node0 to Node0) and/or Central Office to Regional Tandem (Node0 to Node00). From the Regional Tandem, dual connections are made to Internet Peering locations.

In SBCM the middle mile is assumed to extend between the service provider's point of interconnection with the internet and the service provider's point of interconnection ("POI" or CO) with the second and last mile network built to support end user broadband demand locations in unserved areas. This relationship is illustrated in the Figure 10.

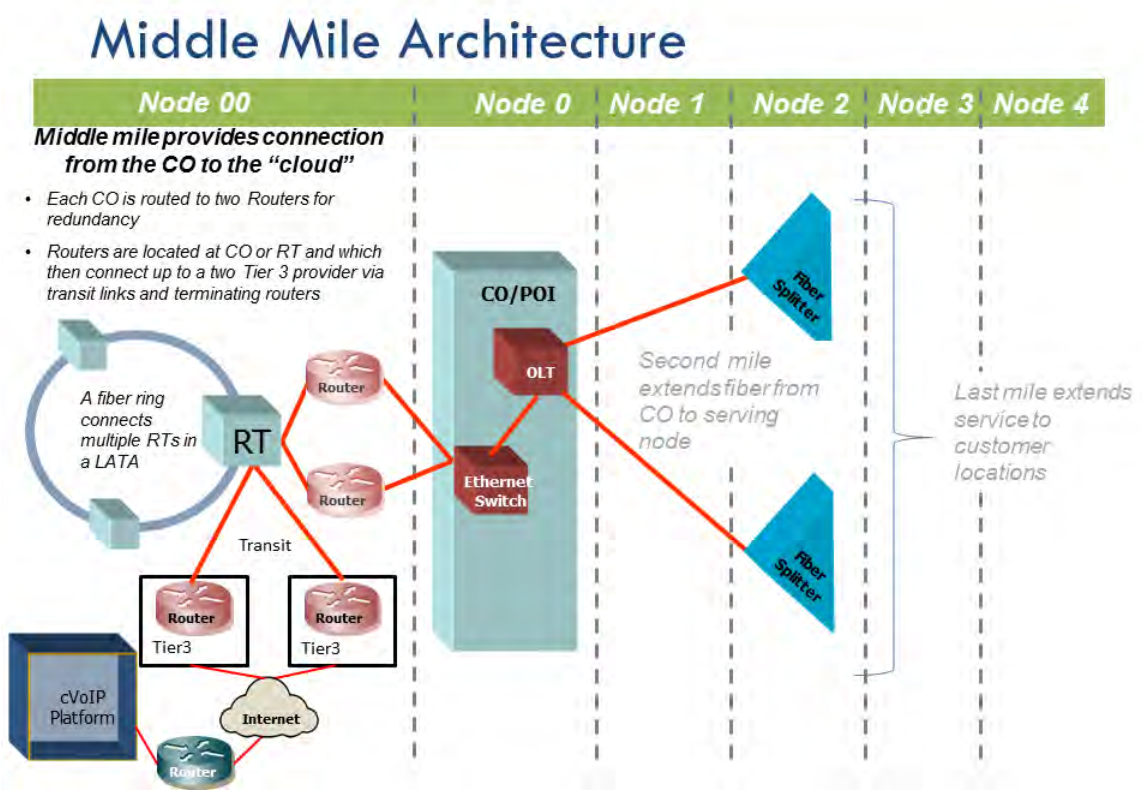


Figure 10--Middle Mile Architecture

The material that follows provides additional information on how middle mile investments are developed within SBCM.

The approach used to determine middle mile equipment required – and then to compute the related investment costs – is centered in the spatial relationship between the service

provider's point of interconnection (POI or CO) with the second and last mile network (designated as a Central Office) and the service provider's access to a regional access tandem ("RT") or RT ring. From the "RT", connections are made to the two closest Internet Peering locations. Appendix 17 provides a list of peering locations used in SBCM.

Central Office Location: the location of each Central Office (also referred to as POIs, and/or Node0s) is obtained from the Node0 database. The results of this approach align with the Central Office/Node0 locations used in the underlying CQLL Network Topology model used to create the local loop network, including last and second mile related equipment and investments.

Regional Tandem Location: Regional tandem (RT) locations (and the relevant feature groups deployed) were obtained from the LERG® database. Each tandem identified as providing Feature Group D access in LERG 7 is designated an RT. As with COs, a latitude and longitude is identified for each RT.

Internet Peering locations were derived from a combination of third party data sources including provider listed peering locations and open source lists of peering points[37].

The underlying logic (and the process) of developing middle mile investment requirements is grounded in the assumption that for Rate-of-Return voice and broadband service providers, a transit cost-to connect their network to the Internet is necessary. In SBCM, the Tier 3 internet peering point is distinct from the primary aggregation point in each state-- an RT or a node on the RT ring. The modeled design ensures each Node0 is connected to an RT and then from the RT connected to dual Peering point locations. In effect, all Node0 demand has access to the internet.

Given this baseline data on CO, RT and peering locations and working under the assumption outlined above, the middle mile processing logic proceeds as follows:

- The Middle Mile process is run state by state. All Node0's in a state are homed to an RT in that same state

- Within a state, each Node0 is assigned to its nearest RT (Node00) to create the initial spatial relation of ("parentage") Node0s to RTs. Node0s must be in the same state as their related Node 00.

- Node0 records are then routed to other Node0 records with the same Node00 parent using a spanning tree approach based on the shortest (most efficient) distance routing back to their proper Node00 record.

- The Node00 records within the same LATA are routed together in a ring. To ensure an efficient (and hence 'most likely') design the shortest ring distance is used. The shortest ring is chosen by starting at each Node00 point and

[37] Peering locations were extracted from the following sources: DataCenter9 (http://www.datacenter9.com/datacenters/united-states), PeeringDB (https://www.peeringdb.com), Level3 (http://datacenters.level3.com/wp-content/uploads/2015/05/DataCentersGlobal.pdf), and ColocationAmerica (http://www.colocationamerica.com/blog/data-center-locations-arrival-of-server-farms.htm)

storing the ring distances. After stepping through each potential ring route, the shortest ring distance is then used for further computations.

- From the regional tandem location, connections to the two closest peering locations are determined. The distance from each node on the Regional Tandem ring to each node's two nearest Internet Peering location is calculated. SBCM then uses the two nearest (smallest) RT to Internet Peering links as the peering distance.

With that information in hand, SBCM develops middle mile costs thru the following steps:

a. The distance of the RT rings is attributed to each Node0 on the ring in proportion to the number of locations at each Node0 as compared to the total locations for all the Node0s attached to the RT Ring. For each spanning tree connection, distance is calculated as follows. Where a road distance is available,[38] the road distance is used unless the ratio of the road distance to airline distance is > 3.04. In that case the airline distance x 3.04 is used. If the route is classified as partially submarine (see section 8.4), 1.2 x the airline distance is used to develop the overall distance between the points. Within SBCM, the final middle mile distances are multiplied by the TreeToRingRedundancyFactor in the Capex input (the factor is currently set to 1.2).

   The distance on the Node0 tree back to the peering location is attributed much in the same way as the loop feeder routing.

b. For electronics, SBCM captures the broadband routers (it is assumed that each CO/POI will connect to two routers to provide redundancy) which connect up to the fiber at RT/Tier 3 location. A pair routers is placed at each peering location.

c. For the fiber placement, SBCM assumes a portion of the conduit, buried trenching and poles already exist for the local access network (this sharing is controlled in the Capex input workbook). As such, only a portion of additional costs for conduit, buried trenching and poles is captured for middle mile. SBCM does retain the full cost for fiber which supports the end user broadband-capable network.

d. From the total middle mile costs that are calculated, SBCM captures a portion of the costs (some costs are assumed to be absorbed by uses other than SBCM voice and broadband services, e.g., special access services). This sharing assumption is controlled in the Capex input workbook.

e. Finally, SBCM relates the middle mile cost to each Census Block (the basic unit of geography in SBCM). The cable, structure and electronics investment to support the transit function are first attributed to the collection of ROR carriers served by the transit routes based upon the number of ROR Node0s utilizing the transit route compared to all Node0s (including Price Cap

[38] Road distance is calculated using ESRI Network Analyst, version 10.3

Carrier Node0s). This collective ROR carrier cost for transit is then distributed to ROR locations based on the Number of ROR locations served by the transit route.

8.2 Middle Mile Undersea Topologies for Carriers in Non-Contiguous Areas

For carriers who need undersea links to the contiguous United States, SBCM calculates costs associated with the undersea link back to the contiguous United States.

The Undersea tab of the CAPEX workbook provides the following inputs:

- Undersea cable investments including repeater electronics
- Landing station investments including electronics
- Route distances
- Route broadband traffic percentage use factors

Investments calculated within the undersea portion of the CAPEX workbook represent additive investments to the middle mile (Node0 to Node00) portion of the network for non-contiguous areas. These investments capture the costs of undersea cable and landing station investments needed to transport traffic from landing stations in non-contiguous areas to landing stations in the contiguous U.S.

The total route investment is calculated as (Route Distance x Cost Per Foot) +2 x (Landing Station Investment) for each route. It is assumed that each non-contiguous area is connected by two routes to provide redundancy.

Undersea fiber optic cable inputs were developed on a per foot basis for material and labor based on publicly available data for an undersea cable system connecting Alaska with the U.S. mainland.[39]

In addition to the fiber optic cable investments, Landing Station investments are based on publicly available data.[40] SBCM assumes 2 landing stations per route. The total estimated investment (equipment, land and buildings) is for stations at both ends of each undersea route. This investment is broken down between equipment, land and buildings.

After the total route investment is developed, the total route investment is multiplied by the averages listed in the table shown below, which represent the percentage use, utilized for voice and broadband.[41]

---

[39] Presentation available at http://akorn.alaskacommunications.com/#, estimates total construction cost. The submarine values for Alaska were not adjusted with Regional Cost Adjustment factors.

[40] See slide 29 of http://hmorell.com/sub_cable/documents/Basics%20of%20Submarine%20System%20Installation%20and%20Operation.pdf

[41] The percentage use factor inputs are located in the Capex workbook, undersea worksheet.

8.3 Development of Undersea Percentage Use Factors

Percentage use factors reflect the portion of the total route utilized by the SBCM network.

To develop these factors, total SBCM busy hour bandwidth demand was compared to the actual deployed capacities of current undersea routes, both total route capacity and highest lit capacity.[42] Table 8, below, shows both comparisons; the average of both is the value used as the percentage use in SBCM.

Table 8--Percentage Use

AREA	DEMAND (Gbps)	HIGHEST TOTAL CAPACITY (Tbps)	% DEMAND to TOTAL CAPACITY	HIGHEST LIT CAPACITY (Gbps)	% DEMAND to LIT CAPACITY	AVERAGE
Hawaii	213.6	6	3.956%	2,000	11.867%	7.91%
North Marianas Islands (Guam to Oregon)	7.7	7.68	0.111%	5,120	0.166%	0.14%
Puerto Rico	587.9	80	0.816%	310	100%[43]	50.00%
U.S. Virgin Islands (Puerto Rico to Florida)	20.0	80	0.028%	310	7.168%	3.60%
Hawaii to American Samoa	4	12.8	0.035%	1600	0.28%	0.1575%
Guam to Oregon (Route 2)	26.6	7.68	0.38%	5120	0.58%	0.48%

For routes that are utilized for international traffic, SBCM estimates the investment that carriers will face in securing transport to and from the contiguous United States by applying

[42] SBCM calculates the demand for the modeled network assuming that all end users are simultaneously consuming the total busy-hour offered load. Accordingly, estimated demand is based on A-CAM locations * Take Rate * Bandwidth (A-CAM BHOL input).

[43] SBCM caps lit capacity at 100 percent. Because there is unlit capacity available or coming on line, it is assumed that it would not be economically reasonable to build two or more new cables.

the percentage use value to the SBCM calculated total route investment. Because the Alaska route and the Northern Marianas to Guam portion of the Northern Marianas route are not shared with any international traffic, SBCM treats that portion of the undersea routes the same way it does terrestrial middle mile, allocating half the cost to other services connecting Alaska to Oregon and Washington, the Northern Marianas to Guam, and the U.S. Virgin Islands to Puerto Rico.[44] For the remaining routes, the percent use factors are as shown in Table 8.

Investments are converted into costs based upon the Underground Fiber Optic Annual Charge Factor.

8.4 Submarine Topologies

In addition to the airline distances and road distances in non-contiguous areas, two additional data fields are available to middle mile processing code.

- Submarine distance; and,
- An indicator of whether the route is visually on the same or different land masses.

Within CQMM a route is classified as partially submarine where there is no connection between the land masses. In a separate analysis, there was one additional route that was classified as partially submarine, given that the road distance was over 20 times longer than the airline distance.

For each route classified as partially submarine, two beach manholes are placed. Submarine cabling investment is used for the submarine segment while land based cabling is used for the remainder. Submarine cable investment is not shared with other utilities nor impacted by regional cost adjustment.

Submarine investment is converted into costs based upon the Underground Fiber Optic Annual Charge Factor.

[44] SBCM assumes that the other 50% of costa are allocated to special access and private line services and supported by revenues from those services.

9. Appendix 3 – Data Source and Model Application Summary

The table below provides a summary (inputs grouped by category) of the major data inputs to SBCM along with the underlying source for that data and a reference to its use within the model.

Table 9

Data Category	Model Variables	Data Source	Wireline Coverage	Capex	Opex
Census boundaries	Full Census Block; full Census Block Group; full Census Tract; full Census County; Census State	TIGER\Line 2010	X	X	x
Service Area boundaries and Central Office /Node0 locations	Service Area boundaries, codes and Central Office points, as adjusted by public comment and USAC review	A-CAM v 2.1 Service Areas and Node0s. For Price Cap carriers, carrier provided exchange /wirecenter boundaries.	X	X	
Geographic characteristics	Land area; total road length;	TIGER\Line 2010	X	X	
Outside Plant, Percent Aerial, Buried, Underground	Plant Mix by SAC	Submissions to FCC and analysis. On July 29, 2015, the Bureau issued a public notice requesting corrections to plan mix input values, seehttps://apps.fcc.gov/edocs_public/attachmatch/DA-15-869A1.doc		X	
Terrain	Terrain characteristics	USDA, NRCS-STATSGO, SSURGO	X	X	

Data Category	Model Variables	Data Source	Wireline Coverage	Capex	Opex
Housing Units	Occupied housing units; total housing units; total households by block. Adjusted by Census Population and Housing Unit Estimates	Census 2010, SF1 housing units. Census Population and Housing Unit Estimates, 2011	X	X	X
Provider size and organizational structure	Corporate ownership; size of parent company; number of wire centers operated by carrier	FCC and USAC resources. Feedback from Helpdesk.	X	X	X
Company Opex financial data	A wide array of company-specific financial information (and underlying business volumes) from public and subscription service sources. Data centers on operating expense by category (e.g., maintenance, sales, interconnection, sales and marketing, G&A, bad debt, taxes, etc.).	Data sources available in methodology			X
High capacity locations	High capacity locations represent high demand business points and will be used to improve business location points for sizing the network. Community Anchor Institutions (CAI) taken from National Broadband Map.	GeoResults 3Q2012 National Building Database and Detail Business File. CAI from National Broadband Map (June 2012)	X	X	
Wireless tower location	Wireless tower locations represent locations requiring fiber service and are used to supplement business and residential locations for sizing the network.	CostQuest proprietary tower database	X	X	

Data Category	Model Variables	Data Source	Wireline Coverage	Capex	Opex
Wireless broadband service	Fixed wireless provider broadband speed coverage within a Census Block. Categorized based upon the broadband coverage file in use.	FCC Form 477 (December 2014),	X		
ILEC broadband service	ILEC provider broadband speed for wireline area coverage within a Census Block. Categorized based upon the broadband coverage file in use	FCC Form 477 (December 2014),	X		
Wired broadband service	Wired provider broadband speed for coverage within a Census Block. Categorized based upon the broadband coverage file in use	FCC Form 477 (December 2014),	X		

10. Appendix 4 –Data Relationships

The schematic provides an overview of how data are organized and related within SBCM. The diagram is designed to illustrate at a high level the relationships between inputs and the resulting Solution Set.

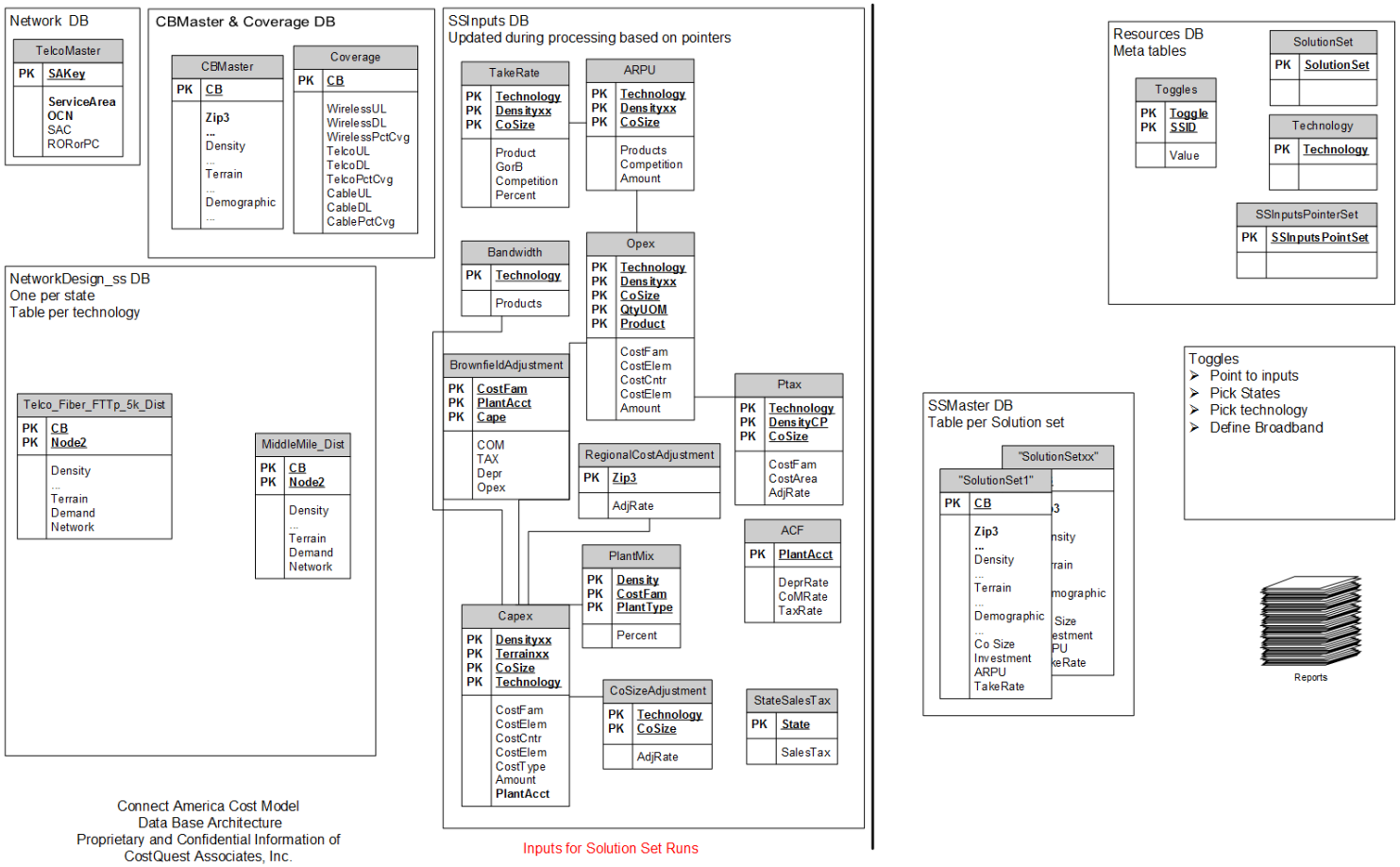


Figure 11—SBCM System Schematic

11. Appendix 5 – SBCM Processing Schematic

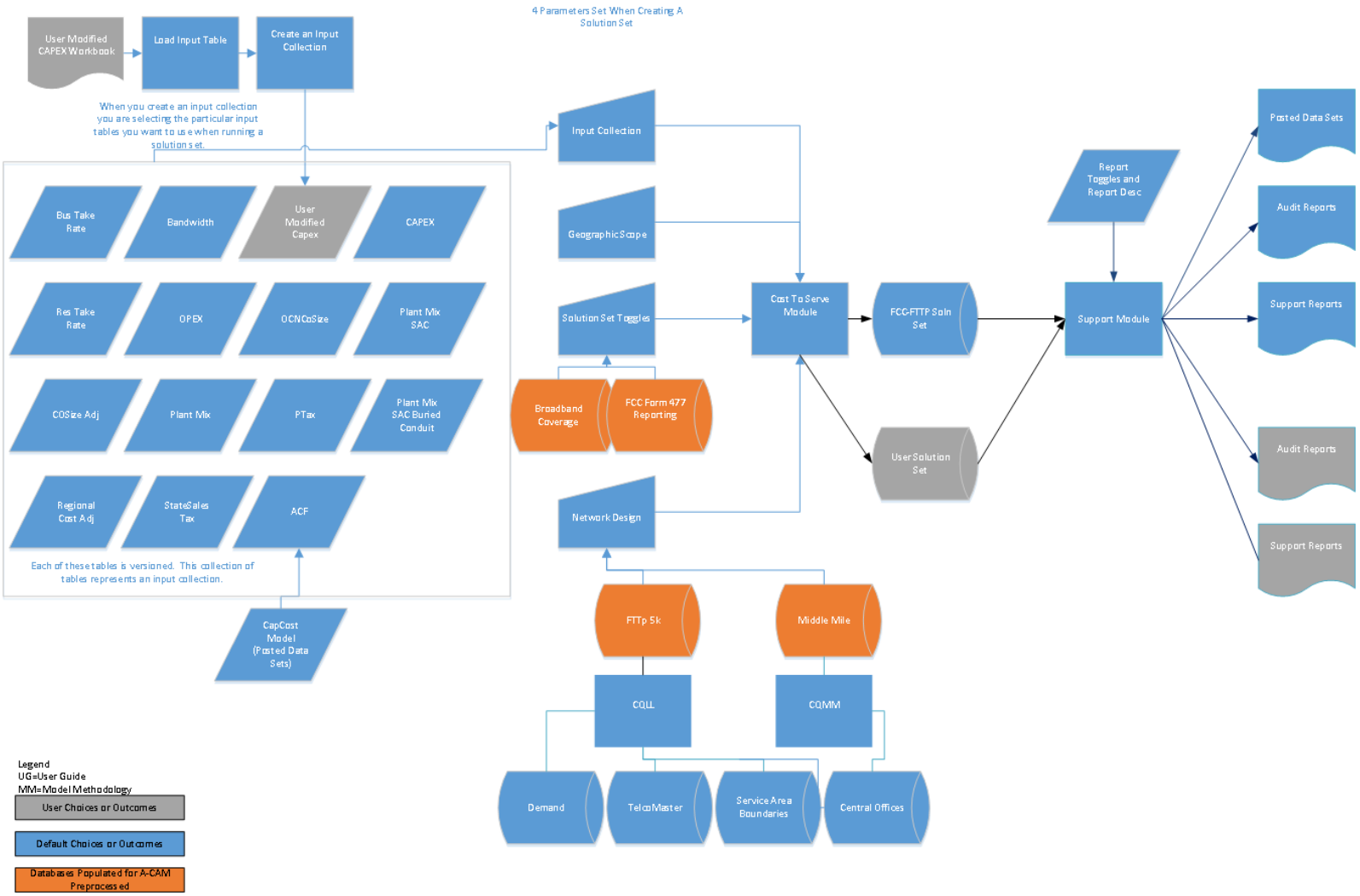


Figure 12—SBCM Processing

The diagram in Figure 13 is color coded to illustrate how information can flow through SBCM. Specifically, the grey colored objects reflect a system input (e.g., an input table) that is driven by a user. Once that input table is loaded into the system, it becomes part of an input collection then a user generated Solution Set. In contrast, many users run SBCM without modifying any inputs and are reliant on default (blue) system objects.

From left to right Figure 13 shows that a group of input tables (i.e., Input Collection) is used by the Cost to Serve Module. Users can either use the default input collection or load their own tables to suit particular analytic needs. The files which constitute an Input Collection are shown in Figure 13 and further described in Appendix 6. The Input Collection is where users provide information about the cost of plant such as structure (e.g., Poles, Conduit) or costs of equipment (e.g., ONTs, Fiber Splitters).

Along with an Input Collection, the Cost to Serve module also requires information on the geographic scope of analysis and the type of network to build to create a Solution Set[45]. Once the Solution Set has run, several types of reports are available from SBCM. Additional information about SBCM reports is also available in the User Guide.

Also note on Figure 13 several orange symbols. These orange components represent additional databases which are preprocessed and available as inputs into SBCM.

[45]A-CAM allows you to export a Solution Set as part of the Audit Solution Set report. The audit report contains the portion of a Solution Set specific to the user entered Service Area name.

12. Appendix 6 –SBCM Input Tables

The inputs which form the basis of an input collection are available as a download from the SBCM website.

- Annual Charge Factor (ACF)
  - This table captures the Annual Charge Factors that convert Investment into monthly costs. The values loaded into SBCM are produced by CostQuest's CapCost model which is available for download. The basis of the model is the economic determination of the depreciation, cost of money, and income taxes associated with various plant categories. The calculation incorporates industry standard procedures, such as Equal Life Group methods, inclusion of future net salvage, impact of deferred taxes, and mid-year conventions.
    - Key inputs into the derivation are lives of plant, assumed tax lives, survival curve shapes, cost of money, cost of debt, debt/equity split, and future net salvage
  - Uses depreciation lives consistent with those prescribed by the FCC's Wireline Competition Bureau's latest general depreciation in CC Docket No. 92-296
  - How Used: Converts Investment into monthly values of Depreciation (DEPR), Cost of Money (COM), and Income Taxes (TAX)

- Bandwidth
  - Provides the busy hour bandwidth
  - Used to size appropriate network components
  - How Used: Based upon current inputs, Bandwidth is currently not a driver of any capex investment or OPEX cost.

- Business Take
  - How Used: Derives the voice and data demand for the business market[46]

- Capex
  - Provides the material and installation costs for the plant build
  - Data are applied against the network topology data to derive total build-out investment levels
  - Inputs capture technology, network node, network function, and plant sharing.[47] Within the CAPEX workbook, all Material inputs are material only. As an example, the OLT inputs found on the FTTp Material worksheet are material prices only. EF&I is included in the "Total Material Loadings" and "Engineering Rate" on the Labor Rates and Loadings" worksheet. The model always adds in labor costs – either through direct inputs such as the Material Labor worksheet for placing and splicing costs and the Structure Labor worksheet for OSP contractor structure

[46] The business and residential take rate inputs can impact A-CAM in two ways. First, they can impact how components of the modeled network are sized. Second, they can impact how the total investment and resulting costs are unitized. See Appendix 10.

[47] See Appendix 7, Methodology for additional information on Plant Sharing.

placing costs, or through the use of the EF&I factors on the Labor Rates and Loadings worksheet.
  - How Used: Values which derive the total capex.

- COSize Adjustment
  - Provides the user the capability to adjust the assumed purchasing power of small, medium, and large providers
  - The current inputs assume that all providers can achieve the same purchasing power (either as a result of their size or their ability to buy as a consortium)
  - Adjusts up or down the Capex costs in the model, current inputs are set to 1
  - How Used: In the current release of the model, COSize Adjustment table is used but the value is set to 1.

- OCNCoSize
  - Provides correspondence for OCN, company size category and SAC.
  - How Used: Categorizes the size of each company.

- Opex
  - Provides the estimated operation costs to run and maintain voice and broadband-capable networks.
  - How Used: Values help to develop the operational cost development.

- PlantMixSAC
  - Provides the estimated mix of facilities by type: aerial, buried, and underground. Updated based upon plant mix submissions as described in the FCC public notice announcing the release of SBCM 2.1.[48] The resulting values are used in the default PlantMixSAC input table used in SBCM 2.1, PlantMixSAC v12.
  - How Used: Determines the mix of facilities required to serve an area.

- Ptax
  - Sourced from property tax rates in each state compared to a national average
  - Provides the impact of property tax on the G&A operation costs given the difference of the state rates versus the national average
  - Captured in the multiplier used for the operational element
  - How Used: Provides an index value to capture the impact of property tax in the operation costs.

- RegionalCostAdjustment
  - Sourced from third party source – RSMeans (2011)
  - Provides the estimated difference in the cost to build and operate in each part of the county
  - Used to drive differences in Capex and Opex costs due to labor and material cost differences across the country
    - Applied to All Capex and indirectly to specific Opex components that are derived from Capex

[48] On December 17, 2015, the Bureau issued a public notice announcing the release of A-CAM 2.1, seehttps://apps.fcc.gov/edocs_public/attachmatch/DA-15-1431A1.pdf .

- How Used: Captures material and labor costs difference at ZIP3 level.

- StateSalesTax
  - Sourced from appropriate sales tax rates for telecommunications plant in each state
  - How Used: Impacts Capex derivation, applies State Sales Tax.

- Residential TakeRate[49]
  - How Used: Derives the data and voice demand for the residential market

[49] The business and residential take rate inputs can impact A-CAM in two ways. First, they can impact how components of the modeled network are sized. Second, they can impact how the total investment and resulting costs are unitized. See Appendix 10.

13. Appendix 7 – SBCM Plant Sharing Input Walkthrough

This material provides an overview of the source and use of the input tables in the Plant Sharing tab of the SBCM Capex input workbook. The order in which we describe the components below is designed to explain the interaction between these functions and is not necessarily the sequence or flow in terms of how the tables are used within SBCM.

Modern telecom networks increasingly enjoy the benefits of sharing facilities and capacities across different services to different demand groups in different geographies/locations. The ability to leverage network investments in this way is vital to the network's economic performance through time. Within the context of SBCM, it is important that mechanisms exist to share facility and structure costs across the relevant network functions and geographies (e.g., ultimately, across Census Blocks).

As outlined below, there are four components of the SBCM plant sharing function (i.e., four types of facilities sharing):

- Sharing Between Distribution and Feeder
- Sharing Between Providers
- Sharing Of The Middle Mile Network
- Sharing Of Middle Mile Routes Associated with Voice and Broadband

Each of these components is explored further in the material that follows. In each section we describe the type of structure sharing and the SBCM Logic which then employs and processes those inputs.

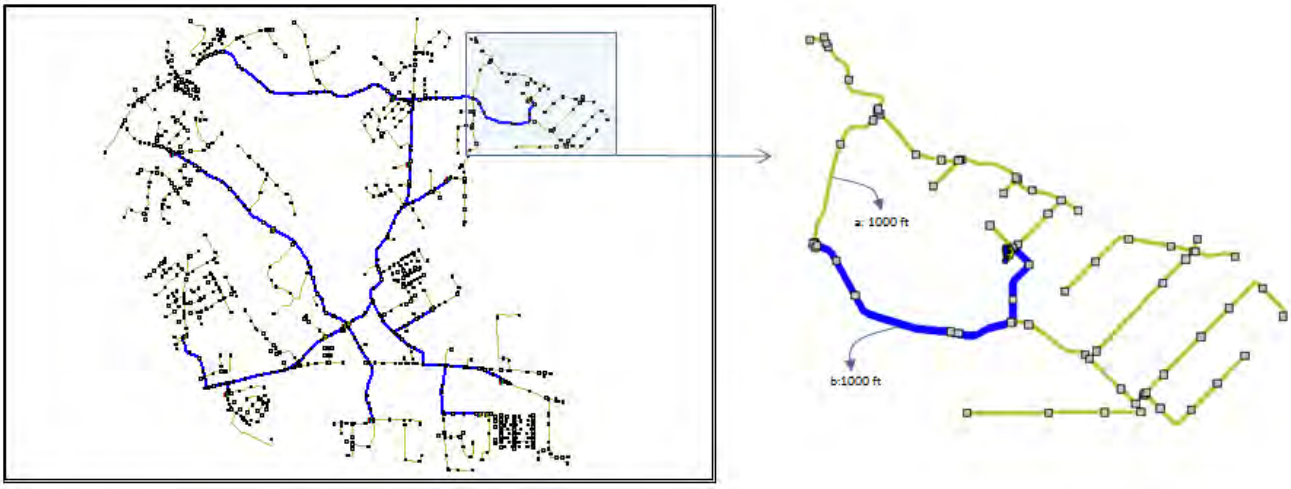
13.1 Sharing Between Distribution and Feeder

This input table provides the percent of common route (both feeder and distribution on the same route) that shares structure in three density categories (i.e., Rural, Suburban and Urban) across three types of plant (i.e., Aerial, Buried and Underground).

	% of common route that that shares structure			
Density	Aerial	Buried	Underground	**UOM**
Rural	78%	41%	67%	percent
Suburban	78%	41%	67%	percent
Urban	78%	41%	67%	percent

Logic: The schematic that follows represents a typical network topology developed by SBCM. For additional information on how network topologies are developed within SBCM please refer to the SBCM Methodology.

In this schematic distribution pathing is represented by golden lines, feeder pathing is represented by blue lines, and pedestals are represented by gray boxes.



The expanded diagram to the right shows a typical Node2 cluster (e.g., the pedestals served by a specific splitter in an FTTp network). Within the topology creation process, each segment (network node to network node) is tracked with information on:

- Density of the area in which the segment resides
- Terrain of the area in which the segment resides
- Length of the segment
- Amount of segment that is shared between distribution and feeder routes

Using the schematic above as an illustration, the discussion that follows explains how SBCM develops structure sharing "Between Distribution and Feeder".

Consider two segments (a) and (b) labeled in the expanded diagram at right in the schematic above. Each segment is 1000 feet long. Segment A is ONLY a distribution route and Segment B is BOTH a distribution route and feeder route (100% of the route is shared). To simplify our example, assume the plant mix for both segments is 50% aerial and 50% buried and further assume that the area is Suburban.

When developing the topology, fiber routes are planned for each segment. For Segment A, 1000 feet of fiber is installed for the distribution plant. For Segment B, 1000 feet of fiber is installed for the distribution plant AND 1000 feet of fiber is installed for the feeder plant.

With these requirements in mind, structure is now designed for each segment. For Segment A, based on the 50/50 split of Aerial and Buried, 500 feet of trench will be dug and poles for a 500ft route will be placed. For Segment B, both feeder and distribution cables are being placed. However, the inputs provide for the fact that there will often be timing differences in design and placement and there is a probability that different forms of structure will be used between feeder and distribution. As such, we will likely need more than 1000 ft of overall structure (though less than the 2000 feet of structure that would be required if the feeder and distribution plant are built entirely independently of one another).

To arrive at the structure needs for Segment B, we refer to the "Between Distribution and Feeder" table to guide the calculation.

Specifically, referring to the input values in the table above, for the 500 feet of required Aerial distribution structure and the 500 feet of required Aerial Feeder structure:

- (100% - 78%) , or 22% is dedicated or non-shared…or 110 feet and
- 78% is shared…or 390 feet.

Since both feeder and distribution are sharing the same pole 78% of the time (or 390 feet for this 500' span of cable), we assign 1/2 of the 390 feet (i.e., 195 feet) to Distribution and ½ of the 390 feet to Feeder. The total Aerial structure feet for distribution is then 110 feet of dedicated and 195 feet of shared for a total of 305 feet of distribution structure; and, for feeder the total Aerial structure feet is 110 feet of dedicated and 195 feet of shared for a total of 305 feet of feeder structure.

Again, referring to the input values above, for the 500 feet of required Buried distribution structure and the 500 feet of required Buried Feeder structure:

- (100% - 41%), 59% is dedicated or non-shared…or 295 feet and
- 41% is shared…or 205 feet.

Since both feeder and distribution are sharing the same trench, we assign 1/2 of the 205 feet (i.e., 102.5 feet) each to Distribution and Feeder. The total Buried structure feet for distribution is then 295 feet of dedicated and 102.5 feet of shared for a total of 397.50 feet of distribution structure. For feeder, the total Buried structure is also 295 feet of dedicated and 102.5 feet of shared for a total of 397.50 feet of feeder structure

13.2 Sharing Between Providers

This input table provides the percent of cost attributed to a studied carrier across three density categories (i.e., Rural, Suburban and Urban) across three types of plant (i.e., Aerial, Buried and Underground). These inputs reflect the fact that portions of structure costs may be shared with other parties (attachment to third party poles rather than owning poles, sharing of joint trenching costs, etc.)

	% of Cost Attributed to Studied Carrier			
Density	Aerial	Buried	Underground	**UOM**
Rural	48%	96.25%	95.78%	percent
Suburban	48%	80.00%	79.53%	percent
Urban	48%	76.25%	75.78%	percent

Logic: Using the schematic and overall assumptions described above and from the logic used for the sharing "Between Distribution and Feeder" we know the structure distances. With this information in hand the cost of the structure attributable to the network of the provider under study is developed using the inputs of the "Structure Sharing" table and is rather straight forward as follows:

- For the aerial routes, 48% of the aerial structure (poles) costs are assigned to the provider

For the buried and underground routes (using suburban values as an example), 80% of the buried trench and/or underground structure is assigned to the provider[50]

13.3 Sharing Of the Middle Mile Network

This input table provides the percent of a interoffice, or middle mile, route that requires dedicated structure (as opposed to sharing structure with feeder and/or distribution cables) across three density categories (i.e., Rural, Suburban and Urban) across three types of plant (i.e., Aerial, Buried and Underground).

Density	% of route that is dedicated structure			UOM
	Aerial	Buried	Underground	
Rural	37%	71%	26%	percent
Suburban	22%	64%	19%	percent
Urban	14%	56%	11%	percent

Logic: Using the schematic and overall assumptions provided above the SBCM logic for the attribution of costs regarding interoffice (IOF)/Middle Mile facilities is described below.

For interoffice routes, the routing runs from Central Office to Central Office. The logic for feeder and distribution structure captures the full cost of structure within the wire center. It is likely that the interoffice routes will often run along the same routes as used by the feeder and distribution and use the same structure. This table reflects the percentage of the time that interoffice cables do not share structure with feeder and/or distribution cables. In other words, this factor captures a similar kind of sharing as was captured in the section on sharing between distribution and feeder (though these figures represent the amount of dedicated middle mile structure; while the feeder-distribution sharing figures represent the amount of structure that is shared.

The inputs in this table reflect when dedicated structure will be incurred solely for the interoffice routes.

For aerial and underground structure, this sharing will likely be much higher than for buried structure, as shown in the low amount of dedicated structure assumed in the input.

For example, in an urban area the model assumes that structure needed for interoffice routes will be shared with distribution and/or feeder cables (100%-14%), or 86%, of the time and those structure costs are already included in the feeder and/or distribution cost calculations. For 14% of the urban interoffice route distances, the model assumes that separate structure is required for the interoffice cables.

13.4 Sharing of Middle Mile Routes Associated with Voice and Broadband

[50] This means, for example, that there is only a 20% chance that an electric, cable or other companies will want to lay fiber along a given route at the same time when the provider has a buried trench open or underground conduit duct available. The sharing of poles is assumed to be much more prevalent (less cost assigned to providers) because other companies do not need to be deploying facilities at the same time in the same place to share the cost of aerial facilities.

Input values (see table below) are based on the assumption that there are two major groups of services traversing the interoffice network: voice/broadband and Special Access services. SBCM only includes the interoffice costs associated with the voice/broadband services. This input table provides the percent of an interoffice route that is attributed to voice/broadband across three density categories (i.e., Rural, Suburban and Urban) across three types of plant (i.e., Aerial, Buried and Underground).

	% of route that is attributed to Broadband			
Density	Aerial	Buried	Underground	**UOM**
Rural	50%	50%	50%	percent
Suburban	50%	50%	50%	percent
Urban	50%	50%	50%	percent

Logic: The SBCM logic for the attribution of costs regarding the assignment of Middle Mile Routes with Voice/Broadband is described below.

For the feeder and distribution routes, the network is built to handle all services but costs associated with Special Access data services (e.g., high caps) are excluded from the SBCM network topology.

The interoffice network is a shared network carrying both voice/broadband and Special Access data (i.e. special access) traffic. SBCM calculates the full cost of the interoffice network and this input table then attributes only 50% of the cost of the interoffice network to the voice and broadband-capable network, excluding the other 50% that is assigned to the Special Access data services.

The 50% attribution impacts the media (Fiber Strands) on the route as well as the structure (Poles, Conduit, etc.) which supports the route. The 50% attribution does not impact electronics costs which are necessary to support middle mile functions.

14. Appendix 8 -- Broadband Network Equipment Capacities

The Connect America Cost Model's Fiber to the Premises (FTTp) network architecture is based on a Gigabit Passive Optical Network (GPON) design (ITU-T G.984). The GPON design allows different bit rates SBCM assumes 2.5 Gbps downstream and 1.2 Gbps upstream bandwidth per fiber. The SBCM network limits the length of the fiber after the splitter to 5,000 feet.

The network that the SBCM models is shown in the figure below:

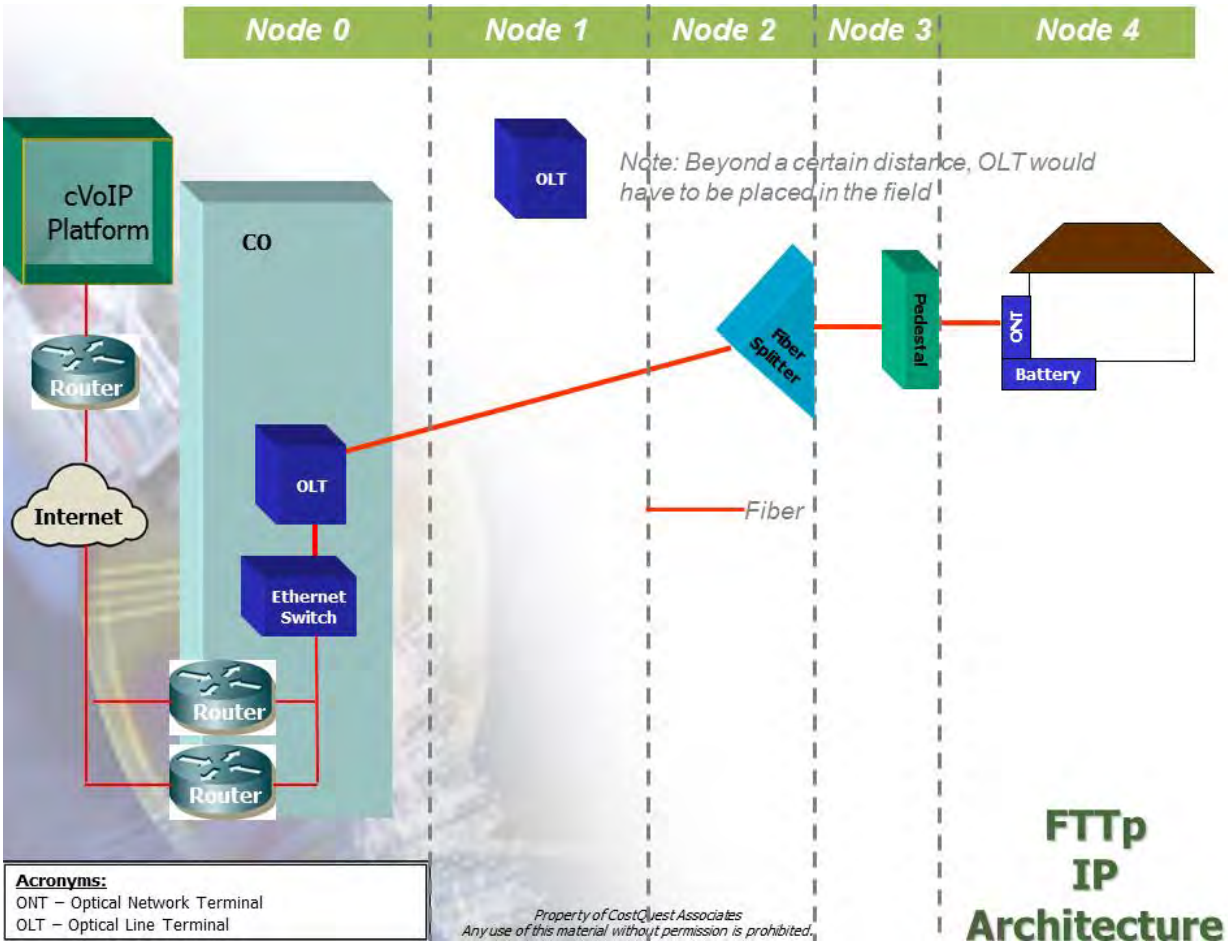


Figure 13--FTTp IP Architecture

Moving back from the premise (on the right-hand side of the network diagram), the components include:

> **Optical Network Termination (ONT)** - at each connected location (inclusive of battery backup and alarm)

Fiber Service Terminal – Serving terminal or pedestal connecting the ONTs with the fiber distribution cables

Splitter– Also referred to as the Primary Flexibility Point (PFP) or a Fiber Distribution Hub (FDH) or simply as a splitter – passive equipment which splits the signal transmitted over each feeder fiber into multiple signals; SBCM utilizes a 32:1 splitter ratio. That is, up to 32 locations can be served per feeder fiber.

Optical Line Terminal – Aggregates traffic from multiple splitter fibers. OLTs are typically located in Central Offices (though they can be located remotely), and can aggregate demand from splitters across a large portion of the serving wire centers service area.

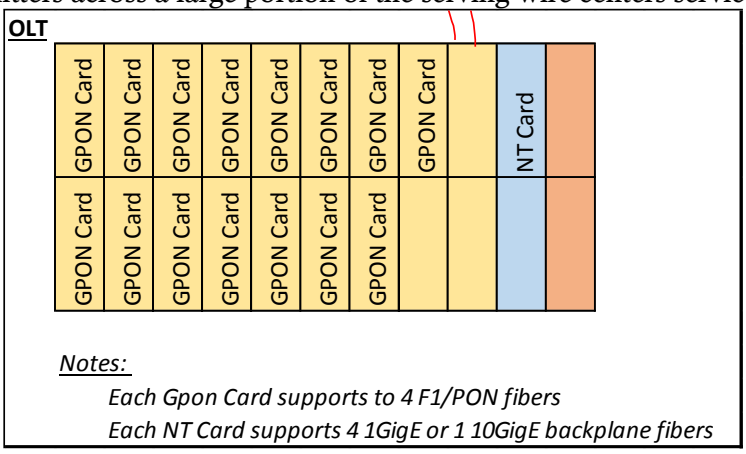
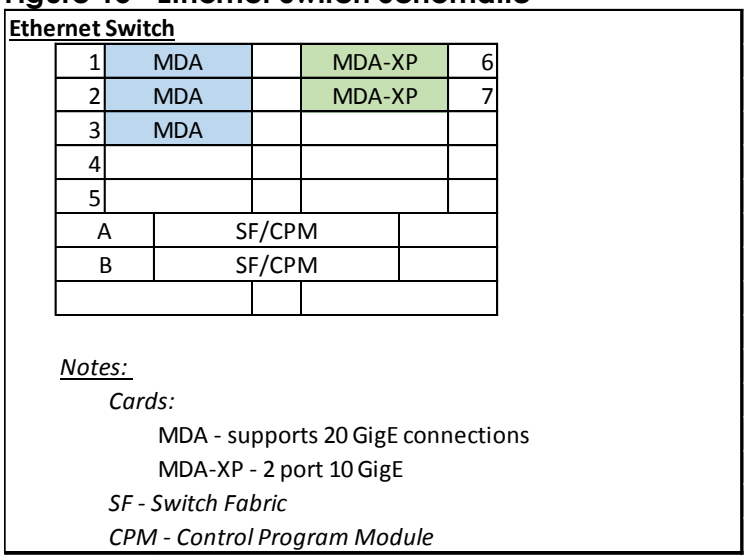


Figure 14--OLT Schematic

Ethernet Switch and Router – Switches and directs IP traffic

Figure 15--Ethernet Switch Schematic



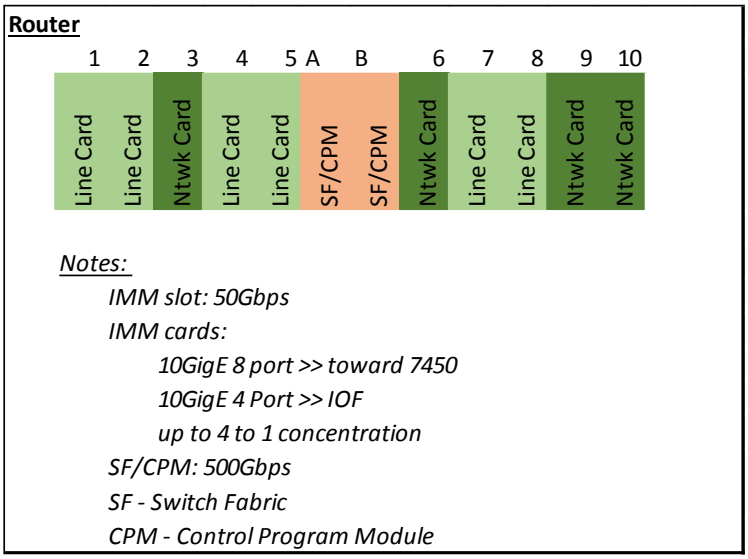


Figure 16--Router Schematic

In the GPON network, there are a limited number of aggregation points that constrain broadband speeds. The first aggregation point is the fiber splitter (PFP or FDH). Up to 32 end-user locations can be served off each splitter feeder fiber, with the 32 locations sharing 2.5 Gbps of capacity.[51] That means that each location is connected, each connection could have a minimum of 75 Mbps of capacity (i.e., 32 connected locations could all receive 75 Mbps on a single 2.5 Gbps fiber).[52] As a result, the maximum per connected location busy hour bandwidth input into SBCM should not exceed 75Mbps.

The next aggregation point is the optical line terminal (OLT), where fiber-optic signals from multiple splitter feeder fibers are aggregated and shifted onto a 10 Gbps connection to Ethernet switches and routers (10 Gbps total bandwidth for each OLT). SBCM assumes that each OLT can handle as many as 58 active splitter feeder fibers, or 1,856 connected locations (i.e., 58 fibers x 32 locations each assuming all locations passed are connected).[53] In other words, the OLT is likely to be the choke-point in the GPON network, where capacity is most limited.[54] The SBCM inputs are expressed on a "per port or per splitter fiber termination" basis assuming the OLT is fully built out with all ports utilized, adjusted for engineering utilization[55]. When both splitters and the OLT are fully utilized, each end user is assumed to receive at a minimum 5.4 Mbps of capacity as shown in the following calculation:

---

[51] In fact, 32 end-user locations may have only a fraction of those locations as connected locations, meaning even more capacity per connected location than described in this example.

[52] Upstream capacity for GPON tends to be one half of downstream.

[53] Equipment can potentially provide 15 cards with 4 ports each for a total of 60 splitter fibers, but A-CAM assumes 2 ports are reserved for maintenance and administration purposes.

[54] As many as 58 2.5 Gbps fibers are backhauled by one 10 Gbps fiber.

[55] Each of the OLT's ports is assumed to support up to a maximum of 32 connected locations per fiber. As such, A-CAM calculates the number of consumed OLT ports by each splitter by dividing the splitter's connected locations by 32 and rounding up.

10 Gbps total backhaul from each OLT / 1856 connected locations = 5.4 Mbps per connected location

As shown in the calculation above, the number of connected locations determines the amount of capacity available to each connected location. In denser areas, the splitter is typically fully consumed (i.e., there are 32 end-user locations within 5,000-feet of the splitter). In contrast, in more rural areas it is likely that there will be fewer than 32 end-user locations aggregated onto a single splitter fiber. Thus, in rural areas, where there are more likely to be fewer connected locations per splitter fiber, the architecture used in the model would result in more capacity per connected location.

In addition, in smaller service areas, the OLT utilization would not be as high as that found in larger service areas. In other words, service areas with fewer end-user locations, as is often the case in more rural areas, would be more likely to have unused splitter-fiber capacity aggregating at the OLT, leaving more backhaul capacity from the OLT available to each end user.[56] The OLT is still likely to be the choke-point in the network, but end-users each would have more capacity.

Regardless, in the most capacity-constrained areas (areas where OLTs are fully utilized: higher density and likely lower cost), each end user is assumed to receive at least 5.4 Mbps of capacity.[57] In rural areas, where it is likely to have fewer than 32 connected locations per splitter fiber and some OLTs underutilized (i.e., less than 58 splitters connected to every OLT), each connected location can have many times this 5.4 Mbps capacity by default, with the exact amount determined by local conditions.

Further toward the core network, the next set of aggregation points are the Ethernet switches and routers, whose capacities (backplane gigabit capability) increases with the number of connected locations assumed to be on the network. In other words, the SBCM captures the need for increased capacity in the Ethernet (backhaul) network in less-costly increments, tied to the number of connected locations. The SBCM inputs for Ethernet switches and routers are developed on a "per OLT port" basis assuming that these network nodes will be fully utilized adjusted for engineering fill. As noted, each of the OLT's ports is assumed to support up to a maximum of 32 connected locations per fiber. As such, SBCM calculates the Ethernet switch and router investment triggered by each splitter by dividing the splitter's connected locations by 32 and rounding up.

[56] As noted above, OLTs often aggregate demand from an entire service area; and each OLT can provide service for up to 1,856 end-user locations. Thus even in rural areas, each serving wire center is likely to have more than one OLT's demand. However, it is likely that each splitter fiber in a rural area has, on average, fewer than 32 connected locations. As such, the maximum capacity per connected location would be higher.

[57] This corresponds to a busy-hour offered load of 5,400 kbps. This is equivalent to a 5.4 Mbps connection being fully utilized through the entire busy hour. Because not all locations served by a splitter will subscribe, rural areas will have fewer locations per splitter, and not all subscribers will require full speeds at all times, the bandwidth required will be much lower than the subscription speed. Thus, it is reasonable for a network offering speeds of 10 Mbps or higher to have a busy hour offered load less than 5.4 Mbps.

In summary, given the network sizing at each of these aggregation points, and the likely range of reasonable take rates, the modeled network provides much more than 5.4 Mbps of capacity per connected location in rural areas.

14.1 Impact of Bandwidth growth on Broadband Network Equipment Capacities

As stated above, SBCM has more capacity than needed for the 10/1 service that carriers are required to offer pursuant to the December 2014 Connect America Order.

In prior versions of the SBCM, given that the network was configured for capacities greater than the supported service definition, there was no logic to capture the impact of increased busy hour loads. This has been addressed in the latest input files released.

Within the CAPEX input workbook, the investment in the OLTs, Ethernet Switches, and Broadband Routers are all triggered by the number of OLT ports consumed by the terminating Splitter fibers. That is, the OLT, Ethernet Switch, and Broadband Router are unitized on a per OLT port basis, where each port can support up to 32 connected locations from each splitter fiber. As such, for every 32 connected locations of splitter demand (referred to in the SBCM methodology as the Node2 demand), SBCM adds an increment of investment for these three components.

As described above the OLT acts as the throttle point by providing a maximum of 5400 kbps busy-hour load per connected location or 172Mbps per splitter fiber. The new input files increment the investment of the OLT, Ethernet Switch, and Broadband Router based on the modeled demand that is calculated at each fiber splitter (i.e., Node2). The total bandwidth at fiber splitter is calculated by multiplying the bandwidth per connected location by the take rate at each fiber splitter/Node 2. The SBCM compares that aggregate demand to the maximum supported demand of 172Mbps per splitter fiber. Where busy hour load increases and causes the aggregated demand to exceed the capacity of the OLT, the SBCM now adds additional cost to account for additional OLT and backhaul capacity.

As an example, if a Fiber Splitter / Node2 location has exactly 32 connected locations (i.e., the take rate times the number of locations leads to a fully utilized splitter with 32 connected locations), there is no incremental cost for any busy-hour load up to 5400 kbps. However, if one were to assume the per-user, busy hour demand had grown to 10,800 kbps, each OLT could handle only half as many fibers (with twice the busy-hour demand each). Therefore, the model calculates additional OLT cost (twice the number of required OLTs), along with added cost for Ethernet Switches, and Broadband Routers In effect, the model has to double the count of OLTs and double the ports consumed on Ethernet Switch, and Broadband Router.

15. Appendix 9 -- Plant Mix Development

The following process was used to derive the Plant Mix (i.e., the percentage of Aerial, Buried, and Underground plant) used in the Connect America Cost Model.

15.1 Carrier-Provided Plant Mix Data Request

As part of the Plant Mix development process, three price cap providers with multi-state operations provided plant mix information in the states in which they operated.[58] In short, Plant Mix information was provided by

- State
- Type of plant – Distribution, Feeder, Inter-Office (IOF)
- Density of Area – Rural, Suburban, Urban

Subsequently, a fourth price cap carrier operating in one state provided proposed plant mix values in the same format. These values were then applied to all Study Area Codes assigned into their corresponding state. The SAC specific plant mix values were incorporated as default values in the plant mix input tables in SBCM.

15.2 Initial Plant Mix Validation Methods

1. Data Validation
    a. Example -- did the percentages sum to 1 for each Type of Plant? Was a Rural, Suburban and Urban value submitted.
2. Calculation of Averages for each state where data was submitted
    a. Averaged submitted values by Density and Type of Plant for those states where more than one provider submitted data. Values showing no decimal places were likely result of operator(s) in a state submitting data without decimal precision.
    b. For those states where no state-level data were submitted, averaged values across all states by Density and Type of Plant to develop national averages
3. Compiled into the SBCM input table at the Study Area Code level.

15.3 SBCM Plant Mix SAC Updates

SAC specific Plant Mix values were further updated based upon corrections submitted for individual study areas.

The A-CAM v 2.1 Public Notice[59], describes the process used to develop Plant Mix SAC updates. The resulting values are used in the default PlantMixSAC input table used in A-CAM v 2.1, PlantMixSAC v12.

[58] The original plant mix values were publically filed in August 2011 and have been subsequently updated since that time.

[59] On December 17, 2015, the Bureau issued a public notice announcing the release of A-CAM v2.1, seehttps://apps.fcc.gov/edocs_public/attachmatch/DA-15-1431A1.pdf .

16. Appendix 10 -- Take Rate Impacts to Network Sizing and Cost Unitization

The business and residential take rate inputs can impact SBCM in two ways. First, they can impact how components of the modeled network are sized. Second, they can impact how the total investment and resulting costs are unitized. For purposes of this discussion, "take rate" refers to the percentage of homes or businesses that are connected to the network; it does not refer to the customer subscription levels.

With respect to network sizing, some components of the modeled network are impacted by the take rate values. In other words, they are sized based upon connected locations. Other components of the modeled network are not impacted by take rate. These components are sized by total locations.

Take rate's impact on network sizing can vary based upon the Network Topology used. Under the SBCM FTTp network, the black text network components (rows 5-14) in the figure below: NID/Drop, OLT, Eswitch, Router, and cVoip are impacted by take rate. This means that the input values in the business and residential take rate tables will impact how these components are sized and the corresponding investment.

	B	C	D	E	F	G
1	*Assume this represents 1 CB*	100% Take Rate example	80% Take Rate Example			
2	Locations	100	100			
3	Take	100	80			
4		Total Investment		Investment Per Unit	Unit	
5	NID/DROP	$ 19,000	$ 15,200	$ 190	per unit Take	
6	Node3	*$ 1,000*	*$ 1,000*	*$ 1,000*	*Total to Run Past all locations*	*Not impacted by Take*
7	DistNetwork	*$ 25,000*	*$ 25,000*	*$ 25,000*	*Total to Run Past all locations*	
8	Splitter	*$ 5,000*	*$ 5,000*	*$ 5,000*	*Total to Run Past all locations*	
9	FDR Network	*$ 15,000*	*$ 15,000*	*$ 15,000*	*Total to Run Past all locations*	
10	OLT	$ 10,000	$ 7,500	$ 2,500	Per 32 units of Take	
11	Eswitch	$ 4,000	$ 3,000	$ 1,000	Per 32 units of Take	
12	Router	$ 2,000	$ 1,500	$ 500	Per 32 units of Take	
13	cVoip	$ 5,000	$ 4,000	$ 50	per unit Take	
14	MM	$ 500	$ 500	$ 500	Total to Run Past all locations	*Not impacted by Take*
15						
16	**Total invest**	**$ 86,500.00**	**$ 77,700.00**			
17						
18	Investment Per Location (NoTakeRate Demand)	$ 865.00	$ 777.00			
19	Investment Per unit Take (TakeRate Demand)	$ 865.00	$ 971.25			
20						
21	*Numbers are for illustrative use only*					

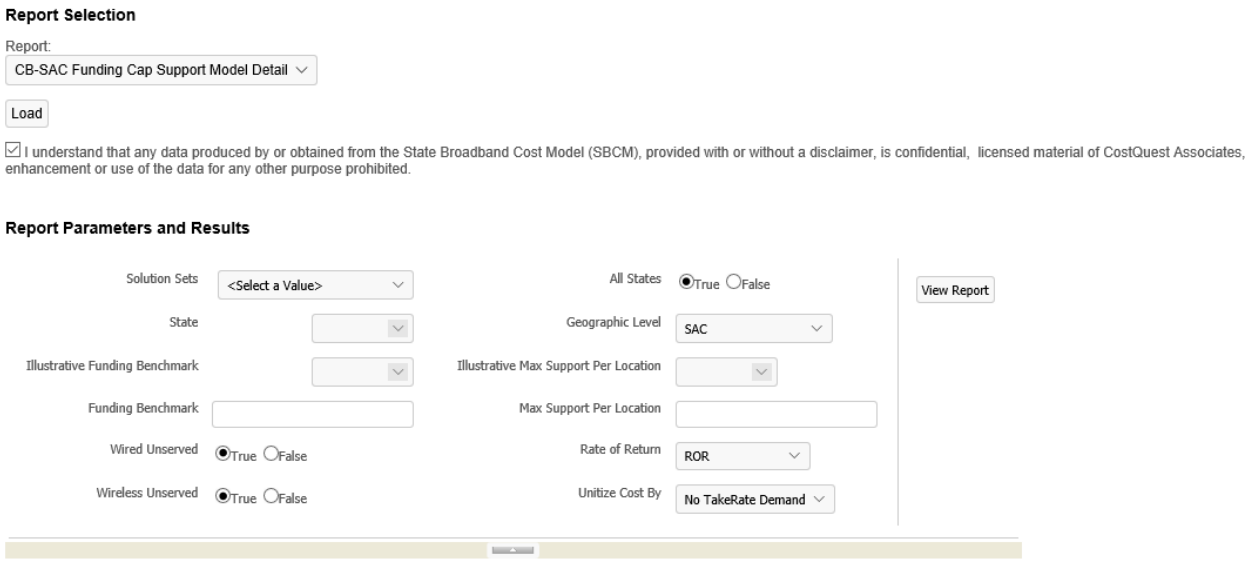
After the total network investment is calculated, the unitization is then applied (rows 18, 19 in this example). Note how unitization impacts how the Total Investment is unitized. Although not shown, Total Cost is handled in the same way.

In summary, the take rate values will impact the total investment in the network. The unitization will only impact the per unit investment or cost which is derived from the total investment. Within SBCM's support model, a unitization toggle setting of "No Take Rate Demand" (locations passed) would generate results based on an investment per location value shown in the illustration above with the corresponding take rate value. If the unitization toggle setting is set to "Take Rate Demand" (connected locations) the report would generate results based on an investment per unit take value shown in the illustration above with the corresponding take rate value.

For clarity, the formulas used in calculating this example are shown below.

B	C	D	E
Assume this represents 1 CB	100% Take Rate example	80% Take Rate Example	
Locations	100	100	
Take	100	80	
	Total Investment		**Investment Per**
NID/DROP	=E5*C3	=D3*E5	190
Node3	=E6	=E6	1000
DistNetwork	=E7	=E7	25000
Splitter	=E8	=E8	5000
FDR Network	=E9	=E9	15000
OLT	=ROUNDUP(C$3/32,0)*$E10	=ROUNDUP(D$3/32,0)*$E10	2500
Eswitch	=ROUNDUP(C$3/32,0)*$E11	=ROUNDUP(D$3/32,0)*$E11	1000
Router	=ROUNDUP(C$3/32,0)*$E12	=ROUNDUP(D$3/32,0)*$E12	500
cVoip	=E13*C3	=D3*E13	50
MM	=E14	=E14	500
Total invest	**=SUM(C5:C14)**	**=SUM(D5:D14)**	
Investment Per Location (NoTakeRate Demand)	=C16/C2	=D16/D2	
Investment Per unit Take (TakeRate Demand)	=C16/C3	=D16/D3	
Numbers are for illustrative use only			

The unitization toggle is available to the user when running a report such as a Support Model Detail report. This toggle is available to a user from the SBCM home page by selecting the Reporting button. Below is a screen capture showing the "Unitize Cost By" toggle. The toggle allows a user to select "Take Rate Demand" or "No Take Rate Demand" as displayed below.



By default, SBCM uses No TakeRate demand.

17. Peering Locations

A map of Internet Peering locations is shown in Figure 18.

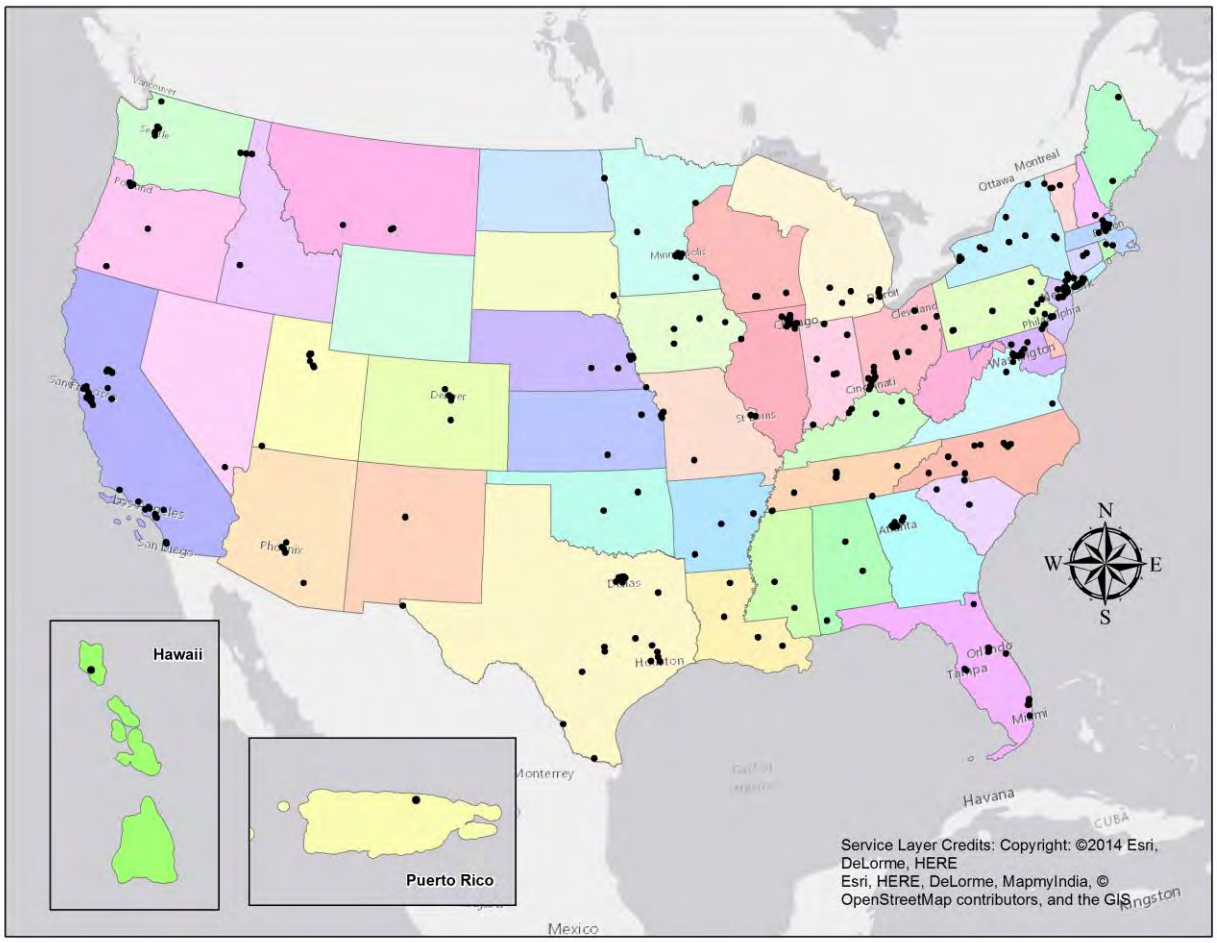


Figure 17~~18~~--Internet Peering locations used in SBCM

The table below provides the quantity of peering locations available in each state[60].

City	State	Number Peering Points
BIRMINGHAM	AL	1
MOBILE	AL	1
MONTGOMERY	AL	1
FORREST CITY	AR	1
HOPE	AR	1
LITTLE ROCK	AR	1

[60] Peering locations were extracted from the following sources: DataCenter9 (http://www.datacenter9.com/datacenters/united-states), PeeringDB (https://www.peeringdb.com), Level3 (http://datacenters.level3.com/wp-content/uploads/2015/05/DataCentersGlobal.pdf), and ColocationAmerica (http://www.colocationamerica.com/blog/data-center-locations-arrival-of-server-farms.htm)

CHANDLER	AZ	2
PHOENIX	AZ	2
SCOTTSDALE	AZ	1
TEMPE	AZ	1
TUCSON	AZ	1
AGOURA HILLS	CA	1
ANAHEIM	CA	1
EL SEGUNDO	CA	2
EMERYVILLE	CA	2
FREMONT	CA	2
HAYWARD	CA	1
LOS ANGELES	CA	2
MCCLELLAN	CA	1
MILPITAS	CA	1
MODESTO	CA	1
MOUNTAIN VIEW	CA	1
OAKLAND	CA	1
ONTARIO	CA	1
PALO ALTO	CA	1
RANCHO CORDOVA	CA	2
SACRAMENTO	CA	2
SAN DIEGO	CA	2
SAN FRANCISCO	CA	2
SAN JOSE	CA	3
SANTA ANA	CA	1
SANTA BARBARA	CA	1
SANTA CLARA	CA	2
STOCKTON	CA	1
SUNNYVALE	CA	2
TUSTIN	CA	1
VERNON	CA	1
WEST SACRAMENTO	CA	1
AURORA	CO	1
CENTENNIAL	CO	1
COLORADO SPRINGS	CO	1
DENVER	CO	1
ENGLEWOOD	CO	2
LOUISVILLE	CO	1
MANCHESTER	CT	1
NEWINGTON	CT	1
STAMFORD	CT	1
WASHINGTON	DC	1
NEWARK	DE	1
WILMINGTON	DE	2
BOCA RATON	FL	2
FT LAUDERDALE	FL	1
JACKSONVILLE	FL	2

LGHTHSE POINT	FL	1
MELBOURNE	FL	1
MIAMI	FL	2
OAK RIDGE	FL	1
ORLANDO	FL	2
POMPANO	FL	1
TAMPA	FL	2
WINTER PARK	FL	1
ATLANTA	GA	2
AUSTELL	GA	1
LITHIA SPRINGS	GA	1
MARIETTA	GA	1
NORCROSS	GA	1
SMYRNA	GA	1
SUWANEE	GA	1
HONOLULU	HI	1
BETTENDORF	IA	1
BOONE	IA	1
CEDAR FALLS	IA	1
DES MOINES	IA	1
MONTICELLO	IA	1
BOISE	ID	2
COEUR D ALENE	ID	1
ALSIP	IL	1
ARLINGTON HEIGHTS	IL	1
BANNOCKBURN	IL	1
CHICAGO	IL	2
ELK GROVE VILLAGE	IL	2
LAKE IN THE HILLS	IL	1
LISLE	IL	1
LOMBARD	IL	2
MOUNT PROSPECT	IL	1
MT. PROSPECT	IL	1
NAPERVILLE	IL	1
OAKBROOK	IL	1
SCHAUMBURG	IL	1
WOOD DALE	IL	1
EVANSVILLE	IN	1
FORT WAYNE	IN	1
INDIANAPOLIS	IN	2
LAFAYETTE	IN	1
SOUTH BEND	IN	2
KANSAS CITY	KS	1
LENEXA	KS	1
OVERLAND PARK	KS	1
TOPEKA	KS	1
WICHITA	KS	1

FLORENCE	KY	1
LEXINGTON	KY	1
LOUISVILLE	KY	1
OLIVE HILL	KY	1
PROSPECT	KY	1
ALEXANDRIA	LA	1
BATON ROUGE	LA	1
MONROE	LA	1
NEW ORLEANS	LA	1
ANDOVER	MA	1
BEDFORD	MA	1
BOSTON	MA	2
CAMBRIDGE	MA	2
FALL RIVER	MA	1
LYNN	MA	1
MARLBOROUGH	MA	1
NEEDHAM	MA	1
SOMERVILLE	MA	1
WAKEFIELD	MA	1
WALTHAM	MA	2
BALTIMORE	MD	1
FREDERICK	MD	1
LAUREL	MD	1
SILVER SPRING	MD	1
BRUNSWICK	ME	1
PRESQUE ISLE	ME	1
ANN ARBOR	MI	1
BATTLE CREEK	MI	1
DEARBORN	MI	1
GRAND RAPIDS	MI	1
LANSING	MI	1
SOUTHFIELD	MI	3
TROY	MI	1
ALEXANDRIA	MN	1
DULUTH	MN	1
EAGAN	MN	1
EAST GRAND FORKS	MN	1
EDEN PRAIRIE	MN	1
MINNEAPOLIS	MN	2
MINNETONKA	MN	1
ROCHESTER	MN	1
ST. PAUL	MN	1
KANSAS CITY	MO	2
MARYLAND HEIGHTS	MO	1
RICHARDSON	MO	1
SAINT LOUIS	MO	1
SPRINGFIELD	MO	1

ST. LOUIS	MO	1
HATTIESBURG	MS	1
JACKSON	MS	1
BILLINGS	MT	2
BOZEMAN	MT	1
ASHEVILLE	NC	1
CARY	NC	1
CHARLOTTE	NC	2
DURHAM	NC	1
GREENSBORO	NC	1
LENOIR	NC	1
MORRISVILLE	NC	1
NEWTON	NC	1
RALEIGH	NC	1
WINSTON-SALEM	NC	1
AURORA	NE	1
BELLEVUE	NE	1
LINCOLN	NE	1
OMAHA	NE	2
PAPILLION	NE	1
MANCHESTER	NH	1
CARLSTADT	NJ	1
CEDAR KNOLLS	NJ	1
CLIFTON	NJ	1
EDISON	NJ	1
JERSEY CITY	NJ	2
NEWARK	NJ	1
NORTH BERGEN	NJ	1
PARSIPPANY	NJ	1
PENNSAUKEN	NJ	1
PISCATAWAY	NJ	1
SECAUCUS	NJ	2
SOMERSET	NJ	1
ALBUQUERQUE	NM	2
LAS VEGAS	NV	2
ALBANY	NY	1
AMHERST	NY	1
BRENTWOOD	NY	1
BROOKLYN	NY	1
BUFFALO	NY	1
CHAPPAQUA	NY	1
COLONIE	NY	1
COMMACK	NY	1
FARMINGDALE	NY	1
GARDEN CITY	NY	3
HAWTHORNE	NY	1
ISLANDIA	NY	1

MALONE	NY	1
MT. SINAI	NY	1
NESCONSET	NY	1
NEW YORK	NY	2
ORANGEBURG	NY	1
PITTSFORD	NY	1
PLATTSBURGH	NY	1
ROCHESTER	NY	1
SETAUKET	NY	1
STATEN ISLAND	NY	1
SYRACUSE	NY	2
UTICA	NY	1
WATERTOWN	NY	1
WESTBURY	NY	1
WILLIAMSVILLE	NY	1
WOODBURY	NY	1
YORKTOWN HEIGHTS	NY	1
CANTON	OH	1
CINCINNATI	OH	2
CLEVELAND	OH	2
COLUMBUS	OH	2
DAYTON	OH	1
HAMILTON	OH	1
LEBANON	OH	1
MASON	OH	1
MIAMISBURG	OH	1
NEWARK	OH	1
WEST CHESTER	OH	1
WORTHINGTON	OH	1
YOUNGSTOWN	OH	1
OKLAHOMA CITY	OK	1
TULSA	OK	2
BEAVERTON	OR	1
BEND	OR	1
CEDAR HILLS	OR	1
HILLSBORO	OR	1
MEDFORD	OR	1
PORTLAND	OR	2
TIGARD	OR	1
AUDUBON	PA	1
BETHLEHEM	PA	1
BREINIGSVILLE	PA	1
PHILADELPHIA	PA	2
PITTSBURGH	PA	2
SCRANTON	PA	1
STATE COLLEGE	PA	1
WYOMISSING	PA	1

SAN JUAN	PR	1
PROVIDENCE	RI	1
COLUMBIA	SC	1
GREENVILLE	SC	1
ROCK HILL	SC	1
SIOUX FALLS	SD	1
BERRY HILL	TN	1
BRENTWOOD	TN	1
CHATTANOOGA	TN	1
FRANKLIN	TN	1
JACKSON	TN	1
KNOXVILLE	TN	1
MEMPHIS	TN	2
NASHVILLE	TN	2
AUSTIN	TX	2
BREDFORD	TX	1
BRYAN	TX	1
CARROLLTON	TX	2
DALLAS	TX	2
EL PASO	TX	1
FARMERS BRANCH	TX	1
HOUSTON	TX	2
KATY	TX	1
LAREDO	TX	1
LEWISVILLE	TX	1
MCALLEN	TX	1
MONTGOMERY	TX	1
PLANO	TX	1
RICHARDSON	TX	1
SAN ANTONIO	TX	1
THE WOODLANDS	TX	1
TYLER	TX	1
BLUFFDALE	UT	1
LINDON	UT	1
OREM	UT	1
SAINT GEORGE	UT	1
SALT LAKE CITY	UT	2
WEST VALLEY CITY	UT	1
ASHBURN	VA	2
CULPEPER	VA	1
HERNDON	VA	2
MANASSAS	VA	1
MCLEAN	VA	1
NORFOLK	VA	1
RESTON	VA	2
VIENNA	VA	2
BURLINGTON	VT	1

SOUTH BURLINGTON	VT	1
STOWE	VT	1
WILLISTON	VT	1
BELLINGHAM	WA	1
BOTHELL	WA	1
LIBERTY LAKE	WA	1
LYNNWOOD	WA	1
SEATTLE	WA	2
SPOKANE	WA	1
TUKWILA	WA	1
MADISON	WI	2
MILWAUKEE	WI	1

18. Document Revisions

1/1672016
Initial release from root version A-CAM 2.1