CostProLoop

Loop Economic Modeling

Model Documentation

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Introduction / Summary

This document provides an overview of how the wireline loop economic modeling data was developed for the Broadband Analysis Model ("BAM"). It includes an overview of the underlying model platform (i.e., CostPro) as well as a discussion of methods used in the modeling, a summary of key data sources and an overview of results.

CostPro configures the telecommunications networks, for the BAM application. It produces the network topology including cable lengths, DSLAM sizes and locations, etc.. The cost of the network is then developed within the BAM application.

Corresponding documentation provides similar information relative to the development of fixed wireless economic design.

Current economic modeling across all plant categories are grounded in similar design principles applied by comparable network models and use real-world forward-looking engineering practices and assumptions.

The goal of economic modeling is to develop an estimate of the network required to provide the desired level of service. The modeling of network includes all components to prepare the asset / system for productive use.

Central to understanding the resulting network topology that is designed is an appreciation of the underlying inputs, assumptions and economic models.

- Inputs, as outlined in this document, are based on publicly available data for customers, service area boundaries, and switch or cable service areas.

- Assumptions reflect real-world / current engineering practices, including how these practices are applied within specific terrain.

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

The economic network topology is based on results from the CostProLoop model. With longstanding use in the telecom industry, CostPro is a next-generation network modeling platform. It provides an economic topology of a network based on the design of an optimal, forward-looking network developed by a current customer-by-customer analysis of network utilization.

What sets the CostPro platform apart from other modeling approaches and methods is its granular approach, its use of spatial analysis, and its reality-based engineering guidelines. Derivations of the CostPro model are used by companies with operations in over 30 states in the U. S, have been adopted by public utility commissions in every state where it has been filed, have been used in property tax valuations, have been used to value networks in acquisitions, and have been used by international government agencies.

At its core, the CostProLoop modeling platform is a "spatial" model. It determines where customers are located and "lays" cable along the roads of the service area to reach them. In fact, a cable path can literally be traced from each customer's premises to the serving central office or headend; a path that follows the actual roads in the service area.

Through the use of C++ and Visual Basic code, databases, and a user- friendly interface, CostPro determines the economic topology for wire-line network components, across all categories of plant required to connect a specific service demand group; e.g. customers, former customers or potential customers, to their serving central office or headend and to provide a wide-range of wire-line services to these customers. The model assumes the installation of forward looking, commercially available telecommunications technologies and uses generally accepted engineering practices and procedures.

Accurate Bottoms-Up Design

CostPro's network related topologies are grounded in a model of network connections between each and every customer. Just like an engineer, the model tallies the necessary length and type of network facilities, including relevant network components and electronics, based on actual customer demand, switch or headend locations and service architectures.

Developing Costs for the Full Complement of Services

The CostPro platform can model the full complement of services provided by modern communication carriers, including POTS services, fiber in the loop strategies and high bandwidth enterprise fiber services such as MetroEthernet and SONET based DS3 and greater services.

For the BAM application, CostProLoop was used to develop a network platform to provide a desired level of broadband service. For example, if one is interested in understanding the network topology required to provide 3-4Mbs download speed, the minimum required build would use a 12kft copper distribution design. If, on the other hand, one is interested in 100+Mbs download service, a fiber to the premise (FTTp) network design could be utilized. In all, 6 versions of the model were run for BAM:

- ✓ 15kft copper distribution design for DSLAM service
- ✓ 12kft copper distribution design for DSLAM service
- ✓ 5kft copper distribution design for DSLAM service
- ✓ 3kft copper distribution design for DSLAM service
- ✓ Fiber to the premise for a telco provider
- ✓ Fiber to the premise for a cable provider[1]

Beyond these baseline runs, additional designs were produced to support National Purpose analysis.

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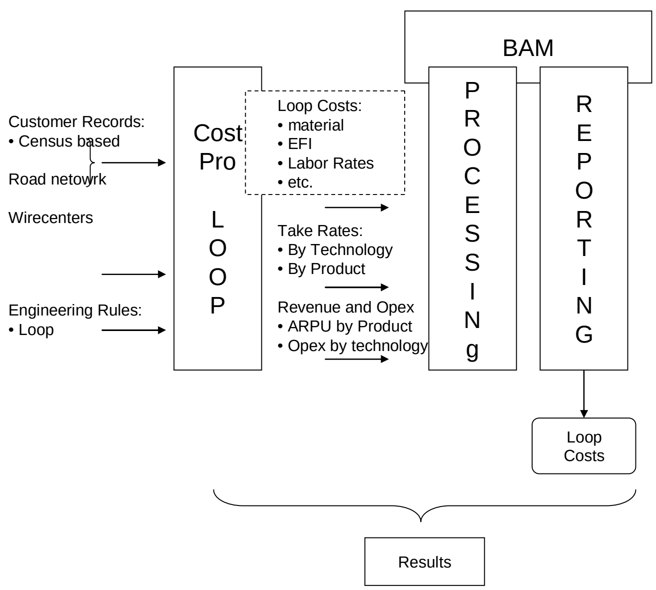
[1] It was assumed the current HFC systems in the country would commercially migrate to DOCSIS3 and would be sufficient to provide most levels of broadband service. The fiber to the premise runs for cable encompassed the currently unserved cable areas of the country.

Overview and Administrative Features

Inputs / Processing Schematic

As an overview, the CostProLoop modeling platform accepts, processes and forwards required inputs along the high level path outlined below. Each component of the model builds from and is coordinated with the component that precedes it. The end result is a logical computation of comprehensive network economic deployment costs.

The other important point is that the inputs reflect the real world. Demand, is considered within the context of real engineering rules applied to real, geographic-specific, roads and terrain.



Network Assets

The logic behind economic network modelling is derived from a realistic, engineering-based understanding of what drives; i.e., causes, additional investments.

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

Loop: Wireline loop plant connects customers to central offices or headends. The basic drivers of loop plant investment, including electronics, include all manner of customer demand and location. The loop is typically broken into a distribution portion and feeder portion. Distribution runs to the customers' locations while feeder runs to the central offices or headends.

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

Network Interface Device (NID) -- The NID serves as a demarcation point between customer wiring 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 NID. In regard to the NID, for telecom deployment it is sized based upon copper pair demand, which is triggered by service demand.

Optical Networking Terminal (ONT) – An ONT is used to provide Voice, Video and Data services to customers in an FTTP topology. An ONT is hosted by an Optical Line Terminal. An ONT is placed at each customer's premise.

Customer Premise Equipment (CPE) – CPE can be capitalized equipment that is placed on a customer premise. Its use is driven by a particular service. This can include the modem for DSL and DOCSIS service and the Set Top Box for video service. CPE investment is driven by the count of services, customers served, and ultimate ownership of the equipment.

Drop Wire (Drop)—For telecom deployment, a cable sheath consisting of two or more pairs of copper wires, which permanently connects the NID to a Distribution Terminal (DT). Essentially, the drop wire connects between the customer premises and the distribution cable at the street. A drop wire can be buried or aerial and is driven by customer demand. For Fiber to the Premise (FTTP) deployments, this drop is fiber, rather than copper, and connects up to the fiber service terminal. For hybrid fiber-coax ("HFC") cable deployments the drop is coaxial cable which then connects to the tap on the distribution run.

Distribution Terminal / Building Terminal (DTBT)—For telecom deployment, the Distribution Terminal (DT) is the point where the drop wires from several customers are connected to pairs in a larger cable. This cross-connect or 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 customer's premise rather than using drop cables and NIDs. For FTTP (Fiber To The Premise), the DTs and BTs are replaced by fiber service terminals (FSTs) and are fed by fiber cable. For typical Hybrid Fiber-Coaxial ("HFC") cable systems, the tap provides the connection with the distribution network.

For reporting purposes, the cross-connect point, whether it is a DT or BT, Tap or FST is described and tracked as a DTBT within CostPro.

Distribution Cable (DT-FDI)--The loop component that connects the DTBT with the feeder cable at the Feeder Distribution Interface (FDI). Distribution cable in the loop network for Fiber to the DLC (FTTD) and Fiber to the Node (FTTN) architectures is copper. For FTTP designs, along with optical Ethernet and wideband services, the distribution cable is fiber. For typical HFC cable designs, the distribution cable is coaxial cable.

CostPro allows the user to specify the percentage of distribution cable that is buried, underground or aerial through the entries in the plant mix table.

Amplifier – In typical HFC cable designs, signal amplifiers are placed within the distribution pathing based upon distance parameters.

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/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 customers' premises.

DSL Access Multiplexer (DSLAM) – In a copper loop architecture, a DSLAM provides broadband service capability and receives data from multiple customer DSL connections and aggregates the data onto a high speed Gigabit Ethernet (GigE) backbone.

Digital Loop Carrier (DLC) System— In copper loop architecture, a DLC provides voice service capability and consists of equipment required in a CSA (Carrier Serving Area) and at the Central Office to multiplex channels and to convert electrical signals to and from optical signals for efficient transport. In the CSA, the DLC equipment is referred to as a Remote Terminal (DLC-RT). At the central office, the DLC equipment is referred to as the Central Office Terminal (DLC-COT).

FiberNode (FN) – In typical HFC cable designs, the fiber node is the point at which the coaxial cable terminates and the signal is converted from analog to optical for transmission back to the CMTS.

Optical Line Terminal (OLT) – In a FTTP design, the fiber cable from the PFP terminates on an OLT. The OLT performs optical-electrical conversion from the ONUs towards the network. This OLT can either be housed in the central office or at an RT site.

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 used to transport data from DSLAMs to the Central Office.

Cable Modem Termination System (CMTS) – Used to terminate the cable modem signals from the customer sites. The CMTS provides many of the same functions as the DSLAM, including the provision of broadband service.

Multiprotocol Label Switching (MPLS) – A set of quality-of-service (QoS) standards used to manage different kinds of data streams based on priority and service plan. MPLS enables an IP network to maintain priority for voice and video traffic.

Metro Ethernet COT (MeCOT) – A generic description of equipment placed at a Central Office to support Metro Ethernet services.

Feeder Cable (FDI-DLC and DLC-CO) — The feeder cable transports traffic, either voice or data, between the FDI/PFP and the central office in the telecom environment and between the fiber node and the head end in the HFC design.

Administrative Features

CostPro has a user-friendly GUI interface provides the ability to run and report from easy to follow wizards. The model includes all portions of the wireline loop network, both facilities and electronics. The model is capable of modeling new services and technologies as they are developed and deployed. There is minimal use of hard-coded engineering values. Rather, the model provides user control over engineering rules and functions to more accurately reflect actual / real-world engineering practices. The model produces outputs at a geographically de-averaged level including customer or groups of customers.

With respect to the modeling of loop investment, important engineering features include the following capabilities:

- Toggles to switch on and off various technologies and approaches including Fiber to the Premise (FTTP), Fiber to the Node (FTTN), Hybrid Fiber-Coaxial (HFC), and Fiber to the DLC (FTTD).

- User-controlled engineering rules enhance the model's ability to reflect actual engineering practices. More specifically, the Model reflects engineering rules for:
    - Limits of copper distribution, copper feeder and electronics
    - Use of fiber in the feeder and the use of fiber-fed DLC
    - Capacity of electronics (e.g., DLC system, Fiber nodes, etc...)
    - Deployment of FTTP, FTTN, Coax and FTTD
    - Engineering fills

The model supports all offered services including basic local service (including second lines), Centrex, PBX, ADSL, HDSL, ISDN, Coin, Specials (DS0, DS1, DS3, DS1, E3, etc…), MetroEthernet, broadband, and unbundled loops.

Additional important elements of the overall modeling methodology are described below.

Customer Point Data

Within CostPro, the modeling exercise can begin with address-geocoded customer point data. Address geocoding is a method used to match a customer address to a location on a road network. Address geocoding is a well established technique to derive a locational attribute, such as longitude and latitude, from an address.

CostPro then augments actual geocoded point data with surrogate locations for the customer data points 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 addition, CostPro can add locations of actual non-working lines or add estimated locations (based on Census data) of potential customers who currently are not taking service. The use of this data, toggled by user inputs, allows the modeling of a more robust network and the carrier of last resort obligation.

Alternatively and as used to run the BAM output, CostPro can use Census information and surrogate an entire data set of estimated customer location data.   As noted above, the surrogation of points is based upon generally accepted practices and occurs at the finest level of public geography. That is, the surrogation of data takes place at the census block level using the roads and customer counts within each census block. Care is taken so as not to place customers on specific types of roads such as interstate highways.

Engineering Areas

Using industry standard engineering rules, road distance and service demand information (e.g., DS0s, pairs, Living Units, Average Information Rate, etc), service clusters are formed. A service cluster is a group of demand points (customers) which share a common loop network technology. For example for a voice network, a service area could be described for all customers sharing the same remote terminal.   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).

Route Information

Based on user adjustable inputs, engineering rules, and Minimum Spanning Road Trees (MSRT), optimized plant routing is developed to each and every customer. MSRTs are used to develop the routing for distribution and feeder plant.

Methods - MSRT and Network

CostPro designs a network to serve customers within a service area (e.g., wire center, headend service area, etc.) based on where they actually reside. The model "lays" cable along the actual roads in the service area to connect customer premises with their serving central office or headend. 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, as shown in Figure 1.

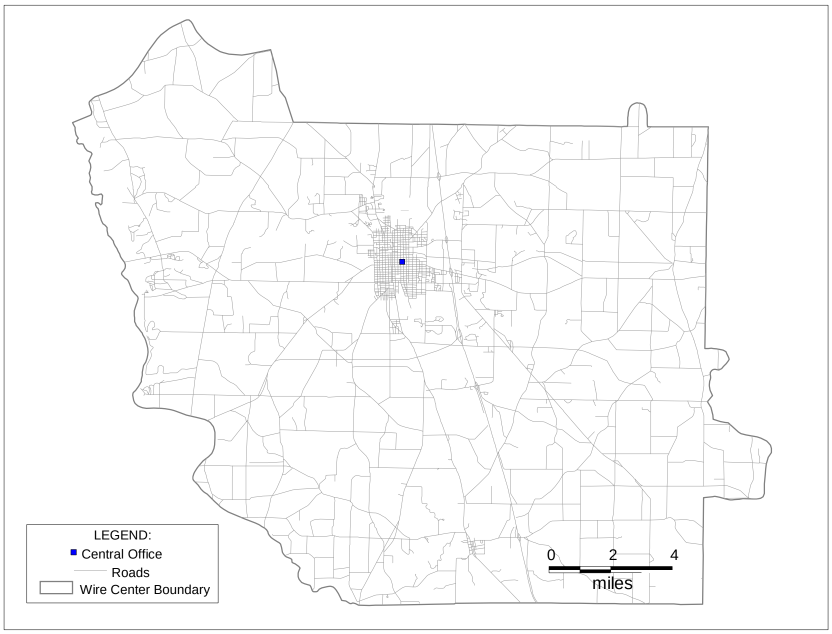


Figure 1 -- Road Network

Demand Data Preparation

For the CostPro BAM runs, the customer data (both business and residential) was pulled from public sources. For residential data, Census based data was used. For business data, third party vendor information was used. In each case, counts of locations by census block are provided. Before the customer 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 this public census based data, 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). In addition, census units in structure information is used to approximate the location of multifamily locations.

Figure 2, presents a section of the view shown in Figure 1 with customer locations shown as circles. In this example, these circles represent *all* of the service demand points (e.g., both business and residences). The customer and service data are now ready for processing by CostProLoop.

Figure 2 -- Customer Locations

Optimal Routing

Using the spatially located customer locations and the road network, specifically designed and reviewed algorithms determine optimal network routing and placement based upon standard industry engineering rules. As a first step, CostPro uses a minimum spanning road tree ("MSRT") algorithm to develop the optimized routing from the central office or headend to all customer locations. Once a full service area MSRT is determined, CostProLoop walks back from the furthest customer toward the Central Office or headend. As the walked path reaches the maximum road-distance for the specified build (e.g., 12kft of copper distribution), an initial node placement is made for a terminal. The model then walks past this node placement until the maximum distance is reached again. As the path is walked, branch road segments are captured for inclusion in the area served by the terminal. Once all customer locations to be served by a terminal node are determined, appropriate components such as Feeder Distribution Hubs (FDHs), Fiber Nodes (FNs) and Feeder Distribution Interfaces (FDIs) are located within each serving area. Once the serving nodes are placed within these "remote" served serving areas, an MSRT is formed to provide the optimal path by which to serve all customers from the remote terminal node. The MSRT 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 customers served by a terminal in the central office or headend, an MSRT is determined. CostProLoop then compares the customer count against user inputs to determine if this tree is to be "pruned" into multiple central office or headend served trees to meet engineering constraints. Once the main central office served areas are determined, these tree paths are then walked to determine points at which feeder distribution interface (for copper areas) or fiber distribution hub (for fiber served areas) terminals are to be place. These placements are driven by user inputs guiding customer counts and distance limits. The MSRT within each serving area then becomes the distribution cable path.

As a final step in the pathing algorithms, an MSRT for feeder plant is determined. That MSRT links the nodes outside of the Central Office or headend to the Central Office (CO) or headend.

Figure 3 depicts a distribution network created by the process based on the optimized MSRT approach. Figure 4 depicts the same type of information for the feeder network.

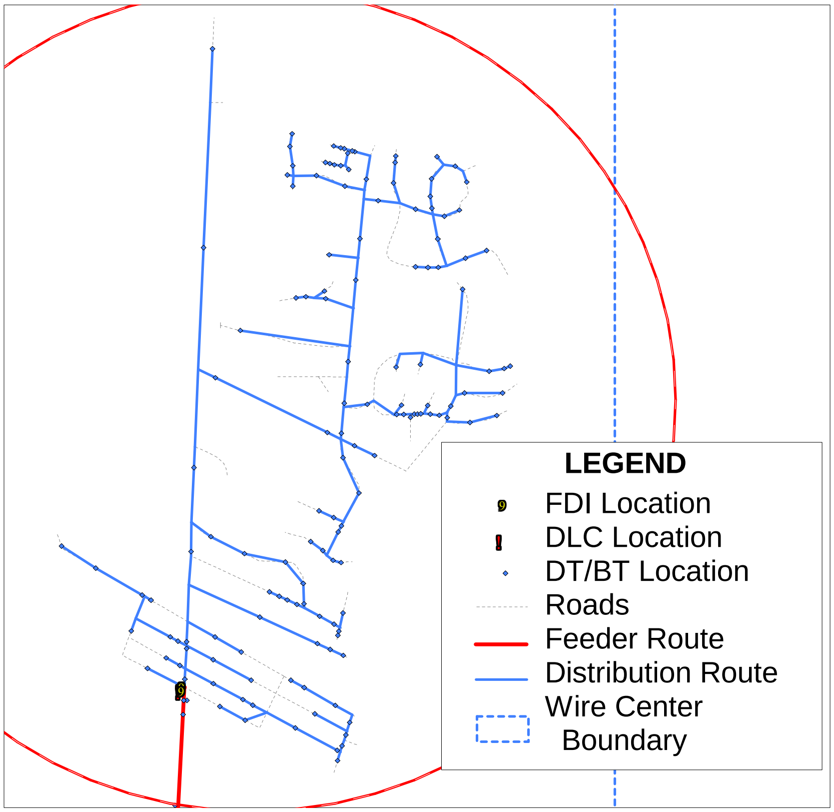


Figure 3—MSRT for Distribution Plant

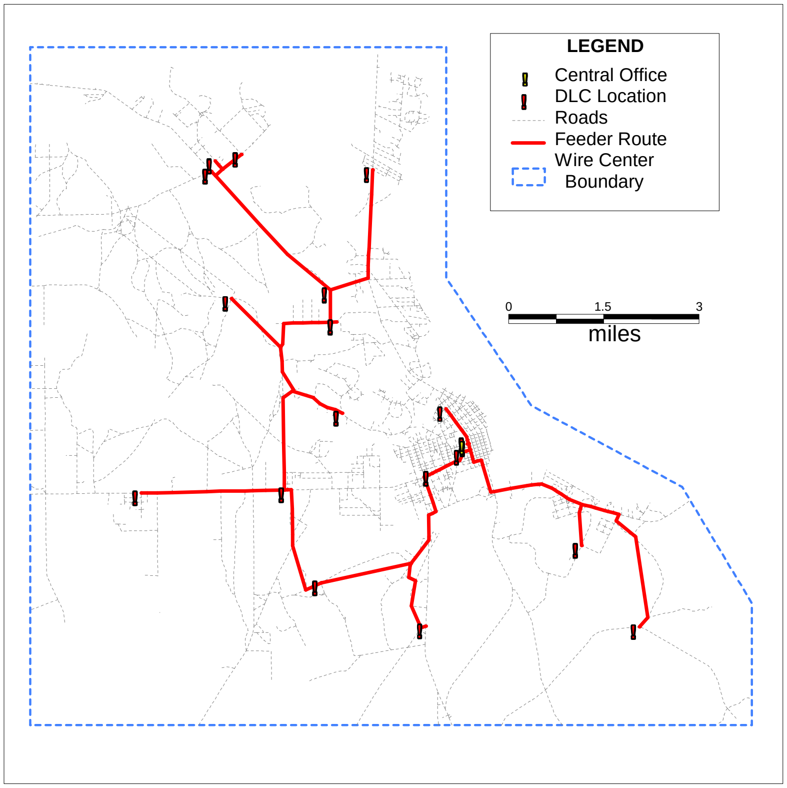


Figure 4 -- MSRT for Feeder Plant

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

Once the spatial layout of the network is determined, CostProLoop'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 Remote Terminal type. Once the network is configured, CostPro summarizes the network topology information to create the source file for the BAM application. In this summarization, the information about the network build is pushed out to the census block records. As such, each census block record captures the size of the main serving terminal (e.g., DSLAM, FiberNode, FDH, etc..) the customer count at the central office or headend, 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.

Methods - CostProLoop Engineering

CostProLoop develops investment estimates for wireline loop plant. The loop is the portion of the telecommunications network that extends from the Central Office (CO) or Headend to the customer's premises. The loop delivers access to voice, data, special access or video services from the Central Office or headend.

A loop extends from a customer premise (a business or living unit). It can be terminated on a Class 5 circuit switch, a soft switch, specific customer equipment, CLEC equipment or any multitude of routers, gateways or specialized equipment necessary to support IP driven services like VoIP or video.

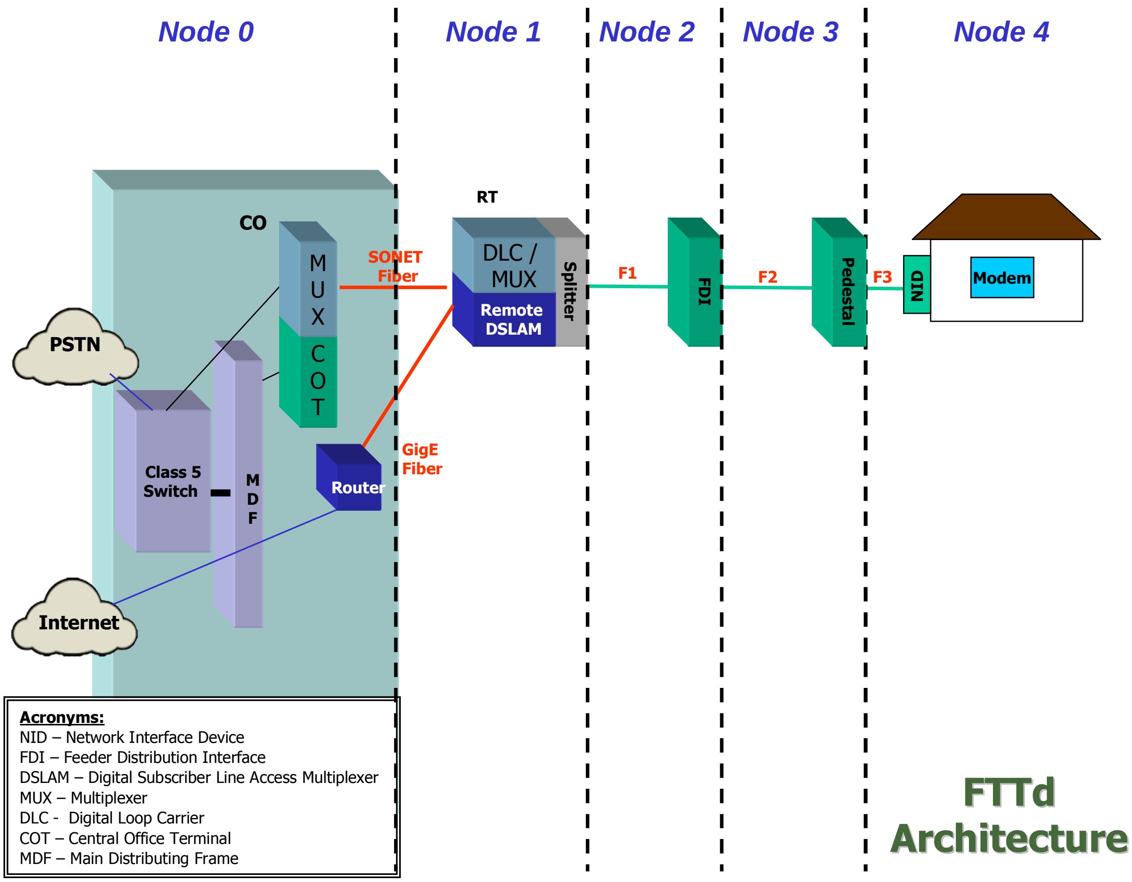
The loop consists of two plant families: distribution and feeder. Distribution plant covers the connection between the customer premises and the Feeder Distribution Interface (FDI). At the FDI, distribution cable is "cross connected" to feeder cable. Feeder plant covers the connection between the FDI and the CO.

CostProLoop designs a network using forward-looking technologies and design principles. To meet the heterogeneous engineering characteristics of today's service providers, CostProLoop is capable of modeling different wireline topologies.

The first topology is the 'traditional' CSA, Class 5 Circuit Public Switched Telephone Network (PSTN), as seen in Figure 5. We refer to this topology as Fiber to the DLC or CSA (FTTD). This topology deploys both fiber feeder and copper distribution cable along with associated loop electronics (such as Digital Loop Carriers) to provide switched voice, low speed data, xDSL and special access circuits. This network design provides minimal broadband service levels.

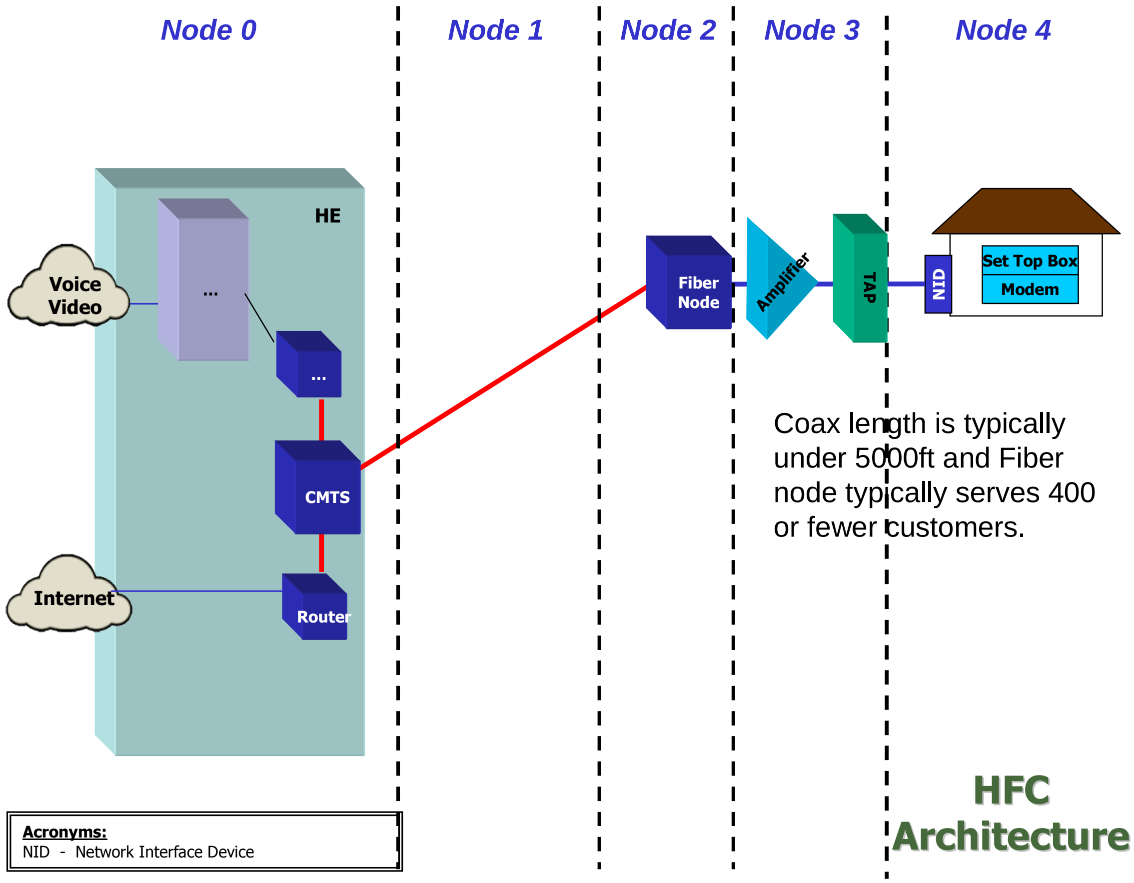
As you will see in each of the following network designs, we have tried to standardize the reference to network by using the values of Node0 through Node4. Node identifiers are used to help bridge the understanding of functionality across the differing technologies (wireless and various forms of fiber and hybrid fiber solutions) that were used in BAM. The "nodes" are significant in that they represent the way in which costs are assigned / aggregated to enable neutral comparisons across technologies.

Figure 5—Typical PSTN Engineering Design



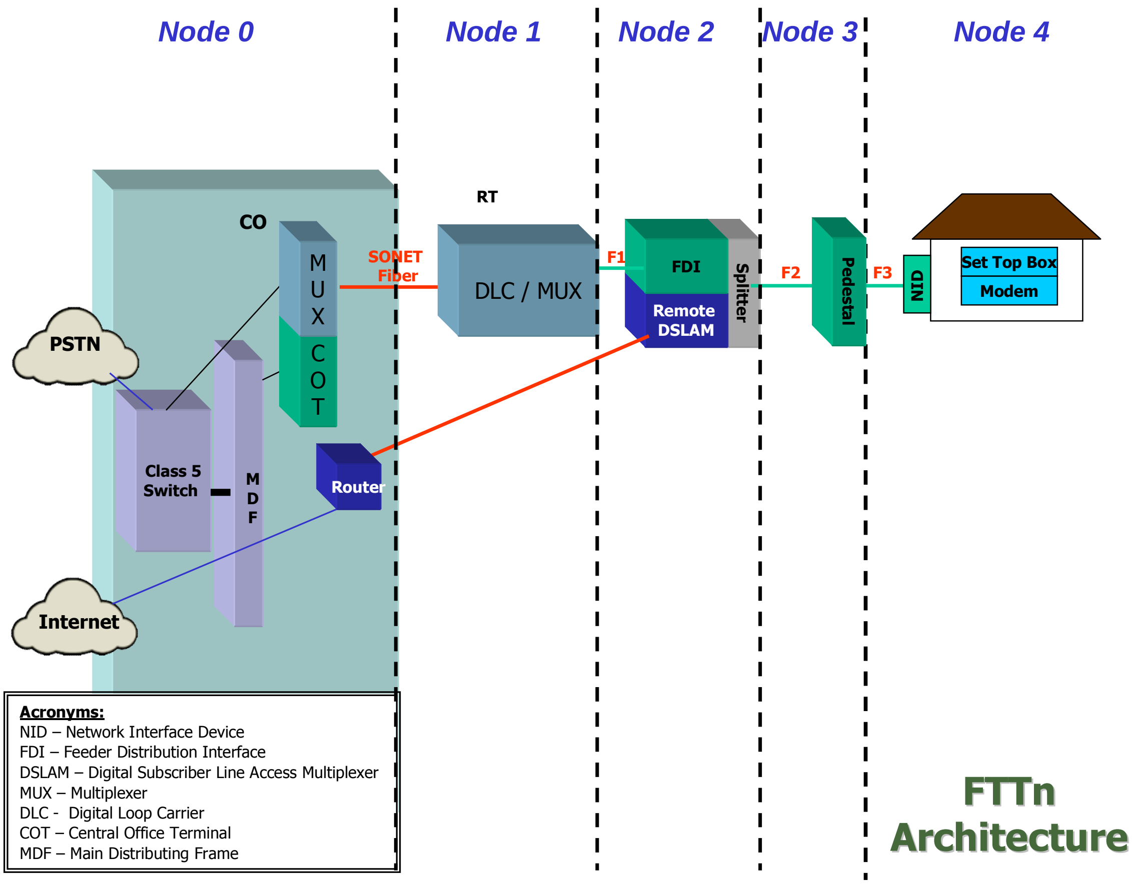
The second topology, as depicted in Figure 6, is the HFC cable build used historically by the cable industry. This topology uses coaxial cable for the distribution plant up to the fiber node. At the fiber node the signal is converted from analog to optical and then transmitted over fiber cable to the CMTS at the headend. This design can support DOCSIS2 and DOCSIS3 deployments and can provide broadband speeds pushing 100mbs.

Figure 6—HFC cable



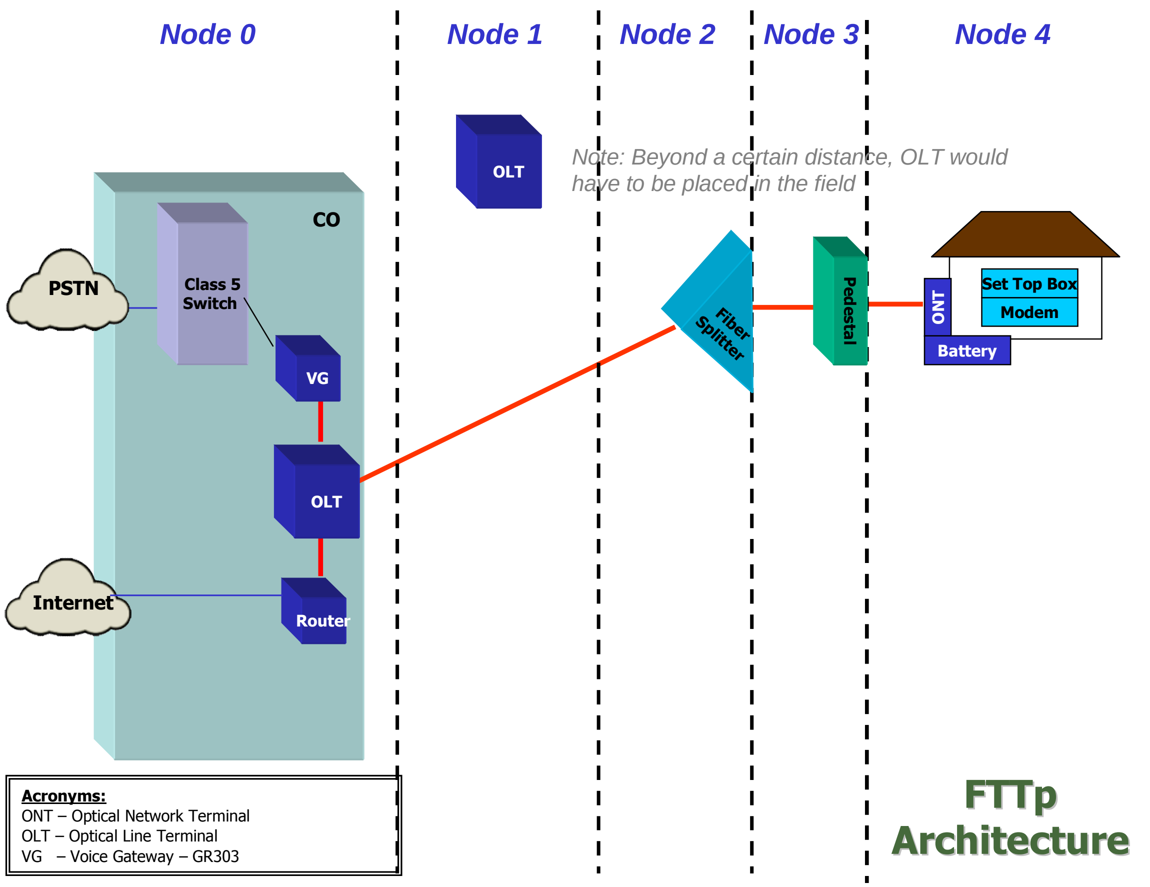
The third topology is FTTN (Fiber to the Node), as depicted in Figure 7. In this topology a DSLAM is deployed at the FDI. In a circuit switch deployment, the customer's loop is 'split' at the FDI rather than the DLC in the FTTD design. This split separates the voice from the data packets. The data stream is sent to the DSLAM, while the voice stream is passed back to the traditional DLC. The topology pushes the availability xDSL services to customers farther away from the Central Office and typically reduces the copper distance from the customer to the DSLAM to ~3000 ft. This topology expands the footprint of where xDSL services can be provisioned, increases the potential bandwidth to up to 50Mbs (with pair bonding), and allows for the provisioning of services including video. To support the Gigabit Ethernet data stream, fiber optic cables go from the DSLAM to the Central Office.

Figure 7-FTTn Topologies



The final topology is passive optical, FTTP (Fiber to the Premise), as depicted in Figure 9. In this topology an ONT (Optical Network Terminal) is placed at the customer's house, along with a battery for back up power. Fiber cable then connects the customer to the Central Office or headend. Along the path, the fiber from the customers is concentrated at the FDH (Fiber Distribution Hub) in a typical 32 to 1 ratio. At the central office or headend, the fiber from the FDH terminates on an OLT (Optical Line Terminal). The traffic is then sent to an Ethernet switch. In circuit switching is to be used, the voice packets are routed to a class 5 switch. Data packets are routed to the IP network via a connection to a router. This gateway router can be in central office or headend or can be located at an intermediate office to support multiple central offices or headends. Broadband speeds over this design are only limited by the electronics used. Currently, providers are deploying 50-100Mbs broadband speeds.

Figure 8—FTTP topology



Data Sources

The CostProLoop modeling process requires data inputs and modeling assumptions unique to BAM's requirements and assumptions. Input data and relevant sources are outlined below.

Engineering data

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

Telecom Wire center boundaries

- TeleAtlas, wire center boundaries (Jun, 2009).

Switch Location and Function

- TeleAtlas wire center boundaries (Jun 2009). If there was no point located in wire center boundary, fall back to NECA tariff 4 switch point. If there was no NECA point, an interior centroid was used.

Cable Greenfield Service Area

As noted earlier, the cable build used in BAM reflected those areas not currently serviced by cable. The development of a Greenfield cable network required a specific augmentation to the general wireline demand scenario.

In this case all demand in Census Blocks covered within Census Block Groups identified by Media Prints Cable Boundaries as Operating Internet was excluded.

This left only residential and business demand in currently unserved cable areas. New service areas were derived by dissolving unserved Block Group boundaries and placing a serving node at the interior centroid of the Block Group boundary. This process created an analog to a telecommunications wire center boundary and serving central office.

The new serving node proxied for as a fiber served network hub under the Greenfield Cable FTTP design. Each serving node was linked homed to the nearest head end point via middle mile logic. Headend location was derived as the centroid of a census place boundary sharing a common name with the Media Prints system information. If a common name link couldn't be made, the headend was the interior centroid of the Media Prints served community.

Cable System Information

- Media Prints, September 2009

Demand data

Demand Data - Customer Address and Services Table

As the 'goal' of BAM was to produce investment for all potential broadband customers, CostPro developed a broadband network serving all potential residential and business locations.

Residential demand was based upon Geolytics (2009) estimates of housing unit counts at a Census block level. Housing Unit demand points were placed randomly along the roads of each census block based upon the Geolytics estimates.

Business demand was based upon Georesults (July 2009) estimates of business counts at a Census block level. Business locations were placed randomly along the roads of each Census block based upon Georesults estimates.

Supporting Demographic Data

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

These data sources are described below:

- Roads
  - Source: US Census TIGER
  - Vintage: 2008
- Census Blocks
  - Source: US Census TIGER
  - Vintage: 2008
- Residential Demographics
  - Source: Geolytics Block Estimates 2009
- Business Demographics
  - Source: Business Counts by Census Block, Georesults
  - Vintage: 2008 (2ndQ)
- ZIP Centroids
  - Source: StopwatchMaps
  - Vintage: 2009

Key Engineering Inputs

To better model real world network deployments, the CostPro platform allows the user to enter a variety of adjustable inputs. These inputs affect not only the investment of the provisioned network, but also the manner in which the network is provisioned.

These inputs were based upon FCC direction and CostQuest's understanding of industry standard practices.

User Adjustable Investment Inputs--Samples rule inputs include the following:

♦ Maximum fiber and copper cable size	♦ Percentage of plant placement of aerial, buried and underground plant by density zone and plant location
♦ Minimum fiber and copper cable size	♦ Maximum copper distances for voice and data services
♦ Effective Fill/Utilization percent of equipment	♦ FTTx trigger points
♦ Average distance between manholes	♦ FTTx specific engineering
♦ Average distance between poles	♦ Service engineering
♦ Percentage of sharing of structure paths	♦ Etc.

Results

Model results are a set of files for each state that capture the feeder and distribution network topology.