BAM Attachment 6 – CostProWireless

CostProWireless®

Wireless Economic Model

Model Documentation

Underlying CostProWireless® Model:

Contents

Background

The purpose of this document is to further the understanding of users of the FCC Broadband Assessment Model (BAM) concerning the design logic and structure of the 4G wireless network architecture used as the basis for deriving the wireless cost to serve.

The primary purpose of the BAM is to support FCC policy consideration relevant to the development of the National Broadband Plan. To that effect, the 4G Wireless component of the BAM was designed to estimate the financial impact associated with providing wireless broadband to areas deemed unserved by adequate broadband speed and/or broadband capacity required to fulfill national purposes.

The underlying 4G wireless network architecture is created through CostProWireless® and its derived investment is determined within Investment Module of Broadband Assessment Model. The purpose of the Investment Module is to estimate incremental deployment investment (capex) required for delivery of broadband services to unserved areas. The modeled architecture employs a granular approach, the use of spatial analysis and a set of defined 'real world' engineering rules as the approach to modeling network design. The resulting bottom-up costing takes into account minimum transport routing, traffic demanded at or traversing a network node, sizing and sharing of network components resulting from all traffic, and capacity and component exhaustion. Output unit costs are developed using a classic capacity costing technique and include all necessary plant, structure and electronics to support the designed network.

Overview of Network Modeling

Current economic modeling across all plant categories is grounded in similar design principles applied by comparable network models which 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.

Introduction to CostPro®

CostPro® configures the telecommunication network for the BAM application. It produces the network topology including tower counts, RAN capacity configuration, backhaul type, distance of backhaul fiber, etc.. The cost of

the network is then developed within the BAM application. CostProWireless® is the application used for development of the 4G wireless network[1].

The economic network topology is based on results from the CostProWireless® 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 are its granular approach, its use of spatial analysis, and its reality-based engineering guidelines. Derivations of the CostPro® platform 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" the network required to reach them.

Through the use of SQL and Visual Basic code, databases, and a user- friendly interface, CostPro® determines the economic topology for wireless 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 tower and to provide a wide-range of wireless services to these customers. The model assumes the installation of forward looking, commercially available telecommunications technologies and uses generally accepted engineering practices and procedures.

Specific to the 4G Wireless network design, CostProWireless® was crafted to incorporate forward looking technology using well understood network architecture and methods of deployment. The design criteria was targeted to practical dimensioning of a deployable network and simplifying assumptions that underpin the logic, purpose, and the computational strategy have been employed.

The 4G wireless network design is intended to produce an efficient network infrastructure in unserved areas assumed to be deployable within 24 months and maintainable for a period of no less than five years to consistently deliver designated user realized broadband performance.

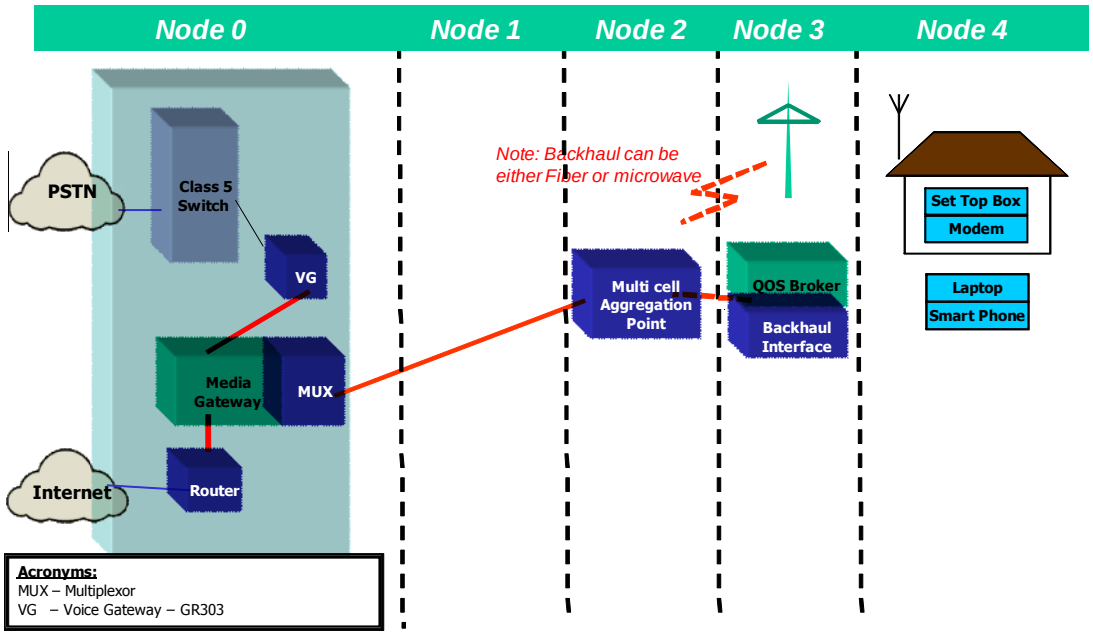
The 4G wireless network must be cost effective, efficient, and designed to achieve the desired standard of speed and reliability. The design was assumed to leverage existing and accessible infrastructure components when known (a 'brownfield' augmentation approach). If no such infrastructure was available, the design defaulted to create a 'greenfield' network. Accomplishing this includes the consideration of issues such as population density within the market area; available infrastructure within in unserved area and in adjacent areas, the size of firm to be providing broadband services, as well as assumptions about the use of existing broadband capable network elements (e.g., an existing fiber node as a point to aggregate the transport of newly deployed services to a network core).

[1] Corresponding documentation provides similar information relative to the development of wireline loop economic design.

4G Network Architecture

The 4G network architecture for the FCC BAM is designed to produce outcomes for broadband coverage and the related financial expectations (i.e., revenue, capex, opex and economic contribution margin) for contemporary wireless deployments to fill broadband gaps in unserved areas.

The following diagram reflects the fundamental technology architecture for modeling 4G wireless within the BAM. Node identifiers (e.g., Node 0 thru Node 4) 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 the BAM. The "nodes" are significant in that they represent the way in which costs are assigned / aggregated to enable neutral comparisons across technologies.



CostProWireless® Process

Locating 4G Users

The BAM is designed to provide broadband information at a Census Block level. Census Blocks are the primary unit of data collection and presentation thereby allowing for granular analysis of relevant information (e.g., infrastructure, demographic, and economic) that can then be rolled up into larger geo-political areas as desired. The 4G Wireless model produces the cost to provide broadband service at the Census Block level.

Within the CostProWireless® processing, population and, therefore, potential 4G wireless broadband customer data (e.g. population, number of households, housing units, business locations, and anchor institutions) are developed at the Census Block level. However, the available national data does not exist to precisely pinpoint the location of both business and residential populations and must be estimated using a combination of secondary data sources.

Road networks are to be used as the basis to allocate population among census blocks so as to determine demand and the related costs to serve that demand. This approach best reflects where people live and how networks are built.

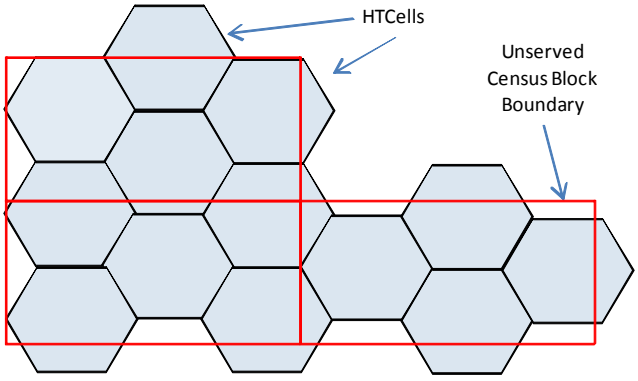
4G user customer adoption rates (or take rates) are developed in the BAM (see Attachment 9 – Gompertz Penetration Rate) and applied to the distributed population within a census block and used to determine demand levels to be satisfied with the 4G network design.

Coverage Approach

The methodology for creating coverage in the 4G wireless architecture for BAM is intended to produce a reasonable dimensioning of base station requirements for early stage planning. Spectrum frequency, channel bandwidth, and actual performance characteristics of yet to be deployed 4G technology is not fixed in the model but are, instead, user input parameters. The methodology used to assign coverage to unserved areas is complicated by the array of existing 3G wireless coverage data juxtaposed to the census block boundary data required for the FCC BAM. Further, because of the geographical scale of the BAM, specific topology data typical for high accuracy radio propagation study and site search ring identification was not available. Instead, CostProWireless® employs method using hexagonal tessellation cell (HTCell) application was selected to approximate site coverage in unserved areas.

HT Cell

The use of HTCell is symbolic of a three sector cell site and the hexagonal shape provides a method to simulate 100% coverage. The following diagram depicts a hypothetical overlay of HTCells in three census blocks deemed to be unserved by broadband. In this example, the unserved census blocks could be covered by thirteen HTCells.



While it is the case that antenna sites would typically lie at the edge of HTCells, for purposes of this model each HTCell would house at least one antenna site. In the case where an existing site structure (e.g., a leasable tower[2]) is used to place a 4G antenna, the actual location of that tower within the HTCell is used in the model. In the case of a 'greenfield' build, the site is assumed to be at the center point of the HTCell.

To prepare the model, a national overlay of HTCells of predetermined radii was created. The range of selectable HT Cell radii[3] provide the model user a basis for adjusting attenuation performance based on demand, density,

[2] Tower locations were extracted from Towermaps database(September 2009)
[3] The hexagon was fully inscribed within the selected radius.

topology, and speed characteristics. The HTCell radii incorporated into the model are 2, 3, 5, 8, 10, 15, and 20 mile.

To deal with HTCells where demand exceeds the capacity of a single site, a simple cell splitting methodology captured in the CAPEX inputs for BAM is used that results in the addition of one or more sites to meet the overall capacity demanded within the HTCell.

In areas, where the HTCell straddles coverage with served and unserved areas, no adjustment was made to adjust the HTCell counts and tower requirements. As such, the count of HTCells is a conservative value.

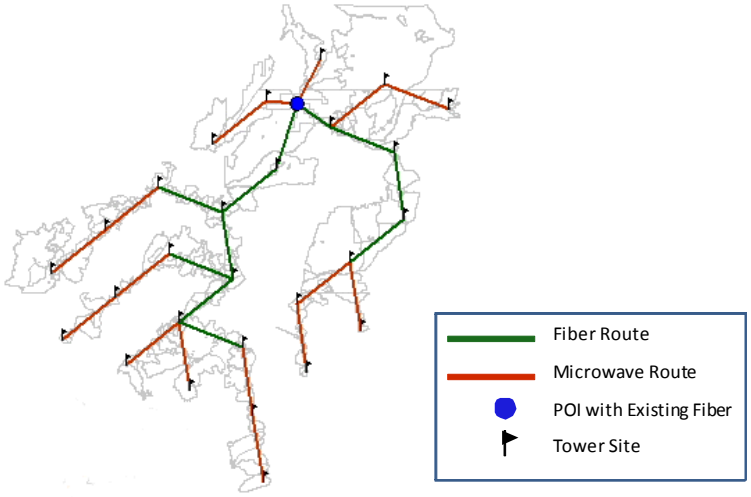
It is important to note that variances in accuracy that occur at the HTCell or Census Block level will tend to be mitigated as the model is applied to larger aggregations of unserved area Census Blocks (e.g., in to market areas).

Backhaul Design and Investment

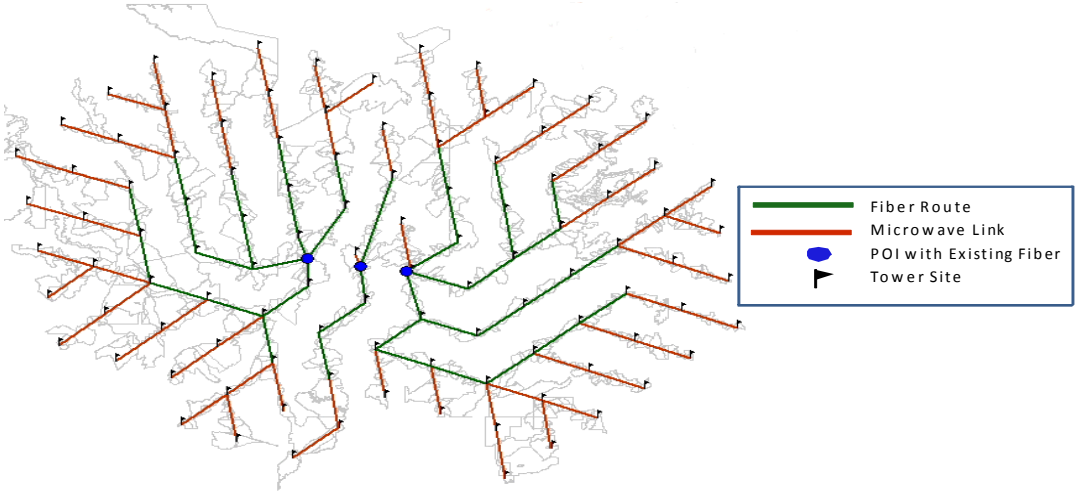
The design for backhaul (also called second mile) of the 4G wireless network involves the transport of broadband traffic between an existing fiber point of interconnection (POI) and 4G deployed sites (Node 3 sites) in an unserved area. The backhaul design incorporates both fiber and microwave in an efficient manner. The model relies on a series of steps for the development of backhaul routes:

- Identification of existing fiber points of interconnection (POIs). This is accomplished using publicly available data that identifies whether a LEC end office provides fiber based services. These POIs are designated as the interface between backhaul (second mile) and middle mile transport (see Attachment 6 of the Broadband Assessment Model (BAM) Model Documentation).
- Association of 4G cell sites to the nearest existing fiber point of interconnection (POI). The 4G Node 3 sites are assigned to the nearest POI to create the initial spatial relationship ('parentage') that is most likely to provide least cost backhaul routing.
- For Node 3 sites subtending the same POI, the establishment of backhaul routes uses a spanning tree approach based on shortest distance routing to the POI. Beginning with the most distant Node 3 site, each site is routed to next closest cell site using the lowest cost transport medium (subject to performance parameters of that medium). In most instances, microwave was the lowest cost transport when user established threshold constraints were not met (see below for more detail on microwave constraints).

An example of the implementation of the CostProWireless model logic for backhaul is shown below. The typical result is a site backhaul configuration that uses microwave beginning at the 'edge' of the unserved area and converting to fiber when microwave threshold constraints are reached.



Here is an example of backhaul in a multi-POI unserved area



The use of microwave backhaul is subject to a link distance threshold. For this model, the maximum microwave link distance was set at 20 miles. If maximum link distance is exceeded the model assumes the site needs to be served by fiber.

The 4G backhaul design is sensitive to the aggregate demand associate with sites in an unserved area. The methodology used is based on threshold capacity of microwave links over differing distances. The use of microwave backhaul is also subject to a threshold for parameter for the number of microwave links that can be supported at a single tower. This is a user selectable parameter. If the parameter is exceeded at a site, the model assumes the site needs to be served by fiber.

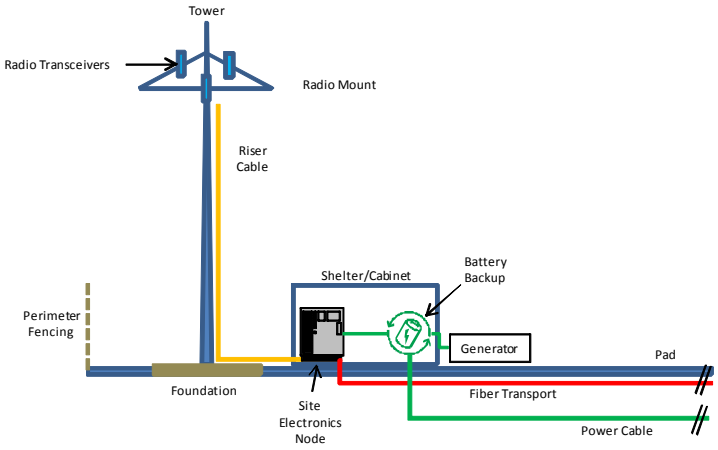
Output to BAM

Once the CostProWireless® processing is complete, two files per state are stored in the BAM databases. The DIST file contains information about the census blocks, including the HTCell ID. The FDR file contains information about the HTCell and the backhaul components.

BAM Processing

Site Design and Investment

With the CostProWireless® topology/design complete, BAM uses a uniform design set of equipment and investment components for developing costs associated with the deployment of 4G wireless coverage at each site. Since the model incorporates the use of some existing infrastructure (e.g., existing tower locations assumed to be available for commercial lease) certain equipment or investment may not be necessary at a 'brownfield' site. Certain investment may also be different at a 'brownfield' and a 'greenfield' site (e.g., zoning, site improvements, utility access, etc.). Following is a summary of the key components used in 4G wireless site design. This diagram is a depiction of standard 'greenfield' site equipment and structure components.



Radio Access Network (RAN)

This category incorporates site costs specific to the radio access function. Equipment in this category includes site based radio control, antenna costs, antenna cabling, radio frequency (RF) engineering and optimization.

Depending on the demand density associated with a given site, the antenna array may be different and antenna costs are adjusted accordingly. The determination of the antenna array is typically defined as follows (can be adjusted in the CAPEX User Input workbook):

C = Capacity of single sector 10 Mhz network
S = Total spectrum available
Npop = Total population covered by site
Ncells = Number of cells required to cover area

$$\text{If } \overbrace{\frac{\text{Npop} * \text{Take Rate} * \text{Busy Hour Load}}{80\% * C}}^{A} <= (S/10), \text{ Then deploy A} * \text{10Mhz Single-sector site}$$

$$\text{Else If } \overbrace{\frac{\text{Npop} * \text{Take Rate} * \text{Busy Hour Load}}{80\% * 3C}}^{B} <= (S/10), \text{ Then deploy B} * \text{10Mhz 3-sector site}$$

$$\text{Else deploy Ncells} = \frac{\text{Npop} * \text{Take Rate} * \text{Busy Hour Load}}{(S/10) * 80\% * 3C}$$

Channel spectrum size is user controllable and will also impact the level of RAN investment that is applied in the model.

Towers

This category incorporates site costs specific to site preparation, tower structure, construction, and power necessary to support the radio access network. Equipment and investment in this category include site acquisition, zoning, fees permits, design and civil engineering, site preparation, tower, tower installation, utility connections, and on-site power supplies. Land is assumed to be leased.

For 'brownfield' sites where an existing tower is leased, costs associated with tower structure and erection are excluded. Certain other costs associated with leasehold improvements, permits, and project management are included but are less than what is incurred at a 'greenfield' site.

Huts:

This category incorporates site costs specific to the shelter or 'hut' that is associated with most sites to house certain electronic equipment, power control, and battery power supplies. Most of these 'huts' are prefabricated and subject to minor modifications to support site specific needs. Equipment and investment in this category include the hut, any modifications or retrofits to the hut, the foundation the hut is placed on, and the cost of placing the hut.

Backhaul:

Based on the aforementioned parameters utilized in CostProWireless®, the model develops backhaul investment based on the medium (fiber or microwave) used for transport:

Investment in second mile fiber backhaul is based on Ethernet over a passive optical network (Ethernet PON). Fibered Node 3 sites have PON equipment that is connected via fiber to an Ethernet edge router assumed to be collocated with the POI. For the fiber links the model computes a cost for fiber material and placement. Investment is developed and allocated thru the following steps:

- The distance of the fiber route is attributed to each tower based on the cumulative potential customers than can use the route.
- For fiber electronics, the model places an Ethernet edge router at each fibered tower location.
- For the fiber placement, the model assumes conduit and poles already exist and does not assign additional costs for conduit and pole attachments. However, the model does compute a cost for fiber and related trenching for the portion that is assumed buried.
- Finally, the model allocates the fiber backhaul cost to each census block based on the proportion of potential customers in the census block (as compared to the total potential customers in the POI serving area).

Investment in microwave is done on a per link basis (i.e., antennas and equipment at both ends of a microwave span are combined to form a link cost). Each link cost is attributed to the location of the tower site requiring microwave. The model then allocates the microwave cost to each census block based on the proportion of potential customers in the census block (as compared to the total potential customers in the Node 3 serving area).

Network Core Design and Investment

For the purpose of this model, the core network functionality is based on user input. Currently, the value is based on a percentage of total RAN investment. As such, the development of costs at a CB level follows how the RAN investment is attributed.

Glossary

Term/Phrase	Definition and Issues Relevant to FCC BAM
Broadband	Generally used to refer to a high data rate internet access capability typically contrasted with dial-up access using a 56k modem. The general term of broadband includes a variety of speed tiers ranging from 768kbps and greater (768kbps, 1.5mbps, 3.0mbps, 6.0mbps etc.) BAM is designed to model revenue and costs in a discrete range of broadband speed tiers.
CostPro® and CostProWireless®	Network infrastructure modeling applications developed by CostQuest Associates, Inc.
Middle Mile	High capacity transport connections between a service provider's network core and its second and last mile network. In the BAM the Middle Mile reaches the point of interconnection (which is a designated existing fiber location) with second and last mile network built for unserved areas.
Second Mile	Transport connections between the Middle Mile and Last Mile. In the BAM the Second Mile is the transport between Middle Mile connection and network nodes (e.g., 4G base station sites) providing Last Mile customer connections.
Last Mile	This is the link between the customer (end user) and the service provider's network node. Also referred to as a local loop, in a 4G network this connection is achieved by radio interface.
Augmentation	Refers to an area for which broadband must be installed or increased to accommodate the defined broadband need. Also refers to the required incremental network modeled to provide service and the related capex and opex costs and revenues.
Greenfield	A term used to describe the situation where service is provided to an area where, to this point, there has been no such service.
Brownfield	A term used to describe the situation where service is provided to an area where related services exist but not in a sufficient capacity or feature set.
Census Block	The smallest geographic unit used by the United States Census Bureau for tabulation of 100-percent data (i.e., data collected from all houses, rather than a sample of houses). Within the BAM the census block is the most granular geography for which service availability is assessed.
Market Area	A collection of census blocks that represent a larger relevant collection of households / subscribers and potential business customers. Market areas can be census block groups or census block tracts, are often defined by geo-

	political boundaries (e.g., counties, states, trading areas), and can also be defined by carrier service areas (e.g., franchise areas, license areas, wire centers, study areas).
Opex	Operating expenses generally experienced by broadband providers including network related operating costs, sales and marketing costs and a wide range of administrative costs (including bad debt).
Capex	Capital expenditures representing the investments required to design and install communications facilities – including the related cost of money associated with capital investments.
3G	Third generation wireless technology – digital broadband technology still being introduced in parts of the country providing bandwidth in a range of… allows the simultaneous use of voice, data, and video on a wireless network and includes technology standards such as GSM EDGE, UMTS, CDMA2000 and WiMAX.
4G	Fourth generation wireless technology based on Long Term Evolution (LTE) and WIMAX standards –is advanced digital broadband just emerging in domestic markets
GIS	Geographic Information System – computer applications involving the storage and manipulation of maps and related data in electronic format
POI	Point of Interconnection – in this document, a physical location that allows an 4G service provider to access the fiber network of another carrier (typically a local exchange carrier) in order to lease fiber transport capacity.
QoS	Quality of Service – a measure of the quality of telephone service provided to a subscriber which embraces a wide range of specific definitions depending on the type of service provided
IP	Internet Protocol – a protocol describing software used on the internet that routes outgoing messages, recognizes incoming messages and keeps track of address for different nodes
VoIP	Voice Over Internet Protocol – a process of sending voice telephone signals over the internet which involves converting signals to digital format and the development of information packets when the initiating signal is analog
Capacity Threshold	A threshold demand level based on total demand at an existing fiber fed POI