BIOGRAPHICAL INFORMATION

Jeffrey C. Eichler
Director – Communication Products
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Specific Responsibilities

Joined Bentley April 2004 when Communications Information Software (d/b/a/ C.I.S.) was acquired. Responsible for all aspects of software development for Bentley Systems products to the communications industry. Currently these products consist of Bentley Fiber, Bentley Coax and Bentley Inside Plant.

Past Experience

President, CEO and founder - C.I.S, Suwanee, GA. 23 years experience in the communications industry developing GIS applications. Primary product line consisted of FOCUSOne suite of engineering and design tools. Used by CATV, Telephone, Utility companies and Municipalities for planning HFC, FTTC and FTTH networks around the world. Also used for designing any type of fiber telecommunication network.

Education Information

BA – Business Administration – Moravian College, Bethlehem, PA
MBA – Marketing/Finance – Lehigh University, Bethlehem, PA

Professional Memberships

GITA
Society of Cable Telecommunication Engineers (SCTE)
Broadband GIS Leadership Forum (BGIS)

Broadband Engineering and Geospatial Technology

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ABSTRACT

As consumer demand for services such as high-speed internet access, multiple voice lines, and video on demand continues to grow, broadband networks are increasingly being recognized worldwide as the only single, proven, residential access network that can deliver the enormous bandwidth necessary to supply these services. Any network built today must be "future-proof," capable of scaling to whatever amount of bandwidth necessary to support any future services and applications that may appear in the next several years. Even in existing telecom networks with extensive legacy equipment, it is possible to apply solutions developed for new builds when planning system upgrades.

In this paper, optimal broadband designs for such "green field" builds are reviewed. The expected growth in bandwidth demand from consumers and businesses over the next several years is first discussed. The three competing broadband architectures (Hybrid Fiber Coax – HFC, Fiber to the Curb – FTTC and Fiber to the Home – FTTH) are then presented. The differences in these architectures and the impacts geospatial technology has on each of the architectures are discussed. Particular emphasis will be placed as to how geospatial tools are used to engineer these architectures. Finally, the role geospatial technology plays with Operational Support Systems is presented.

BANDWIDTH DEMAND

Over the past few years, the exploding popularity of the internet has revealed a bottleneck in the local access network. Uptake of internet services has been delayed by the frustratingly slow speed of 14 kbps dial-up modems. Recently, new technologies such as cable modems and xDSL have improved peak available downstream residential bandwidth to a bearable 500 kbps. Although the associated customer premises equipment (CPE) is capable of much higher bandwidths, the shared access networks themselves typically do not yet support them. Network operators in the process of deploying new systems do not want to face any such service bandwidth limitations, and so are typically choosing deep fiber architectures, due to their unparalleled bandwidth delivering capabilities – 800 MHz or 5 Gbps per laser transmitter. The key to making this enormous bandwidth available to subscribers is dedicating narrowcasting services to transmitters and optical nodes serving small service areas in a scalable fashion. Before detailing of this process, it is first reasonable to characterize the services whose demand is giving incentive to broadband providers to build new networks or upgrade their existing ones.

Peak data rates for current typical internet usage is more than sufficient at 1 Mbps. The increasing popularity of applications like streaming video probably adds another 1 Mbps to the potential bandwidth demand. The expanding prevalence of digital cameras, both for still pictures and video will increase both up- and downstream bandwidth demand, as individuals exchange such material over the internet. This bandwidth forecast is probably conservative, since internet backbone traffic is forecasted to increase by 10x per year, and this increase must also then be reflected in the access network. In addition, the improving economics of video-on-demand (VOD) delivery systems will likely soon result in one or two movies per household at 4 Mbps per movie commonly being purchased. Based on this analysis, the peak rate to a single subscriber could be as much as 10 Mbps in the next one to two years. The services mentioned above are particularly downstream intensive, so a traffic asymmetry of 10:1 downstream to upstream is assumed. Peak upstream bandwidth might be on the order of 1 Mbps in this case. New services such as video conferencing, interactive gaming, and future services that have yet to be conceived must also be taken into account. Consumers will likely use as much bandwidth as is made available to them. Therefore, network operators must choose architectures that will scale to support this almost unlimited bandwidth demand.

Key to the decision of what type of network to deploy is ascertaining the growth rate of residential bandwidth demand. Along with today's common services such as telephony, video and low- to moderate-speed data, a wide variety of future applications should increase consumer bandwidth enormously. Broadcast services such as analog and digital video will be supplemented by HDTV, which is a tremendous bandwidth burden. Many other services will be delivered via Internet Protocol (IP), as applications such as IP telephony and streaming video are perfected.

Because of the inherent uncertainty associated with how fast the demand for bandwidth will grow, service operators are understandably concerned that the networks they deploy will cost-effectively support the bandwidth requirements of today, while simultaneously being scalable to support future bandwidth needs, whatever those may be. If, at any point in time, an operator cannot provide the necessary bandwidth demanded by its customers, it is likely a competitor will appear who will.

Hybrid Fiber Coax - HFC

Although it has only been recently that HFC networks were transformed to provide interactive services such as high-speed data and cable telephony, HFC is a proven architecture with a working business model. When transmission equipment, fiber and coax cable, construction, and customer premises equipment (CPE) are all taken into account, a green field HFC network can be deployed for less than $1000 per home passed. This assumes that most of the fiber and coax is pulled through existing ducts or lashed on telephone poles; significant amounts of trenching can dramatically increase the cost. The greatest strength of an HFC network is its ability to deliver vast numbers of broadcast video channels, whether in analog, digital or HDTV format. In fact, most FTTC and FTTH solutions include a parallel HFC-like network simply for broadcast video, which provides the additional advantage of not requiring a set top box. HFC also can provide video on demand (VOD) services, telephony (either switched circuit or IP) and peak data rates of up to 10 Mbps. A cable modem is theoretically capable of carrying 36 Mbps, but most operators limit subscribers to a maximum of 1.5 Mbps. Providing higher bandwidths when 30% customer penetration is achieved would require an unmanageable number of CMTS (cable modem termination systems) in the head end or hub site. So while the Data-Over-Cable-Services-Interface-Specification (DOCSIS) does provide HFC system operators with a standard to provide high-speed data services, the maximum speeds are somewhat limited and probably are not future-proof.

Fiber to the Curb - FTTC

FTTC architectures have an advantage over HFC networks in that they typically provide 10/100BaseT connectivity, and they eliminate the need for cable modems or DOCSIS. The 100 Mbps of interactive bandwidth, however, comes at a price. Due to the 100-meter distance limitation for 100BaseT, fiber nodes must be pushed very close to the home. Some FTTC solutions employ nodes serving as few as 12 homes. This can increase the cost of an FTTC network by more than 50% over an HFC network. In order to transmit Ethernet over CAT5 beyond 100 meters, repeaters are necessary, which also adds to the cost of the system. An additional concern with FTTC is the inherent bandwidth limitations of CAT5 cable relative to fiber or coax. CAT5 probably cannot be considered future proof, even though transmission speeds of 1 Gbps are possible over short distances.

One situation in which FTTC networks are extremely cost-effective is when high-density subscribers are involved, such as for multi-dwelling units (MDU's). In such cases, a single optical node can serve 100-200 subscribers, although the bandwidth is shared over more customers, so the average dedicated speed is lowered.

Fiber to the Home - FTTH

The one type of network that can be considered to be completely future-proof is FTTH. It can support peak speeds of up to 1 Gbps, and can be upgraded to higher bandwidths by replacing the electronics on either end of the system. An additional advantage is that the same basic network can be used to serve business customers and residential subscribers. The drawback of deploying an FTTH network is the high cost, which is on the order of $1500 per home passed. The expense results mainly from fiber, construction and splicing, as well as the NIU (Network Interface Unit) that is necessary to make the optical to electrical conversion at each home.

The question that needs to be asked when considering deploying FTTH or even FTTC is: Can an operator charge consumers more for 1 Gbps than for 10 Mbps? Today, the answer is no; no killer application for residential services yet exists that requires more than a few Mbps of bandwidth. It is unclear at what point in the future tens of Mbps or Gbps data rates will be required. However, an argument in favor of FTTH is that there will likely only be one fiber installed to any particular dwelling unit. If you do not own it, then you are out of the game. So although FTTH may be a little more expensive, it is very important not to let a different operator beat you to the home with fiber.

So what architectural choice should an operator deploying a green field network or upgrading an existing system make today? Of course, it's desirable to have a future-proof network, but investors also demand that the system be profitable in the short term.

HFC has been the technology of choice for traditional cable television (CATV) companies. Since 1995, CATV companies have spent $60 billion upgrading their all-coax networks to HFC. In addition to reasons stated above, certainly a major factor as to why CATV companies have chosen HFC architecture is to leverage the investment they already have in their coaxial networks.

It has been estimated that building the "last mile" will require upwards of 75% of the total cost of supplying broadband access to residents and businesses, and anything a provider can do to lower that cost will be very attractive.

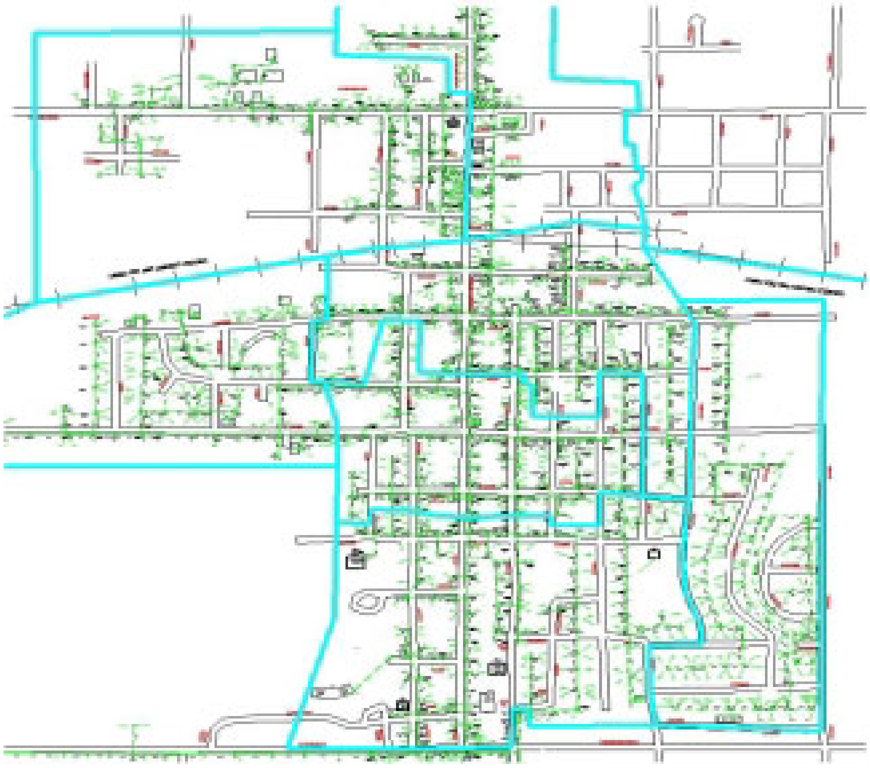
Accordingly, the traditional telephone companies are trying to leverage their investments in their copper infrastructure. SBC has announced they will be spending $4 - $6 billion over the next five years building FTTC and while not announcing specific numbers, BellSouth has indicated that they are going to provide broadband access with FTTC.

While many other smaller providers and municipalities have announced or are building FTTH networks, only Verizon is doing so on a grand scale, and grand it is, passing one million homes in 2004 and 2-3 million homes in 2005.

ROLE OF GEOSPATIAL TECHNOLOGY

Whether building HFC or FTTC, the architecture is very similar. In both cases, fiber is used as the primary transport mechanism. These deep fiber architectures take fiber down to "pockets" of customers from anywhere to 500 homes (in the case of HFC) to 50-100 homes (in the case of FTTC). In both cases, fiber is run from a central location (head end in the case of CATV and wire center in the case of FTTC) to a device called a node. At the node, optical signal is converted to electrical impulses for transmission the rest of the way to residences and businesses. In the case of HFC, coax cable is used as the transmission medium while copper cable is used for FTTC networks.

One of the roles geospatial technology plays in planning these networks begins with the laying out of the node service areas. Homes passed information is gathered and drawn on maps along with existing infrastructure data as well as geographical features. As seen below, geospatial tools can analyze the data and provide the engineer/designer with suggested node service boundary areas taking into account population density, construction rules and other factors.



500 home Node Service Areas shown in light blue

Geospatial tools are very important in designing these architectures because they ensure the optimum number of homes is serviced in each area. In addition, the tools ensure that the distance from the node to the edge of a boundary does not exceed engineering limitations. This "rule validation" plays a critical role in engineering these networks. Indeed when xDSL service was first introduced, many providers did not use these tools. Consequently, a great deal of unnecessary expense and marketing blunders were made by these companies because service was sold to customers and only after the order was taken and the installer was on-site at the customer location was it discovered that service could not be provided.

While FTTH is not concerned with node service areas, certainly FTTH boundary areas are established which follow existing wire center boundaries. Indeed wire center boundary areas containing 2000-3000 customers are subdivided into 500 home pockets which represent FTTH cabinet serving areas. As is true with HFC and FTTC builds, distance measuring tools ensure engineering design parameters are met.

Another example of Geospatial Technology and its use in Broadband engineering deals with the connectivity made between the engineering equipment (cable, nodes, amplifiers, taps, splitters, cabinets) and the infrastructure where the equipment is placed (poles, pedestals, duct, manholes, etc). In addition, knowing which customers are being fed from which piece of equipment has profound impacts on Network Management and Operation Support Systems.

FTTH cabinet serving area showing the node, splices, pedestals and fiber cable

GEOSPATIAL TECHNOLOGY AND NETWORK MANAGEMENT APPLICATIONS

Operational Support Systems (OSS) are applications that manage inside plant business processes such as inventory, provisioning, order entry, service design, etc., and have been helping service providers manage their businesses for some time now. An OSS solution that integrates both outside plant (OSP) functionality and OSS can make service providers even more efficient by enabling all operations teams (OSP, OSS, etc.) to make more informed decisions – no longer in a vacuum, but based on current sales, service, and inventory information. Making decisions with valid data to rapidly deploy services and to maximize network capacity and performance increases profitability and success.

OSS solutions take the guesswork out of provisioning services and maintaining a service provider's infrastructure by allowing for a flow of information from module to module and the automation of routine tasks. For example, when a new sales order is received by customer service, the OSS forwards the information to the network inventory system to validate service availability and delivery date. Once availability and delivery date are established, the information could be forwarded to the provisioning application to activate the service. Meanwhile, network management systems monitor the network to ensure that existing service is not interrupted as new equipment is added.

At each stage, each module uses the relevant information gathered from other OSS modules to generate the network/circuit design, produce work orders, and determine billing information. An integrated OSS incorporates data from across multiple business functions, producing an effective way to manage service operations. This reduces network and service problems, eliminates paperwork, simplifies interaction between departments, and ensures that deployment is handled correctly, efficiently, and profitably. It's good for business.

Service providers are constantly striving to better utilize and integrate their OSS applications in order to:

- Eliminate task redundancy
- Achieve a faster time to market for new services and customers
- Lower overhead costs
- Streamline business processes such as service provisioning and network audits
- Equip departments with hard data to develop future plans
- Provide the vehicle to offer a solid customer experience, reducing churn

Integrated Operational Support Systems bring together service providers' network resource management and service fulfillment functions. They empower departments with real time information for maximum productivity to serve their customers with the utmost of speed and precision.

WHAT'S MISSING FROM THE EQUATION?

Historically, OSP operations and the data contained in GIS systems have been left out, even though they help to ensure that the right equipment is installed and operational. OSP systems provide critical input to the network inventory system and circuit design and assignment process. It makes sense, therefore, to be able to administer the whole deployment: sales order, service validation (including the last mile), service availability, activation, and network management as part of a single business process. Why stop with an incomplete view of the network when it is possible to bring it right out to the field? Information gathered from OSS is an integral part of OSP operations, and the inclusion of OSP information in the OSS better positions the service provider to deliver services efficiently, providing a better customer experience and increasing profitability.

A comprehensive solution that tightly integrates the OSS with GIS expands visibility across all levels of the organization. Let's first take a look at how it affects the Order Management Module. Because the application gives OSP field personnel access to the entire business, they have access to new customer sales information from the sales order itself. The sales order tells OSP teams what new services are to be added and what equipment is needed. It can even provide a topology roadmap for any installation issues that may need to be resolved prior to installation. With everyone working from the same virtual page, the OSP is armed with all of the customer data necessary to complete their fieldwork on time, and with increased accuracy.

The merging of OSS and GIS makes a difference in attracting and retaining customers by making companies better able to give those customers what they need because OSP operations can now see all customer requirements and track status activity from end-to-end. Using the Network Inventory Management Module, which houses information about facilities, circuits, network design, equipment, and customer settings data, OSP staff has the information needed to track all network and customer equipment information. OSP personnel can quickly see what circuits have been assigned, what equipment is earmarked for a customer, and even customer network properties such as IP addresses. This information functions as a verification tool for the OSP so that the installation process will be handled appropriately and all of the network design parameters are met. Network Inventory data also ensures that the network is not developed in a haphazard fashion, which helps to create a standard for future build outs.

Access to network inventory data also enables OSP field operations teams to identify and locate service problems quickly and efficiently. Because vital data is available in real time, an integrated GIS/OSS improves troubleshooting and reduces downtime (Pinpointing a break in fiber or where a manhole cover has impacted lines is far easier when the information is at the technician's fingertips). Whatever problem arises, it is more efficient to see your topology graphically, right down to the fiber bundle, in order to identify the location of the problem.

When OSP field operations look to provision new customers without an integrated GIS/OSS, the process requires numerous phone calls to gather all of the necessary information: services, equipment, promised installation dates, and more. Precious time is wasted waiting for callbacks, faxes, or emails. Network Inventory provides the real time link between order management and service provisioning. And the OSS information can be accessed via a Web-based environment, making it extremely simple to access from any location, even at a customer site.

ASSET MANAGEMENT – IN REAL TIME

Asset Management also is a key area with which OSP executives wrestle. With the mundane task of tracking each and every piece of equipment already in place within the Asset Management Module, half of the battle is already won. This logical storage repository for all network equipment can save hours of OSP field personnel time researching who has an old switch that is becoming obsolete and should be replaced; what revision of software needs to be updated; or which circuits or hardware require upgrades. Asset management can even track equipment that is moved from one location to another and then automatically modify inventory numbers accordingly so that provisioning services to customers is not negatively impacted.

While not traditionally considered part of the OSS or the OSP, asset management is increasingly being included in system evaluation and functional requirements as service providers look to better manage their businesses. An asset management database sets the stage for developing a product life-cycle plan, maintaining equipment repair histories, storing accurate software licensing information and keeping product service contract information readily available – all areas that can make OSP operations run more smoothly.

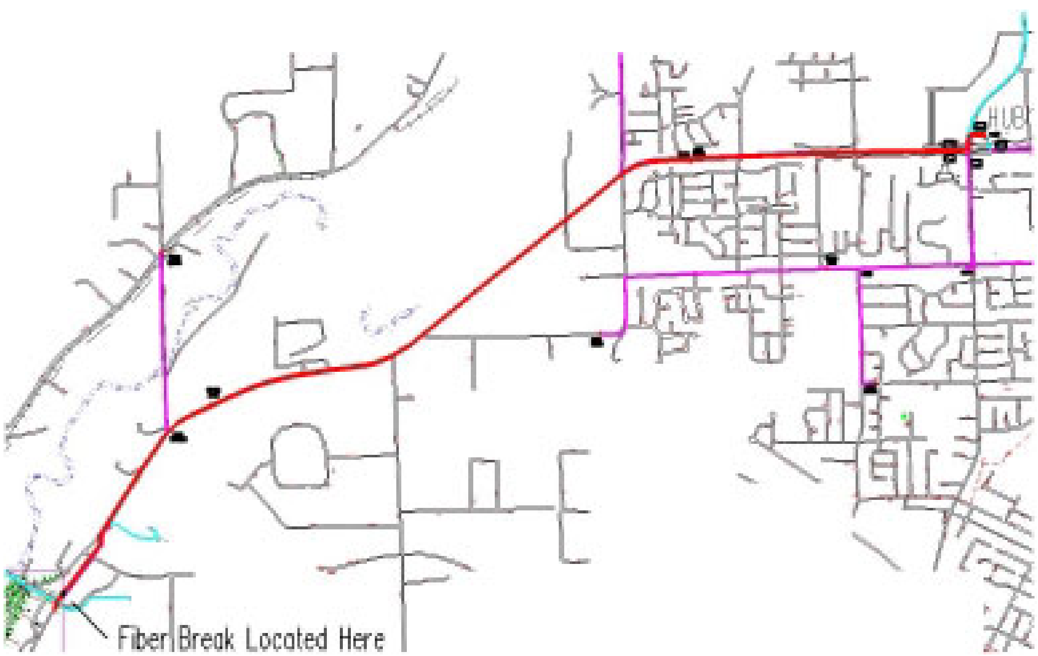
Integrating the GIS and OSS functions creates a central knowledge repository that supports a logical, integrated information flow. It establishes an environment through which all resources can be monitored for maximum performance, future build out needs, and the addition of new services. The integration of OSS and OSP easily supports the business processes that have been put in place so that all services are uniformly defined and pre-set network design parameters are met. With an integrated network view, a service provider has the ability to build out new services quickly and within specified guidelines.

This natural extension of OSP functions merging into OSS procedures, operations, and data provides a way to simplify the management of a service provider's business. OSP managers not only can track the minute details of circuits and cables, but also have the power to use OSS information to gain a logical association of information about facilities and customers. The OSS gives OSP operations total visibility into all of the information necessary to maintain quality network operations – right down to what equipment is in what rack. And, all OSP data is available to other departments for a complete, multi-faceted, streamlined operation.

INTEGRATION IN ACTION

All types of service providers are beginning to see the benefits of an integrated OSS-GIS application, and are starting to put the organizational structure and software in place to realize these benefits.

One of the first areas for this integration deals with the locating and trouble-shooting of network outages caused by fiber breaks. Network management tools have existed for some time that will indicate to a trained operator that a fiber break has occurred some distance from a given point. The problem, however, is locating exactly where that distance is so proper repair crews can be dispatched. In other words, knowing a break has occurred on a specific fiber 50,000 ft from a wire center or hub site does not help a dispatcher determine where to roll a truck. It is only after integrating this OTDR reading with the geospatial database can the exact location of the break be determined.



With the amount of information and data (and value of this data) transported on today's networks, outages can be extremely costly not only to the customer but also to the service provider. Because of this, customers are demanding Service Level Agreements (SLAs) that include stiff penalties if outages are not located and repaired promptly. Indeed examples exist where service providers have justified the entire cost of their GIS system based solely on locating just the first few fiber outages.

Another example of this integration occurs when data is shared between the GIS system and the OSS. Keeping redundant data in the GIS and OSS is not only inefficient but leads to many wasted man hours attempting to maintain these two systems. As data is changed in the GIS, the information should automatically be made available to the OSS. True integration occurs when new nodes are activated in the GIS, OSS modules such as provisioning, order entry and inventory are made aware of this activation so marketing and sales efforts can begin immediately.

Operations support systems need OSP information to take full advantage of their network's capacity potential, support rapid delivery of services, and maintain network performance. Only through effective use that this interactive data repository can help service providers get the most out of their network and its associated capital investments. OSS and GIS together represent a means to gain market advantage, remain profitable, and expand their existing customer base.