# SCTE Cable-Tec Expo 2007 Case Study
# Delivering reliable business services and TDM (T1) services over HFC

***Enabling reliable performance-sensitive, high capacity business services: cellular backhaul, T1, digital voice and Carrier Ethernet over HFC***

This joint case study, presented by PhyFlex Networks and Hargray Communications, will outline the approach and steps taken across Hargray systems in South Carolina and Georgia to deploy mobile backhaul and business services using existing HFC and meeting ROI requirements.

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## COMMERCIAL SERVICES – AN OVERVIEW

### Cell Tower Backhaul

The cellular backhaul market in the US is a $2.4 Billion[1] business with almost 180,000[2] cell sites. By 2010, the number of towers is forecasted to increase to 250,000, and backhaul capacity will quadruple. New multimedia applications enabled by 3G/3G+ technologies such as CDMA 1X EV-DO & HSDPA are driving bandwidth expansion.

Cable operators are well positioned to capture considerable market share. MSOs have a cost advantage because of proximity of the HFC plant to cell towers. Moreover, they have the network infrastructure to offer a cost-effective, flexible and scaleable Carrier Ethernet solution.

### Business Voice and Data for Small and Medium Businesses (SMB)

The data and voice telecommunication market for small (with 10-99 employees) and mid-sized (with 100-500 employees) businesses (SMB) represents a tremendous economic opportunity. These businesses spend more than $31B[3] annually on voice and data services. Furthermore, these SMBs are traditionally under-served by incumbent local exchange carriers (ILECs). In addition, SMBs generate much higher ARPU than residential and very small businesses (less than nine employees), typically $1,000 to over $3,000. SMBs also drive much larger profit margins, which are generally greater than 70%.

Cable operators can considerably expand their SMB market share by offering flexible, high-capacity services at much lower price points and a faster time to market than incumbents. MSOs can also further expand market share by tailoring solutions for specific vertical markets such as Healthcare, Financial, Government and Education.

The following joint case study outlines how an advanced and pioneering communications services provider, Hargray Communications, approached these opportunities and deployed mobile backhaul and business services using existing HFC to meet ROI requirements.

## HARGRAY OPERATIONS AND SERVICES

Hargray is an independent operating company (IOC) that provides voice, video, data, wireless, high-speed Internet, and directory publishing services to the residents and businesses of southeastern South Carolina and Georgia. Hargray serves several cities within a 100-mile radius of Hilton Head, SC. Hargray's operations are made up of three business lines: cable operations (MSO), cellular carrier (MNO), and ILEC and CLEC.

### Cellular services and infrastructure

Hargray provides cellular services to subscribers in three counties in South Carolina centered around Hilton Head, and nine counties in Georgia centered around Savannah using Hargray owned and operated cell sites. It has 171 cell towers total. Hargray backhauls the cellular traffic to their Pritchardville, SC Mobile Switching Center (MSC) using costly third party T1 circuits. The average cell tower uses 1.5 T-1s per cellular carrier, ranging from one to three T-1 lines, but this traffic is expected to grow substantially as new cellular services are introduced and as cellular backhaul capacity is sold to additional mobile network operators (MNOs). Hargray is using CDMA technology with towers that are in very close proximity to Hargray cable plant, typically within 500 feet. The distance to backhaul cellular traffic over HFC ranges from one to more than six amplifier spans with the average around three spans.

### Business Services

Hargray currently provides the following business services over its ILEC/CLEC network and cable systems**:**

(1) High capacity symmetrical Internet access with committed information rate (CIR) - currently 3x3, 5x5 and 10x10 Mb;
(2) High capacity Metro Ethernet services with committed information rate (CIR) – ELINE, ELAN – 3Mb-20Mb;
(3) Multi-line digital voice (VoIP) lines using IP Centrex technologies; and
(4) T1 leased lines.

Hargray plans to increase its market share in the more lucrative segment of mid-tier businesses by expanding its business service offering to include high ARPU services such as:

(1) Cell backhaul;
(2) Off site storage hosting: data hosting for disaster recovery with low latency high capacity; and
(3) Up to 24 multi-line digital voice (VoIP) lines using either on-premise IP PABX or IP Centrex.

## HARGRAY GOALS AND OBJECTIVES

To maintain its competitive edge and address its diverse customer base, Hargray continues to innovate and expand its product offerings across its various operations. In order to continue to expand cost effectively, Hargray's goals were three fold: (1) reduce the operating cost of its cellular network, (2) grow its commercial revenues, and (3) expand business services to the mid-tier market while minimizing capital expenditure investment in plant and equipment and maximizing ROI.

Specifically Hargray's objectives were:

*Business*

(1) Eliminate costly monthly payments to a third party (ILEC) for cellular backhaul T1 circuits by backhauling its cellular traffic using its own HFC facilities;
(2) Grow Hargray commercial revenue base
    a) Expand business services
    b) Sell cellular backhaul services to other mobile network operators in its markets; and
(3) Increase ARPU of business services over HFC.

*Market and Products*

(1) Expand mid-tier business customer base by leveraging the reach of its HFC facilities and offering services tailored to these customers;
(2) Provide the same portfolio of business services regardless of last mile physical media: fiber, copper, or coax ;
(3) Introduce addition high capacity, guaranteed service level agreements (SLAs) and feature-rich business services such as:
    a) High capacity symmetrical data with committed information rate (CIR) - currently - currently 3x3, 5x5 and 10x10 Mb;
    b) High count multi-line e.g. up to 24 digital voice (VoIP) lines using either on-premise IP PABX or IP Centrex; and
    c) TDM (T1) connectivity. As an ILEC, Hargray had been providing T1 services over fiber and copper and wanted to extend T1 services over its HFC plant.

*Financial*

(1) Meet ROI targets; and
(2) Accomplish the above objectives economically with:
    a) No major plant expansions
    b) Low incremental pay as you grow capital expenditures

## REQUIREMENTS AND CHALLENGES

Hargray needed to adopt a solution that leverages the *existing* HFC plant to support these performance-sensitive and mission critical services while simultaneously minimizing capital investment in plant and equipment, meeting ROI metrics, and minimizing time-to-revenue. Moreover, to minimize operational expenditures, the solution would have to be based on a single platform capable of supporting all these services while providing comprehensive network management and monitoring capabilities. Furthermore, the solution needed to be flexible and support multiple network architectures e.g. Fiber-To-The-Curb (FTTC), Fiber-To-The-Node (FTTN), etc.

### Network Challenges

Cellular Backhaul

Performance: To support cellular backhaul and TDM (T1) services, the coax access network solution must meet stringent cellular network performance requirements including various latency, jitter, and error rate metrics such as:

(1) The network must not introduce more than eight ms of one way delay (latency) due to differential delay requirements to effectively support soft hand-off of calls.
(2) The network must not introduce more than five ms of one way jitter (delay variation) due to differential delay requirements to effectively support soft hand-off of calls.
(3) The network must meet strict T1 Bit Error Rate (BER) metrics of better than 1e-8 to assure no drop calls.
(4) The network must meet strict T1 Severe Error Seconds (SES) metrics of better than 16 SES per day to assure no drop calls.

Meeting stringent BER requirements is instrumental to supporting Hargary's customers as well as ensuring the provider's ability to sell backhaul services to other cellular carriers located in its footprint.

Bandwidth capacity: To support bandwidth growth due to customer growth, advanced multi-media services, and the ability to provide service to multiple MNOs, the backhaul capacity should support growth beyond four T1s to eight T1s today, and 15-20 T1s in the near future. The bandwidth demand per carrier will increase to 4 T1s with 3G EVDO (Evolution Data Only ) services. Each of Hargray's towers has up to five cellular carriers, thus the requirements for 15-20 T1s. However, T1 E-MTA with T1 over DOCSIS can't generally support more than two T1s reliably.

Carrier Class Data and Voice Services

To support the expanding voice and data needs of Hargray's mid-tier business class customers, the coax access network should provide the following capabilities:

(1) High capacity and scalable bandwidth from 1 Mbps to 100 Mbps;
(2) Dedicated bandwidth with CIR;

(3) Symmetrical data-rates;
(4) Hard Quality of Service (QoS) vs best effort to support priority based applications and end-to-end SLA;
(5) Service performance metrics that include low latency, jitter, and packet loss (typically better than 1e-5); and
(6) Reliability: high availability, and security.

Bandwidth capacity: Mid-tier business customers require increasing numbers of voice ports, up to 24. In order to provide up to 24 digital voice channels, the coax network must also support high capacity, symmetrical, dedicated bandwidth with Constant Bit Rate (CBR) and hard QoS. With current DOCSIS technology, it is challenging to service enterprise customers who require more than a few voice ports due to capacity limitations within the node. At present Hargray is limiting the use of VoIP lines over DOCSIS E-MTA to two lines. Furthermore, these dedicated bandwidth capacity requirements increase in order to provide bundled services that include high port count VoIP and Carrier Ethernet services.

*High Availability:* Additionally, to support carrier class business services, the network must provide high availability of better than 99.9%.

*Flexible HFC Access Network Architecture*

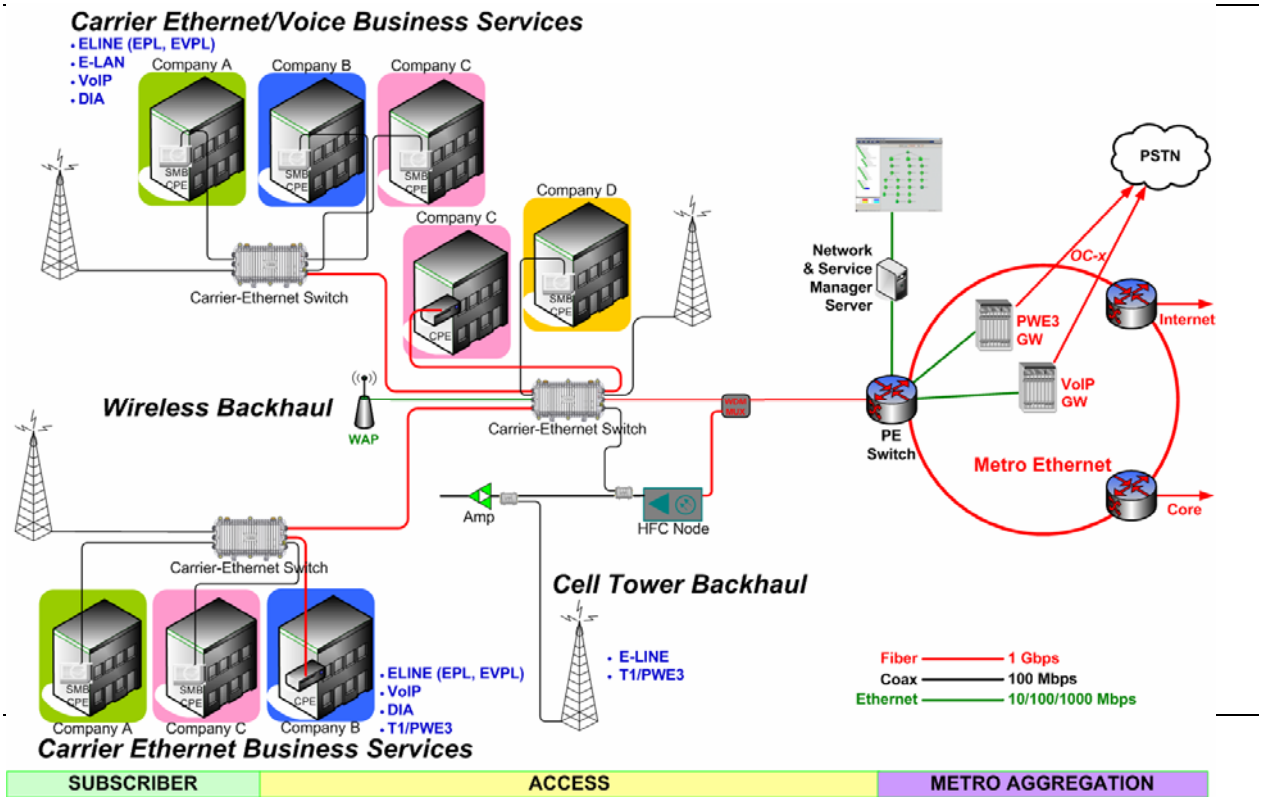
In order to support flexible access network architectures such as Fiber-to-the Curb (FTTC), or Fiber-to-the Node (FTTN), the equipment providing these services should be capable of being placed anywhere in the cable plant, i.e. outdoors. Consequently, the solution must be environmentally hardened.

## Operational Challenges

To provide carrier class services to SMBs, the solution must enable rapid service provisioning, fast time-to-repair (FTTR), and include the ability to record SLAs metrics. Thus, the equipment should provide a comprehensive set of tools to manage both the access network and the services including: (1) services provisioning, (2) real-time network monitoring and fault reporting, (3) diagnostics such as loopbacks, and (4) network and service statistics collection, display and reporting.

## THE SOLUTION – CARRIER CLASS ETHERNET OVER HFC

After thorough evaluation and field trials, Hargray selected a Carrier Ethernet over HFC solution as the access network infrastructure to support its cellular backhaul, expanded data, and voice (VoIP) business services. This solution is based on environmentally hardened outdoor access and aggregation Ethernet switches that provide Carrier-Ethernet services over coaxial cable as well as fiber and copper. Please refer to figure 1. The solution leverages the existing coax plant thus avoiding expensive plant upgrades. Furthermore, it integrates seamlessly with HFC plant. *It enables Hargray to provide the same portfolio of carrier class business services over any last mile access physical media: fiber, copper, or coax.*




## Carrier Ethernet – An Overview

Carrier Ethernet has emerged as the service and network convergence technology of choice for business services and is a very powerful enabler for cellular backhaul. Carrier Ethernet is a ubiquitous, standardized, carrier-class service defined by five attributes that distinguish Carrier Ethernet from familiar LAN based Ethernet. Its attributes include:

- Standardized services;
- Scalability;
- QoS;
- Service management; and
- Reliability.

Carrier Ethernet is carrier-hardened Ethernet, the universal, most widely deployed technology known for its robustness, cost effectiveness, overall ease of use and internetworking. Its advantages are well documented as results of many applications. The key benefits of Carrier-Grade Ethernet include:

- high capacity, support of high bandwidth applications from 1 megabit to 10's, 100's and 1000's megabits
- scalability and granularity, enabling fast provisioning in increments and allowing for progressive bandwidth growth
- Flexibility, it can be easily tailored to meet each individual customer's needs.
- Migration, seamless transition from traditional TDM services to a single interface with multiple services

- Cost effective**,** both in terms of capital expenditures and operational costs. It provides lower cost per megabit. It offers the Ethernet cost model to achieve significant savings.
- Ease of use, facilitates operations, management and provisioning efficiencies

Carrier Ethernet can be considered a viable solution for most applications.

## Solution Overview

The key attributes of the solution are as follows:

### Carrier Ethernet Capabilities

Carrier Ethernet provides fiber class speeds and performance over coax of up to 100 Mbps symmetric, thus extending connectivity to any plant location cost-effectively. In addition, it supports scalable, rate limited, high capacity bandwidth with up to 1 Gigabit Ethernet (GE) over fiber and twisted pair copper. Carrier-Ethernet capabilities include: Hierarchical Hard Quality-of Service (QoS), 32 independent service profiles per port (UNI), 127 service classifiers, support of VLAN 802.1q, 802.1p, Q-in-Q. The service descriptors include Bandwidth, QoS level and VLAN ID.

### Stringent latency and Jitter

Carrier Ethernet is capable of meeting stringent low latency, jitter and packet loss requirements over both coax and fiber as required by ANSI T1 specifications such as ANSI T1.506-1997(R2001) & ANSI T1.403-1999. The measured delay and jitter of the Carrier-Ethernet implementation in Hargray network is considerably lower than the requirements of 8 ms & 5 ms respectively. Similarly the packet loss and BER were lower than the 1e-5 and 1e-8 respectively.

### Enabling High ARPU Services

The Hargray solution enables mission critical, performance-sensitive, high ARPU Carrier Ethernet services with flexible SLA over HFC including:

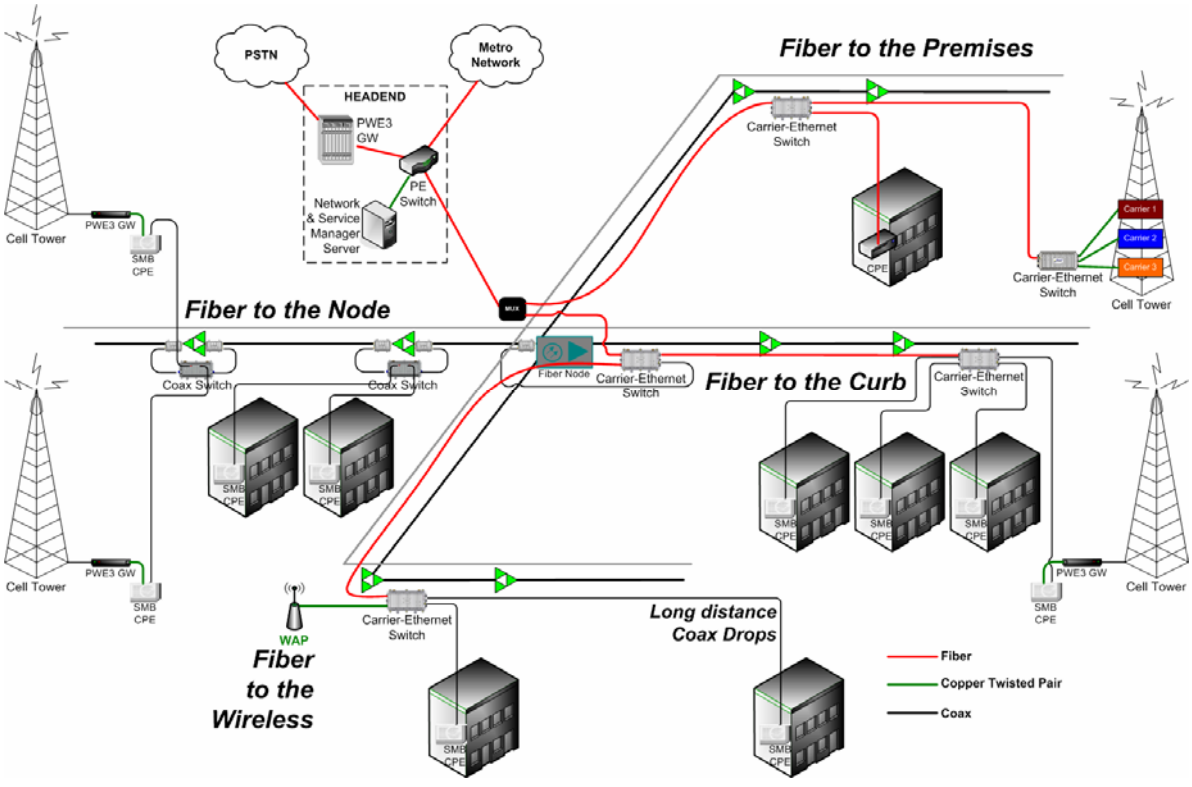
- Cell tower and wireless backhaul (T1 PWE3 and Ethernet)
- Data and voice business services such as:
    - Ethernet private line (EPL)
    - Ethernet virtual private lines (EVPL)
    - E-LAN, TLS (Transparent LAN Services), VPN
    - Digital voice (VoIP) – high count multi-line
- TDM (T1) services over Ethernet

### Flexible HFC Access Network Deployment Architectures

The combination of physical media flexibility and environmentally hardened outdoor enclosure enables the switch to be located anywhere in the outside plant and to be deployed in any access network architecture. These architectures are depicted in Figure 2 and include Fiber-to-the Curb (FTTC), Fiber-to-the Premise (FTTP), Fiber-to-the Node (FTTN), Fiber-to-the-Wireless (FTTW) or any combination of these.

In a Fiber-to-the Curb (FTTC) deployment, the switch is placed at a drop location near the target customers. A fiber trunk is over-lashed from the fiber node to the curb. Service is provided over existing coax drops. This deployment architecture is cost effective because it leverages the existing coax drops, utilizes relatively inexpensive short to medium distance fiber trunks, and is non-disruptive to the HFC plant. Ethernet/IP traffic coexists on the coax trunk/drops with the 860 MHz CATV spectrum. It utilizes spectrum above the 860 MHz plant and is inserted via a passive Diplex Filter (NDF). On the customer side, Ethernet/IP traffic is separated from CATV traffic via a Customer Premise Filter (CPF) and terminated on a coax termination and demarcation device. The switch can receive AC power from the coax plant through an NDF or through a power-passing tap or a power inserter.

Fiber-to-the Node (FTTN) architecture utilizes only coax trunks. The switch is co-located with an HFC fiber node feeding up to four coax trunks. The switch receives standard Gigabit Ethernet traffic originating at the hub or headend off the fiber trunk. It connects to coax trunks through a Diplex Filter (NDF) that also provides AC power to it. An access switch is used to bypass OSP coax amplifiers and regenerate the Ethernet/IP traffic. The coax modem support coax trunk cable distances of over 2000' without regeneration. This deployment architecture maximizes plant asset utilization by leveraging existing coax trunk and drops in the outside plant and doesn't require expensive fiber construction.



Network and Service Management

Carrier Ethernet supports comprehensive end-to-end network and service management to create, deploy, provision, operate, and maintain high value, high margin business services. Its capabilities include Fault, Configuration, Accounting, and Performance and Service (FCAPS) management and provide access link, connectivity and service Operation, Administration and Maintenance (OAM).

Network Management

The automated Network Management ensures high availability via reduced Mean Time to Detect (MTTD)/Mean Time to Repair (MTTR) failures and minimizes truck rolls. Its capabilities include:

- Automatic discovery of network elements and topology;
- Automatic configuration of network elements;
- Real-time network health monitoring and fault reporting;
- Performance reporting, real-time and historical;
- Security management;
- Loopbacks.

Service Management

Service Management enables service provisioning for customers by site supporting multiple service tiers per site/port (UNI). Its capabilities enable service providers to:

- Create service plans;
- Subscribe customers to the defined plans;
- Generate billing events such as service activation, service deactivation, interruption, and resume;
- Display real-time service alarms and correlate them to network device alarms identifying users and services affected by network outages;
- Collect statistics and produce performance and alarm reports to support SLAs.

## Hargray's initial deployments

To minimize any fiber construction Hargray opted initially to deploy FTTN architecture for cellular backhaul and high port count Centex VoIP. In the future Hargray plans to also evaluate FTTC architecture to further enhance business voice and data services.

Cellular Backhaul

Hargray plans to use Carrier Ethernet to replace third party T-1s with its own backhaul network, thus eliminating costly expense. Next, Hargray plans to grow its commercial revenue base by selling backhaul services over that system to other cell sites in its market. This upcoming market deployment is the first scale deployment of an Ethernet-based backhaul network over coaxial cable.

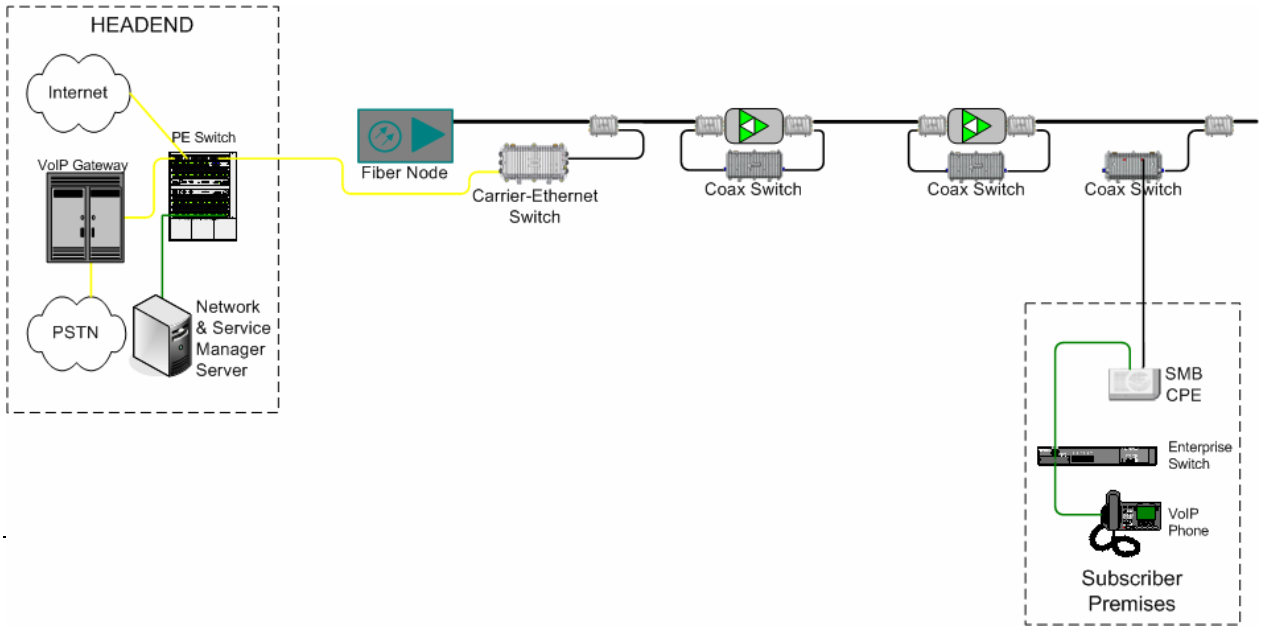
The cell backhaul application is the most demanding access network application. It requires a solution that meets the rigorous requirements for both cellular and the full spectrum of commercial applications.

To avoid costly long haul fiber construction an FTTN architecture was selected. Each trunk includes multiple amplifiers that are bypassed. To transport TDM (T1) over Ethernet, the solution utilizes a Pseudo-Wire Emulation access device (PWE3) at the cell tower and a Pseudo-Wire Emulation Gateway at the headend.

*Business Voice and Data*

Another application that was tested and performed solidly through all of Hargray's rigorous testing was the support for a large number of Centrex VoIP lines via a class 5 softswitch located at the headend. Please refer to figure 3. This solution allows Hargray to leverage its existing coax plant to cost-efficiently provide small and medium-sized businesses with high capacity/high performance data and a large number of voice ports. The Ethernet-over-Coax solution together with a class 5 softswitch at the headend utilizes existing cable infrastructure and takes advantage of Metro Ethernet to deliver increased port count to support the voice needs of SMBs. It will help Hargray to significantly expand its revenue potential in the business services market.

The current target for the Centrex solution is customers with needs in excess of the current DOCSIS limitation of 3-5 ports, with the ability to scale up to 24 ports. This solution will help- fill the gap between DOCSIS and fiber connections to these same customers.




## RESULTS

Carrier Ethernet over coax has proven to be a very cost effective and reliable approach to leverage the HFC plant to enable performance sensitive mission critical business services. *Carrier Ethernet over coax is a powerful new use of the coax plant.*

CBR traffic over HFC

The biggest challenge Hargray has faced in the past was running Constant Bit Rate (CBR) services in the 5-42MHz return path. It is very difficult to keep the plant clean enough to support a service as demanding as a T1 over a period of weeks, months, etc. Hargray tried both DOCSIS and proprietary solutions and both always had problems. In addition, the protocol conversion from IP to DOCSIS back to IP seemed to add unacceptable latency.

Performance

After extensive lab and field testing, Hargray verified that the Carrier-Ethernet access network solution meets stringent cellular network performance requirements including various latency, jitter, and error rate metrics and successfully supports soft hand-off of calls.

Latency

The Carrier-Ethernet solution met the stringent copper based T1 performance metrics including round-trip delay of < 10 ms.

BER

Furthermore, BER performance is equivalent if not better than the existing copper T1.

Reliability

This solution has proven to be very reliable with minimal downtime.

Business Services

The VoIP Centrex application over the carrier-Ethernet access infrastructure has performed solidly throughout all of Hargray's rigorous testing. Hargray feels confident in the solution's ability to support the expanding high count multi-line voice and data needs of its business class customers.

The solution enables high ARPU tiered data and voice services with flexible SLA as well as business TDM (T1) Constant Bit Rate services with less stringent requirements than cellular backhaul.

Carrier Ethernet over coax provides a convergence transport layer over which many services can be provided such as Ethernet point-to-point (Ethernet Private Line (EPL), multipoint-to-multipoint (TLS), T1 circuit emulation, VoIP, and other mission critical performance sensitive services.

## Capacity

Carrier Ethernet over coax supports high capacity, scalable, and symmetric bandwidth.

## Capital Expenditure Savings

The solution provides low cost per Megabit compared to other technologies. It utilizes the existing plant and is success based. It minimizes fiber construction by maximizing fiber and wavelength utilization. Furthermore, it facilitates selection of physical media and network architecture to minimize capital outlays.

## Operational Expenditure Efficiency

Carrier Ethernet over coax is simple to provision, manage, operate and maintain, thus minimizing operational spending. It includes automated network management and configuration tools. Moreover it provides extensive performance monitoring and SLA metrics.

## *ROI*

The payback period meets the required ROI metrics as set by Hargray.

References

[1] CTIA, 2006
[2] IDC, Heavy Redaing, 2006
[3] Frost & Sullivan/Stratecast Partners, 2006, The Yankee Group, 2006