WHITE PAPER

Implementing a Voice over IP Network Using Comtech EF Data IP-Enabled Satellite Modems

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ABSTRACT

As of 2006, Voice over Internet Protocol (VoIP) PBX shipments have surpassed traditional TDM PBX shipments, and by the end of the decade are poised to be the norm by which Telco and service providers offer Triple Play services to their customers.

Service providers can leverage the benefits of this paradigm shift by utilizing the complete line of IP-enabled modems developed by Comtech EF Data (CEFD) to provide and enhance VoIP communications for trunking as well as hosted solutions.

This paper presents a case study for a centrally located network servicing a number of remote locations and defines the desired attributes and requirements for that network. It then presents two proposed implementations within this network featuring powerful product solutions available from CEFD, concluding with a detailed overview of the featured products' capabilities.

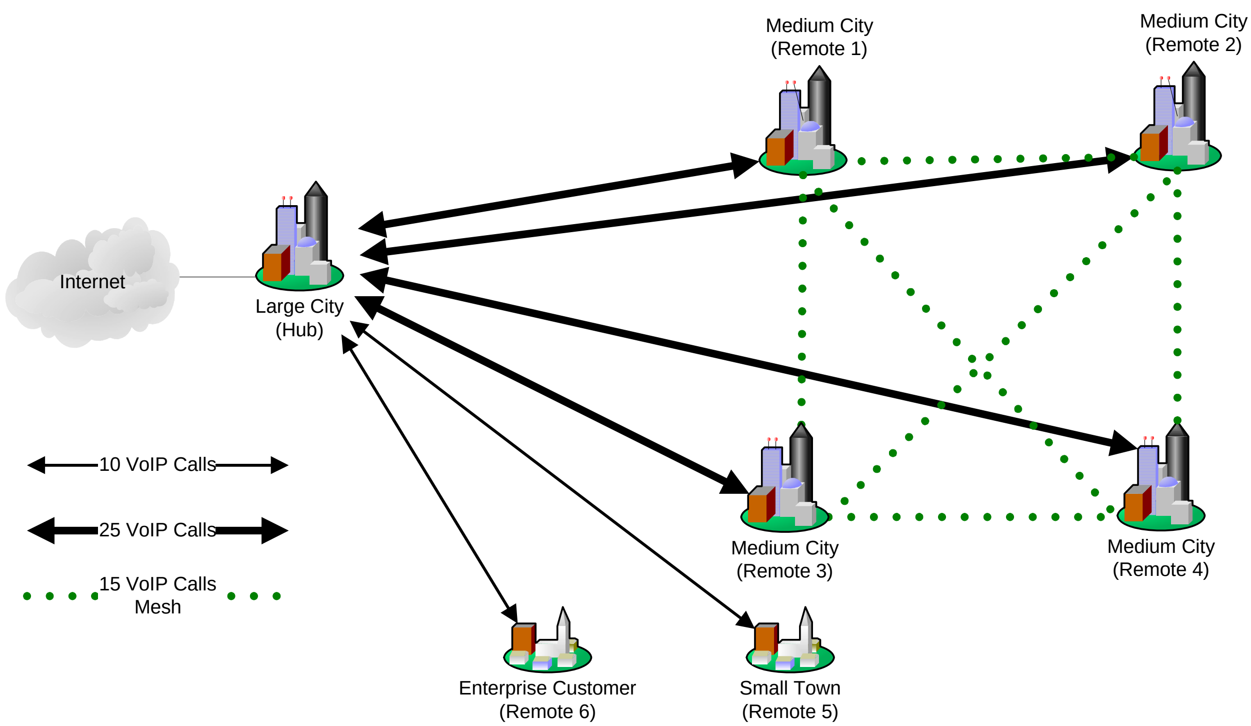
INTRODUCTION

The growing popularity and acceptance of Voice over Internet Protocol (VoIP) is changing the way Telco and service providers administer the Triple Play – voice, video and data. In 2006, for the first time VoIP PBX shipments exceeded traditional TDM PBX shipments. Industry experts estimate that by 2010, 90 percent of all PBX shipments will be VoIP-based. This transition represents a significant new opportunity for IP services providers to offer hosted VoIP services.

I. DESIRED ATTRIBUTES FOR A HOSTED VoIP SERVICES NETWORK

Figure 1 illustrates the hypothetical case where a service provider would like to provide VoIP communications from a central location to six remote locations:

Figure 1. Service Provider Multi-location Network



NETWORK REQUIREMENTS

As shown in the preceding figure, this network features one network hub and six remote locations. Four of the remote locations have significant traffic between them, while the last two are small enterprise locations with a lower number of users. Additionally, there will be a requirement to pass Internet traffic from all remotes to the central location.

For all locations, the VoIP traffic has priority over any other traffic.

MEDIUM-SIZED CITIES

The medium-sized cities in this example require peak time load of 25 bidirectional calls to the hub. In addition, they have a peak time requirement to provide 15 bidirectional calls to each of the other three medium-sized cities. The capacity not used by VoIP calls is made available for data traffic.

SMALL TOWN

The small town in this study requires 10 VoIP calls but, due to call volume, does not warrant mesh connectivity directly to the medium-sized cities.

ENTERPRISE CUSTOMER

The enterprise customer represents the final player in this scenario. While this user needs 10 VoIP calls, there is an additional need to simplify VoIP deployment by having the service provider provide hosted services. This is specifically due to the enterprise customer's preference not to perform maintenance or configuration on customer premise equipment (CPE).

II. COMTECH EF DATA PROPOSED VoIP NETWORK SOLUTIONS

IMPLEMENTATION No. 1 – Static Capacity

This first proposed implementation uses Comtech EF Data IP-enabled modems and quad demodulators, identified in Table 1, with advanced features to minimize the total cost of ownership via reduced capital and operational expenses.

Table 1. Implementation No. 1 Equipment List

Product Type	Quantity	Model	Location
Modem	1	CDM-570	Outbound Hub
	6	CDM-570L	One at each remote
Quad Demodulator	2	CDD-564	Return/shared channels at Hub
	4	CDD-564L	One at each remote for mesh connectivity

As illustrated in Figure 2, at the hub, a CDM-570 satellite modem transmits a large shared outbound signal. At each of the remotes, a CDM-570L will receive on the shared outbound. Additionally, the CDM-570L transmits on a separate shared channel that is used to connect the hub to each of the meshed remotes.

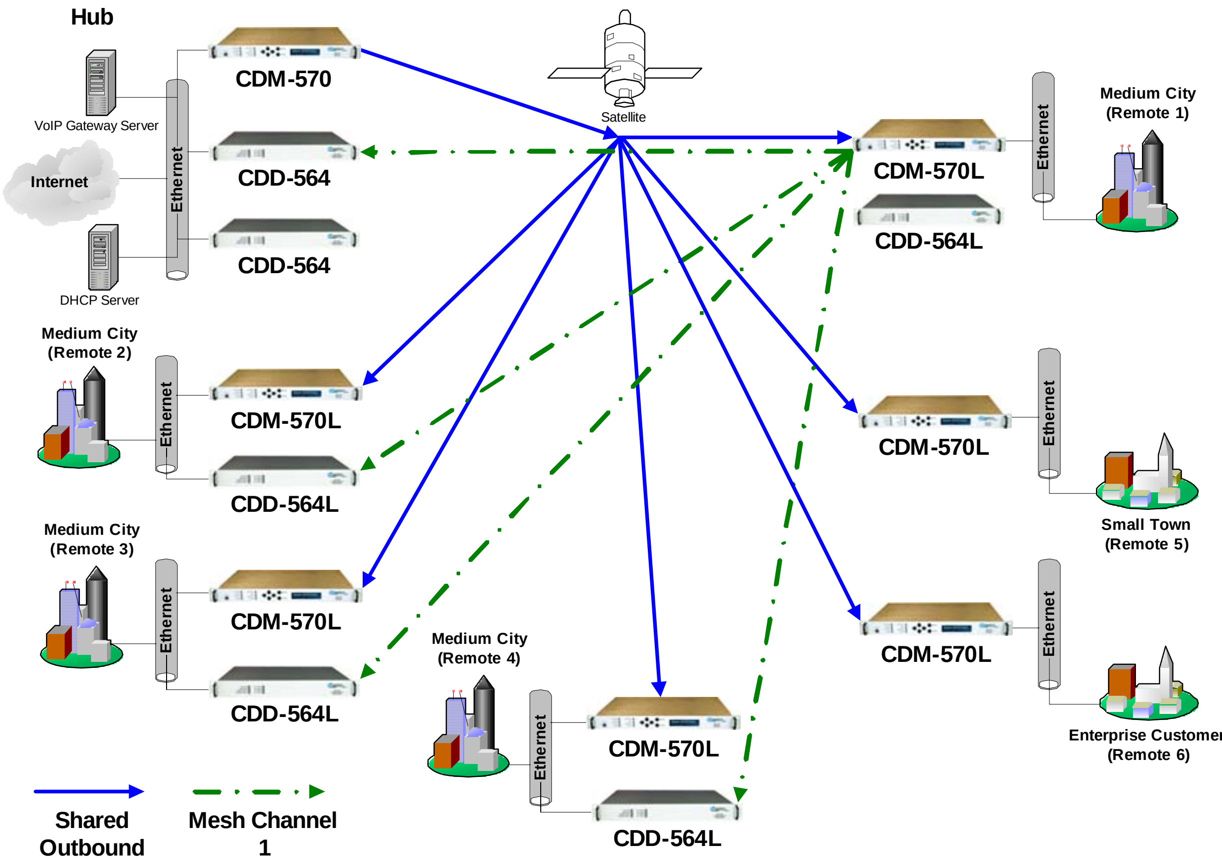


Figure 2. VoIP Mesh Network Diagram

The CDD-564L quad demodulators deployed at Cities 1 through 4 are an efficient, cost-effective way to provide mesh connectivity: the connections to Cities 2, 3 and 4 all have similar connections to the other meshed remotes. The small town and enterprise sites are simple two-way links back to the hub; however, in the interest of readability, the channels from the other five remotes are not shown in Figure 2.

NOTE

At each remote, the user will configure a unique HDLC address. The transmitting router will then configure a per-remote route entry that maps to an HDLC address. When the packets arrive at each of the listening CDD-564Ls, the packets that do not have a matching HDLC address will be filtered. This is critical to avoid routing loops.

NETWORK BENEFITS

With this proposal, the illustrated network benefits from the following CEFD IP-enabled modem features and capabilities:

Quality of Service

The Quality of Service features of the CDM-570 and CDM-570L modems, as outlined in detail in the next section, were built with real-time protocols such as VoIP in mind:

- When backhauling real-time data, voice quality is maintained by reducing latency and jitter.
- With full 7-layer stateful classification, the Comtech modem user can prioritize based upon applications in addition to source/destination IP addresses and/or port numbers.
- Prioritization allows service providers to maximize link utilization while maintaining the latency and jitter requirements for the VoIP calls.

QoS's three modes of functionality are leveraged as follows:

- Max/Priority mode allows the user to configure 32 different rules with eight levels of priority while allowing the user to cap each rule at a maximum kbps.

  For this example, the recommended Quality of Service rule in Max/Priority mode is:

```
                 QoS Rules Configuration

          SrcIP      DestIP     Prot SPort  DPort MaxBW PWF
    RL01..[***/*     ***/*      RTP   ***    ***  99999 1YN
```

  Note that, with this configuration, all other non-VoIP Internet traffic will have the default priority and will have an equal chance of being dropped during periods of congestion. However, customers/operators who wish to differentiate the remaining traffic can prioritize traffic based upon source/destination IP, source/destination port, as well as complete list of protocols such as UDP, TCP, FTP, telnet, HTTP, SNMP, among others.

- Min/Max mode allows the user to specify 32 rules with a minimum kbps (committed information rate) along with a maximum kbps.
- DiffServ mode allows the user to take advantage of end-to-end network prioritization by using the TOS bits in the IP header to designate priority.

Header Compression

Care must be taken when selecting the proper modem to ensure that the unit has enough horsepower to carry the burden involved in supporting a highly intensive voice network.

The CDM-570L modem and CDD-564L quad demodulator currently support a total maximum of 64 bi-directional and 128 unidirectional compressed VoIP calls. This number, it should be noted, is significantly higher than competing devices available in the market, designating the CDM-570L as the satellite modem of choice for any network that carries a large amount of voice traffic. This is mainly due to the fact that, because voice uses very small IP packets, a great deal of on-board processing is required in the modem to perform the proper full packet inspections that are needed to compress voice. Because of this, packets per second (PPS) limits are reached before throughput (kbps) limits in a highly loaded voice satellite network.

DHCP Relay

By using a centralized DHCP server, end customers and service providers who wish to minimize deployment complexity can use the DHCP Relay functionality provided by Comtech's IP-enabled modems. At each of the remotes, the network administrator configures the "DHCP Server IP Address" which is most commonly located at the hub. When DHCP requests are broadcast on the local LAN, the CDM-IP mode receives the message, translates the destination IP address to the DHCP server and passes the packet to the hub. The centralized DHCP server can then process the request and directly configure the new device. In VoIP networks, this is particularly useful when a service provider or enterprise IT organization wishes to provide a hosted VoIP service. In particular, the DHCP server running at the hub can automatically configure the VoIP phones at the remotes.

While all of the end customers in our example could benefit from DHCP relay, the potential to provide hosted services is best at the small town and enterprise user remote sites.

IMPLEMENTATION No. 2 – dynamic SCPC (dSCPC)

For environments where the capacity of the VoIP links is dynamic, Comtech EF Data provides a solution that dynamically assigns SCPC links on an as needed basis via a method called dynamic SCPC (dSCPC).

Using CEFD's Vipersat Management System (VMS), a service provider can manually, automatically, and on a scheduled basis, change the capacity for all of the links described in Implementation No. 1.

Satellite bandwidth utilization is maximized by allowing the service provider to shift capacity as new subscribers come online, throughout the day or potentially as demand shifts from one time zone to another. The exact rules by which remotes change their SCPC bandwidth allocation would differ depending upon traffic load.

III. COMTECH EF DATA IP PRODUCT SOLUTIONS

Comtech EF Data has developed a line of IP-enabled modem products that provide the building blocks necessary to achieve a hosted VoIP network possessing all of the previously defined, desired attributes.

CDM-570 Satellite Modem
CDM-570L Satellite Modem

CDD-564 Quad Demodulator
CDD-564L Quad Demodulator

CEFD's family of IP-enabled modem products includes:

- Two traditional Modems – the CDM-570 and CDM-570L
- Two Quad Demodulator products – the CDD-564 and CDD-564L

All are packaged in rack-mountable 1U enclosures. Each product is available in either L-Band or 70/140 Megahertz (MHz) and feature data rates from 2.4 kbps to 9.98 Megabits per second (Mbps), fast acquisition, and second generation Turbo Product Coding (TPC) – the industry's most bandwidth-efficient Forward Error Correction – providing increased coding gain and lower decoding delay.

A variety of modulation techniques are offered, including Phase Shift Keying (PSK) and Quadrature Amplitude Modulation (QAM) – specifically, 8-PSK, BPSK, QPSK, 8-QAM and 16-QAM, with code rates spanning from Rate 5/16 through Rate 0.95 depending on modulation type.

Designed with IP networking in mind, these robust products optimize satellite communications and provide many of the advanced features previously available only in higher-end modems.

Flexibility and cost-effective performance are integral to these offerings. The CDD-564 and CDD-564L Quad Demodulators are ideally suited for star topologies, reducing both the equipment cost and rack space requirements at the hub.

Both quad demodulators are fully programmable and independent. Each contains a high performance, feature-rich IP routing engine with standard features, including:

- Choice of routed mode or easyConnect™ for maximum flexibility
- Highly efficient satellite framing (3 to 7 bytes overhead)
- Static IP routing for unicast and multicast
- Support for both Point-to-Point or Point-to-Multi-Point configuration
- Internet Group Management Protocol (IGMP) v1 and v2 for management of multicast groups
- Support for symmetric as well as asymmetric operation for maximum bandwidth efficiency
- Powerful network management via Simple Network Management Protocol (SNMP), Web or Telnet

Advanced features, available as options to the IP Module that can be enabled at initial purchase or after installation, focus on providing additional bandwidth efficiencies. These features include QoS, Header Compression, Payload Compression and 3xDES Encryption.

QUALITY OF SERVICE

All CEFD IP-enabled modems are equipped with a state-aware, 7-layer IP classifier to support multi-level QoS. QoS rules can be assigned for up to 32 different types of flows. Flows are defined by any combination of protocol (FTP, UDP, Real Time Protocol (RTP), etc.), Source/Destination IP (specific or range), and/or Layer 3 Source/Destination Port.

The following list of common protocols is provided for selection to simplify QoS rule entry:

Rule name	Description
VOCE	Voice Real Time Protocol
VDEO	Video Real Time Protocol
RTPS	Real Time Protocol Signaling
RTP	All Real Time Protocol
FTP	File Transfer Protocol
HTTP	Hypertext Transfer Protocol
TELN	Telnet Protocol
SMTP	Simple Mail transfer Protocol
SNMP	Simple Network Management Protocol
SQL	Structured Query Language Protocol
ORCL	ORACLE Protocol
CTRX	CITRIX Protocol
SAP	Service Announcement Protocol
UDP	All User Datagram Protocols
ICMP	Internet Control Message Protocol
TCP	All Transmission Control Protocols
IP	All Internet Protocols
N-IP	All Non-Internet Protocols

The QoS system minimizes jitter and latency for real time traffic, including Voice over IP and Video over IP. It provides priority treatment to mission critical applications and still allows non-critical traffic to use the remaining bandwidth for maximum utilization. Three unique modes of QoS are available in these offerings to provide maximum flexibility – Max/Priority, Min/Max, and DiffServ.

MAX/PRIORITY

This QoS mode allows the assignment of a maximum bandwidth per defined traffic flow and a prioritization level of 1 through 8.

MIN/MAX

This QoS mode allows the assignment of both a minimum and a maximum bandwidth per defined traffic flow. From a configuration standpoint, setting the minimum specification for user-defined classes of traffic ensures that a certain level of bandwidth is always applied to given flows.

DIFFSERV

DiffServ, an industry-standard method of adding QoS to IP networks, offers the capability to prioritize certain types of traffic and various methods of traffic handling based on the class of a particular stream. As a standards-based approach to QoS, the DiffServ mode ensures that these offerings can seamlessly co-exist in networks that already have DiffServ deployed. QoS is an optional feature that can be activated via the purchase of the FAST feature.

HEADER COMPRESSION

Header Compression is an optional feature that can be activated via the purchase of the FAST feature. Compression for the following Ethernet and Layer 3 and 4 Headers is provided:

Supported Ethernet Headers	Supported Layer 3 & 4 Headers
Ethernet 2.0	IP
Ethernet 2.0 + VLAN-tag	TCP
Ethernet 2.0 + MPLS	UDP
802.3-raw	RTP (Codec Independent)
802.3-raw + VLAN-tag	
802.3 + 802.2	
802.3 + 802.2 + VLAN-tag	
802.3 + 802.2 + SNAP	
802.3 + 802.2 + SNAP + VLAN-tag	
802.3 + 802.2 + SNAP + MPLS	

Deploying this feature is simple and operation is independent of QoS, with configuration on a per route basis, as well as enabled/disabled for the overall system. Header Compression reduces the required Voice over IP bandwidth significantly. For example, a G.729a voice codec, operating at 8 kbps, will occupy 29.6 kbps once encapsulated into IP framing on a Local Area Network (LAN). Using IP/UDP/RTP Header Compression, the same traffic only needs 10.8 kbps total Wide Area Network (WAN) satellite bandwidth to cross the link.

If the voice codec is equipped with silence suppression, the bandwidth requirement can reduced another 40% to 60%. A total maximum of 64 simultaneous Voice over IP calls can be compressed. Normal Web/HTTP traffic can be reduced an additional 10% via IP/TCP header compression. The user interfaces also provides statistics to display the total bytes of the pre-compressed and post-compressed traffic and effective compression ratio.

PAYLOAD COMPRESSION

Advanced Lossless Data Compressing (ALDC) applied to the payload (data) condenses the size of data frames, reducing the satellite bandwidth required to transmit across the link. These offerings support Payload Compression using the ALDC compression algorithm, which can provide bandwidth savings in excess of 40%. The compression ratio achieved will be dependent upon both the data content and the average IP packet size.

Payload Compression can be activated via the purchase of the FAST feature, and is configurable on a per route basis as well as enabled/disabled for the overall system. Additionally, there are statistics that report the achieved level of compression. Header Compression can be used with Payload Compression for maximum bandwidth optimization.

Table 2 shows the ALDC algorithm's performance using the two most widely used benchmark file sets.

Table 2. Algorithm Performance Benchmarks

Algorithm	IP Payload Size	File Set Corpus	Ratio
ALDC	1472	Calgary	1.76
	1000		1.76
	500		1.77
	100		2.09
	1472	Canterbury	1.71
	1000		1.72
	500		1.74
	100		2.04

LINK LAYER DATA ENCRYPTION

Optional 3xDES-128 data encryption (using National Institute of Standards and Technology (NIST) certified 3x core) is provided to prevent unauthorized access to data over the satellite link, and is configurable on a per route basis. Encryption is performed as the last processing step on the IP packet before it is framed and transmitting over the satellite; this allows encryption to co-exist with all other traffic shaping elements (QoS, Header and Datagram compression) for these offerings. On the receiving end, satellite frames are sent through decryption first before re-entering the routing engine. When encryption is applied, all IP packet data (including headers if not compressed) as well as the Cyclic Redundancy Check (CRC) is encrypted. Only CEFD's proprietary framing header is transmitted in the clear.

A static key management policy is used which supports eight independent encryption keys and eight independent decryption keys (16 keys in all). All keys are static and user-configurable. Each flow can be configured for encryption by any one of the eight available keys, or by random selection of one of the eight keys. If random mode is selected, the key used to encrypt each packet of a given flow will be chosen randomly from the eight available keys. The keys themselves are never transmitted over the satellite link; instead, a simple index is embedded in the variable-length, proprietary framing header.

Operators can use third party, NIST-certified dynamic keys generation products to regularly regenerate the keys sets, and then use the product management interfaces to automatically reconfigure the static key tables. The elegance of this design is in it simplicity and flexibility. Operators who need a greater level of data security call use this link layer encryption in parallel with external encryption devices, such as the *turbo*IP®, CEFD's PEP device; however, in this mode, QoS, Header and Datagram Compression become inoperable.

VIPERSAT MANAGEMENT SYSTEM (VMS)

The VMS provides network and capacity management of satellite transmission systems through the on-demand allocation of dynamic SCPC (dSCPC) links. The Vipersat platform uses the VMS and CEFD's high performance IP modems to provide a seamless IP-based infrastructure for satellite networking. This advanced system automates bandwidth utilization while optimizing space segment efficiency. The VMS is scalable, designed to anticipate and accommodate future growth, and is capable of managing networks of any size.

Beyond just standard monitor and control (M&C) functions, the VMS provides advanced bandwidth management capabilities, automatic shared-to-dedicated inbound channel switching and sizing based on channel load or application. Single Hop On Demand (SHOD) and Multi-Transponder Mode (MTM) features of the VMS enable efficient space segment usage. Dedicated SCPC circuits can also be automatically scheduled using the Vipersat Circuit Scheduler (VCS).

GRAPHICAL USER INTERFACE

The graphical user interface of the VMS enables centralized network configuration and management. It provides auto-detection of satellite modems, configuration and monitoring of the modems, real-time views of network health and transmission quality, and allows operators to easily modify devices while automatically initiating network performance enhancements. The VMS continues to execute its functions as the network configuration is changed and new remote sites are added.

AUTOMATED CAPACITY MANAGEMENT

The VMS platform design has been driven towards an automated capacity manager with focus on supporting higher-level multimedia applications. This allows VMS to serve a variety of markets and allow for partial Mesh or dynamic SCPC networks, or a combination of both to support the end customers needs.

The VMS network solution automates bandwidth allocation and control to eliminate the need for manual intervention when responding to users' changes (traffic) in bandwidth needs. The network is managed intelligently based upon client-defined rules, resulting in optimization of space segment usage and lower transmission costs.

BANDWIDTH ALLOCATION VIA SELECTIVE TIME DIVISION MULTIPLE ACCESS (STDMA)

The addition of STDMA capability to a network allows multiple terminals to share the same satellite resources that would otherwise be dedicated to a single terminal in an SCPC configuration. This means that more terminals can be added to the network with minimal additional cost in either satellite bandwidth or hub terminal hardware. STDMA provides the availability of a switched pool of SCPC channels for occasional high bandwidth traffic such as videoconferences and large file transfers. The overall network topology can consist of anywhere from one to several hundred remote terminals, which are managed from a central hub terminal with the VMS.

Each STDMA upstream channel uses an STDMA frame operating at an aggregate data rate from 64 kbps to 6.75 Mbps and can support upwards of 100 remote terminals. Multiple upstream channels can be utilized if required. To achieve scalability for larger networks, the system allows multiple STDMA channels to operate simultaneously at the hub, and each STDMA controller can operate independently from the VMS to ensure continuous communications in the event of a network server failure.

The dSCPC functionality takes advantage of the fast acquisition demodulator technology inherent in CEFD's family of IP modem products. The role of these modems is defined in software configuration. The hardware for the Time Division Multiplexed (TDM) outbound, burst controllers, switched and SHOD demodulators is functionally identical. Any of CEFD's IP modem products can be configured as a hub or remote, yielding improved logistics (sparing, ordering, inventory), training and re-deployment to other or new sites.

STAR AND MESH NETWORK TOPOLOGIES

The VMS provides multiple access methods and topologies within the same network, using the same hub and remote equipment. This solution allows STDMA, SCPC, and mesh connectivity simultaneously on the same network.

With SHOD, the VMS provides a cost-effective way to mesh remotes for latency sensitive traffic such as voice or video conferencing. At all times, a remote is in single carrier operation, which allows significant cost savings over a fully meshed static SCPC network. Additionally, the VMS provides automatic upstream switching to SCPC based on application detection (voice, video), QoS rules and traffic loading. Manual and scheduled switching is also provided. With L-band modems, VMS provides the ability to switch across entire satellites using MTM.

INTEGRATION INTO EXISTING DIGITAL VIDEO BROADCAST (DVB) NETWORKS

Vipersat fits seamlessly into networks with DVB outbound functionality. This flexibility allows existing 'receive only' networks to expand to 'interactive' networks without replacing expensive hub hardware. Customers who have a mix of 'receive only' and interactive sites will be able to continue using their DVB platform as their outbound for the interactive sites. It also allows a hybrid DVB/Vipersat network to scale much larger outbound throughputs.

AUTOMATIC CIRCUIT SCHEDULING

The Vipersat solution provides users with the ability to automatically schedule and set up ad hoc SCPC connections. Circuits can be scheduled via a web-based interface by date/time, circuit type, participating nodes or bandwidth. The VCS simplifies the network setup process and enables bandwidth-sharing capacity for a variety of applications.

CONCLUSION

Comtech EF Data products combine the best modulation and Forward Error Correction with powerful built-in IP routing and data conditioning features, providing cost-effective, flexible bandwidth and efficient and secure solutions to meet today's – and tomorrow's – VoIP requirements.

ADDITIONAL RESOURCES

Related White Papers from the Comtech EF Data Web site:

- "Solutions for Flexible, Efficient and Secure Satellite-based IP Networks"

Please contact Comtech EF Data Sales for more information about this innovative technology.

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