Advanced VSAT Solutions

• Portfolio of managed network solutions to address
  – Mobile Backhaul
  – IP Trunking & Backhaul
  – Maritime & Offshore Connectivity
  – Corporate/Enterprise Networks
  – Emergency & Disaster Recovery
Unmatched Quality and Efficiency for Hub Spoke Networks

• Comtech EF Data’s Advanced VSAT Solutions
  – Provide superior service quality compared to other VSAT solutions
  – Significantly reduces leased bandwidth
  – Significantly reduces total CAPEX
Value Proposition

• Efficiency
• Scalability
• Lower Total Cost of Ownership
• Better Quality
  – Guaranteed bandwidth
  – Real time traffic
    ▪ Low latency
    ▪ Low jitter
• Shelterless Installation
Advanced VSAT with FX Series WAN OPT

- Vipersat NMS & dSCPC
- CXU-810 RAN Optimizer
- FX-4000 WAN Optimization & Application Acceleration
- CDD-880 Multi-Receiver Router
- CDM-800 Gateway Router
- Content Server
- E1 Traffic Gen.
- Internet/Intranet

CDM-840
FX-1000
E1 Traffic Gen.
Multi-Layer Optimization

- Multi-layer optimization for maximum bandwidth efficiency / throughput

Throughput

- WAN Optimization
- Payload Compression
- Header Compression
- Ultra Low Overhead Framing
- ACM
- DVB-S2 / VersaFEC CCM

300-400% Increase
## Hub Overview

<table>
<thead>
<tr>
<th>Sub-System</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDM-800 Gateway Router</td>
<td>Transmits high-speed DVB-S2 outbound</td>
</tr>
<tr>
<td>CDD-880 Multi-Receiver Router</td>
<td>Multi-receiver for VersaFEC return channel</td>
</tr>
<tr>
<td>CXU-810 RAN Optimizer</td>
<td>E1 aggregation and RAN optimization</td>
</tr>
<tr>
<td>Memotec CX-U 1240/1280</td>
<td>RAN optimization</td>
</tr>
<tr>
<td>CTOG-250 Traffic Optimization Gateway &amp; Protocol Server</td>
<td>Advanced Quality of Service (QoS), Header &amp; payload compression, ACM/VCM controller</td>
</tr>
<tr>
<td>Stampede FX-4000</td>
<td>WAN optimization &amp; application acceleration</td>
</tr>
<tr>
<td>Network Management System</td>
<td>Network management</td>
</tr>
<tr>
<td>Vipersat dSCPC Controller</td>
<td>Dynamic bandwidth management</td>
</tr>
<tr>
<td>CRS-170A/180</td>
<td>Redundancy Switches</td>
</tr>
</tbody>
</table>
Available Products

- CDM-800 Gateway Router
- CDD-880 Multi-Receive Router
- CDM-840 Remote Router
- ODM-840 and ODMR-840 Remote Routers (outdoor version)
- CXU-810 RAN Optimizer
- Vipersat NMS & dSCPC
- Stampede WAN Optimization and Application Acceleration Platforms
  - FX-1000/4000
- Memotec RAN Optimization Platforms
  - CX-U 1010 / 1220 / 1240 / 1280
- Newpoint EMS
  - Drivers available for CDM-800, CDM-840, CDD-880
Remote Terminal

- Based on CDM-840 (or ODM-840 or ODMR-840)
- DVB-S2 outbound reception
- VersaFEC return channel transmission with ACM
- Packet processing and optimization including advanced QoS, header compression and lossless payload compression
- RAN optimization – integrated E1 RAN optimization
  - Memotec CX-U 1010/1220 can be used to support multiple E1s
- WAN optimization
  - Stampede FX-1000 can add WAN optimization and application acceleration
ODMR-840

- Reduced size version of ODMR-840
- Ethernet only
- External DC power supply
- Low power consumption
  - 15 W to 20 W (depending on configuration)
Shelterless & Off Grid Installations

• In Emerging Countries, Energy expenditure represents a significant portion of network OPEX costs (approximately 40%*)

• Grid Connectivity Challenges
  – The portion of the population targeted by current mobile network expansion is increasingly off-grid.*
  – Where grid power can be attained, the costs of extending the grid to power off-grid base stations can be enormous.*
  – Lead times for grid extension can materially affect network planning.*
  – Grid reliability is a major concern in rural regions of developing countries.*

*Source: GSMA
Shelterless & Off Grid Installations

• To minimize energy costs and reduce grid dependence, operators are increasingly turning to
  – Shelterless installations
    ▪ Minimize/eliminate need for Air Conditioning
  – Renewable energy sources, such as solar power

• The outdoor modem (ODM-840) enables low powered outdoor installations for satellite backhaul
  – Low power consumption by the modem
  – Eliminates air conditioning
  – Advanced FEC and optimization techniques minimize the transmit EIRP
    ▪ Minimizes BUC power
      – Minimizes DC power consumption
Solar Powered Outdoor Base Station

- 1 - 3W BUC
- ODM-840
- Micro Outdoor BTS

~ 50-70 Watts

100-150 Watts
Advanced VSAT Series Benefits

Significant Reduction in OPEX & CAPEX While Providing Superior Service Quality

OPEX Reduction

- Highest spectral efficiency
  - Most efficient physical layer in both directions
  - Low overhead framing
- Most efficient transport of higher layers
  - 2nd gen payload compression
  - Header compression
- E1 RAN optimization options
- WAN optimization options
- **30-60+%** overall leased bandwidth savings

CAPEX Reduction

- Value pricing
- Significant reduction in antenna and/or BUC size
  - VersaFEC reduces the site’s transmit EIRP
  - Bandwidth optimization reduces the site’s transmission requirements
- BUC/SSPA sized for site traffic requirements
- Integrated RAN optimization for low traffic sites (up to 1 E1) eliminates the need for a separate mediation device at Remote
- **30-60+%** total CAPEX savings
High-Speed DVB-S2 Shared Outbound

- CDM-800 (Hub) to CDM-840 (Remote)
- Up to 160 Mbps / 62 Msps
- Variable Coding & Modulation (VCM)
- Constant Coding & Modulation (CCM)
- Normal Frame, Short Frame
- Low overhead Enhanced Generic Stream Encapsulation
- Advanced Quality of Service (QoS)
  - Group QoS
    - DiffServ
    - Rule-based – CIR/MIR, Priority/MIR
- Header compression
- 2nd generation lossless payload compression

40% – 60% More Efficient Outbound
High Performance VersaFEC Return

- CDM-840 (Remote) to CDD-880 (Hub)
- VersaFEC low latency LDPC (Patented)
  - Up to 15.35 Mbps / 4.5 Msps
  - Adaptive Coding & Modulation (ACM)
  - Constant Coding & Modulation (CCM)
- Ultra low overhead Streamline Encapsulation (SLE) (Patent Pending)
- Advanced Quality of Service (QoS)
  - DiffServ
  - Rule-based – CIR/MIR, Priority/MIR
- Header compression
- 2nd generation lossless payload compression

60 – 70% More Efficient Return
Outbound Adaptive Coding & Modulation

Hub

Remote 1

Remote 2

Remote 3

Remote 4
Return Channel ACM

• Based on VersaFEC ACM
• **Only product to support ACM with E1 RAN while maintaining service quality**
• ACM allows for automatic change in modulation and code rate in response to changing link conditions
  – Converts link margin into increased capacity
    ▪ Most of the year, the link operates at significantly increased throughput
    ▪ For the worst few hours of the year, the link may be available with lower throughput
  – Optimizes channel coding and modulation on a frame-by-frame basis
  – Allows each remote to operate optimally subject to antenna size, location within the footprint, rain fade and other impairments
ACM Maximizes Throughput During Rain Fade

User Traffic

Additional Capacity From ACM

Available Capacity Without ACM (Fixed Margin)
Ultra Low Overhead Encapsulation

• Ultra low overhead Streamline Encapsulation (SLE)
  - Patent pending
  - Reduces encapsulation overhead
    ▪ Up to 65% compared to HDLC
    ▪ Up to 95% compared to AAL5 used in DVB-RCS
    ▪ Up to 90% compared to proprietary framing used by other VSATs

• Enhanced Generic Stream Encapsulation
  - 70-80% more efficient compared to MPE
  - 20-30% more efficient compared to GSE

Comtech SLE overhead is 90-95% lower compared to traditional VSAT return framing / encapsulation
Stampede WAN Optimisation

“Reduce OPEX, Improve User Experience”

- **Reduce OPEX by:**
  - Shrinking the Data
  
  - Keeping the Pipe Full

- **Improve User Experience by:**
  - Getting the Data there faster
    
    - Getting the Right Data there
Stampede technology optimizes Satellite Bandwidth

- **Content Reduction**
  
  “ Shrinks the Data”

  - Compression (lossless compression)
  - Image Smoothing (optional lossy compression)
  - Caching
    - Static (ADC-based)
    - Cache Differencing (including dynamic HTTP)
    - Microsoft updates (saves bandwidth on “Patch Tuesday”)
    - Data De-duplication (TCP applications)

- **Makes the pipe bigger** *(40-60+% with remotes, 10-15+% without)*
  
  - ISPs can support more users and applications without increasing bandwidth

  (requires remote appliances)
Stampede technology optimizes Satellite Bandwidth

- **Acceleration** (application & protocol)
  
  "Keep the pipe full, Get it there faster"
  
  - TCP Session Multi-threading (improves thru-put)
  
  - Improved TCP Congestion Control
  
  - Persistent Connections (reuses TCP sessions)
  
  - Protocol Optimization (reduces round trips, i.e., “chattiness”)
  
  ▪ specific personality modules for TCP, HTTP, FTP, CIFS, MAPI, POP3, SMTP, etc.

(requires remote appliances)
Memotec RAN Optimization

- RAN Optimization reduces the satellite bandwidth required for cellular backhaul
- Advanced VSAT Series provides maximum user control by allowing them to select the level of RAN optimization to achieve desired link quality and bandwidth savings
- Pre-emptive bandwidth management maintains superior voice and service quality even under WAN congestion
- Supporting E1 RAN and IP RAN, the Advanced VSAT Series for the first time provides a seamless migration from a legacy E1 RAN to an all IP RAN
E1 RAN Optimization

- CDM-840 supports integrated E1 RAN optimization
  - Abis Optimization
  - TDM compression
  - Support simultaneous E1 and Ethernet operation in Hub Spoke topology
  - Supports ACM with E1 RAN

- CXU-810 used at Hub
  - 16 x E1 version
  - 32 x E1 version
  - 63 x E1 version (TBD)

- Traffic trending
  - Ingress (E1 & LAN) and egress (WAN) traffic
  - Savings
  - Link quality
Vipersat NMS & dSCPC

- Full element management
  - CDM-800
  - CDD-880
  - CDM/ODM-840
  - CXU-810
  - CTOG-250
- Alarms and events
- Network wide firmware upgrade utility
- IP discovery and configuration utility
- Hub side M:N redundancy for CDD-880
- Basic catalog of Virtual Network Operator (VNO) templates
- Entry Channel Mode (ECM) for easy commissioning
- Centralized FAST code management
Vipersat NMS & dSCPC

• Dynamic bandwidth management
  – Bandwidth can be increased or decreased on demand
  – Lossless switching

• Switching Modes
  – Automatic Switching
    ▪ Load Switching
      – Transmission buffer capacity fill level triggers BW request
    ▪ Application Switching
      – Detection of specific application types triggers BW request
    ▪ ToS Switching
      – Predefined DiffServ values triggers BW request
  – Manual Switching
    ▪ Operator
    ▪ Maintenance
Virtual Network Operator (VNO)

VNO for Customer 1

VNO for Customer 2

Internet

HTTP/HTML

Firewall

Service Provider Hub

Customer 1

Customer 2

Comtech EF Data Proprietary & Confidential
Return Channel Spread Spectrum

- Supports Communication on the Move (COTM) and Maritime applications
- Programmable chip rate
  - 1 (no spreading)
  - 2
  - 4
  - 8
  - 16
Bandwidth Efficiency

• DVB-S2 Outbound
  – Low Overhead Enhanced Generic Stream Encapsulation
  – Adaptive Coding & Modulation (ACM)
  – Variable Coding & Modulation (VCM)

• VersaFEC Return
  – Ultra Low Overhead Streamline Encapsulation (SLE)
  – Adaptive Coding & Modulation (ACM)

• Header Compression
  – IP/UDP/RTP, TCP/IP, IP/UDP etc

• 2nd Generation Lossless Payload Compression

• RAN Optimization

• WAN Optimization

• Vipersat dSCPC
Total Cost of Ownership

- Advanced VSAT Solutions provide the lowest Total Cost of Operation (TCO)
  - OPEX Savings
    - Advanced Modulation & FEC combined with higher layer optimization provide maximum bandwidth efficiency
      - Highest bps / Hz
  - CAPEX Savings
    - High bandwidth efficiency combined with advanced FEC, minimize transmit power requirement
      - Smaller Antenna
      - Smaller BUC
    - Integrated E1 RAN optimization
    - Integrated WAN optimization (future)
Lossless Payload Compression (2\textsuperscript{nd} Generation)

- Most real world data has statistical redundancy
- Lossless data compression works by encoding source information using fewer bits
  - E.g. a repeating pattern is replaced with a pointer

11 bytes of data is replaced by 3 bytes

60\%+ savings for Calgary test suite
**Header Compression**

Layer 3 & 4 Header Compression
- IP
- TCP
- UDP
- RTP (Codec Independent)

60%+ Savings for Voice
Mobile Backhaul
(IP BTS Traffic Optimization)

Almost 50% Savings
Mobile Backhaul
(IP BTS Traffic Optimization)

Almost 50% Savings
Service Quality

• Multi-service platform
  – Optimized for seamlessly delivering multiple services in a hub-spoke environment
    ▪ 2G/3G cellular backhaul
    ▪ Real-time interactive voice and video
    ▪ Streaming video and audio
    ▪ Enterprise data
    ▪ Internet access
  – While providing superior Quality of Service
    ▪ Minimal latency for real-time traffic
    ▪ Minimal jitter for real-time traffic
Voice Quality Factors

- ITU has specified Quality of Experience Factors for voice traffic

<table>
<thead>
<tr>
<th>MOS</th>
<th>Quality</th>
<th>Impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Excellent</td>
<td>Imperceptible</td>
</tr>
<tr>
<td>4</td>
<td>Good</td>
<td>Perceptible but not annoying</td>
</tr>
<tr>
<td>3</td>
<td>Fair</td>
<td>Slightly annoying</td>
</tr>
<tr>
<td>2</td>
<td>Poor</td>
<td>Annoying</td>
</tr>
<tr>
<td>1</td>
<td>Bad</td>
<td>Very annoying</td>
</tr>
</tbody>
</table>

Mean Opinion Score

<table>
<thead>
<tr>
<th>Network parameter</th>
<th>Good</th>
<th>Acceptable</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay</td>
<td>0-150 ms</td>
<td>150-300 ms</td>
<td>&gt; 300 ms</td>
</tr>
<tr>
<td>Jitter</td>
<td>0-20 ms</td>
<td>20-50 ms</td>
<td>&gt; 50 ms</td>
</tr>
<tr>
<td>Loss</td>
<td>0-0.5 %</td>
<td>0.5-1.5%</td>
<td>&gt; 1.5%</td>
</tr>
</tbody>
</table>
Traditional VSAT Jitter & Latency

- A number of independent tests have noted excessive jitter and latency for traditional VSATs
- Testing performed by a major operator found wide variations in delay, jitter and voice quality

<table>
<thead>
<tr>
<th>VSAT Configuration</th>
<th>Metric</th>
<th>Measured Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outbound ~ 6.5 Mbps&lt;br&gt;Return ~ 825 kbps</td>
<td>Speech Quality (MOS)</td>
<td>2.07 (Codec MOS is 4.1)</td>
</tr>
<tr>
<td>Committed Information Rate (CIR)&lt;br&gt;Bandwidth On Demand (BoD)&lt;br&gt;Frequency Hopping (Intended to improve BW sharing)</td>
<td>Round Trip Delay</td>
<td>988 – 1198 ms</td>
</tr>
<tr>
<td></td>
<td>Jitter</td>
<td>Up to 183.9 ms</td>
</tr>
</tbody>
</table>

This level of Jitter & Latency would degrade voice services while making data services practically non-functional with throughput as low as 100’s of bps to a few kbps
Flexible & Scalable Platform

• Highly scalable and flexible platform that can grow with the network
  – Start with a few remotes
  – Add remotes and hub receivers as needed
  – Outbound can scale to 160 Mbps
  – Returns can scale to 15.35 Mbps