GE Multilin Lentronics Multiplexers

SONET 101

Aman Mangat
What is SONET?

SONET = Synchronous Optical NETwork

- **Optical** = This is a standard for optical telecommunications. (Although some SONET rates can be transported over microwave radio.)

- **Synchronous** = All terminals in a SONET network are normally timed from the same clock source.
What Preceded SONET?

- Prior to SONET, digital transmission systems were generally asynchronous, with each terminal running on its own clock.

**North American Asynchronous Digital Transmission Hierarchy (PDH)**

- The bit rates produced by devices running at nominally the same rate could be slightly different (within specified range).
  - DS1: 1544 kb/s ± 50 ppm (±77 bits/sec)
  - DS3: 44,736 kb/s ± 20 ppm (±895 bits/sec)

- PDH = Plesiochronous Digital Hierarchy (Plesiochronous = Almost Synchronous)

* Not recognized by ITU-T
Timing in Asynchronous System

Site A

- $f_{1A}$
- $T_{1A}$
- $R_{1A}$
- $f_{nA}$
- $T_{nA}$
- $R_{nA}$

Site B

- $f_{1B}$
- $R_{1B}$
- $T_{1B}$
- $f_{nB}$
- $R_{nB}$
- $T_{nB}$
Timing in Synchronous System
## Asynchronous vs. Synchronous

<table>
<thead>
<tr>
<th>Asynchronous Multiplexing</th>
<th>Synchronous Multiplexing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit stuffing. During multiplexing, extra bits are added to account for bit rate variations.</td>
<td>No need for bit stuffing.</td>
</tr>
<tr>
<td>No “visibility” of lower order signals in a higher-order multiplex signal.</td>
<td>Full “visibility” of lower order signals in a higher-order multiplex signal.</td>
</tr>
<tr>
<td>Lower-order signals cannot be accessed without demultiplexing.</td>
<td>Lower-order signals can be added/dropped without demultiplexing of the higher order signal.</td>
</tr>
</tbody>
</table>
Asynchronous “Drop/Insert”

- Multi-stage multiplexing/demultiplexing
- Multiplex equipment connected back-to-back
Synchronous “Drop/Insert”

- Single-stage multiplexing/demultiplexing
- Complete add/drop functionality provided in one box
SONET Objectives

- Eliminate need for multi-stage multiplexing
- Provide optical interconnectivity in multi-vendor environment ("mid-span meet")
- Enhance Operations, Administration, and Maintenance (OAM)
  - Provide sufficient capacity for transmitting overhead information
  - Create basis for efficient Network Management System
- Come up with a universal multiplex signal structure applicable to all (even future) SONET rates
- Ensure scalability of bandwidth allocations to services
  - Position the network for transport of new services (ATM, IP, Video...)
- Ensure backward compatibility
  - Transparent for legacy PDH transport signals
## SONET Signal Hierarchy

<table>
<thead>
<tr>
<th>STS Level</th>
<th>OC Level</th>
<th>Bit Rate (Mbit/s)</th>
<th># of DS1s</th>
<th># of DS0s</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS-1</td>
<td>OC-1</td>
<td>51.84</td>
<td>28</td>
<td>672</td>
</tr>
<tr>
<td>STS-3</td>
<td>OC-3</td>
<td>155.52</td>
<td>84</td>
<td>2016</td>
</tr>
<tr>
<td>STS-12</td>
<td>OC-12</td>
<td>622.08</td>
<td>336</td>
<td>8064</td>
</tr>
<tr>
<td>STS-48</td>
<td>OC-48</td>
<td>2488.32</td>
<td>1344</td>
<td>32,256</td>
</tr>
<tr>
<td>STS-192</td>
<td>OC-192</td>
<td>9953.28</td>
<td>5376</td>
<td>129,024</td>
</tr>
</tbody>
</table>

STS = Synchronous Transport Signal  
OC = Optical Carrier
Building the future together

STS-1 Frame Format

810 bytes (125 µs)

STS-1 signal (51.84 Mbit/s)

3 columns

87 columns

9 rows

125 µs

90 columns

Column width = 1 Byte (8 bits)
Building the future together

STSS-N Frame Format

N x 90 columns

Transport Overhead

STS-1 Envelope Capacity

N x 87 columns

9 rows

N x 3 columns

125 μs

N x 90 columns
SONET Multiplexing Hierarchy

10 Gb/s
- OC-192
- STS-192

2.5 Gb/s
- OC-48
- STS-48

622 Mb/s
- OC-12
- STS-12

155 Mb/s
- OC-3
- STS-3

52 Mb/s
- OC-1
- STS-1
- SPE

VT Group

VT-6
- 6 Mb/s
- x2

VT-3
- 3 Mb/s
- x3

VT-2
- 2 Mb/s
- x4

VT-1.5
- 1.5 Mb/s
- x7

Building the future together
STS-1 Signal Structure

SONET CLOCK

STS-1 or OC-1 (51.84 Mb/s)

TOH

STS-1 SPE
(STS-1 Synchronous Payload Envelope)

} 3.3%
Sub-STS-1 Synchronous Signals

STS-1 or OC-1 (51.84 Mb/s) → TOH

STS-1 SPE (∼ 50 Mb/s)
- VT6 (1 x DS2)
- VT3 (1 x DS1C)
- VT2 (1 x E1)
- VT1.5 (1 x DS1)

STS-1 SPE =
- 1 x DS3 (or a broadband tributary signal), or
- VT-structured (7 x VT Groups)

VT Group
- 1 x VT6, or
- 2 x VT3, or
- 3 x VT2, or
- 4 x VT1.5

STST-1 SPE = 28 VT1.5 = 28 DS1s = 672 DS0 channels
Sub-STS-1 Synchronous Signals

OC-12

STS-1 SPE # 1
STS-1 SPE # 2
STS-1 SPE # 3
STS-1 SPE # 12

ATM
Ethernet
DS3

DS1
Ethernet

VT1.5 # 1
VT1.5 # 2
VT1.5 # 28

DS0 # 1
RS-232
VF
Teleprotection
56/64k Data

DS0 # 2

DS0 # 24

Optical Level
STS-1 SPE Level
VT Level
DS0 Level
STS-1 Frame Format

- **Transport Overhead**: 3 columns
- **Payload**: 87 columns

**STS-1 SPE** (Synchronous Payload Envelope)
87 columns

125 µs
Building the future together

STS-1 Pointer

STS-1 Frame

Transport Overhead

0 µs

250 µs

125 µs

STS-1 POH

STS-1 SPE

1 2 3

H1 H2 H3

J1 B3 C2 G1 F2 H4 Z3 Z4 N1

STS-1 POH

Negative Stuff Opportunity Byte

N = New Data Flag bit

To indicate:
Positive Stuff - Invert 5-I bits
Negative Stuff - Invert 5-D bits
New pointer value - Invert NDF bits

Normal:

0 1 1 0 0 0

Pointer Value (0-782 dec)
Positive Justification

1 2 3

STS-1 Frame

0 µs

125 µs

250 µs

375 µs

Pointer value = p

H1 H2 H3

Frame n

Positive Stuff Byte

Pointer value = “+”

H1 H2 H3

Frame n+1

Pointer value = p+1

H1 H2 H3

Frame n+2

157

169

125

90
Negative Justification

 Pointer value = p

 Pointer value = “-”

 Pointer value = p-1

 STS-1 Frame

 Frame n

 125 µs

 Frame n+1

 250 µs

 Frame n+2

 375 µs

 Negative Stuff Byte
Benefits of Pointer Use

- Dynamic and flexible phase alignment of SPEs
  - Ease of dropping, inserting, and cross-connecting payloads

- Transparent transport of SPEs across network boundaries with plesiochronous timing sources.

- Accommodate transmission signal wander (low frequency jitter).

- Eliminate delays and loss of data associated with use of large (125 μs frame) slip buffers for synchronization.
VT Superframe

VT1.5 Superframe

VT Envelope Capacity (excludes V1, V2, V3, V4 bytes)

VT SPE floats within VT Envelope Capacity.

VT Payload Pointer (V1 and V2 bytes) points to the start of VT1.5 Payload).

VT Payload Capacity = VT SPE – VT POH

Asynchronous Mapping of DS1

Byte-Synchronous Mapping of DS1

I - Information bit
R - Fixed stuff bit
O - Overhead bit
S - Stuff opportunity bit
C - Stuff control bit

P - Sig. Phase Indicator
S - Signaling bit
F - DS1 framing bit
R - Fixed stuff bit
VT Pointer Bytes (V1 and V2)

General:

<table>
<thead>
<tr>
<th>N</th>
<th>N</th>
<th>N</th>
<th>N</th>
<th>S</th>
<th>S</th>
<th>I</th>
<th>D</th>
<th>I</th>
<th>D</th>
<th>I</th>
<th>D</th>
<th>I</th>
<th>D</th>
<th>I</th>
<th>D</th>
</tr>
</thead>
</table>

10-bit Pointer Value

VT1.5:

| 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | '6C' |

| Pointer Value (0-103 dec) |

S bits = VT Type (Size) Indication

<table>
<thead>
<tr>
<th>SS</th>
<th>VT Type</th>
<th>VT Size</th>
<th>VT Pointer Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>VT6</td>
<td>428</td>
<td>0 - 427</td>
</tr>
<tr>
<td>01</td>
<td>VT3</td>
<td>212</td>
<td>0 - 211</td>
</tr>
<tr>
<td>10</td>
<td>VT2</td>
<td>140</td>
<td>0 - 139</td>
</tr>
<tr>
<td>11</td>
<td>VT1.5</td>
<td>108</td>
<td>0 - 103</td>
</tr>
</tbody>
</table>

To indicate:
- Positive Stuff - Invert 5-I bits
- Negative Stuff - Invert 5-D bits
- New Pointer Value - Invert NDF bits

VT SPE Size = VT Envelope Capacity = VT Superframe Size

V1, V2, V3, V4
VT Path Overhead Byte (V5)

**Signal label coding:**

<table>
<thead>
<tr>
<th>0</th>
<th>0</th>
<th>0</th>
<th>Unequipped (unassigned)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Equipped – non-specific</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>Equipped – asynchronous mapping (DS1/E1/DS1C/DS2)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Bit-Synchronous Mapping of DS1/E1 (removed from standard)</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Byte-Synchronous Mapping of DS1/E1</td>
</tr>
</tbody>
</table>

**ACRONYM** | **NAME** | **USAGE**
---|---|---
BIP-2 | Bit Interleaved Parity | Error Detection (used to calculate BER at receive end)
REI-V | VT Path Remote Error Indication | Info on errors detected in opposite signal direction (so far-end BER can be calculated)
RFI-V | VT Path Remote Failure Indication | Used in byte-synchronous DS1 mapping applications only
RDI-V | VT Path Remote Defect Indication | Status of signal received at transmit end (opposite signal direction) (1 = ‘VT Yellow Alarm’; 0 = No ‘VT Yellow Alarm’)

FEBE | Far End Block Error |
FERF | Far End Receive Failure |
VT1.5 Superframe

Example with Byte-Synchronously mapped payload capacity

<table>
<thead>
<tr>
<th>Bit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>Next Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

* H4 Byte is an STS-1 POH Overhead byte.
VT1.5 Frame within STS-1 SPE Frame*

*Carrying only VT1.5s
**VT1.5 Superframe within STS-1 signal**

<table>
<thead>
<tr>
<th>H1</th>
<th>H2</th>
<th>H3</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>B3</td>
<td>60</td>
</tr>
<tr>
<td>82</td>
<td>C2</td>
<td>63</td>
</tr>
<tr>
<td>85</td>
<td>G1</td>
<td>66</td>
</tr>
<tr>
<td>88</td>
<td>F2</td>
<td>69</td>
</tr>
<tr>
<td>91</td>
<td>H4</td>
<td>72</td>
</tr>
<tr>
<td>94</td>
<td>Z3</td>
<td>75</td>
</tr>
<tr>
<td>97</td>
<td>Z4</td>
<td>78</td>
</tr>
<tr>
<td>100</td>
<td>N1</td>
<td>81</td>
</tr>
<tr>
<td>103</td>
<td>J1</td>
<td>84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>H1</th>
<th>H2</th>
<th>H3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>C2</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>G1</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>F2</td>
<td>11</td>
</tr>
<tr>
<td>13</td>
<td>H4</td>
<td>14</td>
</tr>
<tr>
<td>16</td>
<td>Z3</td>
<td>17</td>
</tr>
<tr>
<td>19</td>
<td>Z4</td>
<td>20</td>
</tr>
<tr>
<td>22</td>
<td>N1</td>
<td>23</td>
</tr>
<tr>
<td>25</td>
<td>J1</td>
<td>26</td>
</tr>
<tr>
<td>27</td>
<td>B3</td>
<td>28</td>
</tr>
<tr>
<td>30</td>
<td>C2</td>
<td>31</td>
</tr>
<tr>
<td>33</td>
<td>G1</td>
<td>34</td>
</tr>
<tr>
<td>36</td>
<td>F2</td>
<td>37</td>
</tr>
<tr>
<td>39</td>
<td>H4</td>
<td>40</td>
</tr>
<tr>
<td>42</td>
<td>Z3</td>
<td>43</td>
</tr>
<tr>
<td>45</td>
<td>Z4</td>
<td>46</td>
</tr>
<tr>
<td>48</td>
<td>N1</td>
<td>49</td>
</tr>
<tr>
<td>51</td>
<td>J1</td>
<td>50</td>
</tr>
<tr>
<td>53</td>
<td>B3</td>
<td>51</td>
</tr>
<tr>
<td>56</td>
<td>C2</td>
<td>52</td>
</tr>
<tr>
<td>59</td>
<td>G1</td>
<td>53</td>
</tr>
<tr>
<td>62</td>
<td>F2</td>
<td>54</td>
</tr>
<tr>
<td>65</td>
<td>H4</td>
<td>55</td>
</tr>
<tr>
<td>68</td>
<td>Z3</td>
<td>56</td>
</tr>
<tr>
<td>71</td>
<td>Z4</td>
<td>57</td>
</tr>
<tr>
<td>74</td>
<td>N1</td>
<td>58</td>
</tr>
</tbody>
</table>

**STS-1 Frame**

<table>
<thead>
<tr>
<th>VT#3 - Column 1 (STS-1 SPE Column#4)</th>
<th>VT#3 - Column 2 (STS-1 SPE Column#33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>125 µs</td>
</tr>
<tr>
<td>15</td>
<td>250 µs</td>
</tr>
<tr>
<td>26</td>
<td>375 µs</td>
</tr>
<tr>
<td>41</td>
<td>500 µs</td>
</tr>
<tr>
<td>67</td>
<td>625 µs</td>
</tr>
</tbody>
</table>

---

**Building the future together**
Multiplexing of VTs into STS-1 SPE

VT Group 1
4 x VT1.5

VT Group 2
3 x VT2

VT Group 3
2 x VT3

VT Group 4
1 x VT6

VT Groups 5, 6, 7

STS-1 POH

Fixed Stuff

Fixed Stuff

Fixed Stuff

STS-1 SPE
# TOH and STS POH Structure

![Diagram of TOH and STS POH Structure](image)

<table>
<thead>
<tr>
<th>Framing</th>
<th>Framing</th>
<th>Trace</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>A2</td>
<td>J0</td>
</tr>
<tr>
<td>BIP-8</td>
<td>Orderwire</td>
<td>User</td>
</tr>
<tr>
<td>B1</td>
<td>E1</td>
<td>F1</td>
</tr>
<tr>
<td>Data Com D1</td>
<td>Data Com D2</td>
<td>Data Com D3</td>
</tr>
<tr>
<td>Pointer</td>
<td>Pointer</td>
<td>H1</td>
</tr>
<tr>
<td>H1</td>
<td>H2</td>
<td>H2</td>
</tr>
<tr>
<td>BIP-8</td>
<td>APS</td>
<td>APS</td>
</tr>
<tr>
<td>B2</td>
<td>K1</td>
<td>K2</td>
</tr>
<tr>
<td>Data Com D4</td>
<td>Data Com D5</td>
<td>Data Com D6</td>
</tr>
<tr>
<td>Data Com D7</td>
<td>Data Com D8</td>
<td>Data Com D9</td>
</tr>
<tr>
<td>Data Com D10</td>
<td>Data Com D11</td>
<td>Data Com D12</td>
</tr>
<tr>
<td>Sync</td>
<td>REI-L</td>
<td>Orderwire</td>
</tr>
<tr>
<td>S1</td>
<td>M0</td>
<td>E2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Line Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section Overhead</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STS Path Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS-1 SPE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transport Overhead</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Trace</th>
</tr>
</thead>
<tbody>
<tr>
<td>J1</td>
</tr>
<tr>
<td>B3</td>
</tr>
<tr>
<td>BIP-8</td>
</tr>
<tr>
<td>C2</td>
</tr>
<tr>
<td>Signal Lab.</td>
</tr>
<tr>
<td>User Chan.</td>
</tr>
<tr>
<td>F2</td>
</tr>
<tr>
<td>Path Status</td>
</tr>
<tr>
<td>G1</td>
</tr>
<tr>
<td>Multiframe</td>
</tr>
<tr>
<td>H4</td>
</tr>
<tr>
<td>Growth Z3</td>
</tr>
<tr>
<td>Z4</td>
</tr>
<tr>
<td>Growth</td>
</tr>
<tr>
<td>Z4</td>
</tr>
<tr>
<td>Tand. Conn. N1</td>
</tr>
</tbody>
</table>
SONET Network Elements

- **Terminal Multiplexer**
  - Tributaries
  - TM
  - SONET Aggregate

- **Add/Drop Multiplexer**
  - SONET Aggregate
  - ADM
  - Thru-Traffic
  - SONET Aggregate/Tributary
  - Async (PDH) Tributary or Wide/Broadband Service (Ethernet, ATM etc.)
  - Tributaries
## SONET Network Elements

- **Wideband Digital Cross-Connect (W-DCS)**

  A diagram showing cross-connects at VT level:
  - VT Switch
  - VT1.5
  - DS1
  - DS3
  - STS-N
  - VT Switch
  - VT1.5
  - DS1
  - DS3

  Arrows indicating connections between these elements.

  Cross-Connects at VT level

- **Broadband Digital Cross-Connect (B-DCS)**

  A diagram showing cross-connects at STS-1 level:
  - STS-1 Switch
  - STS-N/STS-nC
  - STS-1/STS-nC
  - STS-1
  - STS-1
  - DS3
  - DS1

  Arrows indicating connections between these elements.

  Cross-Connects at STS-1 level
SONET Network Elements

- Cross-Connect Functions

- Flexible Routing

- Traffic Consolidation

- Traffic Segregation

- Add/Drop
SONET Network Elements

- **Regenerator**

Needed when, due to long fiber distance, the optical signal level becomes too low.

- **Digital Loop Carrier (DLC)**

A concentrator for narrow-band services between subscribers, remote digital terminals and Central Office switches.

(For telco’s & carriers only)
SONET Network Topologies

- **Point-to-Point Topology**

- **Linear Add/Drop Topology**
SONET Network Topologies

- Hub Network

DCS = Digital Cross-Connect System
SONET Network Topologies

- Ring Network
SONET Network Topologies

- **Multiple Ring Network**

  - Single tie point
  - Two tie points ("Matched Nodes")
SONET Network Topologies

- "Combined" Network
Automatic Protection Switching

- Requires presence of alternate route
- Criteria for making the switching decision include:
  - AIS
  - Loss of pointer
  - Bit-error ratio
  - Path label set to “Unequipped”
    - STS POH: C2 byte
    - VT POH: Bits 5-7 of V5 byte
  - Remote Defect Indication (to prevent asymmetric delays)
**Automatic Protection Switching**

- **Linear Protection mechanisms**

  - **1+1**
  - **1:1**
  - **1:N**

   - No APS protocol required.
   - APS protocol required. May carry additional traffic in “P”.
   - APS protocol required. May carry additional traffic in “P”.

[Diagram of 1+1, 1:1, and 1:N protection mechanisms]
Automatic Protection Switching

- Bidirectional Line Switched Ring (BLSR)

24 Working STS-1 Channels
24 Protection STS-1 Channels
Automatic Protection Switching

- Unidirectional Path Switched Ring (UPSR)
RDI: Remote Defect Indication

Standby Signal Path

Online Signal Path

VT#1

OC-48
RDI: Remote Defect Indication

Symmetrical Standby Signal Path

OG-48

Symmetrical Online Signal Path

VT#1

Los

VT#1

A

B

C

RDI: Remote Defect Indication
Building the future together

OC-48

A

B

C

LOS

VT#1

RDI: Remote Defect Indication

Asymmetrical Signal Path

Asymmetrical Signal Path
RDI: Remote Defect Indication

- RDI Enabled
- AIS
- LOS
- OC-48

VT#1
RDI: Remote Defect Indication
Enabled

VT#1
AIS
RDI
Enabled
RDI: Remote Defect Indication

Building the future together

OC-48

A

B

C

LOS

VT#1

RDI: Remote Defect Indication

VT#1

AIS

RDI Enabled

RDI Enabled

AIS

RDI Enabled
<table>
<thead>
<tr>
<th>VT#1</th>
<th>RDI: Remote Defect Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS</td>
<td>RDI Enabled</td>
</tr>
<tr>
<td>Symmetrical Signal Path</td>
<td>Symmetrical Signal Path</td>
</tr>
</tbody>
</table>

**Symmetrical Signal Path**

**OC-48**

**VT#1**

**RDI: Remote Defect Indication**

**Enabled**
## Automatic Protection Switching

<table>
<thead>
<tr>
<th></th>
<th>BLSR</th>
<th>UPSR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Characteristics</strong></td>
<td>One half of each hop’s capacity is used for working traffic; other half for protection. Only working path for each bidirect. circuit is provisioned.</td>
<td>Each tributary signal mapped is sent both ways around the ring. At the demapping point, the better of the two receive paths is chosen.</td>
</tr>
<tr>
<td><strong>Type of switching</strong></td>
<td>Line layer (revertive or non-revertive). Both directions are switched simultaneously.</td>
<td>Path layer (revertive or non-revertive). Each direction is switched independently.</td>
</tr>
<tr>
<td><strong>APS protocol</strong></td>
<td>Yes (K1 &amp; K2 bytes). Rather complex protection switching mechanism limits the number of nodes to 16.</td>
<td>No. (Simple implementation.)</td>
</tr>
<tr>
<td><strong>Switch completion time</strong></td>
<td>Close to 50 ms.</td>
<td>Typically less than 10ms.</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Generally less expensive than UPSR.</td>
<td>Generally more expensive than BLSR (more hardware).</td>
</tr>
<tr>
<td><strong>Maximum total amount of traffic in ring</strong></td>
<td>Depends on traffic matrix. Generally higher than in UPSR rings.</td>
<td>Does not depend on traffic matrix. Limited to “hop capacity”.</td>
</tr>
<tr>
<td><strong>Potential for asymmetric delay</strong></td>
<td>No</td>
<td>Yes, but can be addressed by use of “Switch on RDI” function.</td>
</tr>
<tr>
<td><em><em>Able to carry additional</em> traffic?</em>*</td>
<td>Yes</td>
<td>No (Not/Applicable)</td>
</tr>
<tr>
<td><strong>Typical use</strong></td>
<td>Core networks</td>
<td>Access networks and some core networks.</td>
</tr>
</tbody>
</table>

* Additional traffic is lost in case of any hop failure.
SONET Benefits

- Single-stage multiplexing
  - No need for back-to-back multiplexing
  - Simple add/drop functionality
  - Simple implementation of linear and ring configurations
- Scalability of bandwidth allocation to various services.
- Reduced end-to-end delays (thanks to pointers)
- Traffic grooming (consolidation/segregation)
  - More efficient use of facilities
- Ability to interconnect different vendors’ equipment optically (“mid-span meet”)
- Powerful Network Management System
Are all SONET products acceptable for utilities?

- Can it operate in harsh environment?
- Does it implement a fast enough protection switching mechanism? (Important for mission critical applications.)
- Can the protection switching mechanism ensure the same delay for both directions of a bidirectional circuit regardless of the ring failure type? (Some relays are sensitive to “asymmetric” delays.)
- Does the overall solution provide acceptable end-to-end delays for mission critical applications?
- Is the implemented redundancy and related system availability acceptable?
- Does NMS cover all equipment in the system? (May be an issue if multiple vendor equipment is used, if “access” and “transport” are separated etc.)
- Can it support switching to alternate traffic routing for backup control center implementations (if required)?