IP Over SONET

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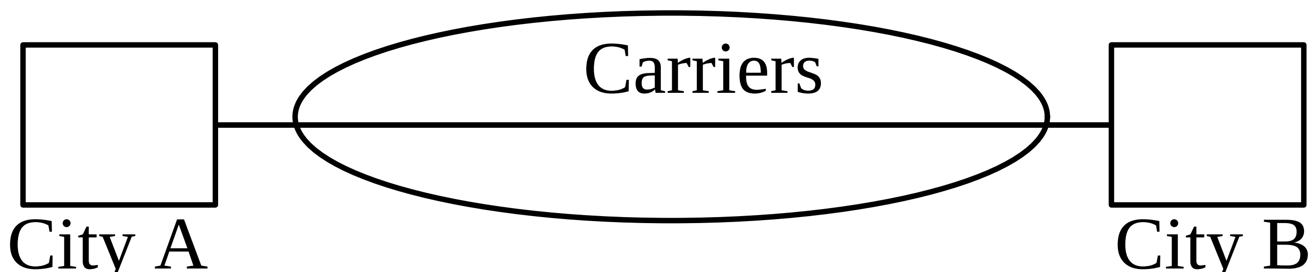
- IP over SONET: Trends, Users, Why?
- SONET: Key features
- PPP: Key features
- SONET vs ATM
- IP over SONET: Key Issues
- Products

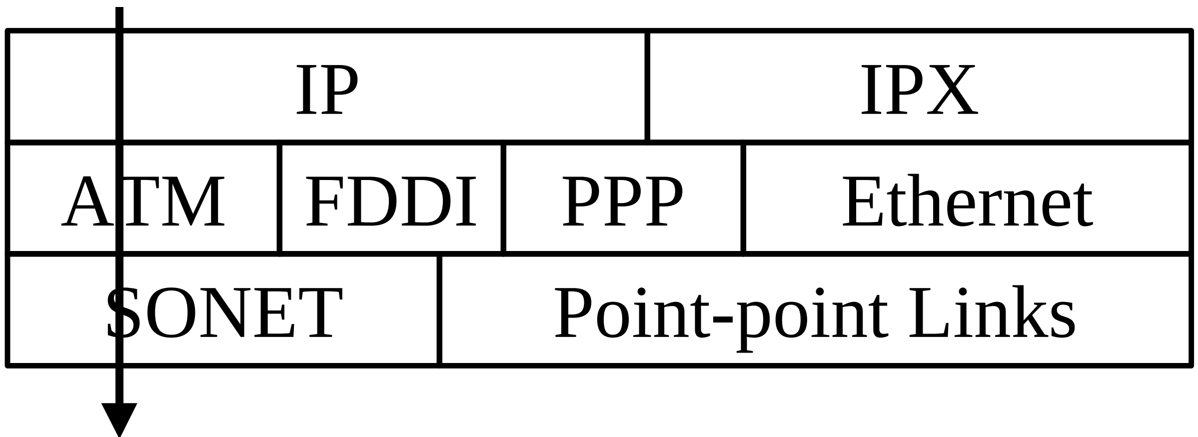
What is SONET?

- Synchronous optical network
- Standard for digital optical transmission (bit pipe)
- Developed originally by Bellcore.
  Standardized by ANSI T1X1
  Standardized by CCITT
  $\Rightarrow$ Synchronous Digital Hierarchy (SDH)
- You can lease a SONET connection from carriers

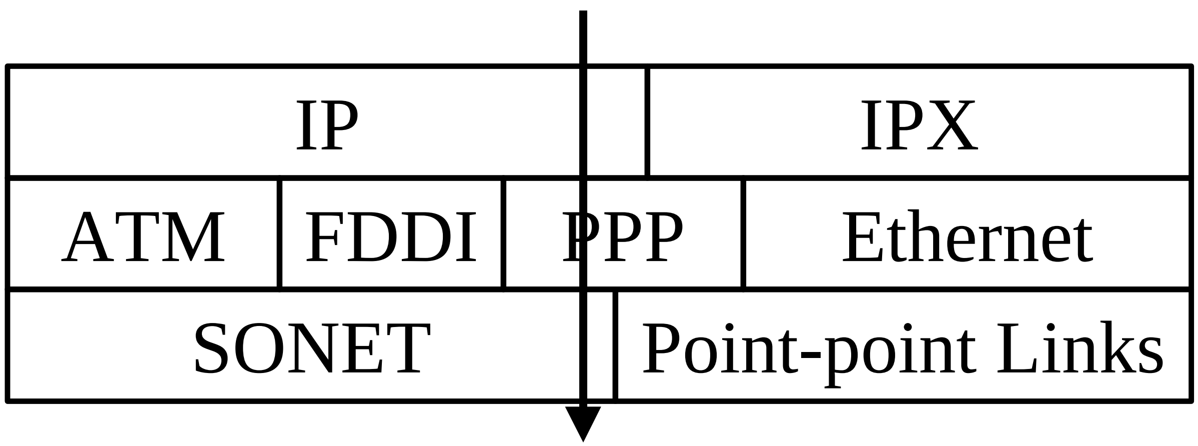


Changing Trends

- View Until Early 1996:



- View in Late 1996:



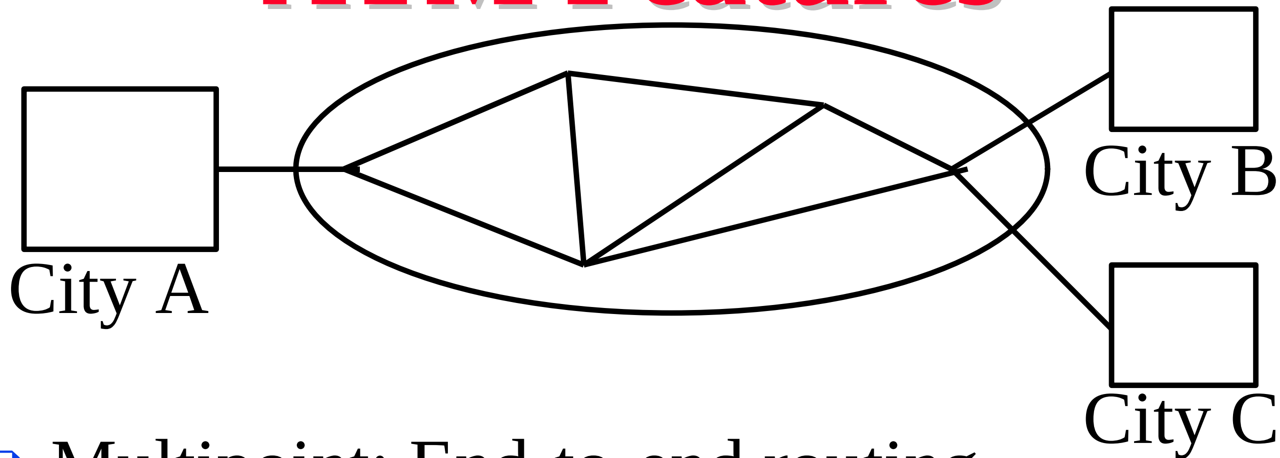
Trends (Cont)

- Originally, ATM has been designed for high-speed transfer of data, voice, video
- Carriers were expected to move to ATM networks
- SONET was designed as a high-speed physical layer for transmission over fiber-optic links
- ATM was expected to run over carrier's SONET links
- "IP over SONET" allows IP datagram transfers over high-speed carrier links using PPP
- SONET is appearing as a competition to ATM

IP over SONET: Users

- Trans-Atlantic IP-over-SONET between NYC and Stockholm in Sept'96.
- OC-3c SONET ring between US, England, and France by Sprint using CISCO 750's Oct'96.
- AT&T and Kokusai Denshin Denwa (KDD) 155 Mbps between San Francisco and Tokyo
- Internet Servers Inc (ISI) uses for high-volume Web server. Netscape and Yahoo use ISI.
- Ascend and IXC Communications trialed 155 Mbps between Fort Worth TX and El Paso TX (11/96).
- BBN PLANET, UUNET Technologies, and Sprint were experimenting in Jul'96.

ATM Features

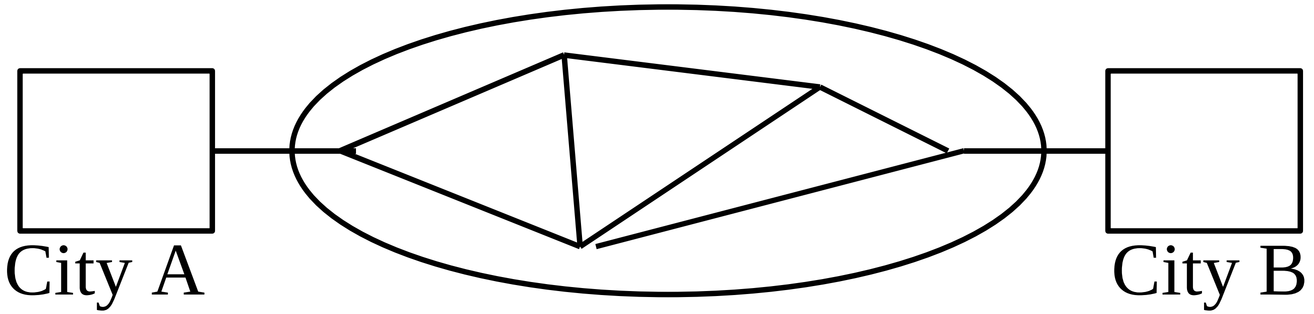


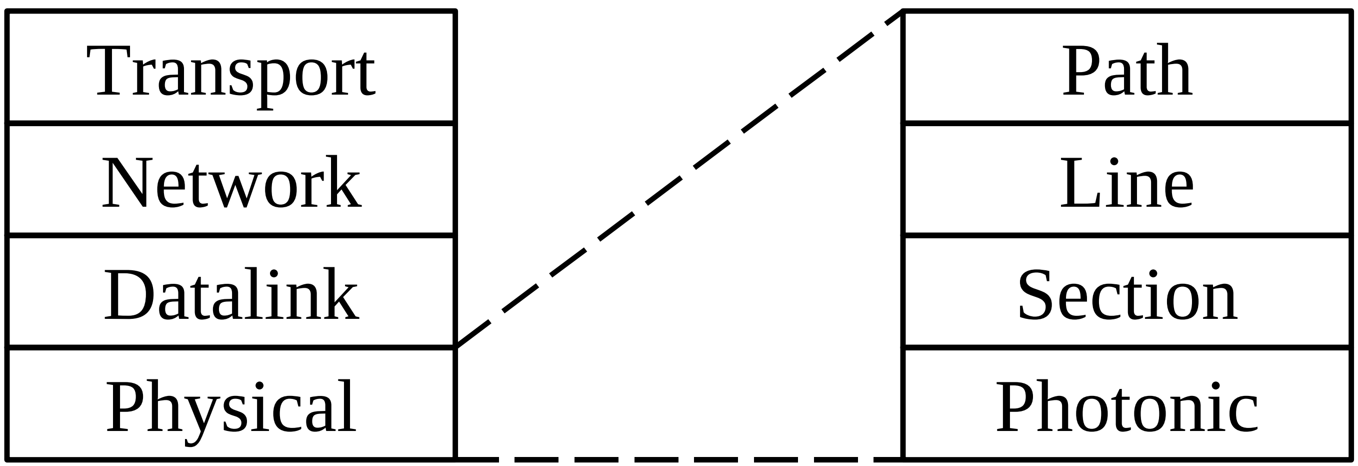
- Multipoint: End-to-end routing
- High-speed switching vs slow routing
- Quality of service
- Multiplexing of different QoS: Voice, Video, and data
- Signaling: Dynamic bandwidth
- Traffic Management: Overload/underload Control

All features cost overhead.

SONET Protocols

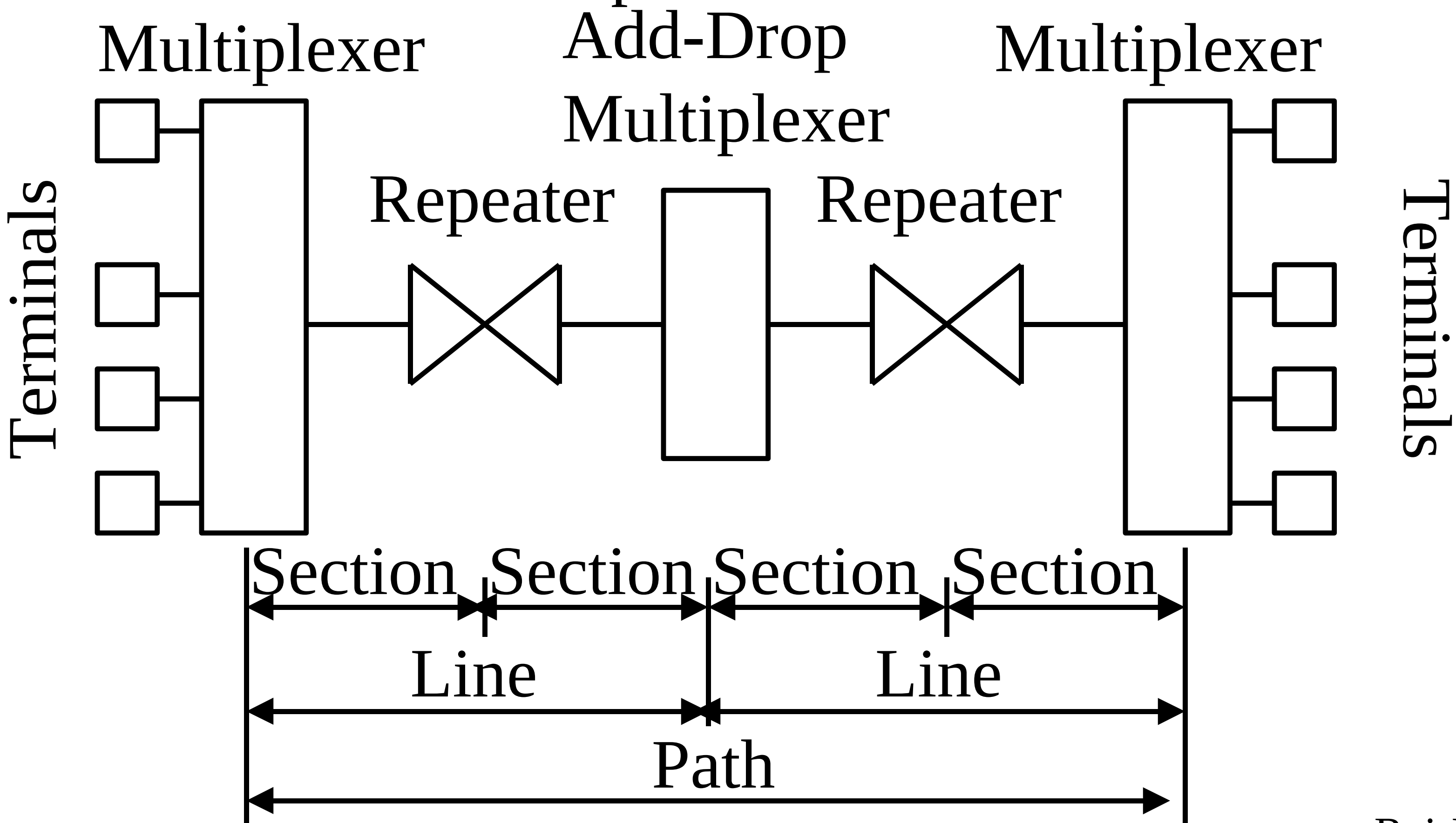
- Synchronous Optical **Network**





Physical Components

- Section = Single run of fiber
- Line = Between multiplexers



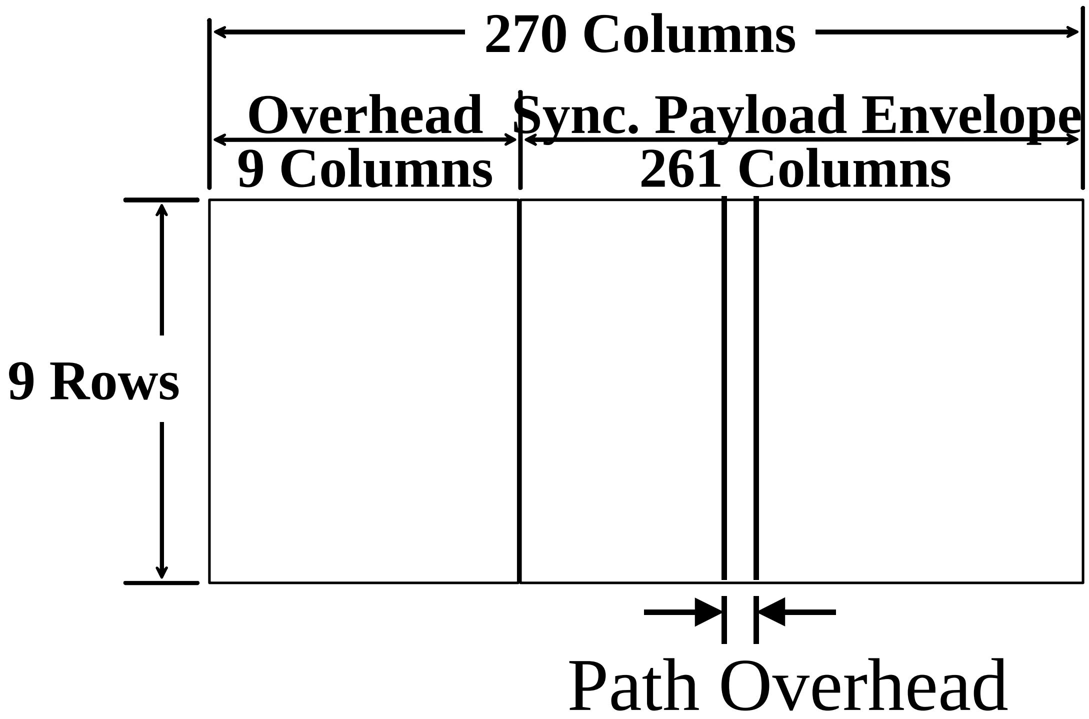
Signal Hierarchy

Synchronous Transport Signal Level *n* = STS-*n* = *n* × 51.84 Mbps
STM=Synchronous Transport Module, OC=Optical Carrier level

ANSI Designation	Optical Signal	CCITT Designation	Data Rate (Mbps)	Payload Rate (Mbps)
STS-1	OC-1		51.84	50.112
STS-3	OC-3	STM-1	155.52	150.336
STS-9	OC-9	STM-3	466.56	451.008
STS-12	OC-12	STM-4	622.08	601.344
STS-18	OC-18	STM-6	933.12	902.016
STS-24	OC-24	STM-8	1244.16	1202.688
STS-36	OC-36	STM-12	1866.24	1804.032
STS-48	OC-48	STM-16	2488.32	2405.376
STS-96	OC-96	STM-32	4976.64	4810.176
STS-192	OC-192	STM-64	9953.28	9620.928

STS-3c Frame Format

- STS-3c is similar to STM-1
- 125 μs = 2430 bytes at 155.54 Mbps



- Note: All sizes are multiples of 3

Scrambling

- SONET uses NRZ coding.
  1 = Light On, 0 = Light Off.
- Too many 1's or 0's ⇒ Loss of bit clocking information
- All bytes (except some overhead bytes) are scrambled
- Polynomial $1 + x^6 + x^7$ with a seed of 1111111 is used to generate a pseudo-random sequence, which is XOR'ed to incoming bits.

  1111 1110-0000 0100-0001 … 010
- If user data is identical to (or complement of) the pseudo-random sequence, the result will be all 0's or 1's.

Automatic Protection Switching

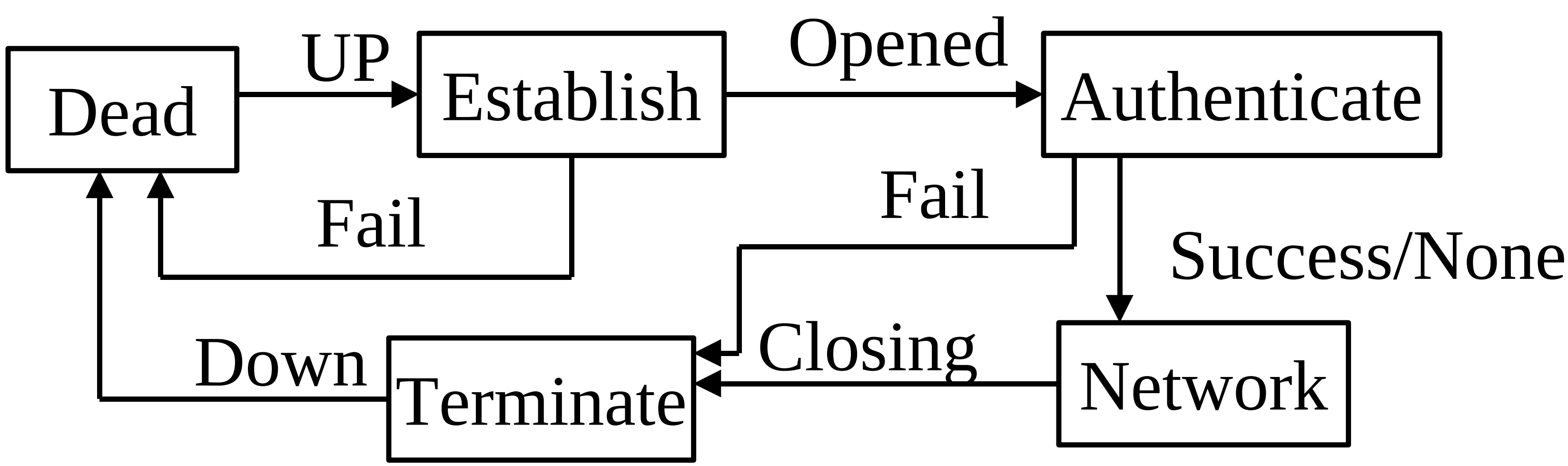
- 100 μs or more is "loss of signal"
  2.3 μs or less is not "loss of signal"
  In-between is up to implementations
- Most implementations use 13-27 μs
  ⇒ Higher speed lines ⇒ maintain sync for more bits
- APS allows switching circuits on fault
- May take up to 50 ms to complete
- Wastes entire links as standby.
- Protection by routers works faster than by SONET

HDLC Family

- Synchronous Data Link Control (SDLC): IBM
- High-Level Data Link Control (HDLC): ISO
- Link Access Procedure-Balanced (LAPB): X.25
- Link Access Procedure for the D channel (LAPD): ISDN
- Link Access Procedure for modems (LAPM): V.42
- Link Access Procedure for half-duplex links (LAPX): Teletex
- Point-to-Point Protocol (PPP): Internet
- Logical Link Control (LLC): IEEE
- Advanced Data Communications Control Procedures (ADCCP): ANSI
- V.120 and Frame relay also use HDLC

PPP: Introduction

- Point-to-point Protocol
- Originally for User-network connection
- Now being used for router-router connection
- Three Components: Data encaptulation, Link Control Protocol (LCP), Network Control Protocols (NCP)



PPP Procedures

- Typical connection setup:
  - Home PC Modem calls Internet Provider's router: sets up physical link
  - PC sends series of LCP packets
    - Select PPP (data link) parameters
    - Authenticate
  - PC sends series of NCP packets
    - Select network parameters
      E.g., Get dynamic IP address
- Transfer IP packets

PPP in HDLC-Like Framing

Flag	Address	Control	Protocol
01111110	11111111	00000011	

Info	Padding	CRC	Flag

- Flag = 0111 1110 = 7E
- Byte Stuffing:

  7E $\Rightarrow$ 7D 5E

  7D $\Rightarrow$ 7D 5D

Framing (Cont)

- Address=FF ⇒ All stations
- Control=03 ⇒ Unnumbered
  Poll/final = command/response = 0 ⇒ Response
- Protocol = 8/16 bits. lsb=1 of LSB ⇒ End of address
  All protocols are odd and lsb of MSB = 0
- Packets may be padded up to MRU.
  Maximum receive unit = 1500 default
- 16-bit FCS default
  32-bit FCS can be negotiated using LCP
- HDLC Shared zero mode:
  011111101111110 = Flag-Flag. Not used in PPP

LCP Config Options

- Maximum Receive Unit
- Authentication Protocol: C0 23 $\Rightarrow$ Password
  C2 23 $\Rightarrow$ Challenge Handshake
- Quality Protocol: C025 $\Rightarrow$ Will expect link reports
- Magic Number: To related responses with requests
  Randomly number in sequence of the request
  Helps detect looped back links
- Protocol Field Compression:
  Only one byte is used even for 2-byte protocols
- Address and Control Field Compression:
  FF03 is not transmitted. CRC is on compressed frame.

PPP over SONET

- In PPP/LCP [RFC 1619]:
  - Magic Number
  - No Address and Control field compression
  - No Protocol field compression
  - 32-bit FCS
- In SONET:
  - No Scrambling of Payload
  - PATH Signal Label (C2) = 207 = CF
    = Content type

SONET vs ATM

1. Overhead:
   - SONET claimed to provide 25-30% higher throughput than ATM.
   - IPOA encaptulation, AAL5 trailer, ATM cell headers eliminated in SONET
   - 155.52 Mbps Link ⇒ 149.76 ATM ⇒ 135.63 ATM payload
   - 9.5% more throughput (135.63 Mbps vs 149 Mbps) = 9 T1 Lines out of 96
   - 6% for ABR flow control. Nothing for UBR/CBR/VBR.
   - Signaling overhead for SVCs.

SONET vs ATM (Cont)

2. SONET Reliability through APS
   APS wastes entire links as standby.
   Long APS times can badly interact with routing
3. ATM provides multiservice integration
4. ATM provides traffic management (oversubscription)
5. SONET needs to be provisioned.
   ATM allows SVCs also.
6. ATM allows multiple secure VCs on the same physical interface.

SONET vs ATM (Cont)

7. SONET managed by TL-1 protocol. Will migrate to CMIP. IP and ATM can be managed by SNMP. Can't configure SONET equipment/ bandwidth from IP platform.
8. PPP byte stuffing create unpredictable traffic $\Rightarrow$ QoS difficult
9. No Priorities or preemption in IP/PPP/SONET $\Rightarrow$ QoS not feasible currently
10. PPP is a single-destination protocol. You can reach only one destination using one link. ATM is a multi-destination protocol.

SONET vs ATM (Cont)

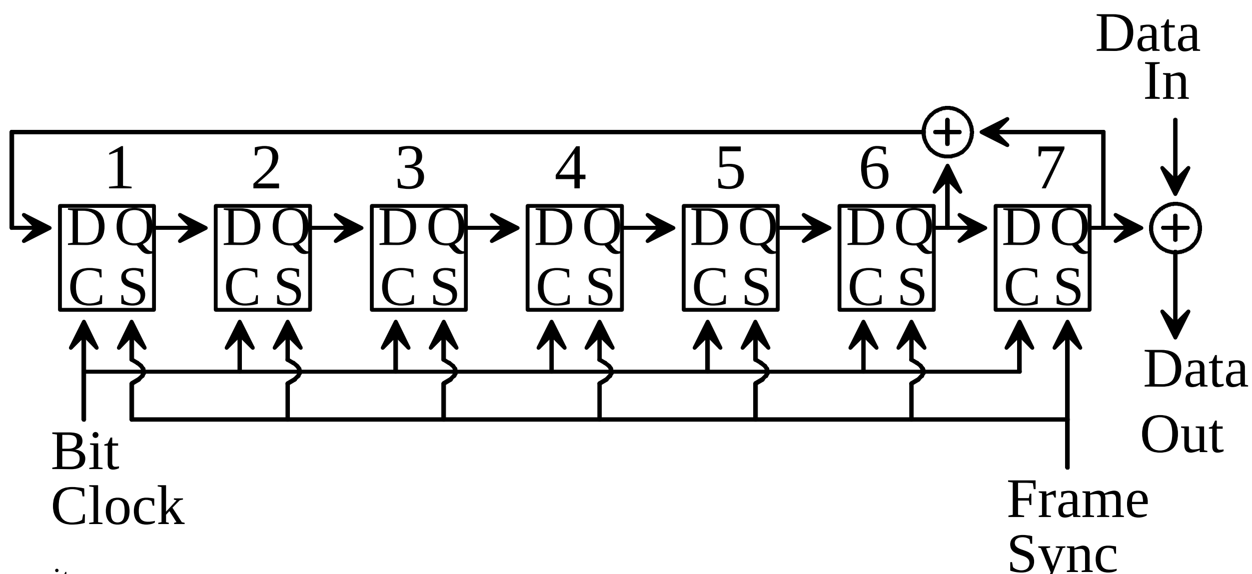
SONET allows multiple destinations from one link using multiple OC-n frames but PPP cannot use this feature.

11. Multicast: No support in SONET.
    Handled in IP.
    Multicast over SONET being designed.
    Multiple Access Protocol Over SONET (MAPOS)
12. Delay: Every hop of SONET
    introduces a 125-μs delay regardless of speed
    ⇒ Cut through routing is difficult
13. SONET payload scrambling is an issue.

Scrambling: Introduction

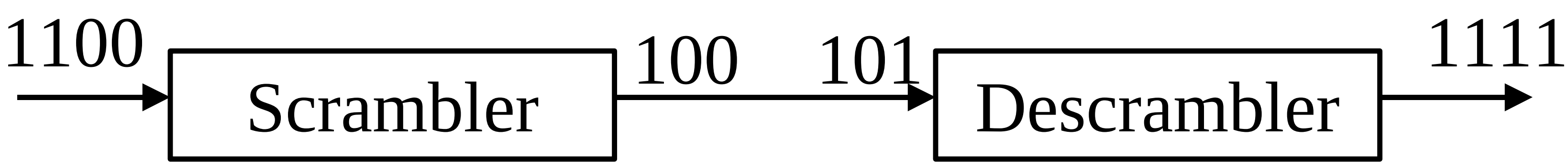
1. Add random sequence
2. Divide by a number and send quotient.
   Similar to CRC.

Both implemented by shift-registers.
   Analyzed using polynomials. $1+x^6+x^7$



Scrambling (Cont)

- Set-Reset Synchronous scrambler:
  Add a fixed random bit pattern.
  Need to tell where to start adding
  $\Rightarrow$ Need to synchronize.
- Self-synchronous scrambler: Divide by a fixed number. No need for synchronization.
  Errors multiply.
- Example: Send 12 using divider 3 $\Rightarrow$ Send 4.
  Received 5 $\Rightarrow$ 15.



Payload Scrambling Issue

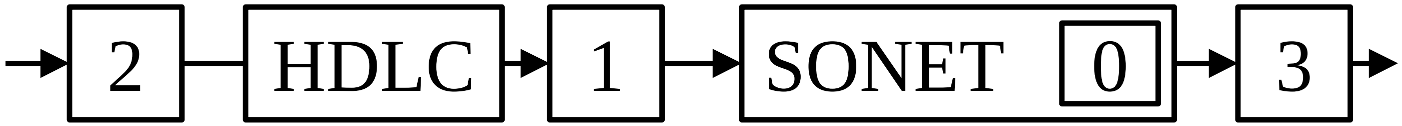
- 21 1500-byte datagrams will ensure 2080 bits of 0's/1's (13 μs at STS-3c) resulting in Loss of signal, framing, and Sync [T1X1.5/97-134, 97-130]
- Standard requires 2.3-100 μs LOS. Most interfaces are on the low end. Most interfaces can't keep clock sync after 80 bits
- Carriers tariffs based on failures and errors guarantees ⇒ Customer can cause excessive failures and no way for carriers to trace it.
- A single packet can disrupt a large number of users.
- APS is triggered ⇒ Disruption could last up to 50 ms.

Scrambling: Solutions

1. ANSI T1X1.5+IETF recommend using $1+x^{43}$ for PPP over SONET for STS-1 through STS-48. Higher or lower rates require further study.

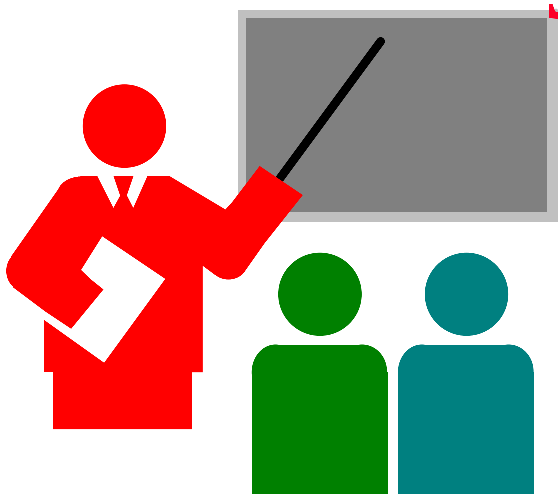
- A path signal label different from 207 will be used to differentiate scrambled and non-scrambled payloads.
- Self-synchronous scrambler ⇒ error-multiplying. 1-bit error on the line ⇒ 2-bit errors in packet
- Some error patterns detectable w/o scrambler are undetectable with scrambler
- FCS bit ordering (lsb) and scrambler bit ordering (msb) also have some effect.

Solutions (Cont)



2. Scramble PPP before HDLC framing
   ⇒ Requires disabling errored HDLC
   frame discard. Does not protect against framer errors.
3. Scramble the SONET scrambler output.
4. Use $1+x^2+x^{19}+x^{21}+x^{40}$ set-reset frame synchronous scrambler
5. Avoid long sequences of zeros in the SONET scrambler output by pattern matching HDLC packet and byte-stuffing.

Summary



- IP over SONET = IP over PPP in HDLC-like framing over SONET/SDH
- SONET does not provide QoS, Dynamic bandwidth (SVCs), QoS multiplexing, traffic management
- Payload scrambling is a hot issue

References

- For a detailed list of references, see http://www.cis.ohio-state.edu/~jain/refs/snt_refs.htm
- RFC 1619, PPP over SONET/SDH,
- RFC 1662, PPP in HDLC-like Framing
- RFC 1661, The Point-to-Point Protocol (PPP)
- "PPP Over SONET Mapping", 10/23/1997, draft-allen-pppsonet-mapping-00.txt
- "PPP over SONET/SDH", 10/16/1997, draft-ietf-pppext-pppsonet-scrambler-00.txt
- "PPP over SONET/SDH", 11/17/1997, draft-ietf-pppext-sonet-ds-00.txt

IP over SONET: Products

- CISCO:
  - Cisco 7505, Cisco 7507, Cisco 7513: up to 6 OC-3 Cisco 12004,8,12: 5-60 Gbps, 12-44 OC-3, 3-11 OC-12
  - 12012 has 12 chassis slots. Up to 5 can be configured as fabric (15-60 Gbps)
  - Up to 11 can be configured for line cards
  - Line cards: 4-port OC-3 or 1-port OC-12
  - 4-port OC-12 and 1-port OC-48 planned.

Products (Cont)

- IP, IPX, DECnet over SONET
- Payload scrambling
- Automatic protection switching
- Monitoring and fault detection
- Line rate forwarding
- Carrier Class: redundant processors, fabric, power, fans, line cards, hot swap
- Ref:
  http://cio.cisco.com/warp/public/733/12000/gsrfs_ds.htm
  http://www.cisco.com/warp/public/733/12000/gspos_an.htm

Products (Cont)

- Ascend: GRF 400 IP switches
  - 2.8 Mpps
  - IP forwarding media card
  - 120 kpps
  - Hot swap, Automatic Protection switching, CISCO compatible HDLC
- Essential Communications: ERF IP Gateway (Cross-point Switch) [Same as Ascend?]
  - ERF-400 up to 4 Gbps, 2.8 Mpps
  - ERF-1600 up to 16 Gbps, 10 Mpps
  - OC-3c and OC-12c

Abbreviations

ABR	Available Bit Rate
ACCM	Async Control Character Map
ANSI	American National Standards Institute
APS	Automatic Protection Switching
ATM	Asynchronous Transfer Mode
CCITT	Consultative Committee
CMIP	Common Management Information Protocol
CMISE	Common Management Information Service Element
COBS	Consistent overhead byte stuffing
CRC	Cyclic Redundancy Check
FCS	Frame Check Sequence
FDDI	Fiber Distributed Data Interface
HDLC	High-Level Data Link Control

IP	Internet Protocol
IPCP	IP Control Protocol
IPOA	IP over ATM
IPV6CP	IPv6 Control Protocol
ISDN	Integrated Service Digital Network
L2TP	Layer Two Tunneling Protocol
LCP	Link Control Protocol
LoS	Loss of Signal
lsb	Least significant bit
LSB	Least Significant Byte
MPOA	Multiprotocol over ATM
MPV	Maximum pad value
MRU	Maximum Receive Unit

msb	Most significant bit
MSB	Most Significant Byte
MSP	Multiplex Section Protection Function
MTU	Maximum transmission unit
NCP	Network Control Protocols
NRZ	Non-return to Zero
OC	Optical Carrier
PPP	Point-to-Point Protocol
PPTP	Point-to-point Tunneling Protocol
QoS	Quality of Service
RFC	Request for Comments
SNMP	Simple Network Management Protocol
SONET	Synchronous Optical Network

SPE	Synchronous Payload Envelop
SVC	Switched Virtual Circuit
TCP	Transmission Control Protocol
XOR	Exclusive-OR