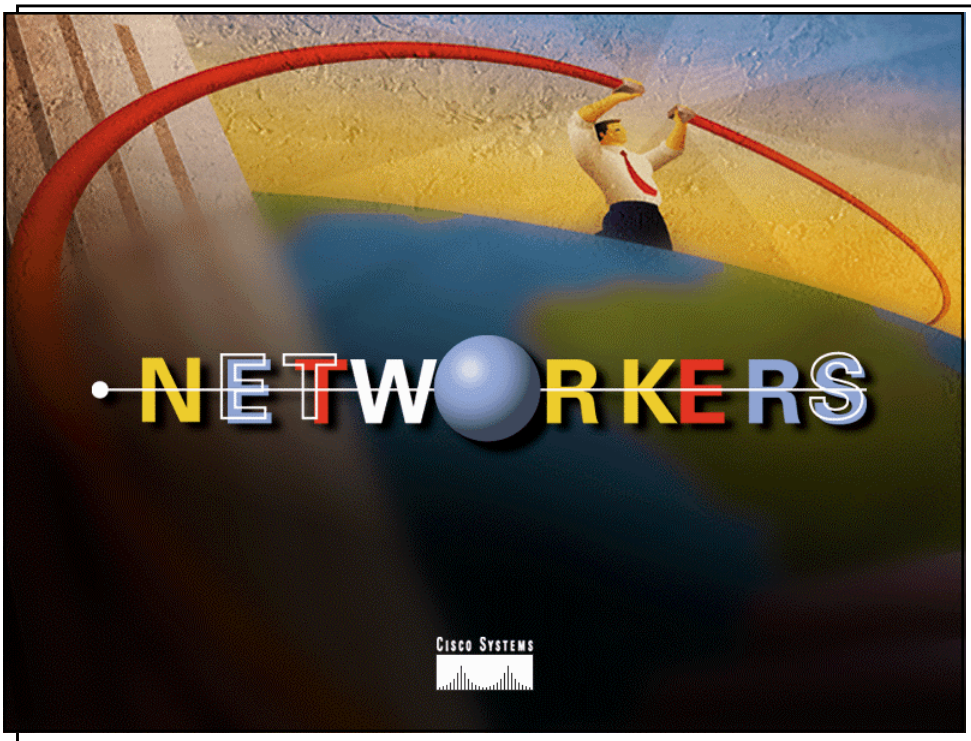

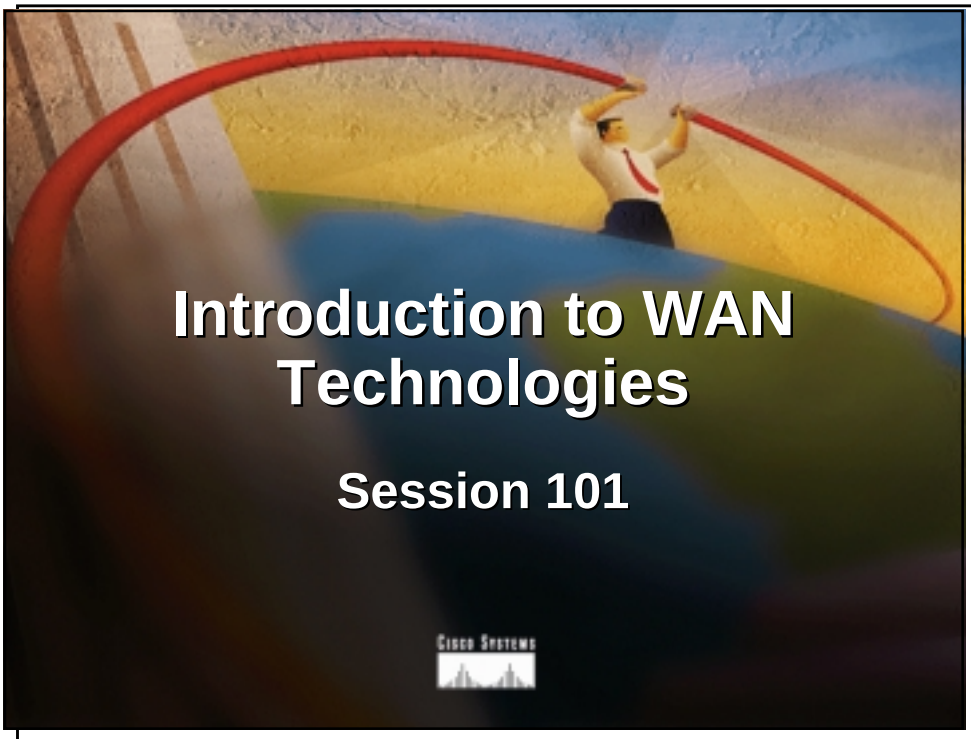

Agenda

Wide Area Network (WAN)

- **Environment**
- **Requirements**
- **Technologies**
- **Interface Signaling Protocols**

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Take-Away Message

- **By selecting the right WAN technology and hardware, you can:**
  - **Build a uniform multiservice network for DVV consolidation**
  - **Reduce recurring network operation costs (such as bandwidth)**

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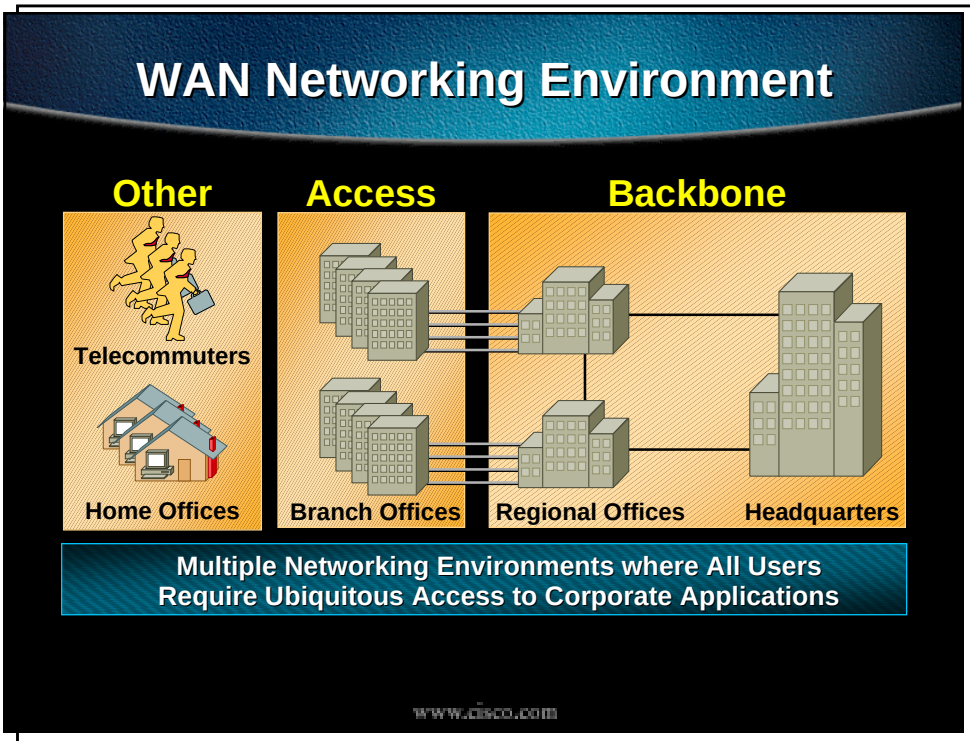
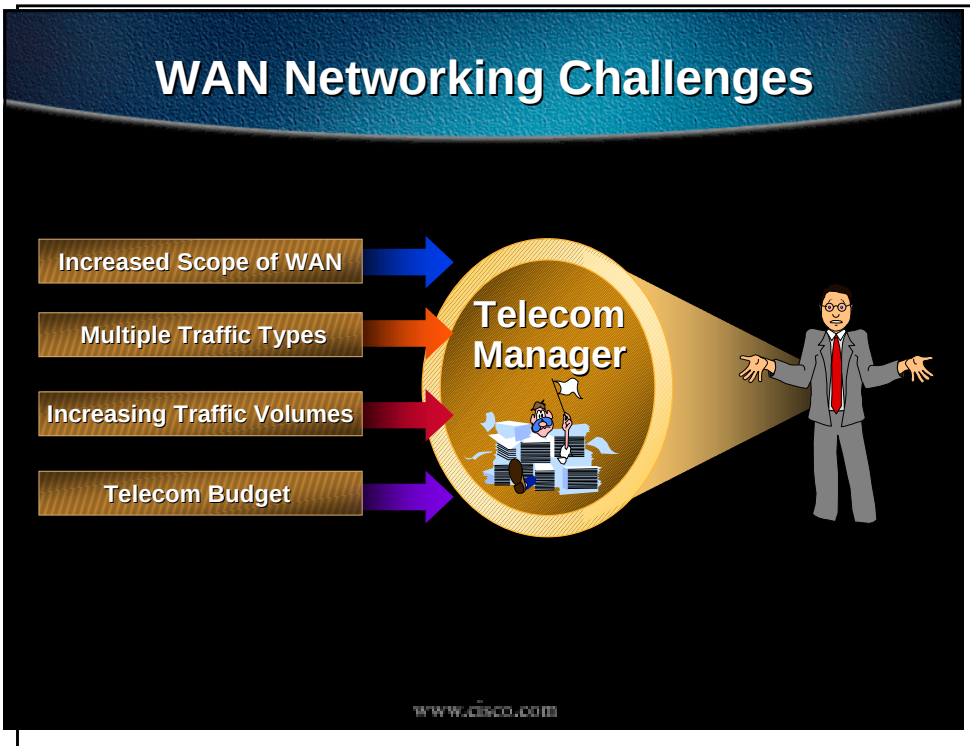
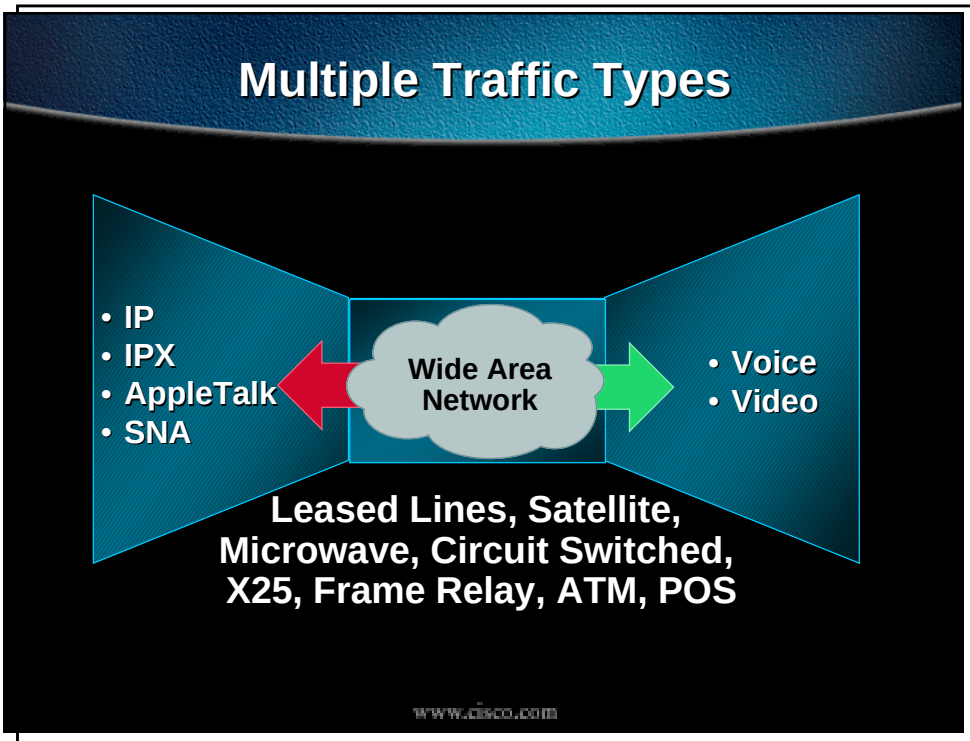
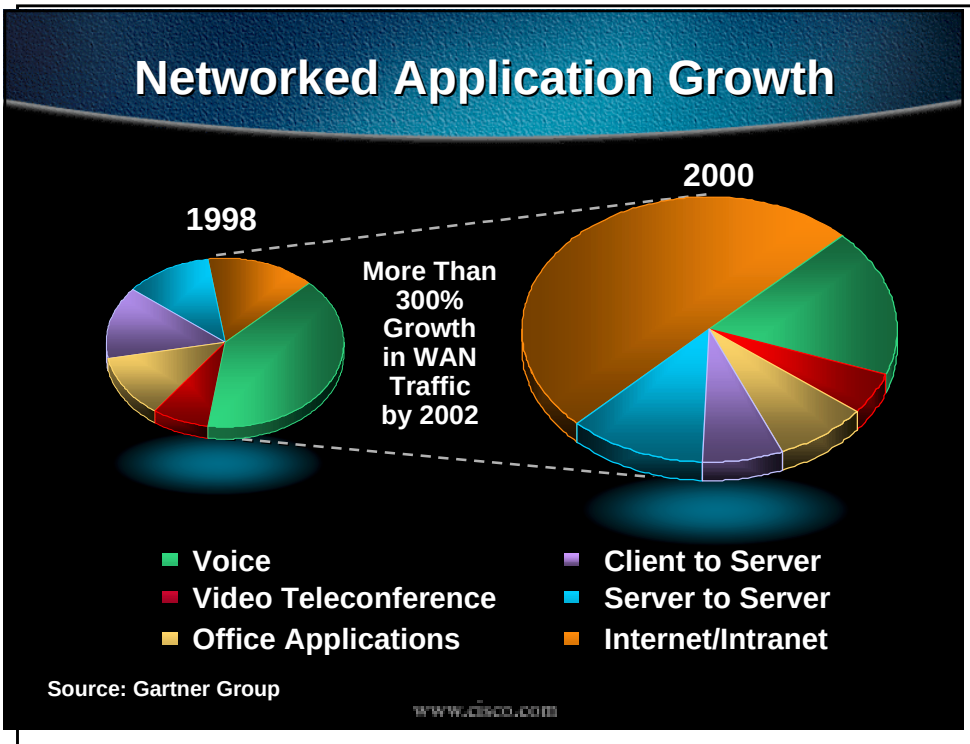


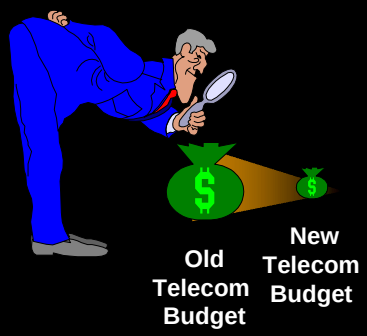






Telecom Budgets

Although Traffic Volumes Are Increasing, Telecom Budgets Are Not— in Fact in Some Cases Decreasing



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Agenda

Wide Area Network (WAN)

- Environment
- **Requirements**
- Technologies
- Interface Protocols

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Wide Area Network Requirements

Minimize Bandwidth Costs
Maximize Efficiency
Maximize Performance
Support New/Emerging Applications
Maximize Availability
Minimize Management and Maintenance

Multiservice Consolidation
Bandwidth Efficiency
Performance and QoS Guarantees
Emerging IP Services
Carrier-Class Reliability
Ease of Operation and Management

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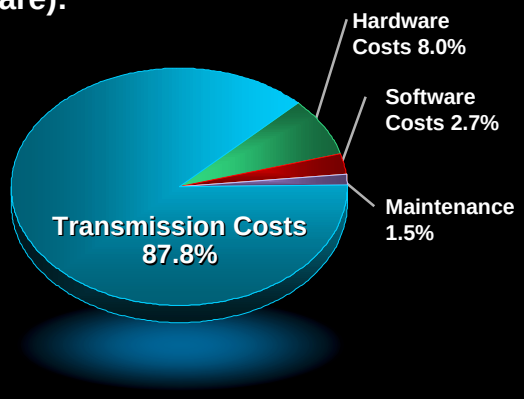
Wide Area Network Costs

- **Capital costs (hardware): non-recurring**
  - Written off over three to five years
- **Bandwidth rental costs: recurring**
  - One to five year contracts
  - Penalties for cancellation
  - Highest month recurring expense



Source: Data Communications

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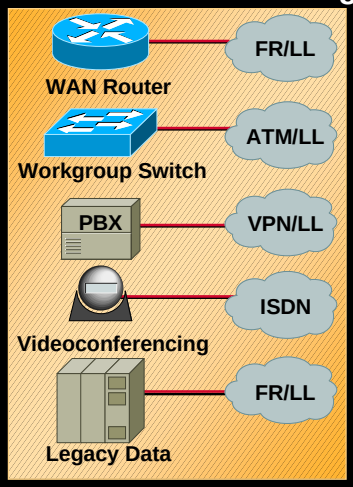
WAN Service Requirements

- LAN interconnectivity
  - Router and workgroup switches
- Emerging IP services
- Voice toll bypass
  - PBX tie trunking and voice switching
- Videoconferencing
  - Room-to-room, desktop
- Legacy data
  - SNA, X.25, async data
- TDM migration
  - Transport option for aging TDM systems

Multiservice Networking



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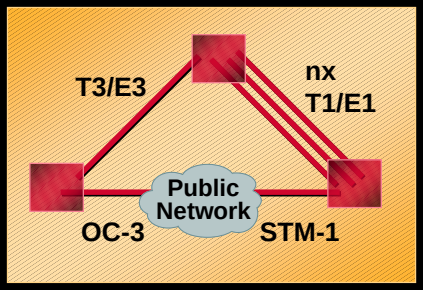
Wide Area Connectivity Requirements

- Flexible trunking
  - Sub-rate leased lines (64kbps to T1/E1)
  - n x T1/E1 leased lines
  - T3/E3 leased lines
  - OC-3/STM-1 leased lines
  - Public/private services
- Bandwidth efficiency



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Agenda

Wide Area Network (WAN)

- Environment
- Requirements
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Message

- **By selecting the right WAN technology and hardware, you can:**
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  - **Reduce recurring network operation costs (such as bandwidth)**

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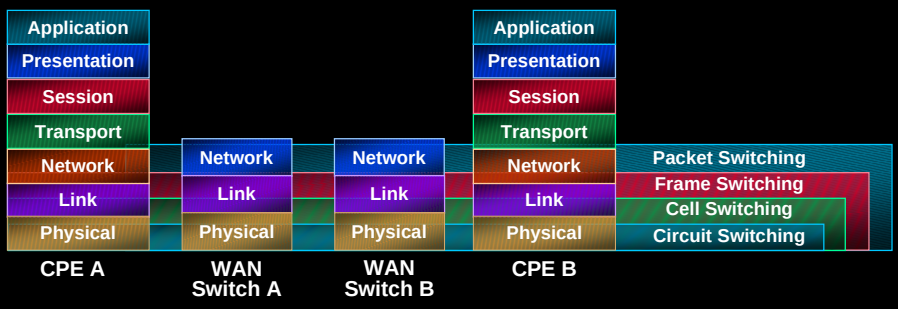
WAN Technologies



Circuit Switching	Time Division Multiplexing (TDM)
Frame Switching	X.25/HDLC, SNA/SDLC
Cell Switching	ATM
Frame/Cell	POS

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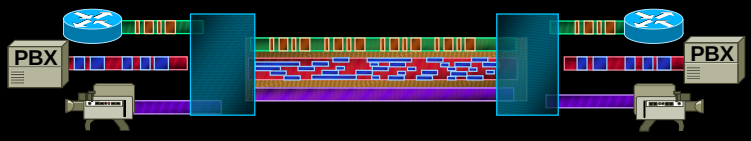
Circuit Switching (TDM) Overview



- Available bandwidth is statically partitioned amongst the applications
- Each application has access to the allocated bandwidth only; no single application can burst up to the entire bandwidth capacity
- Example: available bandwidth = 24 DS0s
  - Four channels for router data; eight for voice calls; six for video; six channels not allocated
- Circuit switching delay: application frame size/ allocated bandwidth
- Variability in delay: low

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Circuit Switching—Pros and Cons

Pros

- Predictable Performance
  - As Bandwidth Is Allocated Statically, All Applications Get Consistent Performance and Predictable Delay
- Protocol-Independent
  - End Devices Can Be Using Any Protocol over the Wide Area Network
- Can Be Used for Multiservice Applications Consolidation

Cons

- Inefficient Bandwidth Utilization
  - No Dynamic Allocation of Bandwidth
  - No Bursting Capability—One Application Cannot Use Bandwidth Allocated to the Other Even if That Traffic Is Not Present
- Bandwidth Limited
  - Once All of the Available Bandwidth Is Allocated, Additional Bandwidth Must Be Procured

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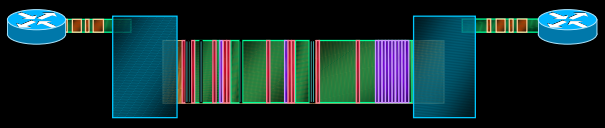
X.25 Switching Overview



- Cells, frames, or packets within a switch but X.25 packets at egress
- Available bandwidth is dynamically allocated
- Only useful for data applications
- X.25 switching delay: can increase with number of switches in path
- Variability in delay: high
- Layer 3 switching—PVC, SVC-based

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Traffic Handling in an X.25 Network

- Router sends X.25 packet to first X.25 switch

  Assume that the call has been set up and a data size of 128 agreed by both ends with a window size of 7

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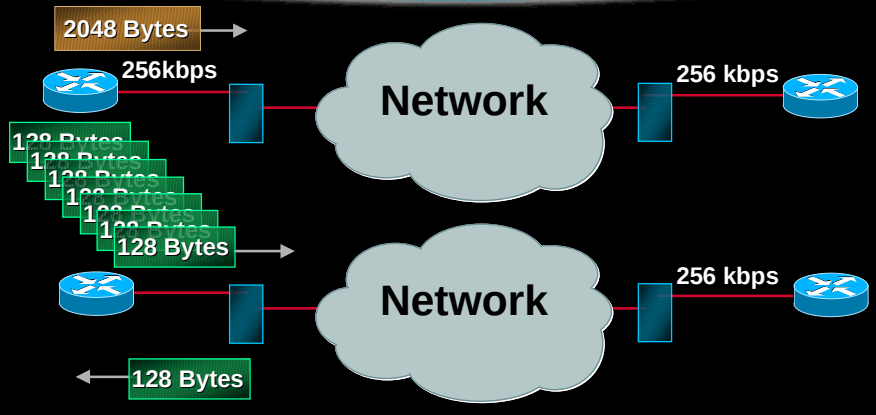
Traffic Handling in an X.25 Network



- Router sends X.25 a window (7) of (128) packets; the X.25 switch responds with “RR’s” for correctly received packets or “RNR” for incorrect ones

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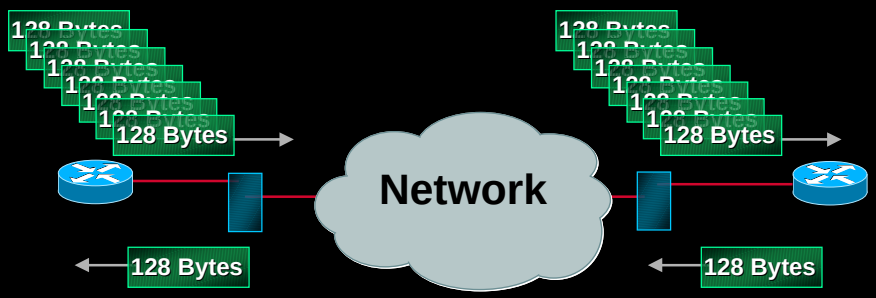
Traffic Handling in an X.25 Network



- The network transports the packets across the network; the packets are delivered to the far end using the same window mechanism as the input to the network

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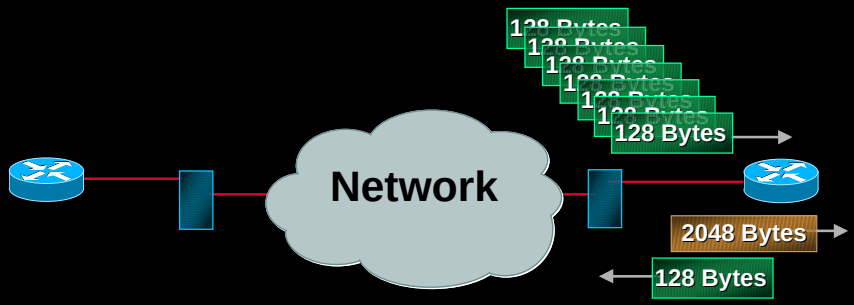
Traffic Handling in an X.25 Network



- Last window sent to router and whole frame re-assembled and sent

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X.25 Switching—Pros and Cons

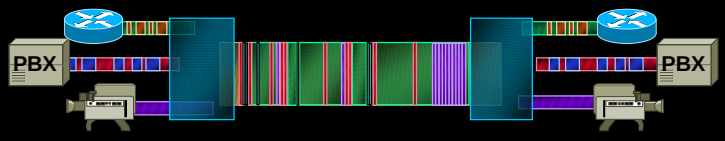
Pros

- Excellent in Highly Errored Environments
  - Protocol Goes Looking for an Error
- Protocol-Independent
  - End Devices Can Be Using any Protocol over the Wide Area Network

Cons

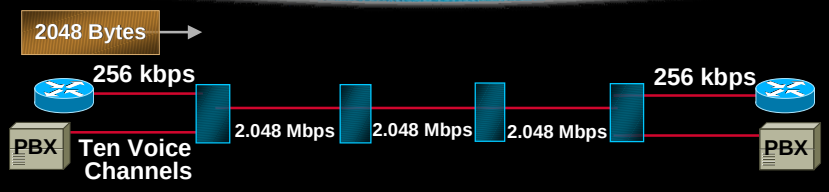
- Unable to Guarantee Performance
  - Due to Windowing Mechanism, Throughput and Performance Is Very Slow
- High Delay and Variability in Delay
  - Each Switch Has to Receive an Entire Window before Forwarding It to the Next Switch; Therefore Transit Delay Increases with Number of Switches in the Path
  - The FIFO Mode of Each Switch Causes a Variability at Each Switch
- Typically Data Only
  - As a Result of High Delay and Variability in Delay, X.25 Switches Are More Suited for Data-Only Environments that Have Little or No Delay-Sensitive Applications

Frame Switching Overview



- Either cells or frames within a switch but frames only at egress
- Available bandwidth is dynamically allocated
- Each application gets access to all available bandwidth; any application can burst up to the entire bandwidth capacity
- Frame switching delay: increases with number of switches in path (queuing and serialization delay)
- Variability in delay: can be high for FIFO queuing switches

Traffic Handling in Frame-Switched Network



- Router sends frame to first frame switch

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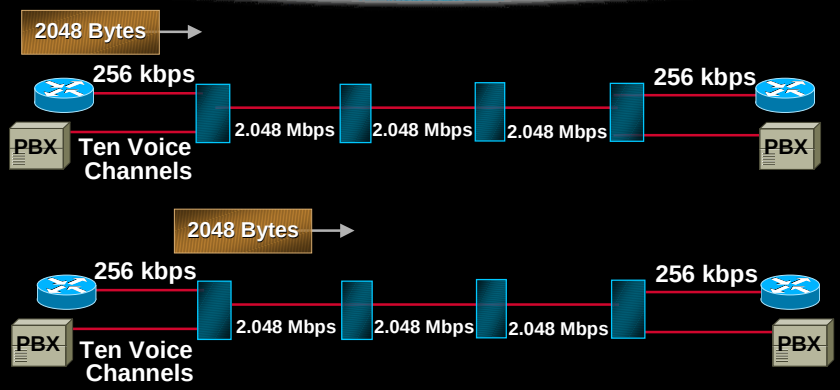
Traffic Handling in Frame-Switched Network



- First frame switch waits for the entire frame, adds header and forwards to next switch

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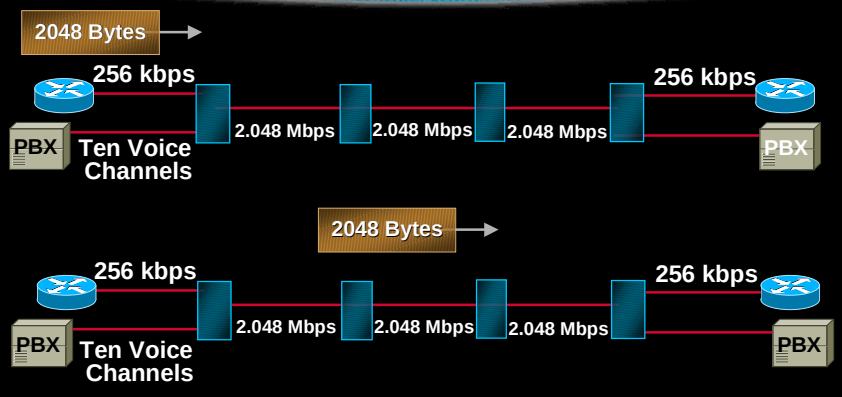
Traffic Handling in Frame-Switched Network



- Second frame switch waits for the entire frame, and forwards to next switch

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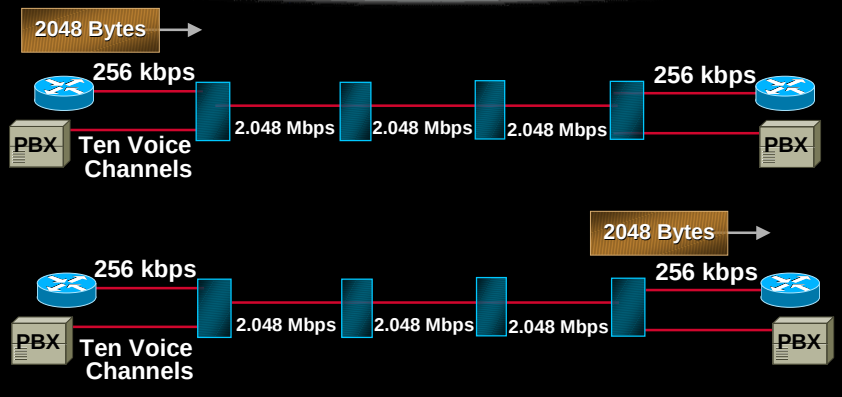
Traffic Handling in Frame-Switched Network



- Last frame switch waits for the entire frame, adds header and forwards it to router

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Frame Switching—Pros and Cons

Pros

- Dynamic Allocation of Bandwidth
  - Available Bandwidth Is Allocated Dynamically to Any Application That Needs It
  - One Application Can Use Bandwidth Allocated to the Other If That Traffic Is Not Present
- Can Be Used for Multiservice Applications
  - Frame Switches Are Used for Multiservice Applications (DVV) (Less over Subscription and Reasonable Speed Links)

Cons

- Unable to Guarantee Performance (in FIFO Mode)
  - Frame Switches 'Typically' Operate in FIFO (First in-First out) Mode, so One Application Can Impact the Performance of Others
- Medium Delay and Variability in Delay
  - Each Switch Has to Receive an Entire Frame before Forwarding It to the Next Switch; Therefore Transit Delay Increases with Number of Switches in the Path
  - The FIFO Mode of Each Switch Causes a Variability at Each Switch

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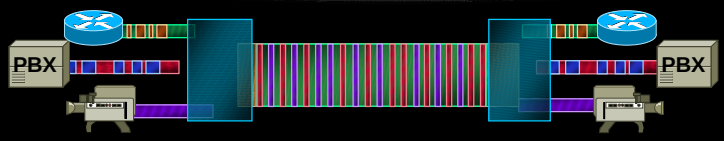
Cell Switching Overview



- Cells only within a switch and cells only at the egress of a switch
- Available bandwidth is dynamically allocated
- Each application gets access to all available bandwidth; any application can burst up to the entire bandwidth capacity
- Cell switching delay: low delay
- Variability in delay: low

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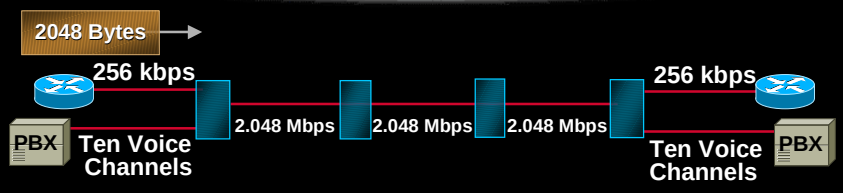
Traffic Handling in Cell-Switched Network



- Router sends frame to first cell switch

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Traffic Handling in Cell-Switched Network

- First cell switch starts to receive the frame; as it receives enough data to fill up the payload of one cell, it adds header and forwards to next switch

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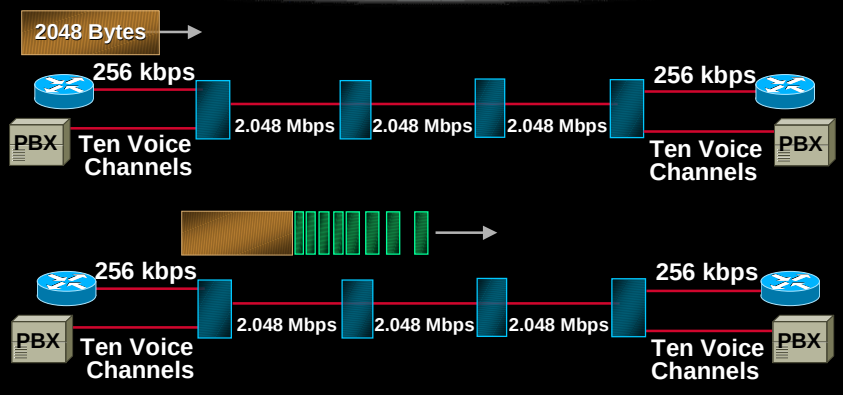
Traffic Handling in Cell-Switched Network



- Second cell switch receives the cell and switches it to the next switch

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Traffic Handling in Cell-Switched Network

- Next cell switch receives the cells and forwards to next switch till the last switch where all cells are collected until the last cell is received

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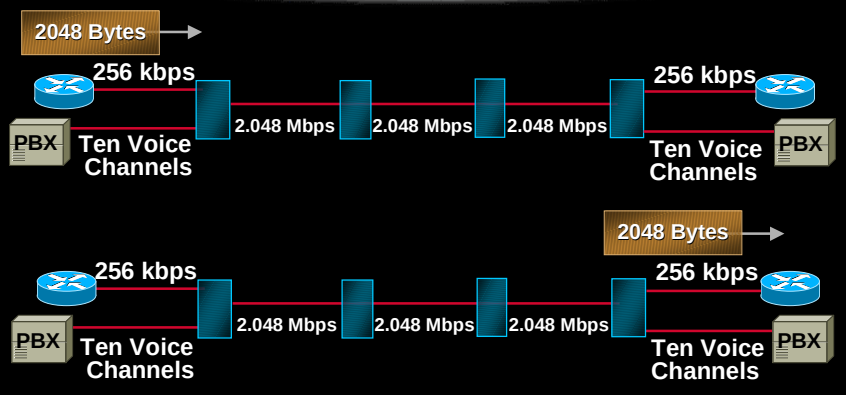
Traffic Handling in Cell-Switched Network



- Last switch assembles the frame and forwards to the attached router

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Cell Switching—Pros and Cons

Pros

- Dynamic Allocation of Bandwidth
  - Available Bandwidth Is Allocated Dynamically to Any Application That Needs It
  - One Application Can Use Bandwidth Allocated to the Other if That Traffic Is Not Present
- Guaranteed Performance
  - Cell Switches with Efficient Traffic and Bandwidth Management Schemes Can Ensure That Each Application Receives Guaranteed Performance (TM, QoS Queuing, CAC, PNNI/UNI, Etc.)
- Low Delay (Controlled and Bounded) and Low Variability in Delay
  - Using Fixed Length Cells Ensures That Network Transit Delay and Variability in Delay Is Minimized
  - Switches Use QoS-Based Queuing and Scheduling Such as CBR, VBR, ABR
- Typically Multiservice
  - As a Result of Low Delay, Low Variability in Delay and the Ability to Guarantee Performance, Cell Switches Are Ideally Suited to Support Multiple Services Concurrently

Cons

- Overhead
  - However the Bandwidth Efficiency and Ability to Provide Low Delay and Low Variability in Delay in Cell Switching Easily Overcomes the Small Incremental Overhead

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Frame/Cell Switching Overview

- Either cells or frames within a switch and both frames and cells at egress of switch
- Frame switching is used for data and cells are injected for delay-sensitive traffic
- Available bandwidth is dynamically allocated
- Each application gets access to all available bandwidth; any application can burst up to the entire bandwidth capacity
- Frame/cell switching delay: increases with number of switches in path
- Variability in delay: high

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Frame/Cell Switching—Pros and Cons

Pros

- **Dynamic Allocation of Bandwidth**
  - Available Bandwidth Is Allocated Dynamically to Any Application That Needs It
  - One Application Can Use Bandwidth Allocated to the Other if That Traffic Is Not Present
- **Multiple Traffic Types**
  - Cell Injection Process Is Used to 'Insert' Delay Sensitive Traffic (Like Voice) During the Transfer of a Data Frame

Cons

- **Proprietary**
  - There Are No Standards for Frame/Cell Switching
- **Unable to Guarantee Performance**
  - Cell Injection Causes Frames to Be Partially Transmitted and Possibly Buffered Along the Path; Frame-Based Traffic (Data) Suffers at the Expense of Cell Traffic; Increased Volumes of Cell Traffic Can Impact Quality Throughput and Performance of Frame-Based Traffic
- **Bandwidth Inefficiency**
  - Increased Cell Traffic Can Cause Frame Traffic to Be Discarded in the Network, Thereby Reducing the 'Quality Throughput' or 'Goodput' of the Network
- **High Delay and Variability in Delay**
  - Frame/Cell Switches Operate as Frame Switches for Data and Have Similar Delay Characteristics; Cell Injection Causes Additional Delays for Frame Traffic

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Packet over SONET Overview

- Either cells or frames within a switch and SONET/SDH payload at egress of switch
- POS is serial transmission of multiprotocol packets over SONET/SDH frames—efficient high-speed transport with low overhead
- Available bandwidth is dynamically allocated
- Any application can burst up to the entire available bandwidth capacity-packet based infrastructure
- Switching delay: low
- Variability in delay: low

Packet over SONET—Pros and Cons

Pros

- **Dynamic Allocation of Bandwidth**
  Bandwidth Is Available to Any Application That Needs It
- **Scalable**
  Underlying Technology Can Scale in Speeds with Increase in Traffic Volume
- **Efficiency-Overhead**
  Direct Mapping of Packets over SONET Payload Increases Efficiency by Removing Overhead
- **Fault-Tolerant, Reliability Carrier Class Redundancy with APS**
  With Automatic Protection Switching, Very Fast Switchovers in Case of Failure
- **Underlying Transport Flexibility**
  Can Be Used with Different Underlying Transport-SONET/SDH ADMs, DWDM Equipment

Cons

- **More Suited Towards Packet-Based Applications**
  Direct Mapping of Packets over Transport SONET/SDH Media
- **QoS Evolving from Best-Effort to Guaranteed Approach**
  Efforts Underway to Include Differentiated Service Mechanisms
- **Not Suitable for Low Speed Links**
  'Typically' Used over High-Speed Fiber-Based Infrastructures

Summary of Technologies

	Bandwidth Efficiency	Multiservice	Traffic Mgmt./QoS	Appl. Performance	Scalability
Circuit Switching (TDM)	*	* * *	*	* *	*
X.25	* *	*	*	*	*
Frame Switching	* * *	* * *	* * *	* * *	* * *
Cell Switching (ATM)	* * * *	* * * *	* * * *	* * * *	* * * *
Frame/Cell Switching	* * *	* * *	* * *	* * *	* * *
Packet over SONET	* * * *	* *	* *	* * *	* * *

* = Weak * * = Fair * * * = Good * * * * = Excellent

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Agenda

Wide Area Network (WAN)

- Environment
- Requirements
- Technologies
- **Interface Protocols**

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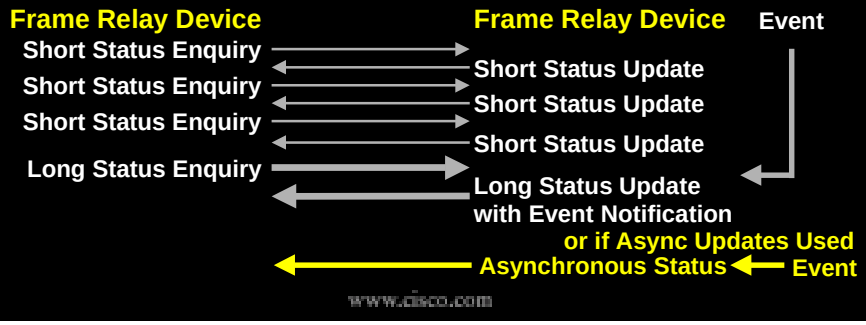
Frame Relay UNI LMI

- UNI between end device and network
- Event notification
- Unidirectional update requests
- E-LMI allows one config. of switches and router
- Same frame format as NNI

ANSI	T1.617 Annex D
ITU-T	Q.933 Annex A Signaling
LMI	"Gang of Four" Cisco, NT, DEC



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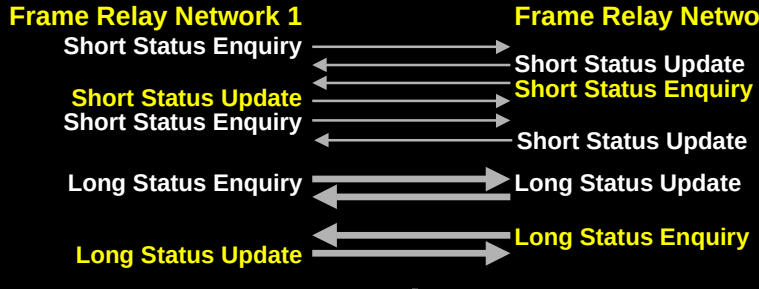
Frame Relay NNI

- NNI between networks
- Event notification
- Bi-directional update requests
- Allows foresight updates between two Cisco networks using CLLM
- Same frame format as UNI

ANSI	T1.618 Annex D
ITU-T	Q.933 Annex A



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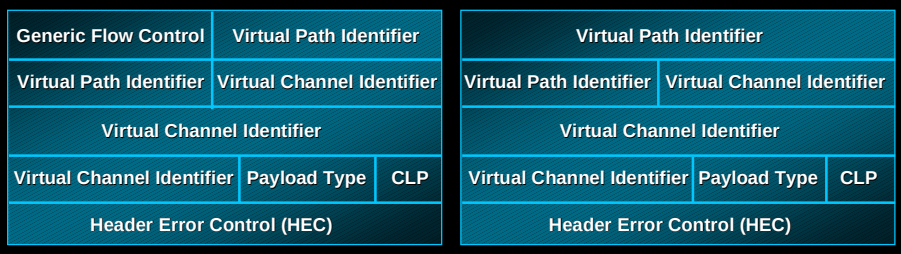
ATM UNI and NNI



UNI Header Format **NNI Header Format**

- Unlike Frame Relay ATM UNI and NNI formats are different
- UNI VPI range is 256 and VCI range is 65,535
- NNI VPI range is 4,096 and VCI range is 65,535

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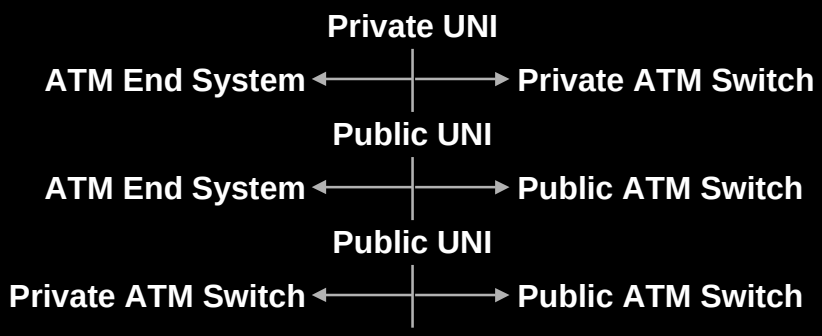
ATM I—LMI



- Integrated local management interface-ilmi
- Use SNMP across UNI and NNI for ILMI MIB
- Uses AAL 5 encapsulation
- Used for ATM end system address (AESA) formerly NSAP addressing for services
- Automatic recognition of UNI or NNI interface protocol

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ATM I—LMI (Cont.)

- Get—retrieve specified management information
- GetNext—retrieve via traversal of MIB, management information
- Set—alter management information
- Trap—report extraordinary information

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Summary

- By selecting the right WAN technology and hardware, you can:
  - Build a uniform multiservice network for DVV consolidation
  - Reduce recurring network operation costs (such as bandwidth)

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Follow-on Sessions

- **WAN**
  - Session #102 (Level 2)—Deploying WAN Technologies
  - Session #103 (Level 3)—Advanced WAN Concepts and Troubleshooting
  - Session #1201 (Product)—IGX/BPX/MGX Product Update
  - Session #1208 (Product)—26xx/36xx/3810 Product Update
- **Optical**
  - Session #604 (Level 1)—Introduction to Optical Carrier Services
  - Session #605 (Level 2)—Deploying Optical Infrastructure
  - Session #606 (Level 3)—Advanced Optical Technology Concepts
  - Session #1202 (Product)—GSR Product Update

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