1.264 Lecture 37

Telecom: Enterprise networks, VPN

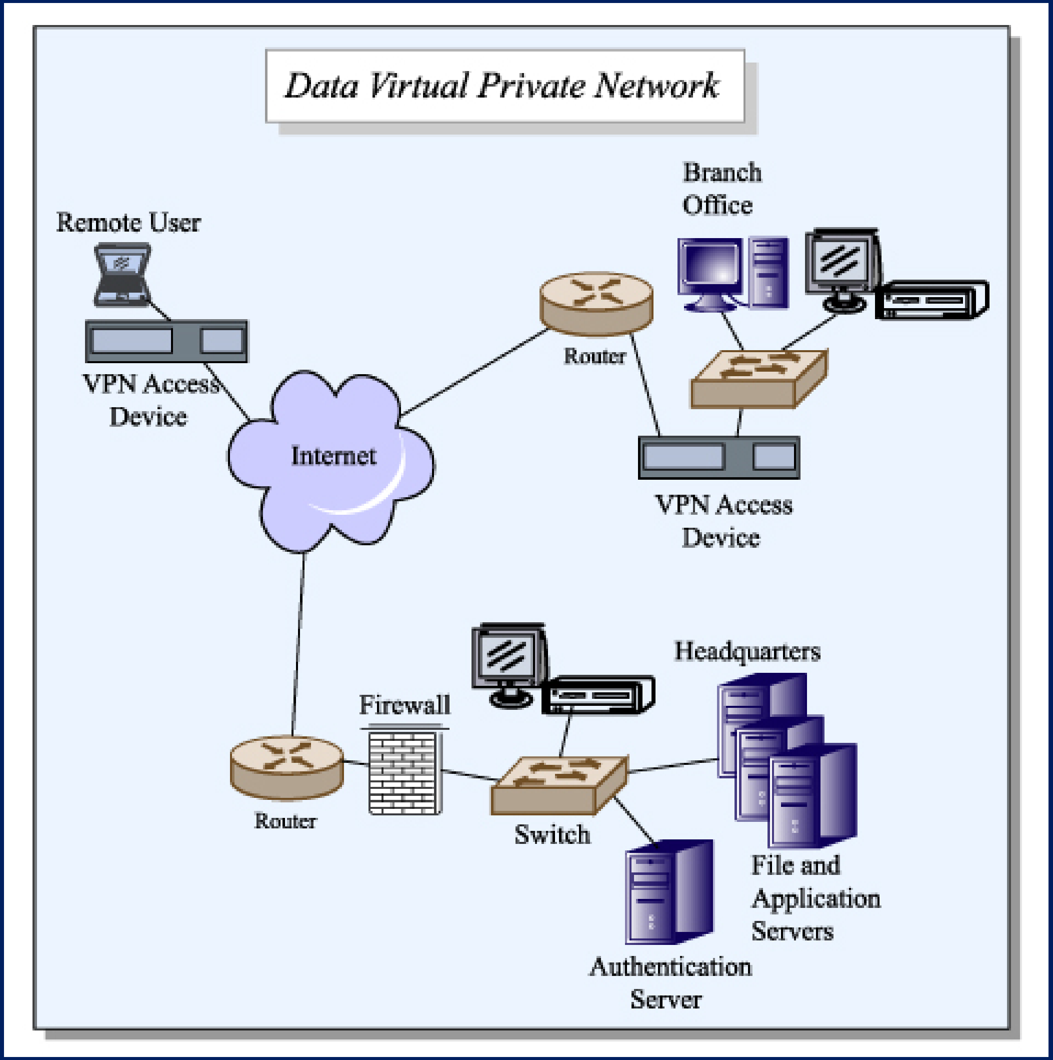
Enterprise networks

- Connections within enterprise
- External connections
  - Remote offices
  - Employees
  - Customers
  - Business partners, supply chain partners
  - Patients…and other actors with special requirements
- Principles of enterprise network design
  - Standards based
  - Secure
  - Reliable: disruptions affect all external connections
  - Quality of service: latency, throughput, services, …

Building blocks of enterprise network

- Local area networks
- Wide- or metro-area networks: include 1 or more of:
  - Private lines (point to point circuits)
  - “Carrier Ethernet” MAN over carrier fiber in metro areas
  - Virtual private net (VPN) over Internet
  - Private or carrier-provided networks separate from Internet
    - Frame relay (pre-Internet, still used but being superseded)
    - Label switched (MPLS), over carrier IP network
    - Covered later in this lecture
- Voice network: includes one or more of:
  - Integrated with data network
  - Private lines shared between data and voice
  - Voice carried over IP or MPLS network
- Video network
  - Usually carried as service over data network

Virtual private networks (VPN)



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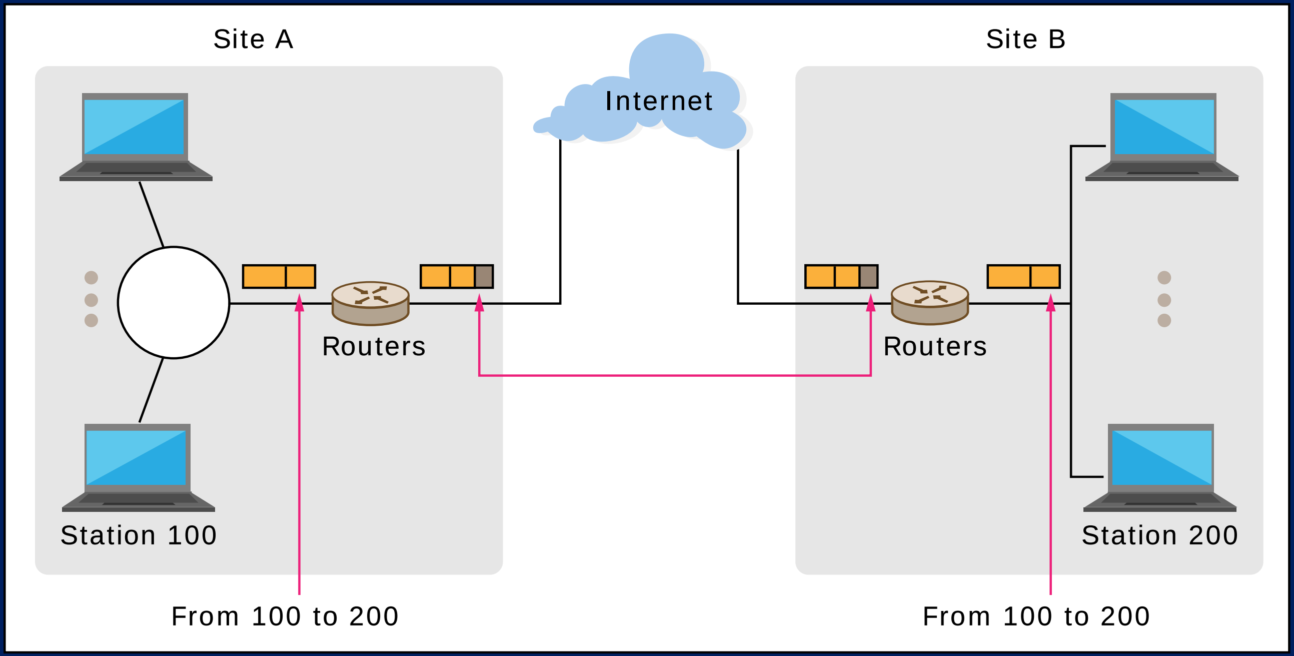
Virtual private networks (VPNs)

- Definition: VPN is set of sites that
  - Communicate over the open Internet but
  - With the security and management capabilities of dedicated circuit or frame relay network
  - Supporting applications without modification
  - With simple management for admins and users
  - And with low overhead and good communications performance
  - Typically handle data only but can handle voice, video
- VPN basic functions
  - Authentication (identity), authorization (privileges)
  - Establishment of secure tunnel (path) in network

VPN technology

- VPN tunnel encapsulates data of one protocol inside the data field of another protocol
  - VPN encrypts corporate data inside IP packet data field (which is managed by TCP, which is called by HTTP)
    - HTTP and TCP data is inside the IP packet and is encrypted
  - The corporate data is encrypted via the VPN’s security protocol (symmetric, asymmetric keys, message digests)
    - SSL is frequently used; Kerberos-like options also available
- VPNs operate at layer 2 (Ethernet) or layer 3 (IP)
  - Layer 3: Routers use IP information to route
    - Most common: Easier to manage, but lower performance
  - Layer 2: uses Ethernet addresses; corporation responsible for routing packets across WAN and LANs
    - Harder to manage, but better performance
- VPNs operate over DSL, cable, etc.
  - Simple network topology (all links to/thru central point)
  - Limited redundancy, resiliency

VPN tunnel



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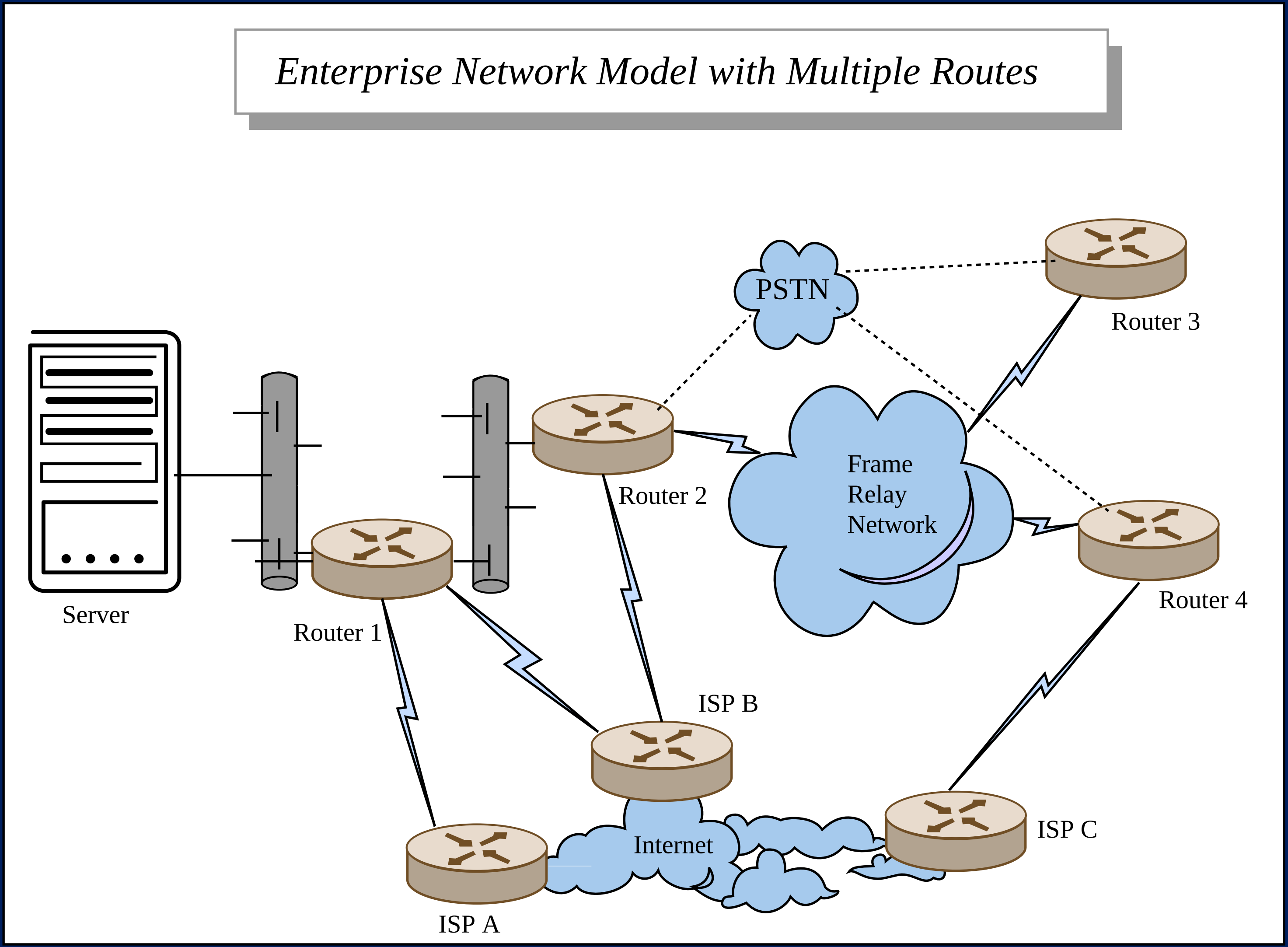
- Internet carries packet between routers R1 and R2
- Packet is encrypted, and intruder only sees R1 and R2 IP addresses
- Actual IP addresses (100 and 200) cannot be seen, nor the packet contents

VPN terminology

- Intranet
  - Portion of VPN connecting internal sites
- Extranet
  - Portion of VPN connecting external sites
- Security protocols
  - Secure Sockets Layer (SSL)
  - IPsec (secure IP standard) at layer 3
    - Can encrypt entire packet (tunnel mode) or just the data field (transport mode)
    - All devices must share a common (public) key, in digital certificate
    - Devices negotiate secure tunnel using Internet Key Exchange (IKE) protocol
  - Layer 2 tunneling protocol (L2TP)
    - Requires pre-arranged paths between devices or to/from secure server

Enterprise routing: IP and other protocols



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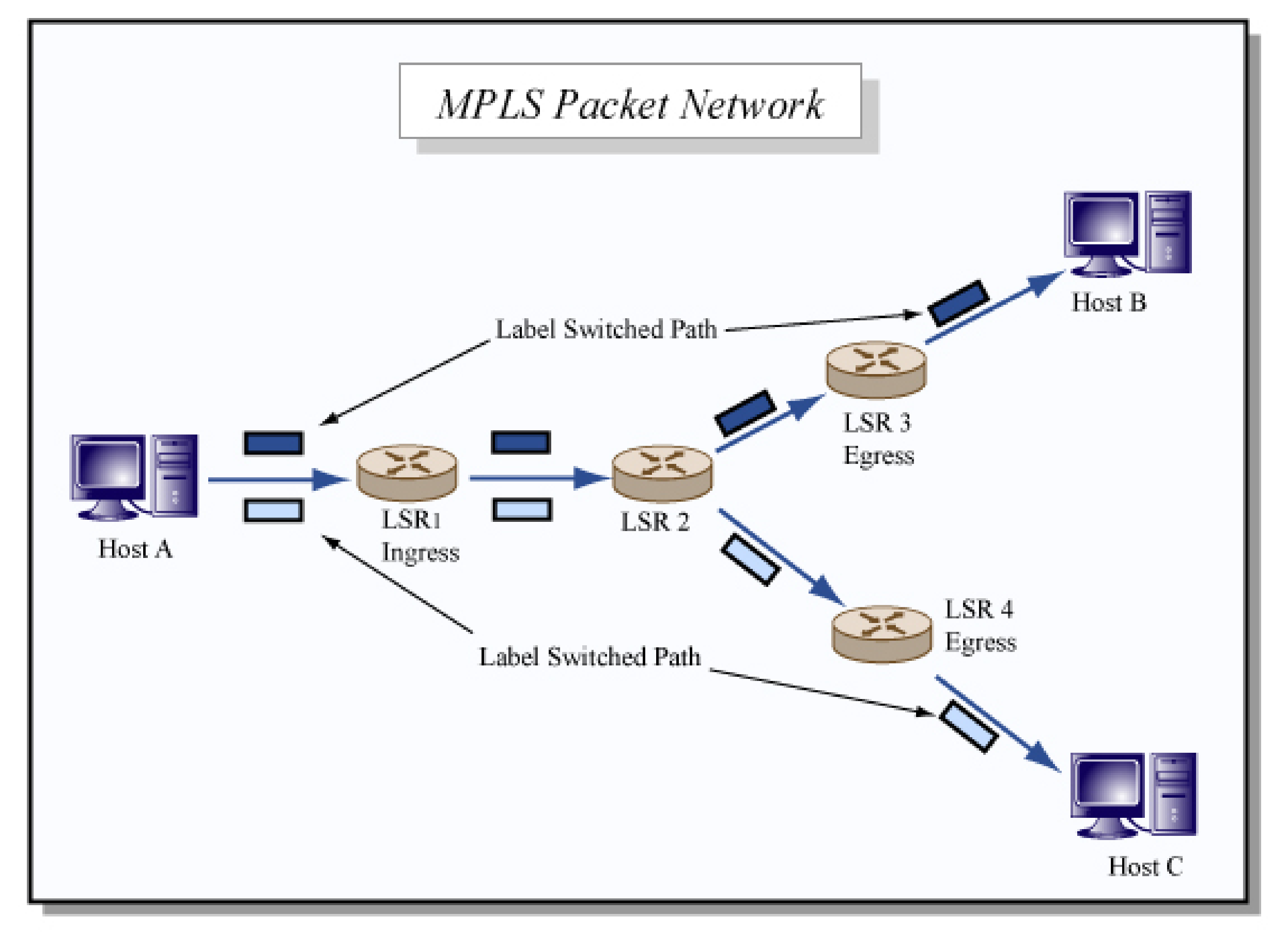
Multiprotocol Label Switching (MPLS)

- Label edge routers (LERs) assign a label that defines the path the packet will take through the IP network
  - Routing happens only once, at edge
  - Routing at interior routers (label switched routers, or LSRs) is done in hardware, not a software lookup of IP routing tables
    - Much faster, cheaper
    - A stack of labels allows complex, hierarchical networks
  - Label distribution protocol (LDP) used to distribute labels to all LSRs and LERs, using TCP/IP
  - MPLS allows QoS, security (strict traffic rules)
    - MPLS VPNs operate at layer 2 or layer 3
    - Corporate routers don’t need to support MPLS; they connect to LER via IP
  - MPLS is a fiber-only technology, national but not global scope (yet), complex network, “Ethernet-like” operation

Multiprotocol Label Switching



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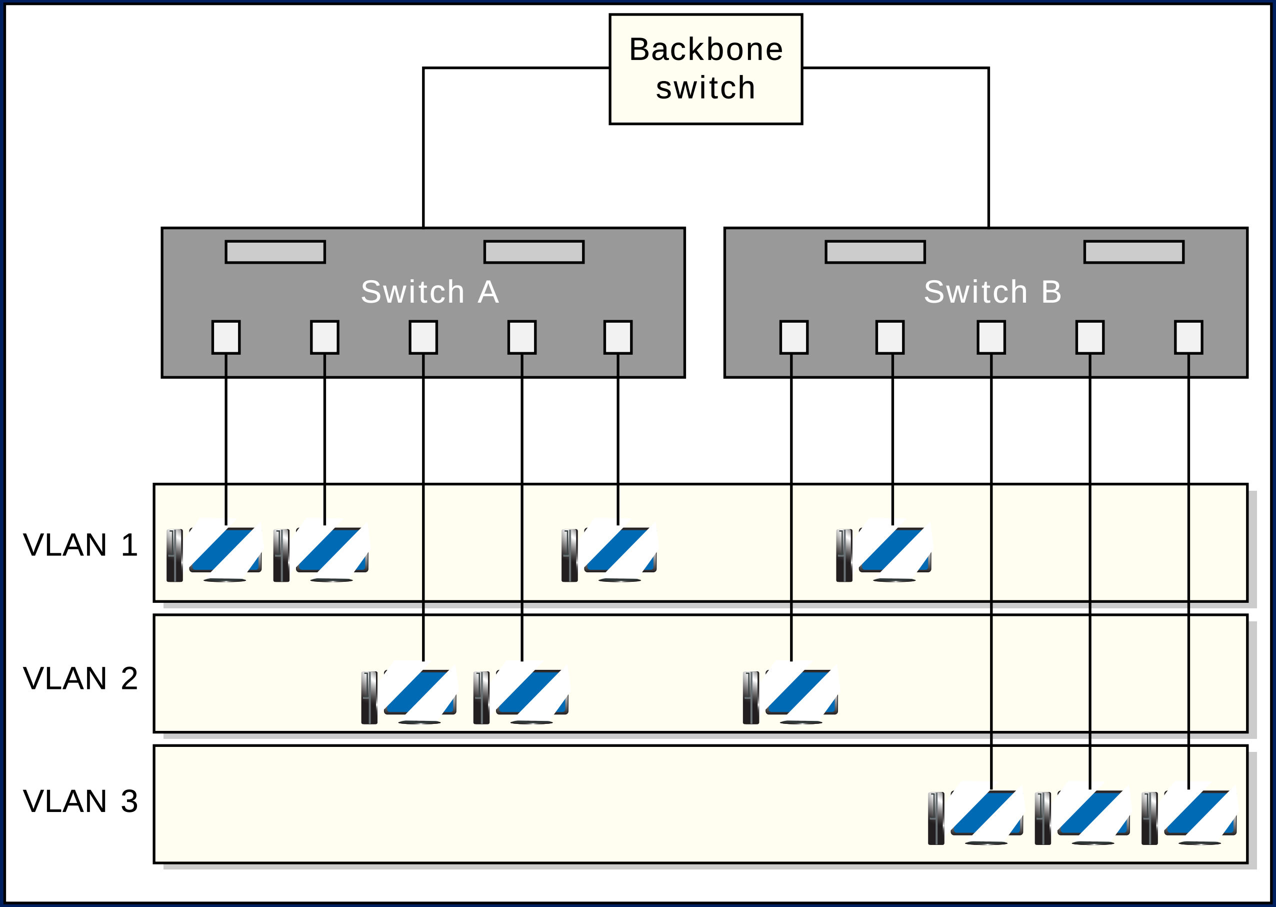
Network neutrality debate…

Virtual LANs

- MPLS is sometimes described as implementing a virtual LAN, or VLAN: set up LANs in software



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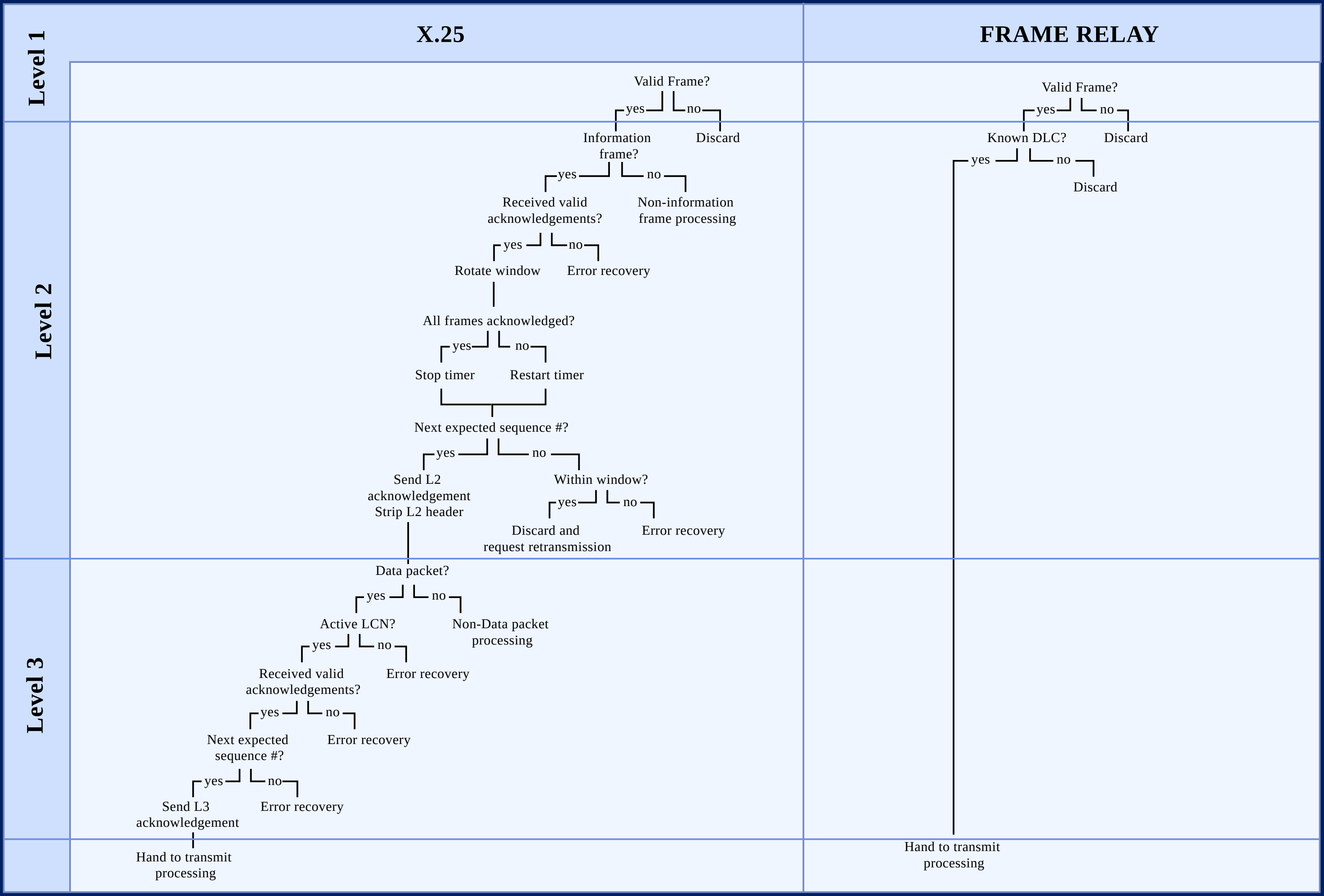
Technology changes

- Next slide compares X.25 and frame relay
  - X.25 was developed for copper or radio long-haul networks with high error rates
  - Link-by-link error correction as a message travels across the network
  - Assumes ‘dumb’ equipment at the edges, so the X.25 protocol takes full responsibility for delivering messages correctly
- Frame relay (or any other protocol carried on fiber optics such as TCP/IP)
  - Relies on low fiber optic error rate. No link-by-link error correction, just a retransmission triggered by end node if message not correctly received
- A wireless long haul net would need roughly the same protocols as X.25
  - Smart edge devices make it easier than X.25

Frame relay vs X.25



X.25

FRAME RELAY

Level 1

Level 2

Level 3

Valid Frame?
yes
no
Information frame?
Discard
yes
no
Received valid acknowledgements?
Non-information frame processing
yes
no
Rotate window
Error recovery
All frames acknowledged?
yes
no
Stop timer
Restart timer
Next expected sequence #?
yes
no
Send L2 acknowledgement Strip L2 header
Within window?
yes
no
Discard and request retransmission
Error recovery
Data packet?
yes
no
Active LCN?
Non-Data packet processing
yes
no
Received valid acknowledgements?
Error recovery
yes
no
Next expected sequence #?
Error recovery
yes
no
Send L3 acknowledgement
Error recovery
Hand to transmit processing

Valid Frame?
yes
no
Known DLC?
Discard
yes
no
Discard
Hand to transmit processing

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Frame relay/Internet vs. X.25

- Difference between reliable and unreliable networks
  - Fiber has error rate of 1 bit in 10^{14}; can correct end-to-end
  - Wireless has error rate of 1 bit in 10^{6}; must correct link-by-link
- Difference between smart and dumb terminals
  - Formerly, terminals had no CPU and just displayed what the communications line sent to them
    - Could not detect or correct errors
  - PCs, servers, smart phones as terminals can correct and detect errors
- “Hollowing out of the network”
  - Network (switches, etc.) used to have all the intelligence
  - Now network is just a set of ‘bit pipes’
  - Edge devices have the intelligence

Telecom convergence

- Convergence: Moving all voice, data and video traffic onto Internet
  - Consumer service reasons:
    - Smart cards and mobile phones: browsers, phone as payment medium, smart posters, cameras
    - E-commerce generally
  - End of the personal computer (PC) as we know it, for most users
  - Cost reduction: one network versus many
    - Private nets morph into carrier nets with Internet protocols
  - Increased mobility services
    - Tying wireless access to fiber optic backbone flexibly
  - Barriers:
    - Low quality, chaos of open Internet to reach customers
    - Security to reach customers
    - Broadband in the ‘last mile’ to reach businesses and homes

Glossary

- VPN: Virtual private network
- IPsec: Secure IP (layer 3 security used in VPNs)
- L2TP: Layer 2 tunneling protocol (VPN)
- PSTN: Public switched telephone network, or carrier network
- MPLS: Multiprotocol Label Switching, a WAN technology to connect LANs transparently
  - LER: MPLS Label Edge Router
  - LSR: MPLS Label Switched Router (interior)
  - LDP: MPLS Label Distribution Protocol
- QoS: Quality of service

Steps and skills for building these systems are same as we’ve covered in class this semester

- Software engineering and project management
  - People, process, product, technology dimensions
  - Select development method (often spiral model)
  - Requirements, design, resource estimation, implementation, QA
- Process modeling
  - UML: describe use cases, states, activities, classes, components
  - Used in requirements, scoping, design early; architecture late
- Data modeling
  - Model business rules, verify with users (internal, customers, …)
  - Normalization, referential integrity
- Database
  - Relational databases, SQL at core of applications, Web
  - Databases read/write XML

Steps, continued

- World Wide Web:
  - Connect clients and servers: HTTP, XML, Web services
  - Use HTTP, XML as universal data access
  - XML allows human, machine and document interpretation
  - XML documents include business rules, database schema
- Security
  - Protocols codify rules, principals, risks, …
  - TLS and Kerberos
  - TLS encryption, certificates, digital signatures
  - People, process, product, technology dimensions again
- Networks
  - Multi tier : Web, application, database
  - 7 layer data comm model: HTTP (7), TCP/IP (4/3), Ethernet (2)
  - LANs, MANs, WANs: LANs, MANs are Ethernet, WANs vary
  - Fiber optic core, wireless/copper/CATV for access
  - Use private/carrier network, not open Internet in many cases

Course summary: process

- If you spent 12 hours per week for 14 weeks, that's 168 hours, or 4 40 hour weeks
- Ready for second spiral after 8 person weeks of work (4 person weeks times 2 people)
  - This can be done in the wasted “up-front” time to prepare for an anticipated project
  - It will usually take this long because you'll usually be learning a new domain and/or new technology
- By using the spiral model and being able to do requirements, UML, data models, SQL, Web sites, initial security approach and initial telecom approach, you can:
  - Work effectively with IT staff
  - Manage engineering or logistics projects with IT components
- By knowing technical areas covered in class, you can:
  - Specify, design and build databases, Web sites, etc. as a consultant