Firewalls and VPNs

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Audio/Video recordings of this lecture are available at:

http://www.cse.wustl.edu/~jain/cse571-17/

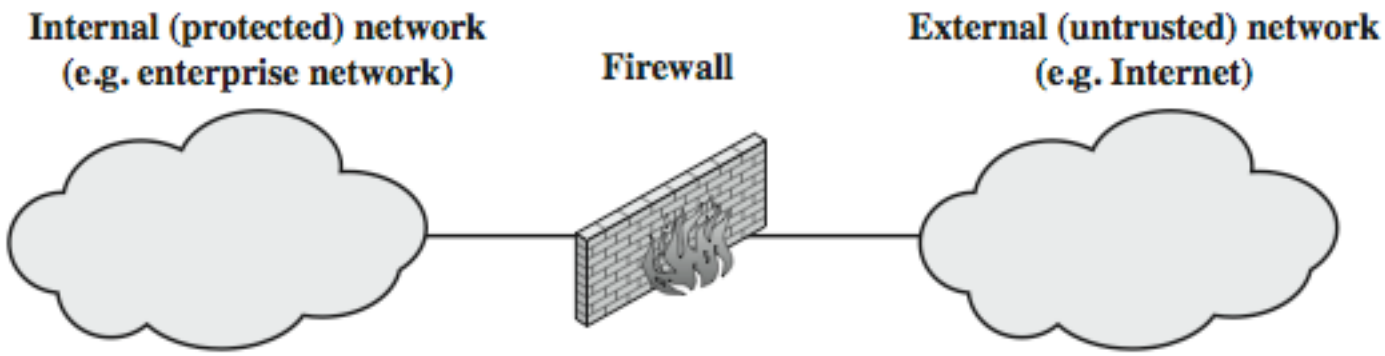
Overview

1. What is a Firewall?
2. Types of Firewalls
3. Proxy Servers
4. Firewall Location and Configuration
5. Virtual Private Networks

These slides are based on Lawrie Brown's slides supplied with William Stalling's book "Cryptography and Network Security: Principles and Practice," 7th Ed, 2017.

What is a Firewall?

- Interconnects networks with differing trust
  - Only authorized traffic is allowed
- Auditing and controlling access
  - Can implement alarms for abnormal behavior
- Provides network address translation (NAT) and usage monitoring
- Implements VPNs

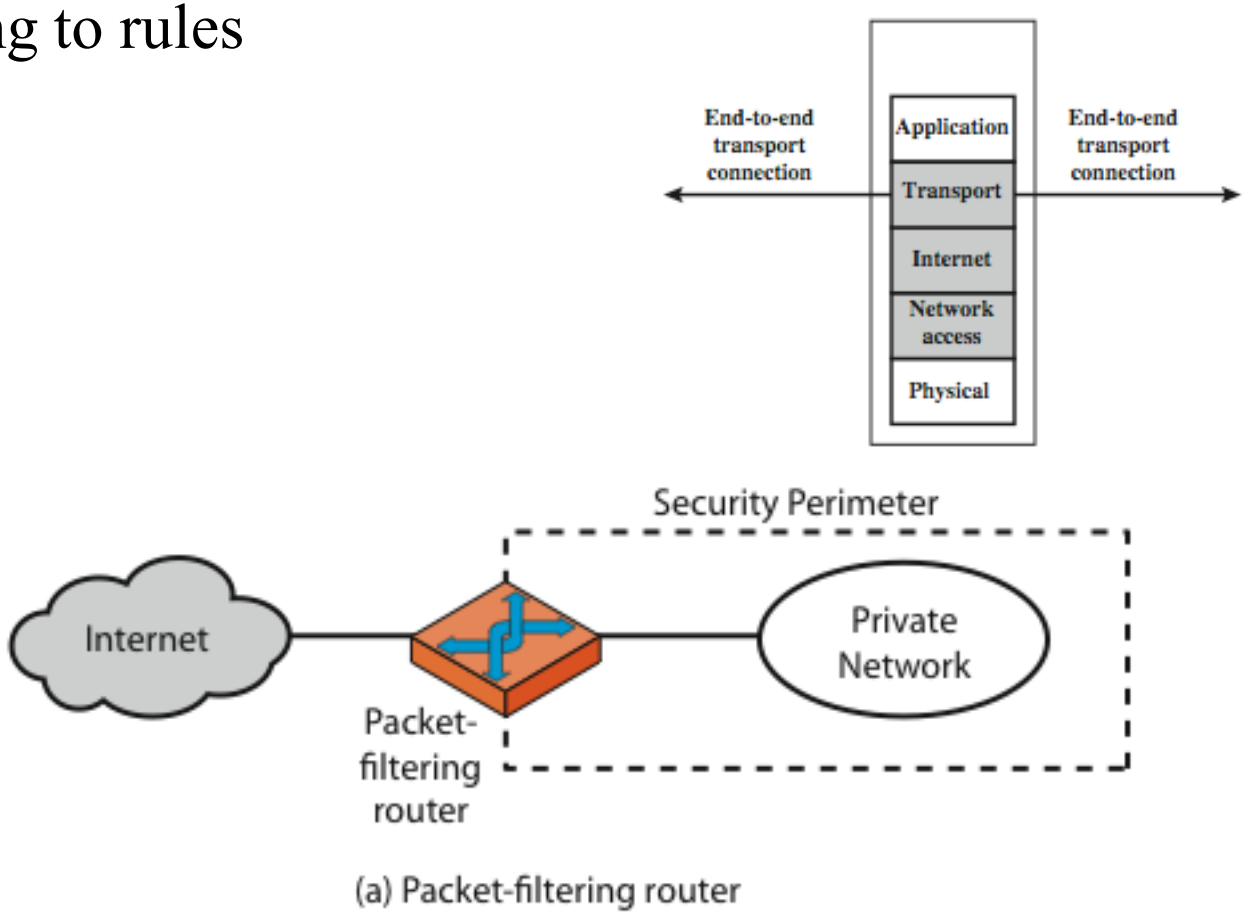


Firewall Limitations

- Cannot protect from attacks bypassing it
  - E.g., sneaker net, utility modems, trusted organisations, trusted services (e.g., SSL/SSH)
- Cannot protect against internal threats
  - E.g., disgruntled or colluding employees
- Cannot protect against access via Wireless LAN
  - If improperly secured against external use, e.g., personal hot spots
- Cannot protect against malware imported via laptops, PDAs, and storage infected outside

Firewalls – Packet Filters

- Examine each IP packet (no context) and permit or deny according to rules



(a) Packet-filtering router

Firewalls – Packet Filters

Table 20.1 Packet-Filtering Examples

A

action	ourhost	port	theirhost	port	comment
block	*	*	SPIGOT	*	we don't trust these people
allow	OUR-GW	25	*	*	connection to our SMTP port

B

action	ourhost	port	theirhost	port	comment
block	*	*	*	*	default

C

action	ourhost	port	theirhost	port	comment
allow	*	*	*	25	connection to their SMTP port

D

action	src	port	dest	port	flags	comment
allow	{our hosts}	*	*	25		our packets to their SMTP port
allow	*	25	*	*	ACK	their replies

E

action	src	port	dest	port	flags	comment
allow	{our hosts}	*	*	*		our outgoing calls
allow	*	*	*	*	ACK	replies to our calls
allow	*	*	*	>1024		traffic to nonservers

Attacks on Packet Filters

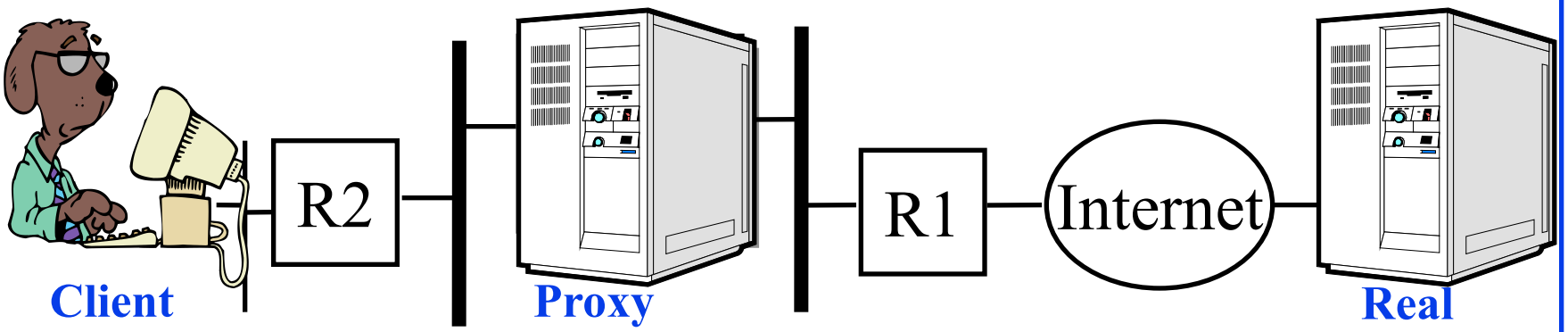
- IP address spoofing: Add filters on router to block
- Source routing attacks: Attacker sets a route other than default
  - Block source routed packets
- Tiny fragment attacks: Split header info over several tiny packets ⇒ Either discard or reassemble before check

Firewalls – Stateful Packet Filters

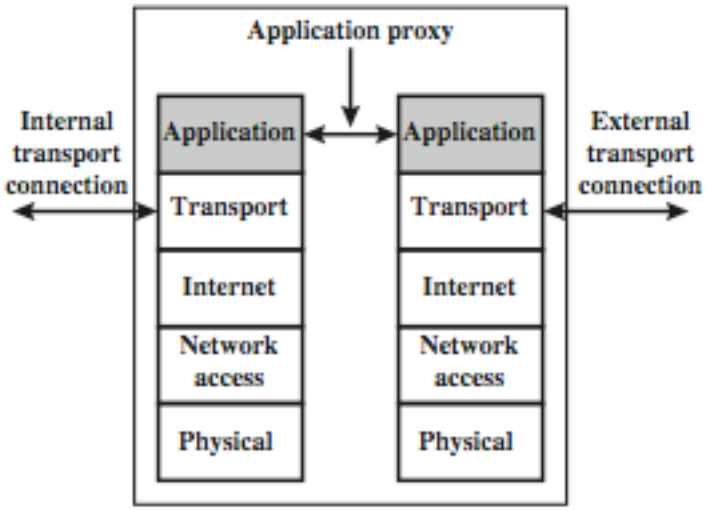
- Examine each IP packet in context
  - Keep track of client-server sessions
- May even inspect limited application data

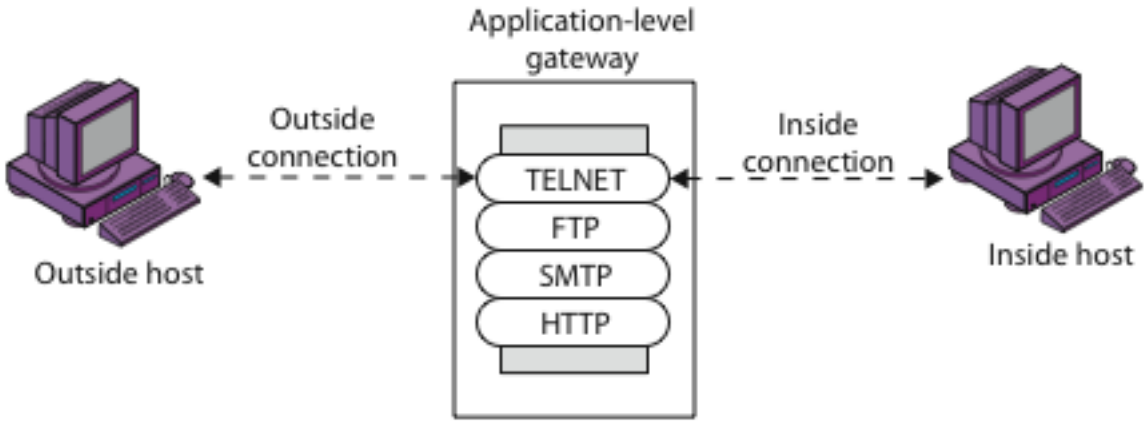
Proxy Servers

- Specialized server programs
- Take user's request and forward them to real servers
- Take server's responses and forward them to users
- Enforce site security policy ⇒ Refuse some requests.
- Also known as application-level gateways
- With special "Proxy client" programs, proxy servers are almost transparent



Application Level Gateway (Cont)

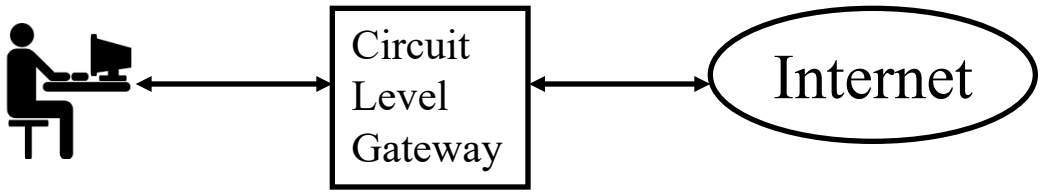




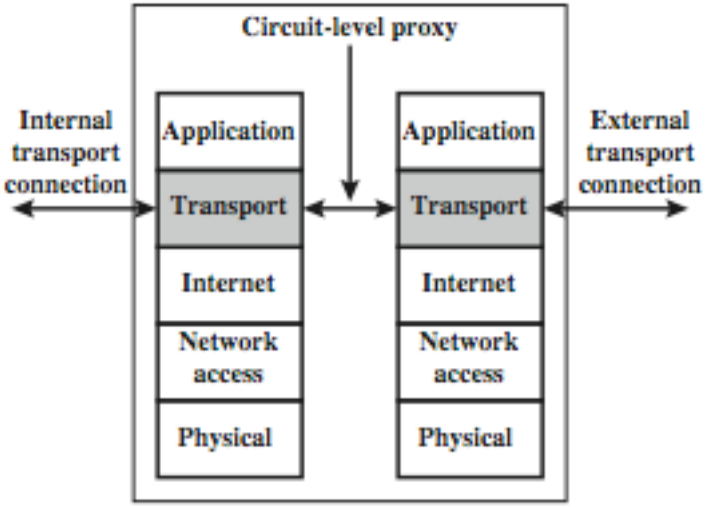
(b) Application-level gateway

Circuit Level Gateway

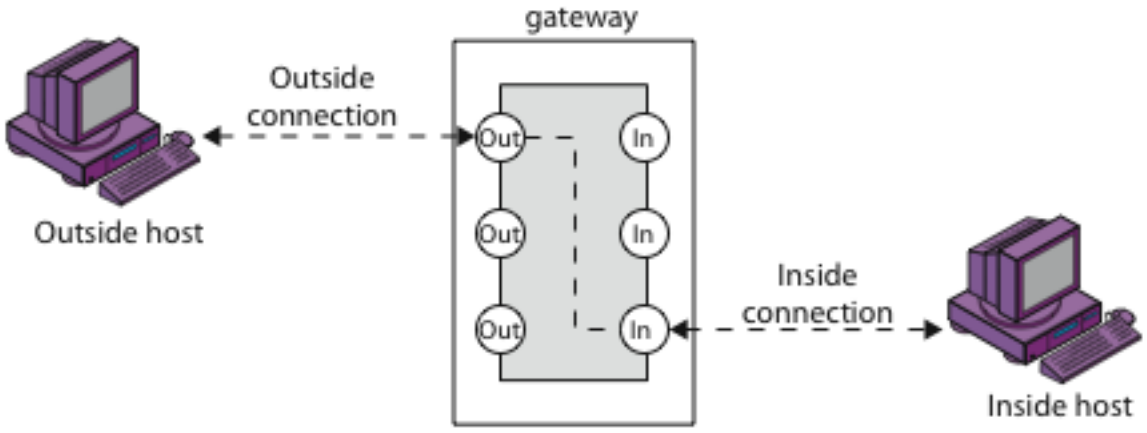
- Relays two TCP connections
- Imposes security by limiting which such connections are allowed
- Once created usually relays traffic without examining contents
- Typically used when trust internal users by allowing general outbound connections
- Socket Secure (SOCKS) is commonly used



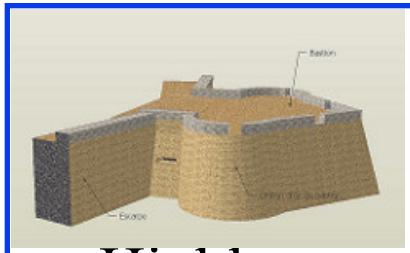
Circuit Level Gateway (Cont)



(e) Circuit-level proxy firewall

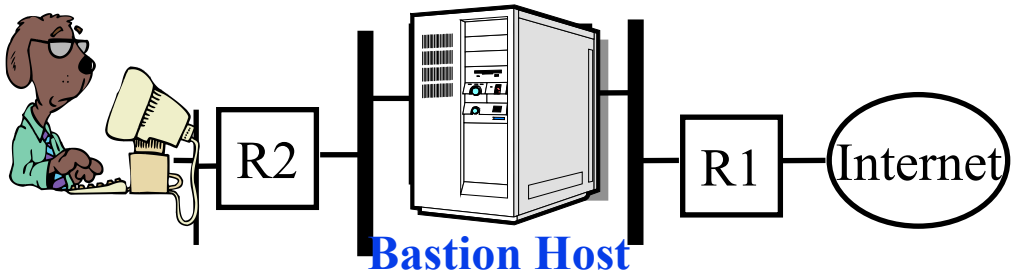


(c) Circuit-level gateway



Bastion Host

- Highly secure host system
- Runs circuit / application level gateways
- Provides externally accessible services
- Potentially exposed to "hostile" elements
  - Hardened O/S, essential services, extra auth
- May support 2 or more net connections
- May be trusted to enforce policy of trusted separation between these net connections



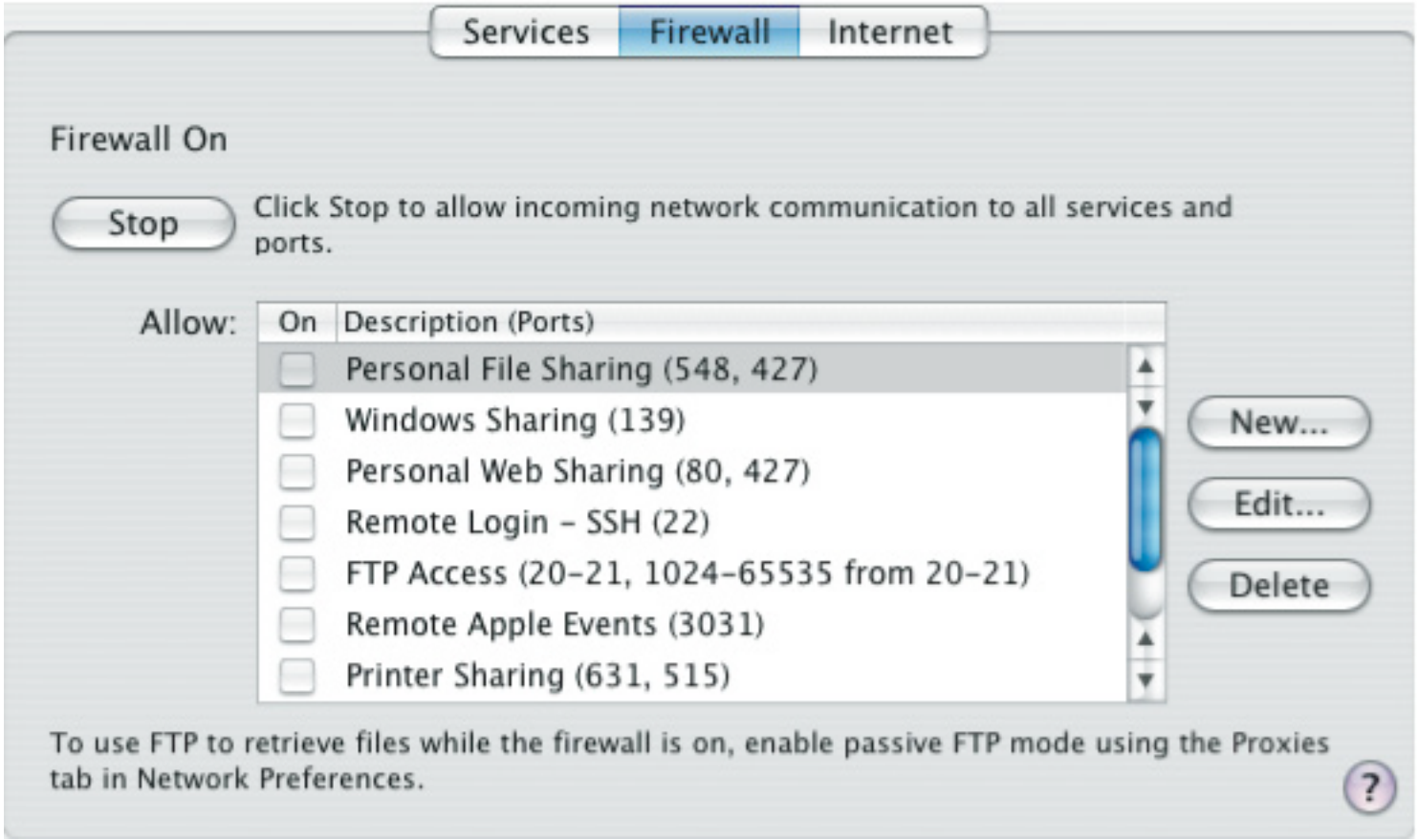
Host-Based Firewalls

- S/W module used to secure individual host
  - Available in many operating systems or an add-on package
- Mostly on servers.
- Advantages:
  - Can tailor filtering rules to host environment
  - Protection is provided independent of topology
  - Provides an additional layer of protection

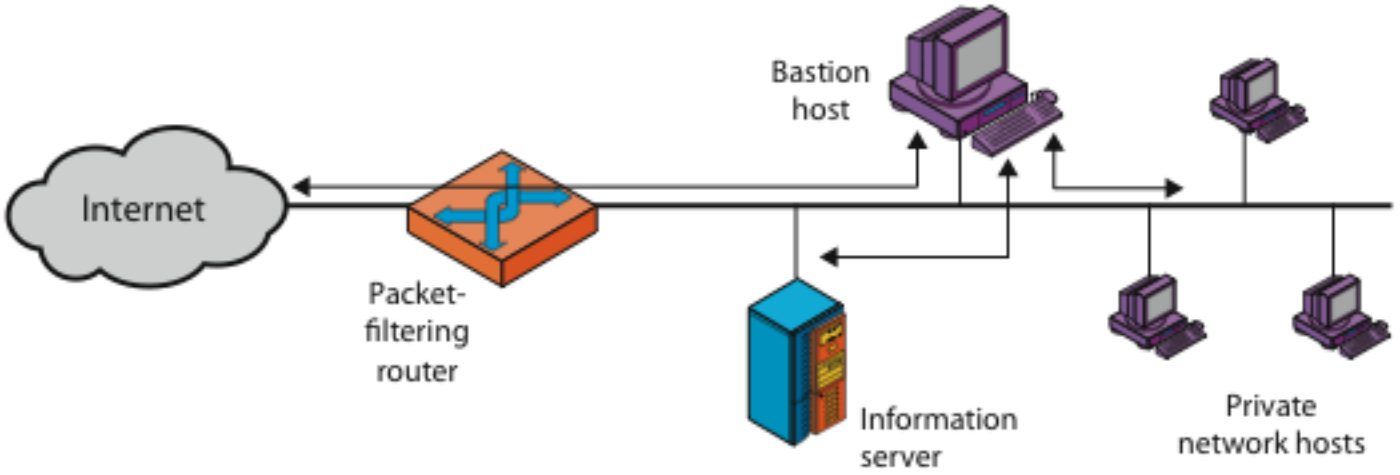
Personal Firewalls

- Controls traffic between PC/workstation and Internet or enterprise network
- A software module on personal computer or in home/office DSL/cable/ISP router
- Typically much less complex than other firewalls
- Primarily to deny unauthorized remote access to the computer and monitor outgoing activity for malware

Personal Firewalls

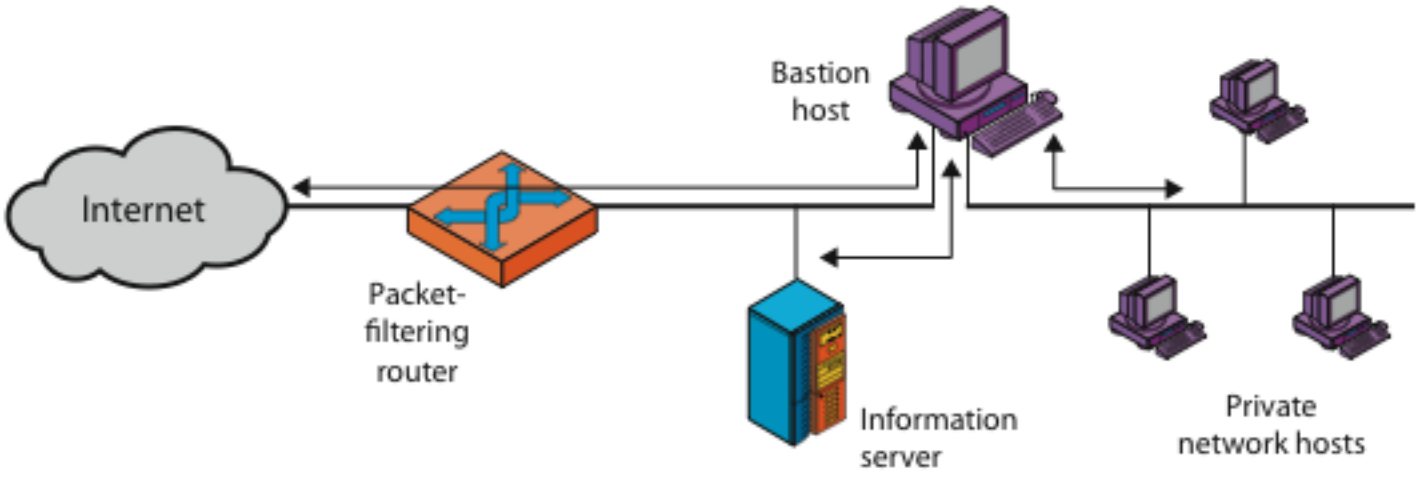


Firewall Configurations



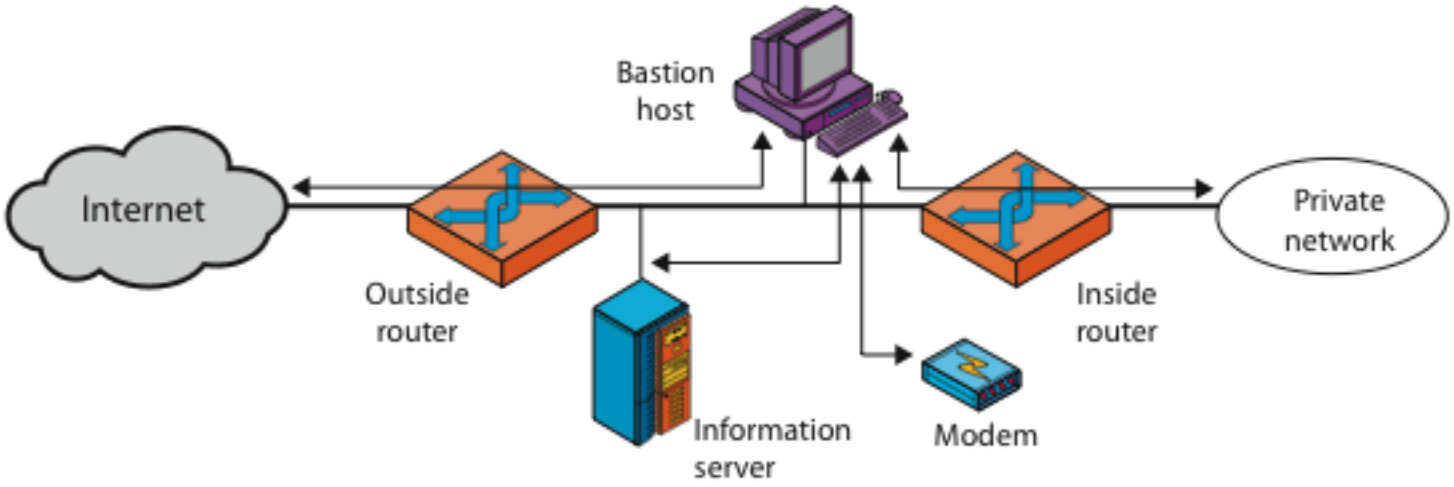
(a) Screened host firewall system (single-homed bastion host)

Firewall Configurations (Cont)



(b) Screened host firewall system (dual-homed bastion host)

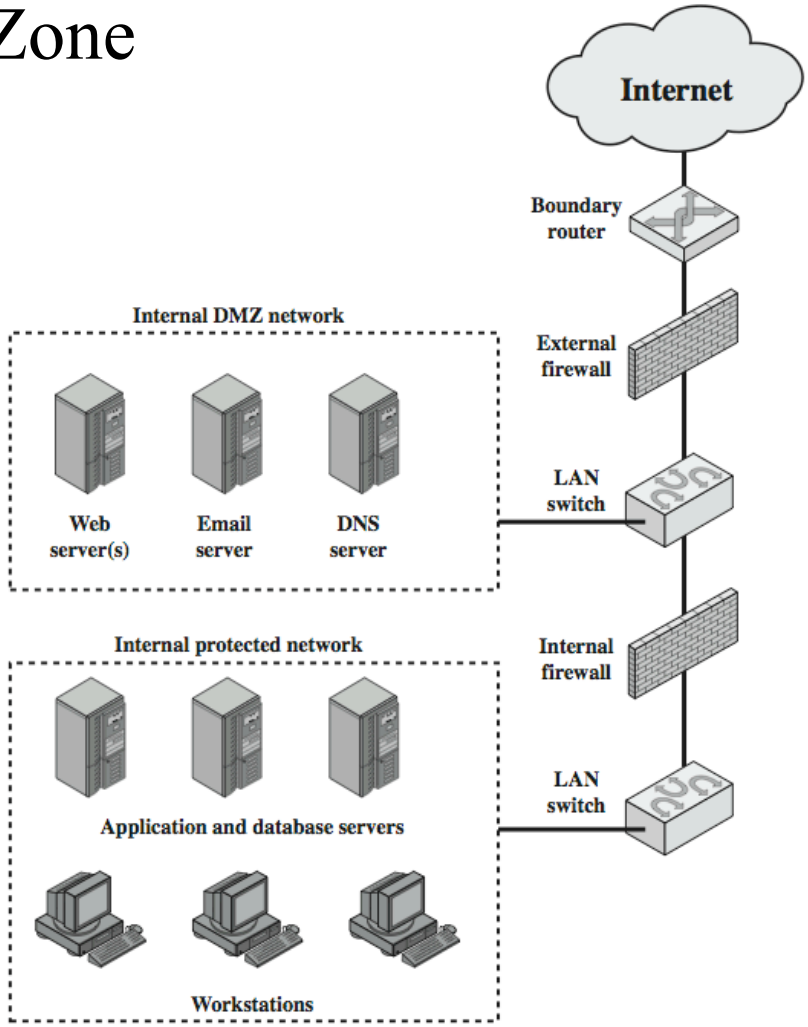
Firewall Configurations (Cont)



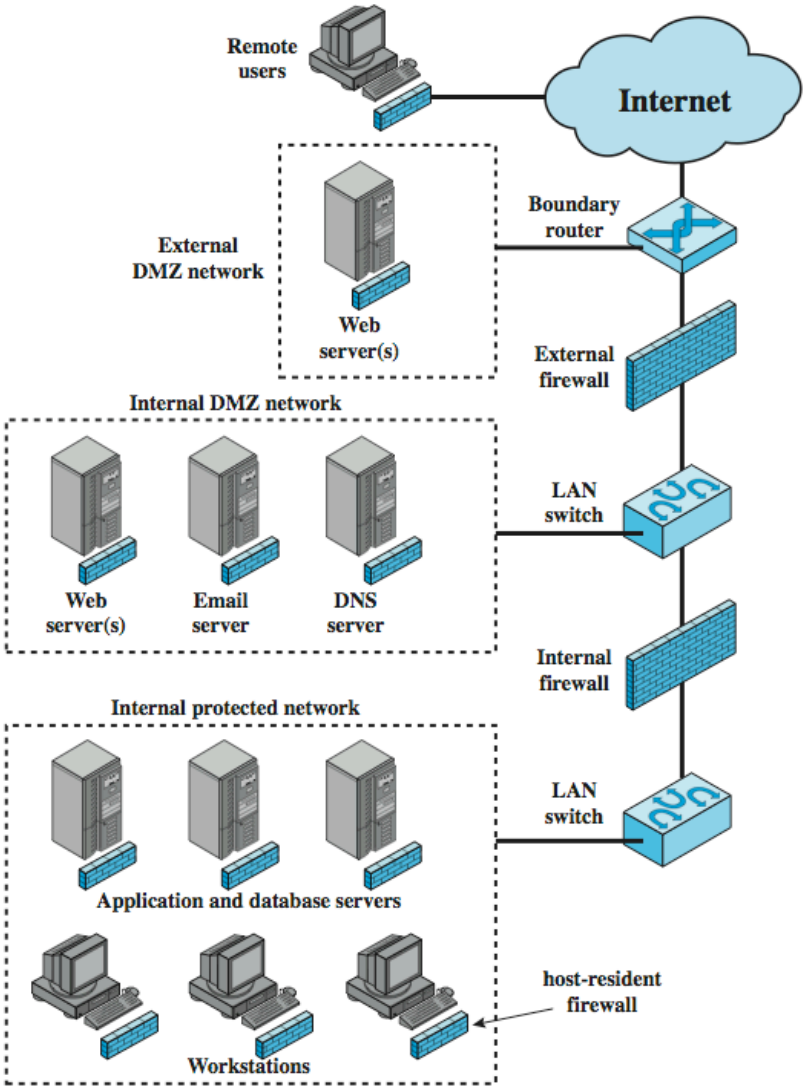
(c) Screened-subnet firewall system

DMZ Networks

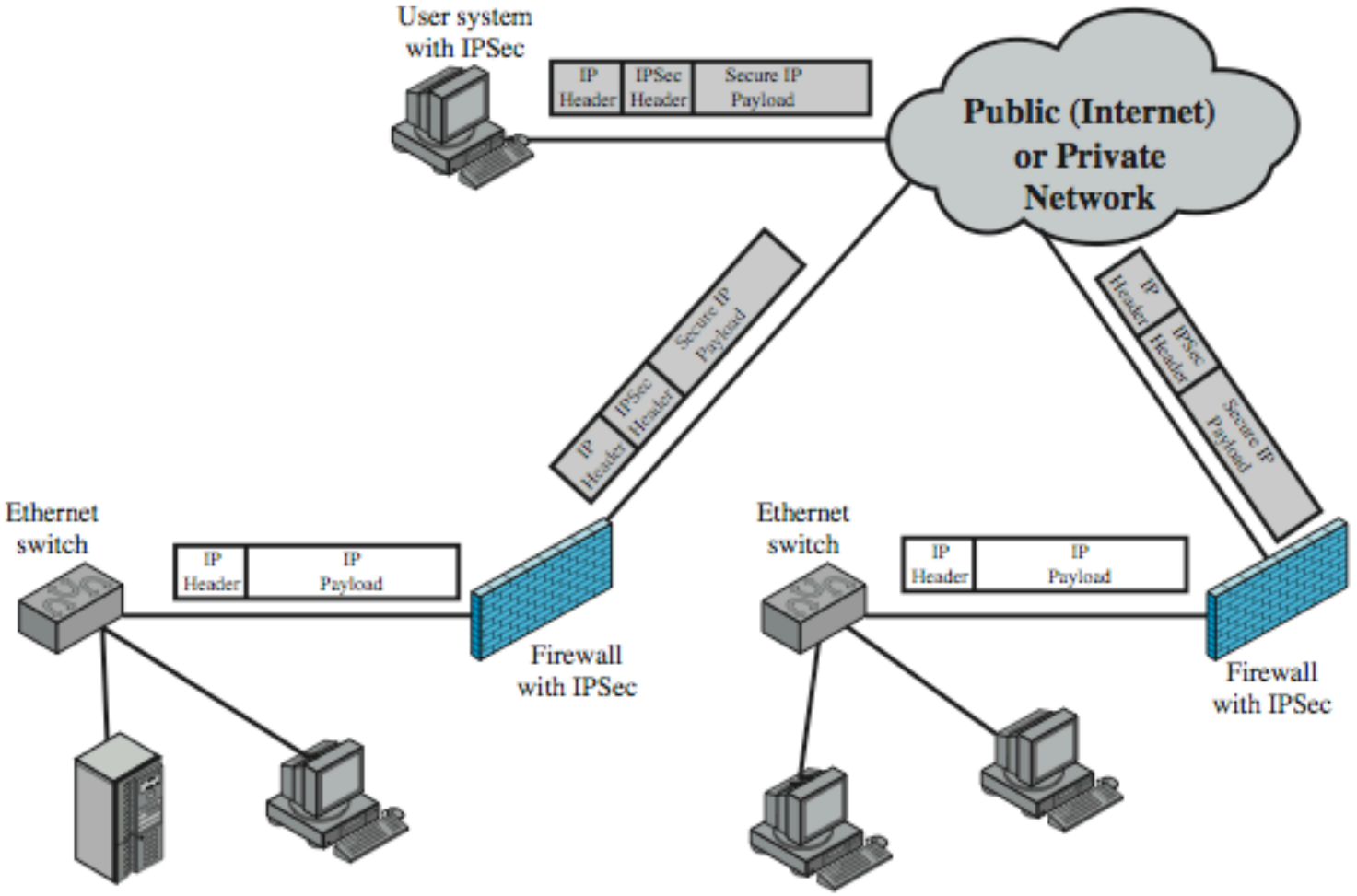
- Demilitarized Zone



Distributed Firewalls

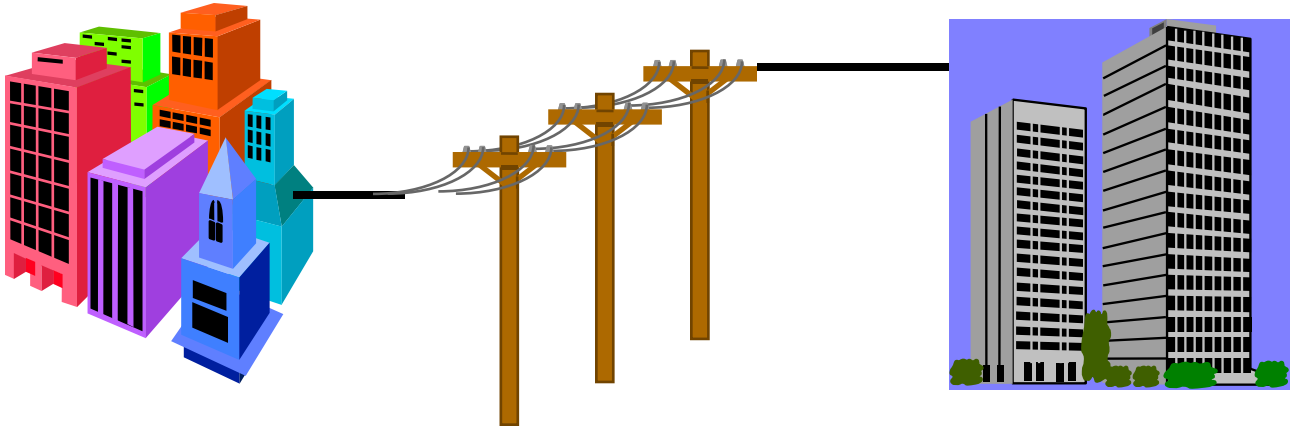


Virtual Private Networks

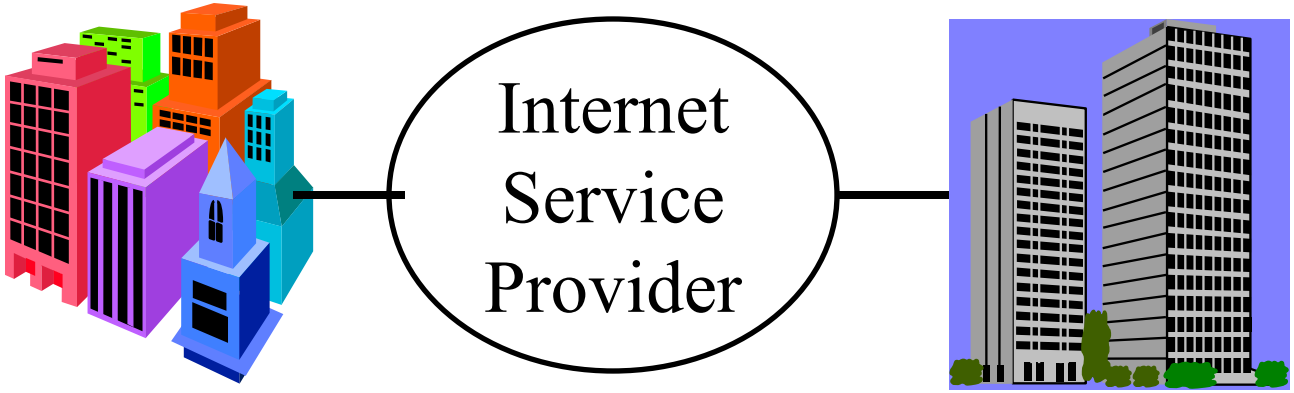


What is a VPN?

- Private Network: Uses leased lines

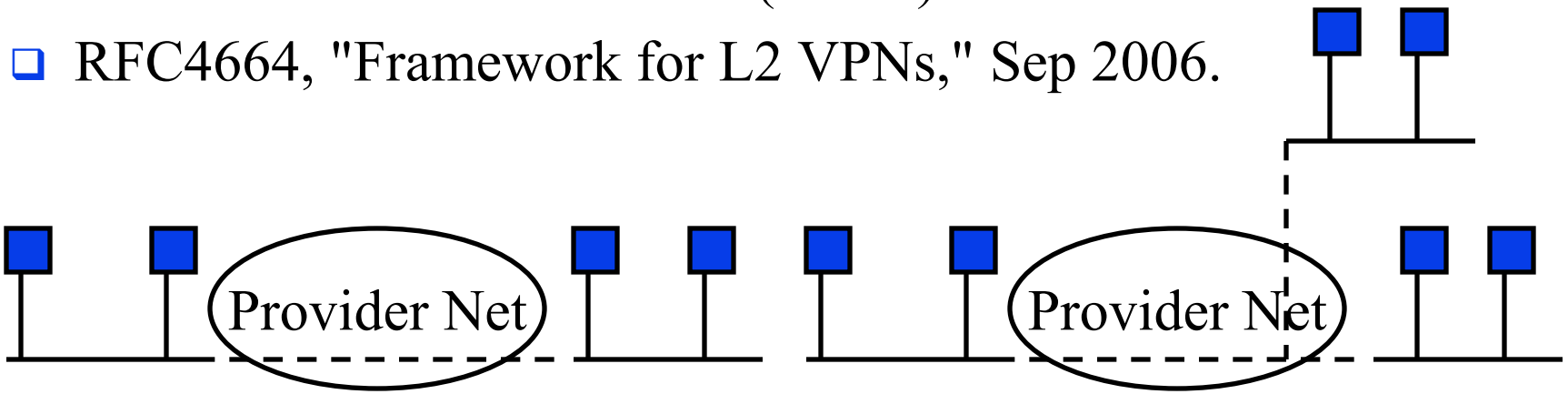


- *Virtual* Private Network: Uses public Internet



Layer 2 VPNs

- Customers' Layer 2 packets are encapsulated and delivered at the other end
- Looks like the two ends are on the same LAN or same wire
  ⇒ Provides Ethernet connectivity
- Works for all Layer 3 protocols
- Virtual Private Wire Service (VPWS)
- Virtual Private LAN Service (VPLS)
- RFC4664, "Framework for L2 VPNs," Sep 2006.



Layer 3 VPN

- Provides Layer 3 connectivity
- Looks like the two customer routers are connected
- Usually designed for IP packets

VPN Tunneling Protocols

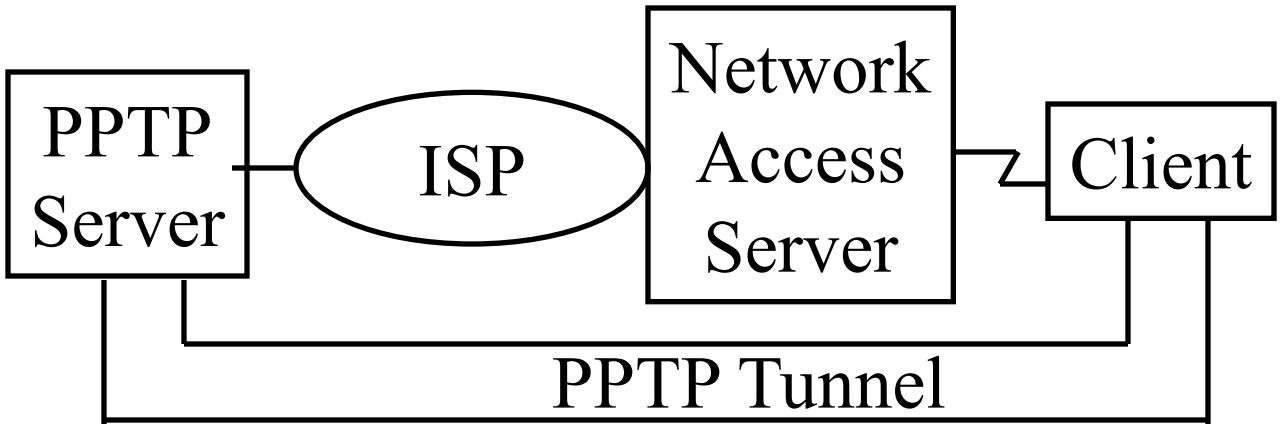
- GRE: Generic Routing Encaptulation (RFC 1701/2)
- PPTP: Point-to-point Tunneling Protocol
- L2TP: Layer 2 Tunneling protocol
- IPsec: Secure IP
- MPLS: Multiprotocol Label Switching

GRE

- Generic Routing Encaptulation (RFC 1701/1702)
- Generic ⇒ X over Y for any X or Y
- Optional Checksum, Loose/strict Source Routing, Key
- Key is used to authenticate the source
- Over IPv4, GRE packets use a protocol type of 47
- Allows router visibility into application-level header
- Restricted to a single provider network ⇒ end-to-end

Ref: https://en.wikipedia.org/wiki/Generic_Routing_Encapsulation

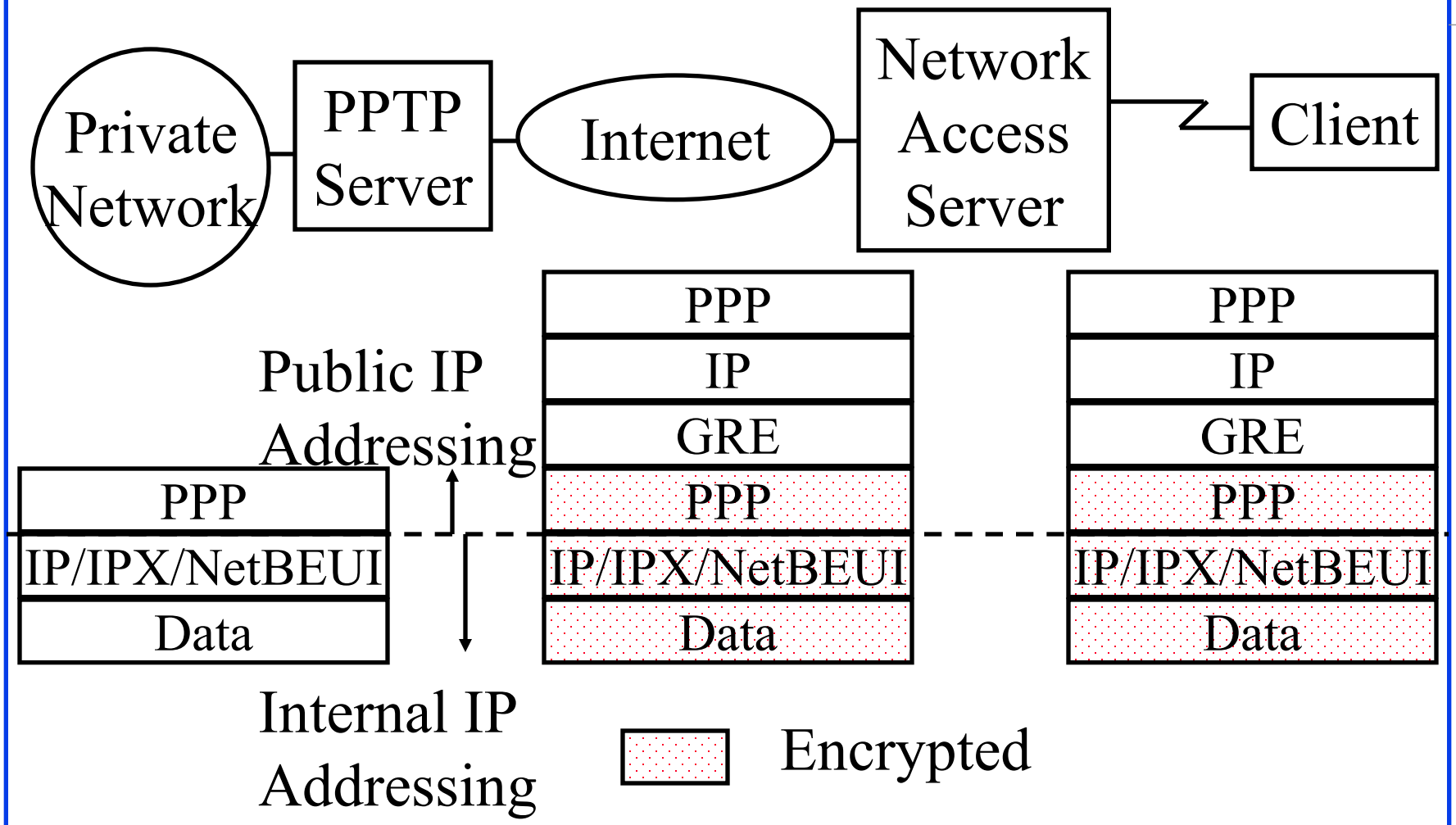
PPTP



- PPTP = Point-to-point Tunneling Protocol
- Developed jointly by Microsoft, Ascend, USR, 3Com and ECI Telematics
- PPTP server for NT4 and clients for NT/95/98

Ref: https://en.wikipedia.org/wiki/Point-to-Point_Tunneling_Protocol

PPTP Packets



L2TP

- Layer 2 Tunneling Protocol
- L2F = Layer 2 Forwarding (From CISCO)
- L2TP = L2F + PPTP
  Combines the best features of L2F and PPTP
- Easy upgrade from L2F or PPTP
- Allows PPP frames to be sent over non-IP (Frame relay, ATM) networks also (PPTP works on IP only)
- Allows multiple (different QoS) tunnels between the same end-points. Better header compression.
  Supports flow control

Ref: https://en.wikipedia.org/wiki/Layer_2_Tunneling_Protocol

L2TPv3

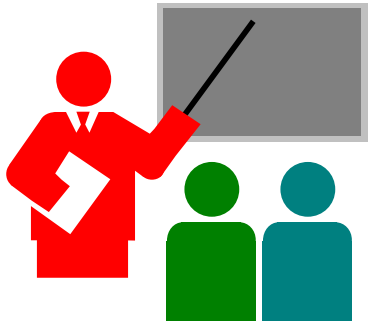
- Allows service providers to offer L2 VPN over IP network.
- L2TPv2 was for tunneling PPP over packet switched data networks (PSDN)
- V3 generalizes it for other protocols over PSDN
  $\Rightarrow$ PPP specific header removed
- Can handle HDLC (High-Level Data Link Control), Ethernet, 802.1Q VLANs, Frame relay, packet over SONET (Synchronous Optical Network)

OpenVPN

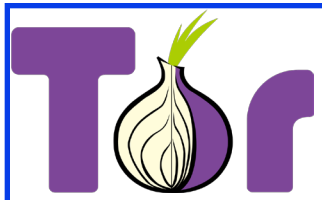
- Most popular open source VPN software for client and servers
- Can be implemented in firmware, e.g., DD-WRT, OpenWRT, …
- Available on most operating systems, e.g., Windows, Linus, Mac, IoS, Android, …
- Many routers come with OpenVPN support
- Does not use IKE, IPSec, PPTP, L2TP
- Uses OpenSSL library for SSL/TLS on TCP/UDP
- Provides all encryption/authentication methods in OpenSSL, e.g., pre-shared key, certificates, username/password, …
- OpenSSL allows servers to issue certificates to clients
- Extendable using modular plugins
- Uses a single TCP/UDP port ⇒ can traverse NAT/firewalls23

Ref: https://en.wikipedia.org/wiki/OpenVPN

Summary



1. Firewalls separate networks of different trust levels
2. Some traffic, such as, laptops, smart phones, and wireless can bypass firewall
3. Firewall can be a simple packet filter or an application level proxy
4. Servers for external public are often placed in DMZ that separates two networks of differing trusts
5. Firewall locations: single bastion inline, single bastion T, double bastion inline, double bastion T, distributed
6. PPTP and L2TP are layer 2 VPN protocols. IPSec provides Layer 3 VPN. OpenVPN is an implementation using SSL.



Lab 23: Tor

- Read about Tor (The Onion Router) from: https://en.wikipedia.org/wiki/Tor_(anonymity_network)
- Download and install Tor browser from: https://www.torproject.org/projects/torbrowser.html.en
- Open both Tor browser and your regular browser (Firefox or Internet Explorer, etc.)
- Browse to "WhatIsMyIP.com" on both browsers and capture the results.
- Repeat the previous step on both browsers and capture the results.
- Browse to http://thehiddenwiki.org/2013/08/23/list-of-onion (*Hidden Wiki | Tor .onion urls directories » How to access the Deep Web*) on both browsers and capture the results

Acronyms

- ACK Acknowledgement
- DMZ Demilitarized Zone
- DNS Domain Name System
- DSL Digital Subscriber Line
- FTP File Transfer Protocol
- HD High Definition
- IM Instant messaging
- IKE Internet Key Exchange
- IP Internet Protocol
- IPSec Secure IP
- ISP Internet Service Provider
- LAN Local Area Network
- L2F Layer 2 Forwarding
- L2TP Layer 2 Tunneling Protocol
- NAT Network Address Translator
- PPTP Point-to-Point Tunneling Protocol

Acronyms (Cont)

- OS Operating System
- PC Personal Computer
- PDA Personal Digital Assistant
- RFC Request for Comments
- SIPS Secure Session Initiation Protocol
- SMTP Simple Mail Transfer Protocol
- SOCKS Secure Socket
- SOHO office/home office
- SSH Secure Shell
- SSL Secure Socket Layer
- TCP Transmission Control Protocol
- Tor The Onion Router
- UDP User Datagram Protocol
- VPN Virtual Private Network
- WAN Wide Area Network
- WLAN Wireless Local Area Network

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http://www.cse.wustl.edu/~jain/cse571-17/index.html

CSE473S: Introduction to Computer Networks (Fall 2016),
http://www.cse.wustl.edu/~jain/cse473-16/index.html

Wireless and Mobile Networking (Spring 2016),
http://www.cse.wustl.edu/~jain/cse574-16/index.html

CSE571S: Network Security (Fall 2014),
http://www.cse.wustl.edu/~jain/cse571-14/index.html

Audio/Video Recordings and Podcasts of
Professor Raj Jain's Lectures,
https://www.youtube.com/channel/UCN4-5wzNP9-ruOzQMs-8NUw