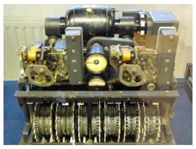

Network Security Protocols

Mike Freedman
COS 461: Computer Networks

http://www.cs.princeton.edu/courses/archive/spr14/cos461/

Network Security

- Application layer
  - E-mail: PGP, using a web-of-trust
  - Web: HTTP-S, using a certificate hierarchy
- Transport layer
  - Transport Layer Security/ Secure Socket Layer
- Network layer
  - IP Sec
- Network infrastructure
  - DNS-Sec and BGP-Sec

Basic Security Properties

- **Confidentiality:**
- **Authenticity:**
- **Integrity:**
- **Availability:**
- **Non-repudiation:**
- **Access control:**

Basic Security Properties

- **Confidentiality:** Concealment of information or resources
- **Authenticity:** Identification and assurance of origin of info
- **Integrity:** Trustworthiness of data or resources in terms of preventing improper and unauthorized changes
- **Availability:** Ability to use desired information or resource
- **Non-repudiation:** Offer of evidence that a party indeed is sender or a receiver of certain information
- **Access control:** Facilities to determine and enforce who is allowed access to what resources (host, software, network, …)

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Encryption and MAC/Signatures

Confidentiality (Encryption)

Sender:
- Compute $C = Enc_K(M)$
- Send C

Receiver:
- Recover $M = Dec_K(C)$

Auth/Integrity (MAC / Signature)

Sender:
- Compute $s = Sig_K(Hash\ (M))$
- Send <M, s>

Receiver:
- Compute $s' = Ver_K(Hash\ (M))$
- Check s' == s

These are simplified forms of the actual algorithms

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Email Security:
Pretty Good Privacy (PGP)

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E-Mail Security

- Security goals
  - Confidentiality: only intended recipient sees data
  - Integrity: data cannot be modified en route
  - Authenticity: sender and recipient are who they say
- Security non-goals
  - Timely or successful message delivery
  - Avoiding duplicate (replayed) message
  - (Since e-mail doesn't provide this anyway!)

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Sender and Receiver Keys

- If the sender knows the receiver's public key
  - Confidentiality
  - Receiver authentication
- If the receiver knows the sender's public key
  - Sender authentication
  - Sender non-repudiation

Sending an E-Mail Securely

- Sender digitally signs the message
  - Using the sender's private key
- Sender encrypts the data
  - Using a one-time session key
  - Sending the session key, encrypted with the receiver's public key
- Sender converts to an ASCII format
  - Converting the message to base64 encoding
  - (Email messages must be sent in ASCII)

Public Key Certificate

- Binding between identity and a public key
  - "Identity" is, for example, an e-mail address
  - "Binding" ensured using a digital signature
- Contents of a certificate
  - Identity of the entity being certified
  - Public key of the entity being certified
  - Identity of the signer
  - Digital signature
  - Digital signature algorithm id

Web of Trust for PGP

- Decentralized solution
  - Protection against government intrusion
  - No central certificate authorities
- Customized solution
  - Individual decides whom to trust, and how much
  - Multiple certificates with different confidence levels
- Key-signing parties!
  - Collect and provide public keys in person
  - Sign other's keys, and get your key signed by others

HTTP Security

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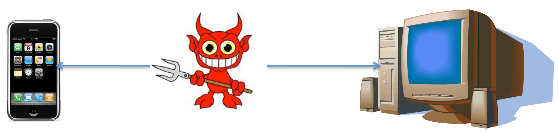
HTTP Threat Model

- Eavesdropper
  - Listening on conversation (confidentiality)
- Man-in-the-middle
  - Modifying content (integrity)
- Impersonation
  - Bogus website (authentication, confidentiality)



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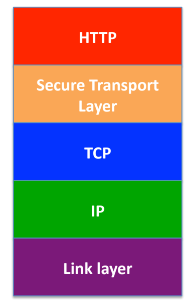
HTTP-S: Securing HTTP

- HTTP sits on top of secure channel (SSL/TLS)
  - https:// vs. http://
  - TCP port 443 vs. 80
- All (HTTP) bytes encrypted and authenticated
  - No change to HTTP itself!
- Where to get the key???



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Learning a Valid Public Key

- What is that lock?
  - Securely binds domain name to public key (PK)
    - If PK is authenticated, then any message signed by that PK cannot be forged by non-authorized party
  - Believable only if you trust the attesting body
    - Bootstrapping problem: Who to trust, and how to tell if this message is actually from them?

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Hierarchical Public Key Infrastructure

- Public key certificate
  - Binding between identity and a public key
  - “Identity” is, for example, a domain name
  - Digital signature to ensure integrity
- Certificate authority
  - Issues public key certificates and verifies identities
  - Trusted parties (e.g., VeriSign, GoDaddy, Comodo)
  - Preconfigured certificates in Web browsers

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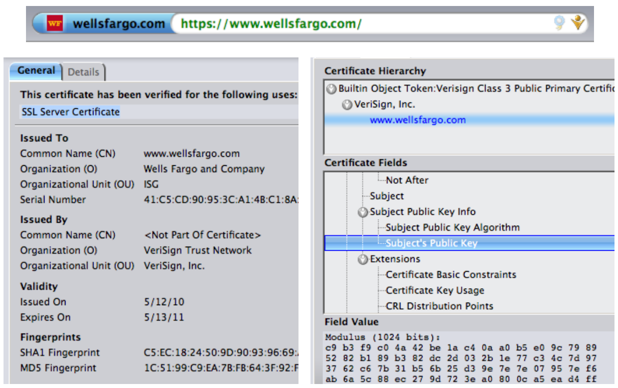
Public Key Certificate



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Transport Layer Security (TLS)

Based on the earlier Secure Socket Layer (SSL) originally developed by Netscape

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TLS Handshake Protocol

- Send new random value, list of supported ciphers →
- → Send new random value, digital certificate with PK
- Send pre-secret, encrypted under PK ←
- →
- Create shared secret key from pre-secret and random
- Create shared secret key from pre-secret and random
- Switch to new symmetric-key cipher using shared key
- Switch to new symmetric-key cipher using shared key

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TLS Record Protocol

- Messages from application layer are:
  – Fragmented or coalesced into blocks
  – Optionally compressed
  – Integrity-protected using an HMAC
  – Encrypted using symmetric-key cipher
  – Passed to the transport layer (usually TCP)
- Sequence #s on record-protocol messages
  – Prevents replays and reorderings of messages

Comments on HTTPS

- HTTPS authenticates server, not content
  – If CDN (Akamai) serves content over HTTPS, customer must trust Akamai not to change content
- Symmetric-key crypto after public-key ops
  – Handshake protocol using public key crypto
  – Symmetric-key crypto much faster (100-1000x)
- HTTPS on top of TCP, so reliable byte stream
  – Can leverage fact that transmission is reliable to ensure: each data segment received exactly once
  – Adversary can't successfully drop or replay packets

IP Security

IP Security

- There are range of app-specific security mechanisms
  – eg. TLS/HTTPS, S/MIME, PGP, Kerberos, …
- But security concerns that cut across protocol layers
- Implement by the network for all applications?

Enter IPSec!

IPSec

- General IP Security framework
- Allows one to provide
  – Access control, integrity, authentication, originality, and confidentiality
- Applicable to different settings
  – Narrow streams: Specific TCP connections
  – Wide streams: All packets between two gateways

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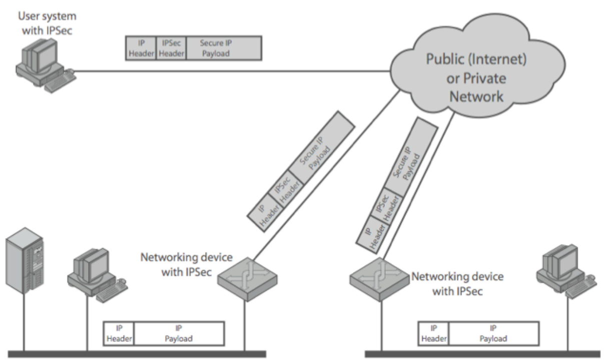
IPSec Uses



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Benefits of IPSec

- If in a firewall/router:
  - Strong security to all traffic crossing perimeter
  - Resistant to bypass
- Below transport layer
  - Transparent to applications
  - Can be transparent to end users
- Can provide security for individual users

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IP Security Architecture

- Specification quite complex
  - Mandatory in IPv6, optional in IPv4
- Two security header extensions:
  - Authentication Header (AH)
    - Connectionless integrity, origin authentication
      - MAC over most header fields and packet body
    - Anti-replay protection
  - Encapsulating Security Payload (ESP)
    - These properties, plus confidentiality

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Encapsulating Security Payload (ESP)

- Transport mode: Data encrypted, but not header
  - After all, network headers needed for routing!
  - Can still do traffic analysis, but is efficient
  - Good for host-to-host traffic
- Tunnel mode: Encrypts entire IP packet
  - Add new header for next hop
  - Good for VPNs, gateway-to-gateway security

Replay Protection is Hard

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- Goal: Eavesdropper can't capture encrypted packet and duplicate later
  - Easy with TLS/HTTP on TCP: Reliable byte stream
  - But IP Sec at packet layer; transport may not be reliable
- IP Sec solution: Sliding window on sequence #'s
  - All IPSec packets have a 64-bit monotonic sequence number
  - Receiver keeps track of which seqno's seen before
    - [lastest – windowsize + 1 , latest] ; windowsize typically 64 packets
  - Accept packet if
    - seqno > latest (and update latest)
    - Within window but has not been seen before
  - If reliable, could just remember last, and accept iff last + 1

DNS Security

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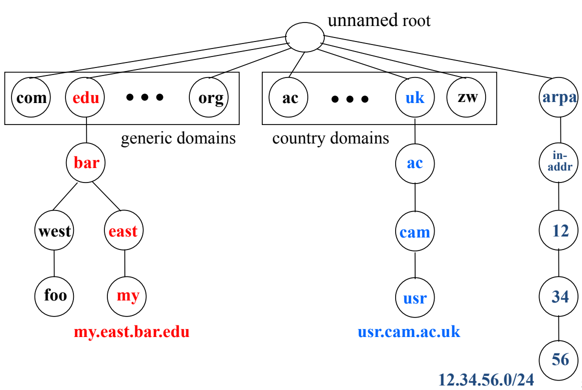
Hierarchical Naming in DNS



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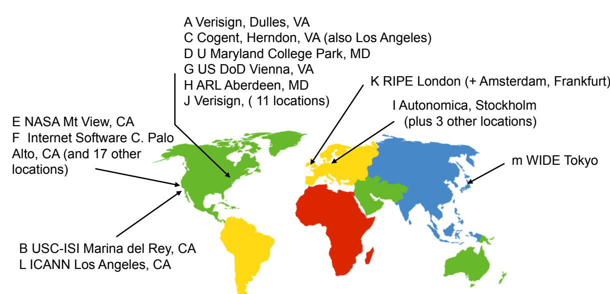
DNS Root Servers

- 13 root servers (see http://www.root-servers.org/)
- Labeled A through M



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DoS attacks on DNS Availability

- Feb. 6, 2007
  - Botnet attack on the 13 Internet DNS root servers
  - Lasted 2.5 hours
  - None crashed, but two performed badly:
    - g-root (DoD), l-root (ICANN)
    - Most other root servers use anycast

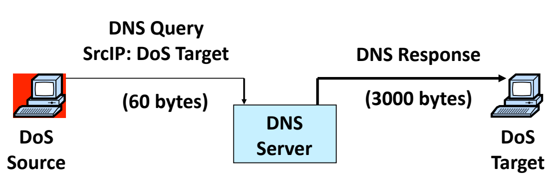
Defense: Replication and Caching

Letter	Old name	Operator	Location
A	ns.internic.net	VeriSign	Dulles, Virginia, USA
B	ns1.isi.edu	ISI	Marina Del Rey, California, USA
C	c.psi.net	Cogent Communications	distributed using anycast
D	terp.umd.edu	University of Maryland	College Park, Maryland, USA
E	ns.nasa.gov	NASA	Mountain View, California, USA
F	ns.isc.org	ISC	distributed using anycast
G	ns.nic.ddn.mil	U.S. DoD NIC	Columbus, Ohio, USA
H	aos.arl.army.mil	U.S. Army Research Lab	Aberdeen Proving Ground, Maryland, USA
I	nic.nordu.net	Autonomica	distributed using anycast
J		VeriSign	distributed using anycast
K		RIPE NCC	distributed using anycast
L		ICANN	Los Angeles, California, USA
M		WIDE Project	distributed using anycast

source: wikipedia

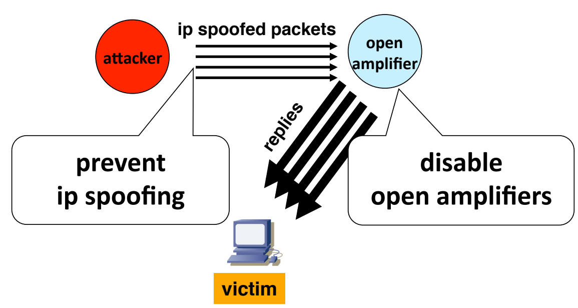
Denial-of-Service Attacks on Hosts

×40 amplification



580,000 open resolvers on Internet (Kaminsky-Shiffman'06)

Preventing Amplification Attacks



DNS Integrity and the TLD Operators

- If domain name doesn't exist, DNS should return NXDOMAIN (non-existant domain) msg
- Verisign instead creates wildcard records for all .com and .net names not yet registered
  - September 15 – October 4, 2003
- Redirection for these domain names to Verisign web portal: "to help you search"
  - And serve you ads…and get "sponsored" search
  - Verisign and online advertising companies make $$

DNS Integrity: Cache Poisoning

- Was answer from an authoritative server?
  - Or from somebody else?
- DNS cache poisoning
  - Client asks for www.evil.com
  - Nameserver authoritative for www.evil.com returns additional section for (www.cnn.com, 1.2.3.4, A)
  - Thanks! I won't bother check what I asked for

DNS Integrity: DNS Hijacking

- To prevent cache poisoning, client remembers:
  - The domain name in the request
  - A 16-bit request ID (used to demux UDP response)
- DNS hijacking
  - 16 bits: 65K possible IDs
  - What rate to enumerate all in 1 sec? 64B/packet
  - 64*65536*8 / 1024 / 1024 = 32 Mbps
- Prevention: also randomize DNS source port
  - Kaminsky attack: this source port… wasn't random

http://unixwiz.net/techtips/iguide-kaminsky-dns-vuln.html

Let's strongly believe the answer! Enter DNSSEC

- DNSSEC protects against data spoofing and corruption
- DNSSEC also provides mechanisms to authenticate servers and requests
- DNSSEC provides mechanisms to establish authenticity and integrity

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PK-DNSSEC (Public Key)

- The DNS servers sign the hash of resource record set with its private (signature) keys
  - Public keys can be used to verify the SIGs
- Leverages hierarchy:
  - Authenticity of name server's public keys is established by a signature over the keys by the parent's private key
  - In ideal case, only roots' public keys need to be distributed out-of-band

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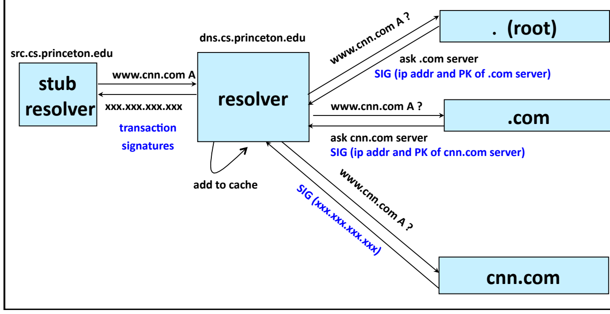
Verifying the Tree

Question: www.cnn.com ?



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Conclusions

- Security at many layers
  - Application, transport, and network layers
  - Customized to the properties and requirements
- Exchanging keys
  - Public key certificates
  - Certificate authorities vs. Web of trust
- Next time
  - Interdomain routing security
- Learn more: take COS 432 in the fall!