Network Security

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CPS 214

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Telco/Internet Comparison

- Telephone System
  - central authority
  - network in control
  - billing records per connection
  - legal issues well understood
  - provisions for law enforcement (wiretapping)
- Internet
  - no central authority
  - end systems in control
  - no central knowledge of connections
  - no per-packet billing
  - legal issues not well understood
  - anonymity is easy

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Internet Security Stinks

- Hosts are hard to secure
- Bad defaults
- Poor software
- Fixes rarely applied
- Average user/administrator is clueless
- An overly secure system is not useful
- It's difficult to coordinate among sites

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Security Goals

- Confidentiality
  - Snooping
  - Encryption
- Integrity
  - Deletion, changes
  - Backups
- Availability
  - Denial of service attacks
- Authentication
  - Are who you say you are?
- Nonrepudiation
  - No denying it
- Access Control
  - Don't touch that!
- Reputation
  - Ensure your good name

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Challenges

- Increased overhead
- Complexity
- Performance!
- Is it really secure?
- Management

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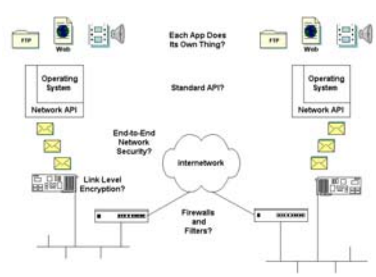
Where to Put the Protection?



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Which Layer?

Function				Example
Ultimate data destination	Application	↔	Application	Web browser
Format conversion	Presentation	↔	Presentation	ASCII/XDR
Interaction across presentation	Session	↔	Session	Restartable file transfer
Reliable, ordered delivery	Transport	↔	Transport	TCP
Routing/ Internetworking	Network	↔	Network	IP
Data framing over links	Data link	↔	Data link	Ethernet, ATM
Bits on the wire	Physical	↔	Physical	SONET, 100BT

Which Layer?

Function			
Ultimate data destination	Application	↔	HTTPS/SSH
Format conversion	Presentation	↔	
Interaction across presentation	Session	↔	
Reliable, ordered delivery	Transport	↔	TLS/SSL
Routing/ Internetworking	Network	↔	IPSec
Data framing over links	Data link	↔	WEP
Bits on the wire	Physical	↔	Lock bldg!

Physical Security

- Trash bins
- Social engineering
  - Rubber hose attacks are the most dangerous
  - Disgruntled employee
  - Curious, but dangerous employee
  - Clueless and dangerous employee
- It's much easier to trust a face than a packet
- Protect from the *whoops*
  - power
  - spills
  - the clumsy
  - software really can kill hardware

Host Based Security

- Recall End-to-End Argument
- Security is ultimately a host problem
- Key idea: protect the *DATA*
- End hosts are in control of data
- Users are in control of end hosts
- Users can and often will do dumb things
  - Especially when others help them to!
- Result: very difficult to protect all hosts

Security by Obscurity

- Is no security at all.
- However
  - It's often best not to advertise unnecessarily
  - It's often the only layer used (e.g. passwords)
- Probably need more security

Password Cracking

- Very common today
- If attacker can get a hold of the password file, they can go offline and process it
- Recall
  - passwords are a form of obscurity
  - multiple defenses may be needed
- Given enough time, passwords alone are probably not safe

Viruses, Worms, and SpyBots

- Programs written with the intent to spread
- Worms are very common today
  - Often email based (e.g. ILOVEYOU)
- Viruses *infect* other programs
  - Code copied to other programs (e.g. macros)
- All require the code to be executed
  - Proves users continue to do dumb things
  - Sometimes software is at fault too

Network Based Security

- Should augment host based security
- Useful for
  - Protecting groups of users from others
  - Prohibiting certain types of network usage
  - Controlling traffic flow
- Difficult to inspect traffic
  - Encryption can hide bad things
  - Tunneling can mislead you

Layered Defenses

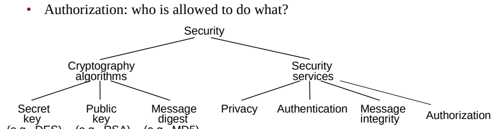
- The *belt and suspenders* approach
- Multiple layers make it harder to get through
- Multiple layers take longer to get through
- Basic statistics and probability apply
  - If Defense A stops 90% of all attacks and Defense B stops 90% of all attacks, you might be able to stop up to 99% of all attacks
- Trade-off in time, money, performance and convenience

Exploits Overview

- Passwords
  - hacking and sniffing
- System specific holes
  - NT, UNIX, NetWare, Linux
- Application (implementation) specific
  - web browser, ftp, email, finger
- Protocol specific
  - spoofing, TCP session hijacking, ICMP redirects, DNS
- Denial of Service
  - PING of death, SYN flood

Security Methods

- Cryptography functions
  - Secret key (e.g., DES)
  - Public key (e.g., RSA)
  - Message digest (e.g., MD5)
- Security services
  - Privacy: preventing unauthorized release of information
  - Authentication: verifying identity of the remote participant
  - Integrity: making sure message has not been altered
  - Authorization: who is allowed to do what?



Encryption

- Use a “secret” machine or algorithm
  - How do you know when it has been compromised?
  - German “Enigma”. First cracked in 1932 by Marian Rejewski, a Polish Mathematician. Then again in WW2 by British in 1939 by Alan Turing (founder of computer science)

Encryption

- Make a readable message unreadable
- Math intensive
- Plain text versus cipher text
- Algorithms and keys
  - public
  - private
  - key size

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An unbreakable method

- One Time Pad – Hide message in noise!
  - Start with a sequence of random numb
    - r1, r2, r3, ….
  - Break message into number sequence
    - m1, m2, m3, ….
  - Compute x-or sum
    - c1= r1+m1, c2 = r2+m2, c3 = r3+m3, …
  - Recover message by
    - m1=c1+r1, m2=c2+r2, …
- Both parties must have copy of random sequence
  - Sequence must be truly random
    - Otherwise patterns can be detected

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Shared Secret Key

- Each party knows a secret
- The secret is used to decrypt the cipher text
  - Book: Ulysses
  - Page: 7
  - Line: 23
  - Word: 4
- Must know the book and keep it a secret

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Shared Secret Key Illustrated

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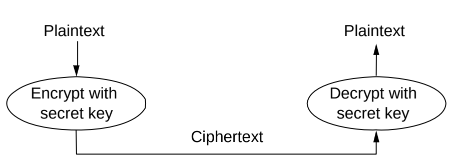
Secret Key (DES)

Data Encryption Standard uses a secret key.



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Main ideas of DES

- **1972 - NBS issued a call for proposals:**
  - **Must provide high level of security.**
  - **Must be completely specified and easy to understand.**
  - **The algorithm itself must provide the security.**
  - **Must be available to all users.**
  - **Must be adaptable for use in diverse applications.**
  - **Must be economical to implement in electronic devices.**
  - **Must be efficient.**
  - **Must be able to be validated.**
  - **Must be exportable.**
- **1974 - IBM responded with "Lucifer"**
- **1976 - DES officially adopted.**

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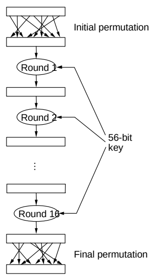
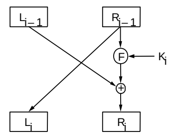
- 64-bit key (56-bits + 8-bit parity)
- 16 rounds



- Each Round



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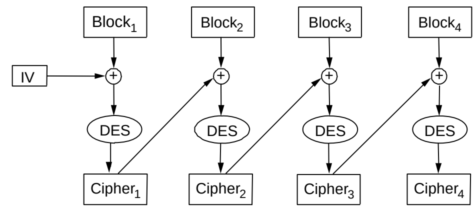
- Repeat for larger messages



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Public Key Cryptography

- Public Key
  - Everyone can use it to encrypt messages to you
- Private Key
  - Only you know this key and only it decrypts messages encrypted with your public key
- Keyring
  - Contains other people's public keys
  - How do you build this? Why is this hard?

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Public Key Illustrated

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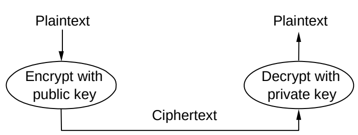
Public Key (RSA)



- Encryption & Decryption
  - Let (e,n)=encryption key, (d,n) = decryption key
  - Let m = message, c = cipher text

$$c = m^e \bmod n$$
$$m = c^d \bmod n$$

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How does this work?

- Every person x has a public key e(x) and a private key d(x)
- If I want to send a an encrypted message m to x, I compute $c = m^{e(x)} \bmod n$
  - X decripts it with his private key $m = c^{d(x)} \bmod n$
- Assumptions
  - Everybody that wants to send me a message must know my public key and n
  - I am the only person who has my private key
- How do we get d, e and n?

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RSA in detail

- Choose two large prime numbers *p* and *q* (each 256 bits)
- Multiply *p* and *q* together to get *n*
- Choose the encryption key *e*, such that *e* and (p - 1) x (q - 1) are relatively prime.
  - Two numbers are relatively prime if they have no common factor greater than one
- Compute decryption key *d* such that

$$d = e^{-1} \bmod ((p - 1) \times (q - 1))$$

- Construct public key as (e, n)
- Construct private key as (d, n)
- Discard (do not disclose) original primes *p* and *q*

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How can I break it?

- Suppose we have cipher text c and public key (e, n). We want m so we need d.
  - If $c = m^e$ then need to do $m = c^{(1/e)} = \sqrt[e]{c}$
  - Need to find d so that e*d = 1 mod (p-1)(q-1)
  - So find p and q!
  - n = p*q so just factor n.
    - Oh, that is hard!
  - Is there another function that can be used to get e given d and n?
    - Unknown.
    - Widely believed that any other method would be just as hard as factoring.

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Performance Issues

- To protect the contents of a message, encrypt it!
  - Can use DES or RSA.
    - DES can do several hundred Mbps.
    - RSA is slow (100 Kbps)
  - Must use DES, but the key may be discovered.
    - Solution: only use it for a while.
    - Called a session key
  - How do we share the session key?
    - If we have RSA infrastructure, can exchange key with RSA and use DES for the session
    - Key distribution problem

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Key Distribution

- Certificate
  - special type of digitally signed document:
    - *"I certify that the public key in this document belongs to the entity named in this document, signed X."*
  - the name of the entity being certified
  - the public key of the entity
  - the name of the certified authority
  - a digital signature
- Certified Authority (CA)
  - administrative entity that issues certificates
  - useful only to someone that already holds the CA's public key.

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Key Distribution (cont)

- Chain of Trust
  - if *X* certifies that a certain public key belongs to *Y*, and *Y* certifies that another public key belongs to *Z*, then there exists a chain of certificates from *X* to *Z*
  - someone that wants to verify *Z*'s public key has to know *X*'s public key and follow the chain
- Certificate Revocation List

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Message integrity

- I send a message M.
  - I don't care who sees the message but
    - I don't want it tampered with (no modifications)
    - I don't want anybody to forge messages from me.

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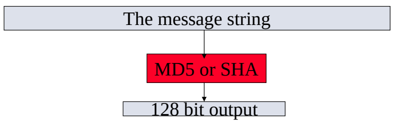
Message Digest

- Cryptographic checksum
  - Like a regular checksum which protects eceiver from accidental changes to the message
  - A cryptographic checksum protects the receiver from malicious changes to the message.



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Message Integrity Protocols

- Digital signature using RSA
  - special case of a message integrity where the code can only have been generated by one participant
  - compute signature with private key and verify with public key
- Keyed MD5
  - sender: *m* + MD5(*m* + *k*) + E(*k*, *senders private key*)
  - receiver
    - recovers random key using the sender's public key
    - applies MD5 to the concatenation of this random key message
- MD5 with RSA signature
  - sender: *m* + E(MD5(*m*), *senders private key*)
  - receiver
    - decrypts signature with sender's public key
    - compares result with MD5 checksum sent with message

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The important properties

- One-way function
  - given a cryptographic checksum for a message, it is virtually impossible to figure out what message produced it
  - it is not computationally feasible to find two messages that hash to the same cryptographic checksum.
- Relevance
  - if you are given a checksum for a message and are able to compute exactly the same checksum for that message, then it is highly likely this message produced the checksum you were given

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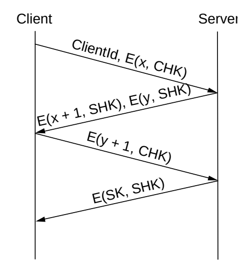
Authentication Protocols

- Three-way handshake
  - Assume client and server each know the others secret keys.
  - Client selects a random number x.
  - At end of handshake authentication is established?
- How did each side get the keys?



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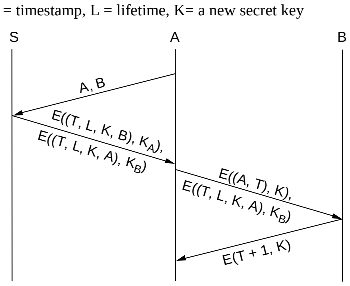
- Trusted third party (Kerberos)
  - K_A is a secret key shared between A and S. K_B similar
  - T = timestamp, L = lifetime, K= a new secret key



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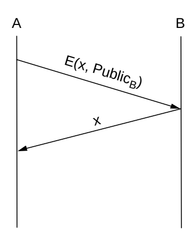
- Public key authentication :
  - One way: A wants to know if it is talking to B



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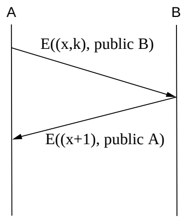
- Using RSA to authenticate and establish a session Key :
  - Let x be random and k be a session key



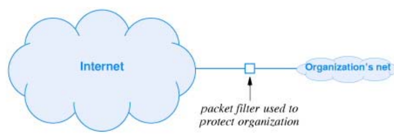
Firewall Solutions

- They help, but not a panacea
- A network response to a host problem
  - Packet by packet examination is tough
- Don't forget internal users
- Need well defined borders
- Can be a false sense of security
- Careful not to break standard protocol mechanisms!

Packet Filtering Firewalls

- Apply rules to incoming/outgoing packets
- Based on
  - Addresses
  - Protocols
  - Ports
  - Application
  - Other pattern match

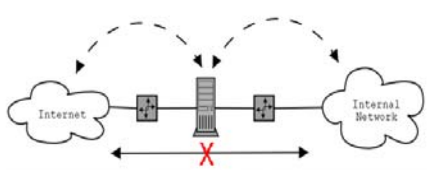
Packet Filtering Firewall Illustrated



Example Firewall: ipchains

```
-A input -s 192.168.0.0/255.255.0.0 -d 0.0.0.0/0.0.0.0 -j DENY

-A input -s 172.0.0.0/255.240.0.0 -d 0.0.0.0/0.0.0.0 -j DENY

-A input -s 10.0.0.0/255.0.0.0 -d 0.0.0.0/0.0.0.0 -j DENY

-A input -s 224.0.0.0/224.0.0.0 -d 0.0.0.0/0.0.0.0 -j DENY

-A input -s 0.0.0.0/0.0.0.0 -d a.b.c.d/255.255.255.255 22:22 -p 6 -j ACCEPT

-A input -s 0.0.0.0/0.0.0.0 -d a.b.c.d/255.255.255.255 1024:65535 -p 6 ! -y -j
   ACCEPT
```

Application Level Gateway



Network Address Translation

- Removes end-to-end addressing
- Standardized in RFC 1918
- NAT has been bad for the Internet
- Provides relatively no security with a great deal of cost - this slide shouldn't be here
- NAT has been required for sites with IP address allocation problems
- NAT may be used for IPv6 transition

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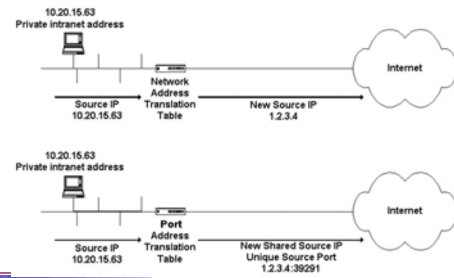
NAT Illustrated



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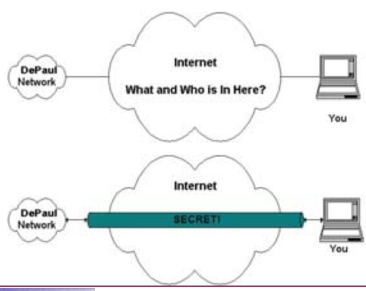
Virtual Private Networks



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Why VPNs?

- Cost, Cost, Cost!
- Ability to make use of a public, insecure network, rather than building your own private, secure network
- Connect business branches as if we had an expensive leased line

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IPSec

- Authentication Header (AH)
  - Data Origin Authentication
  - Anti-replay service
  - Data Integrity
- Encapsulating Security Payload (ESP)
  - Confidentiality
  - Data Origin Authentication
  - Anti-replay service
  - Connectionless Integrity

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AH

- AH provides authentication for as much of the IP header as possible, as well as for upper level protocol data
- Tow modes: transport mode/tunnel mode

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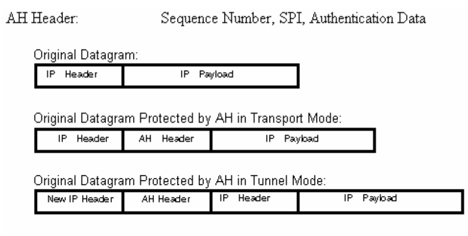
AH Location



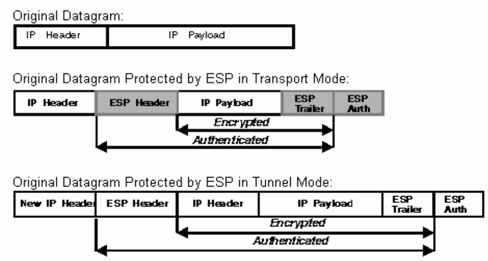
AH Algorithms

- Keyed Message Authentication Codes (MAC) based on Symmetric Key Encryption(DES)
- One-way hash function (MD5/SHA-1)

ESP

- Provides Data Confidentiality to IP payload using Encryption
- It can provide Data Integrity and connectionless Integrity, but the coverage is different from AH
- Two: transport Mode/Tunnel Mode

ESP Format



ESP Algorithms

- Encryption Algorithms
  - Symmetric Encryption Algorithms
- Authentication Algorithms
  - The same as AH