Secure HTTP (HTTPS)

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COMP 2405

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Contents

- Symmetric encryption
- Public-Key encrypt
- Public-Key Infrastructure
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HTTP and Security

- Most users believe that HTTP transactions take place between clients and servers with no third party involved
- This isn't at all true

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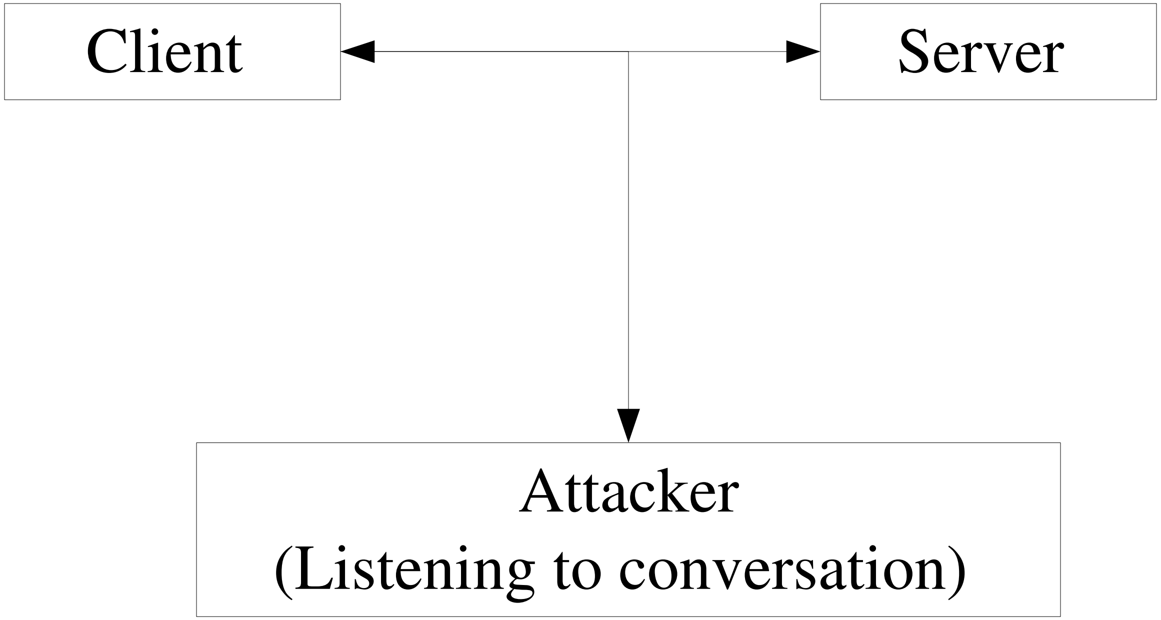
```
[morin@archimedes notes]$ traceroute www.google.com
traceroute to www.google.com (72.14.205.99)
 1  gateway.scs.carleton.ca (134.117.27.1)
 2  10.50.254.10 (10.50.254.10)
 3  10.30.34.1 (10.30.34.1)
 4  10.30.53.1 (10.30.53.1)
 5  134.117.254.242 (134.117.254.242)
 6  10.30.57.1 (10.30.57.1)  103.759
 7  AL-7304-GigE0-1978.telecomottawa.net (142.46.196.129)
 8  tol-gw.hydroone.com (142.46.130.9)
 9  142.46.128.5 (142.46.128.5)
10  gw-google.torontointernetxchange.net (198.32.245.6)
11  66.249.94.92 (66.249.94.92)
12  72.14.232.62 (72.14.232.62)
13  qb-in-f99.google.com (72.14.205.99)
```

Attackers Could Be Everywhere

- Any host on the traceroute path can
  - Monitor traffic between the client and server
  - Modify traffic between the client and server
  - Pretend to be the server (to the client)
  - Pretend to be the client (to the server)
- Anyone on your local network can
  - Monitor all traffic on the local network (includingrequests and responses)
- The local network administrator can
  - Monitor all traffic
  - Provide bad DNS information to reroute requests to servers

Attacker Listens to Conversation



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Attacker Listens to Conversation

- An attacker listening in on an HTTP exchange can
  - Record passwords for later use
  - Record cookies (almost as good as passwords) for later use
  - Record any personal data sent to or retrieved from a server
- myspace.com has a real problem with this right now (Mar. 20, 2008)
  - Student in residence logs in to myspace.com
  - Attacker (another student living in residence) collects student's myspace password and login (usually a gmail address)
  - Attacker logs in to student's gmail account (which uses the same password) and searchs for 'password' and 'login'
  - Attacker now has many of student's passwords and logins for online services (banking, shopping, credit cards, Paypal, ...)

Encryption

- An *encryption function* takes a key k and a message M and computes an encrypted text $k(M)$
  - Knowing only $k(M)$ it is difficult to compute M
- M is called the *plaintext*
- $k(M)$ is called the *encrypted text* or *cyphertext*
- A *decryption function* takes a key k and an encrypted message $k(M)$ and computes $k^{-1}(k(M)) = M$

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An Encrypted HTTP Exchange

- To avoid an attacker listening in, the client and server can use encryption
- this the client and server should *encrypt* their traffic using a secret key that they both know
  - Client and server share a secret key *sec*
  - Client has a request *R* but sends $sec(R)$ to the server
  - Server receives $sec(R)$ and computes $sec^{-1}(sec(R))=R$
  - Server computes response *M* and send $sec(M)$ to the client
  - Client receives $sec(M)$ and recovers $sec^{-1}(sec(M))=M$
- The attacker sees only $sec(R)$ and $sec(M)$, which is not enough to know *R* or *M*

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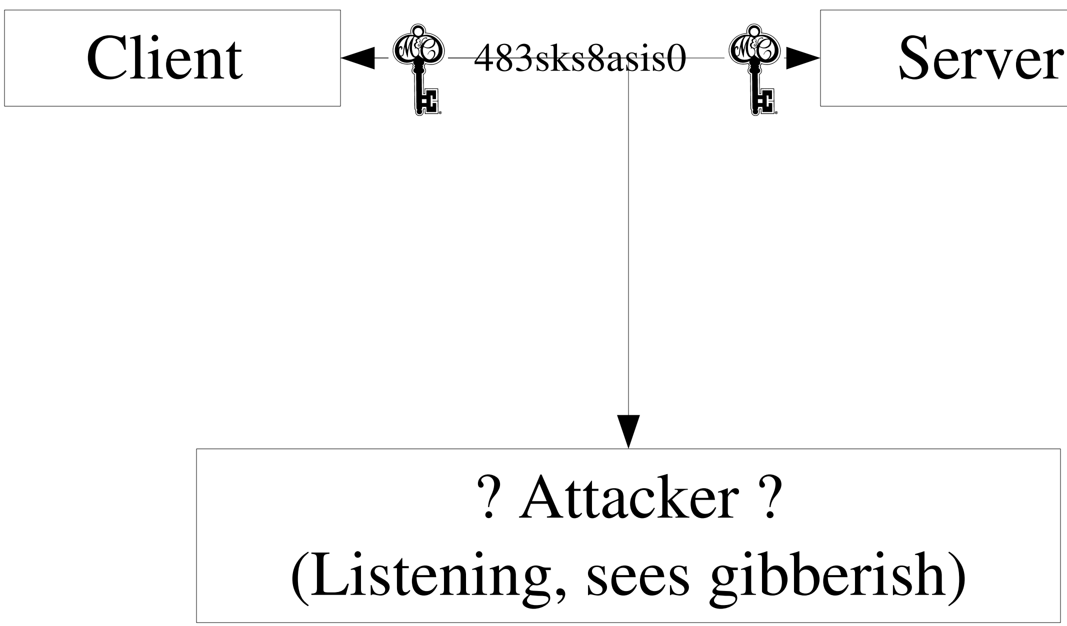
Encrypted Conversation



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Encryption

- Encryption requires that the client and server share a piece of information *sec* (the key) that only they know
- One of them (the client) needs to select *sec* and send it to the other one (the server)
- Oops: The attacker might be listening in and receive the key

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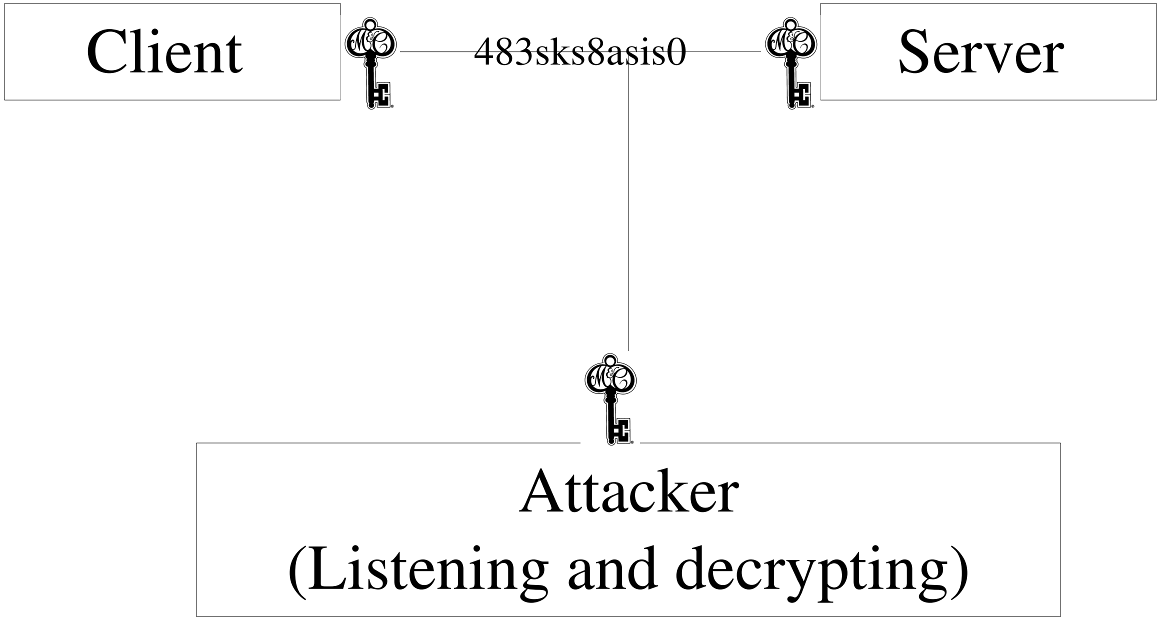
An Attacker with the Secret Key



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Public-Key Cryptography

- Public-key cryptography offers a solution
  - The server has a key (*priv*, *pub*) with two parts
  - The private part (*priv*) is a secret that only the server knows
  - The public part (*pub*) is not secret at all
    - The server announces pub to anyone who will listen
  - For a message *M*
    - *pub*(*M*) is an encrypted version of *M*
    - it's difficult to recover *M* from *pub*(*M*) without knowing *priv*
    - *priv*(*pub*(*M*)) = *M*
- Just like encryption, but encryption and decryption are done with different keys

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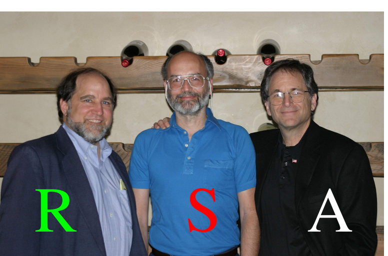

Request-Response with PKE

- When a client wants to send a request R to a server with key pair (*priv*, *pub*)
  - Client chooses a random secret key *sec*
  - Client sends (*pub*(*sec*), *sec*(*R*))
  - Server decrypts *sec* (because *priv*(*pub*(*sec*)) = *sec*
  - Server computes $sec^{-1}(sec(R)) = R$
  - Server processes *R* and decides on a response *M*
  - Server sends *sec*(*M*) to the client
  - Client decrypts *M* using $sec^{-1}(sec(M)) = M$
- We use the secret key to encrypt *R* and *M* because it's faster than using PKE
  - symmetric encryption (with one key) is faster than public-key encryption (with two keys)

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Attacker's View of PKE

- Attacker sees
  - *pub*(*R*) and *sec*(*R*)
  - *sec*(*M*)
- Attacker knows *pub*
- None of this is enough to recover *R* or *M*
  - The client and server have effectively hidden the request and the response from an attacker who is listening in
- Problem solved, but...
  - How does the client learn the server's public key, *pub*?
  - The server will send it to anyone, so the client can just ask for it in an unencrypted request

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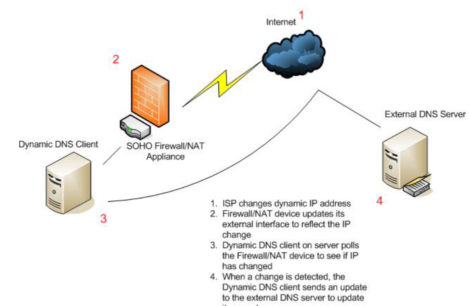
Impersonation

- An attacker can pretend to be the server if they can cut off client's access to the server and redirect it to their own server
  - Can be done with a physical disconnection
  - The attacker might be the client's network admin
    - Consider wireless internet access
  - The attacker might be the DNS admin



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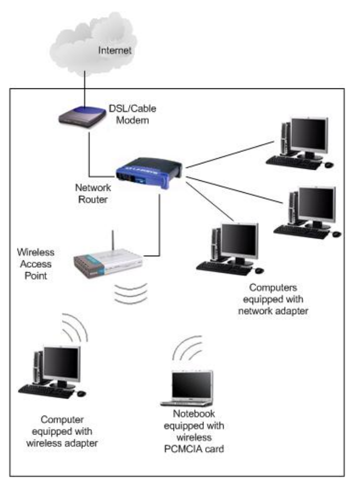

DNS Attack

- Using DNS tricks, an attacker can intercept requests to a server
- When sending a request to the aaa.bbb.com
  - Client send a request to name server to find IP address of aaa.bbb.com
  - Nameserver responds with an IP address (10.233.23.8)
  - Client then starts communicating with 10.233.23.8
- The communication between the client and the DNS server is not authenticated
  - Anyone between the client and the DNS server can intercept and change the response
  - The DNS server may not be trusted (consider wireless browsing)

Active Attacks

- If the attacker can get between the client and server they can do much more than listen in
  - The attacker can impersonate the server
  - The attacker can form a bridge between the server and the client

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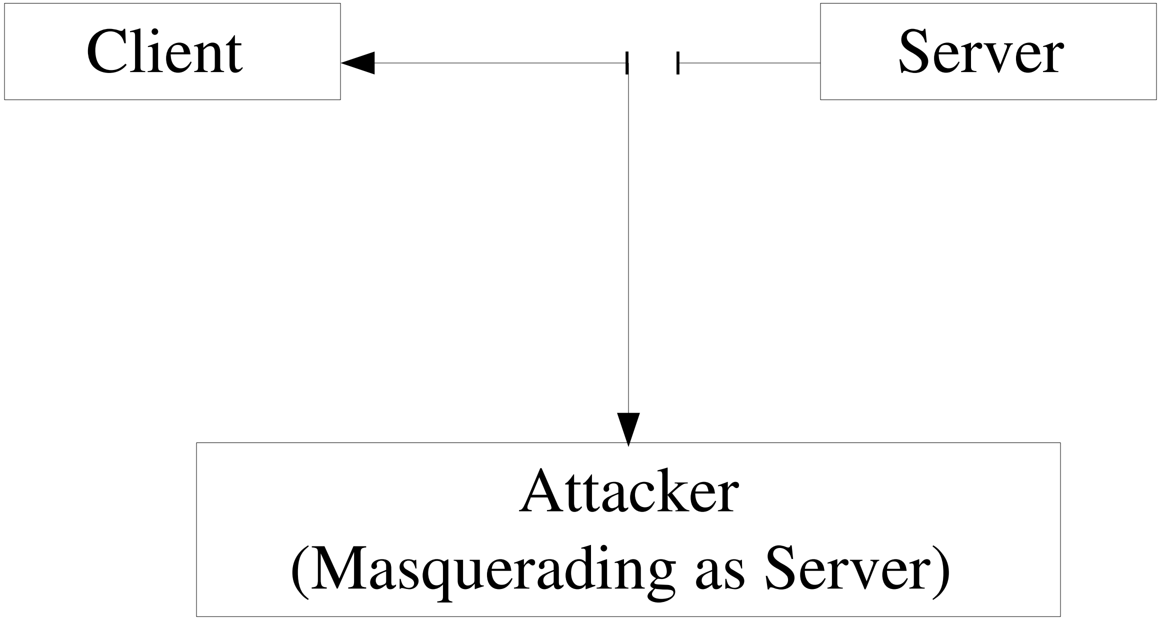
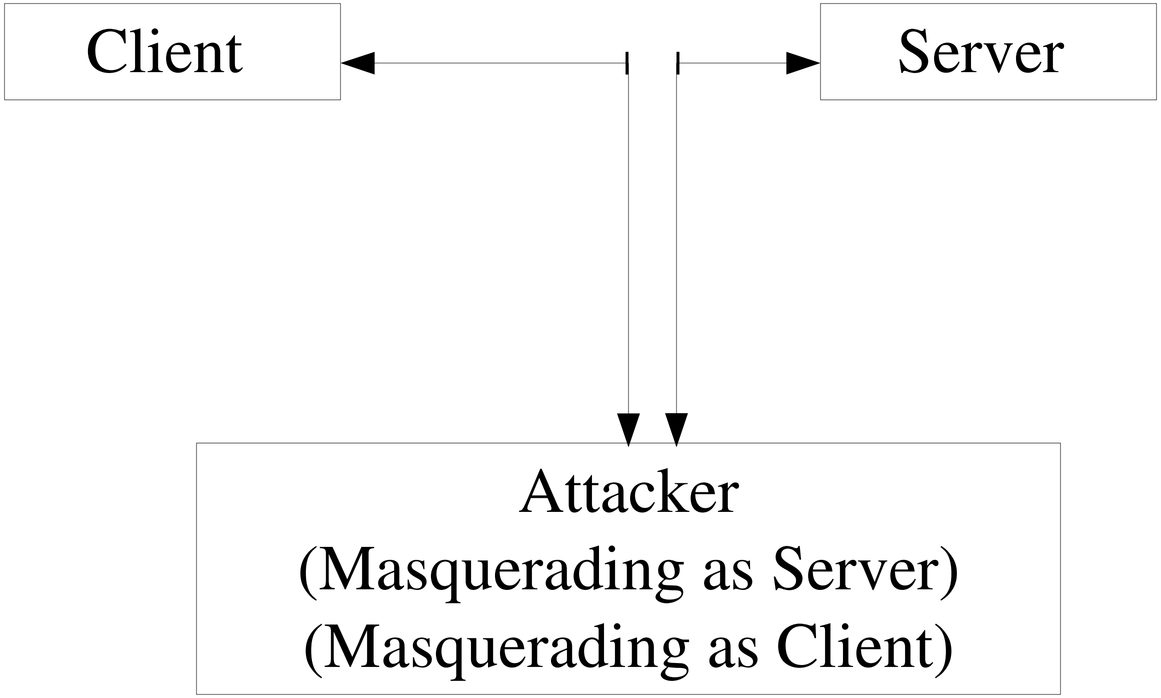
Attacker Pretends to be Server



Man-in-the-Middle Attack



Man-In-the-Middle

- Client (to server)
  - "What is your public key?"
- Attacker (pretending to be server)
  - "my public key is 'pubfake'"
- Client (to server):
  - "here's my request: '(pubfake(sec), sec(R)'"
- Attacker
  - computes privfake(pubfake(sec)) = sec and decodes R
  - Send (pub(sec'), sec'(R)) to real server and receives response sec'(M) and decodes M
- Attacker (to client, pretending to be server)
  - "here's your response: 'sec(M)'"

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The Public Key Infrastructure

- Man-in-the-middle attacks are possible because the client doesn't know the server's public key in advance
  - client has to ask the server, but has no way of knowing that he's really talking to the server
- The PKI infrastructure attempts to address this
  - when the server responds with their public key the present a *certificate* for it
  - the certificate is *signed* by someone that everyone trusts
- Requires a *digital signature* algorithm

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Digital Signatures

- Some public key encryption algorithms have the property of being commutative
  - $priv(pub(M)) = M$
  - $pub(priv(M)) = M$
- This allows the algorithm to be used for digital signing
  - A server takes a document M, computes $priv(M)$, and published $(M, priv(M))$
  - Anyone who knows *pub* can check that $pub(priv(M)) = M$
    - They are convinced that the server examined M and signed it because only the server could compute $priv(M)$
- Actually, digital signatures are slightly more complicated

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Public Key Infrastructure

- The PKI uses signed certificates that are signed by *certification authorities*
- Certificate includes:
  - The name of the server
  - The server's public key and encryption algorithm
  - A serial number
  - A period of validity
  - A digital signature of the above information using the certification authorities private key
- There are very few trusted CAs and their private keys are closely guarded
  - The list of public keys for all trusted certification authorities is broadly distributed

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HTTPS

- HTTPS (HTTP Secure) is a protocol for securely accessing a web server
- How it works:
  - Client opens connection to server and requests a certificate
  - Server sends back certificate containing server's *public key*
  - The client checks the validity of the certificate
  - The client creates a *session key*, encrypts it with the server's public key and sends it to the server
  - The server decrypts the session key using its private key
  - All further communication between the client and server is encrypted using the session key (HTTP is now used over this secure channel)

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Certificates

- Ideally, the certification authority is a third party, trusted by all
- In practice, many certificates are signed by the same authority controlling the server
  - In such cases, the web browser usually informs the user
- In practice, many certificates are completely invalid, or out of date
  - In such cases, the web browser usually informs the user
- This is one area where IE is better than Firefox

What HTTPS Provides

- If the certificate is valid then
  - The client can be sure it is communicating with the server it is supposed to be
  - The client and server can be sure that all HTTP traffic between them is not visible to any third party
- Third parties can still
  - Determine that the client is communicating with the server
  - Measure the amount of information exchanged between the client and server
  - Measure the duration and frequency of exchanges
- This security relies on the assumption that the client will not accept an invalid certificate

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