SSL/TLS Overview

- **SSL offers security for HTTP protocol**
- **Authentication of server to client**
- **Optional authentication of client to server**
  - Incompatibly implemented in different browsers
  - CA infrastructure not in widespread use
- **Confidentiality of communications**
- **Integrity protection of communications**

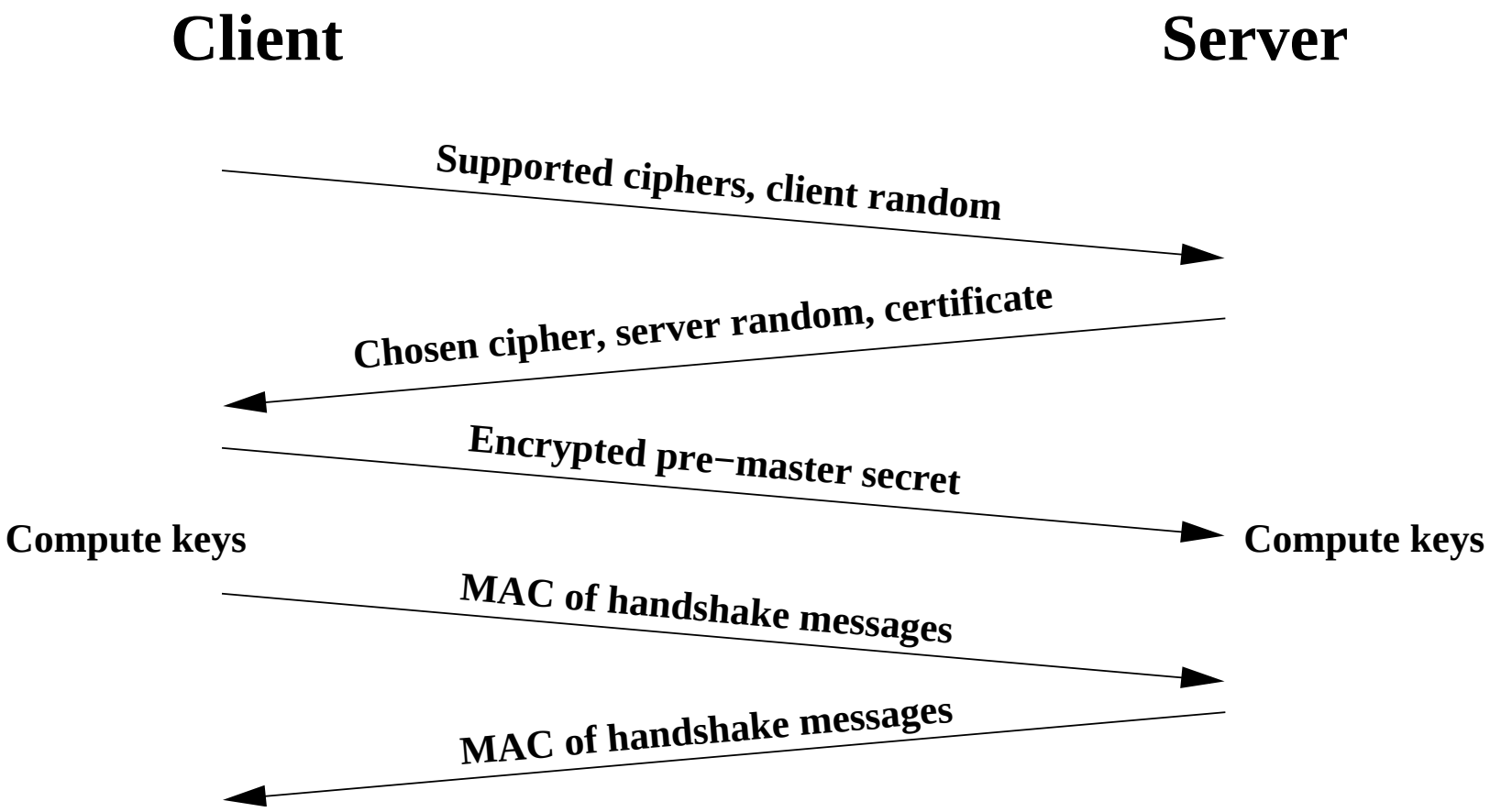
Purpose in more detail

- **Authentication based on certification authorities (CAs)**
  - Trusted third party with well-known public key
  - Certifies who belongs to a public key (domain name and real name of company)
  - Example: Verisign
- **What SSL Does Not Address**
  - Privacy
  - Traffic analysis
  - Trust management

Ciphersuites: Negotiating ciphers

- **Server authentication algorithm (RSA, DSS)**
- **Key exchange algorithm (RSA, DHE)**
- **Symmetric cipher for confidentiality (RC4, DES)**
- **MAC (HMAC-MD5, HMAC-SHA)**

Overview of SSL Handshake



From “SSL and TLS” by Eric Rescorla

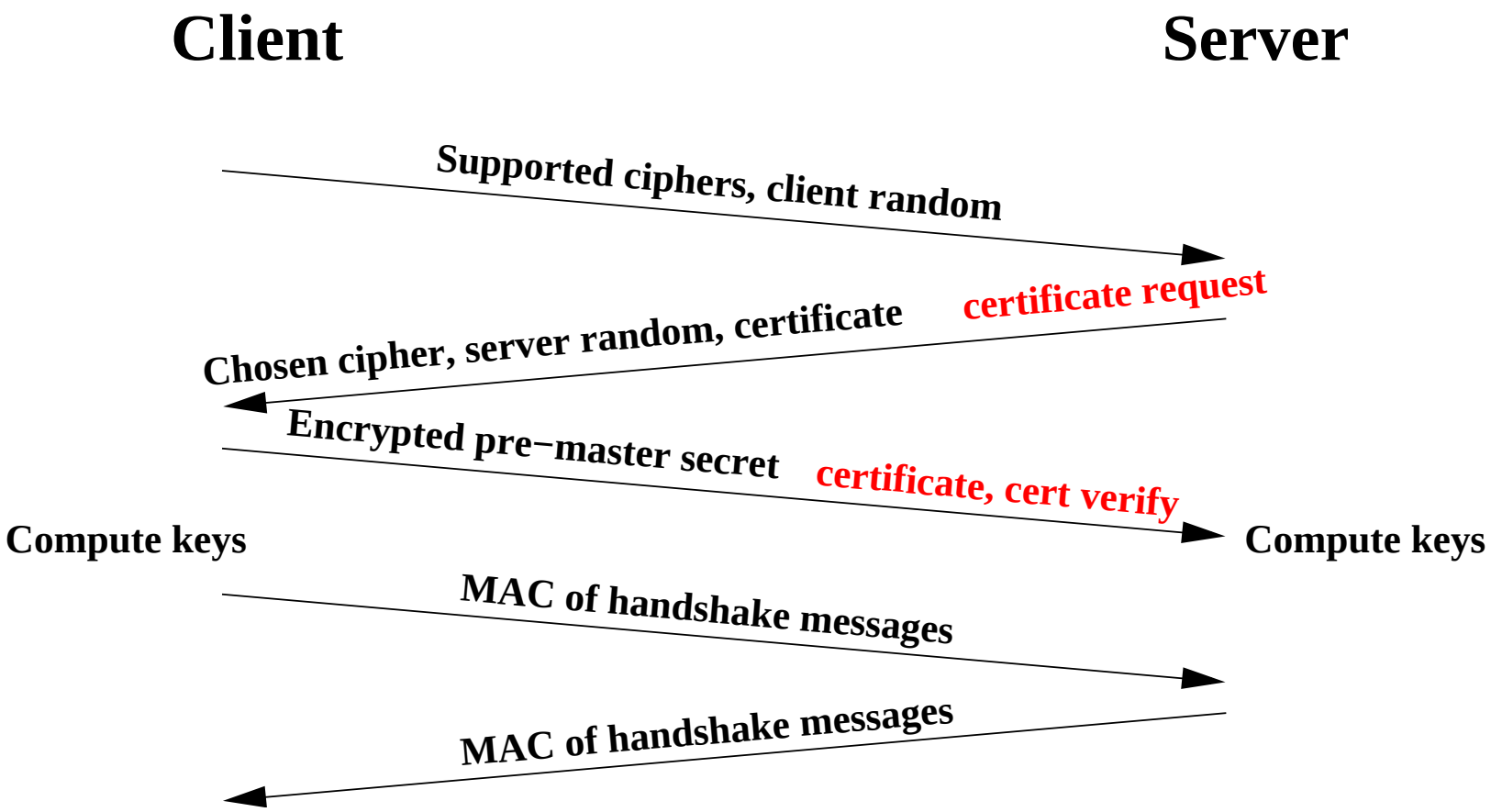
Simplified SSL Handshake

- **Client and server negotiate on cipher selection.**
- **Cooperatively establish session keys.**
- **Use session keys for secure communication.**

Client Authentication Handshake

- **Server requests that client send its certificate.**
- **Client signs a signed digest of the handshake messages.**

SSL Client Certificate

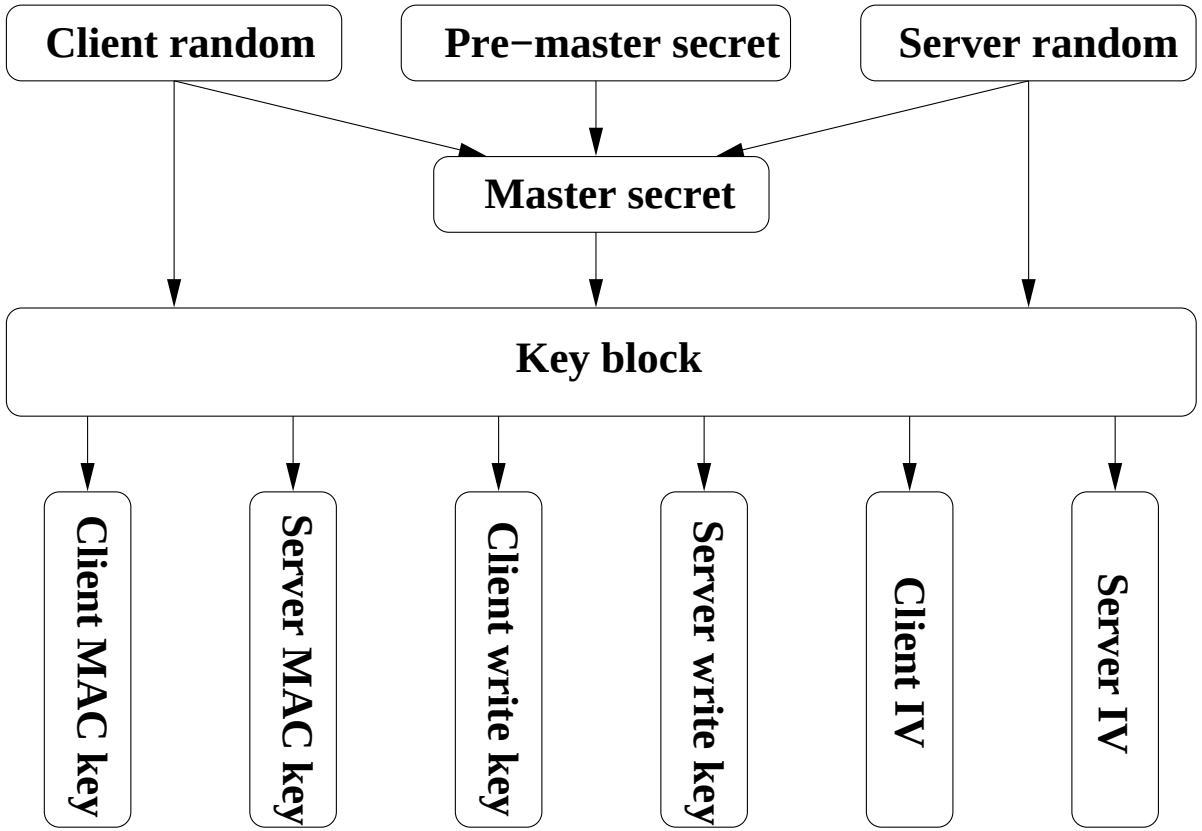


From “SSL and TLS” by Eric Rescorla

Establishing a Session Key

- **Server and client both contribute randomness.**
- **Client sends server a "pre-master secret" encrypted with server's public key.**
- **Use randomness and pre-master secret to create session keys:**
  - Client MAC
  - Server MAC
  - Client Write
  - Server Write
  - Client IV
  - Server IV

Establishing a Session Key



From “SSL and TLS” by Eric Rescorla

Session Resumption

- **Problem: Public key crypto expensive**
- **New TCP connection, reuse master secret.**
  - Avoids unnecessary public key cryptography.
- **Combines cached master secret with new randomness to generate new session keys.**
- **Works even when the client IP changes (servers cache on session ID, clients cache on server hostname).**

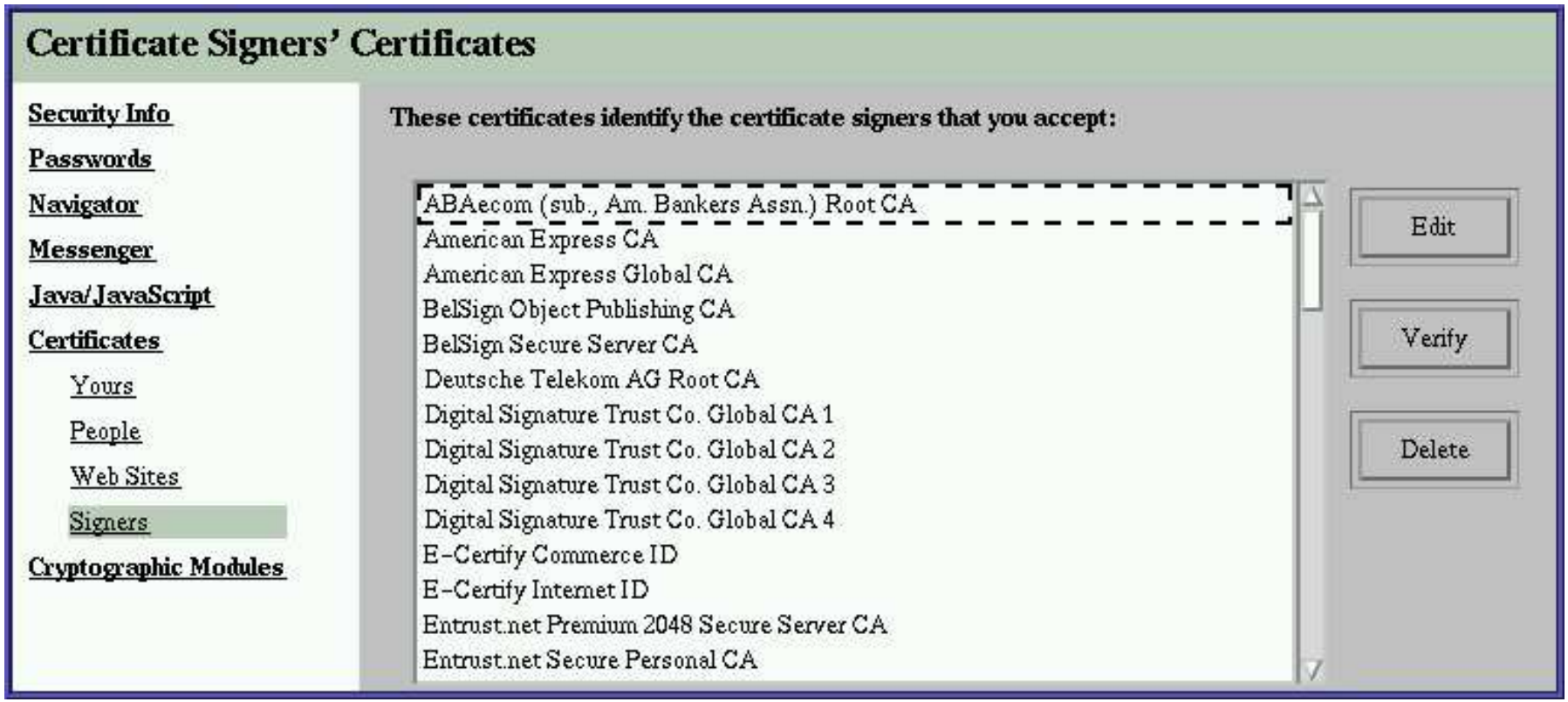
What does a CA-issued Certificate Mean?

- No one knows exactly.
- That a public key belongs to someone authorized to represent a hostname?
- That a public key belongs to someone who is associated in some way with a hostname?
- That a public key belongs to someone who has lots of paper trails associated to a company related to a hostname?
- That the CA has no liability?

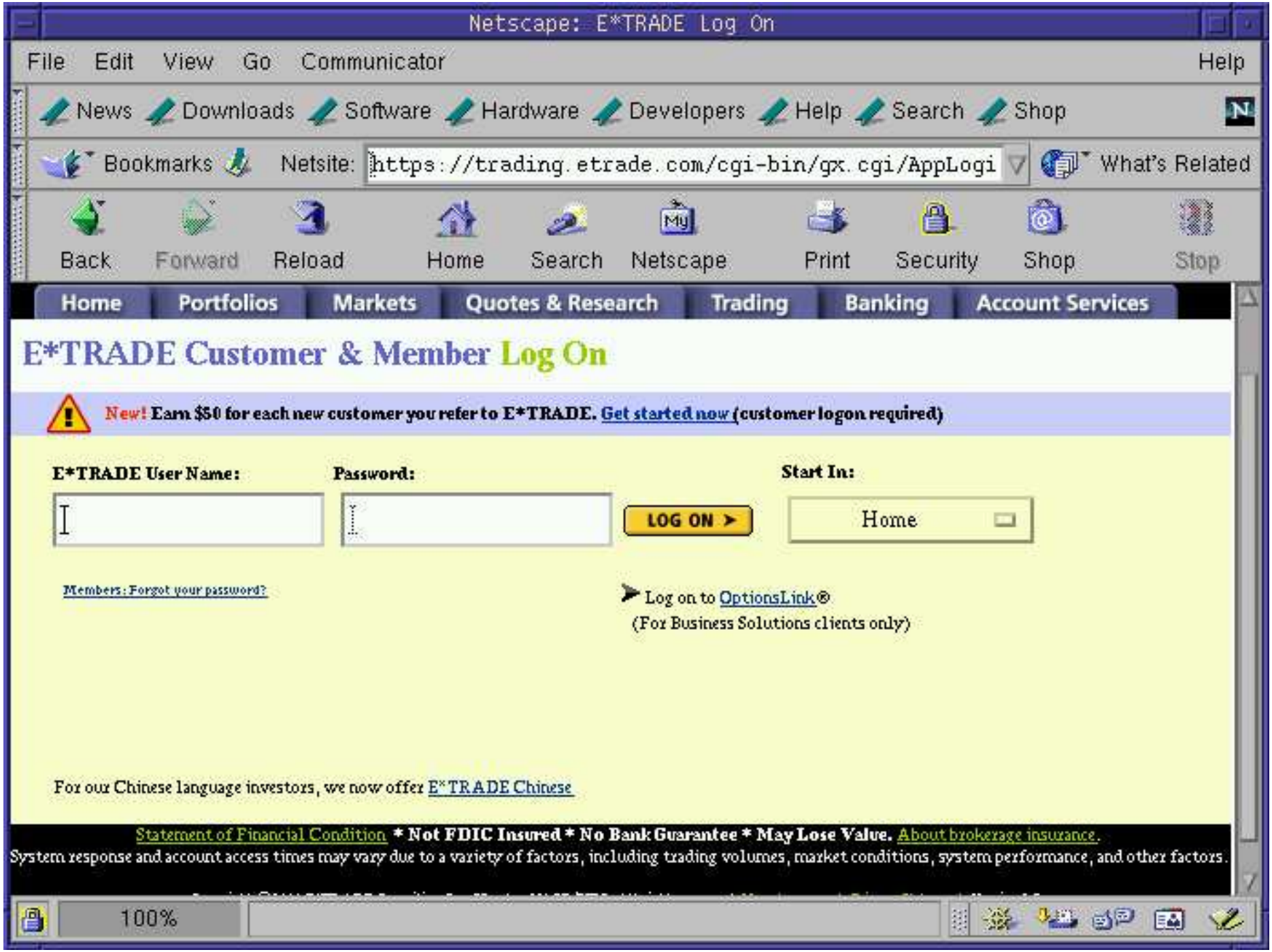
How to get a Verisign certificate

- **Pay Verisign ($300)**
- **Get DBA license from city call ($20)**
  - No on-line check for name conflicts. . . can I do business as Microsoft?
- **Letterhead from company ($0)**
- **Notarized document (need driver's license) ($0)**
- **Conclusions:**
  - Easy to get a fraudulent certificate
  - Maybe not so easy to avoid prosecution afterwards
- **But that's only Verisign's policy**
  - Many CAs can issue certificates

So many CAs...


Certificate Signers' Certificates
Security Info
Passwords
Navigator
Messenger
Java/JavaScript
Certificates
Yours
People
Web Sites
Signers
Cryptographic Modules
These certificates identify the certificate signers that you accept:
ABAecom (sub., Am. Bankers Assn.) Root CA
American Express CA
American Express Global CA
BelSign Object Publishing CA
BelSign Secure Server CA
Deutsche Telekom AG Root CA
Digital Signature Trust Co. Global CA 1
Digital Signature Trust Co. Global CA 2
Digital Signature Trust Co. Global CA 3
Digital Signature Trust Co. Global CA 4
E-Certify Commerce ID
E-Certify Internet ID
Entrust.net Premium 2048 Secure Server CA
Entrust.net Secure Personal CA
Edit
Verify
Delete

Client Authentication on the Web



Interrogative adversaries

- **Adaptively query a Web server a reasonable number of times**
- **Treat server as an oracle for an adaptive chosen message attack**
- **Don't need any eavesdropping or other network tampering**
- **Anyone can do it, but surprisingly powerful attack**
  - C.f., adaptive chosen-ciphertext attacks—sounded improbable

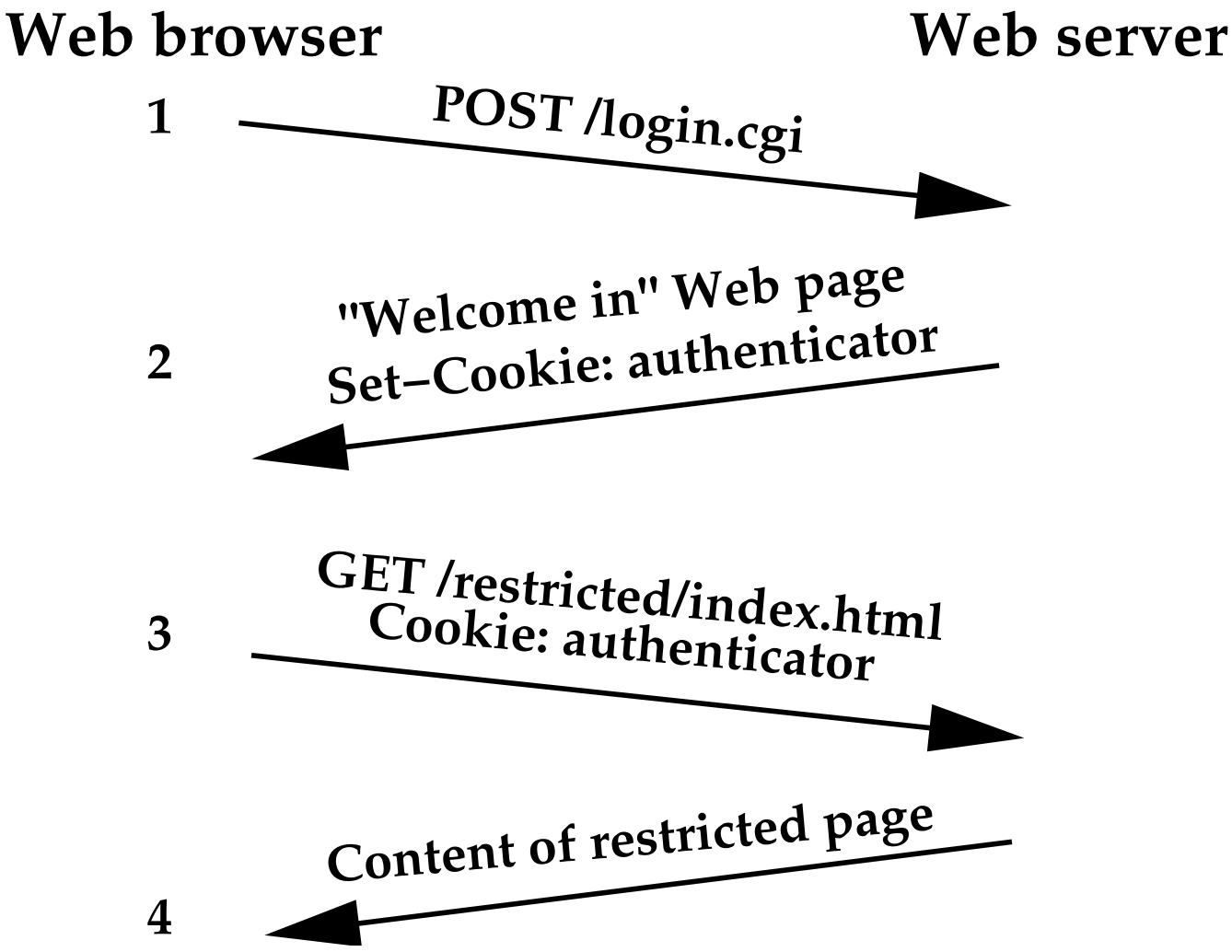
Cookies

- **A Web server can store key/value pairs on a client**
- **The browser resends cookies in subsequent requests to the server**
- **Cookies can implement login sessions**

Netscape cookie example

domain	**.wsj.com**
Path	**/cgi**
SSL?	**FALSE**
Expiration	**941452067**
Variable name	**fastlogin**
Value	**bitdiddleMaRdw2J1h6Lfc**

Cookies for login sessions



Why? Enter a password once per session

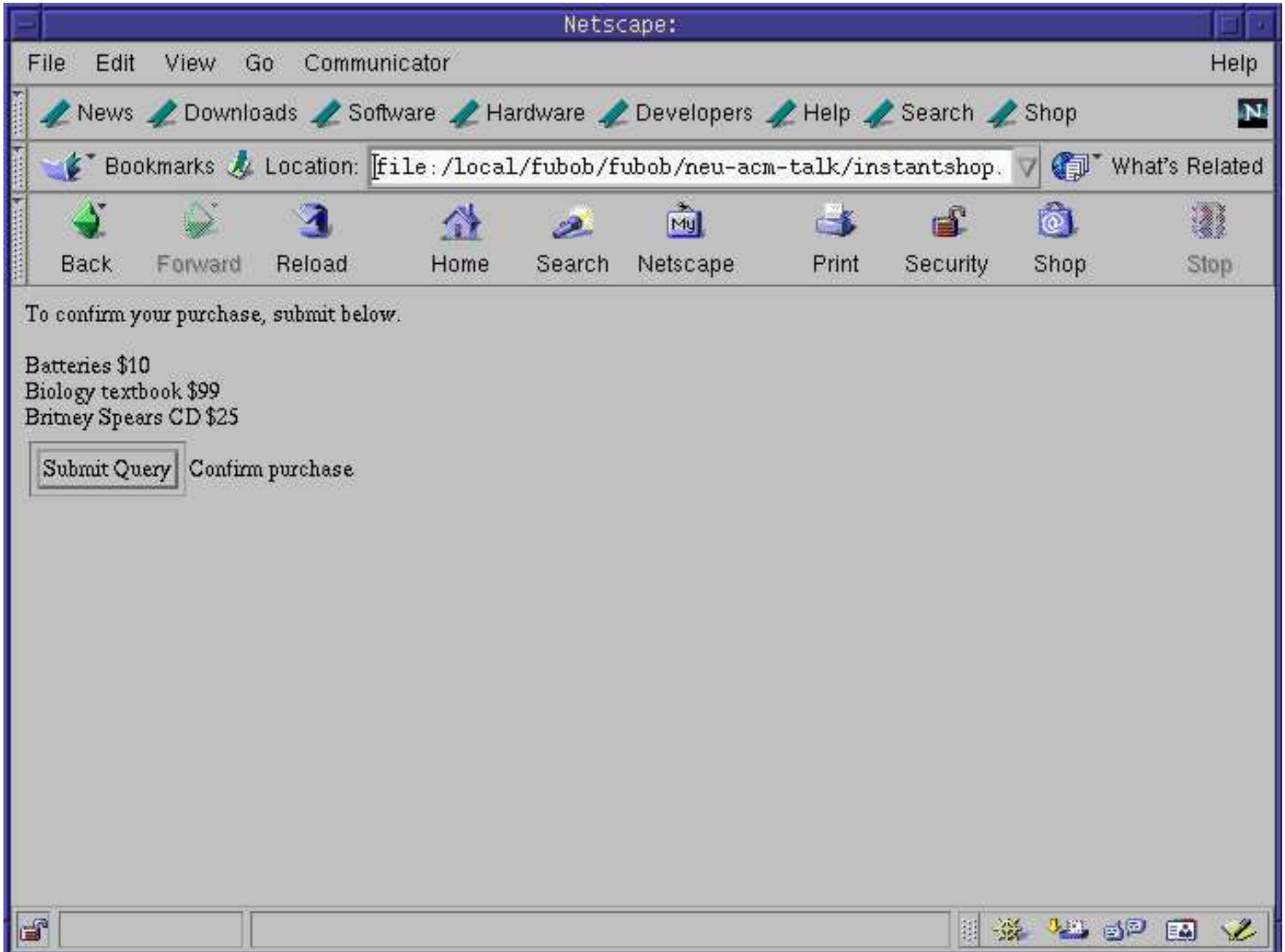
SSL can't protect data sent without SSL

- **Problem: Secure content can leak through plaintext channels**
- **Cookie file has flag to require SSL**
  - Not set by BankOnline.com
- **Trick user into visiting HTTP port**
  - Just need a link from an unrelated web page
  - Cookie automatically sent in the clear
  - Network eavesdropper can record it
  - Might as well not have used SSL

Letting clients name the price: Instant Shop

- **Problem: Servers trust clients not to modify HTML variables.**
- **Price determined by hidden variable in Web page.**
- **Make a personal copy of the web page. Modify it.**

Instant Shop example: What a browser displays



Instant Shop example: What's inside

```
<html><body>
 <form action=commit_sale.cgi>

<input type=hidden name=item1 value=10>Batteries $10<br>
<input type=hidden name=item2 value=99>Biology textbook $99<br>
<input type=hidden name=item3 value=25>Britney Spears CD $25<br>
<input type=submit>Confirm purchase
</form>
 </body></html>
```

Instant Shop example: Malicious client

```
<html><body>
 <form action=commit_sale.cgi>

<input type=hidden name=item1 value=0>Batteries $10<br>
<input type=hidden name=item2 value=0>Biology textbook $99<br>
<input type=hidden name=item3 value=0>Britney Spears CD $25<br>
<input type=submit>Confirm purchase
</form>
 </body></html>
```

Security through obscurity: NeBride.com

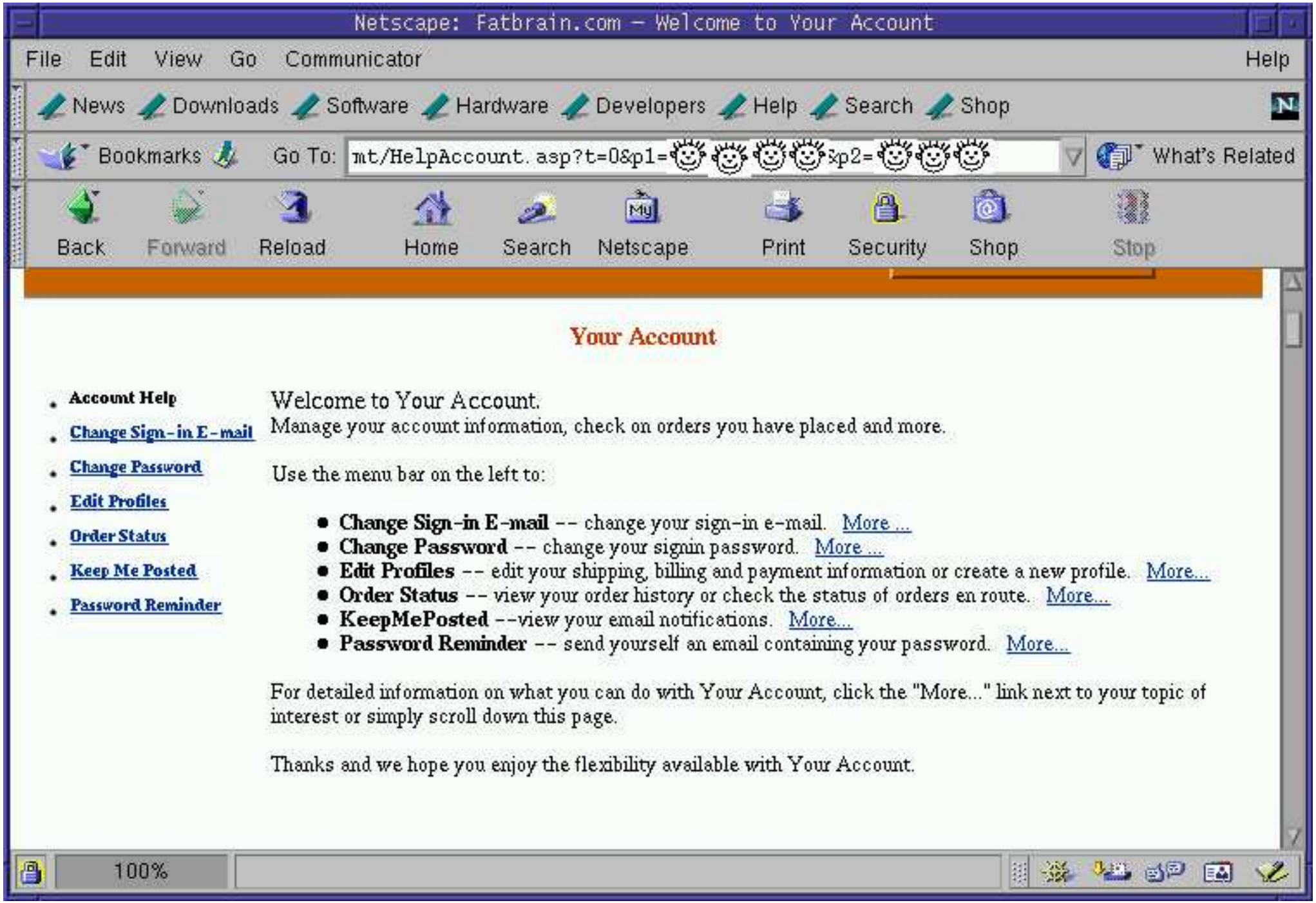
- **Problem: No cryptographic authentication at all**
- **Cookie (authenticator) is the username**
- **Create a cookie with someone's username**
  - Instant access to her name, address, phone number, e-mail address, wedding date and place, and password.

Predictable sequence numbers: fatbrain.com

- **Problem: Customer can determine the authenticator for any other user.**
- **Authenticators are sequence numbers in the URL.**

https://www.fatbrain.com/HelpAccount.asp?t=0&p1=fubob@mit.edu&p2=540555758
https://www.fatbrain.com/HelpAccount.asp?t=0&p1=nobob@mit.edu&p2=540555759

- **Guess a victim's sequence number by decrementing.**
- **Access to personal information**
- **Change address, receive password by email!**


Netscape: Fatbrain.com – Welcome to Your Account
File Edit View Go Communicator Help
News Downloads Software Hardware Developers Help Search Shop
Bookmarks Go To: mt/HelpAccount.asp?t=0&p1=[illegible]&p2=[illegible]
What's Related
Back Forward Reload Home Search Netscape Print Security Shop Stop
Your Account
Account Help
Change Sign-in E-mail
Change Password
Edit Profiles
Order Status
Keep Me Posted
Password Reminder
Welcome to Your Account.
Manage your account information, check on orders you have placed and more.
Use the menu bar on the left to:
Change Sign-in E-mail -- change your sign-in e-mail. More ...
Change Password -- change your signin password. More ...
Edit Profiles -- edit your shipping, billing and payment information or create a new profile. More...
Order Status -- view your order history or check the status of orders en route. More...
KeepMePosted --view your email notifications. More...
Password Reminder -- send yourself an email containing your password. More...
For detailed information on what you can do with Your Account, click the "More..." link next to your topic of interest or simply scroll down this page.
Thanks and we hope you enjoy the flexibility available with Your Account.
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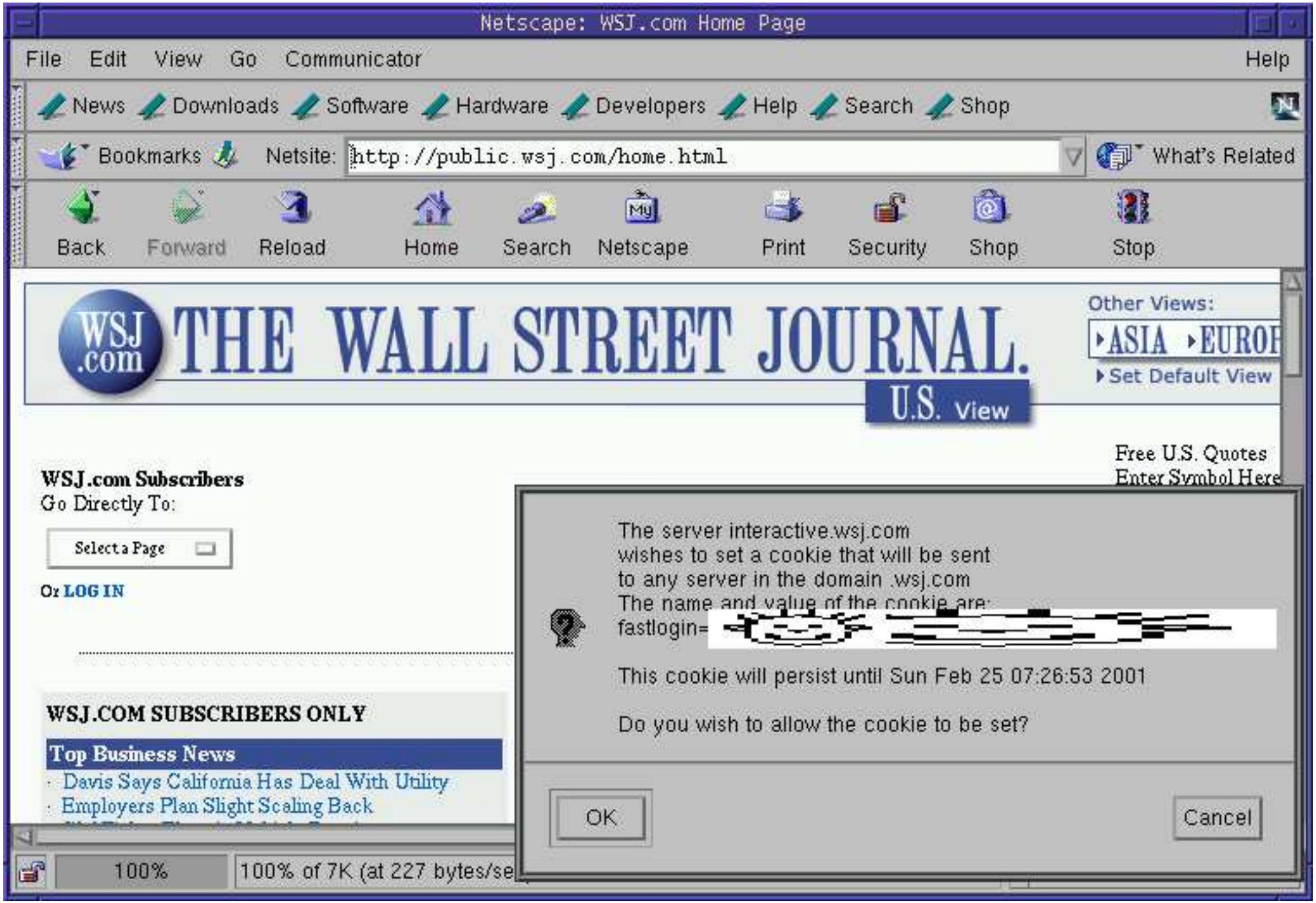
wsj.com

- Authenticate subscribers with stateless servers
- Half million paid-subscriber accounts
- Purchase articles, track stock portfolios


Netscape: WSJ.com Home Page
File Edit View Go Communicator Help
News Downloads Software Hardware Developers Help Search Shop
Bookmarks Netsite: http://public.wsj.com/home.html What's Related
Back Forward Reload Home Search Netscape Print Security Shop Stop
WSJ.com THE WALL STREET JOURNAL.
U.S. View
Other Views:
ASIA EUROP
Set Default View
Free U.S. Quotes
Enter Symbol Here
WSJ.com Subscribers
Go Directly To:
Select a Page
Or LOG IN
WSJ.COM SUBSCRIBERS ONLY
Top Business News
· Davis Says California Has Deal With Utility
· Employers Plan Slight Scaling Back
The server interactive.wsj.com
wishes to set a cookie that will be sent
to any server in the domain .wsj.com
The name and value of the cookie are:
fastlogin=
This cookie will persist until Sun Feb 25 07:26:53 2001
Do you wish to allow the cookie to be set?
OK
Cancel
100%
100% of 7K (at 227 bytes/se

Background: The crypt() hash function

- **Hash function "salted" with 12 extra bits**
  - Prevent attacker from building dictionary of hashes of common passwords
  - Permute the hash function based on 12-bit seed
  - Prepend seed to hashed password for use in verification
- **Produces one-way function of password**
  - Only hashes first 8 characters
  - Encrypt 0s 25 times with password as key
- **Used by Unix login**
  - So put hashed password in world-readable `/etc/passwd`
  - To validate password, hash it and compare to stored hash

wsj.com analysis

- **Design: fastlogin = {user, $\mathtt{MAC}_k$ (user)}**
- **Reality: fastlogin =**

  user + UNIX-crypt (user + server secret)
- **Easily produce fastlogin cookies**

username	crypt() Output	fastlogin cookie
bitdiddl	MaRdw2J1h6Lfc	bitdiddlMaRdw2J1h6Lfc
bitdiddle	MaRdw2J1h6Lfc	bitdiddleMaRdw2J1h6Lfc

- **Usernames matching first 8 characters have same authenticator**
- **No revocation or expiration.**
- **This is already bad, but it gets worse...**

Obtaining the server secret?

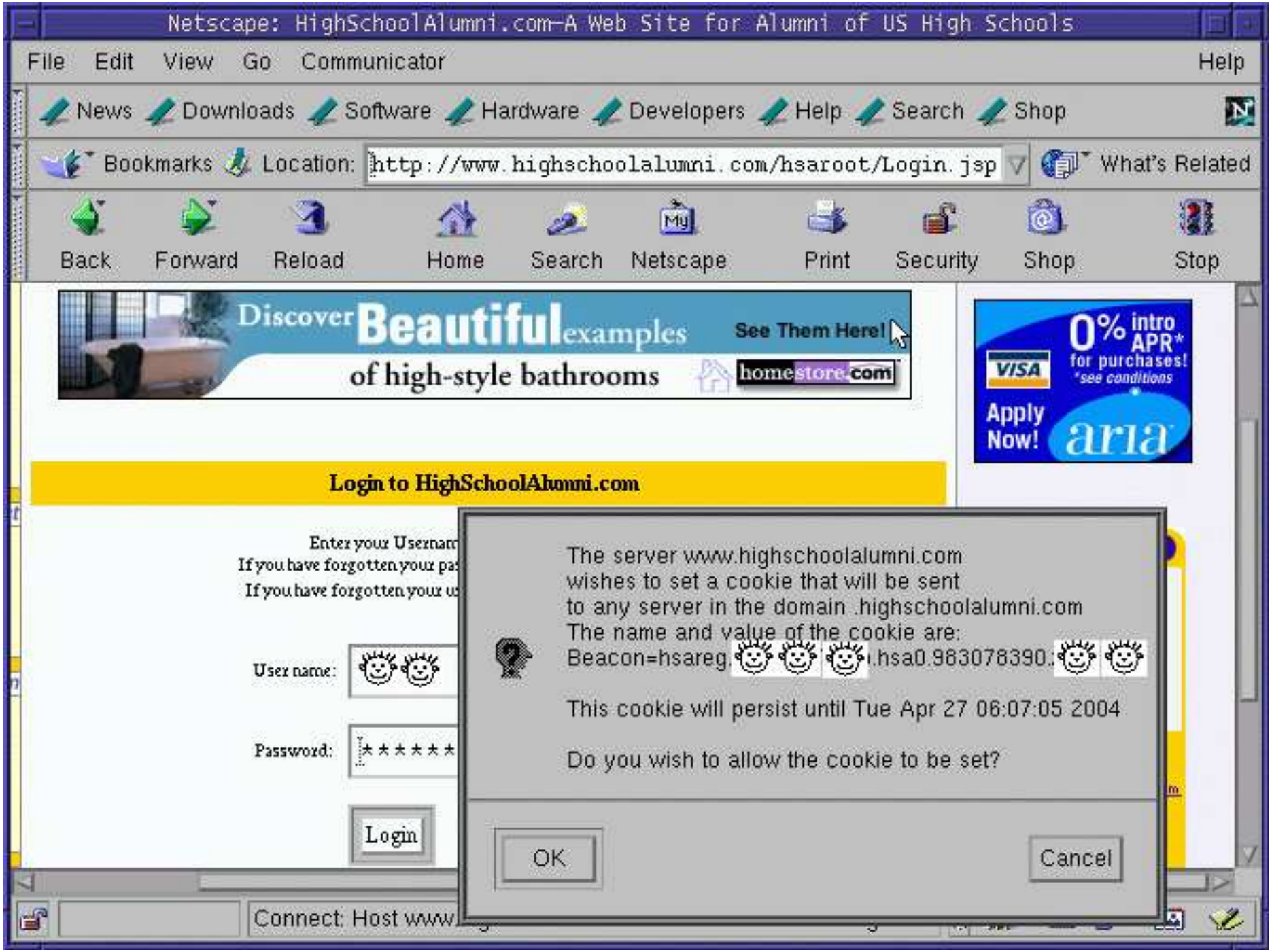
- **Adaptive chosen message attack**
- **Perl script queried WSJ with invalid cookies**
- **Runs in max 128×8 queries rather than intended 128^8 (1024 vs. 72057594037927936)**
- **1 sec/query yields 17 minutes vs. 10^9 years**
- **The key is "March20"**

How the attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	Yes
A	bitdidd	bitdiddA	No
...	...	...	...
M	bitdidd	bitdiddM	Yes
MA	bitdid	bitdidMA	No
...	...	...	...
Ma	bitdid	bitdidMa	Yes
...	...	...	...
March20	b	bMarch20	Yes

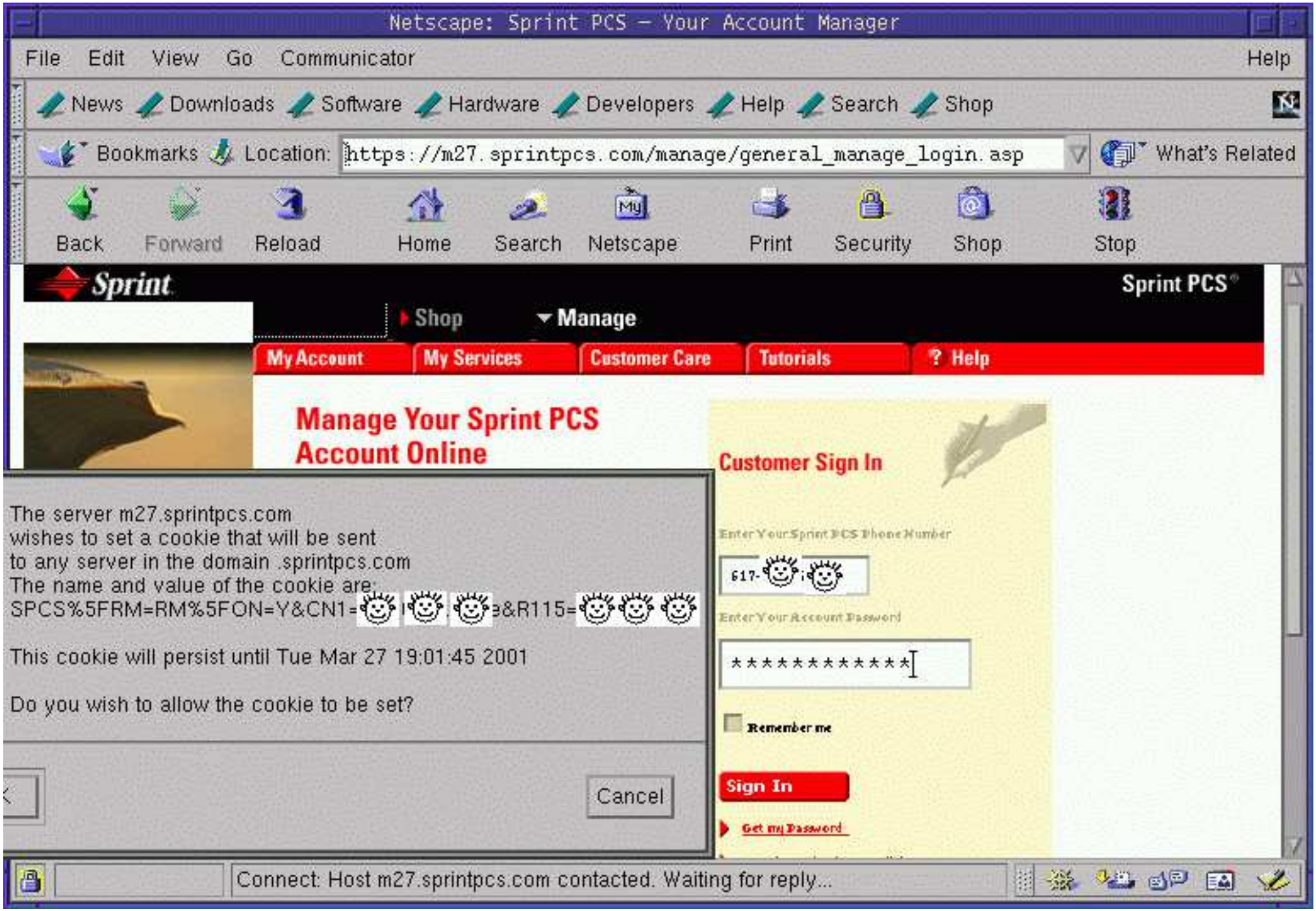
Lack of cryptography: highschoolalumni.com

- **Problem: No cryptographic authentication at all**
- **Cookie authenticator is the public username and public user ID**


Netscape: HighSchoolAlumni.com-A Web Site for Alumni of US High Schools
File Edit View Go Communicator Help
News Downloads Software Hardware Developers Help Search Shop
Bookmarks Location: http://www.highschoolalumni.com/hsaroot/Login.jsp What's Related
Back Forward Reload Home Search Netscape Print Security Shop Stop
Discover Beautiful examples of high-style bathrooms
See Them Here!
homestore.com
0% intro APR* for purchases! *see conditions
Apply Now!
Login to HighSchoolAlumni.com
User name:
Password:
Login
The server www.highschoolalumni.com wishes to set a cookie that will be sent to any server in the domain .highschoolalumni.com
The name and value of the cookie are:
Beacon=hsareg.
.hsa0.983078390.
This cookie will persist until Tue Apr 27 06:07:05 2004
Do you wish to allow the cookie to be set?
OK
Cancel
Connect: Host www

Leaking secrets: sprintpcs.com

- **Problem: Secure content can leak through plaintext channels.**
- **Site didn't set SSL flag on cookies (like BankOnline.com)**
- **User logs in with HTTPS, then clicks back to main HTTP page.**
- **Vulnerable to passive eavesdropper.**


Netscape: Sprint PCS – Your Account Manager
File Edit View Go Communicator Help
News Downloads Software Hardware Developers Help Search Shop
Bookmarks Location: https://m27.sprintpcs.com/manage/general_manage_login.asp What's Related
Back Forward Reload Home Search Netscape Print Security Shop Stop
Sprint
Sprint PCS
Shop
Manage
My Account
My Services
Customer Care
Tutorials
? Help
Manage Your Sprint PCS Account Online
Customer Sign In
Enter Your Sprint PCS Phone Number
617-
Enter Your Account Password
Remember me
Sign In
Get my Password
The server m27.sprintpcs.com
wishes to set a cookie that will be sent
to any server in the domain .sprintpcs.com
The name and value of the cookie are:
SPCS%5FRM=RM%5FON=Y&CN1=
&R115=
This cookie will persist until Tue Mar 27 19:01:45 2001
Do you wish to allow the cookie to be set?
Cancel
Connect: Host m27.sprintpcs.com contacted. Waiting for reply...

Google

- **Google indexed many cookie files inadvertently places on the Web.**
- **Search for:**
  - `cookies.txt`
  - `avenuea.com FALSE FALSE` (cookie set by advertising co.)
  - `CERT7.DB` or `text:CERT7.DB` (in many cookies.txt files)

A simple scheme that works

$$\textbf{auth} = \texttt{expire} + \texttt{data} + \texttt{MAC}_k(\texttt{expire} + \texttt{data})$$

where `MAC` **could be HMAC-SHA1,**

`data` **could be a username or capability, and**

'+' denotes concatenation with a delimiter
Secure against interrogative adversary

But of course, MAC what you mean!

- **Sign *marshalled* data, not data with multiple interpretations**
- **badauth = MAC (key, username + expiration)**
  - (Alice, 21-Apr-2001) → MAC (key, Alice21-Apr-2001)
  - (Alice2, 1-Apr-2001) → MAC (key, Alice21-Apr-2001)
- **Same authenticator!**
- **Use unambiguous representation or delimiters**