The Failure of Client Authentication on the Web

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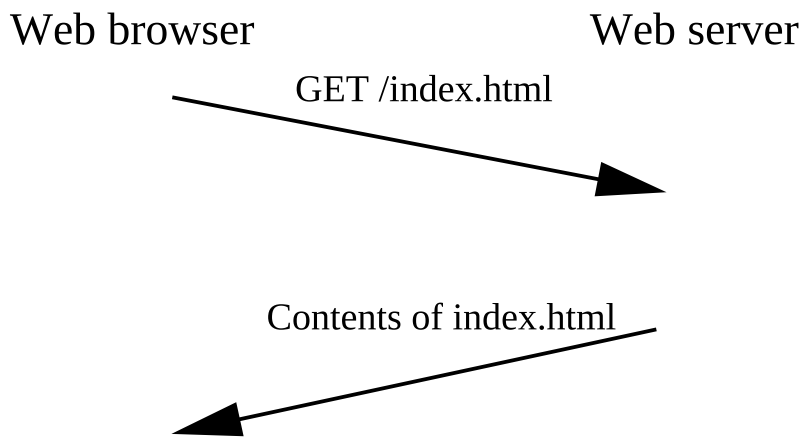
MIT Lincoln Laboratory April 18, 2001

Caveat haxor

- There are fine lines.
- Don’t do this.

The Web Protocol: HTTP



Web browser

Web server

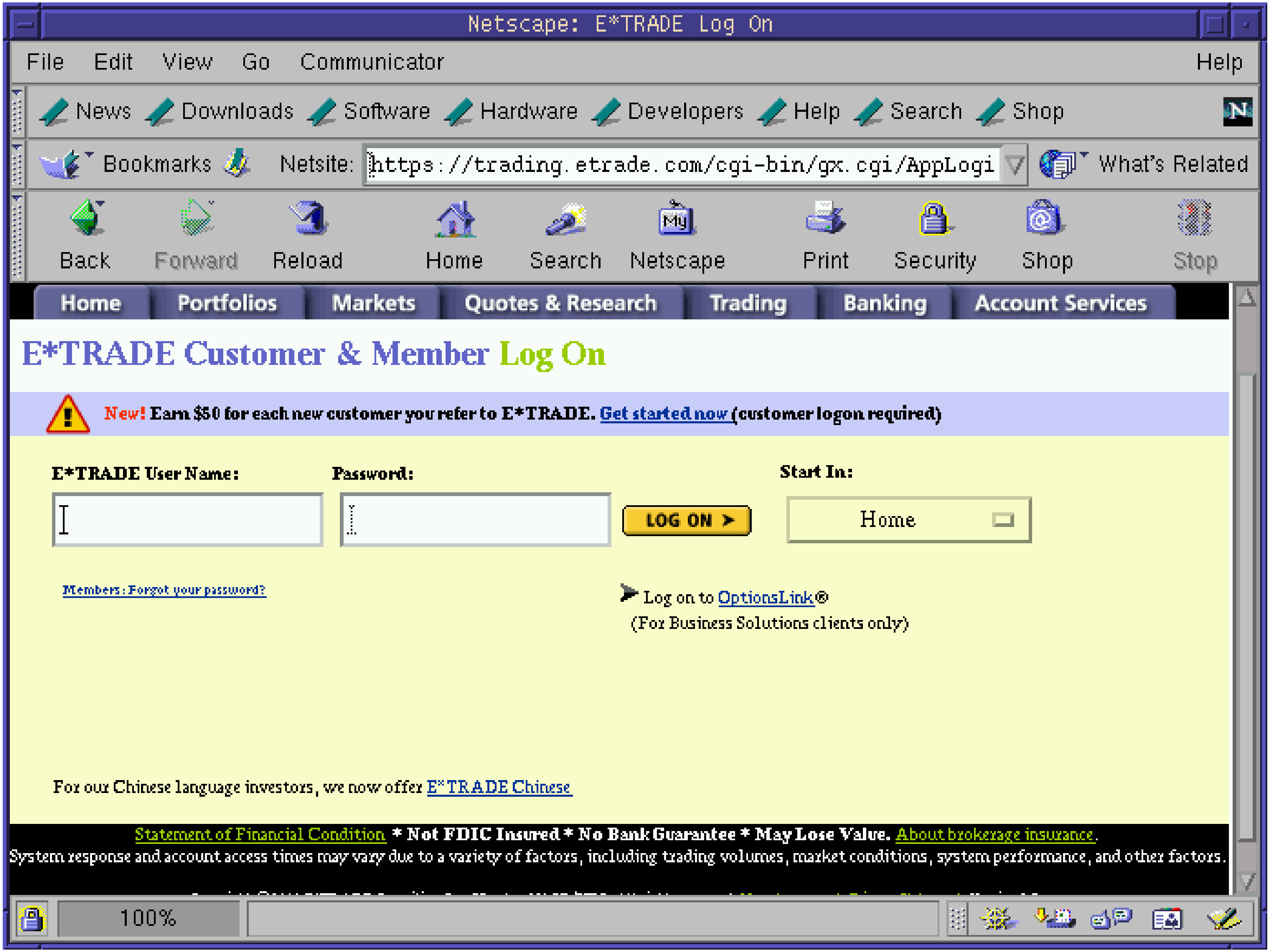
GET /index.html

Contents of index.html

What is authentication?

Helps answer question “who are you?” and verifies the identity of an entity.

- **Knowing something (e.g., password)**
- **Having something (e.g., token)**
- **Being something (e.g., biometrics)**



E*TRADE Customer & Member Log On

New! Earn $50 for each new customer you refer to E*TRADE. Get started now (customer logon required)

E*TRADE User Name:

Password:

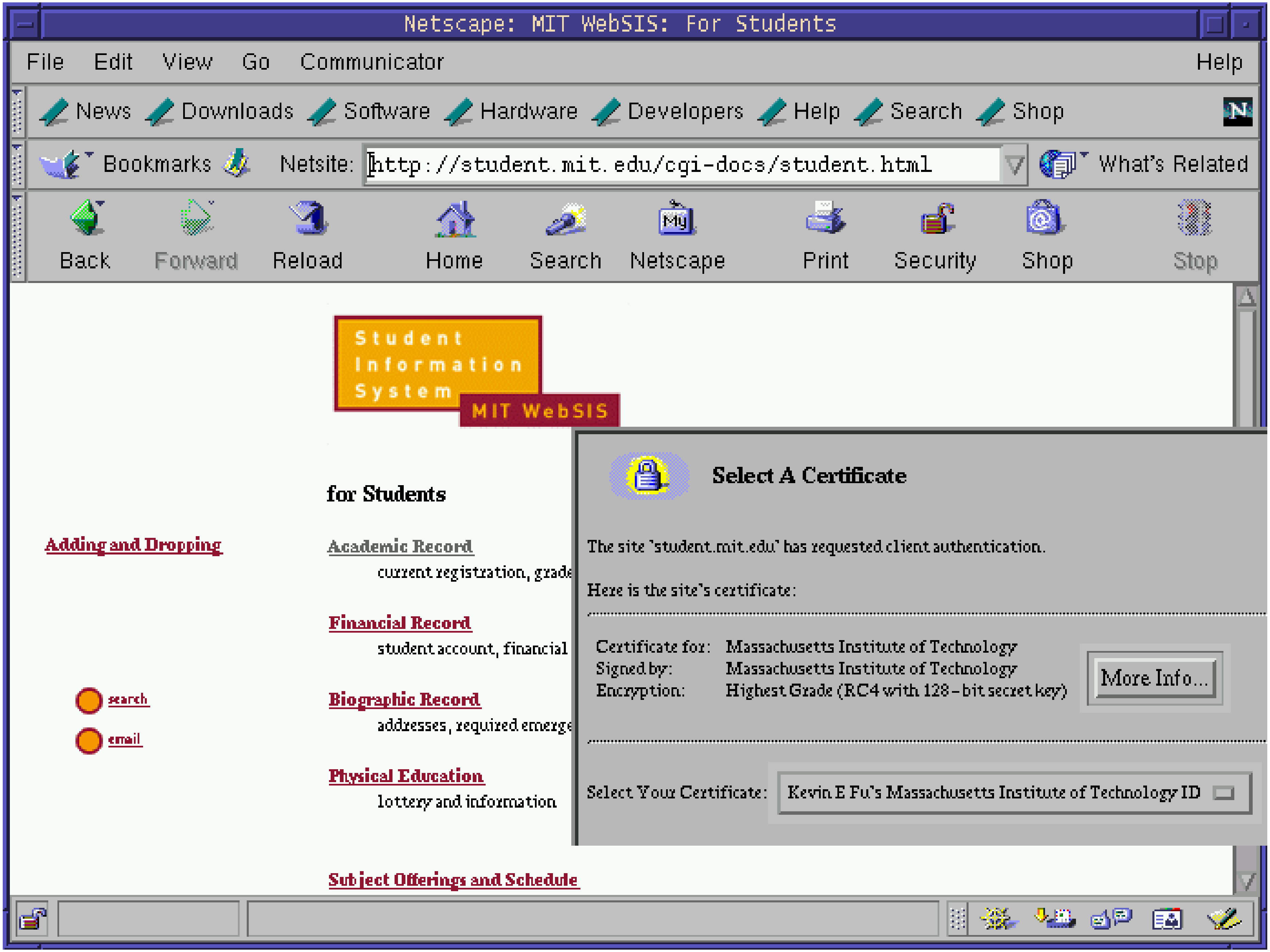
Start In: Home

Members: Forgot your password?

Log on to OptionsLink®
(For Business Solutions clients only)

For our Chinese language investors, we now offer E*TRADE Chinese

Statement of Financial Condition * Not FDIC Insured * No Bank Guarantee * May Lose Value. About brokerage insurance.
System response and account access times may vary due to a variety of factors, including trading volumes, market conditions, system performance, and other factors.



http://student.mit.edu/cgi-docs/student.html

for Students

Adding and Dropping

Academic Record
current registration, grade

Financial Record
student account, financial

Biographic Record
addresses, required emerge

Physical Education
lottery and information

Subject Offerings and Schedule

Select A Certificate

The site 'student.mit.edu' has requested client authentication.

Here is the site's certificate:

Certificate for: Massachusetts Institute of Technology
Signed by: Massachusetts Institute of Technology
Encryption: Highest Grade (RC4 with 128-bit secret key)

Select Your Certificate: Kevin E Fu's Massachusetts Institute of Technology ID

Why is client authentication on the Web difficult?

- **Limited interface.**
- **Hard-to-manage client-side storage.**
- **Solutions that exist are not deployable (e.g., personal certificates).**

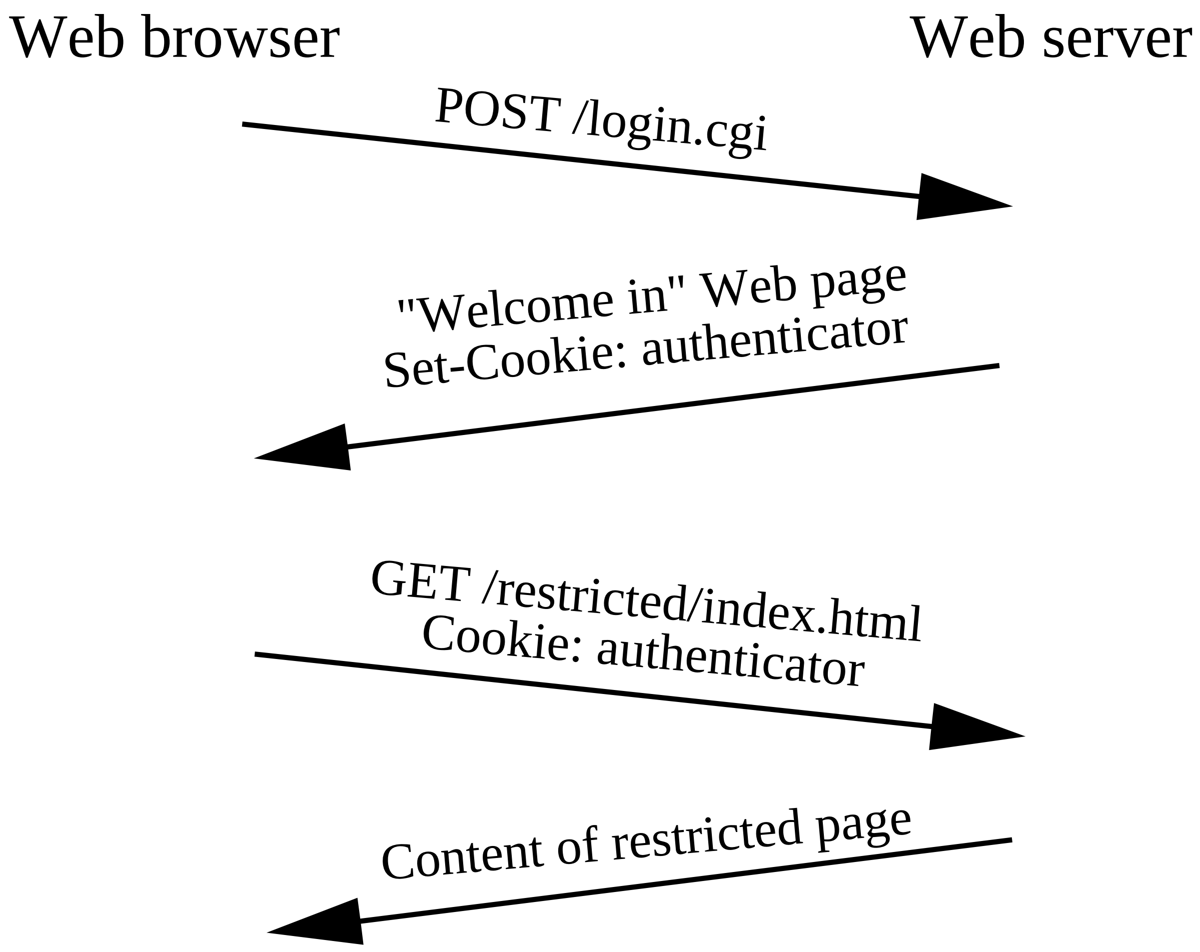
Case studies of Web authentication

- SSL and plain HTTP do not work together: SprintPCS
- Letting clients name the price: InstantShop
- Security through obscurity: HighSchoolAlumni.com
- Predictable sequence numbers: Fatbrain.com
- Misuse of cryptography: WSJ.com

Cookies: What are they?

- **A server can store key/value pairs on a client.**
- **The client sends previously set cookies to the server.**

The Web protocol with cookies



Netscape cookie example

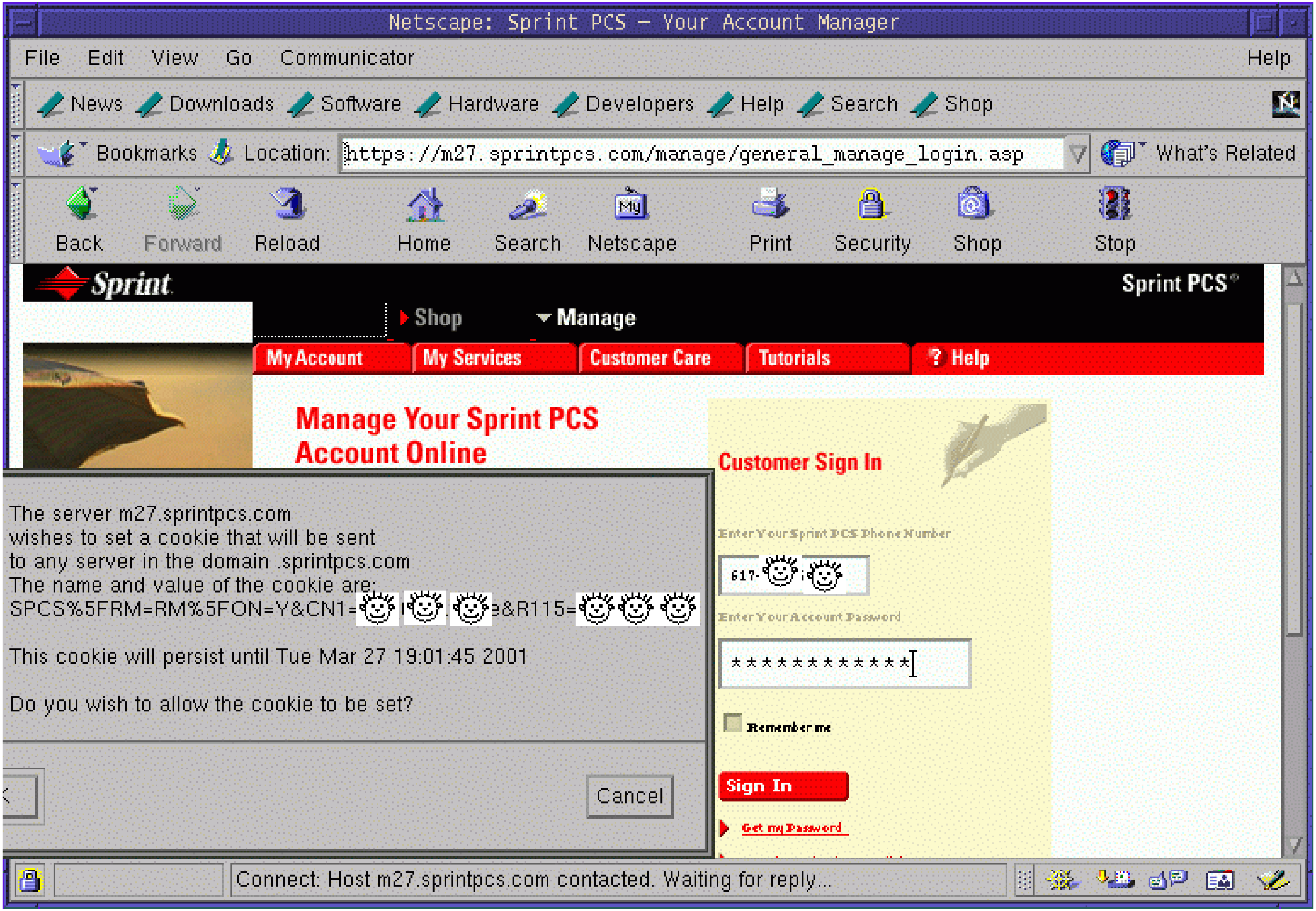
domain	Javascript?	Path	SSL?	Expiration	Variable name	Value
.wsj.com	FALSE	/cgi	FALSE	941452067	fastlogin	bitdiddleMaRdw2J1h6Lfc

Taxonomy of adversaries

- **Oracle. Can query a service.**
- **Passive. Can listen to network traffic.**
- **Active. Can listen, modify, and insert network traffic.**

SSL and plain HTTP do not work together: SprintPCS.com

- Problem: Secure content can leak through plaintext channels.
- Cookie file has flag to require SSL.
- User logs in with HTTPS, then clicks back to main HTTP page.
- Vulnerable to eavesdroppers.


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-[redacted]

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=[redacted]|[redacted].[redacted]e&R115=[redacted]

This cookie will persist until Tue Mar 27 19:01:45 2001

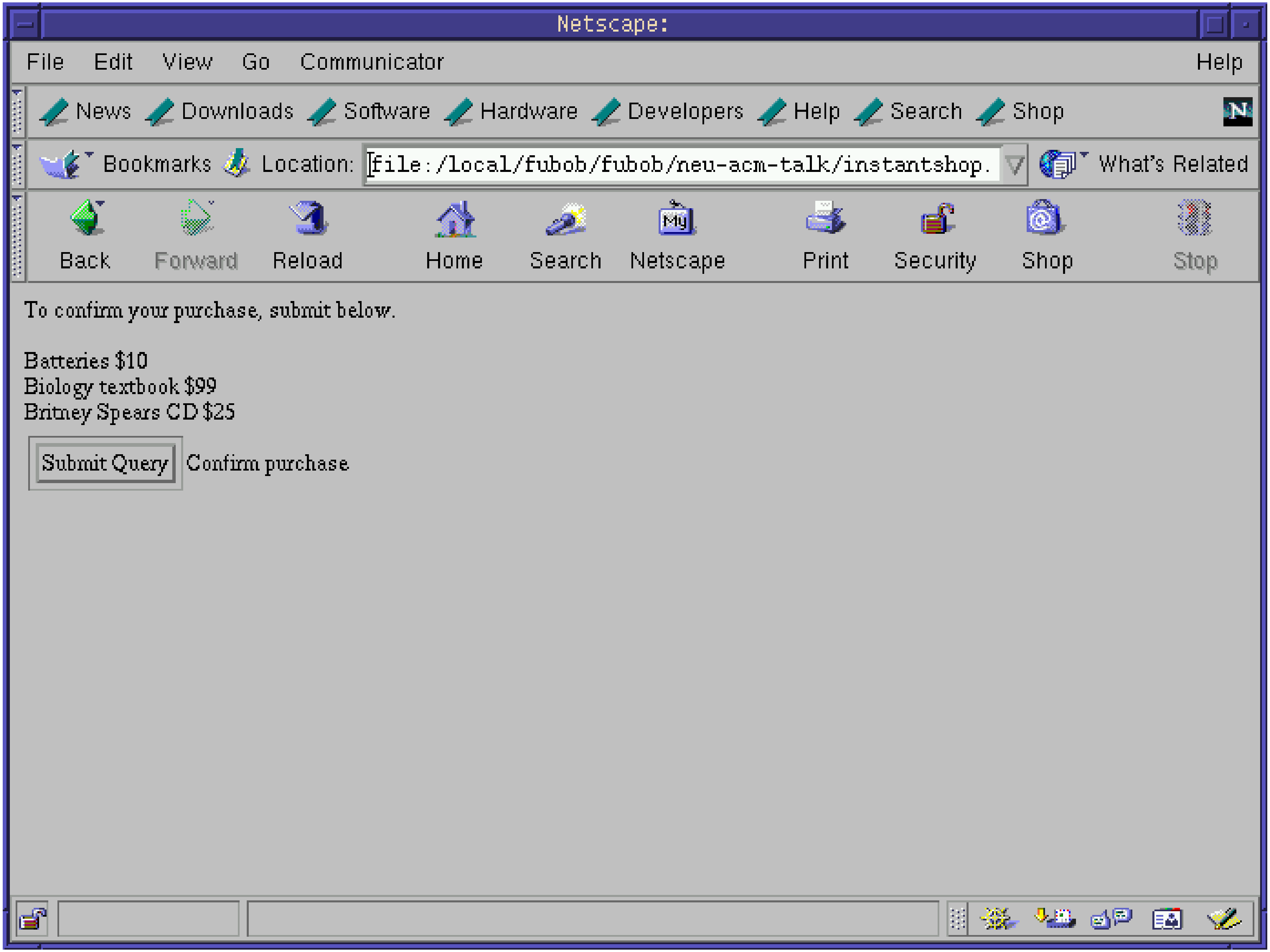
Do you wish to allow the cookie to be set?

Cancel

Connect: Host m27.sprintpcs.com contacted. Waiting for reply...

Letting clients name the price: Instant Shop

- Problem: Trusting clients not to modify HTML variables.
- Price determined by hidden variable in Web page.
- Make a local copy of the Web page. Modify it.


Netscape:
File Edit View Go Communicator Help
News Downloads Software Hardware Developers Help Search Shop
Bookmarks Location: file:/local/fubob/fubob/neu-acm-talk/instantshop. What's Related
Back Forward Reload Home Search Netscape Print Security Shop Stop

To confirm your purchase, submit below.

Batteries $10
Biology textbook $99
Britney Spears CD $25

Submit Query Confirm purchase

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>
```

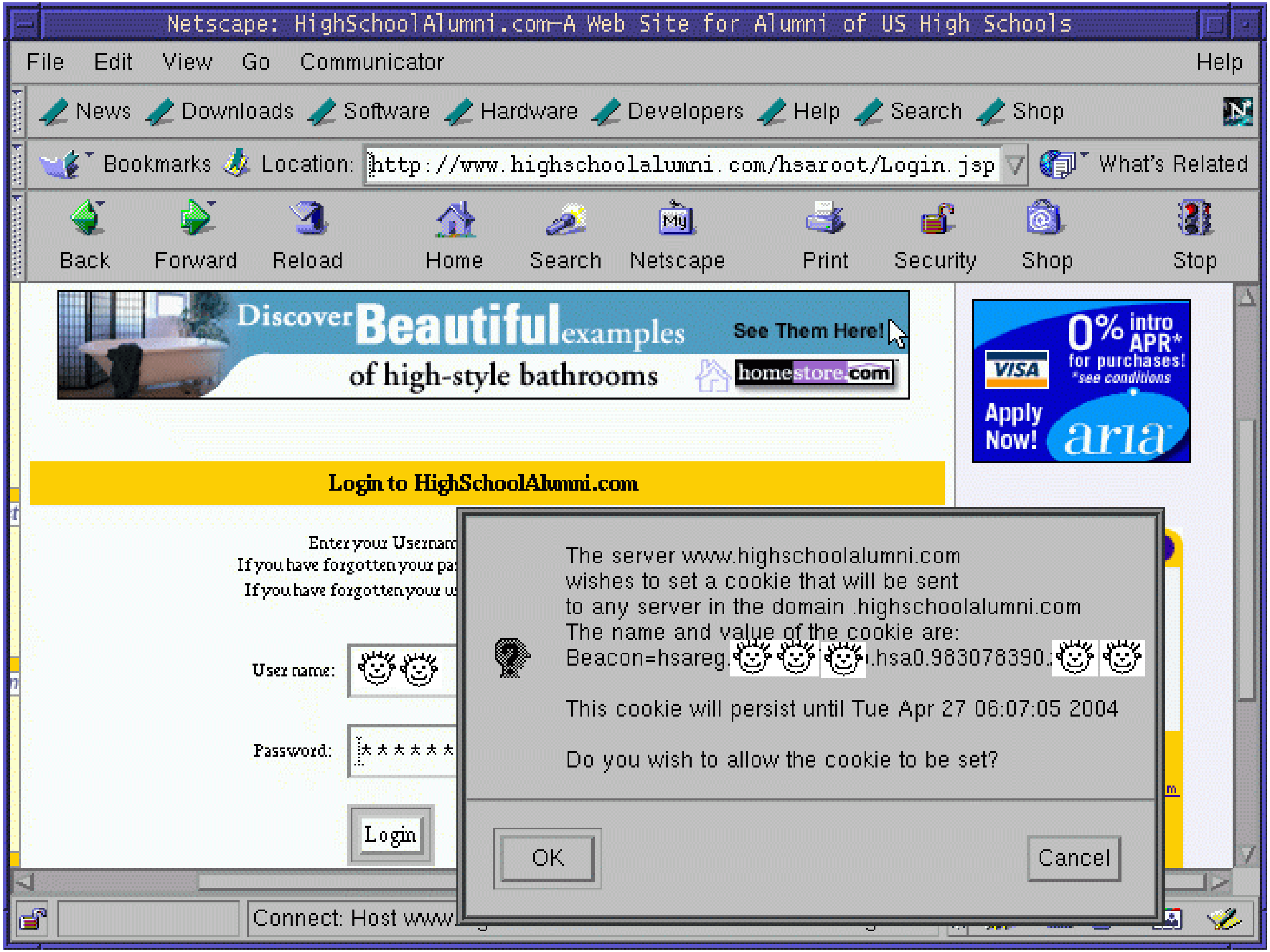
Instant Shop example: Malicious client

```
<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: 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
VISA
Apply Now!
aria
Login to HighSchoolAlumni.com
Login
OK
Cancel
Connect: Host www

Enter your Usernam

If you have forgotten your pa

If you have forgotten your u

User name: [redacted]

Password: ******

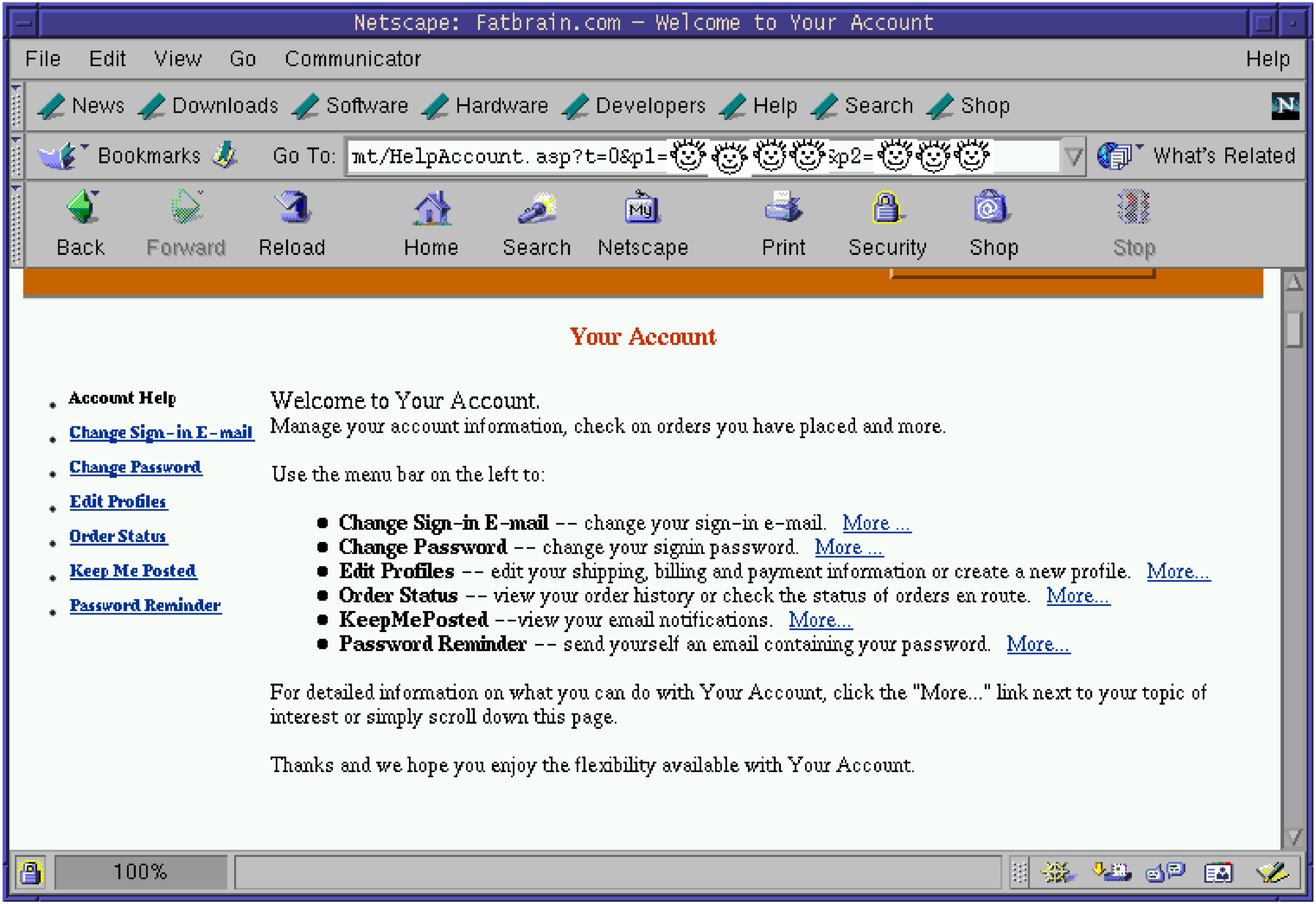
The server www.highschoolalumni.com
wishes to set a cookie that will be sent
to any server in the domain .highschoolalumni.com
The name and value of the cookie are:
Beacon=hsareg.[redacted].hsa0.983078390.[redacted]

This cookie will persist until Tue Apr 27 06:07:05 2004

Do you wish to allow the cookie to be set?

Predictable sequence numbers: fatbrain.com

- Problem: Customer can determine the authenticator for any other user.
- Authenticators are sequence numbers in the URL.
- Guess a victim’s sequence number by decrementing.
- Access to personal information, receive password by email.



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.

Fatbrain URL authenticator

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

Fatbrain response

“Its [sic] frustrating that programmers ... continue to fall prey to the same old tricks. Simple problems like lazy sequence numbers and buffer overflows in most cases can be easily eliminated if we as programmers would be a little vigilant about sound design and solid code reviews. I just *love* being at work on a Friday at midnight managing unscheduled production releases. :)”

—Chris Grant

WSJ.com

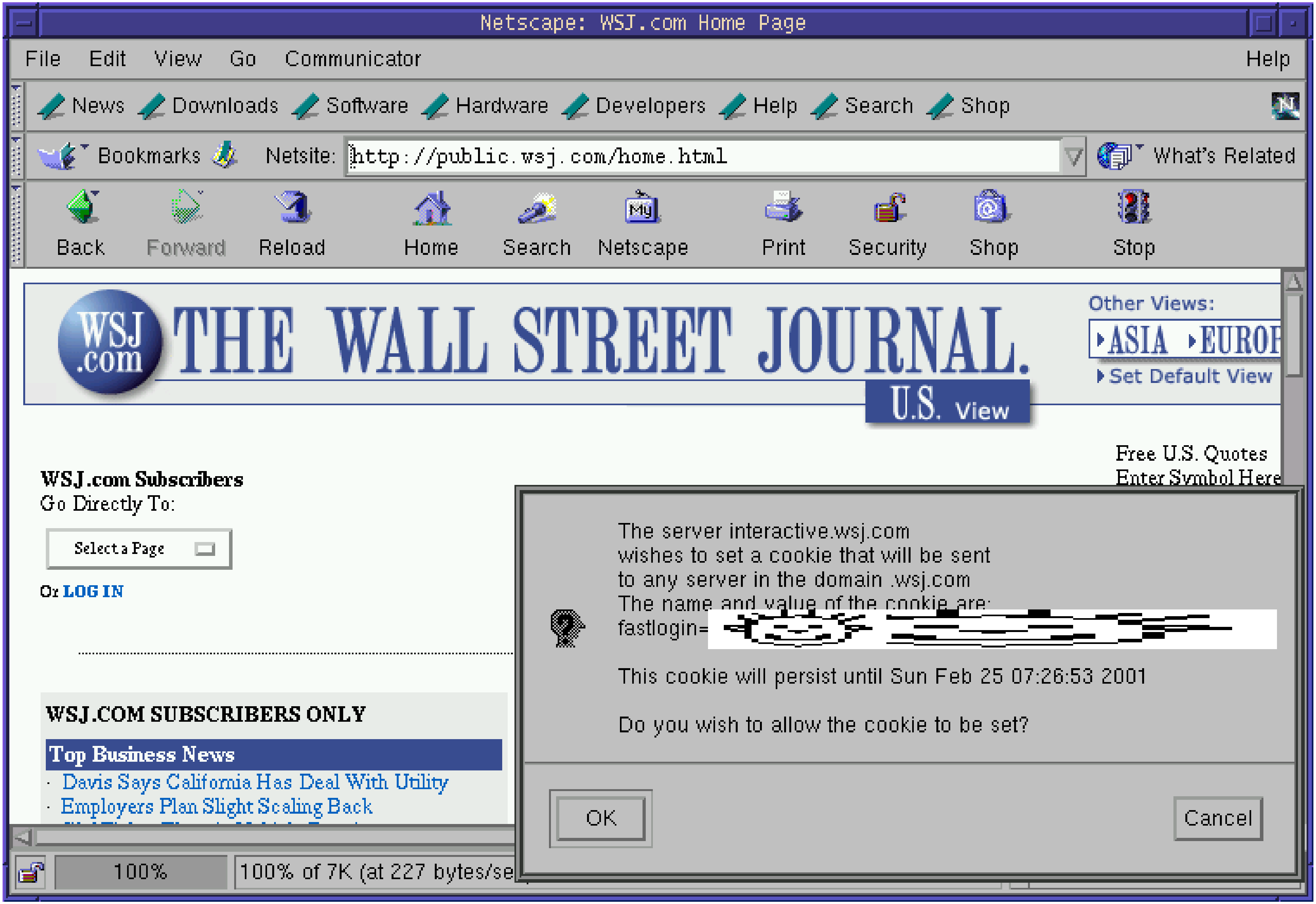
- **Wanted to authenticate paid subscribers with stateless servers.**
- **Half million paid-subscriber accounts.**
- **Can purchase articles. Optional stock portfolio tracking.**

Misuse of cryptography: WSJ.com

- Problem: Cryptography used incorrectly can be worse than no cryptography at all.
- Easily guessable authenticator.
- Given a username, our Perl script produces the authenticator.

WSJ.com analysis: the crypt() hash function

- Takes an 8-character input and salt.
- Ignores all input after the 8th character.
- Produces a hash.


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
100%
100% of 7K (at 227 bytes/se
OK
Cancel

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=[redacted]

This cookie will persist until Sun Feb 25 07:26:53 2001

Do you wish to allow the cookie to be set?

Wsj.com analysis continued

- **fastlogin =**
  user + crypt (user + rotating server secret).
- **Using your fastlogin cookie to produce another:**

username	Crypt() Output	Fastlogin Cookie
bitdiddle	MaRdw2J1h6Lfc	bitdiddleMaRdw2J1h6Lfc
bitdiddler	MaRdw2J1h6Lfc	bitdiddlerMaRdw2J1h6Lfc

- **Lack of revocation.**
- **The fastlogin cookie lasts forever**

How did we obtain the rotating server secret?

- **Adaptive chosen plaintext attack (dynamic programming).**
- **Perl script querried 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 our attack works

Pad 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

Dow Jones Response

"... about the factors affecting design decisions, it is certainly result of time to market considerations. ... we simply didn't have clear security requirements defined within the group and outside the group. So, we did what worked. We tried a better encryption algorithm, but hit a bug that we couldn't fix, so we implemented one that worked even though the architect in charge was fully aware of its short-comings. You must understand that I'm giving you my read on the situation since I've joined WSJ.com just 5 weeks ago."

— Javeh Saleh

Vice President, Technology

Interactive Business Technology Services, WSJ.com

Why do sites use cookies for authentication

- SSL is computationally expensive.
- HTTP authentication exposes passwords in cleartext.
- HTTP digest authentication is not deployed.
- Popular browsers implement cookies.

Simple schemes that work

- **Oracle. cookie** $= \texttt{username} + \texttt{password}$
- **Passive. cookie** $= \texttt{exp} + x_p + \texttt{MAC}_k(\texttt{URL} + \texttt{exp} + x_p)$ **where MAC could be HMAC-SHA1**
- **Active. Same as passive, but over SSL.**

Server authentication is difficult too

- Caching SSL sessions on IP address rather than hostname.
- Netscape demo.

Conclusions

- **Keep It Simple, Stupid (KISS).**
- **Subtle assumptions can lead to insecurity.**
- **No company wants to be the first to publish a cookie authentication scheme.**
- **Work to appear on** `http://cookies.lcs.mit.edu/` **and USENIX Sec01.**

If you leave the door open...

What is SSL: channel security

- **Confidentiality**
- **Authentication**
- **Integrity protection**

Certificates

- **Contains a public key, meta data, and a signature by a trusted third party.**

Certificate Authorities (CAs)

- Trusted third party with well-known public key.
- Certifies who belongs to a public key.
- Example: Verisign.

What does a CA-issued certificate mean?

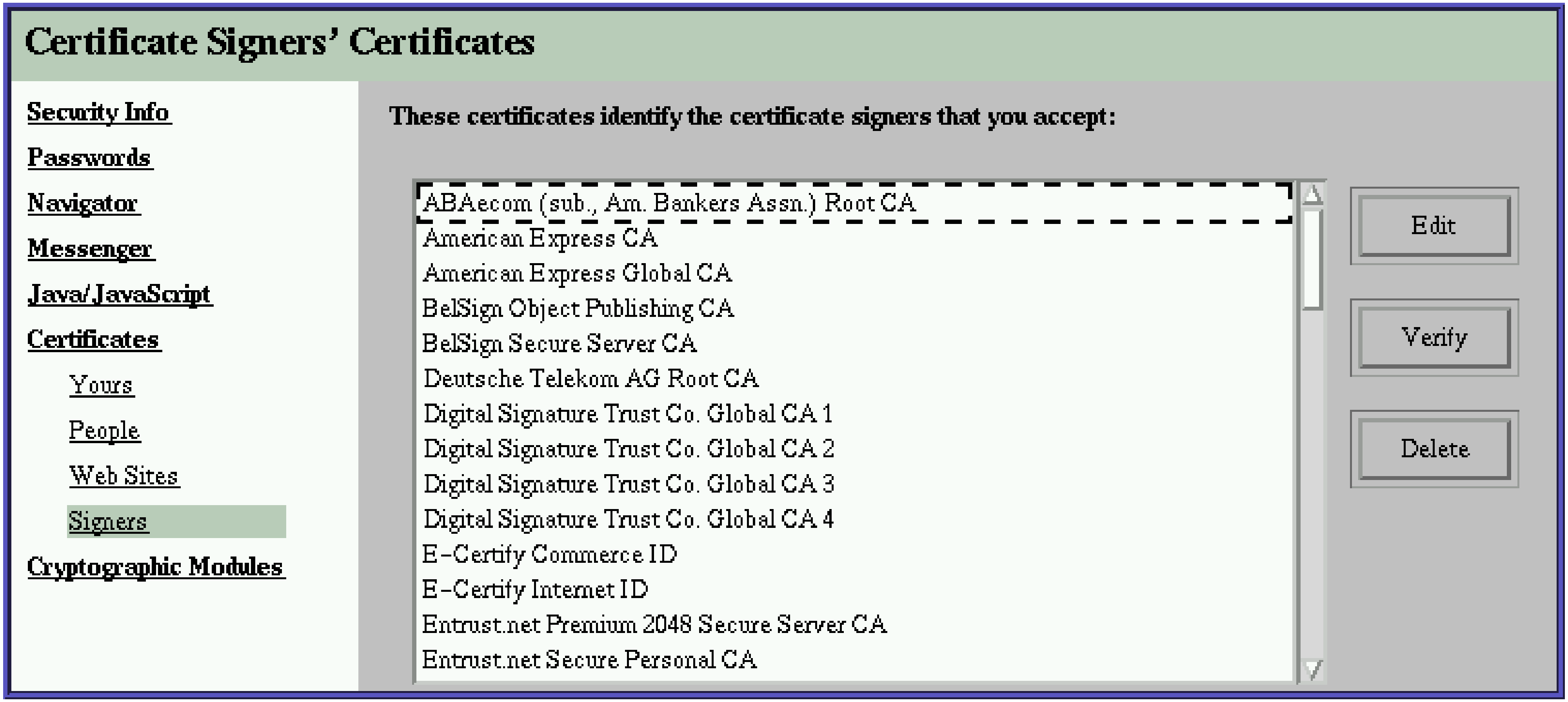
- No one knows exactly.
- That a public key belongs to someone authorized to represent a hostname?
- That a public key belongs to someone who is associated in some way with a hostname?
- That a public key belongs to someone who has lots of paper trails associated to a company related to a hostname?

How to get a Verisign certificate

- Pay Verisign ($300)
- City of Cambridge license ($20)
- Letterhead from company ($0)
- Notarized document (need driver’s license) ($0)

SSL pitfalls: Default CAs in browsers

- Neither Netscape or Microsoft have published their rule set for deciding which CA roots to include in browsers.
- Every CA is equally trusted.
- A single bad CA can disrupt authentication for the whole system.



Certificate Signers’ Certificates

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

SSL pitfalls: CA revocation

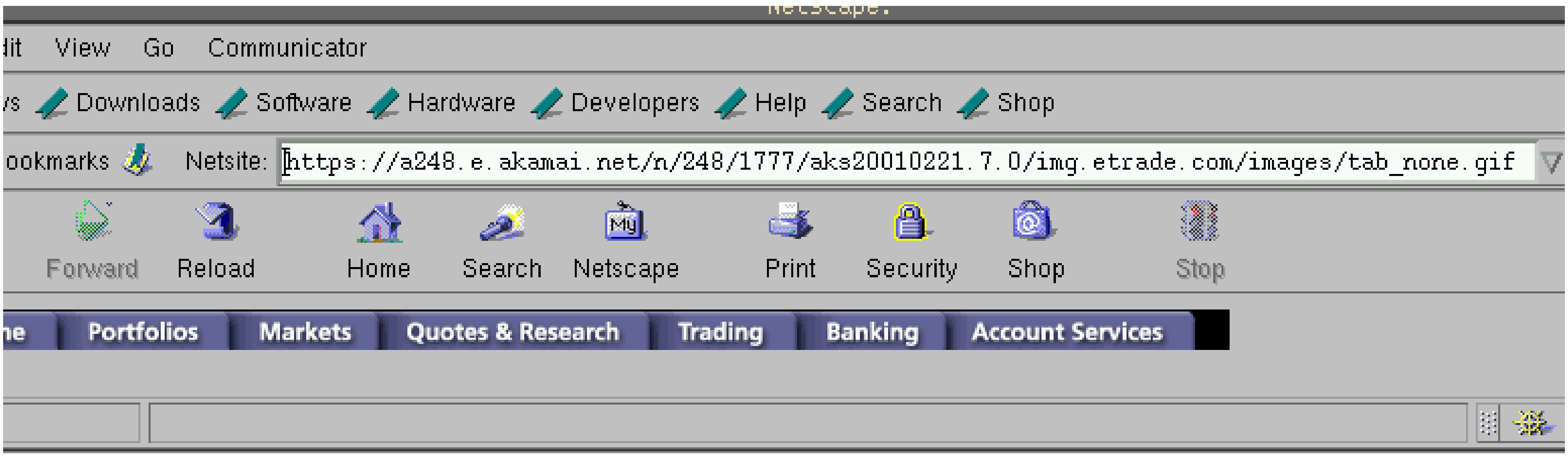
- Certificates last for a long time, typically a year.
- No way to revoke a certificate.
- What if a CA itself is compromised? [Sun CA]

SSL pitfalls: Random number generation

- Netscape used predictable numbers to generate SSL session keys.
- Two Berkeley graduate students were able to predict sessions keys.
- Because of an insecure implementation, SSL was insecure.

SSL pitfalls: End-to-end content authentication

- **SSL authenticates servers, not content. [Akamai]**



Netsite: https://a248.e.akamai.net/n/248/1777/aks20010221.7.0/img.etrade.com/images/tab_none.gif

SSL pitfalls: Perfect forward secrecy

- Compromised server private key → decrypt future and past traffic.