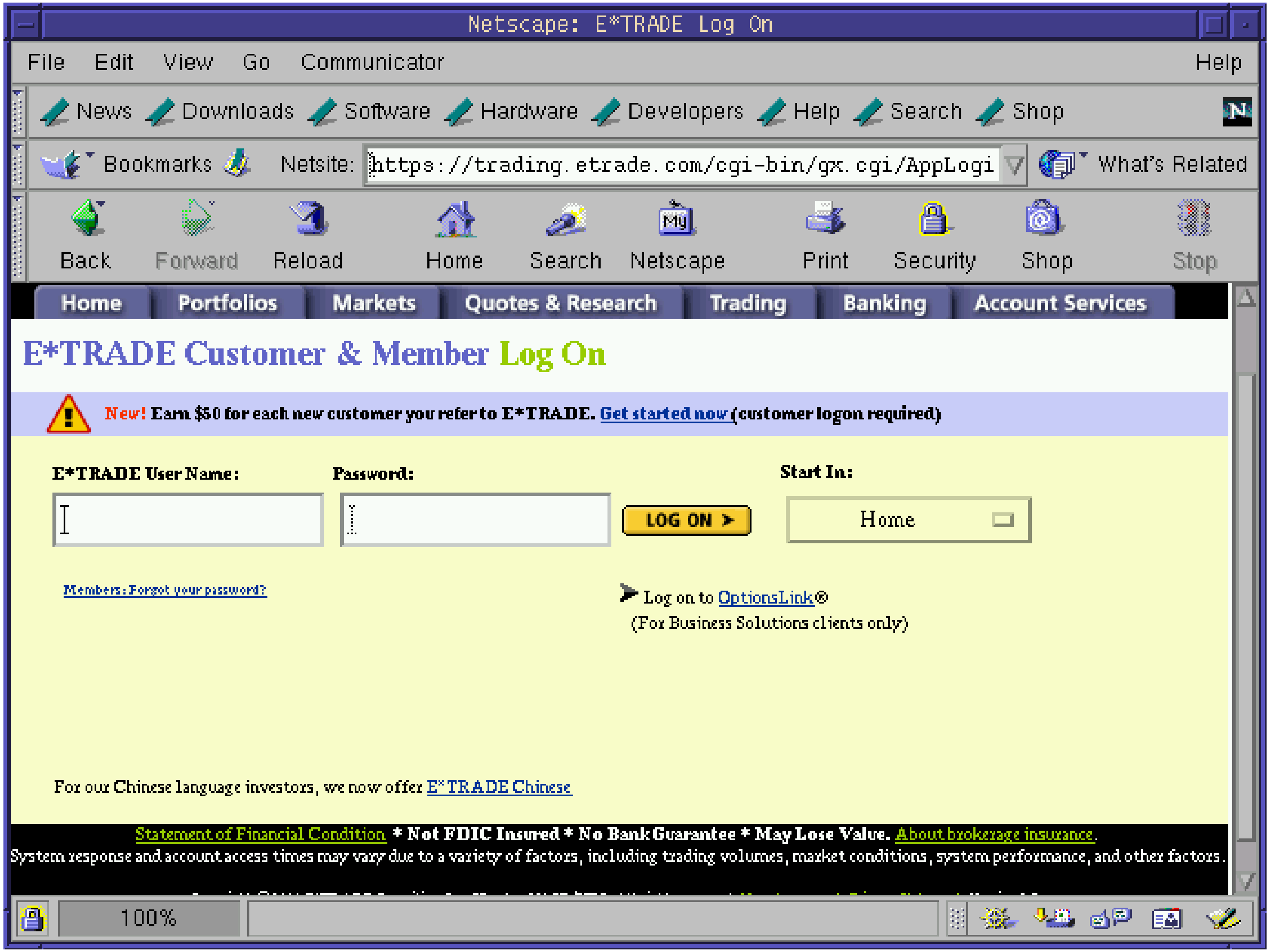
Web User Authentication

6.857 Lecture #2, Kevin Fu

September 10, 2002



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:

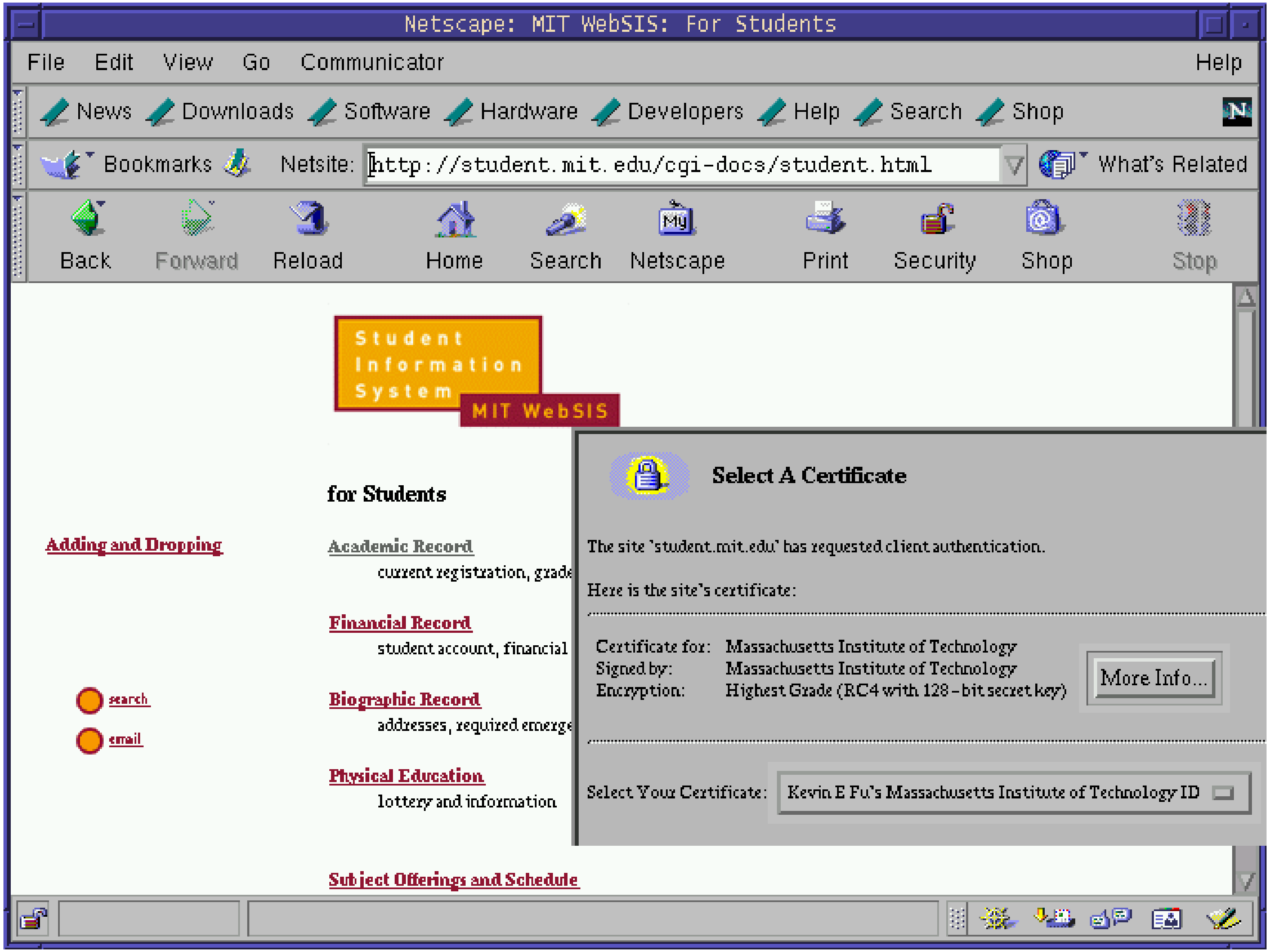
Start In: Home

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

Student Information System

MIT WebSIS

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

search

email

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

What this talk is about

- Improving the security of client authentication on the Web

Where are we now?

- We have HTTP authentication

Where are we now?

- We have HTTP authentication
- We’ve had SSL for 7+ years

Where are we now?

- We have HTTP authentication
- We’ve had SSL for 7+ years
- Client authentication should be easy, right?

Many Web sites get it wrong

Site	Security problem
WSJ.com	crypto misuse, secret key exposed
SprintPCS.com	leaks authenticator in plaintext
FatBrain.com	predictable session ID
HighSchoolAlumni.com	circumvent password authentication
PerformanceBike.com	predictable session ID
NEBride.com	circumvent password authentication
ihateshopping.net	circumvent password authentication
cstc.org	circumvent password authentication

Toolkits are vulnerable too

Toolkit	Security problem
Allaire ColdFusion	predictable session IDs, LCNG
ArsDigita ACS	signs ambiguous messages
Jakarta TomCat	predictable session IDs, random seed
PHP	session IDs based on time of day

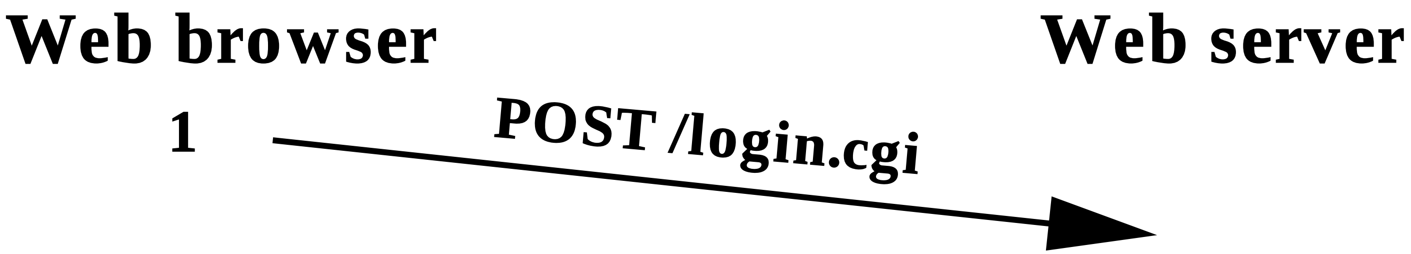
Cookies: what are they?

- 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

Sample cookie

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

Cookies for login sessions



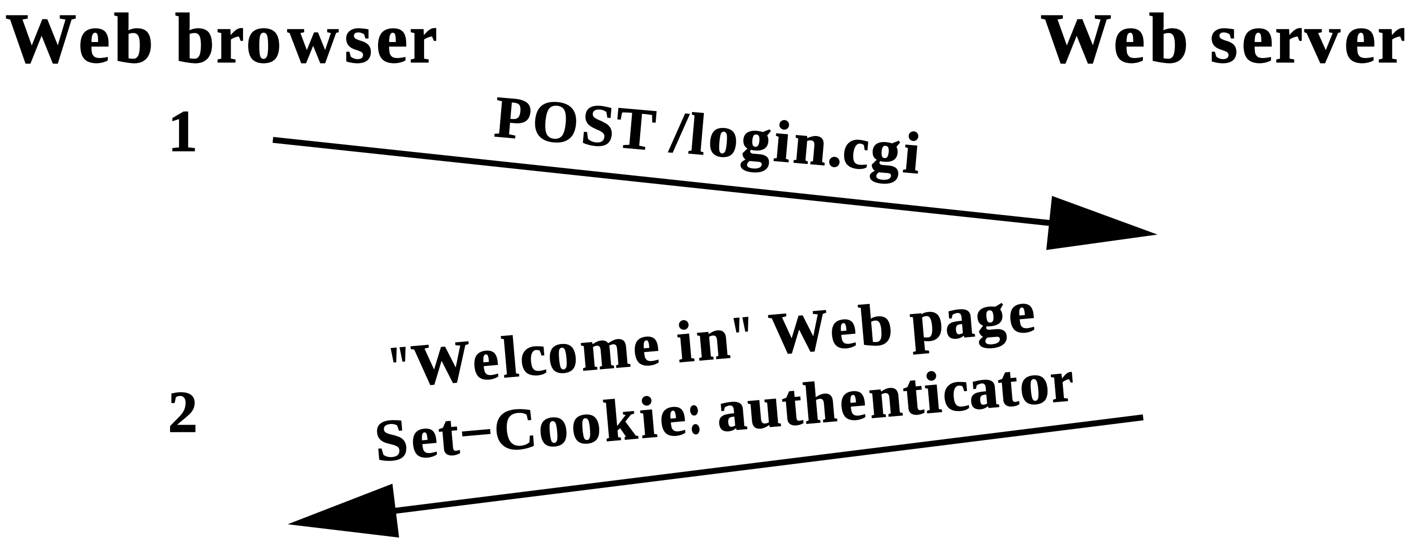
Web browser

Web server

1

POST /login.cgi

Cookies for login sessions



Web browser

Web server

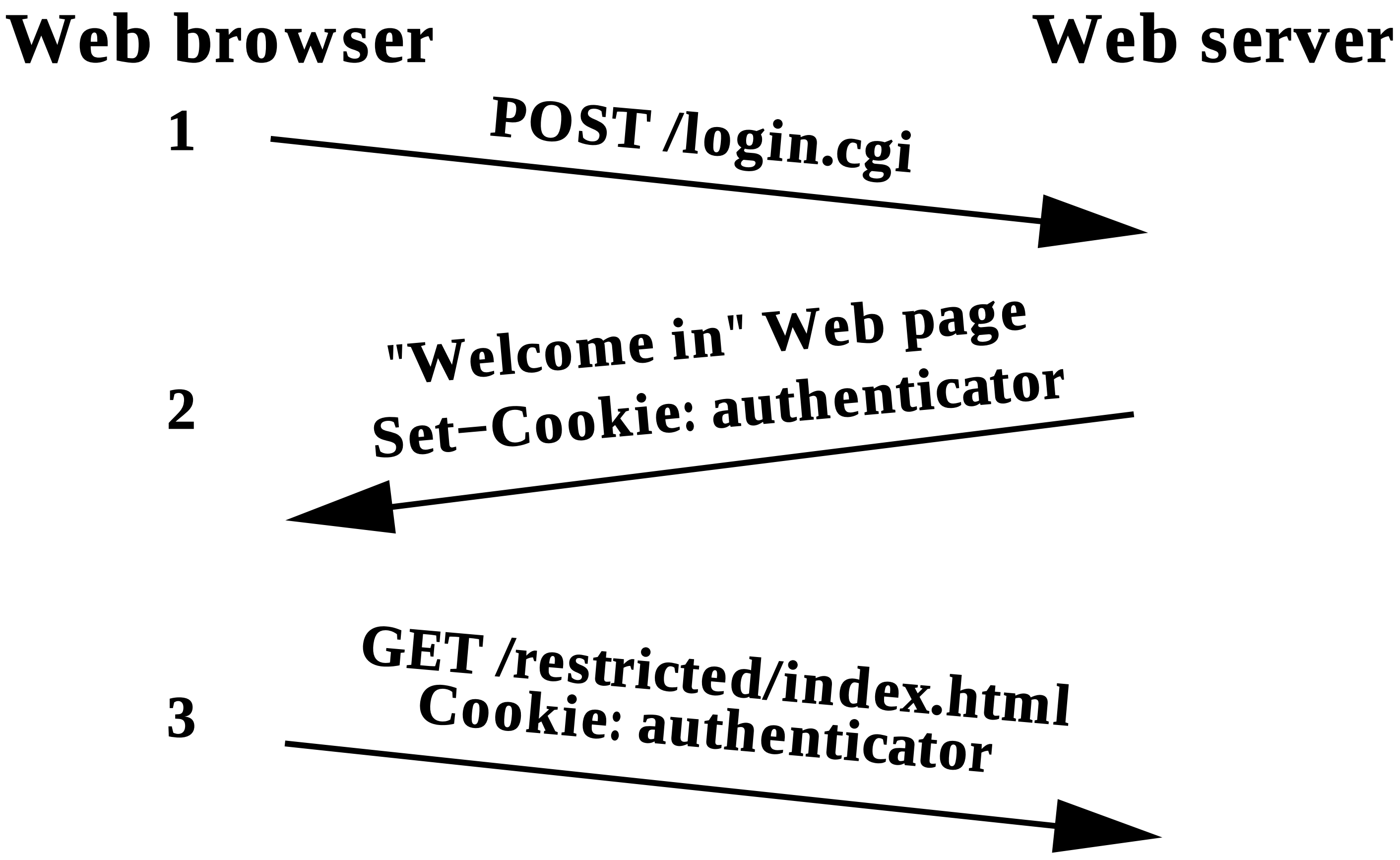
1

POST /login.cgi

2

"Welcome in" Web page
Set−Cookie: authenticator

Cookies for login sessions



Web browser

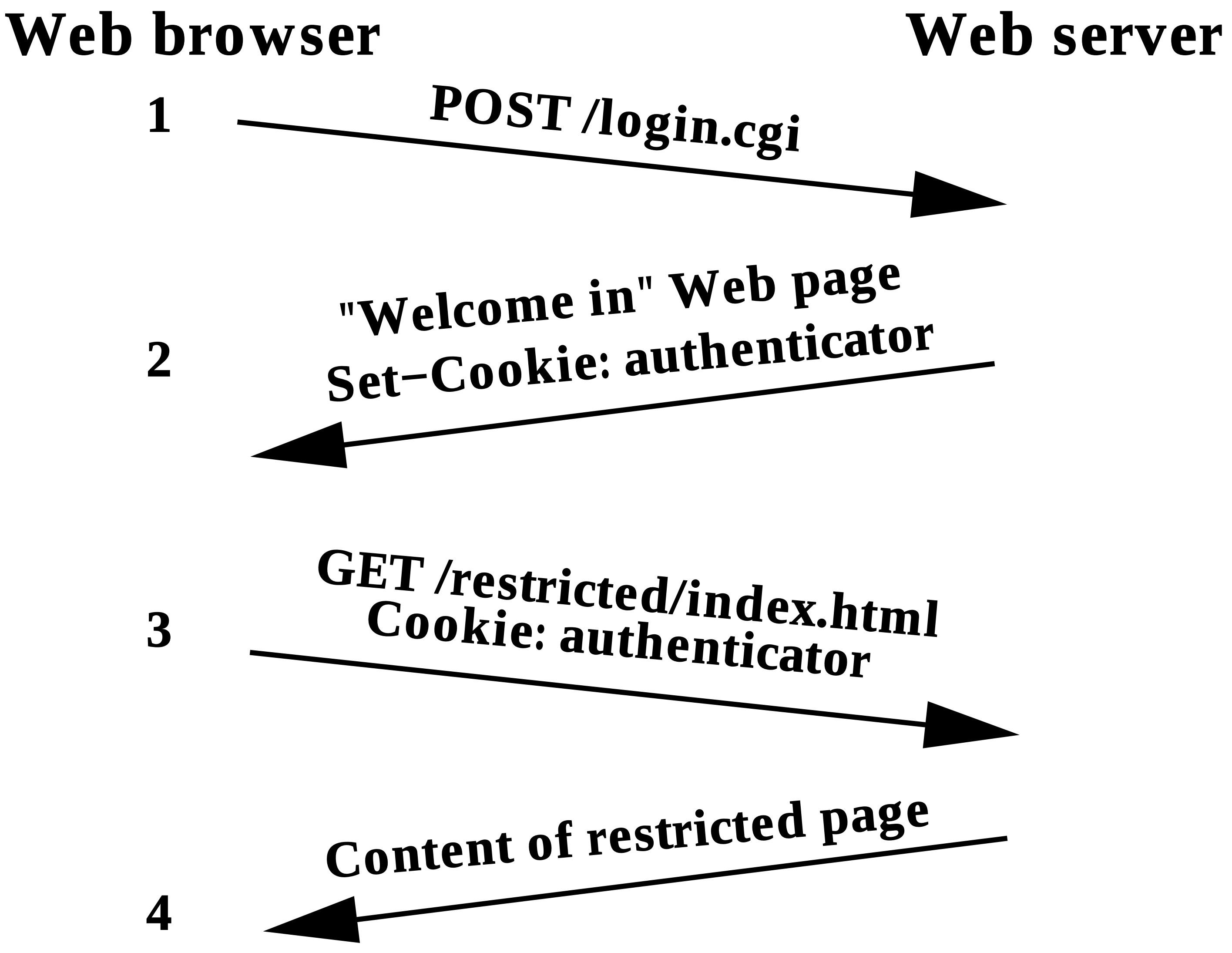
Web server

1 POST /login.cgi

2 "Welcome in" Web page
Set−Cookie: authenticator

3 GET /restricted/index.html
Cookie: authenticator

Cookies for login sessions



Interrogative adversary

- Adaptively query a Web server a reasonable number of times
- Treat server as an oracle for an adaptive chosen message attack
- Extremely limited, but surprisingly powerful

Types of breaks

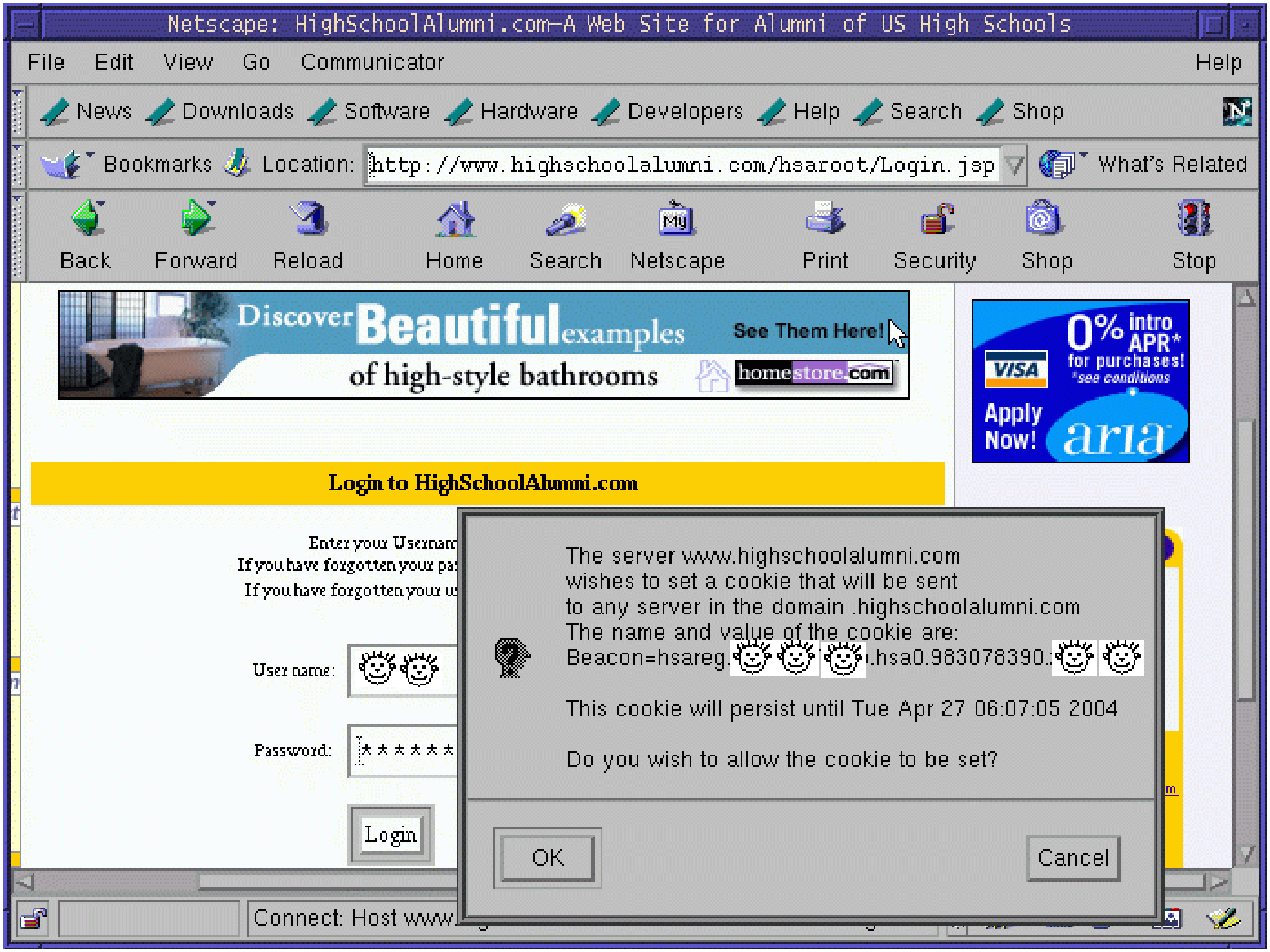
- Replay
- Existential forgery
- Selective forgery
- Total break

The cookie crumbles...

Many Web sites that have invented their own homebrew cookie-based authentication schemes.

Case studies of Web authentication

- Lack of cryptography: HighSchoolAlumni.com
- Trusting user input: Instant Shop
- Leaking secrets: SprintPCS.com
- Predictable sequence numbers: FatBrain.com
- Misuse of cryptography: WSJ.com


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

Enter your Usernam
If you have forgotten your pa
If you have forgotten your u

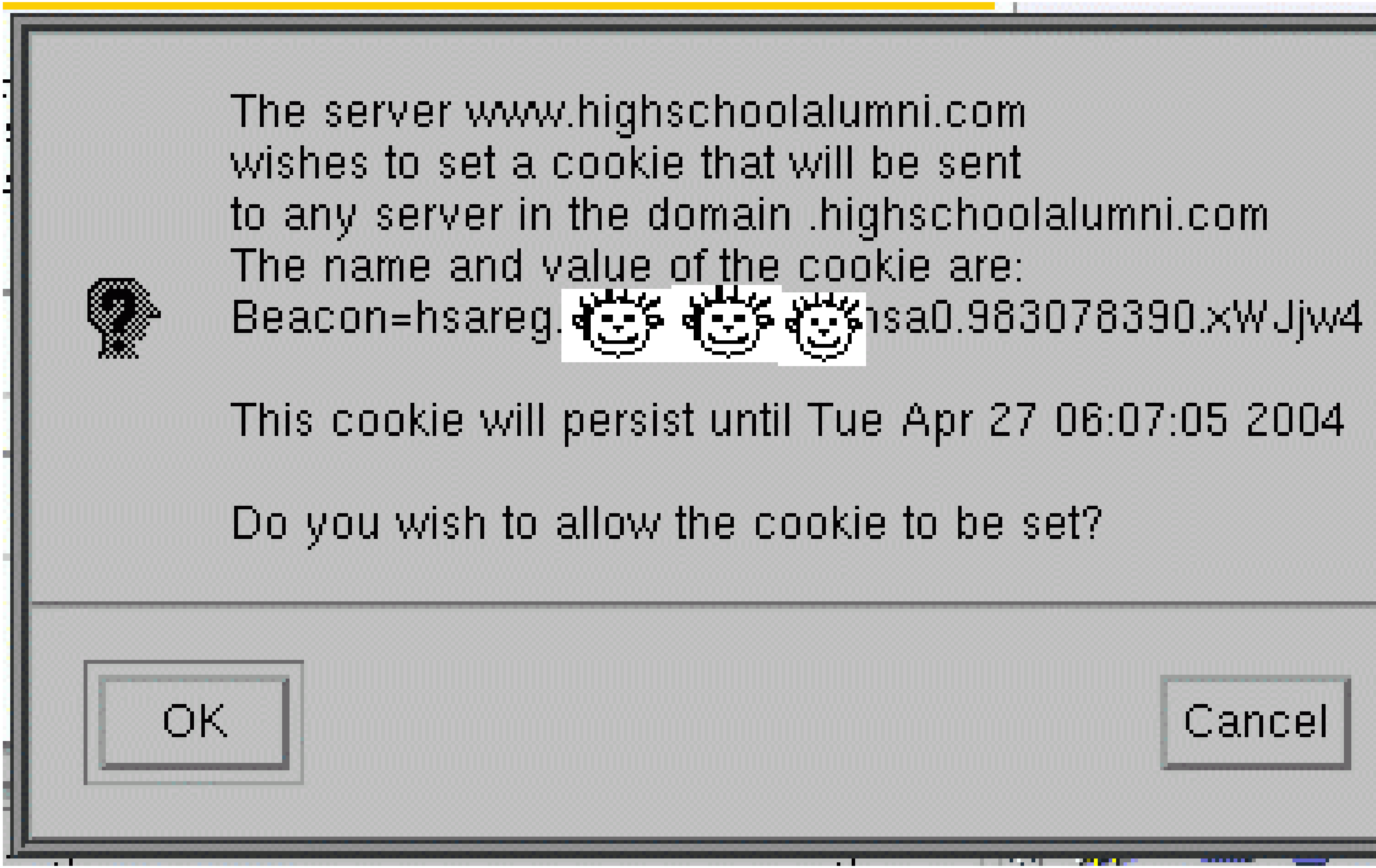
User name: ☺☺

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.☺☺☺.hsa0.983078390.☺☺

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

Do you wish to allow the cookie to be set?



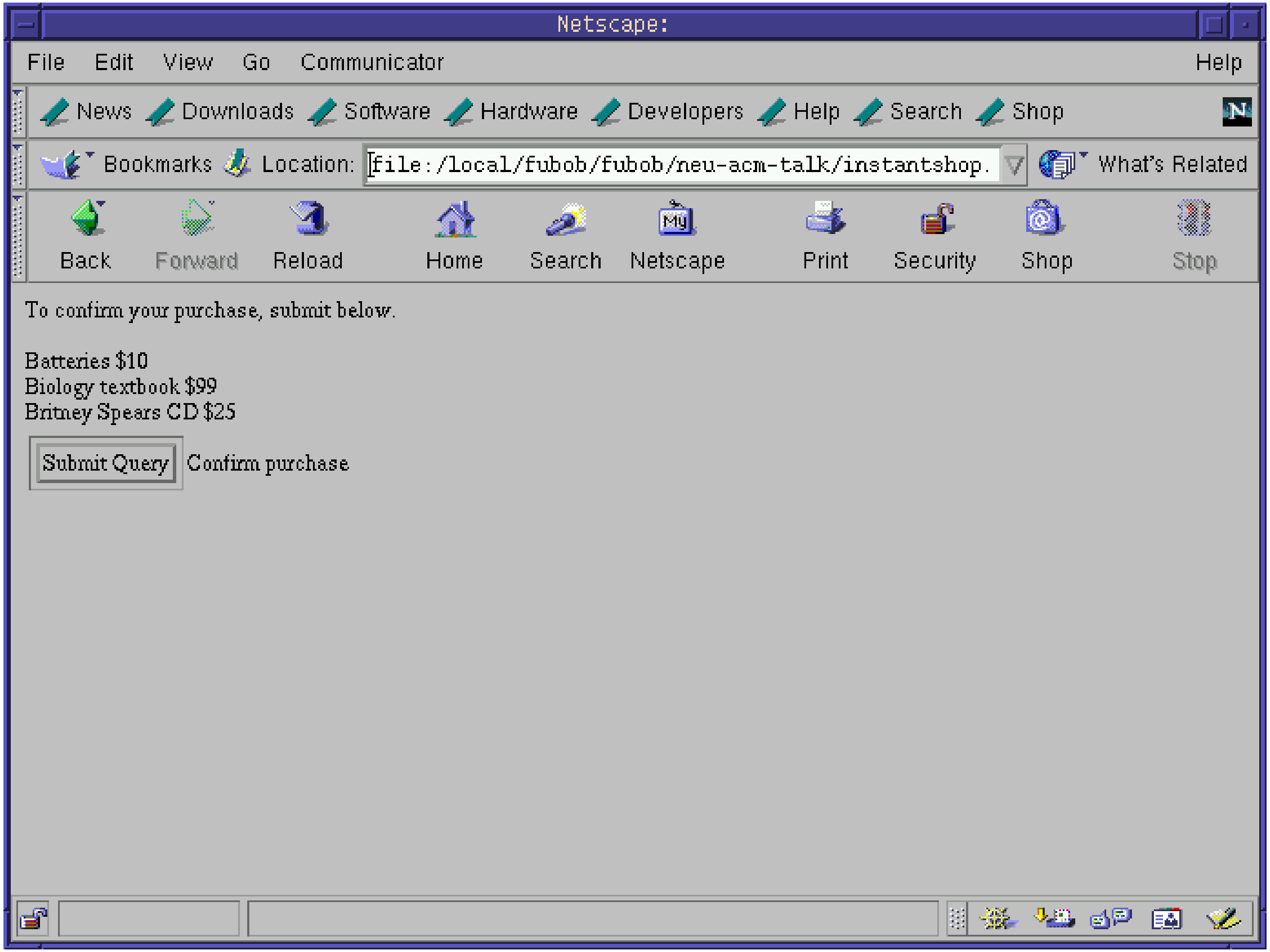
The server www.highschoolalumni.com
wishes to set a cookie that will be sent
to any server in the domain .highschoolalumni.com
The name and value of the cookie are:
Beacon=hsareg.[redacted]sa0.983078390.xWJjw4

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

Do you wish to allow the cookie to be set?

Lack of cryptography

- Site: HighSchoolAlumni.com
- Problem: No cryptographic authentication
- Adversary: Interrogative
- Break: Universal forgery
- Today: Sold to another reunion site



To confirm your purchase, submit below.

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

Submit Query Confirm purchase

Instant Shop: What’s inside

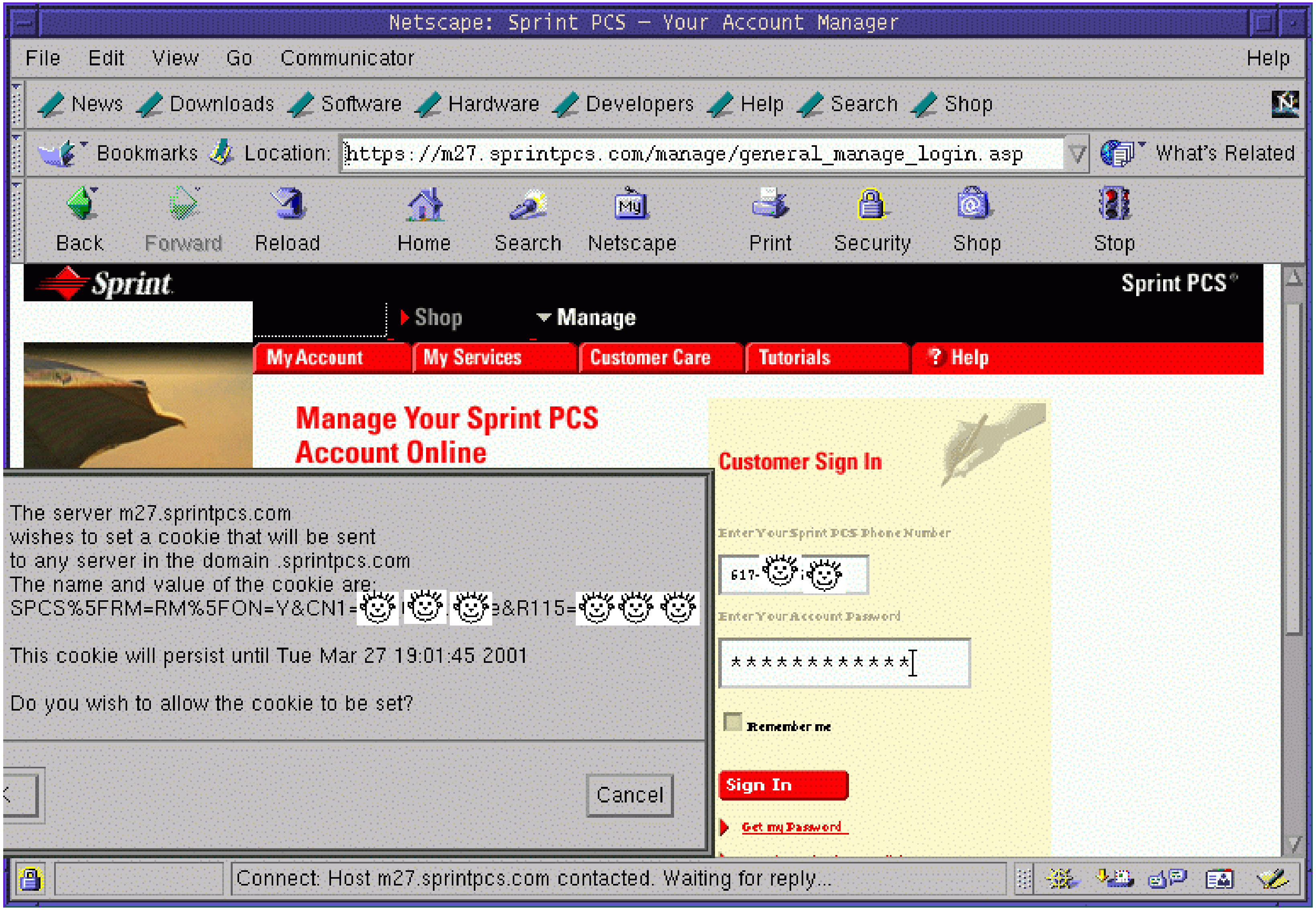
```
<form action=commit_sale.cgi>
<input type=hidden name=item1 value=10>Batteries $10
<input type=hidden name=item2 value=99>Biology textbook $99
<input type=hidden name=item3 value=25>Britney Spears CD $25
<input type=submit>Confirm purchase
</form>
```

Instant Shop: Malicious user

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

Trusting user input

- Site: Instant Shop
- Problem: Server trusts users not to modify HTML variables
- Adversary: Interrogative
- Today: Out of business



Netscape: Sprint PCS – Your Account Manager
File Edit View Go Communicator Help
News Downloads Software Hardware Developers Help Search Shop
Bookmarks Location:
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

Location: https://m27.sprintpcs.com/manage/general_manage_login.asp

Manage Your Sprint PCS Account Online

Customer Sign In

Enter Your Sprint PCS Phone Number

617-[redacted]

Enter Your Account Password

****

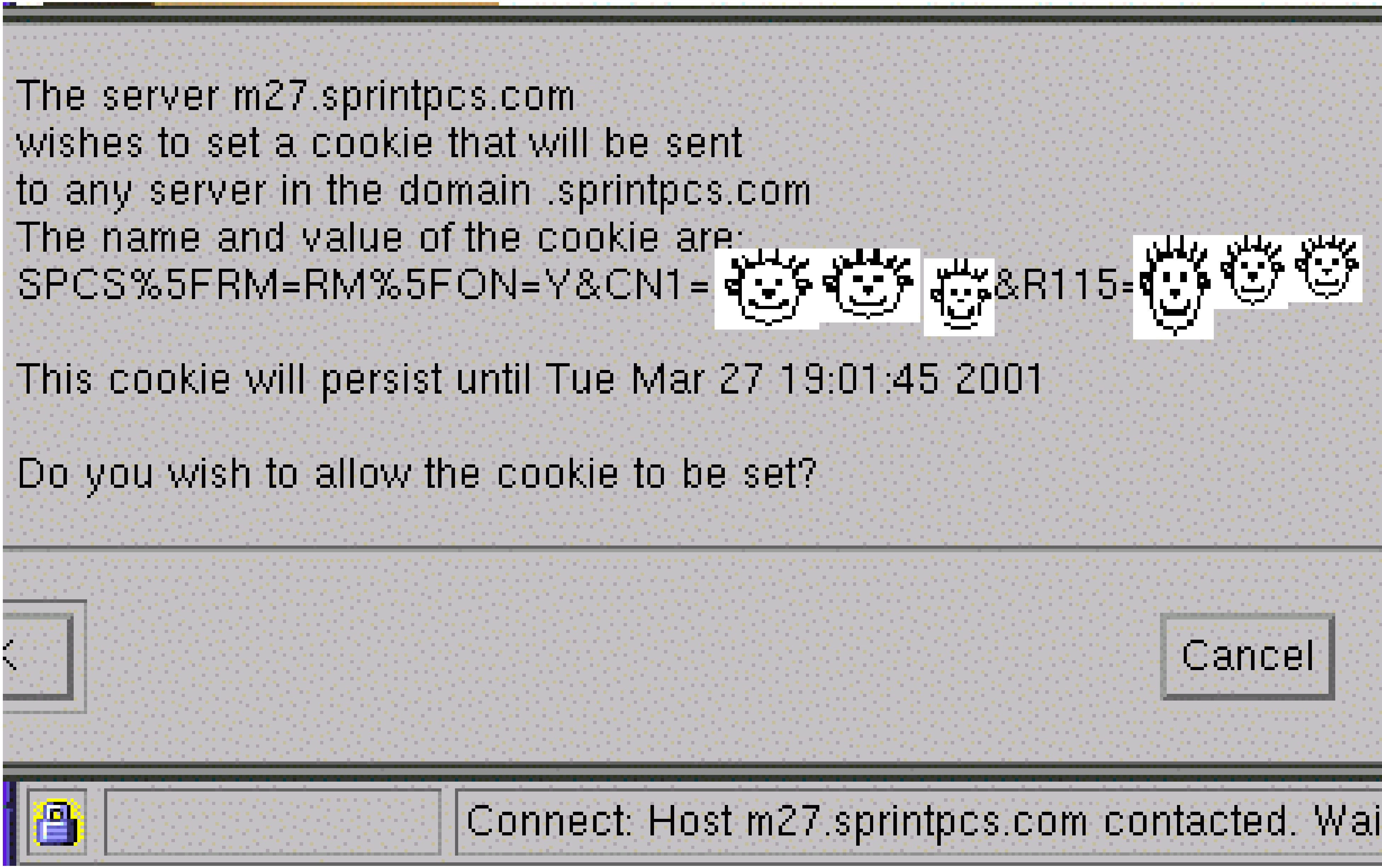
□ Remember me

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]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?

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



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=☺☺☺

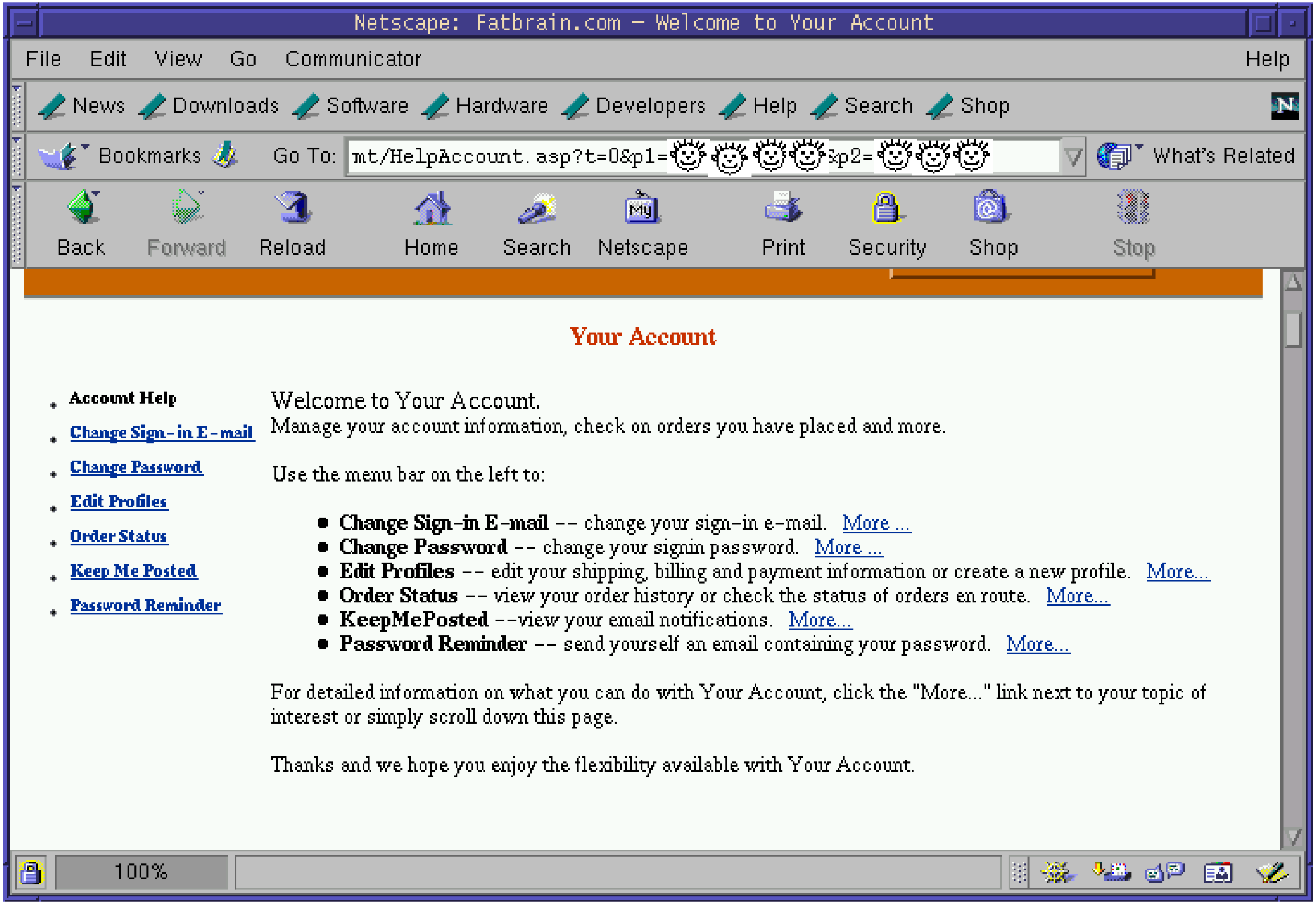
This cookie will persist until Tue Mar 27 19:01:45 2001

Do you wish to allow the cookie to be set?

Connect: Host m27.sprintpcs.com contacted. Wai

Leaking secrets

- Site: SprintPCS.com
- Problem: Secure content can leak through plaintext channels
- Adversary: Eavesdropper
- Break: Replay
- Today: A leading provider of mobile phone service...


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=☺☺☺☺&p2=☺☺☺ What's Related
Back Forward Reload Home Search Netscape Print Security Shop Stop
100%

Your Account

- **Account Help**
- Change Sign-in E-mail
- Change Password
- Edit Profiles
- Order Status
- Keep Me Posted
- Password Reminder

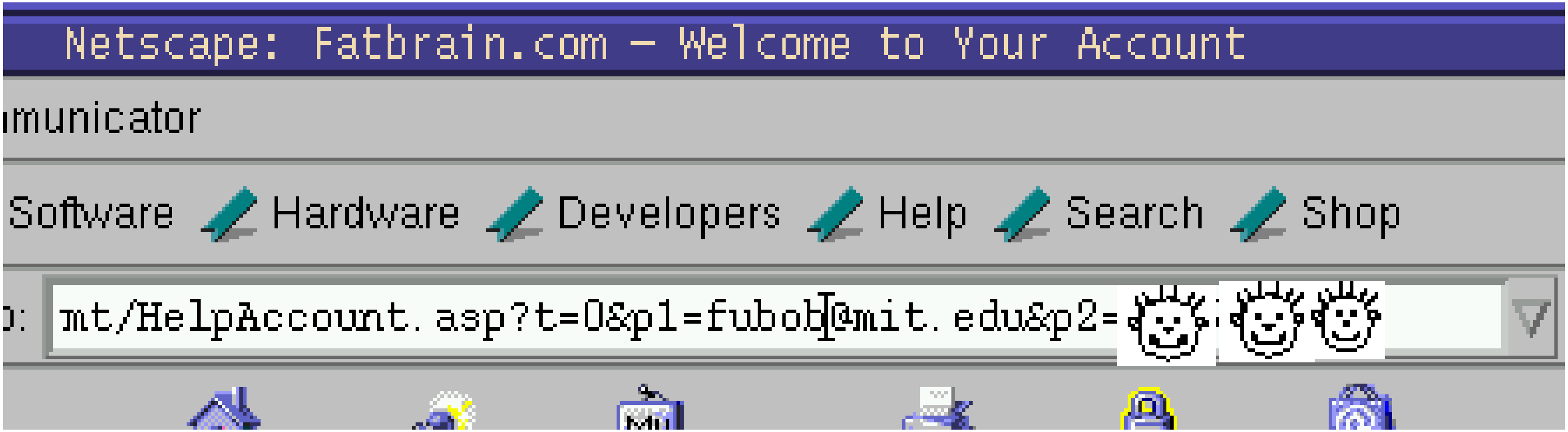
Welcome to Your Account.
Manage your account information, check on orders you have placed and more.

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.



mt/HelpAccount.asp?t=0&p1=fubob@mit.edu&p2=

FatBrain URL authenticator

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

Try: https://www.fatbrain.com/HelpAccount.asp? ✘
t=0&p1=nobob@mit.edu&p2=540555757

Target: https://www.fatbrain.com/HelpAccount.asp?
t=0&p1=nobob@mit.edu&p2=540555752

FatBrain URL authenticator

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

Try: https://www.fatbrain.com/HelpAccount.asp? ✘
t=0&p1=nobob@mit.edu&p2=540555756

Target: https://www.fatbrain.com/HelpAccount.asp?
t=0&p1=nobob@mit.edu&p2=540555752

FatBrain URL authenticator

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

Try: https://www.fatbrain.com/HelpAccount.asp? ✘
t=0&p1=nobob@mit.edu&p2=540555755

Target: https://www.fatbrain.com/HelpAccount.asp?
t=0&p1=nobob@mit.edu&p2=540555752

FatBrain URL authenticator

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

Try: https://www.fatbrain.com/HelpAccount.asp? ✘
t=0&p1=nobob@mit.edu&p2=540555754

Target: https://www.fatbrain.com/HelpAccount.asp?
t=0&p1=nobob@mit.edu&p2=540555752

FatBrain URL authenticator

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

Try: https://www.fatbrain.com/HelpAccount.asp? ✘
t=0&p1=nobob@mit.edu&p2=540555753

Target: https://www.fatbrain.com/HelpAccount.asp?
t=0&p1=nobob@mit.edu&p2=540555752

FatBrain URL authenticator

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

Try: https://www.fatbrain.com/HelpAccount.asp? ✔
t=0&p1=nobob@mit.edu&p2=540555752

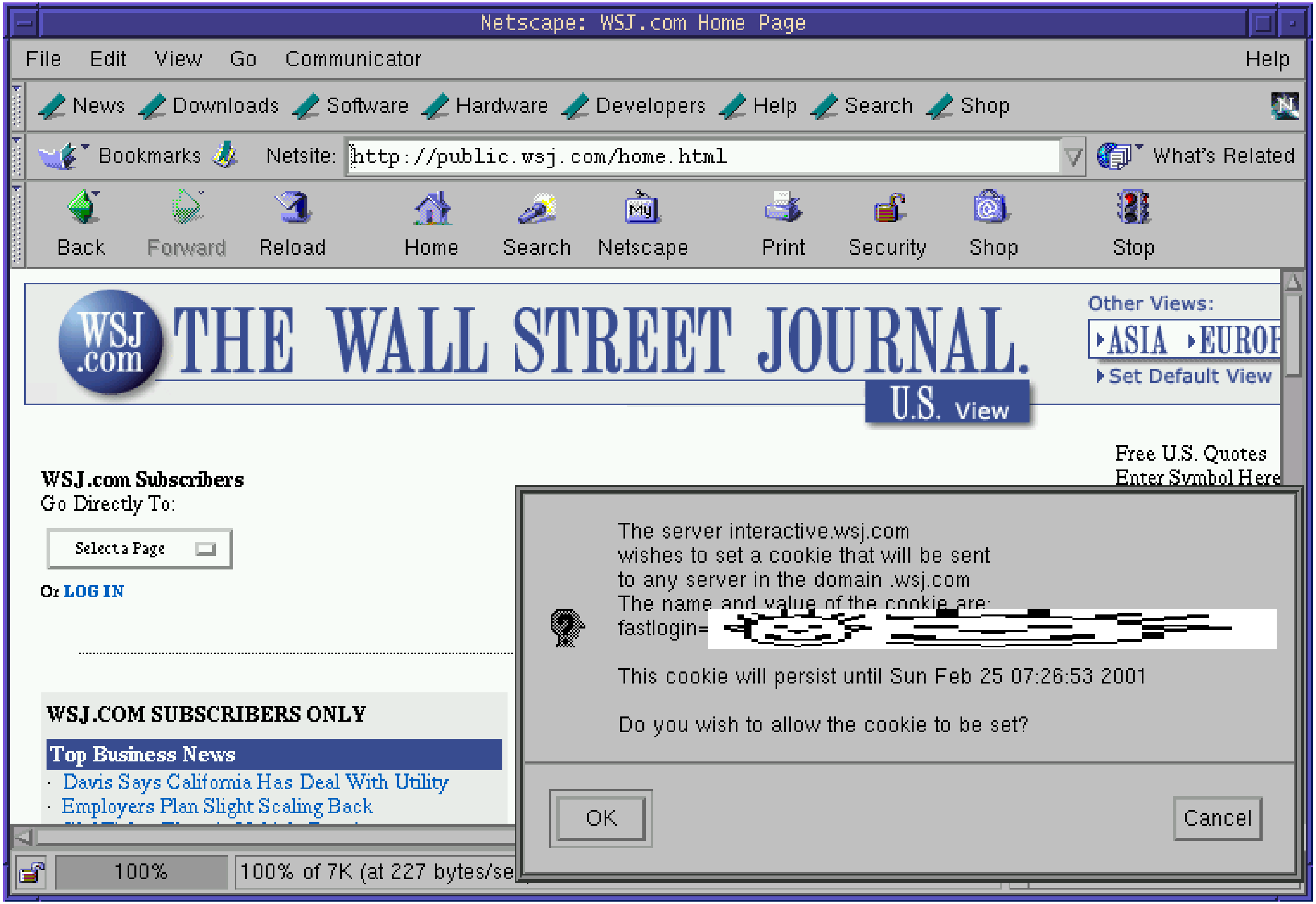
Target: https://www.fatbrain.com/HelpAccount.asp?
t=0&p1=nobob@mit.edu&p2=540555752

Predictable sequence numbers

- Site: FatBrain.com
- Problem: Customer can determine the authenticator for any other user
- Adversary: Interrogative
- Break: Selective forgery
- Today: Acquired by Barnes & Noble

FatBrain response

“It’s 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. :)”



http://public.wsj.com/home.html

WSJ.com Subscribers
Go Directly To:

Or **LOG IN**

WSJ.COM SUBSCRIBERS ONLY

Top Business News

- Davis Says California Has Deal With Utility
- Employers Plan Slight Scaling Back

100% of 7K (at 227 bytes/se

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 login process

- User enters name and password
- If the password is correct, WSJ.com issues a cookie
- User surfs to restricted content and attaches cookie
- If the cookie is authentic, WSJ.com returns content

WSJ.com analysis

- Design: cookie = $\{$user, $\mathtt{MAC}_{\mathtt{k}}$ (user)$\}$
- Reality: cookie =

  user + UNIX-crypt (user + server secret)

WSJ.com analysis cont.

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

- Usernames matching first 8 characters have same authenticator
- No expiration

Obtaining the server secret?

- Adaptive chosen message attack
- Perl script queried WSJ with invalid cookies
- Runs in max $\mathbf{128} \times \mathbf{8}$ queries rather than intended $\mathbf{128^8}$ (1024 vs. 72057594037927936)
- 1 sec/query yields 17 minutes vs. $\mathbf{10^9}$ years
- The key is “March20”

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
A	bitdidd	bitdiddA	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
B	bitdidd	bitdiddB	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
C	bitdidd	bitdiddC	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
D	bitdidd	bitdiddD	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
E	bitdidd	bitdiddE	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
F	bitdidd	bitdiddF	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
G	bitdidd	bitdiddG	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
H	bitdidd	bitdiddH	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
I	bitdidd	bitdiddI	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
J	bitdidd	bitdiddJ	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
K	bitdidd	bitdiddK	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✓
L	bitdidd	bitdiddL	✗

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MA	bitdid	bitdidMA	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MB	bitdid	bitdidMB	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MC	bitdid	bitdidMC	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MD	bitdid	bitdidMD	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
ME	bitdid	bitdidME	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MF	bitdid	bitdidMF	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MG	bitdid	bitdidMG	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MH	bitdid	bitdidMH	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MI	bitdid	bitdidMI	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MJ	bitdid	bitdidMJ	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
MK	bitdid	bitdidMK	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
ML	bitdid	bitdidML	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✓
M	bitdidd	bitdiddM	✓
Ma	bitdid	bitdidMa	✓

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✓
M	bitdidd	bitdiddM	✓
Ma	bitdid	bitdidMa	✓
MaA	bitdi	bitdiMaA	✗

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✓
M	bitdidd	bitdiddM	✓
Ma	bitdid	bitdidMa	✓
Mar	bitdi	bitdiMar	✓

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
Ma	bitdid	bitdidMa	✔
Mar	bitdi	bitdiMar	✔
Marb	bitd	bitdMarb	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
Ma	bitdid	bitdidMa	✔
Mar	bitdi	bitdiMar	✔
Marc	bitd	bitdMarc	✔

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
Ma	bitdid	bitdidMa	✔
Mar	bitdi	bitdiMar	✔
Marc	bitd	bitdMarc	✔
Marcg	bit	bitMarcg	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
Ma	bitdid	bitdidMa	✔
Mar	bitdi	bitdiMar	✔
Marc	bitd	bitdMarc	✔
March	bit	bitMarch	✔

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
Ma	bitdid	bitdidMa	✔
Mar	bitdi	bitdiMar	✔
Marc	bitd	bitdMarc	✔
March	bit	bitMarch	✔
March1	bi	biMarch1	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✓
M	bitdidd	bitdiddM	✓
Ma	bitdid	bitdidMa	✓
Mar	bitdi	bitdiMar	✓
Marc	bitd	bitdMarc	✓
March	bit	bitMarch	✓
March2	bi	biMarch2	✓

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
Ma	bitdid	bitdidMa	✔
Mar	bitdi	bitdiMar	✔
Marc	bitd	bitdMarc	✔
March	bit	bitMarch	✔
March2	bi	biMarch2	✔
March2/	b	bMarch2/	✘

How our attack works

Secret guess	username	crypt input	worked?
	bitdiddl	bitdiddl	✔
M	bitdidd	bitdiddM	✔
Ma	bitdid	bitdidMa	✔
Mar	bitdi	bitdiMar	✔
Marc	bitd	bitdMarc	✔
March	bit	bitMarch	✔
March2	bi	biMarch2	✔
March20	b	bMarch20	✔

Misuse of cryptography

- Site: WSJ.com
- Problem: Weaker than plaintext passwords
- Adversary: Interrogative
- Break: Universal forgery
- Today: The token got longer...

“... 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.”

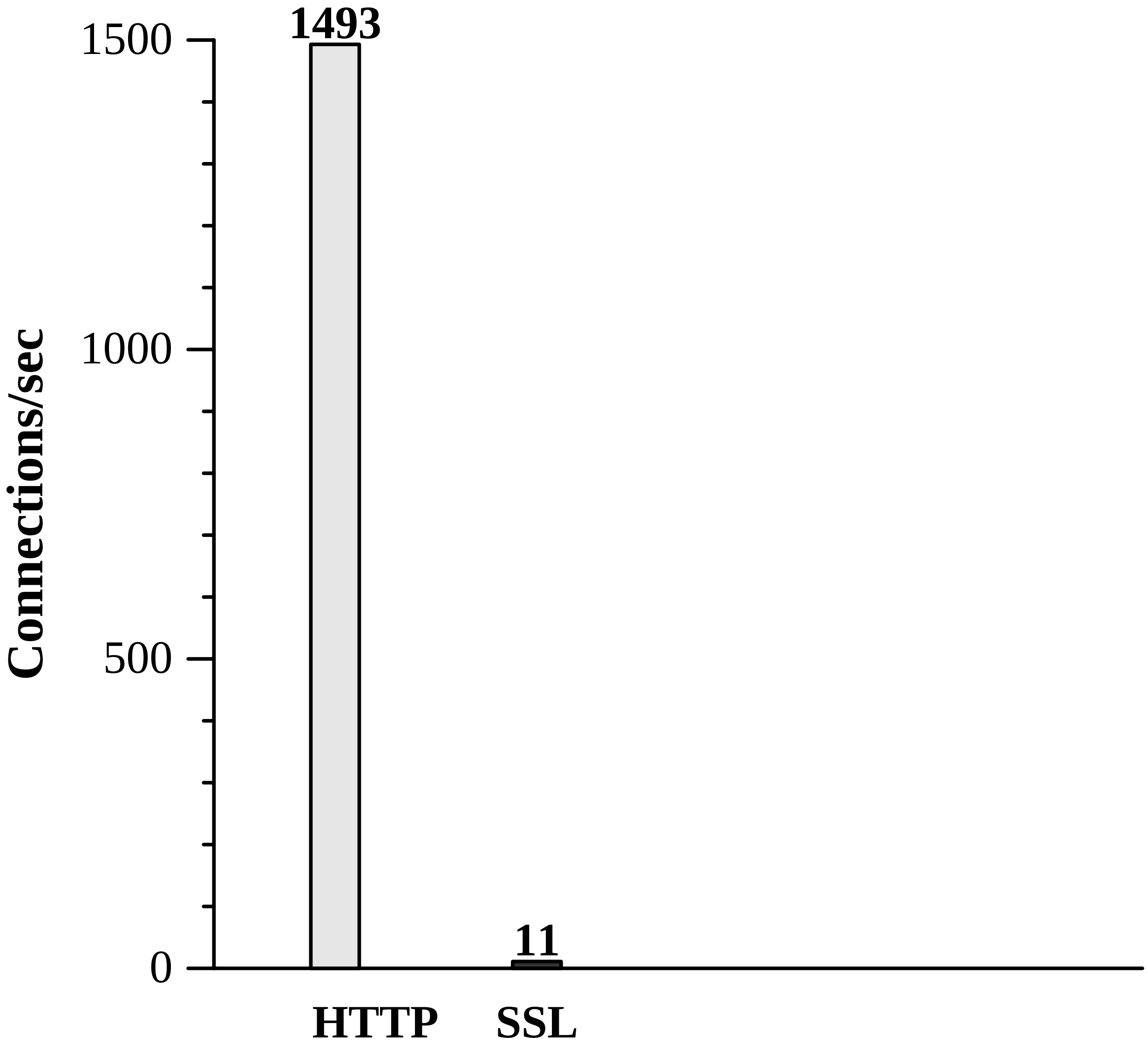
— Javeh Saleh, Vice President, Technology

Interactive Business Technology Services, WSJ.com

Why cookies?

- SSL is computationally expensive
- No one outside enterprises uses SSL client certificates
- Browsers offer an inflexible GUI for HTTP authentication
- Popular browsers implement cookies

HTTPS vs. HTTP handshake cost



How did we break these schemes?

- Gathered public information
  - Observe usernames and Web server HTTP responses
  - Obtain sample authenticators
  - Create guest accounts
- Observe authenticators while varying parameters
- No eavesdropping

Hints for client authentication

- Limit the lifetime of authenticators
- Make authenticators unforgeable
- Sign what you mean

Limit the lifetime of authenticators

- Browsers cannot be trusted to expire cookies
- No revocation of WSJ cookies

Make authenticators unforgeable

- Prevent modification of the cookie
- Do not allow bypass of password authentication
- Encryption alone does not prevent forgery
- HighSchoolAlumni.com

Sign what you mean!

- badauth = sign (username + expiration, key)
  - (Alice, 21-Apr-2001)

    → sign (Alice21-Apr-2001, key)
  - (Alice2, 1-Apr-2001)

    → sign (Alice21-Apr-2001, key)
- Same authenticator!
- Use unambiguous representation or delimiters

A scheme that mostly works

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

where `MAC` could be HMAC-SHA1,
`capa` could be an encrypted capability,
`expire` represents an encrypted expiration, and
’$+$’ denotes concatenation with a delimiter

Secure against interrogative adversary

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Secure against interrogative adversary

Still missing: A policy language for the capability

The interrogative adversary defeats...

- SSL client authentication? No.
- HTTP Basic or Digest authentication? No.
- Homebrew cookie authentication schemes? Often...

Vulnerability disclosure

- Vulnerability reporting is 1% technical analysis and 99% proper handling of disclosure.
- Report the bug to the vendor first. Then ask how long they need.
- There are release cycles and QA testing procedures. Be patient.
- Most companies are reasonable.
- If you are nice, you might get a free T-shirt. :-)

Summary

- Many schemes broken easily by the interrogative adversary
- Hints could prevent vulnerabilities
- There is a simple scheme that works
- Cookies are limited; live with it or move on

What this talk was really about

- Improving the security of client authentication on the Web
- Why the Wall Street Journal Interactive Web site sent me a free sweatshirt

Group formation