CSci 5271
Introduction to Computer Security
Day 24: Anonymizing the network

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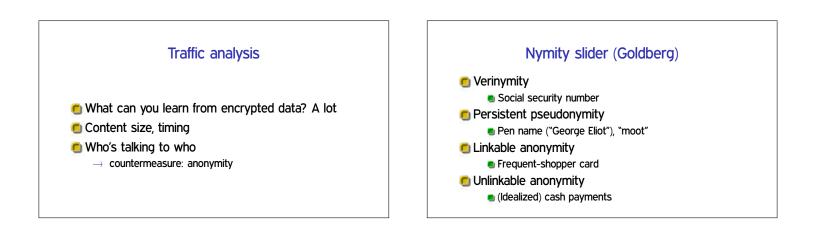
Outline

Anonymous communications techniques

Announcements intermission

Tor basics

Tor experiences and challenges

Traffic analysis

- What can you learn from encrypted data? A lot
- Content size, timing
- Who's talking to who
  - → countermeasure: anonymity

Nymity slider (Goldberg)

- Verinymity
  - Social security number
- Persistent pseudonymity
  - Pen name ("George Eliot"), "moot"
- Linkable anonymity
  - Frequent-shopper card
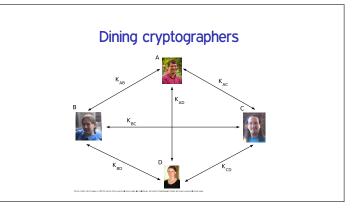- Unlinkable anonymity
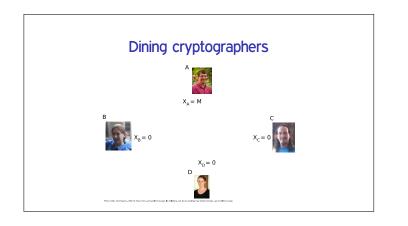 - (Idealized) cash payments

Nymity ratchet?

- It's easy to add names on top of an anonymous protocol
- The opposite direction is harder
- But, we're stuck with the Internet as is
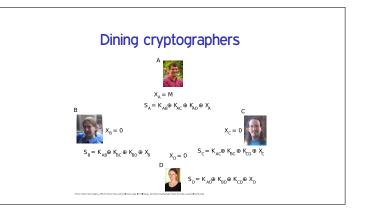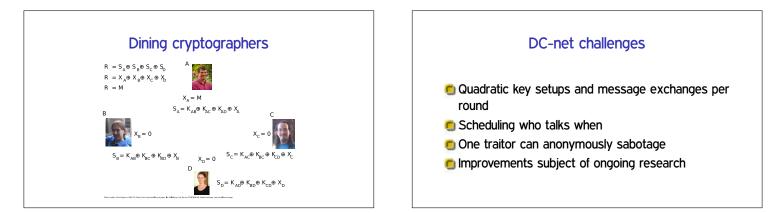- So, add anonymity to conceal underlying identities

Steganography

- One approach: hide real content within bland-looking cover traffic
- Classic: hide data in least-significant bits of images
- Easy to fool casual inspection, hard if adversary knows the scheme

Dining cryptographers

Dining cryptographers

Dining cryptographers

A

$X_A = M$

B

$X_B = 0$

C

$X_C = 0$

$X_D = 0$

D

Dining cryptographers

A

$X_A = M$
$S_A = K_{AB} \oplus K_{AC} \oplus K_{AD} \oplus X_A$

B

$X_B = 0$

C

$X_C = 0$

$S_B = K_{AB} \oplus K_{BC} \oplus K_{BD} \oplus X_B$ $X_D = 0$ $S_C = K_{AC} \oplus K_{BC} \oplus K_{CD} \oplus X_C$

D

$S_D = K_{AD} \oplus K_{BD} \oplus K_{CD} \oplus X_D$

Dining cryptographers

$R = S_A \oplus S_B \oplus S_C \oplus S_D$
$R = X_A \oplus X_B \oplus X_C \oplus X_D$
$R = M$

A

$X_A = M$
$S_A = K_{AB} \oplus K_{AC} \oplus K_{AD} \oplus X_A$

B

$X_B = 0$

C

$X_C = 0$

$S_B = K_{AB} \oplus K_{BC} \oplus K_{BD} \oplus X_B$ $X_D = 0$ $S_C = K_{AC} \oplus K_{BC} \oplus K_{CD} \oplus X_C$

D

$S_D = K_{AD} \oplus K_{BD} \oplus K_{CD} \oplus X_D$

DC-net challenges

- Quadratic key setups and message exchanges per round
- Scheduling who talks when
- One traitor can anonymously sabotage
- Improvements subject of ongoing research

Mixing/shuffling

- Computer analogue of shaking a ballot box, etc.
- Reorder encrypted messages by a random permutation
- Building block in larger protocols
- Distributed and verifiable variants possible as well

Anonymous remailers

- Anonymizing intermediaries for email
  - First cuts had single points of failure
- Mix and forward messages after receiving a sufficiently-large batch
- Chain together mixes with multiple layers of encryption
- Fancy systems didn't get critical mass of users

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Hands-on assignment, type 2

- The one hands-on assignment this semester will on network and web security
  - Like previous "HA2"
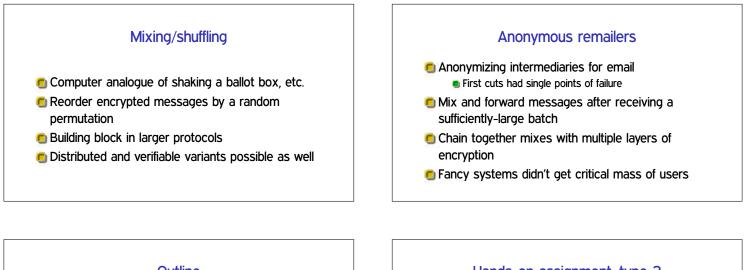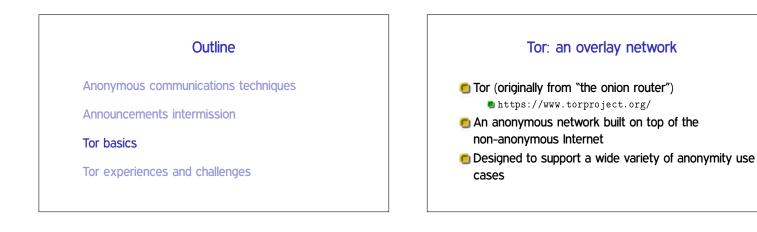- Instructions PDF now available

Hands-on assignment VMs

- Location of attacks, not ready yet
- Email a list of your group members to the TAs to register
- We will send login information when your VM is ready
- Due date of Monday the 13th based on VMs being ready by Monday

HA questions

1. Network sniffing
2. Offline dictionary attack
3. Forging predictable cookies
4. SQL injection
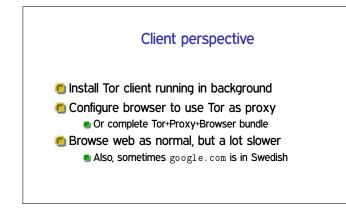5. Cross-site scripting
6. Crypto. attack against a poor MAC

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Tor: an overlay network

- Tor (originally from "the onion router")
    - `https://www.torproject.org/`
- An anonymous network built on top of the non-anonymous Internet
- Designed to support a wide variety of anonymity use cases
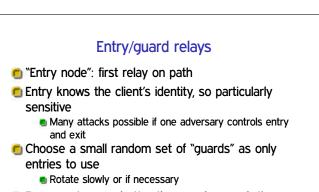
Low-latency TCP applications

- Tor works by proxying TCP streams
    - (And DNS lookups)
- Focuses on achieving interactive latency
    - WWW, but potentially also chat, SSH, etc.
    - Anonymity tradeoffs compared to remailers

Tor Onion routing

- Stream from sender to D forwarded via A, B, and C
    - One Tor circuit made of four TCP hops
- Encrypt packets (512-byte "cells") as $E_A(B, E_B(C, E_C(D, P)))$
- TLS-like hybrid encryption with "telescoping" path setup

Client perspective

- Install Tor client running in background
- Configure browser to use Tor as proxy
    - Or complete Tor+Proxy+Browser bundle
- Browse web as normal, but a lot slower
    - Also, sometimes `google.com` is in Swedish

Entry/guard relays

- "Entry node": first relay on path
- Entry knows the client's identity, so particularly sensitive
    - Many attacks possible if one adversary controls entry and exit
- Choose a small random set of "guards" as only entries to use
    - Rotate slowly or if necessary
- For repeat users, better than random each time

Exit relays

- Forwards traffic to/from non-Tor destination
- Focal point for anti-abuse policies
    - E.g., no exits will forward for port 25 (email sending)
- Can see plaintext traffic, so danger of sniffing, MITM, etc.

Centralized directory

- How to find relays in the first place?
- Straightforward current approach: central directory servers
- Relay information includes bandwidth, exit polices, public keys, etc.
- Replicated, but potential bottleneck for scalability and blocking

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Anonymity loves company

- Diverse user pool needed for anonymity to be meaningful
    - Hypothetical Department of Defense Anonymity Network
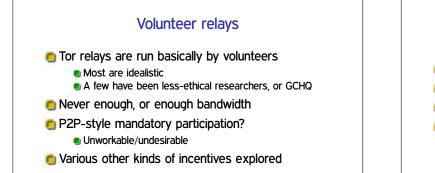- Tor aims to be helpful to a broad range of (sympathetic sounding) potential users

Who (arguably) needs Tor?

- Consumers concerned about web tracking
- Businesses doing research on the competition
- Citizens of countries with Internet censorship
- Reporters protecting their sources
- Law enforcement investigating targets

Tor and the US government

- Onion routing research started with the US Navy
- Academic research still supported by NSF
- Anti-censorship work supported by the State Department
    - Same branch as Voice of America
- But also targeted by the NSA
    - Per Snowden, so far only limited success

Volunteer relays

- Tor relays are run basically by volunteers
    - Most are idealistic
    - A few have been less-ethical researchers, or GCHQ
- Never enough, or enough bandwidth
- P2P-style mandatory participation?
    - Unworkable/undesirable
- Various other kinds of incentives explored

Performance

- Increased latency from long paths
- Bandwidth limited by relays
- Recently 1-2 sec for 50KB, 3-7 sec for 1MB
- Historically worse for many periods
    - Flooding (guessed botnet) fall 2013

Anti-censorship

- As a web proxy, Tor is useful for getting around blocking
- Unless Tor itself is blocked, as it often is
- *Bridges* are special less-public entry points
- Also, protocol obfuscation arms race (uneven)

Hidden services

- Tor can be used by servers as well as clients
- Identified by cryptographic key, use special rendezvous protocol
- Servers often present easier attack surface

Undesirable users

- P2P filesharing
  - Discouraged by Tor developers, to little effect
- Terrorists
  - At least the NSA thinks so
- Illicit e-commerce
  - "Silk Road" and its successors

Intersection attacks

- Suppose you use Tor to update a pseudonymous blog, reveal you live in Minneapolis
- Comcast can tell who in the city was sending to Tor at the moment you post an entry
  - Anonymity set of 1000 → reasonable protection
- But if you keep posting, adversary can keep narrowing down the set

Exit sniffing

- Easy mistake to make: log in to an HTTP web site over Tor
- A malicious exit node could now steal your password
- Another reason to always use HTTPS for logins

Browser bundle JS attack

- Tor's Browser Bundle disables many features try to stop tracking
- But, JavaScript defaults to on
  - Usability for non-expert users
  - Fingerprinting via NoScript settings
- Was incompatible with Firefox auto-updating
- Many Tor users de-anonymized in August 2013 by JS vulnerability patched in June

Traffic confirmation attacks

- If the same entity controls both guard and exit on a circuit, many attacks can link the two connections
  - "Traffic confirmation attack"
  - Can't directly compare payload data, since it is encrypted
- Standard approach: insert and observe delays
- Protocol bug until recently: covert channel in hidden service lookup

Hidden service traffic conf.

- Bug allowed signal to guard when user looked up a hidden service
  - Non-statistical traffic confirmation
- For 5 months in 2014, 115 guard nodes (about 6%) participated in this attack
  - Apparently researchers at CMU's SEI/CERT
- Beyond "research," they also gave/sold info. to the FBI
  - Apparently used in Silk Road 2.0 prosecution, etc.

Next time

- How usability affects security