CSE 484 / CSE M 584: Computer Security and Privacy

Anonymity

Spring 2020

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Thanks to Dan Boneh, Dieter Gollmann, Dan Halperin, Yoshi Kohno, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Admin

- **Lab #2:** Due today!
  - Please make sure UW Net IDs included in writeup
- **Homework #3:** Due next Friday (5/29)
- **Final Project Checkpoint #2:** Due next Friday (5/29)
  - Working outline and list of references
- Next week:
  - No class on Monday (Memorial Day)
  - Guest lecture on Wednesday: Steve Bellovin, "30 Years of Defending the Internet"

"On the Internet, nobody knows you're a dog."

The New Yorker, 1993

Privacy on Public Networks

SSL

- Internet is designed as a public network
  - Machines on your LAN may see your traffic, network routers see all traffic that passes through them
- Routing information is public
  - IP packet headers identify source and destination
  - Even a passive observer can figure out who is talking to whom
- Encryption does not hide identities
  - Encryption hides payload, but not routing information
  - Even IP-level encryption (tunnel-mode IPSec/ESP) reveals IP addresses of IPSec gateways
- Modern web: Accounts, web tracking, etc. …

Questions

Q1: What is anonymity?

- don't know who I am (identity)
- characteristics about me (group etc.)
- link between identity & action

Q2: Why might people **want** anonymity on the Internet?

- protection vs. persecution (e.g., by gov't, other people)
- protect vulnerable groups

Q3: Why might people **not want** anonymity on the Internet?

- identity theft - hard to prove self / authenticate
- crime
- bad behavior - harassment

What is Anonymity?

- Anonymity is the state of being not identifiable within a set of subjects
  - You cannot be anonymous by yourself!
    - Big difference between anonymity and confidentiality
  - Hide your activities among others' similar activities
- Unlinkability of action and identity
  - For example, sender and email he/she sends are no more related after observing communication than before
- Unobservability (hard to achieve)
  - Observer cannot even tell whether a certain action took place or not

Applications of Anonymity (I)

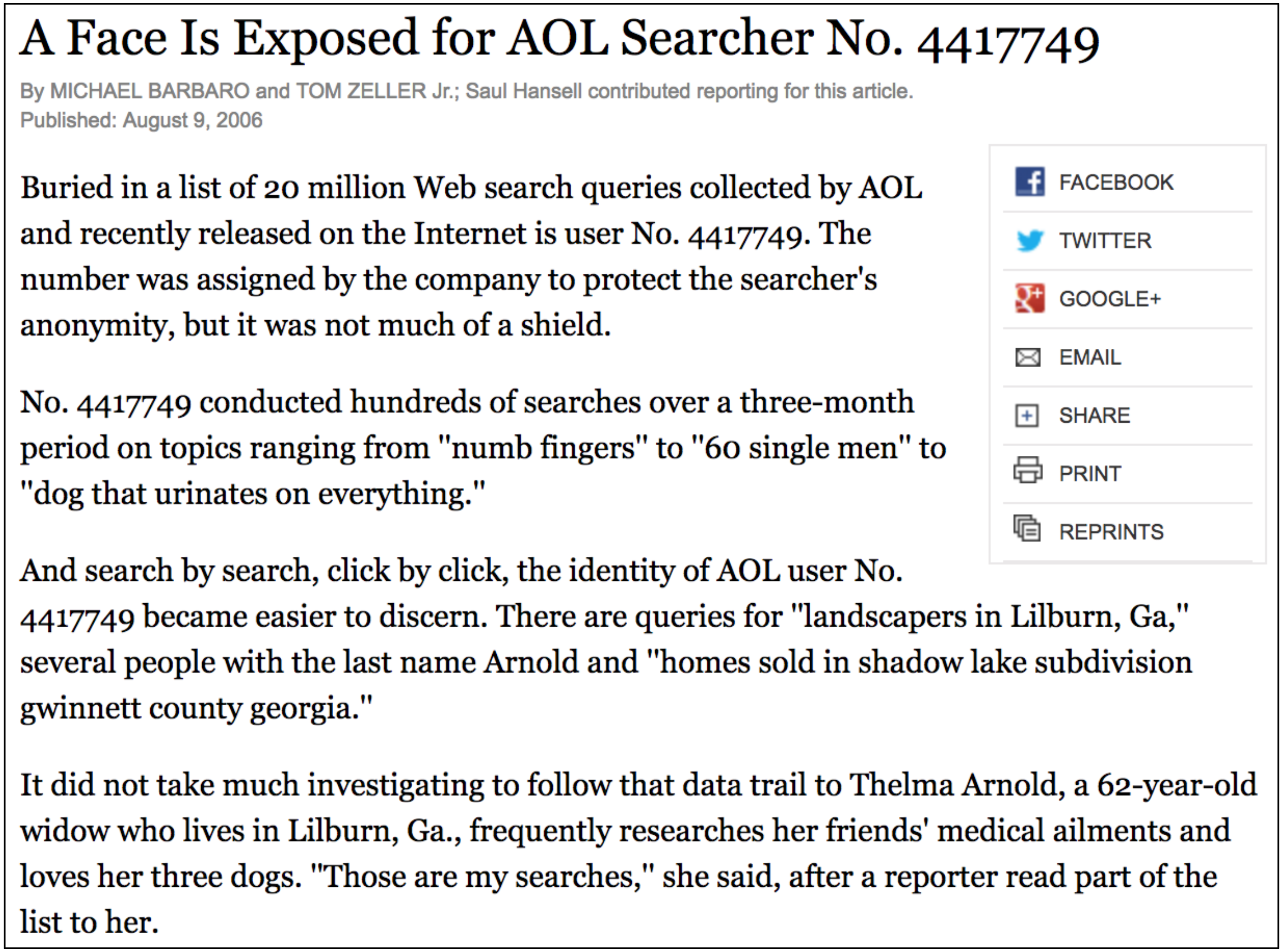
- Privacy
  - Hide online transactions, Web browsing, etc. from intrusive governments, marketers and archivists
- Untraceable electronic mail
  - Corporate whistle-blowers
  - Political dissidents
  - Socially sensitive communications (online AA meeting)
  - Confidential business negotiations
- Law enforcement and intelligence
  - Sting operations and honeypots
  - Secret communications on a public network

Applications of Anonymity (II)

- Digital cash
  - Electronic currency with properties of paper money (online purchases unlinkable to buyer’s identity)
- Anonymous electronic voting
- Censorship-resistant publishing

Part 1: Anonymity in Datasets

How to release an anonymous dataset?



A Face Is Exposed for AOL Searcher No. 4417749

By MICHAEL BARBARO and TOM ZELLER Jr.; Saul Hansell contributed reporting for this article.
Published: August 9, 2006

Buried in a list of 20 million Web search queries collected by AOL and recently released on the Internet is user No. 4417749. The number was assigned by the company to protect the searcher's anonymity, but it was not much of a shield.

No. 4417749 conducted hundreds of searches over a three-month period on topics ranging from "numb fingers" to "60 single men" to "dog that urinates on everything."

And search by search, click by click, the identity of AOL user No. 4417749 became easier to discern. There are queries for "landscapers in Lilburn, Ga," several people with the last name Arnold and "homes sold in shadow lake subdivision gwinnett county georgia."

It did not take much investigating to follow that data trail to Thelma Arnold, a 62-year-old widow who lives in Lilburn, Ga., frequently researches her friends' medical ailments and loves her three dogs. "Those are my searches," she said, after a reporter read part of the list to her.

How to release an anonymous dataset?

- Possible approach: remove identifying information from datasets?

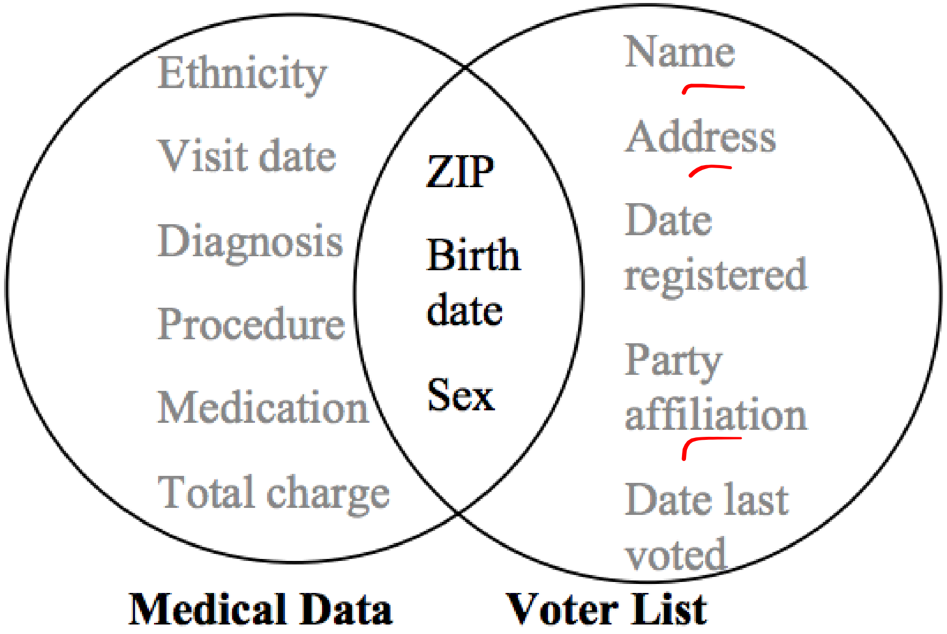


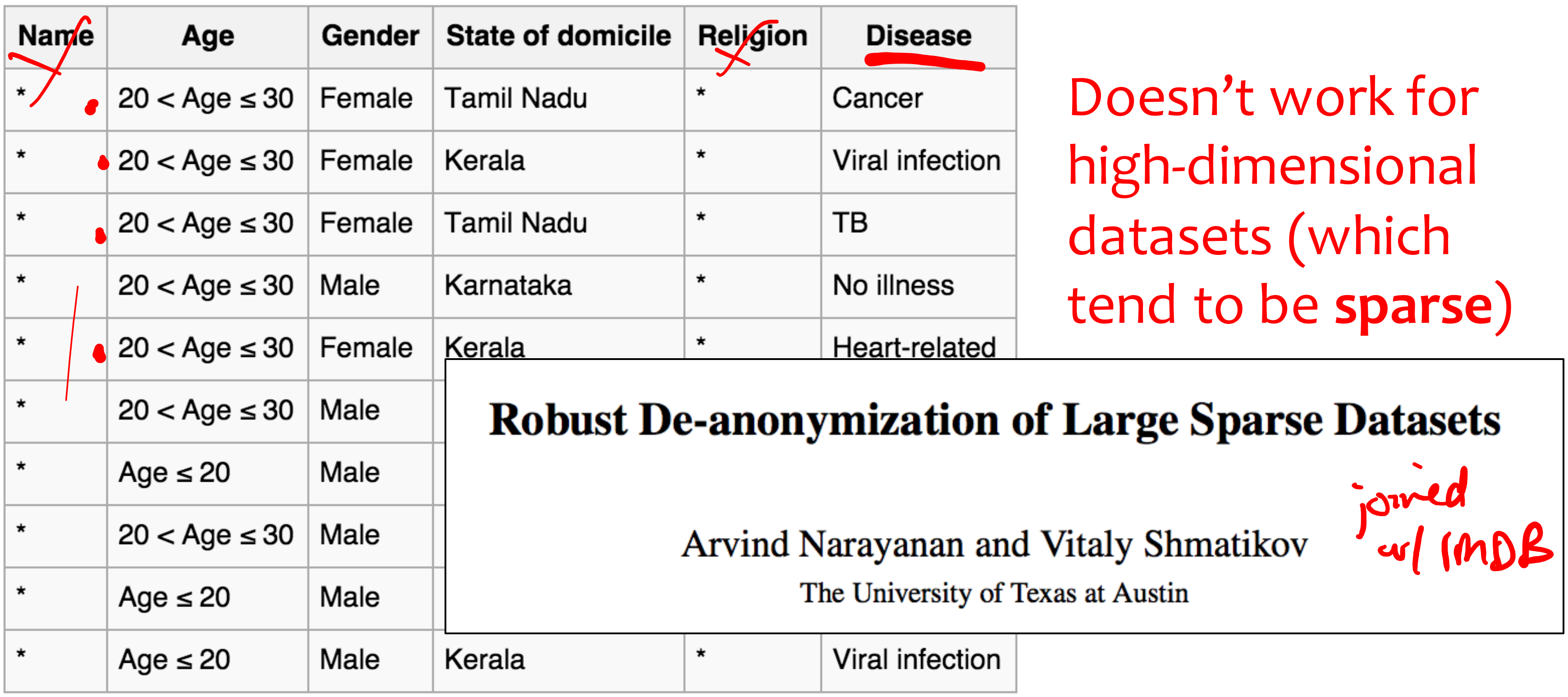
Figure 1 Linking to re-identify data

Massachusetts medical+voter data [Sweeney 1997]

[Sweeney 1998]

k-Anonymity

- Each person contained in the dataset cannot be distinguished from at least k-1 others in the data.



Name	Age	Gender	State of domicile	Religion	Disease
*	20 < Age ≤ 30	Female	Tamil Nadu	*	Cancer
*	20 < Age ≤ 30	Female	Kerala	*	Viral infection
*	20 < Age ≤ 30	Female	Tamil Nadu	*	TB
*	20 < Age ≤ 30	Male	Karnataka	*	No illness
*	20 < Age ≤ 30	Female	Kerala	*	Heart-related
*	20 < Age ≤ 30	Male			
*	Age ≤ 20	Male			
*	20 < Age ≤ 30	Male			
*	Age ≤ 20	Male			
*	Age ≤ 20	Male	Kerala	*	Viral infection

Robust De-anonymization of Large Sparse Datasets

Arvind Narayanan and Vitaly Shmatikov
The University of Texas at Austin

joined w/ IMDB

Doesn't work for high-dimensional datasets (which tend to be **sparse**)

[Dwork et al.]

Differential Privacy

privacy budget

- **Setting:** Trusted party has a database
- **Goal:** allow queries on the database that are useful but preserve the privacy of individual records

Franzi

- **Differential privacy intuition:** add noise so that an output is produced with similar probability whether any single input is included or not
- Privacy of the computation, not of the dataset

Part 2: Anonymity in Communication

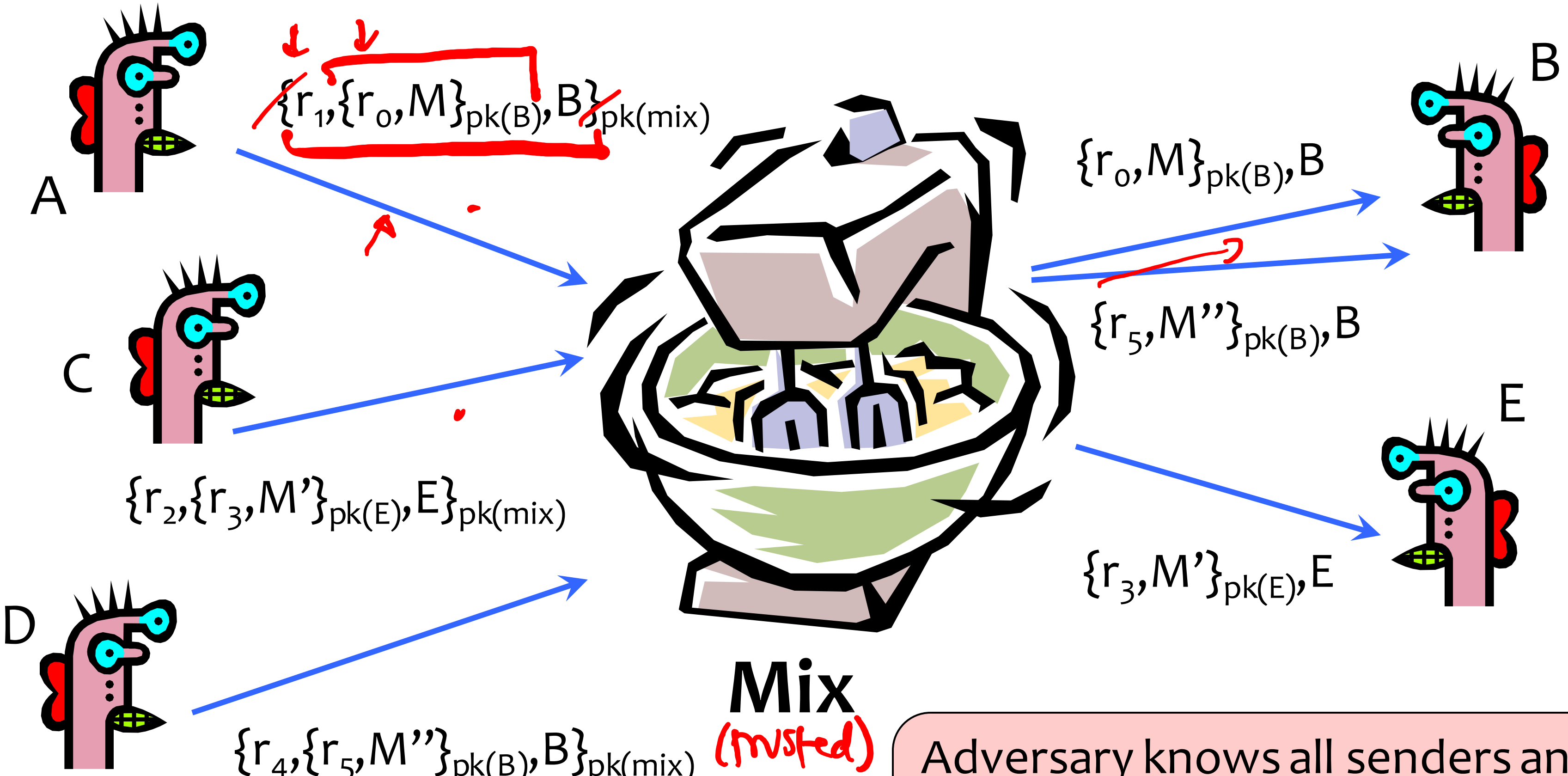
Chaum's Mix

- Early proposal for anonymous email
  - David Chaum. "Untraceable electronic mail, return addresses, and digital pseudonyms". Communications of the ACM, February 1981.

Before spam, people thought anonymous email was a good idea ☺

- Modern anonymity systems use Mix as the basic building block

Basic Mix Design



A

$\{r_1,\{r_0,M\}_{pk(B)},B\}_{pk(mix)}$

C

$\{r_2,\{r_3,M'\}_{pk(E)},E\}_{pk(mix)}$

D

$\{r_4,\{r_5,M''\}_{pk(B)},B\}_{pk(mix)}$

Mix

(trusted)

B

$\{r_0,M\}_{pk(B)},B$

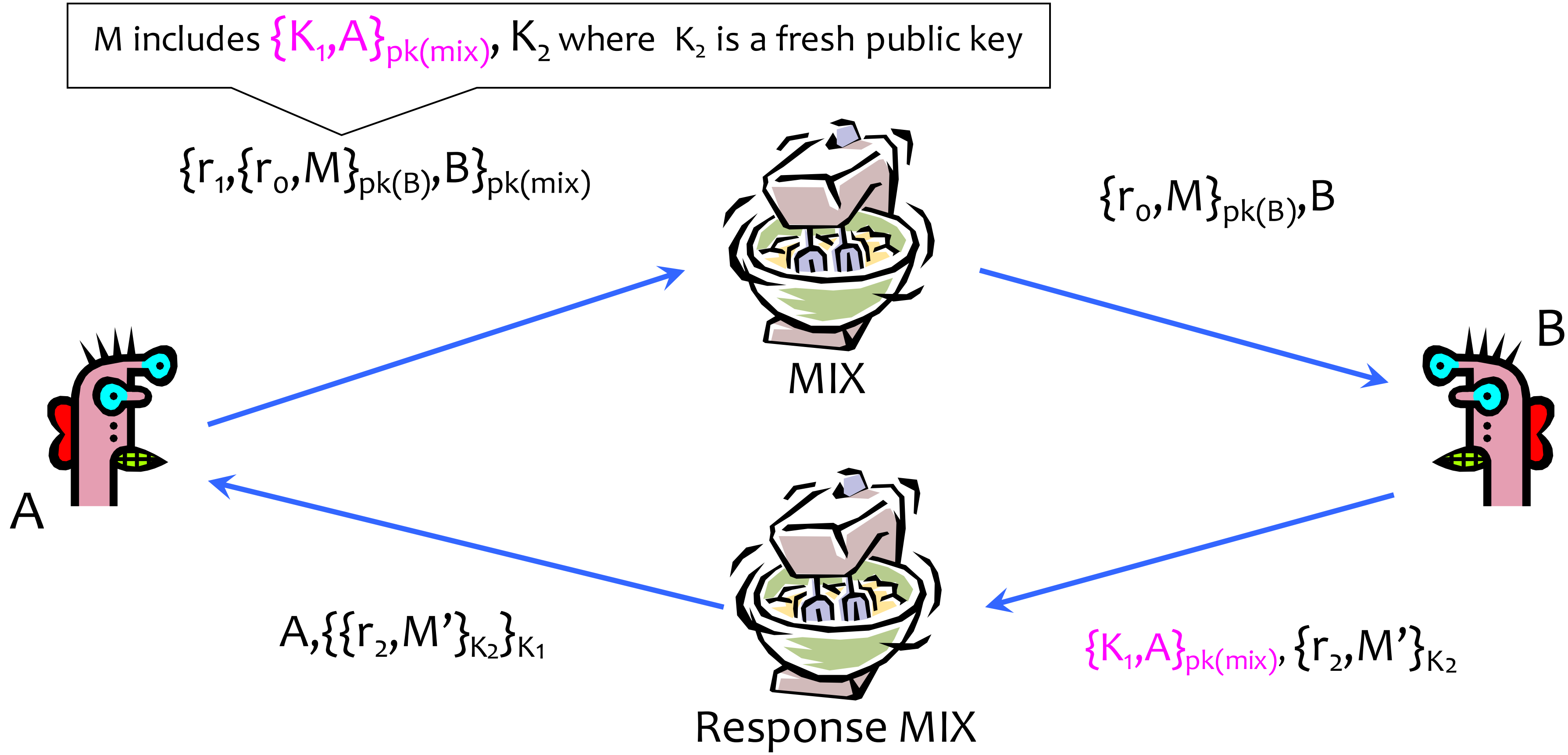
$\{r_5,M''\}_{pk(B)},B$

E

$\{r_3,M'\}_{pk(E)},E$

Adversary knows all senders and all receivers, but cannot link a sent message with a received message

Anonymous Return Addresses



M includes $\{K_1,A\}_{pk(mix)}$, K_2 where K_2 is a fresh public key

$\{r_1,\{r_0,M\}_{pk(B)},B\}_{pk(mix)}$

MIX

$\{r_0,M\}_{pk(B)},B$

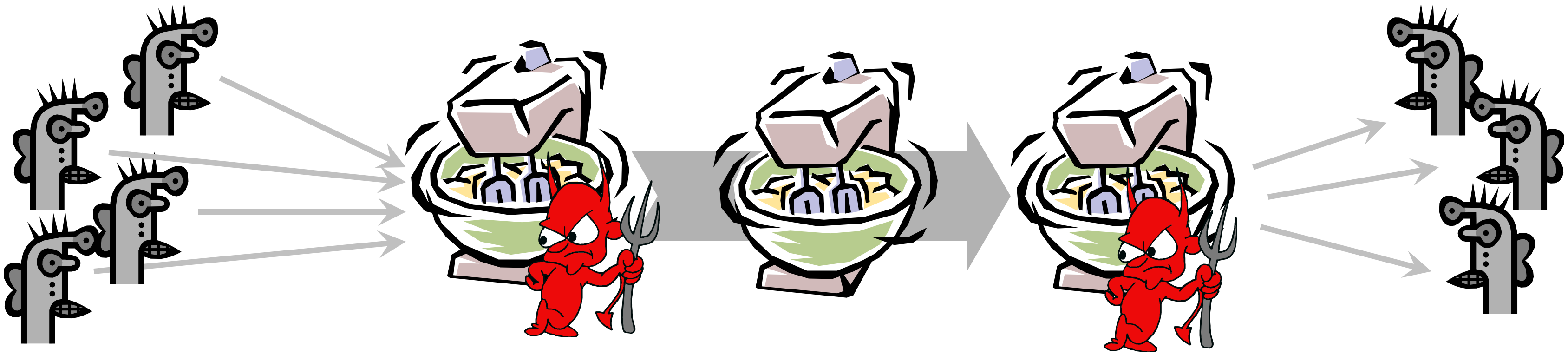
$A,\{\{r_2,M'\}_{K_2}\}_{K_1}$

Response MIX

$\{K_1,A\}_{pk(mix)}, \{r_2,M'\}_{K_2}$

Secrecy without authentication
(good for an online confession service ☺)

Mix Cascades and Mixnets



- Messages are sent through a sequence of mixes
  - Can also form an arbitrary network of mixes ("mixnet")
- Some of the mixes may be controlled by attacker, but even a single good mix ensures anonymity
- Pad and buffer traffic to foil correlation attacks

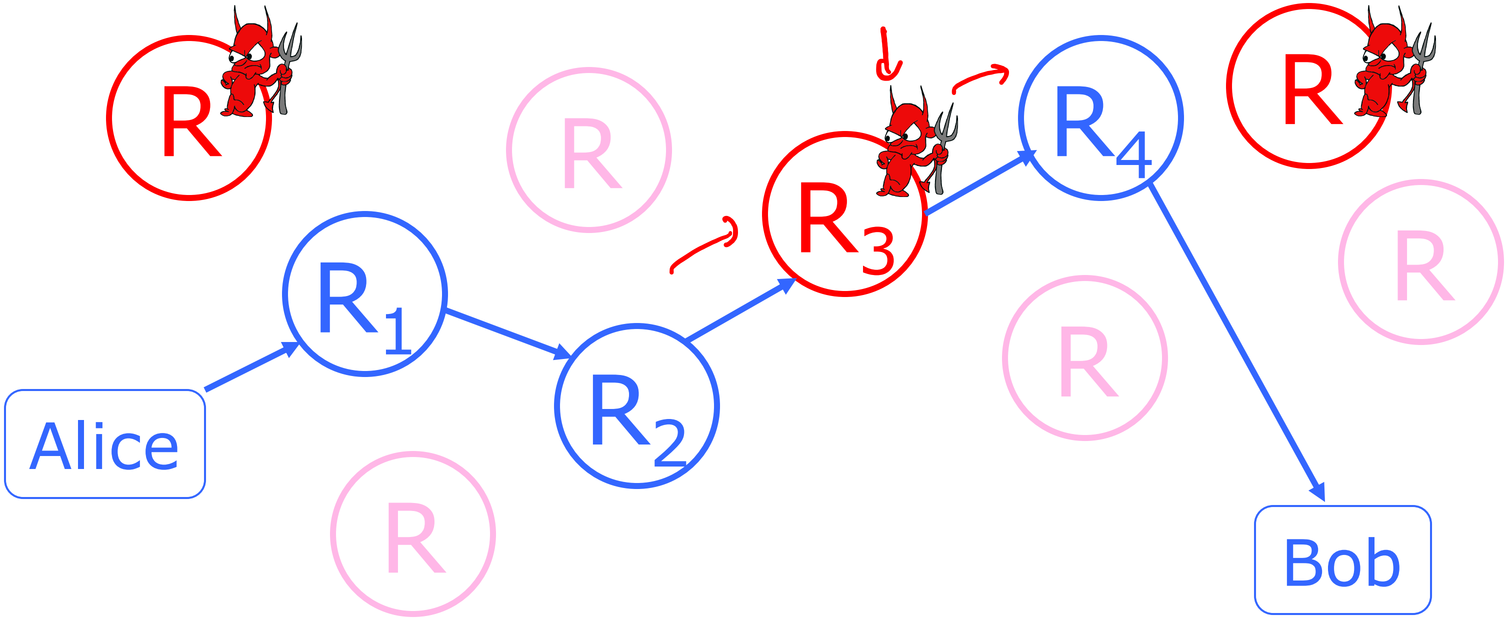
Disadvantages of Basic Mixnets

- Public-key encryption and decryption at each mix are **computationally expensive**
- Basic mixnets have **high latency**
  - OK for email, not OK for anonymous Web browsing
- Challenge: low-latency anonymity network

[Reed, Syverson, Goldschlag 1997]

Another Idea: Randomized Routing

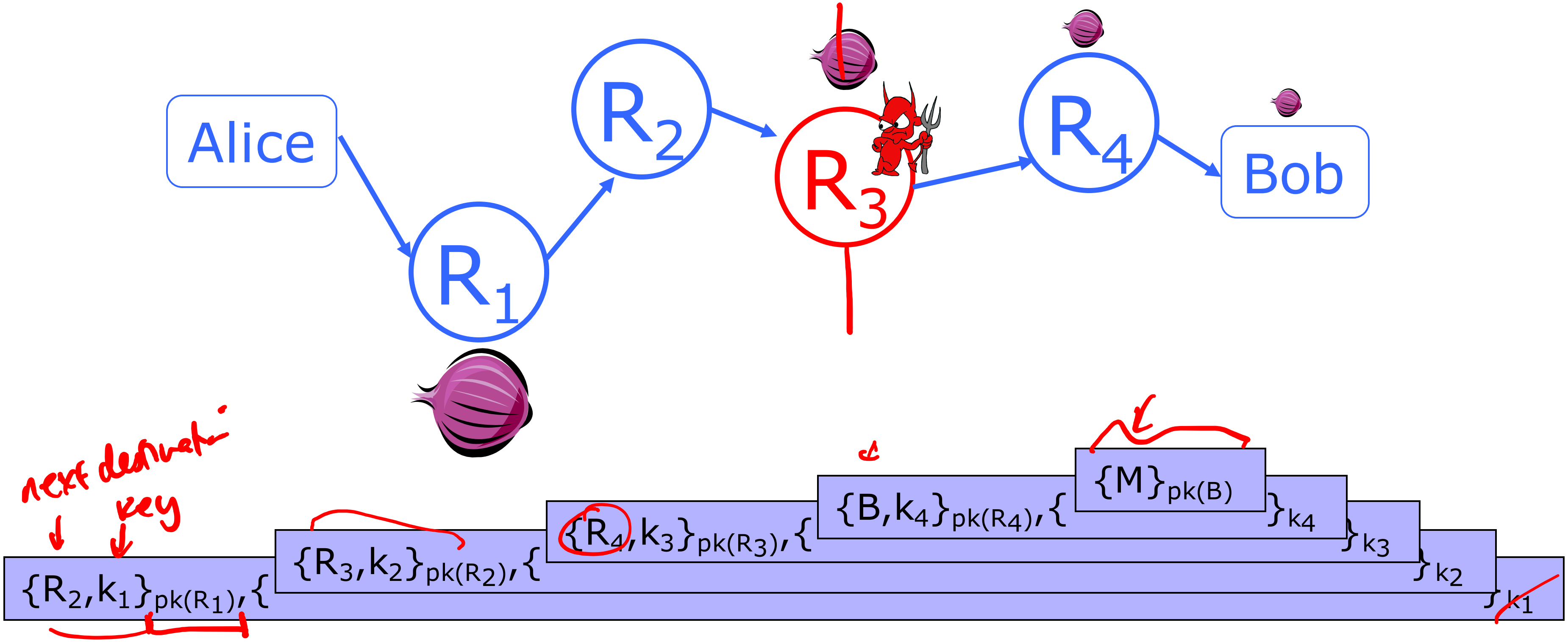
e.g., Onion Routing



- Sender chooses a random sequence of routers
  - Some routers are honest, some controlled by attacker
  - Sender controls the length of the path

TOR

Onion Routing



$$\{R_2,k_1\}_{pk(R_1)},\{\{R_3,k_2\}_{pk(R_2)},\{\{R_4,k_3\}_{pk(R_3)},\{\{B,k_4\}_{pk(R_4)},\{\{M\}_{pk(B)}\}_{k_4}\}_{k_3}\}_{k_2}\}_{k_1}$$

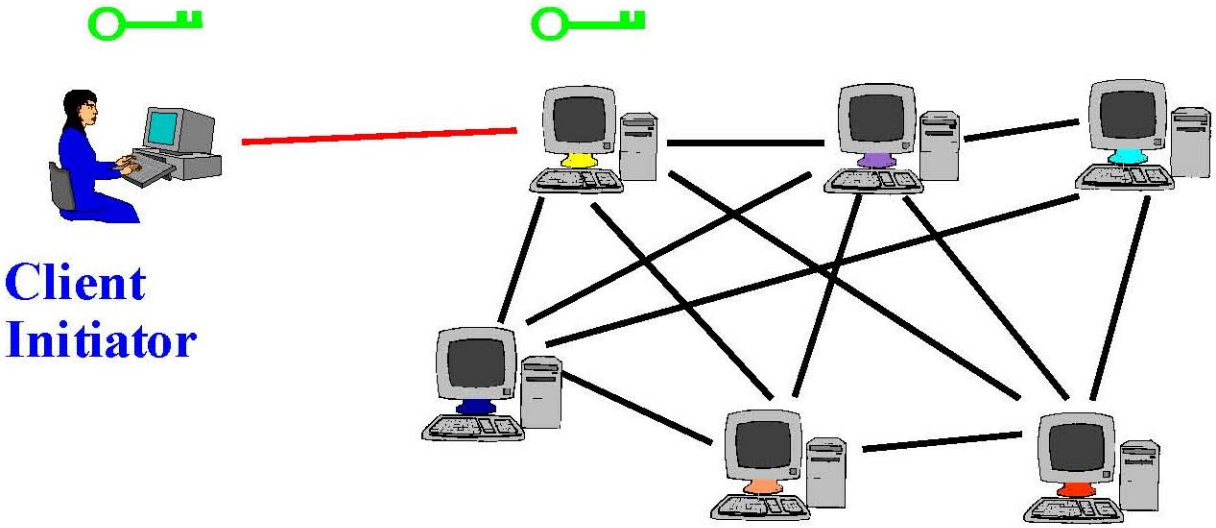
- Routing info for each link encrypted with router’s public key
- Each router learns only the identity of the next router

Tor

- Second-generation onion routing network
  - http://tor.eff.org
  - Developed by Roger Dingledine, Nick Mathewson and Paul Syverson
  - Specifically designed for low-latency anonymous Internet communications
- Running since October 2003
- "Easy-to-use" client proxy
  - Freely available, can use it for anonymous browsing

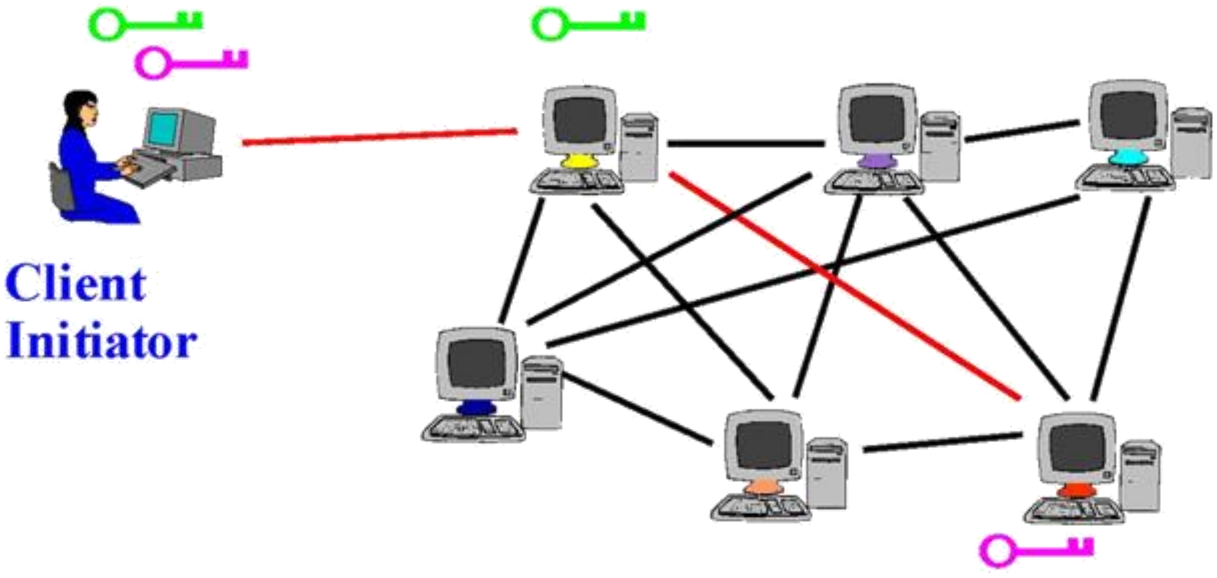
Tor Circuit Setup (1)

- Client proxy establishes a symmetric session key and circuit with Onion Router #1



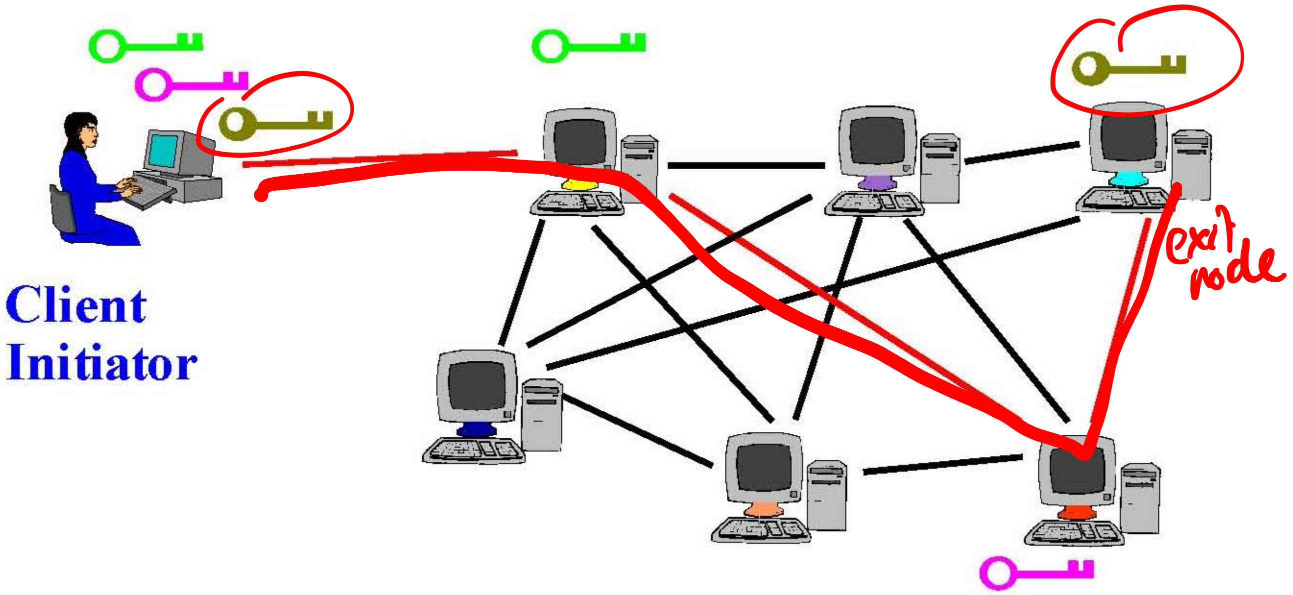
Tor Circuit Setup (2)

- Client proxy extends the circuit by establishing a symmetric session key with Onion Router #2
  - Tunnel through Onion Router #1



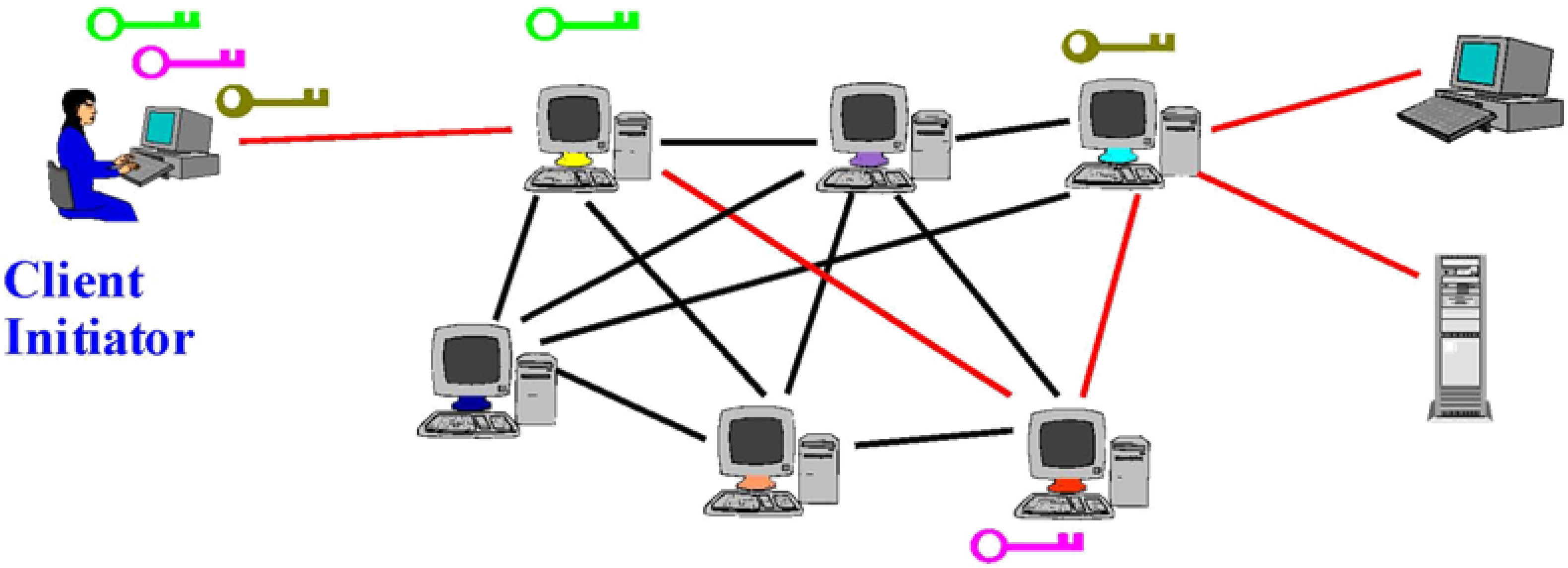
Tor Circuit Setup (3)

- Client proxy extends the circuit by establishing a symmetric session key with Onion Router #3
  - Tunnel through Onion Routers #1 and #2



Using a Tor Circuit

- Client applications connect and communicate over the established Tor circuit.



How do you know who to talk to?

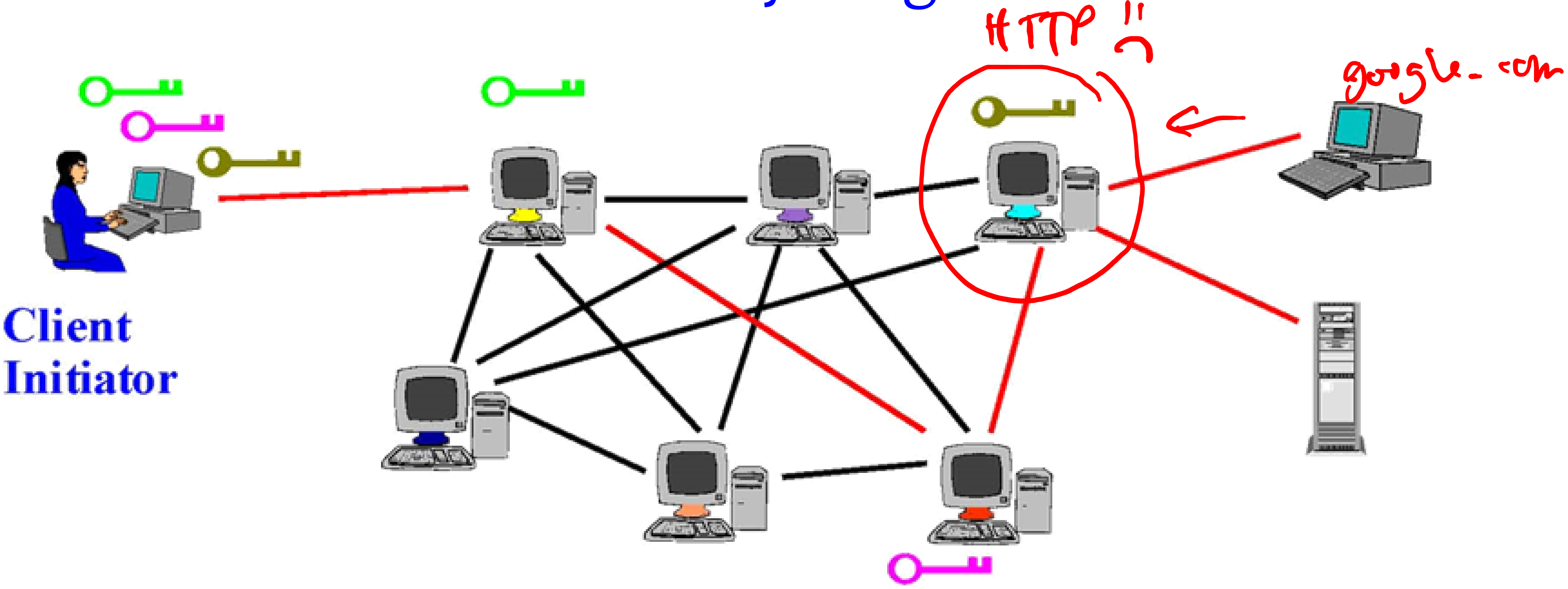
- Directory servers
  - Maintain lists of active onion routers, their locations, current public keys, etc.
  - Control how new routers join the network
    - "Sybil attack": attacker creates a large number of routers
  - Directory servers' keys ship with Tor code

Issues and Notes of Caution

- Passive traffic analysis
  - Infer from network traffic who is talking to whom
  - To hide your traffic, must carry other people’s traffic!
- Active traffic analysis
  - Inject packets or put a timing signature on packet flow
- Compromise of network nodes ←
  - Attacker may compromise some routers
    - Powerful adversaries may compromise “too many”
  - It is not obvious which nodes have been compromised
    - Attacker may be passively logging traffic
  - Better not to trust any individual router
    - Assume that some fraction of routers is good, don’t know which

Issues and Notes of Caution

- Tor isn't completely effective by itself
  - Tracking cookies, fingerprinting, etc.
  - Exit nodes can see everything!



Issues and Notes of Caution

- The simple act of using Tor could make one a target for additional surveillance
- Hosting an exit node could result in illegal activity coming from your machine