CSE 484: Computer Security and Privacy

# FP – pt2
# Anonymity

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David Kohlbrenner

dkohlbre@cs

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# Logistics

- Homework 3: Due today

- Final project:
  - Root cause analysis and patching ☺
  - Out now (part A)
  - **No late days on part C, recommend no late days on part B**

# RCA Strategies

- Read through the server code (see main.c to start)
  - You don't have to understand everything!
- Read through the sploit inputs and try to guess which parts of the tinyserv code might be related; start debugging there!
- Use gdb for debugging and execution tracing
  - `gdb –args ./tinyserv ./files`
  - `break [function name or line number]`
  - `run`
  - From another terminal window, you can now run the sploits
- (Maybe:) Modify main.c to test things out or add print statements

# Other Final Project Notes

- There is an additional cookie: the lab group secret key
  - This is NOT part of the lab, it is there to prevent accidentally interacting with other groups' servers
- You also don't need to dig into the socket-related code

# Turn-in (Group Submissions)

There are 5 Gradescope assignments:

- **Everyone submits to this one:**
  - Final Project Part A – Sploit1
- Submit to **ONE** of these, depending on which sploit you do:
  - Final Project Part B – Sploit3 Version
  - Final Project Part B – Sploit4 Version
- Submit to **ONE** of these, matching your part B:
  - Final Project Part C – Sploit3 Version
  - Final Project Part C – Sploit4 Version

# Anonymity

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

*The New Yorker,*
1993

# Privacy on Public Networks

- 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. …

# 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 they send 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

FACEBOOK
TWITTER
GOOGLE+
EMAIL
SHARE
PRINT
REPRINTS

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?

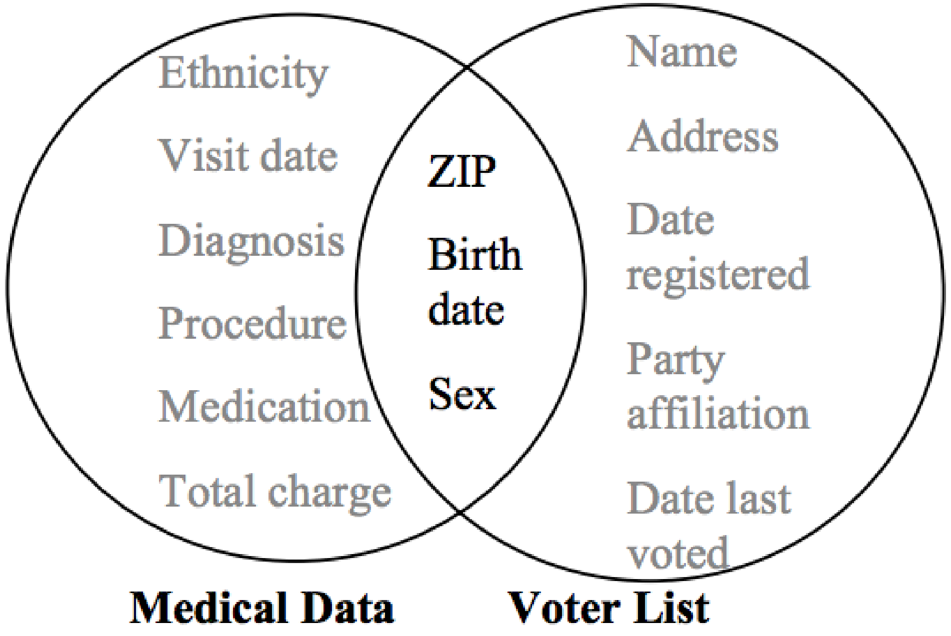


**Figure 1 Linking to re-identify data**

Massachusetts medical+voter data [Sweeney 1997]

# 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 |
|---|---|---|---|---|---|
| Ramsha | 29 | Female | Tamil Nadu | Hindu | Cancer |
| Yadu | 24 | Female | Kerala | Hindu | Viral infection |
| Salima | 28 | Female | Tamil Nadu | Muslim | TB |
| Kaker | 27 | Male | Karnataka | Parsi | No illness |
| Joan | 24 | Female | Kerala | Christian | Heart-related |
| Bahuksana | 23 | Male | Karnataka | Buddhist | TB |
| Rambha | 19 | Male | Kerala | Hindu | Cancer |
| Kishor | 29 | Male | Karnataka | Hindu | Heart-related |
| John | 17 | Male | Kerala | Christian | Heart-related |
| John | 19 | Male | Kerala | Christian | Viral infection |

# 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 |
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| * | 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 |

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

**Robust De-anonymization of Large Sparse Datasets**

Arvind Narayanan and Vitaly Shmatikov

The University of Texas at Austin

[Narayanan and Shmatikov 2008]

# Netflix Challenge:

- Netflix released a (non-uniform) random sample of user’s movie ratings
- Challenge was to build a better recommendation system
- Data was ‘anonymous’
  - ID # only
  - Random selection of a given user’s ratings
  - “noise” added (appears that there was no noise)

[Narayanan and Shmatikov 2008]

# Result: No real anonymity

- Cross-correlate with IMBD ratings
- A handful (6 or fewer) ratings of non-top 500 movies is enough!

# Part 2: Anonymity in Communication

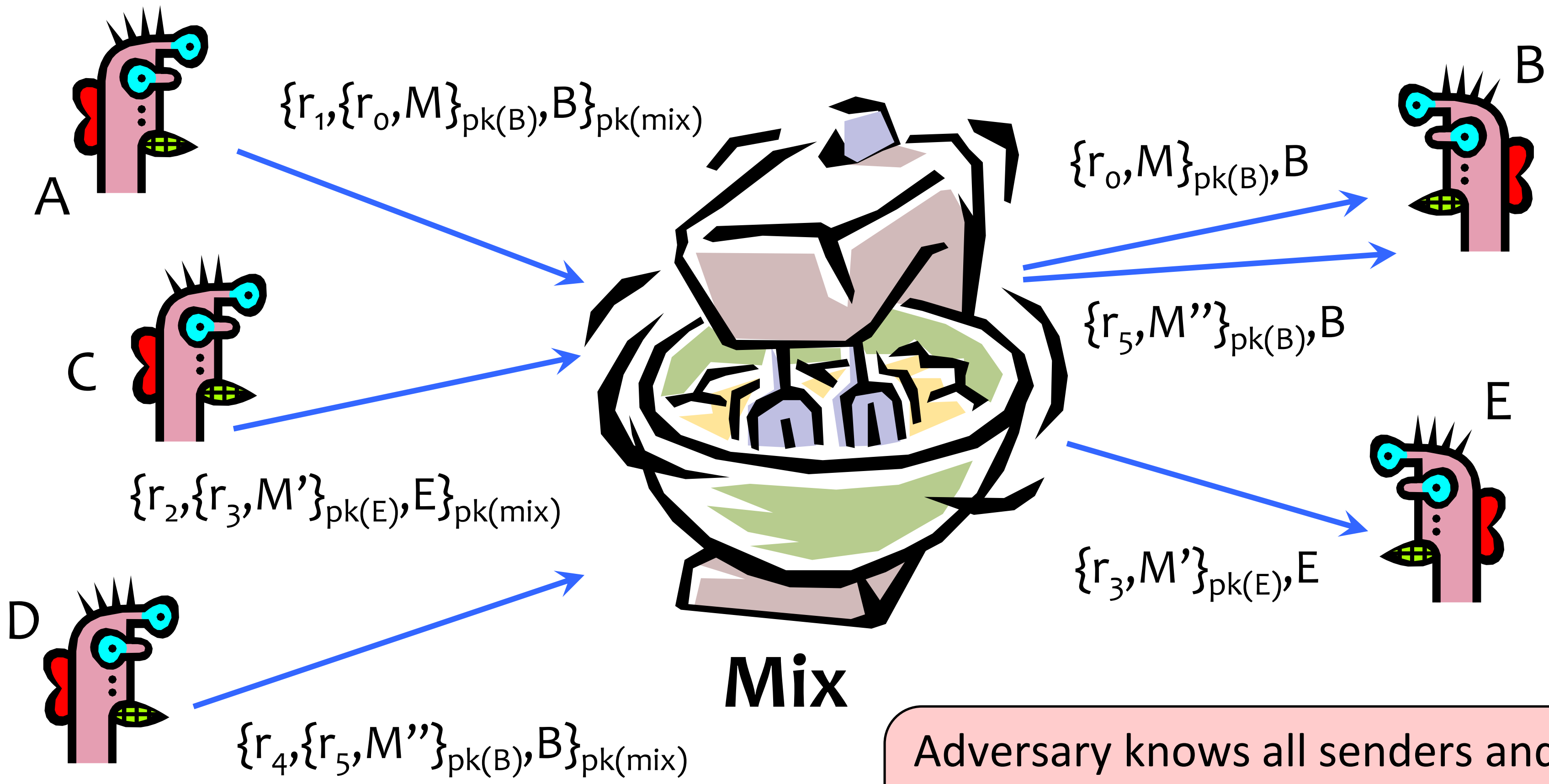
# Chaum’s Mix

- 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 ☺

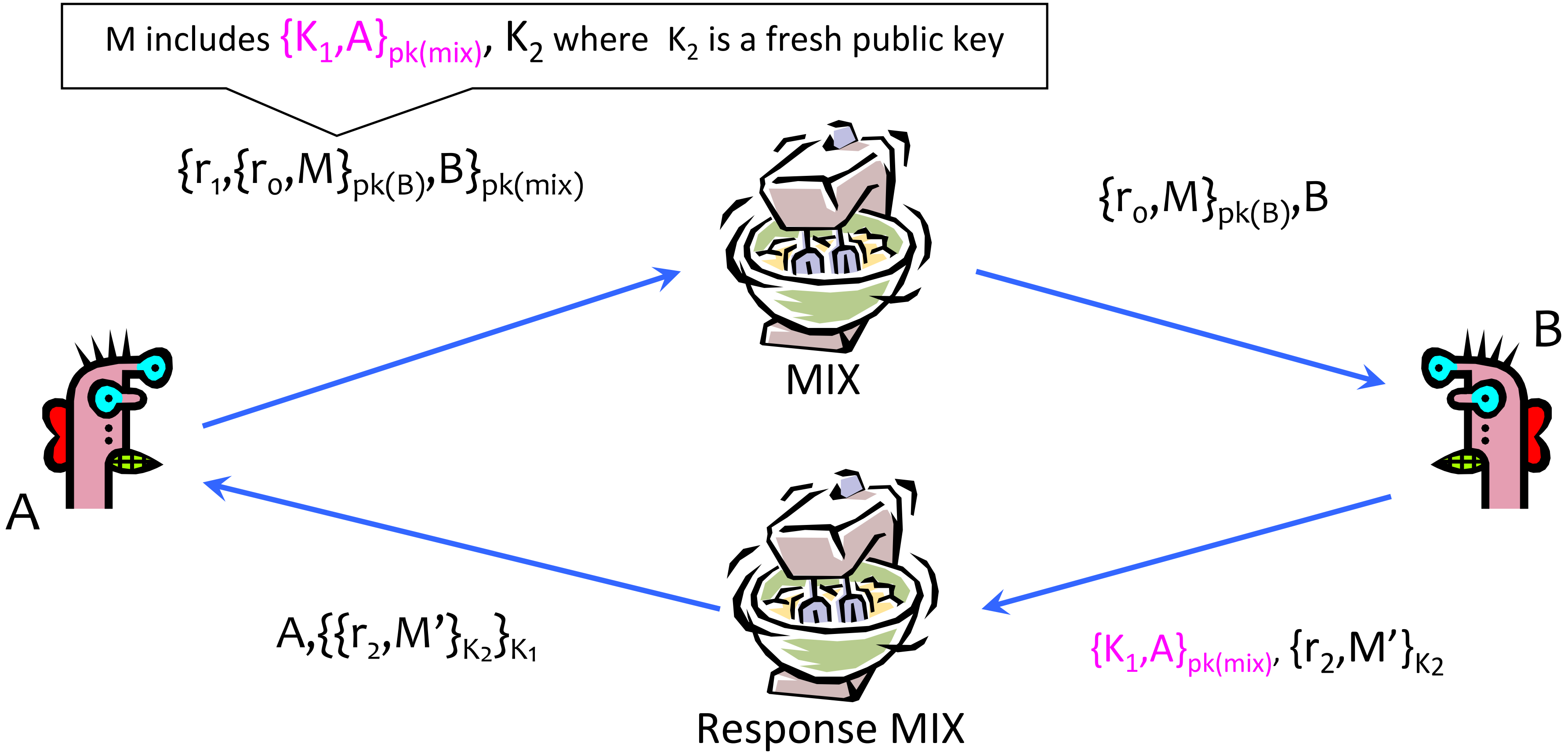
- Modern anonymity systems use Mix as the basic building block

# Basic Mix Design



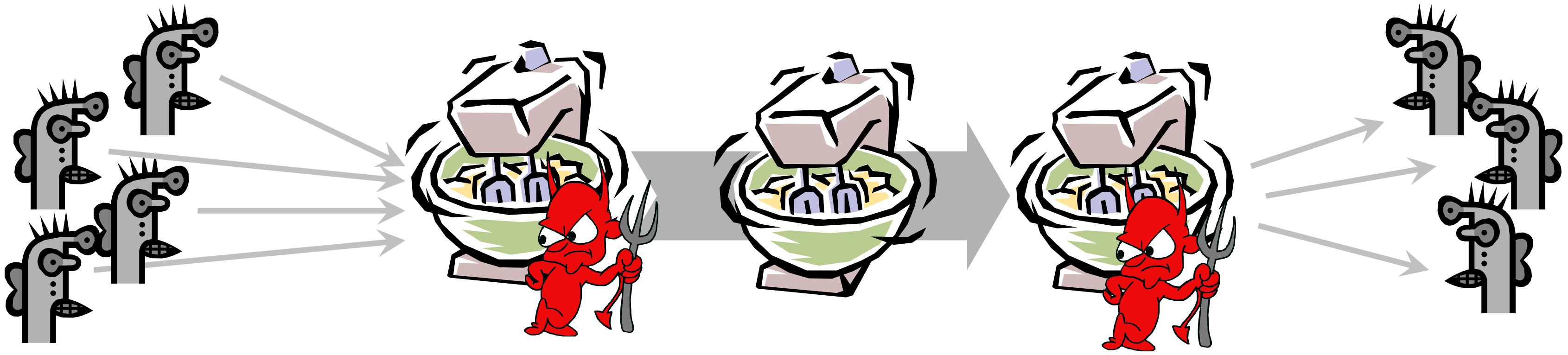

Adversary knows all senders and all receivers, but cannot link a sent message with a received message

# Anonymous Return Addresses




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

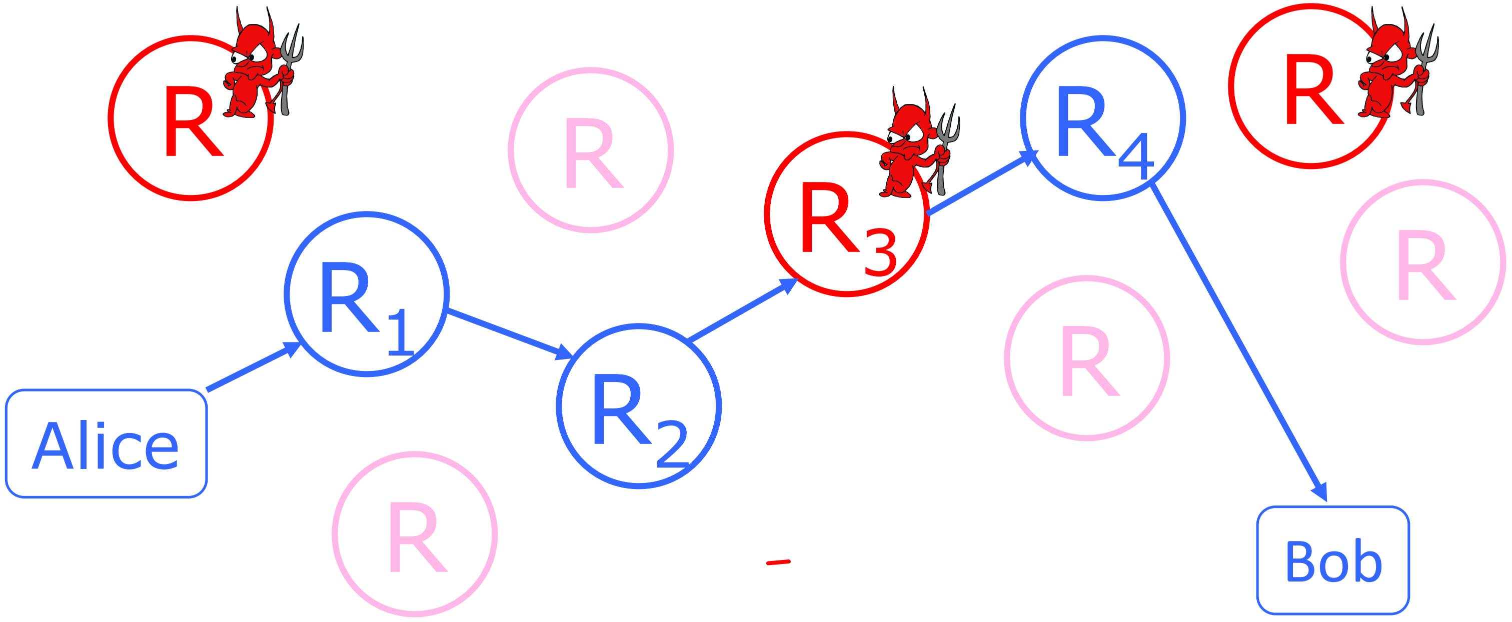
# Disadvantages of Basic Mixnets

- 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]

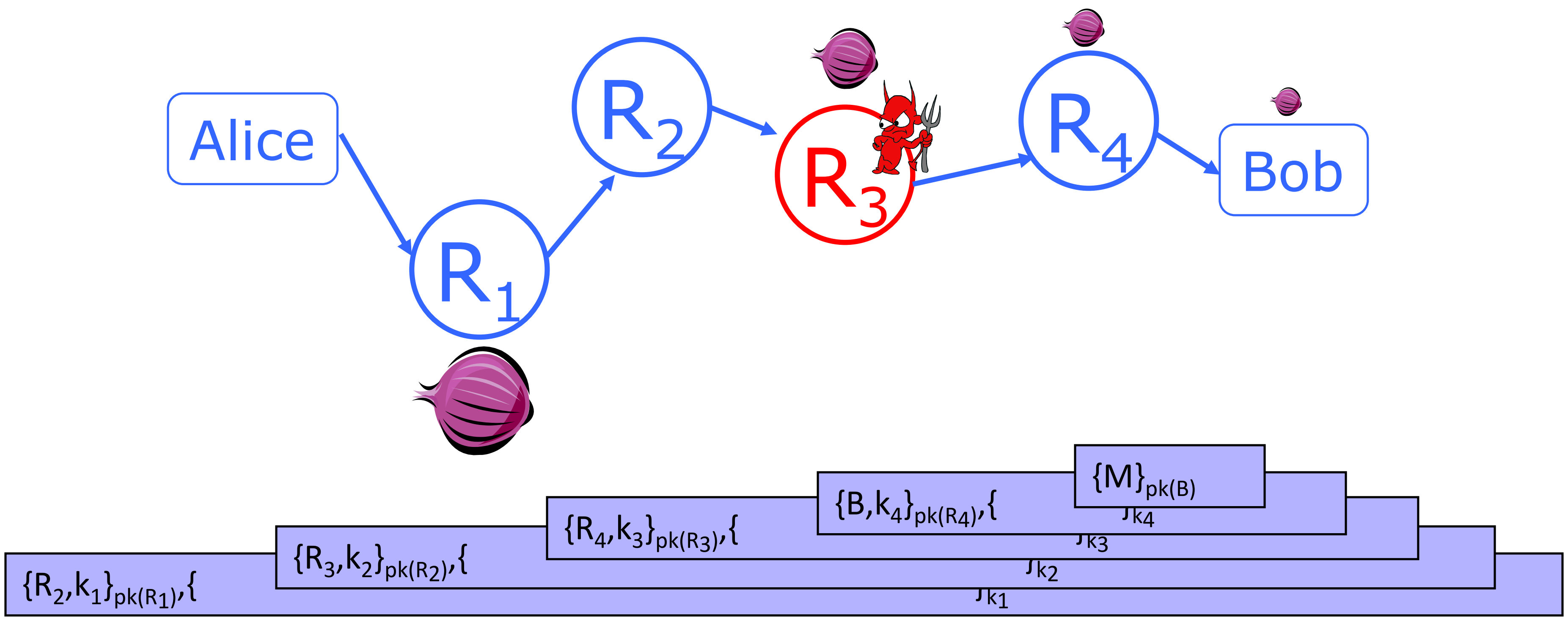
# Another Idea: Randomized Routing

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

# Onion Routing



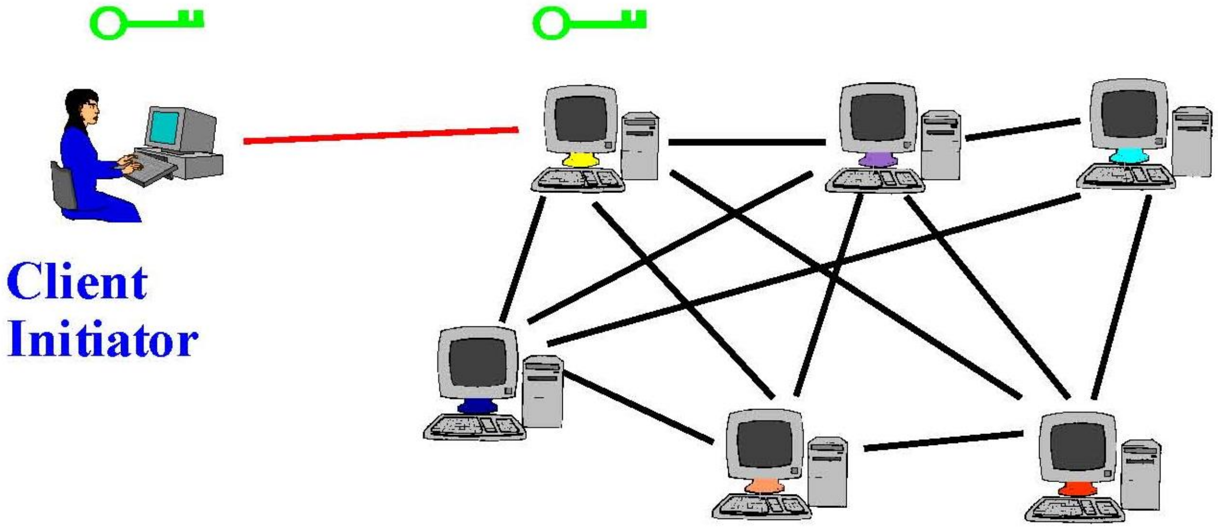

- Routing info for each link encrypted with router's public key
- Each router learns only the identity of the next router

# 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

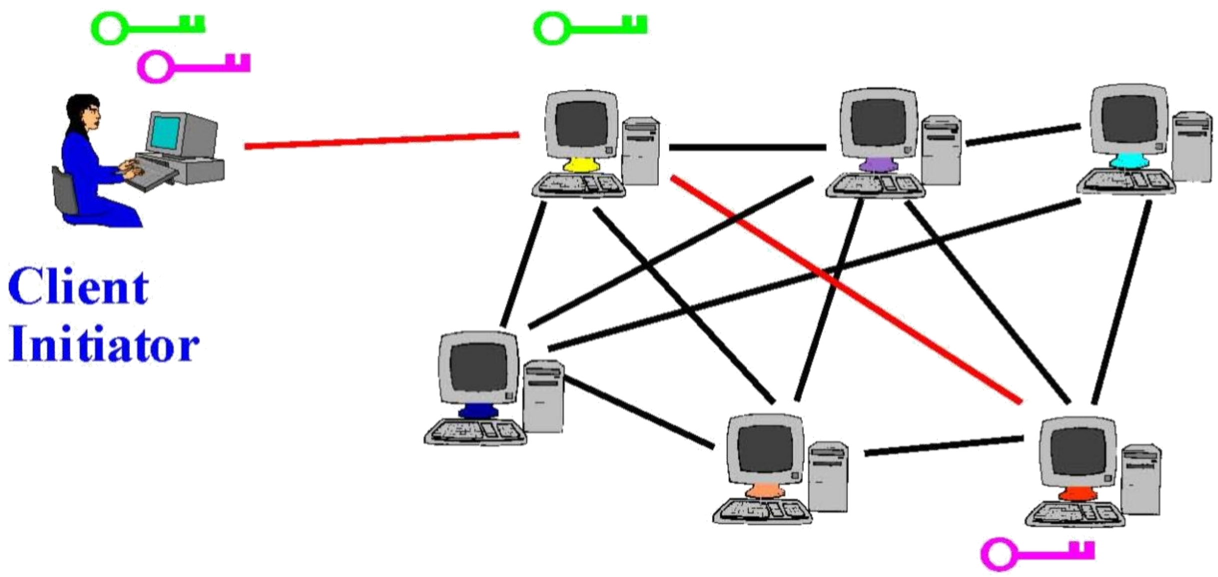
# Tor Circuit Setup (1)

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



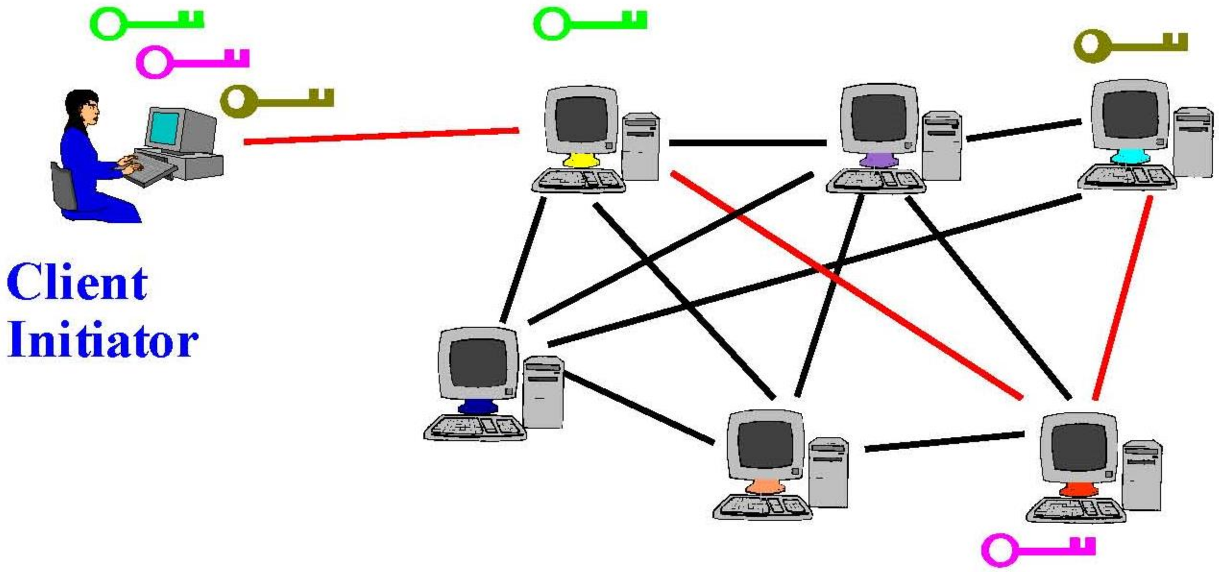
# Tor Circuit Setup (2)

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



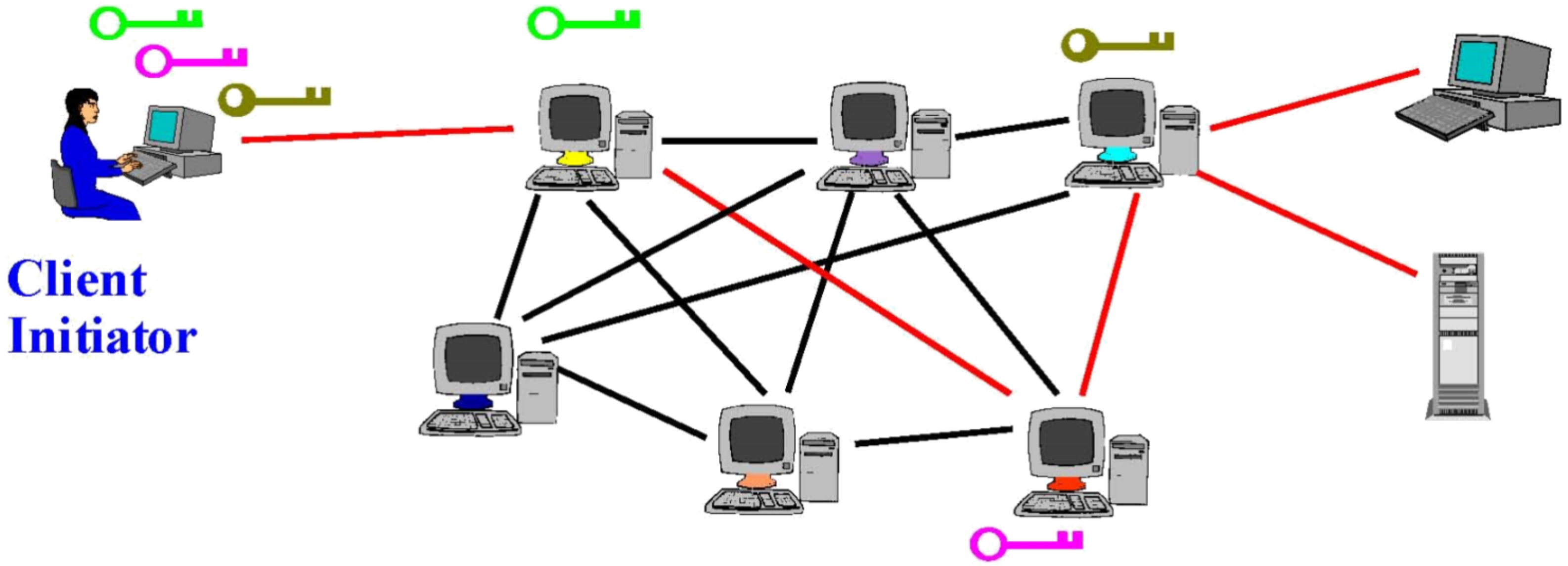
# Tor Circuit Setup (3)

- 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.



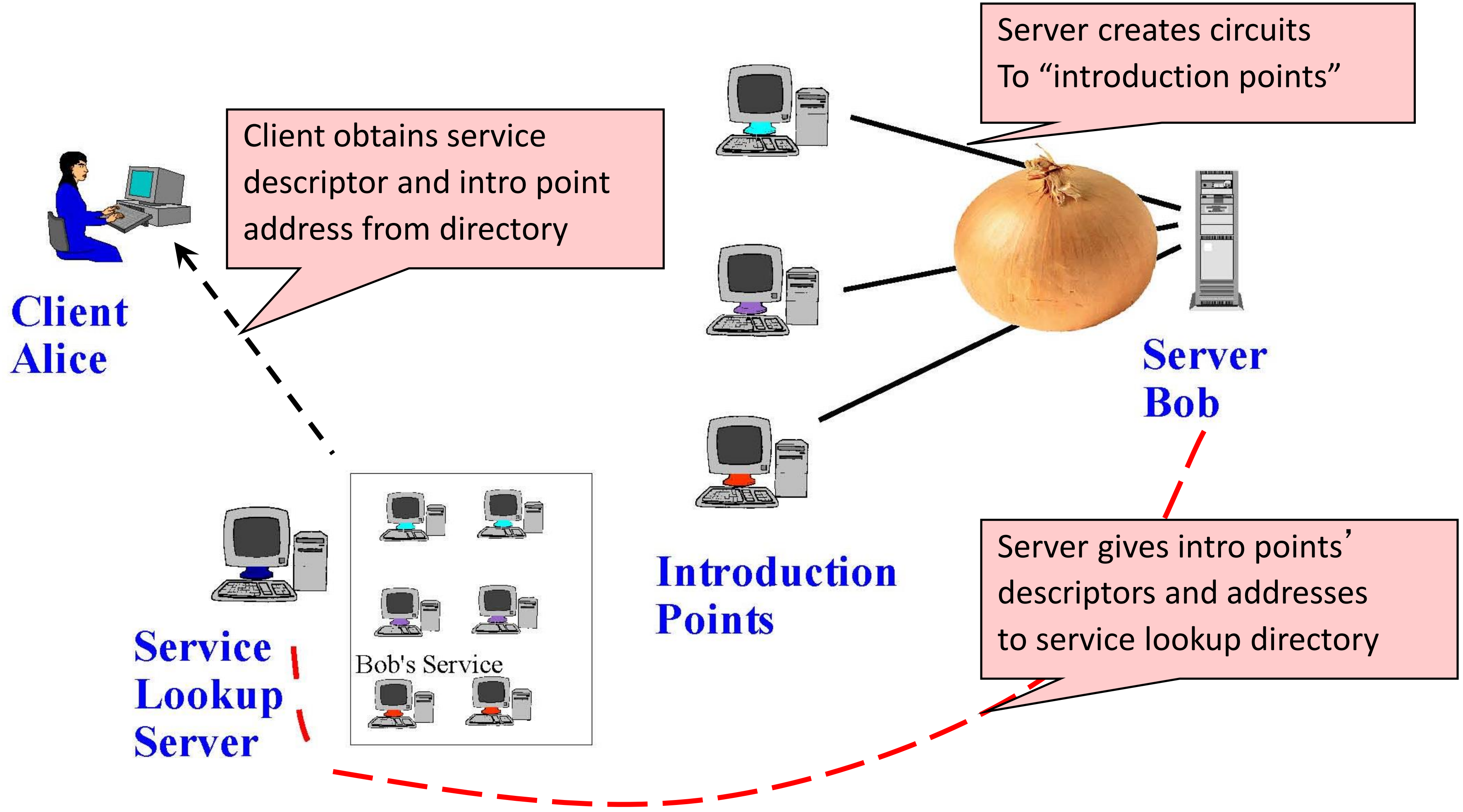
# How do you know who to talk to?

- 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

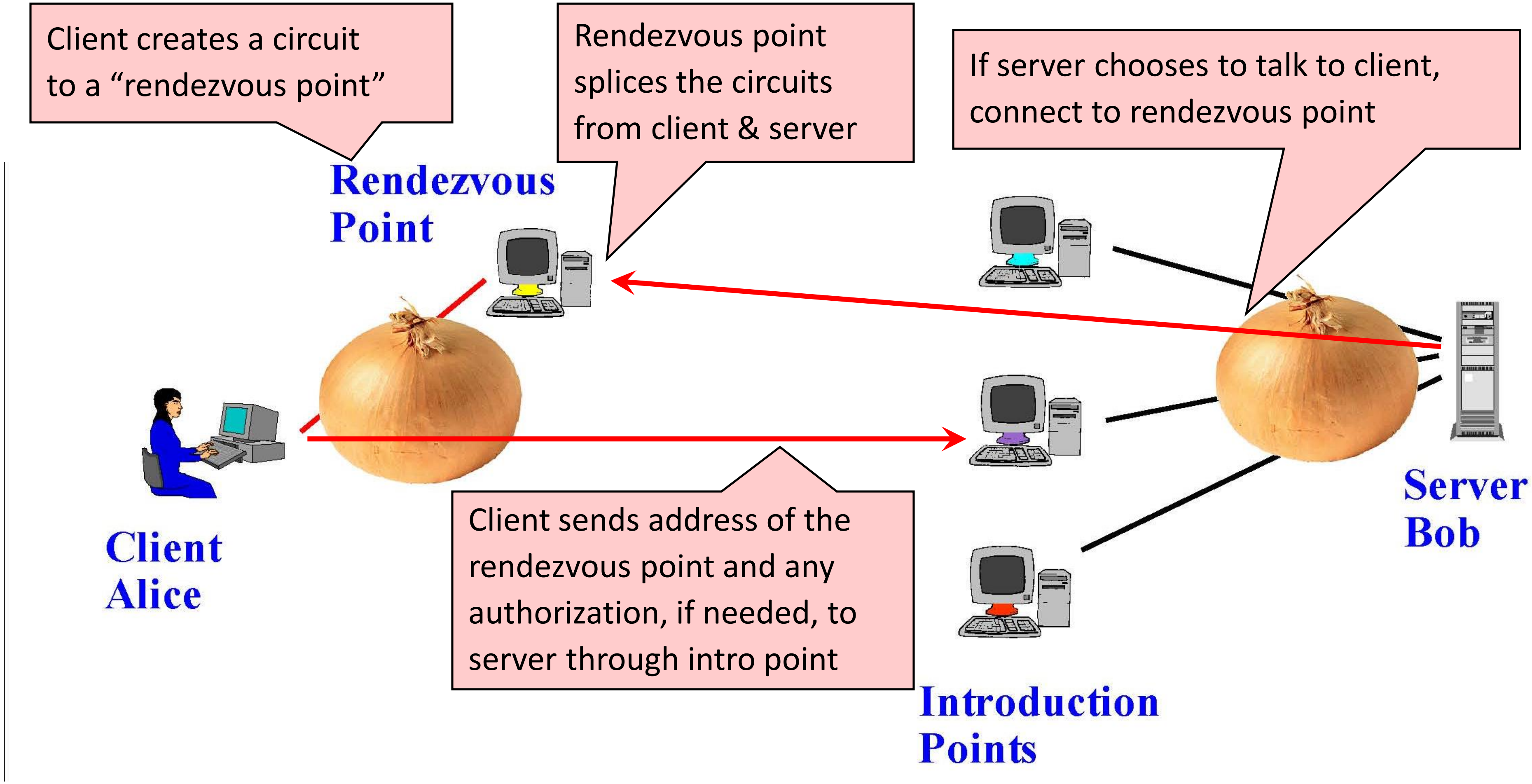
# Location Hidden Service

- **Goal:** deploy a server on the Internet that anyone can connect to without knowing where it is or who runs it
- Accessible from anywhere
- Resistant to censorship
- Can survive a full-blown DoS attack
- Resistant to physical attack
  - Can't find the physical server!

# Creating a Location Hidden Server



# Using a Location Hidden Server

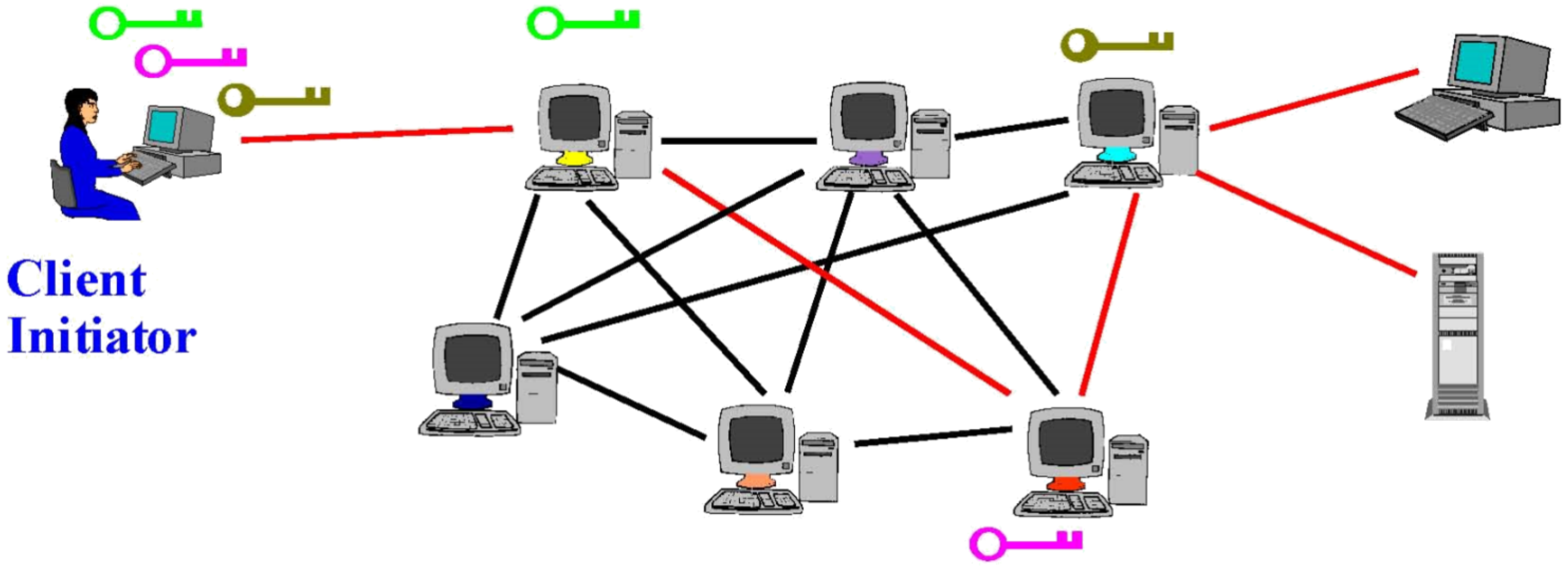


# Issues and Notes of Caution

- 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 <u>fraction</u> 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
- Tor not designed to protect against adversaries with the capabilities of a state (public statement by designers, at least in the past)