Anonymous Communications: Point-to-Point

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Based in part on slides by Anupam Datta, Piotr Mardziel

Administrative

- HW4 due Nov. 22 (<2 weeks from now)
  - “Fairness in Classification” problem updated on Canvas
- Recitation on Friday (Sruti)
  - **New location tomorrow: Panther Hollow, CIC 4101**
  - Anonymous communication
- If you want feedback on your project, please come to OH!

In-class Quiz

- On Canvas

In-class activity: DC Nets

- One of you has been selected from each class as the “rep”
- If you are the rep and you are present in class, your goal is to broadcast a “1”

Shamir secret sharing vs. DC nets

	Shamir Secret Sharing	DC Nets
Goal	Hide message contents from any set of < k participants	Hide message author
Approach	Split data into shares that can only be reconstructed by k+ parties	Mask message through shared randomness that it not visible to all parties
Strengths	Information-theoretic secrecy	Information-theoretic anonymity
Weaknesses	Requires a lot of randomness	Requires a lot of randomness High communication cost Fragile to collisions

Why are DC nets more fragile than secret sharing?

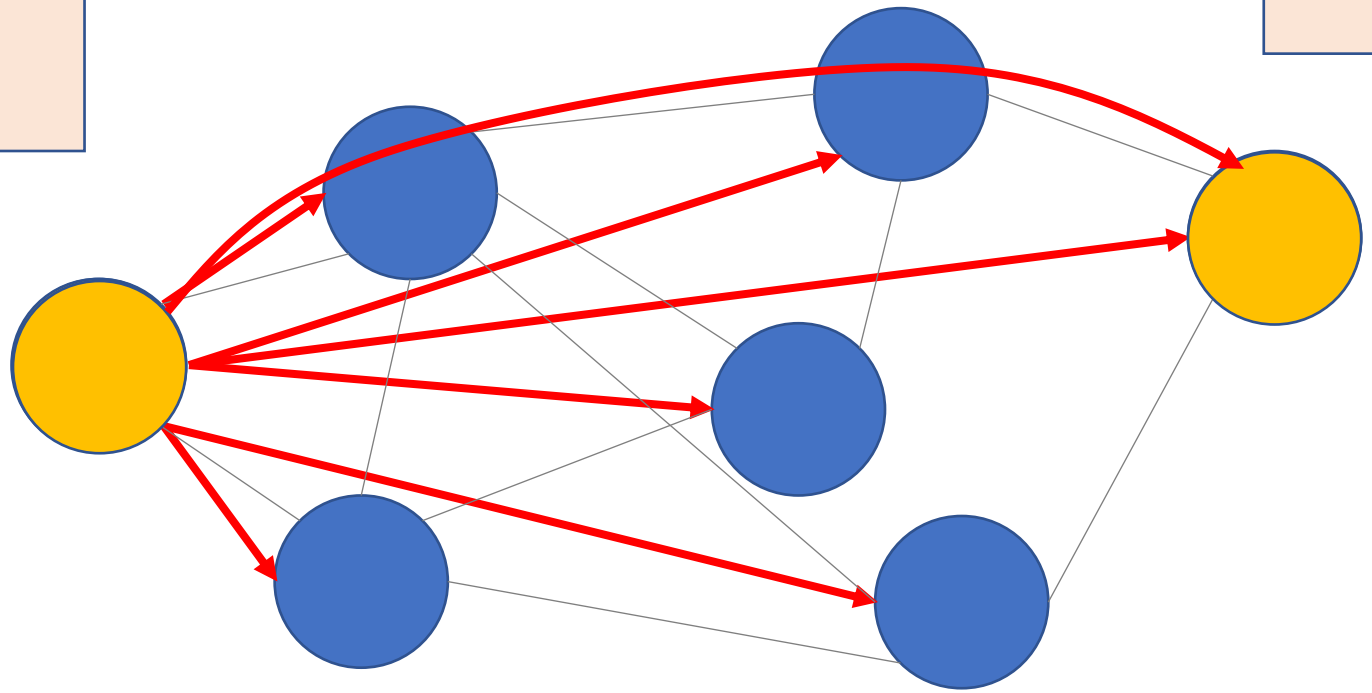
- In DC nets the signal is only being injected in **one** of the observed symbols
  - Corruptions in that symbol cannot be recovered
    - No redundancy
  - Problem is more difficult
    - Similar adversarial model
    - More general task

- State-of-the-art DC-nets can support ~1,000 nodes

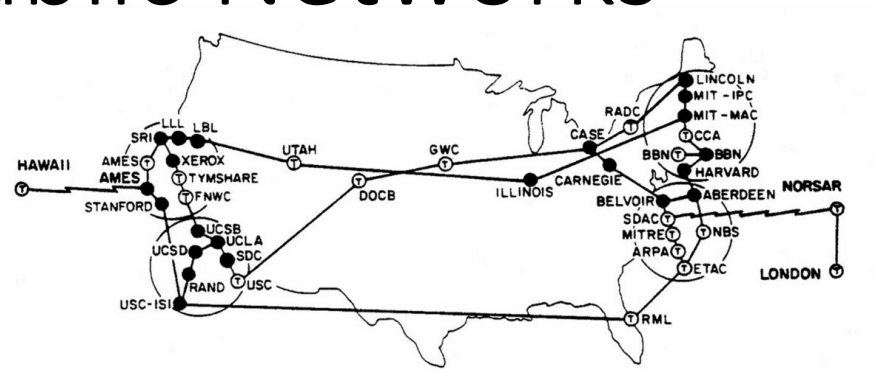
Overview of the Unit

1. One-to-many communication

2. Point-to-point communication



Privacy on Public Networks



- Internet is designed as a public network
  - Nearby computers can see your traffic
  - Routers see all traffic that passes through them
- Routing information is public
  - Packet headers identify source and destination
  - Even a passive observer can easily figure out who is talking to whom
- Encryption does not hide identities (e.g. DNSSEC, HTTPS)
  - Encryption hides payload, but not routing information

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

What is Anonymity?

- Anonymity is the state of being not identifiable within a set of subjects
  - You cannot be anonymous by yourself!
  - Hide your activities among others' similar activities
- Unlinkability of action and identity
  - For example, sender and his email are no more related after observing communication than they were before
- Unobservability (hard to achieve)
  - Any item of interest (message, event, action) is indistinguishable from any other item of interest

Attacks on Anonymity

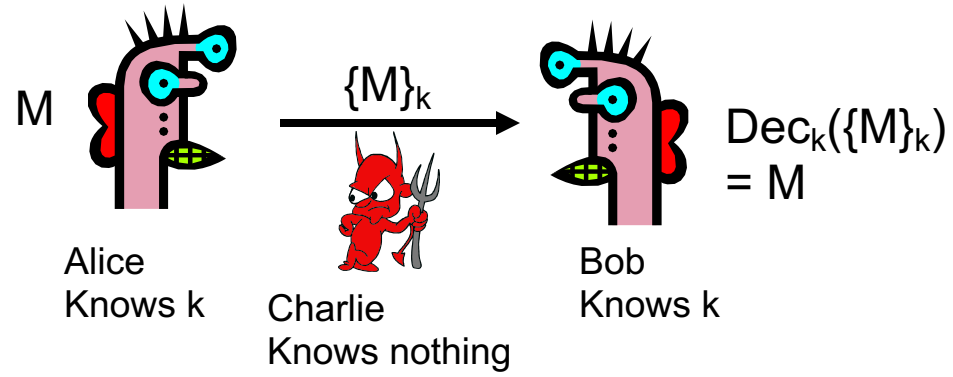
- Passive traffic analysis
  - Infer from network traffic who is talking to whom
  - To hide your traffic, must carry other people's traffic!
- Active traffic analysis
  - Inject packets or put a timing signature on packet flow
- Compromise of network nodes
  - Attacker may compromise some routers
  - 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

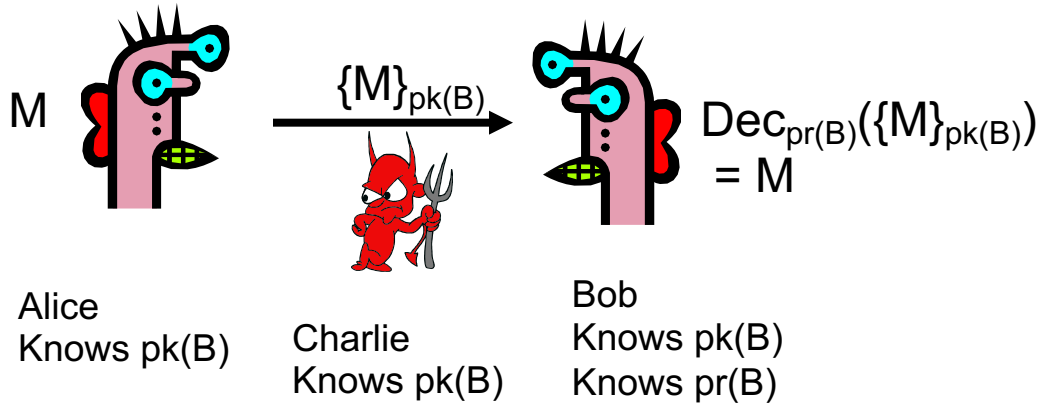
Outline: Point-to-Point Communication

- Symmetric vs Public key cryptography
- Protocols for anonymous communication
  - High-latency
    - Chaum Mixes as a building block, onion routing
  - Low-latency
    - Optimized Onion Routing and Tor

Symmetric vs Public key crypto

- Symmetric
  - (Symmetric) key k
  - Message M
  - Encrypt: $Enc_k(M)$ or $\{M\}_k$
  - Decrypt: $Dec_k(M)$
  - $Dec_k(Enc_k(M)) = M$
  - **Fast**
- Public-private
  - Bob's public key: pk(B)
  - Bob's private key: pr(B)
  - $Dec_{pr(B)}(Enc_{pk(B)}(M)) = M$
  - $Dec_{pk(B)}(Enc_{pk(B)}(M)) \neq M$
  - **Slow**





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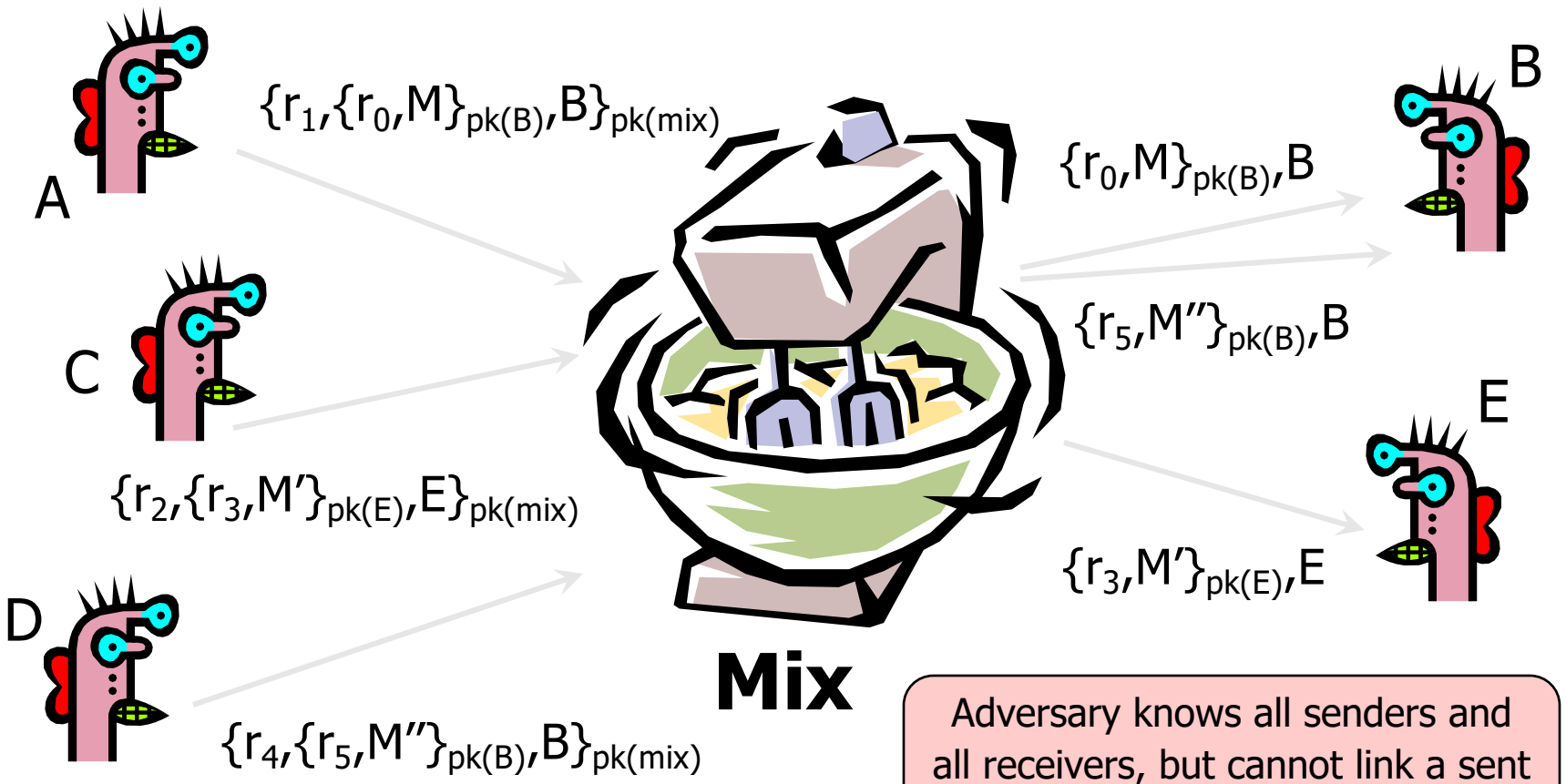
Chaum's Mix

- 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 ☺

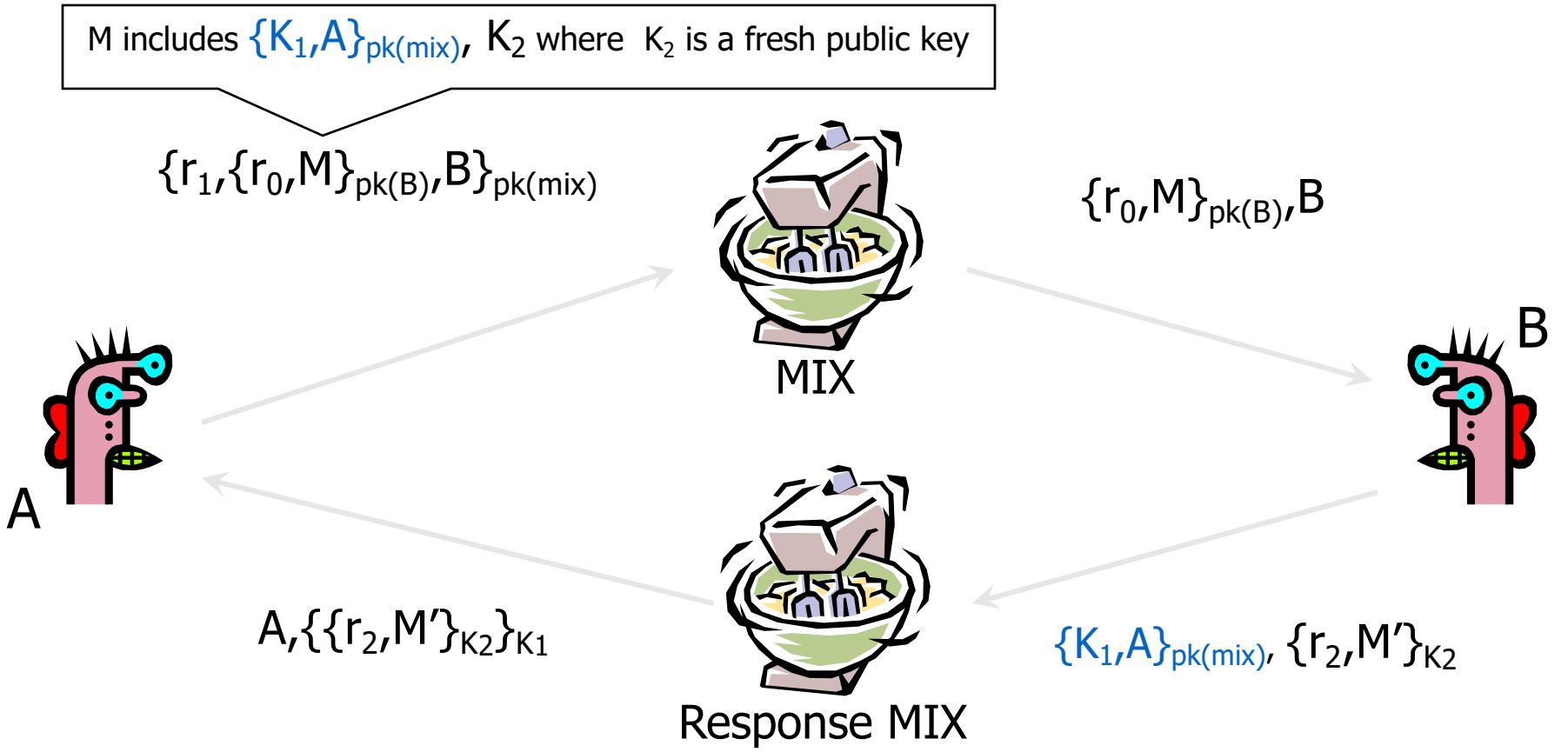
- Public key crypto + trusted re-mailer (Mix)
  - Untrusted communication medium
  - Public keys used as persistent pseudonyms
- Modern anonymity systems use Mix as the basic building block

Basic Mix Design

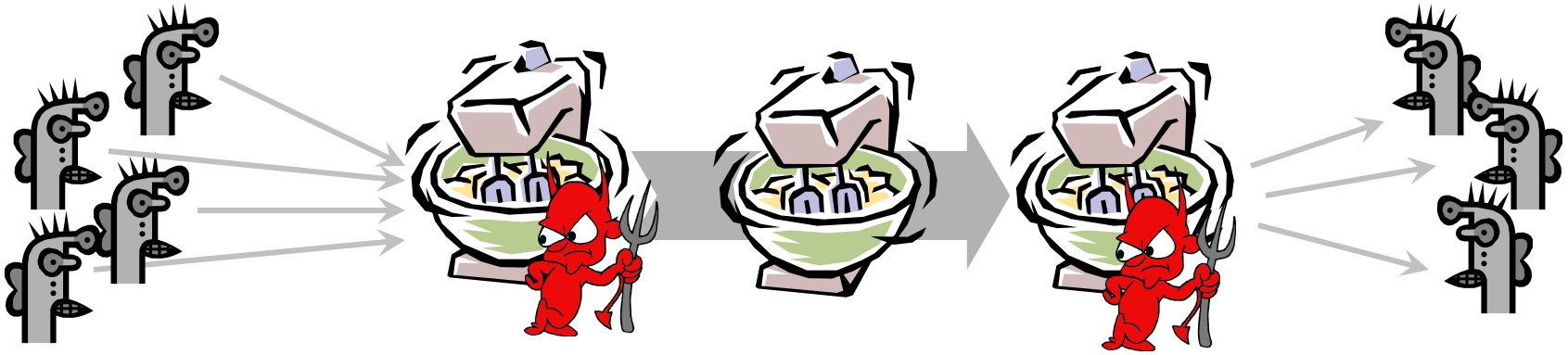


Adversary knows all senders and all receivers, but cannot link a sent message with a received message

Anonymous Return Addresses



Mix Cascade

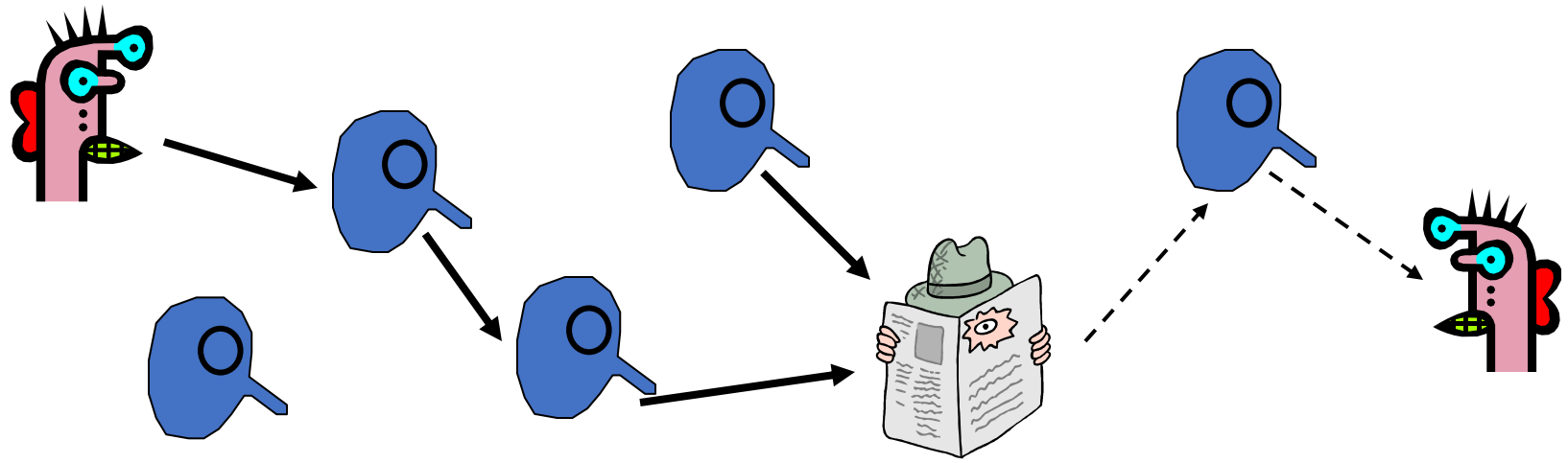


- Messages are sent through a sequence of mixes
  - Can also form an arbitrary network of mixes (“mixnet”)
- Some of the mixes may be controlled by attacker, but even a single good mix guarantees anonymity
- Pad and buffer traffic to foil correlation attacks

What are some downsides of mix networks?

- Susceptible to timing attacks
- Latency can be high
  - Must wait for “enough” inputs before the mix relays traffic
- These challenges led to 2nd commonly-used anonymous routing technique

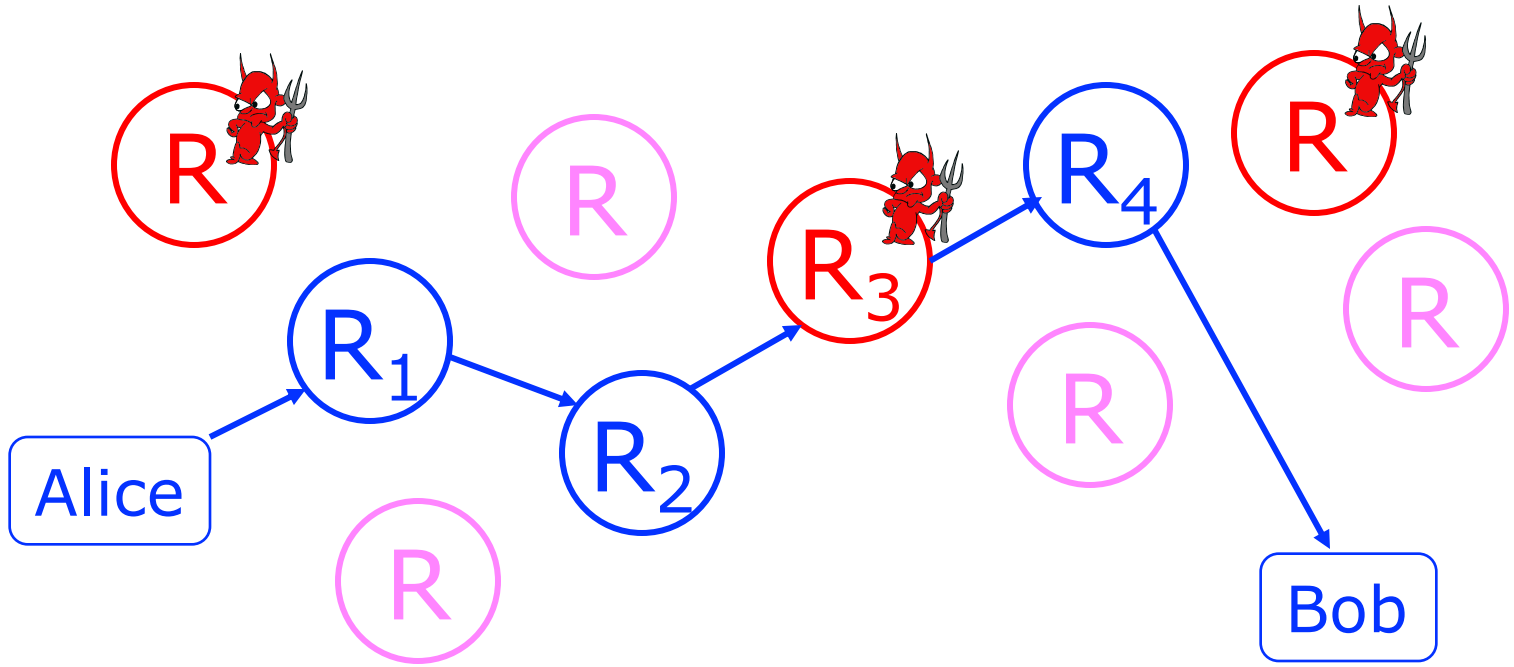
Idea: Randomized Routing



- Hide message source by routing it randomly
  - Popular technique: Crowds, Freenet, Onion routing
- Routers don’t know for sure if the apparent source of a message is the true sender or another router

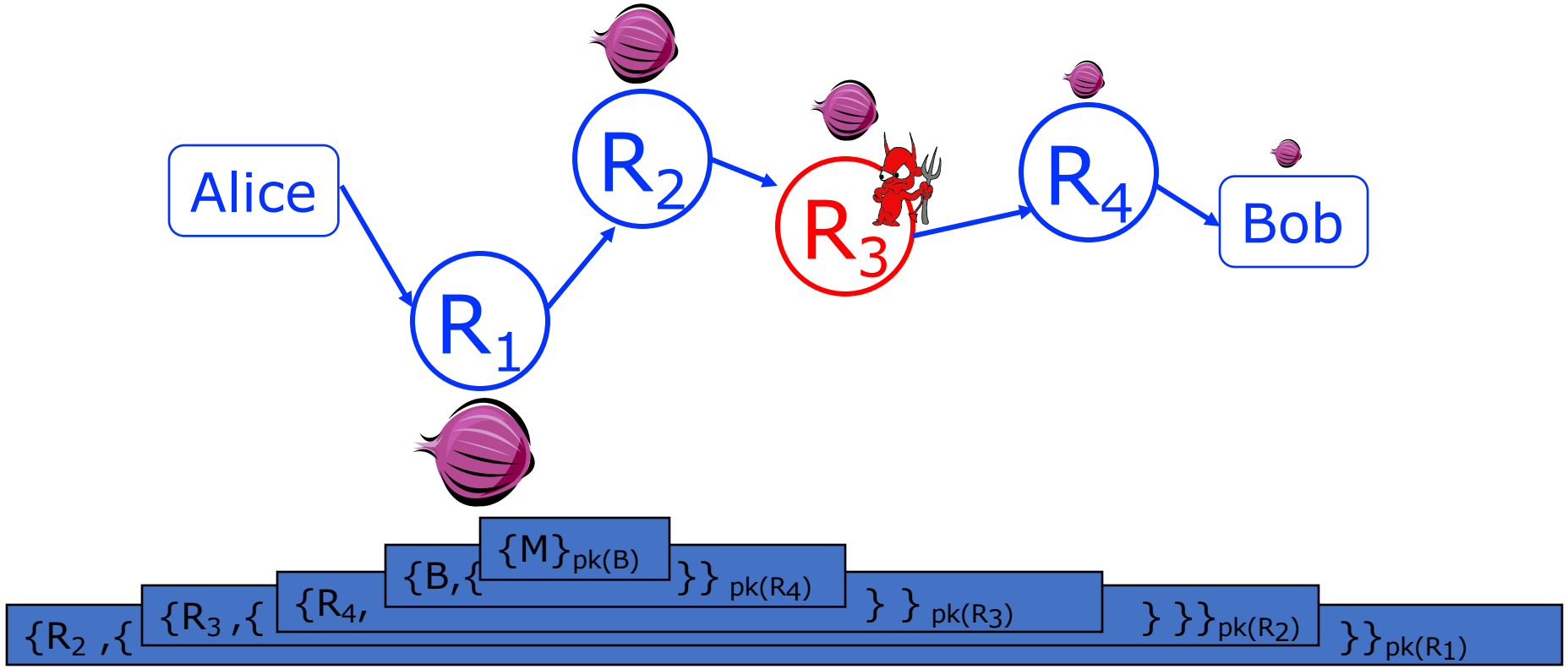
Onion Routing

[Reed, Syverson, Goldschlag '97]



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

Route Establishment



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

Disadvantages of Basic Mixnets/Onion Routing

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

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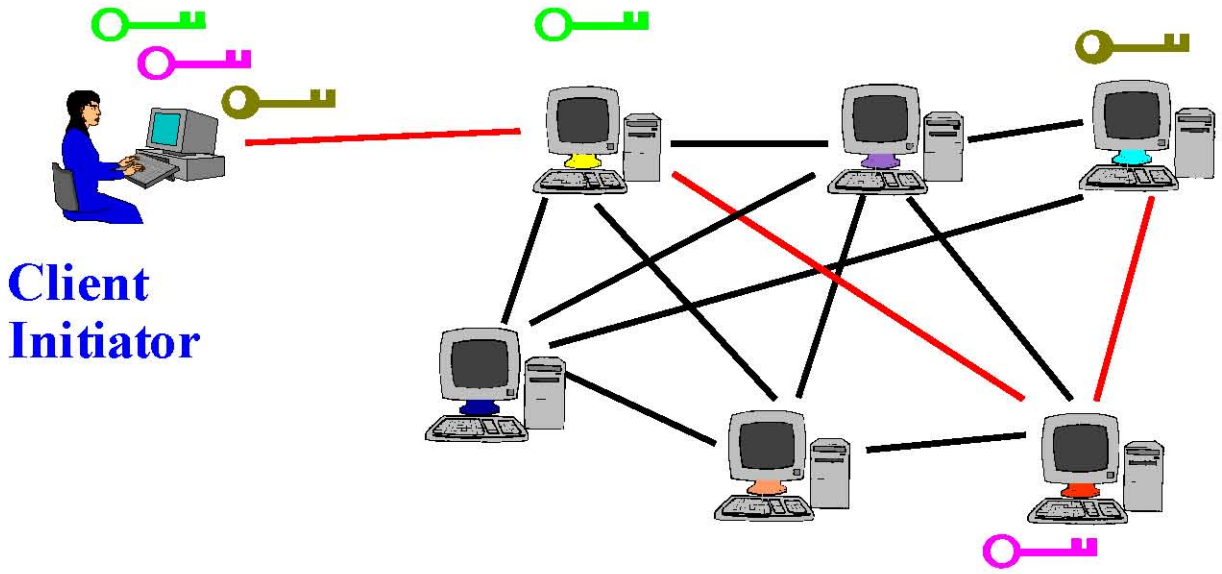
Tor

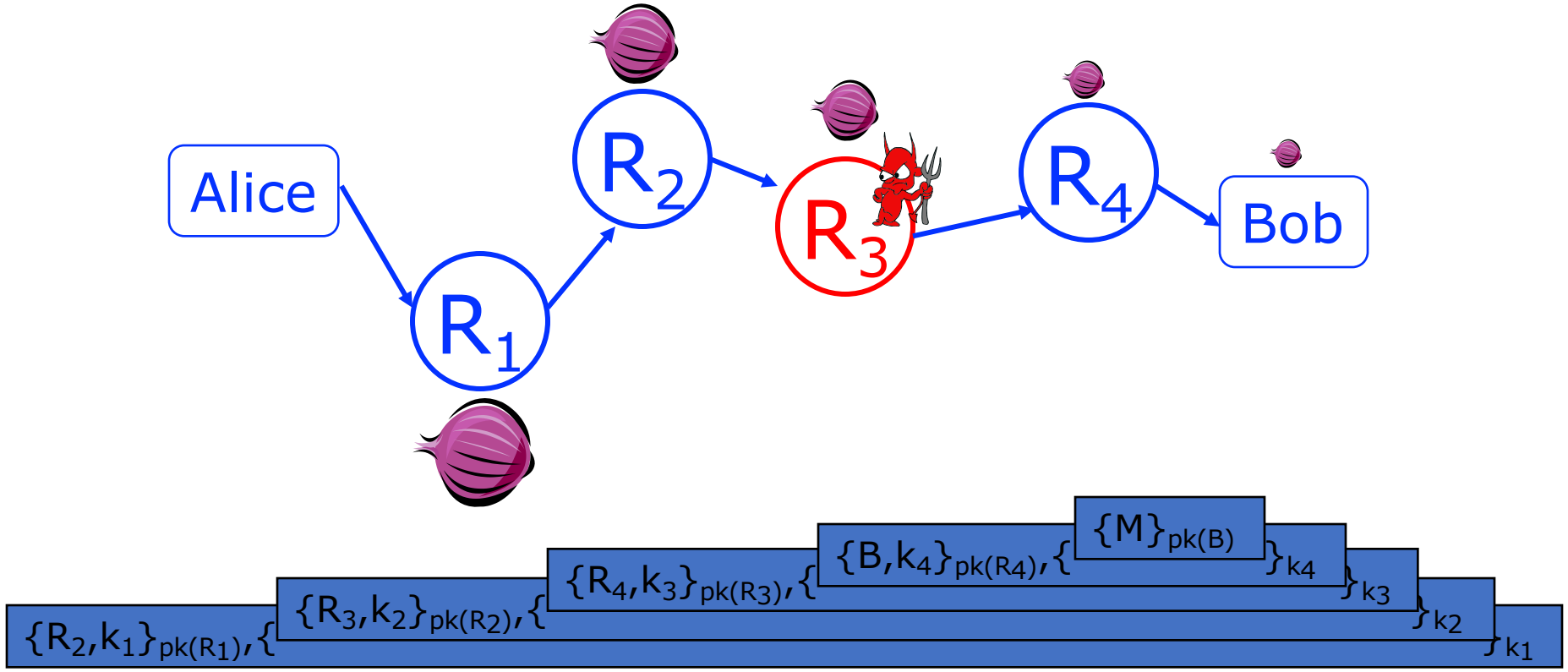
- Second-generation onion routing network
  - http://tor.eff.org
  - Developed by Roger Dingledine, Nick Mathewson and Paul Syverson
  - Specifically designed for low-latency anonymous Internet communications
- Running since October 2003
- Thousands of nodes, 2MM+ users
- “Easy-to-use” client proxy
  - Freely available, can use it for anonymous browsing

Tor Circuit Setup

- Client proxy establishes symmetric session keys with onion routers



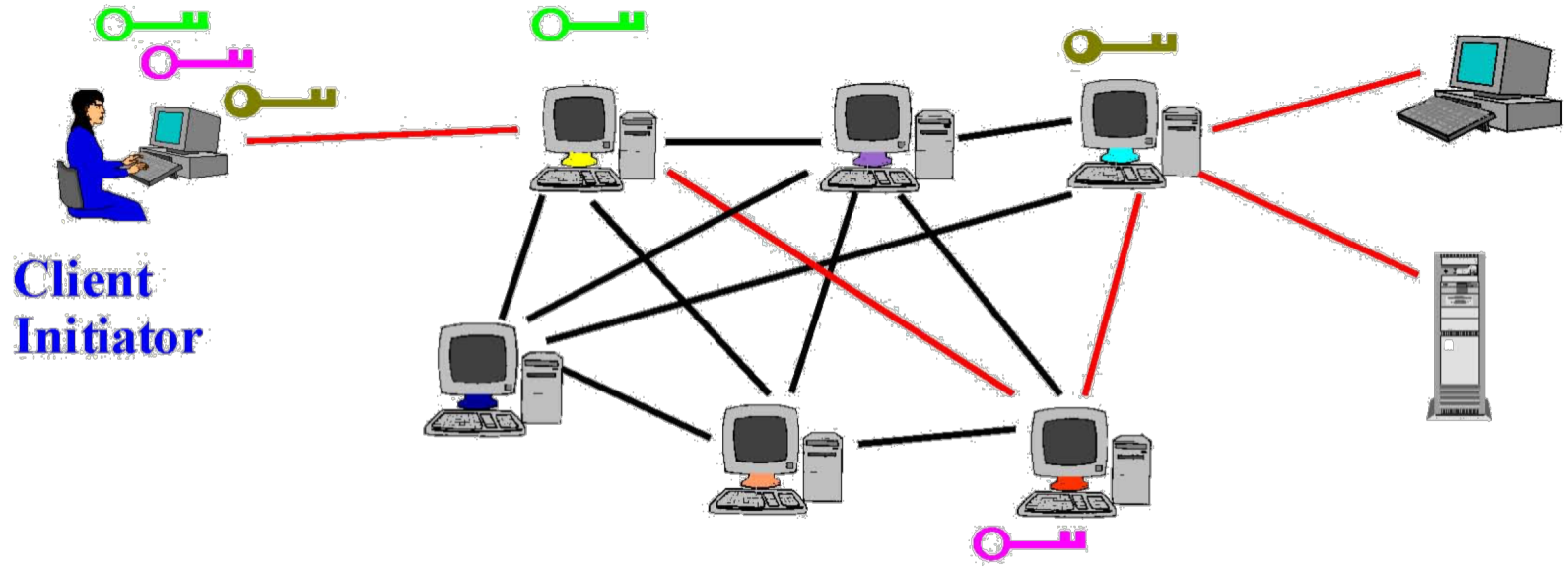
Tor Circuit Setup (details)



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

Using a Tor Circuit

- Client applications connect and communicate over the established Tor circuit
  - Note onion now uses only symmetric keys for routers



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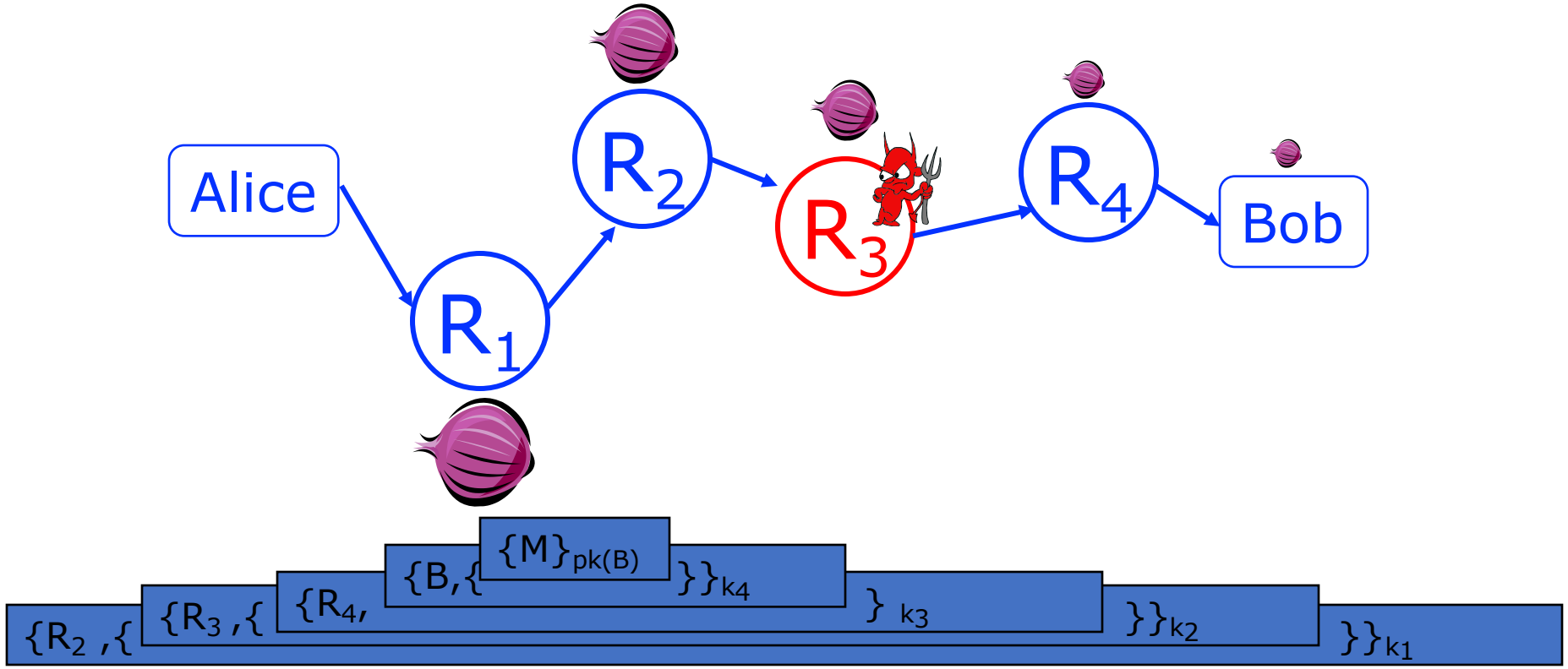
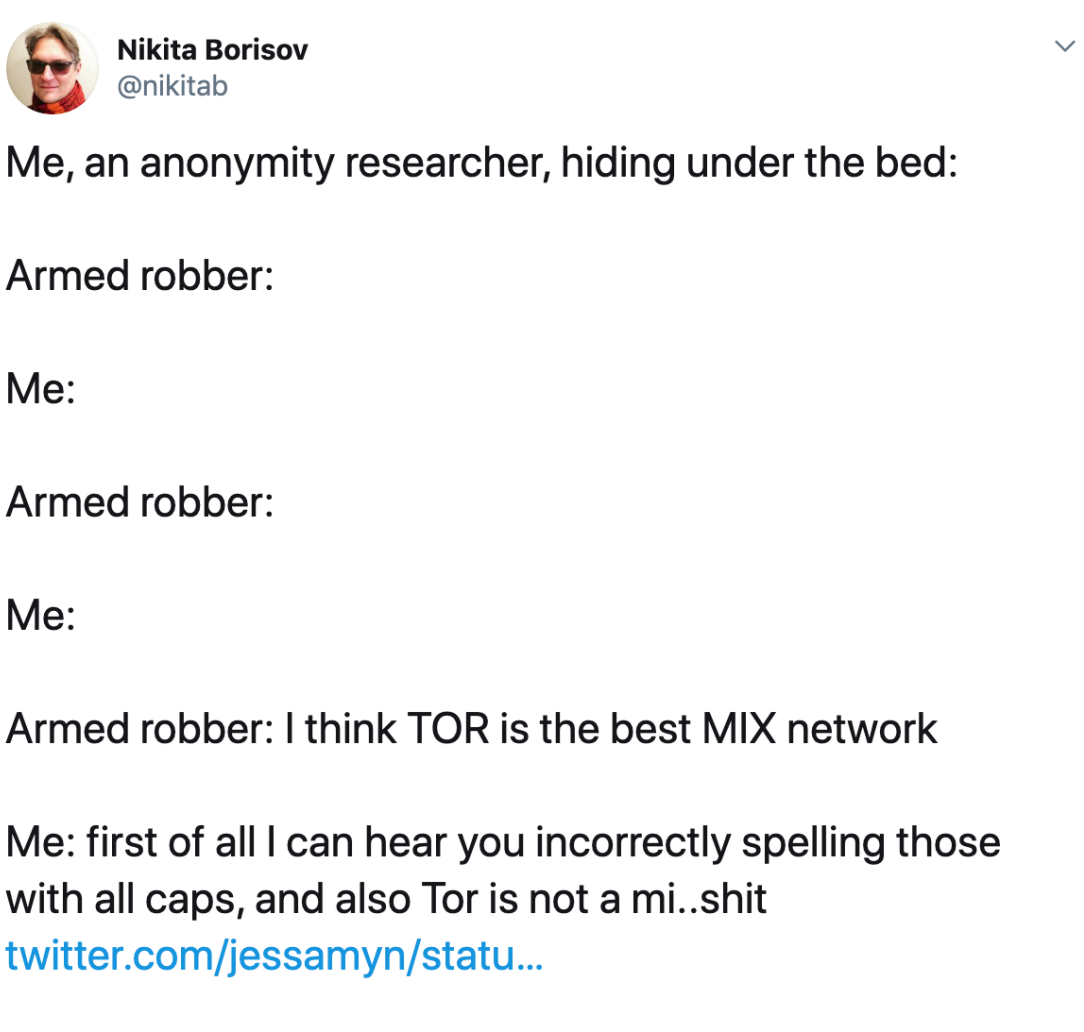


Note onion now uses only symmetric keys for routers

Tor Management Issues

- Many applications can share one circuit
  - Multiple TCP streams over one anonymous connection
- Tor router doesn’t need root privileges
  - Encourages people to set up their own routers
  - More participants = better anonymity for everyone
- 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

Common misconception:
Onion routing = Mix networks



Nikita Borisov
@nikitab

Me, an anonymity researcher, hiding under the bed:

Armed robber:

Me:

Armed robber:

Me:

Armed robber: I think TOR is the best MIX network

Me: first of all I can hear you incorrectly spelling those with all caps, and also Tor is not a mi..shit
twitter.com/jessamyn/statu...

Deployed Anonymity Systems

- Free Haven project has an excellent bibliography on anonymity
- Tor (http://tor.eff.org)
  - Overlay circuit-based anonymity network
  - Best for low-latency applications such as anonymous Web browsing
- Mixminion (http://www.mixminion.net)
  - Network of mixes
  - Best for high-latency applications such as anonymous email

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A simple idea: Basic Anonymizing Proxy

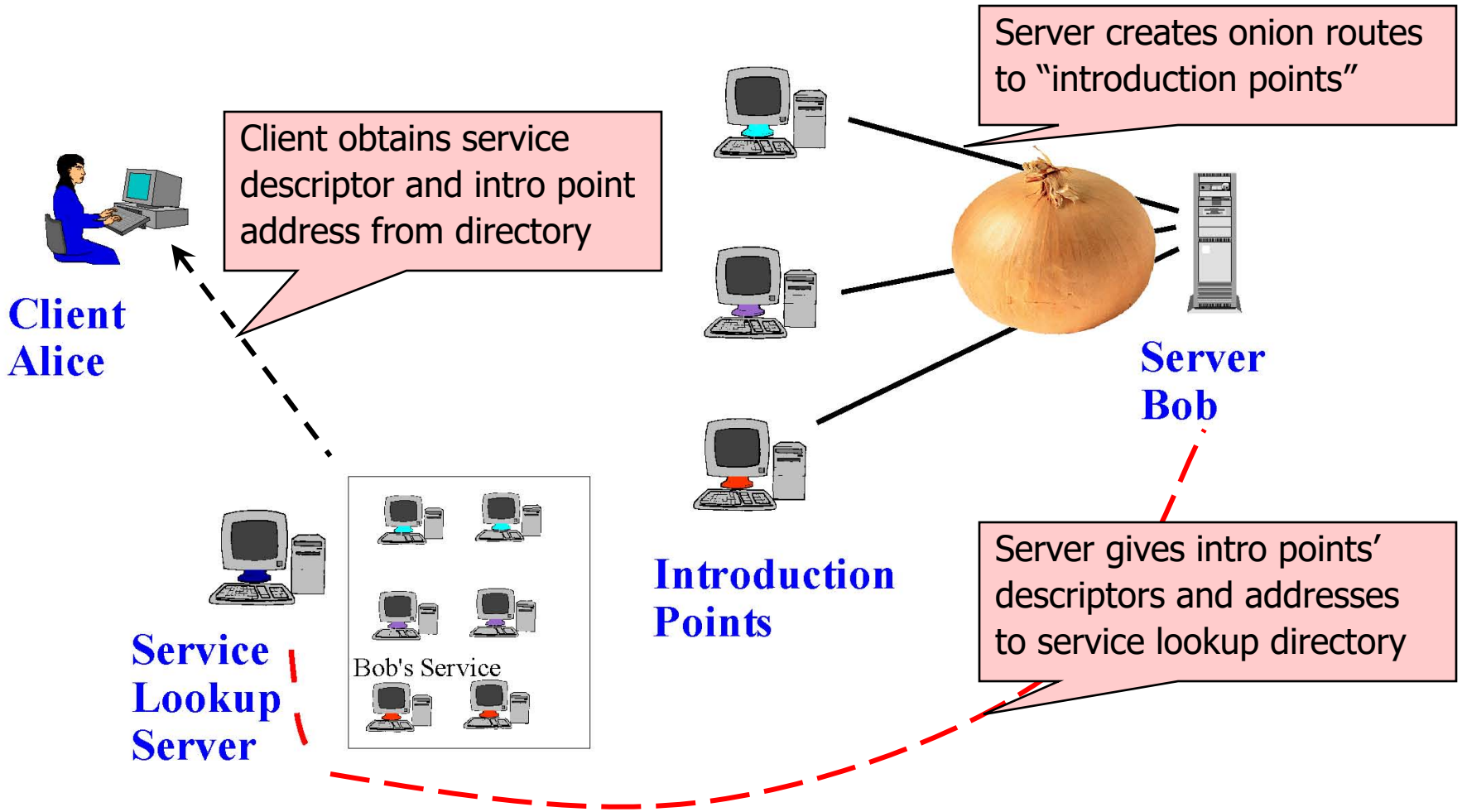
- Channels appear to come from proxy, not true originator
- Appropriate for Web connections etc.: SSL, TLS (Lower cost symmetric encryption)
- Example: Anonymizer (developed at CMU!)
- Simple, focuses lots of traffic for more anonymity
- Main disadvantage: Single point of failure, compromise, attack

Extension: Location Hidden Servers

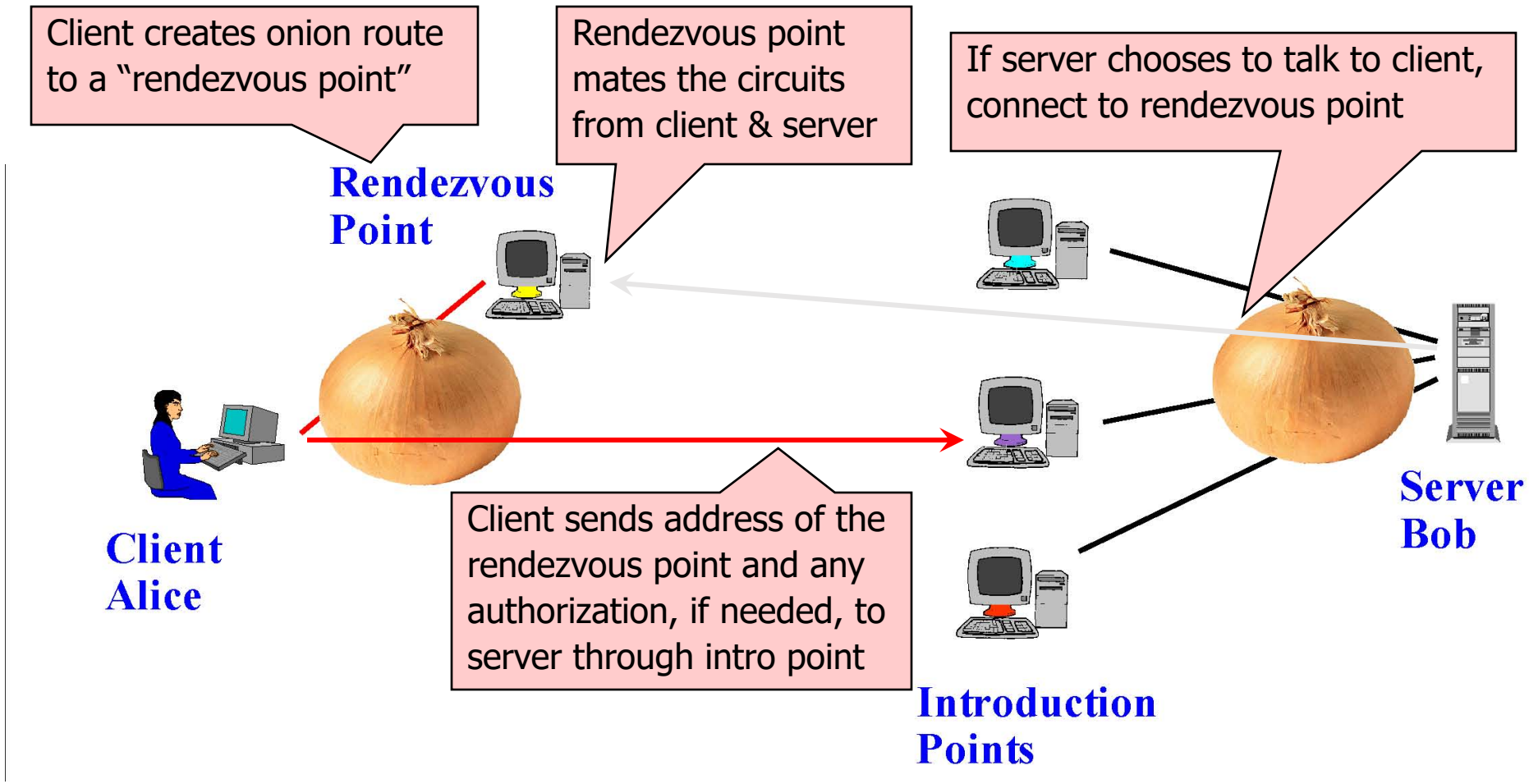
- Goal: deploy a server on the Internet that anyone can connect to without knowing where it is or who runs it
- Accessible from anywhere
- Resistant to censorship
- Can survive full-blown DoS attack
- Resistant to physical attack
  - Can’t find the physical server!

- Commonly referred to as… the dark web

Creating a Location Hidden Server



Using a Location Hidden Server



In-Class Demo: Accessing Hidden Services

- Many news organizations have started offering hidden services
- New York Times
  - https://www.nytimes3xbfgragh.onion/

How would you attack this?

- Try to DoS the rendevouz point?
  - Client can switch rendezvous
- DoS an introduction point?
  - Server can switch introduction points
- DoS the lookup server?
  - This is probably the weakest link