CS 380S

# 0x1A Great Papers in Computer Security

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# Privacy on Public Networks

- Internet is designed as a public network
  - Wi-Fi access points, 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 easily 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

# Anonymity

- Anonymity = the person is 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 his email are no more related after adversary's observations than they were before
- Unobservability (hard to achieve)
  - Adversary can't even tell whether someone is using a particular system and/or protocol

# Attacks on Anonymity

- Passive traffic analysis
  - Infer from network traffic who is talking to whom
- 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
    - Can assume that some fraction of routers is good, but don't know which

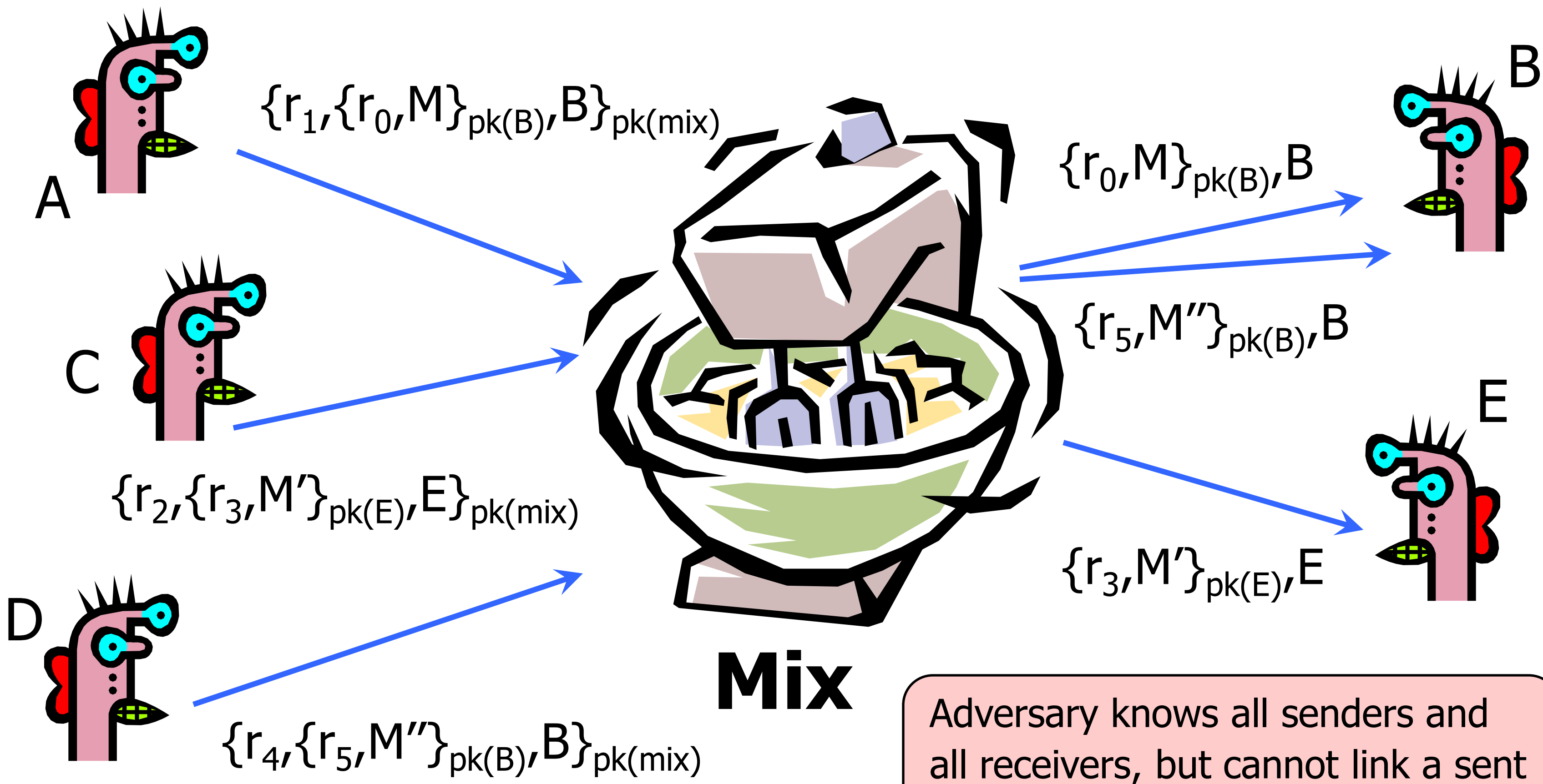
# Chaum's Mix

- 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 ☺

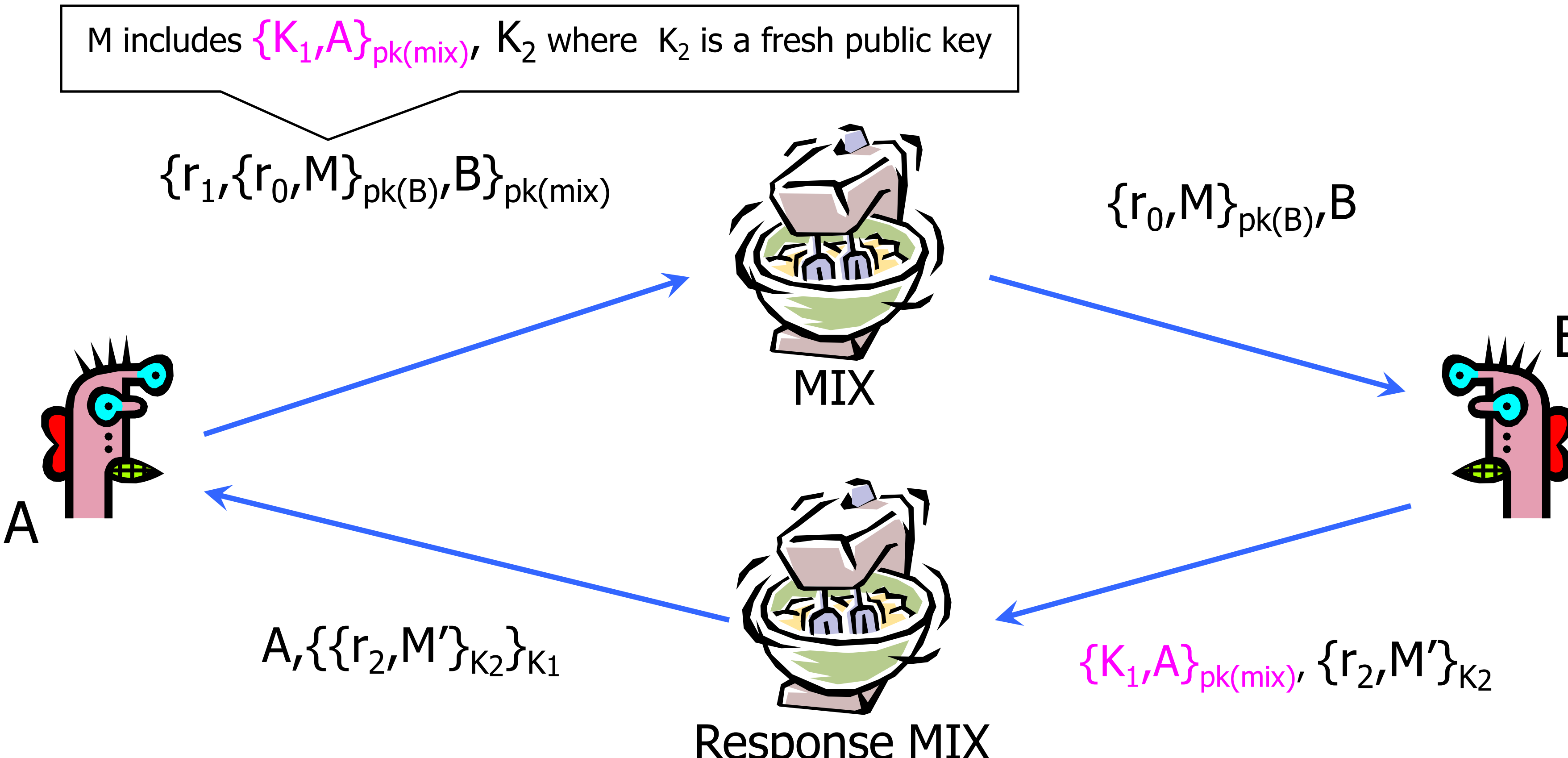
- Public key crypto + trusted re-mailer (Mix)
  - Untrusted communication medium
  - Public keys used as persistent pseudonyms
- Many modern anonymity systems use Mix as the basic building block

# Basic Mix Design



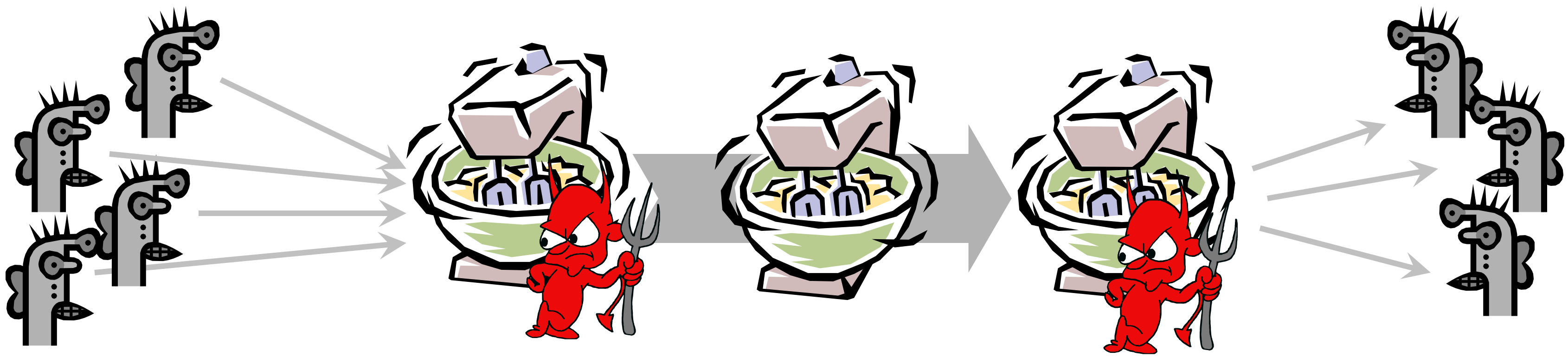

Adversary knows all senders and all receivers, but cannot link a sent message with a received message

# Anonymous Return Addresses



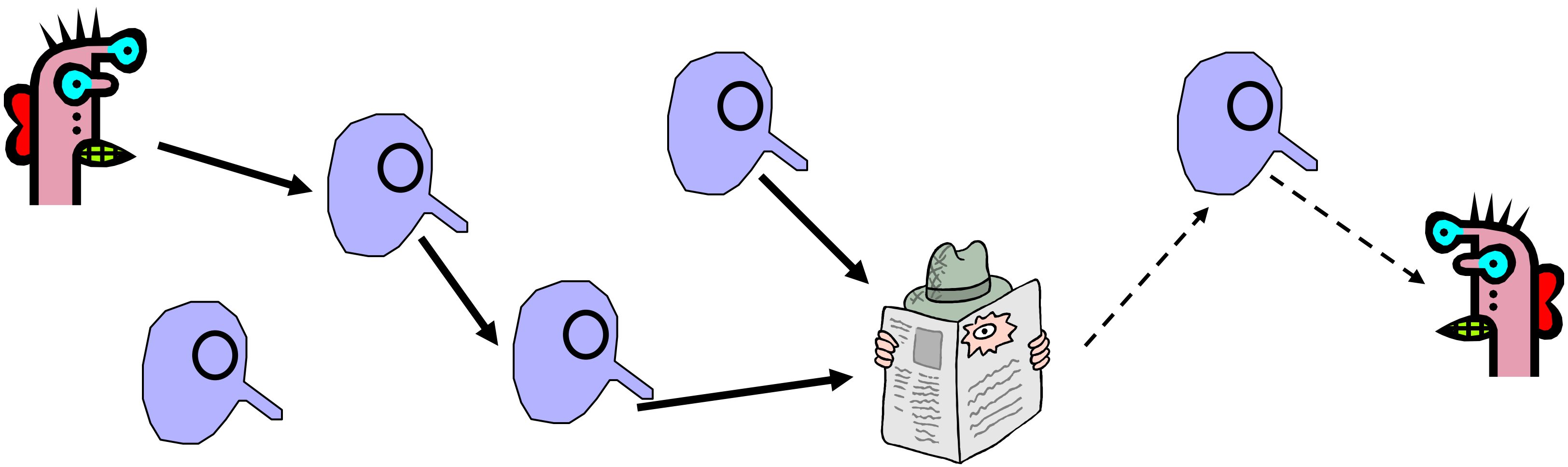

Secrecy without authentication
(good for an online confession service ☺)

# Mix 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

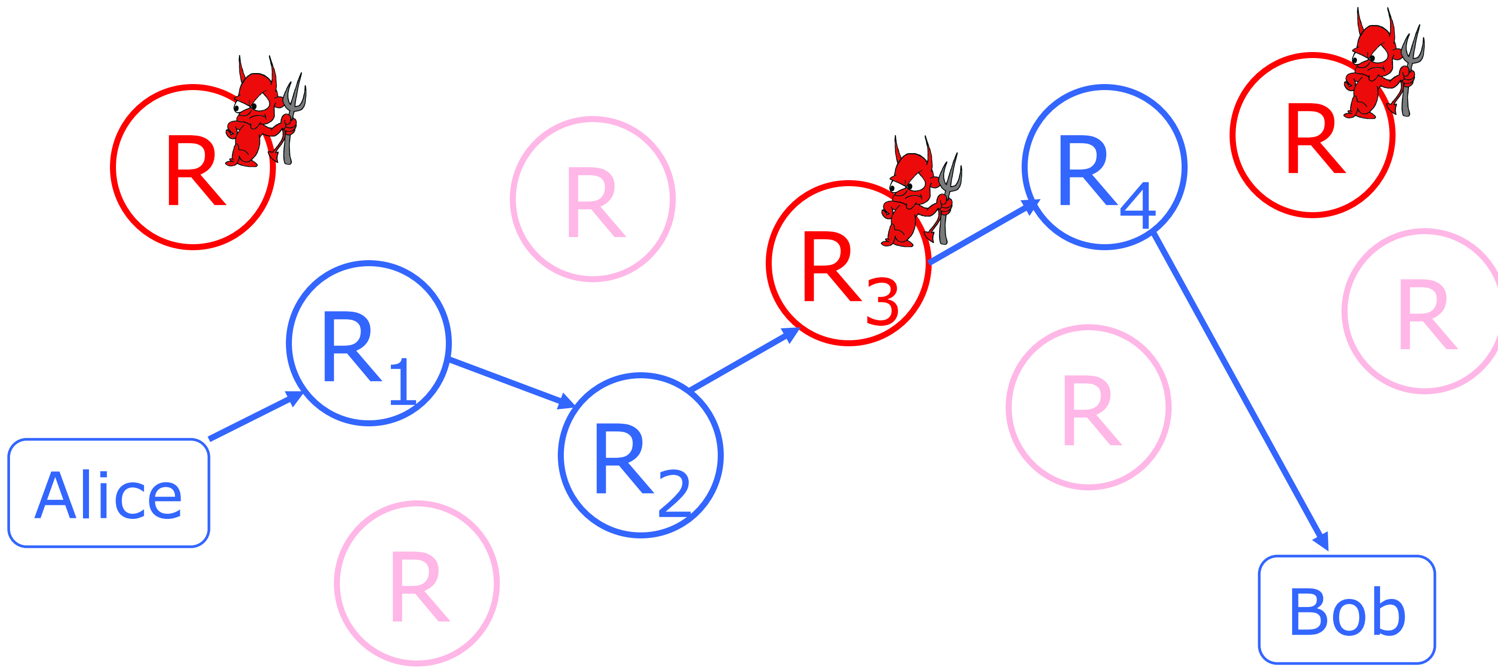
# Randomized Routing



- 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

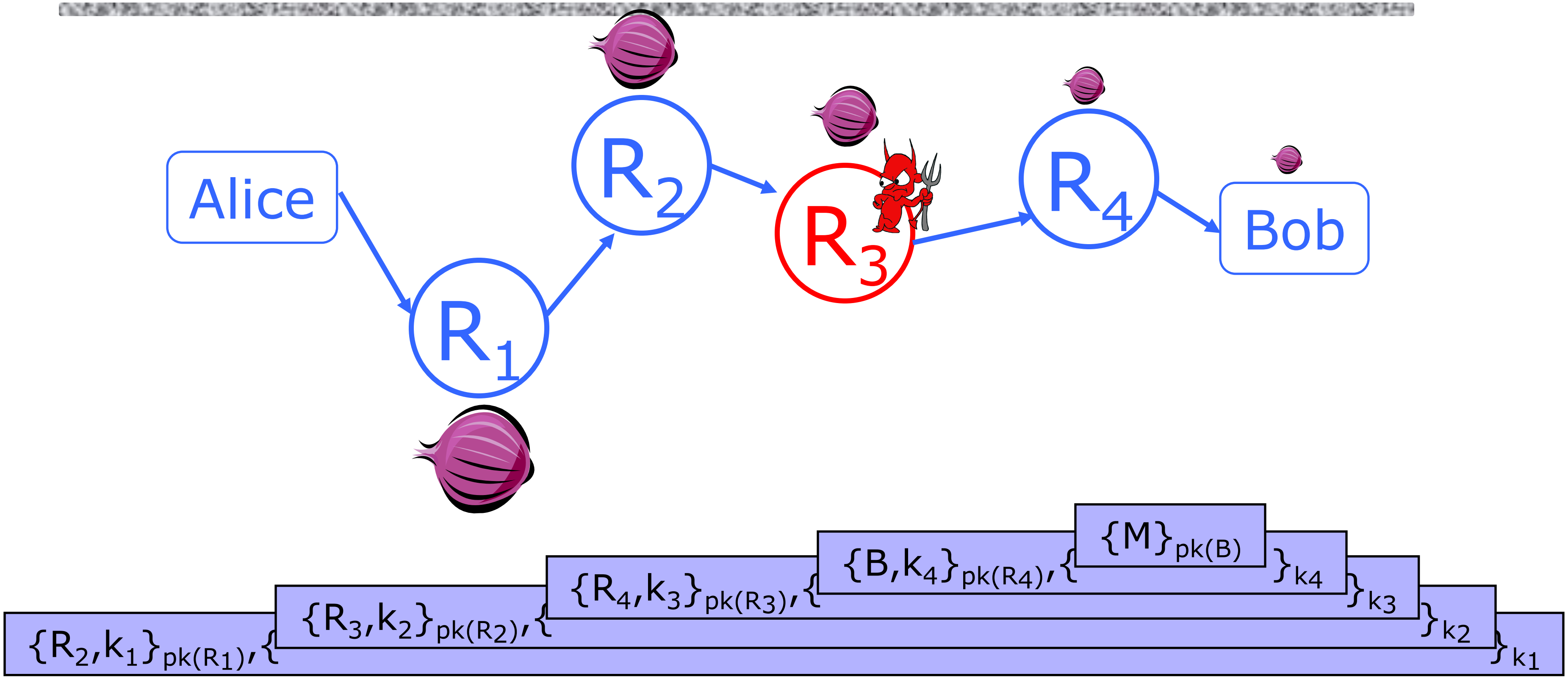
# Onion Routing

[Reed, Syverson, Goldschlag 1997]




- Sender chooses a sequence of routers
  - Some may be 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

- 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
  - Use public-key cryptography to establish a “circuit” with pairwise symmetric keys between hops on the circuit
  - Then use symmetric decryption and re-encryption to move data messages along the established circuits
  - Each node behaves like a mix; anonymity is preserved even if some nodes are compromised

R. Dingledine, N. Mathewson, P. Syverson

# Tor:
# The Second-Generation Onion Router

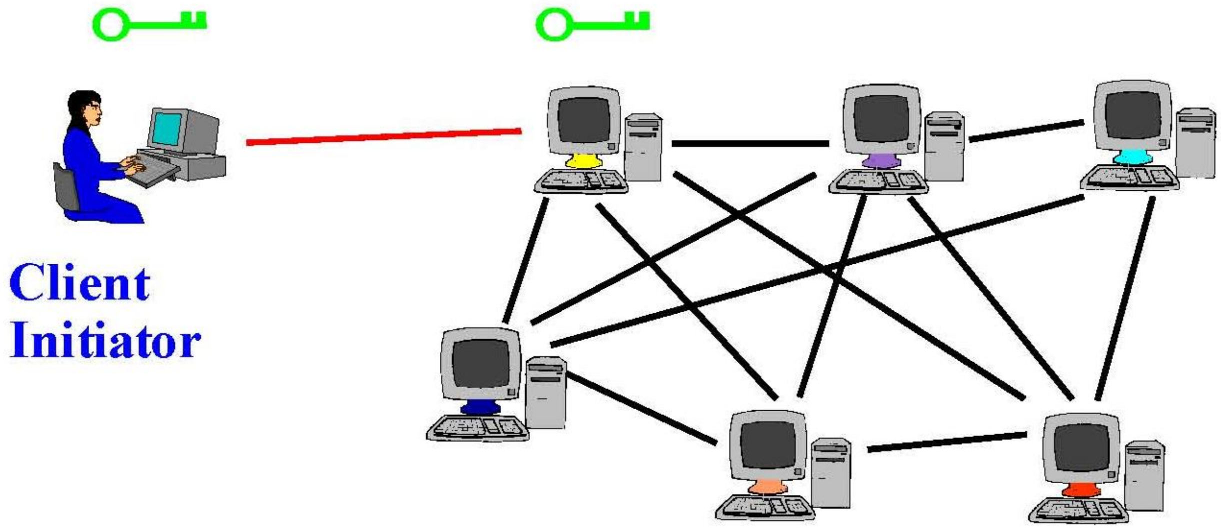
(USENIX Security 2004)

# Tor

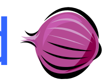
- Deployed onion routing network
  - http://torproject.org
  - Specifically designed for low-latency anonymous Internet communications
- Running since October 2003
  - Thousands of relay nodes, 100K-500K? of users
- Easy-to-use client proxy,
  integrated Web browser

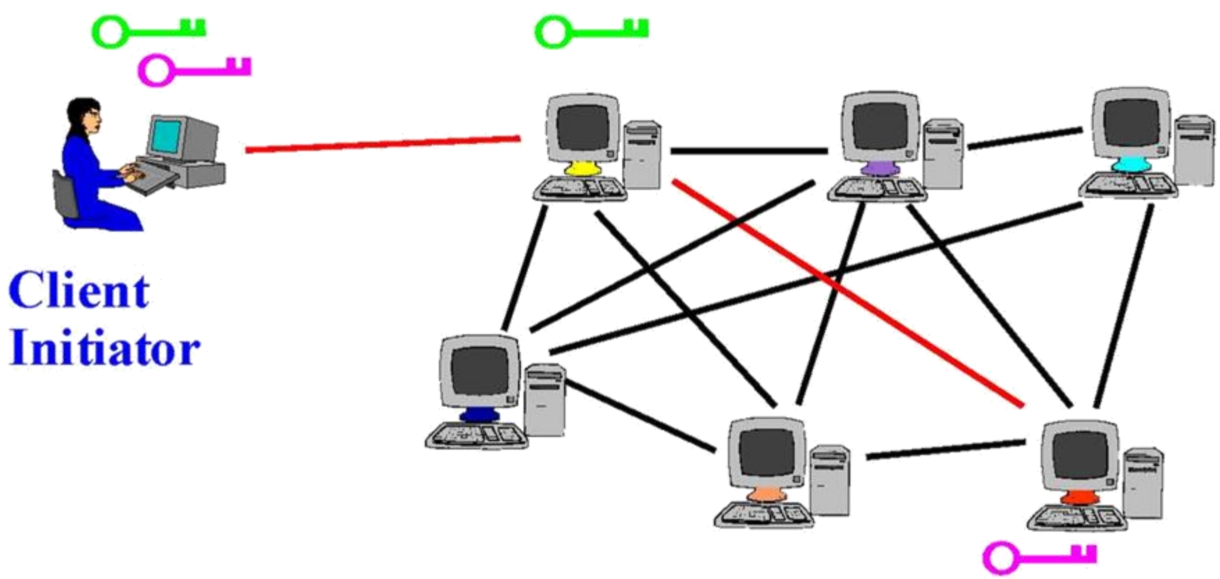
# Tor Circuit Setup (1)

- Client proxy establish a symmetric session key and circuit with relay node #1



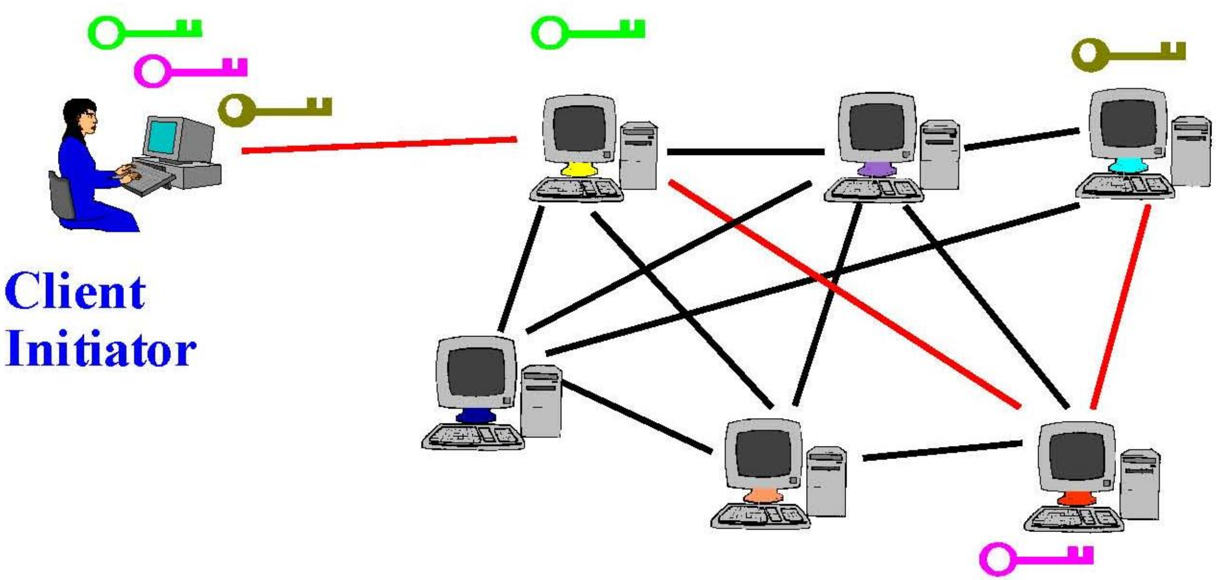
# Tor Circuit Setup (2)

- Client proxy extends the circuit by establishing a symmetric session key with relay node #2
  - Tunnel through relay node #1 - don't need  !



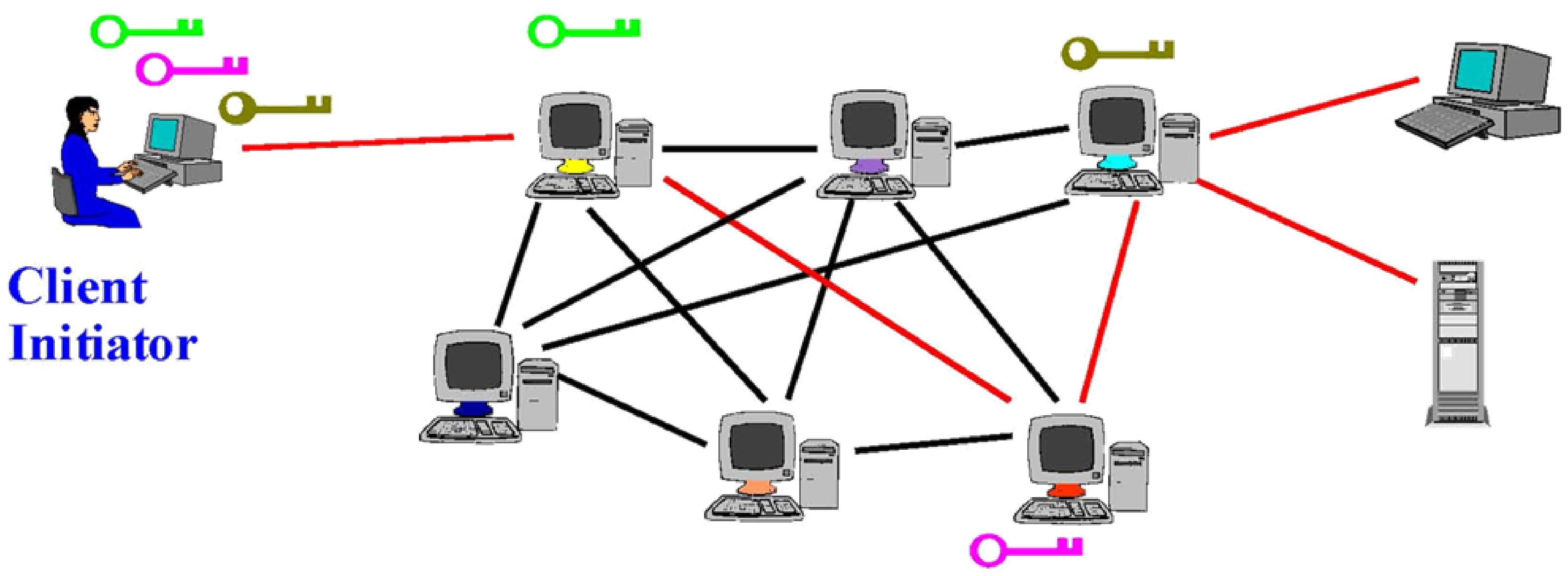
# Tor Circuit Setup (3)

- Client proxy extends the circuit by establishing a symmetric session key with relay node #3
  - Tunnel through relay nodes #1 and #2



# Using a Tor Circuit

- Client applications connect and communicate over the established Tor circuit
  - Datagrams decrypted and re-encrypted at each link



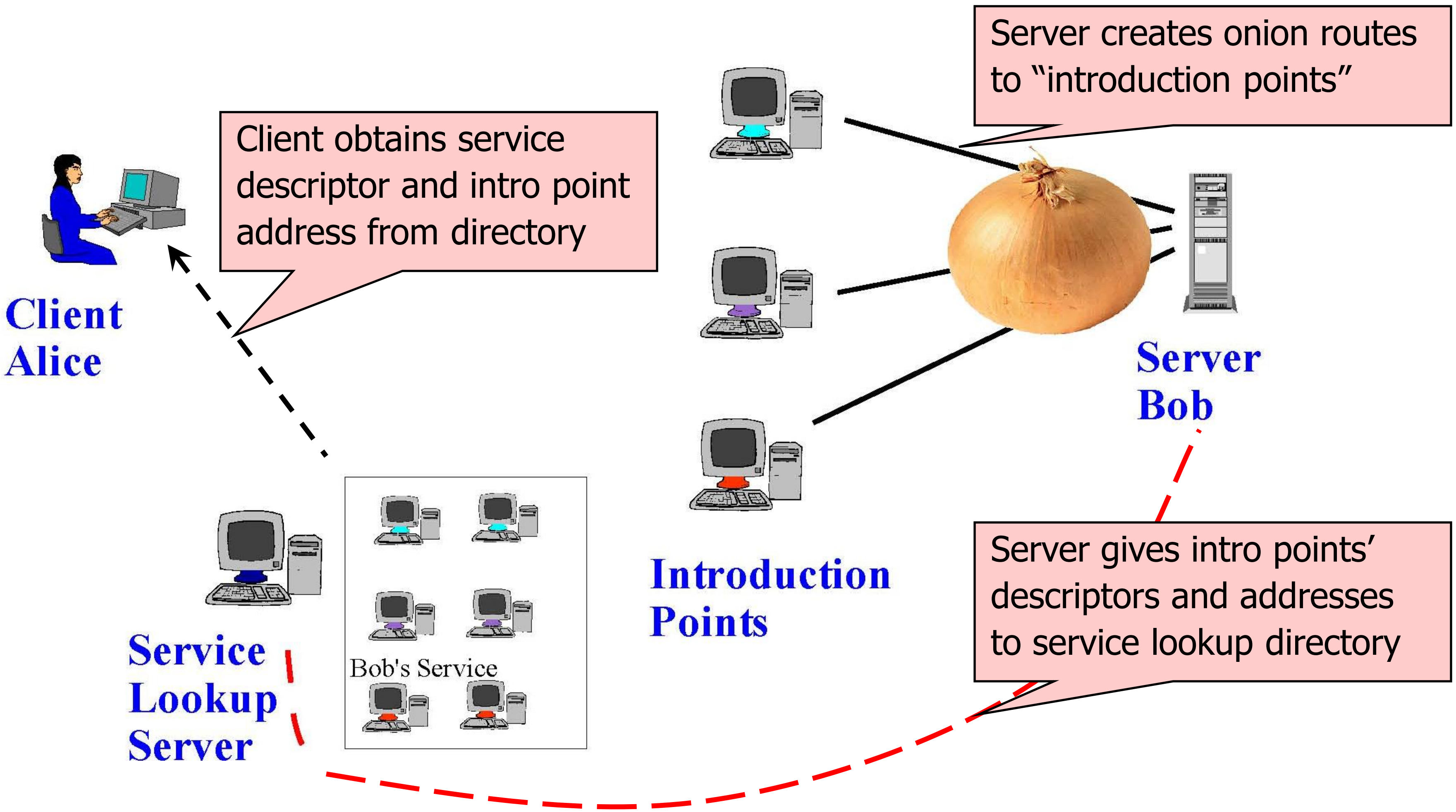
# Using Tor

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

# Hidden Services

- 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, denial of service, physical attack
  - Network address of the server is hidden, thus can't find the physical server

# Creating a Location Hidden Server



# Using a Location Hidden Server