Android and Anonymity

Tadayoshi Kohno

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Goals for Today

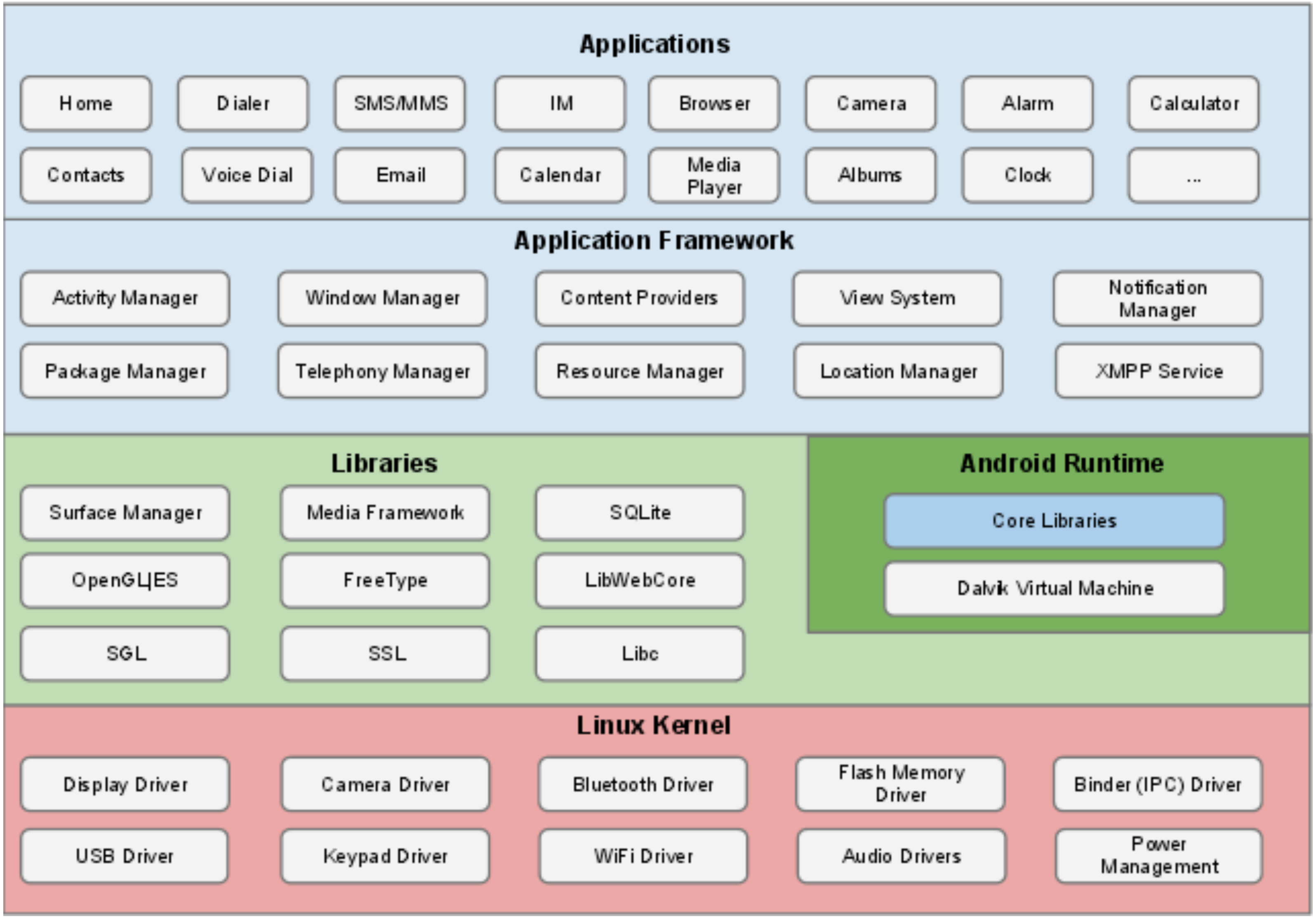
- Lab 3 discussion
- Android
- Anonymity

- HW 3 now out (due Friday)
- Lab 3 out just now

Mobile Device Security (Android)

- Android
  - Based on Linux
  - Layers:
    - Android Application Runtime (generally written in Java, run in the Dalvik virtual machine; sometimes native applications or native libraries)
    - Android OS
    - Device Hardware
  - Applications
    - Pre-installed
    - User-installed
      - Via app stores
      - Via over the air (OTA) updates.

Android Software Stack



http://source.android.com/tech/security/index.html

Application Sandboxes

- Based on Linux: Has clear notion of users and permissions
- Each application
  - Assigns unique user ID (UID)
  - Runs as that user in a separate process
  - **Different than traditional operating systems** where multiple applications run with the same user permissions

Application Sandboxes (II)

- Desktop browser sandbox: language specific
- Android sandbox: baked into the OS, via the kernel
  - No restriction on how applications are written
  - Native code
  - Java code
- Conventional systems: memory corruption errors lead to complete compromise
- Android: memory corruption errors only lead to arbitrary code execution in the context of the **particular** compromised application
- (Can still escape sandbox -- but must compromise Linux kernel to do so)

File permissions

- Files written by one application cannot be read by other applications
  - Not true for files stored on the SD card
- It is possible to do full filesystem encryption
  - Key = Password combined with salt, hashed with SHA1 using PBKDF2.

Memory Management

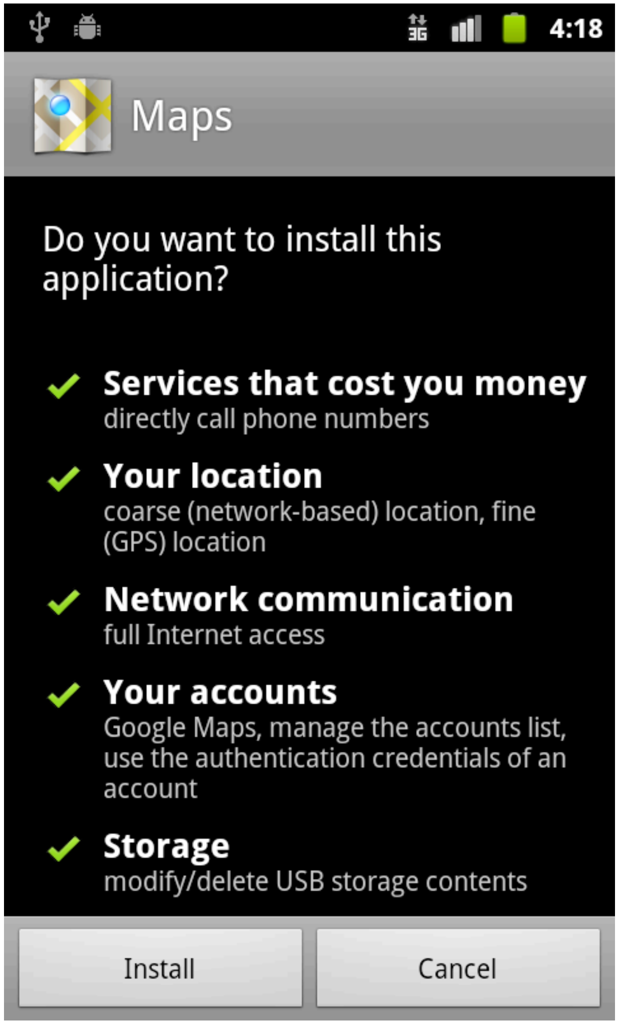
- Address Space Layout Randomization to randomize addresses on stack
- Hardware-based No eXecute (NX) to prevent code execution on stack/heap
- Stack guard derivative
- Some defenses against double free bugs (based on OpenBSD's dmalloc() function)
- …
- (See http://source.android.com/tech/security/index.html)

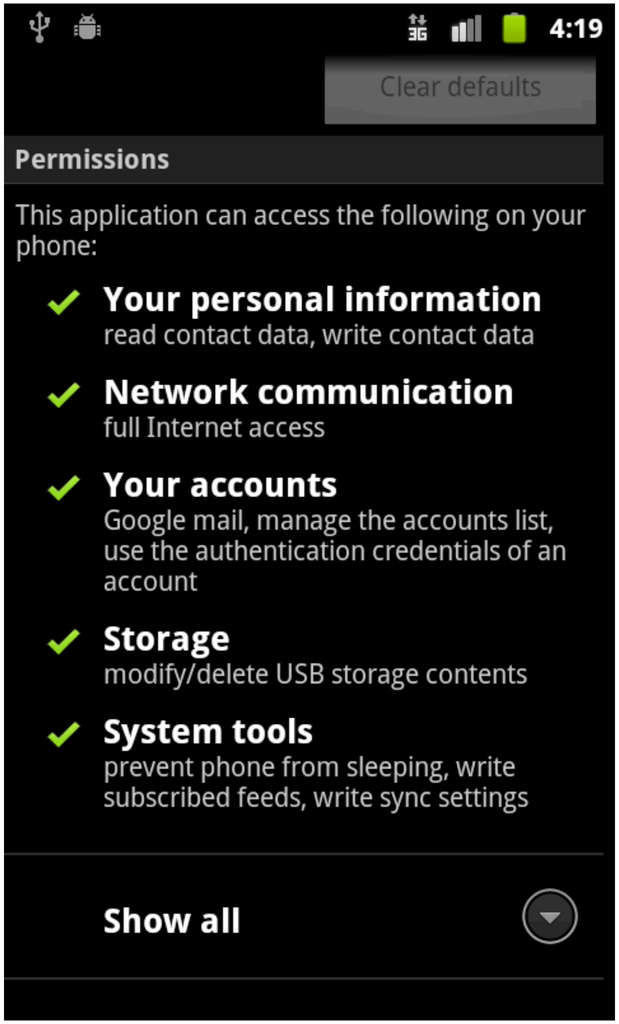
Applications

- Activity: Code for single, user-focused task
- Services: Code that runs in the background
- Broadcast Receiver: Receive Intents (messages from other applications)

- AndroidManifest.xml
  - Overall information about application (activities, services, ...)
  - Also specifies which **permissions** are required by applications

Permissions / Manifests





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Permissions

- Example permissions
  - Camera
  - Location (GPS)
  - Bluetooth
  - SMS functions
  - Network capabilities
- Cannot grant / deny individual permissions
- Once accepted, users not notified of permissions again
- Security exception thrown if attempt to access resource not declared in manifest

Obtaining User Consent for Permissions

- General options:
  - At install time (manifests)
  - At time of use (prompts)
- Why manifests
  - Users are evaluating the application, the developers, etc, to see if they want the app
  - Prompts slow down user; hinder user experience
  - Users may just say "OK" to all dialogs without reading them
- Why prompts
  - At time of resource access
  - Opportunity for user to be more in control of actual resource use (app with GPS permissions should only actually access the GPS when the user wishes -- but can't tell with manifest model)
- (Alternative: User-driven access control, Roesner et al (2012))

Application Signing

- Apps are signed
  - Often with self-signed certificates
- Signed application certificate defines which user ID is associated with which applications
  - Different apps run under different UIDs
- Shared UID feature
  - Shared Application Sandbox possible, where two or more apps signed with same developer key can declare a shared UID in their manifest

Shared UIDs

- App 1: Requests GPS / camera access
- App 2: Requests Network capabilities

- Generally:
  - First app can’t exfiltrate information
  - Second app can’t exfiltrate anything interesting
- With Shared UIDs (signed with same private key)
  - Permissions are a superset of permissions for each app
  - App 1 can now exfiltrate; App 2 can now access GPS / camera

Questions

- Q1: How might malware authors get malware onto phones?
- Q2: What are some goals that mobile device malware authors might have?
- Q3: What technical things might malware authors do?

Malware

- Legitimacy of apps
  - Self-signing means that signers can claim to be whoever they wish
- Installation vector
  - (Seems to be) "drive-by-downloads" and exploits for infection, and more social engineering (tricking users to install)
  - E.g., "sideloading" sites: distribute pirated versions of popular applications, which can be decompiled and modified to include malicious behavior
  - Utilities, games, adult-oriented apps [Lookout Mobile Threat Report, August 2011]

Malware techniques

- Add background Service
- Modify existing application source code
- Component library replacement

- To avoid basic signature detection:
  - Dynamically download new Dalvik bytecode
  - Use DexClassLoader API to run the downloaded code

- Use exploit to obtain root access
- Many other techniques

Malware Functions

- Make a profit
  - Premium number dialers
  - Aggressive adware
  - Data collection (obtain personally-identifiable information that can be sold)
  - Banking trojans (e.g., FakeToken.A to bypass two-factor authentication)
- Bot clients (phone have limited resources, so more useful as a mechanisms to support other goals, e.g., later targeted data collection)
  - Internet C&C
  - SMS C&C
- Privileged Operations Trojans (obtain root)
- Disruptive Trojans (denial of service, destroy data)
  - Not stealthy; no profit

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 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

Questions

- Q1: Why might people want anonymity on the Internet?

- Q2: Why might people **not** want anonymity on the Internet?

Questions

- Q1: How might one go about trying to obtain anonymity? What technical approaches might we use?
- Q2: How might one go about trying to violate someone else's anonymity?

Applications of Anonymity

- 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!
    - Big difference between anonymity and confidentiality
  - Hide your activities among others' similar activities
- Unlinkability of action and identity
  - For example, sender and the email he or she sends are no more related after observing communication than they were before
- Unobservability (hard to achieve)

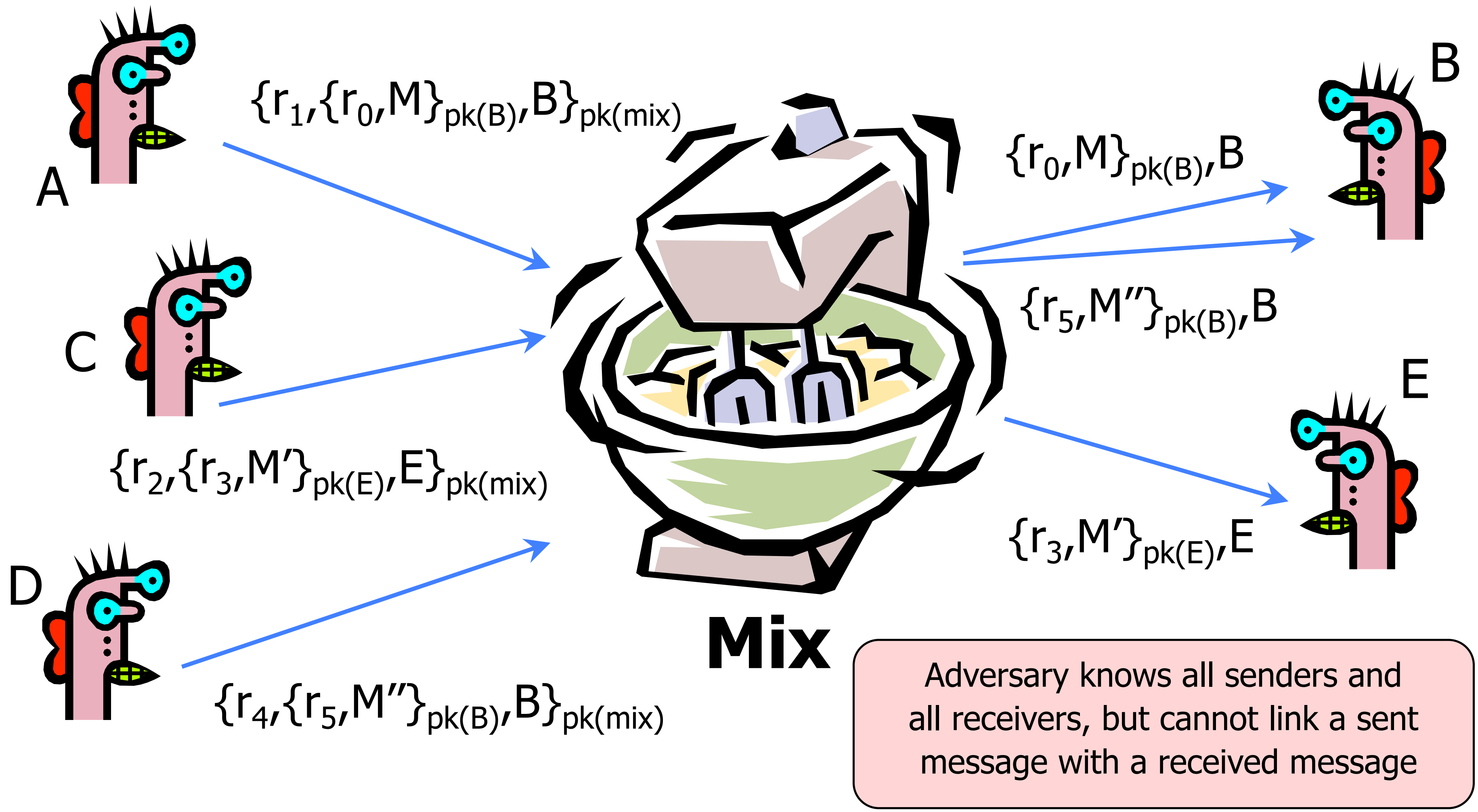
Chaum's Mix

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

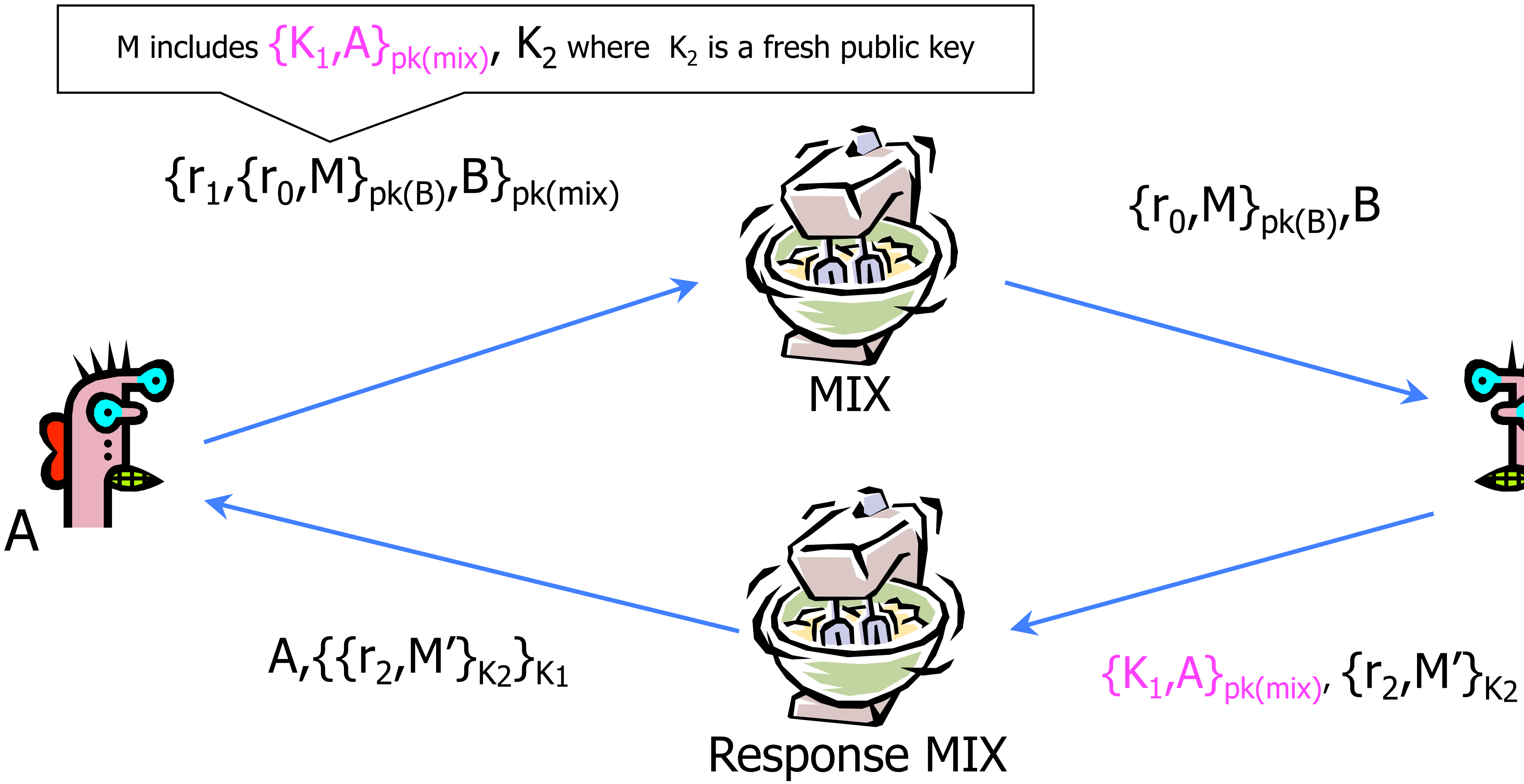
Before spam, people thought anonymous email was a good idea ☺

- 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

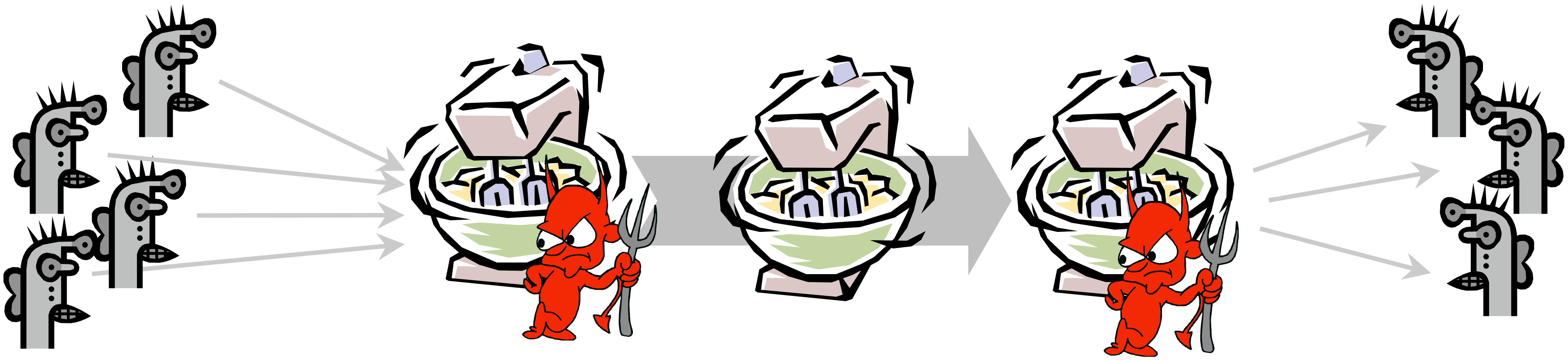
Basic Mix Design



Anonymous Return Addresses



Mix Cascade

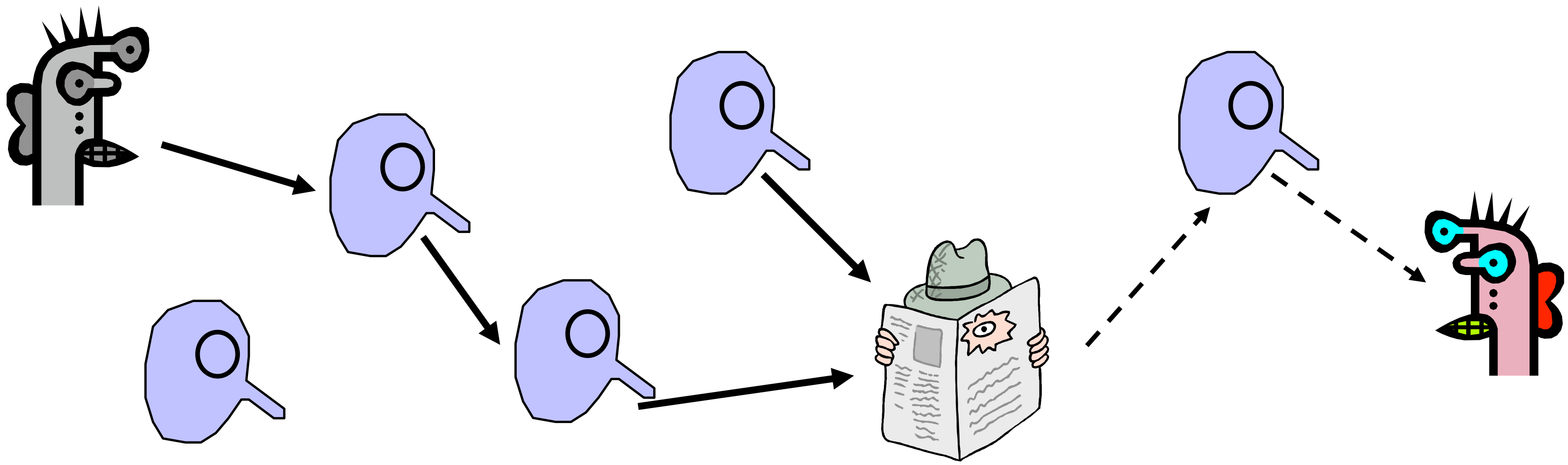


- Messages are sent through a sequence of mixes
  - Can also form an arbitrary network of mixes ("mixnet")
- Some of the mixes may be controlled by attacker, but even a single good mix guarantees anonymity
- Pad and buffer traffic to foil correlation attacks

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

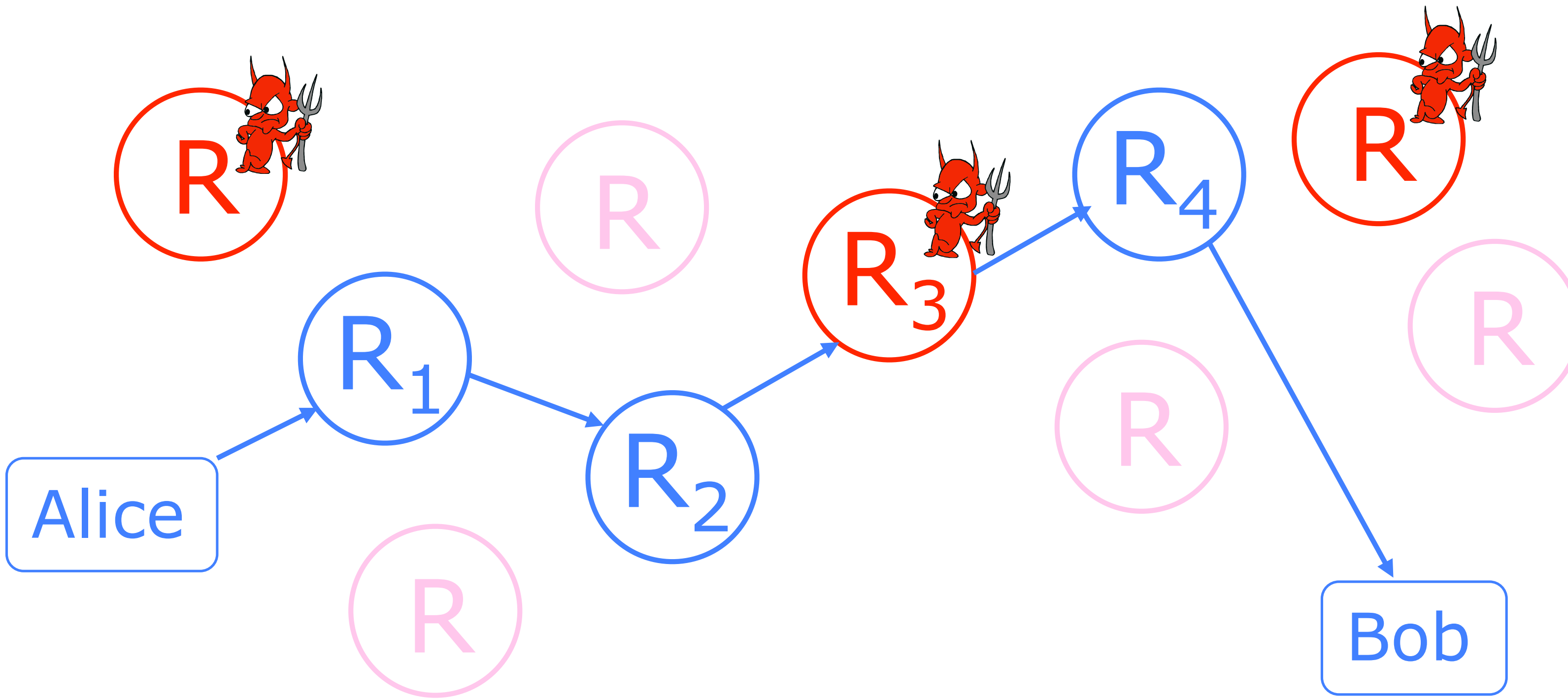
Another Idea: Randomized Routing



- 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

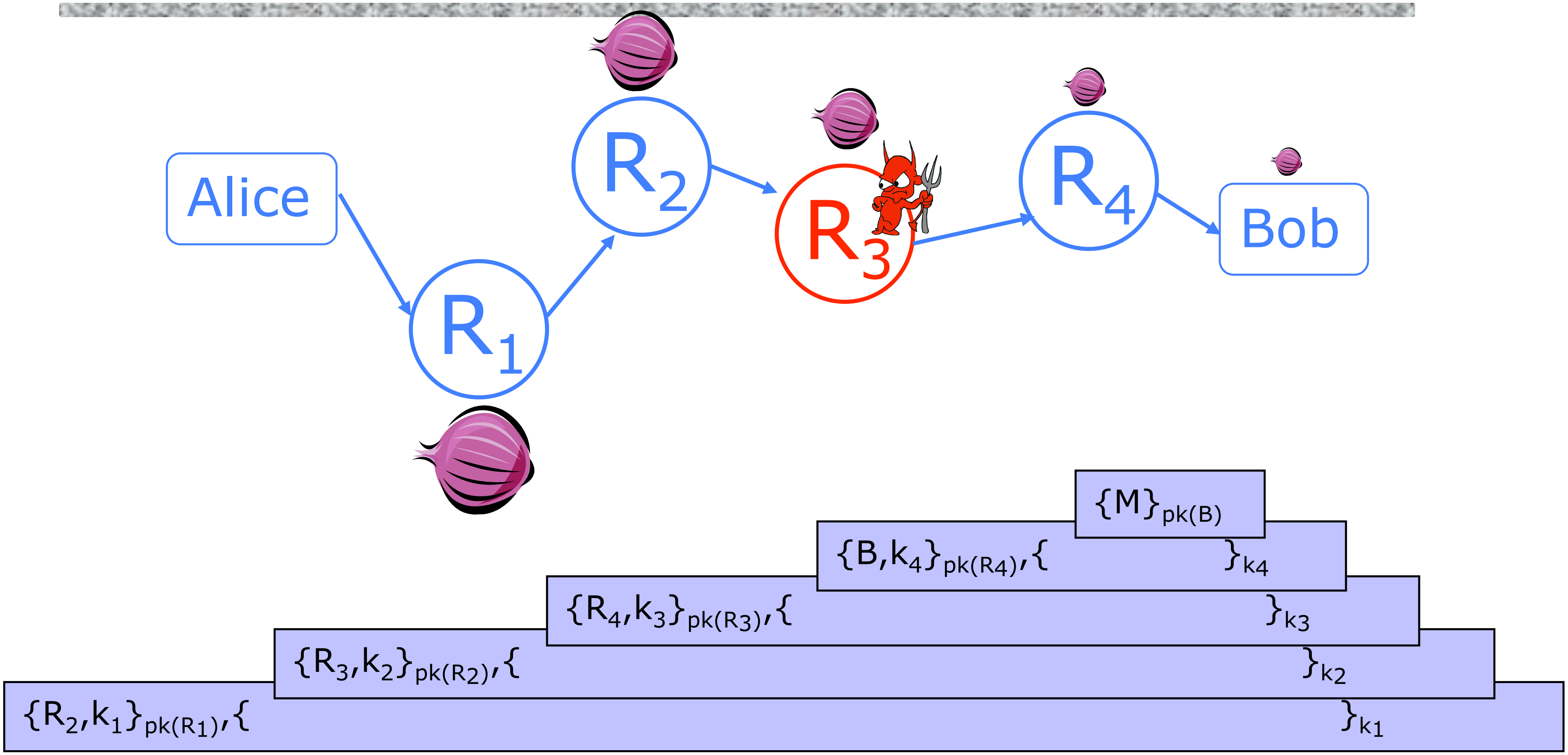
Onion Routing

[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



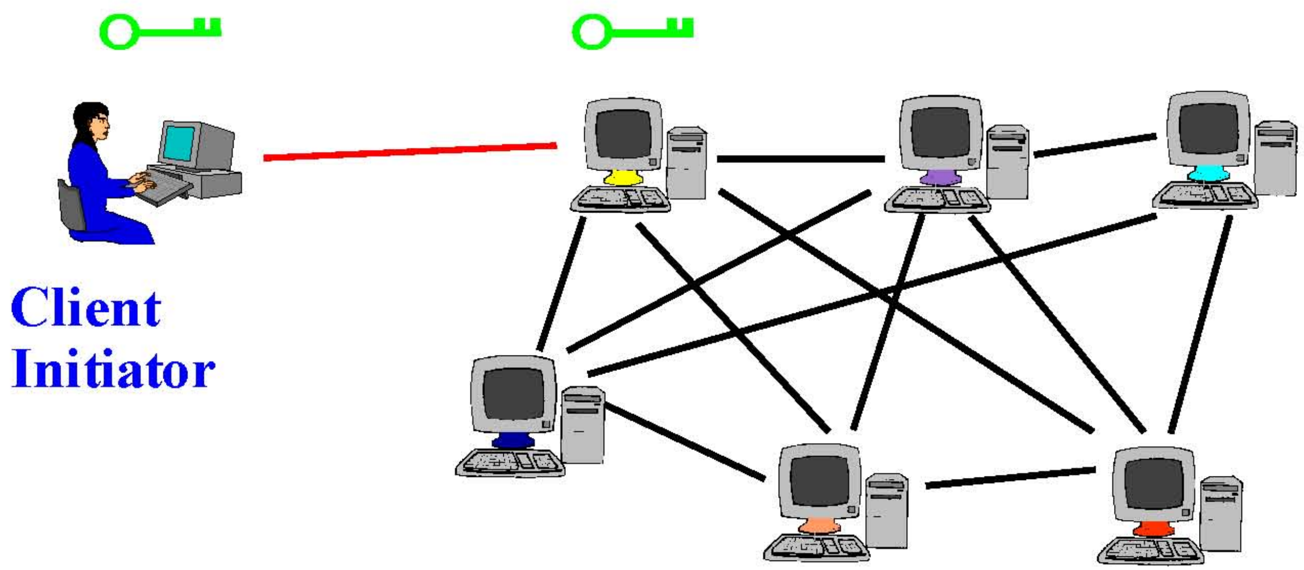
- Routing info for each link encrypted with router's public key
- Each router learns only the identity of the next router

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

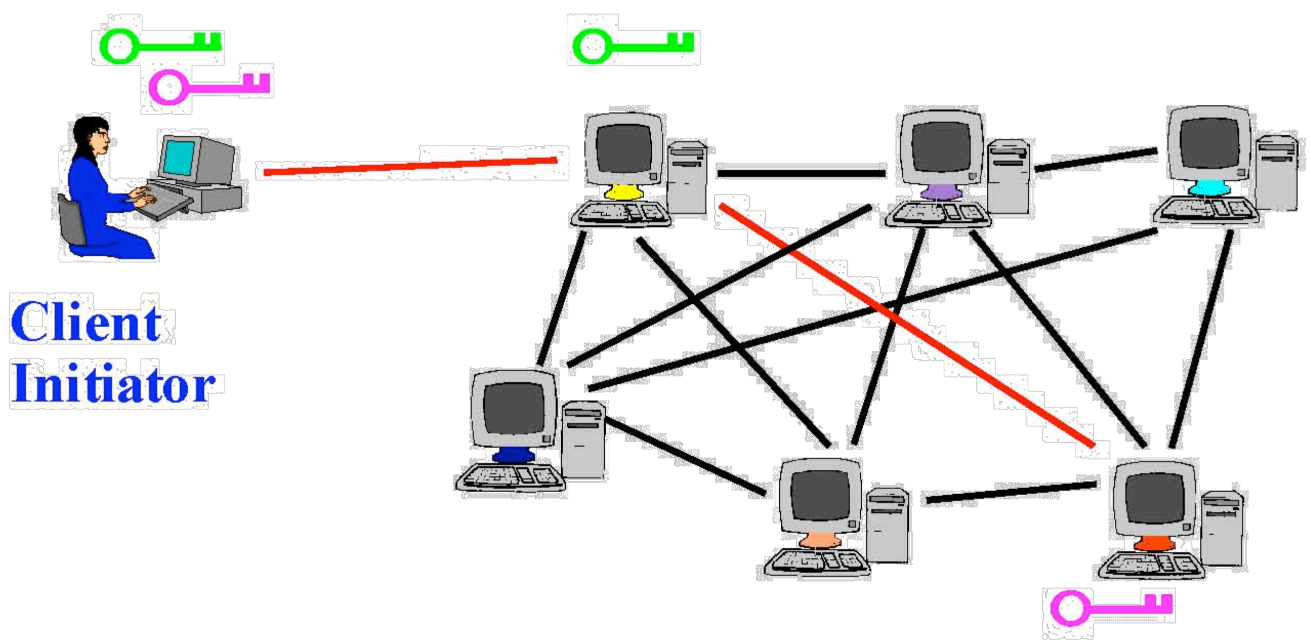
Tor Circuit Setup (1)

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



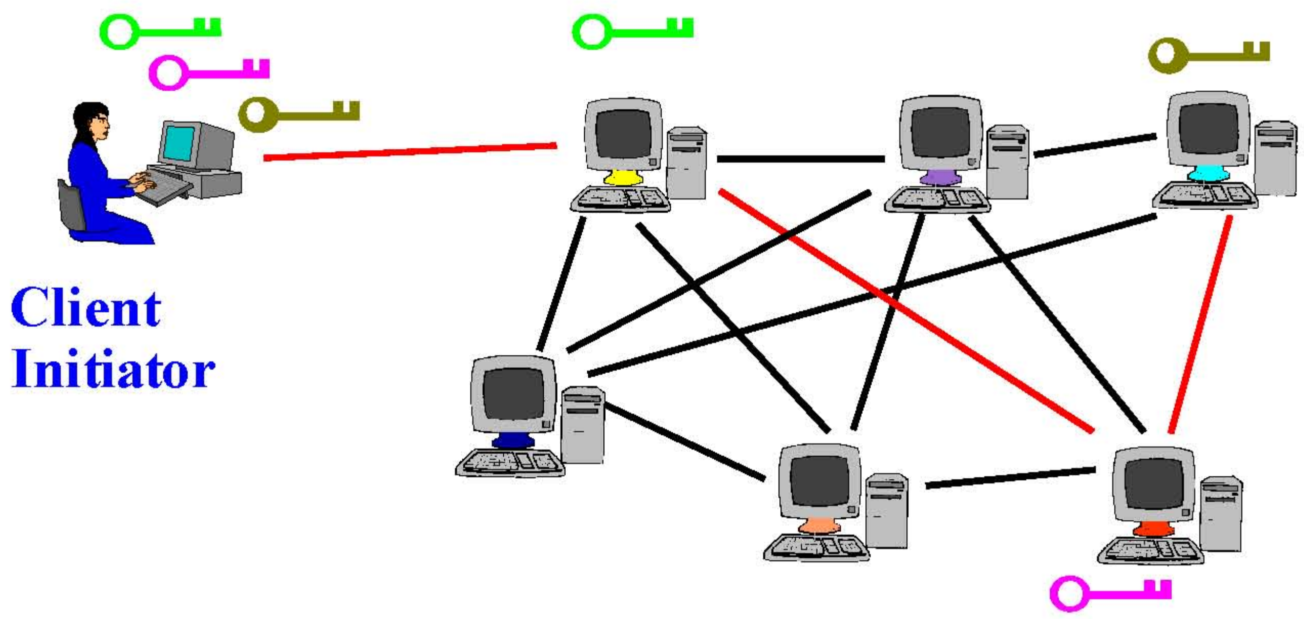
Tor Circuit Setup (2)

- Client proxy extends the circuit by establishing a symmetric session key with Onion Router #2
  - Tunnel through Onion Router #1 (don't need



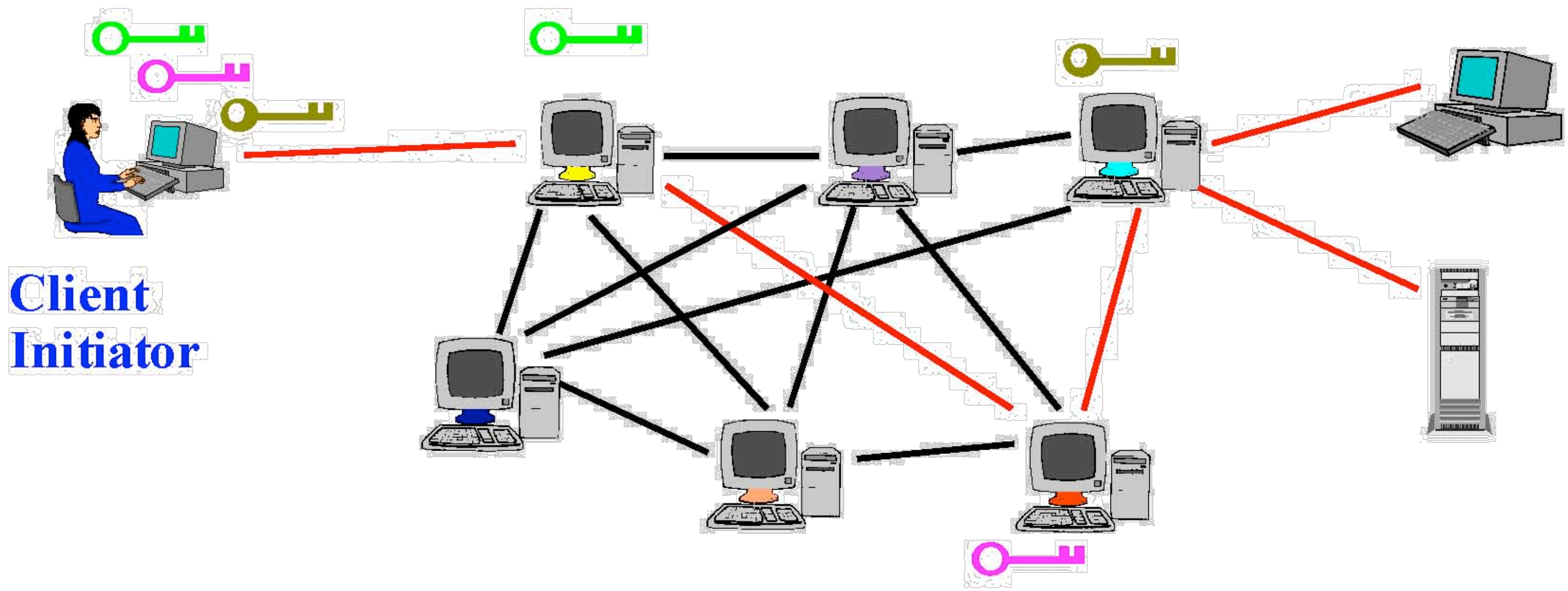
Tor Circuit Setup (3)

- 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



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

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

Deployed Anonymity Systems

- 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

Some caution

- Tor isn't completely effective by itself
  - Challenges if you have cookies turned on in your browser, are using JavaScript, etc.
  - Exit nodes can see everything!