

# A Peel of Onion



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“Our motivation here is not to provide anonymous communication, but to separate identification from routing.”

- “Proxies for anonymous routing”. Reed, Syverson, and Goldschlag. ACSAC 1996

# A Motivational Use Case Example

- Navy Petty Officer Alice is temporarily in Repressia



# Level I Training System ANTTERRORISM



- AT FUNDAMENTALS
- Surveillance Detection
- Government Facility
- Active Shooter
- Residential
- Off-Duty Activities
- Air Travel
- Ground Travel
- Hotel
- Hostage Survival
- CBRNE

## Don't be a Target



Items that display your DOD affiliation may also help identify you as a potential target.

Not all threats are predictable or can be recognized in advance. As a result, you should concentrate on not being an easy target for attack.

Reduce your exposure by being anonymous and blending in with your surroundings.

- Do not wear clothing or carry items that might attract criminal attention
- Remain low key and do not draw attention to yourself
- Avoid places of high criminal activity

In addition to blending in, try to reduce your vulnerability and exposure:

- Select places with security measures appropriate for the local threat
- Be unpredictable and vary your routes and times of travel
- Travel with a friend or in a small group
- Use automobiles and residences with adequate security features

You can greatly increase your personal protection posture by remaining anonymous and reducing your exposure.

*Select Next to continue.*



Anticipate



Be Vigilant



Don't be a Target



Respond & Report

# A Motivational Use Case Example

- Safe back in her room at the Repressia Grand Hotel, PO Alice wants to read and/or post to [sealiftcommand.com](http://sealiftcommand.com)



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SEALIFT  
COMMAND**

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MARITIME EMPLOYMENT RESOURCES

START THE PROCESS

CONTACT US

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[Please download Adobe Flash Player.](#)

## NEWS AND ANNOUNCEMENTS

### Military Sealift Command Accepts Navy's Newest Ship, USNS William McLean

SAN DIEGO (NNS) — Military Sealift Command accepted delivery of dry cargo/ammunition ship USNS William McLean (T-AKE 12) during a ceremony at the General Dynamics NASSCO shipyard in San Diego Sept. 28. The 689-foot long McLean, designated T-AKE 12, is the 12th of 14 new [Read More →](#)

## LET'S TALK JOBS

Career Fairs RSS. [View all career fairs→](#)

- 11.03.11** **MSC Career Fair**  
San Francisco, CA | 9:30AM - 1:30PM
- 11.03.11** **MSC Career Fair – MILITARY ONLY**  
Millington, TN | 11AM - 3PM
- 11.03.11** **MSC Career Fair**  
Pensacola, FL | 11AM - 3PM
- 11.09.11** **Hire a Vet Career Fair**  
Raleigh, NC | 10AM - 3PM
- 11.10.11** **Recruit Military Veterans Expo**  
Miami, FL | 11AM - 3PM

## NOW HIRING

Now Hiring RSS. [View all open positions→](#)

-  **Able Seaman**  
Announcement open 1 November through 30 November 2011.
-  **Medical Services Officer**  
Announcement open 3 October 2011, with periodic cut-offs.
-  **Second Cook**  
Announcement open 5 October 2011, with periodic cut-offs.

## GETTING STARTED

Resources to help you take command of your career.

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-  **Maritime School Graduates**
-  **Entry Level/Skilled Laborers**



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# A Motivational Use Case Example



Navy PO Alice  
in her hotel





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# Connecting when overseas



Navy PO Alice  
in her hotel



Contacted:  
sealiftcommand.com  
05/06/2014, 9PM,  
20 min, encrypted



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Navy PO Alice  
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Contacted:  
sealiftcommand.com  
05/06/2014, 9PM,  
20 min, encrypted  
Rm: 416  
Ckout on:  
05/08/2014



# Security of operations concern as well as personnel security concern



Navy PO Alice  
in her hotel



Contacted:  
nrl.navy.mil  
05/06/2014, 9PM,  
20 min, encrypted  
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05/08/2014



# Some more government uses

- Open source intelligence gathering
- Sensitive communications with untrusted/untrusting parties
- Encouraging open communications with citizens
- Location protected servers for defense in depth
- Protecting the public infrastructure
  - Interacting with network sensors

# Ordinary citizen Alice

- Protecting her behavior from:
- Cyberstalking abusive ex-spouse
- Behavior tracking and DNS shenanigans from her ISP
- Misunderstanding from her employer when she investigates disease info for an ailing friend
- Harassment for blogging her views



## Facebook protest forces Israeli cheese price cuts

Posted 6/30/2011 9:29:01 AM |

JERUSALEM (AP) — A high-profile Facebook protest has scored a victory for consumers in Israel: Their threats of a boycott have forced dairy manufacturers to lower the price of cottage cheese by some 25%.

The two-week campaign drew more than 105,000 people to join a Facebook group vowing to boycott the Israeli staple until prices dropped. The campaign has touched a nerve among Israelis concerned about rising prices and eroding salaries.

spread to other fields: the price of gasoline, which is now over \$8 a gallon, and other food products have recently skyrocketed as well.

It also has highlighted the power of social media outlets in sparking change, with some comparing it to the revolutions taking place elsewhere in the [Middle East](#).

"True, this is not [Tahrir Square](#) yet, the cottage cheese rebellion did not require us to take any real action, just to press 'like' and skip the cottage cheese shelf in the supermarket," columnist Ben Caspit wrote in the Maariv daily, referring to the square that was the epicenter of the Egyptian uprising. "This was inaction, not action, and it demanded no real sacrifice."

The Facebook page of the cottage cheese boycott identifies organizers as regular

# It's not only about dissidents in faraway lands

-  Subscribe
-  Email Story
-  Print Story
-  Discuss Story

## Top StoryChat

- Jury finds in favor of officers in wrongful death case - 64 Comments

## News Choices

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-  Wireless
-  Text Alerts
-  RSS Feeds
-  News Archive

## HOME > BUSINESS

# Freedom of speech? ... better ask your boss

The First Amendment takes on a different role when applied to the workplace

By GARY HABER, *The News Journal*

Convinced you have freedom of speech at work? Think again.

Maybe you should ask the AstraZeneca pharmaceutical sales manager fired earlier this month for comments he reportedly made in a company newsletter comparing physicians' offices to "a big bucket of money."

Or, the Utah Web designer fired for observations about her job she posted on her personal blog.

Or, former Philadelphia Eagles wide receiver Terrell Owens, whose pointed criticism of the team and its quarterback got him suspended in 2005.

The First Amendment experts are quick to point out doesn't



The News Journal/HOWARD JOHNSON

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- Malicious parties watching her log into Club Penguin (and watching her mom logged into twitter from work)
- Spear phishers watching her log into her bank

# Officer Alice

- Setting up a sting operation:
  - as a collaborator
  - as a service provider
- Monitoring criminal activity online
- Encouraging anonymous tips

# Researcher/Reporter/Rights Worker Alice

- Gathering information while protecting sources
- Accessing information that is locally censored or monitored
- Reporting information that is locally censored or monitored

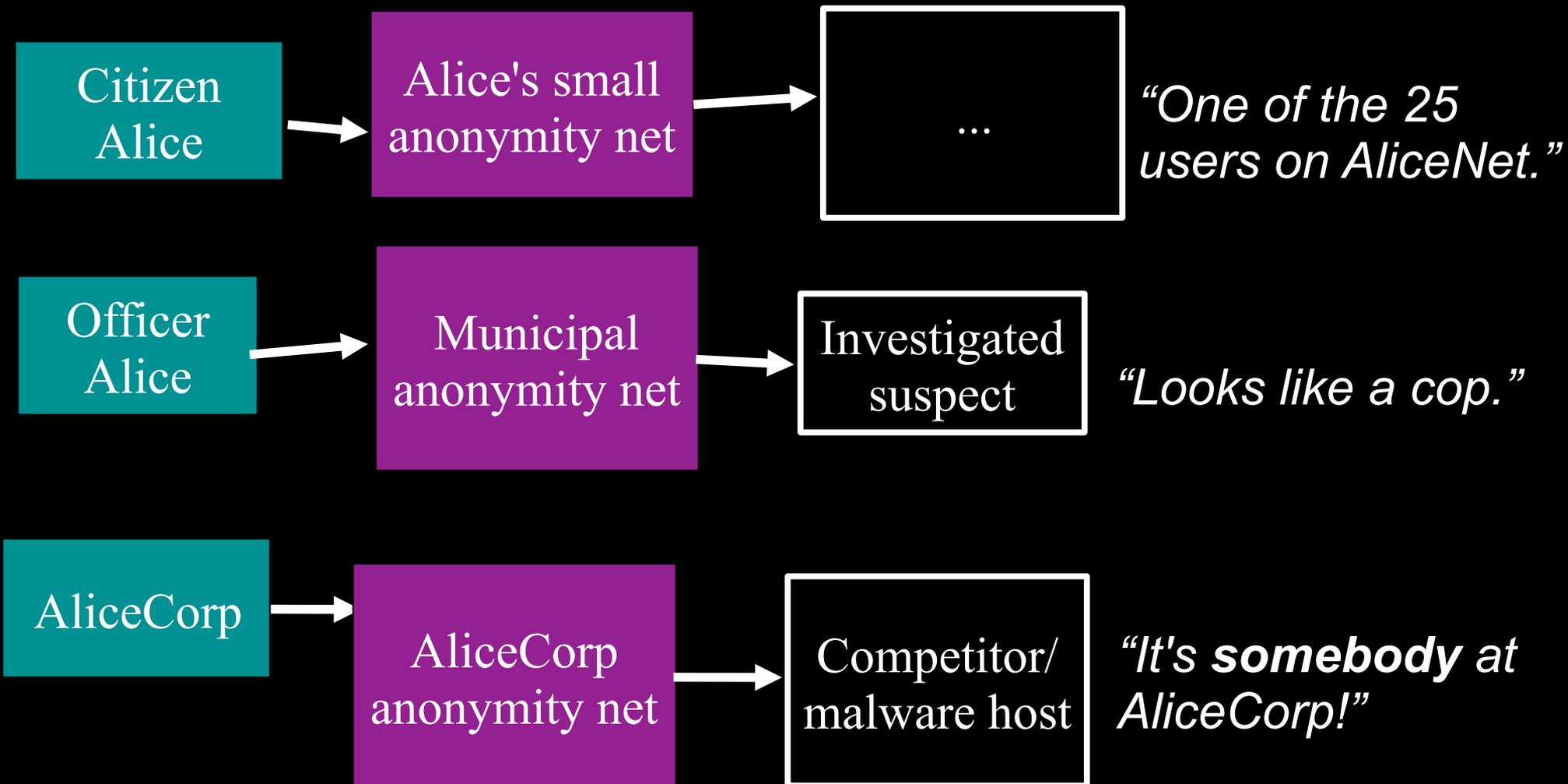
# Corporation Alice

- Investigating competitors' public sites
- Avoiding leaking strategy or nonpublic information
- Protecting customers
  - spearphishing
  - attacks or selective service disruption
  - privacy sensitivity

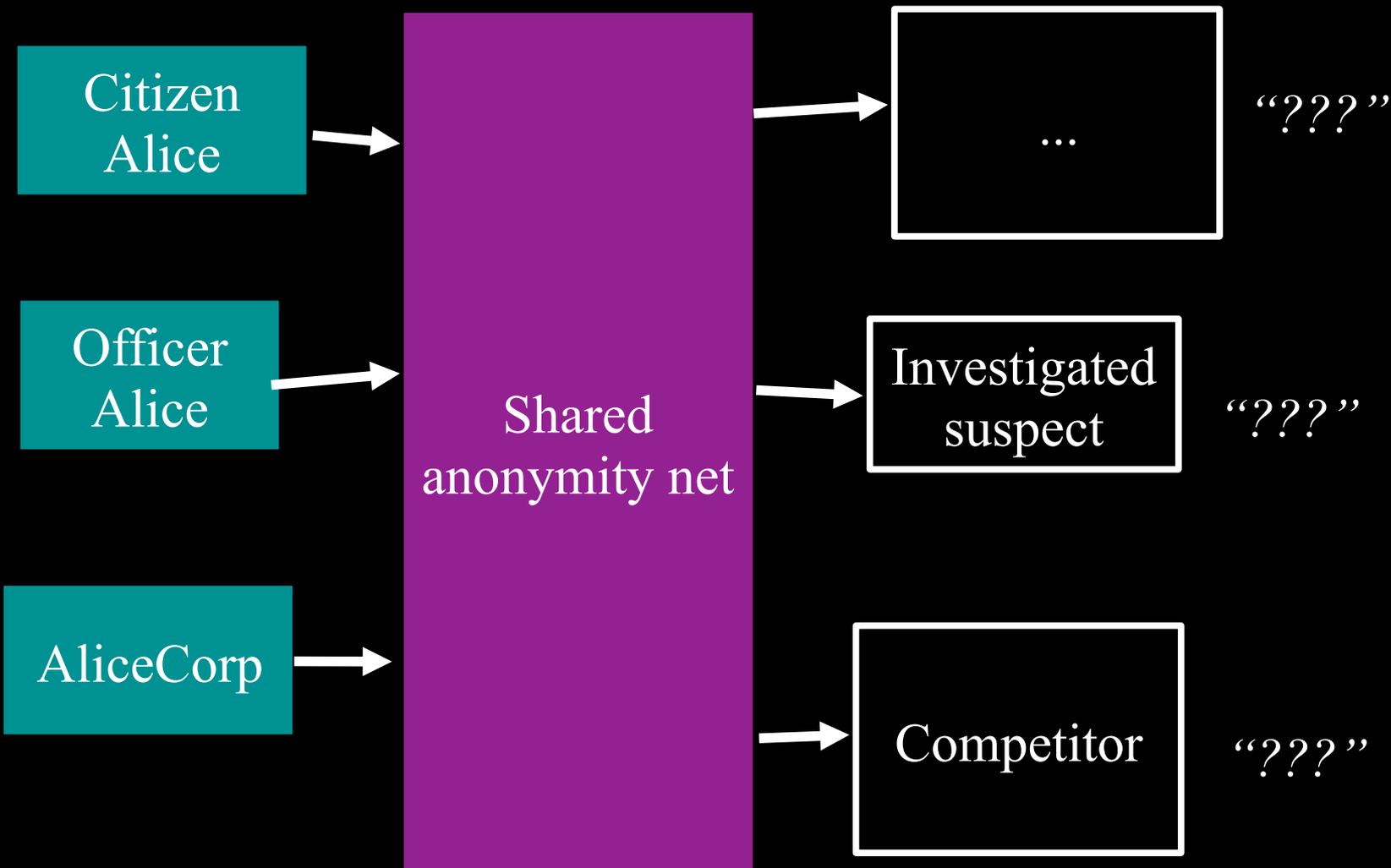
# Aside: some other benefits of an anonymity system

- Besides protecting affiliation, etc. can provide “poor man’s VPN”. Access to the internet despite
  - Network port policy disconnects
  - DNS failure

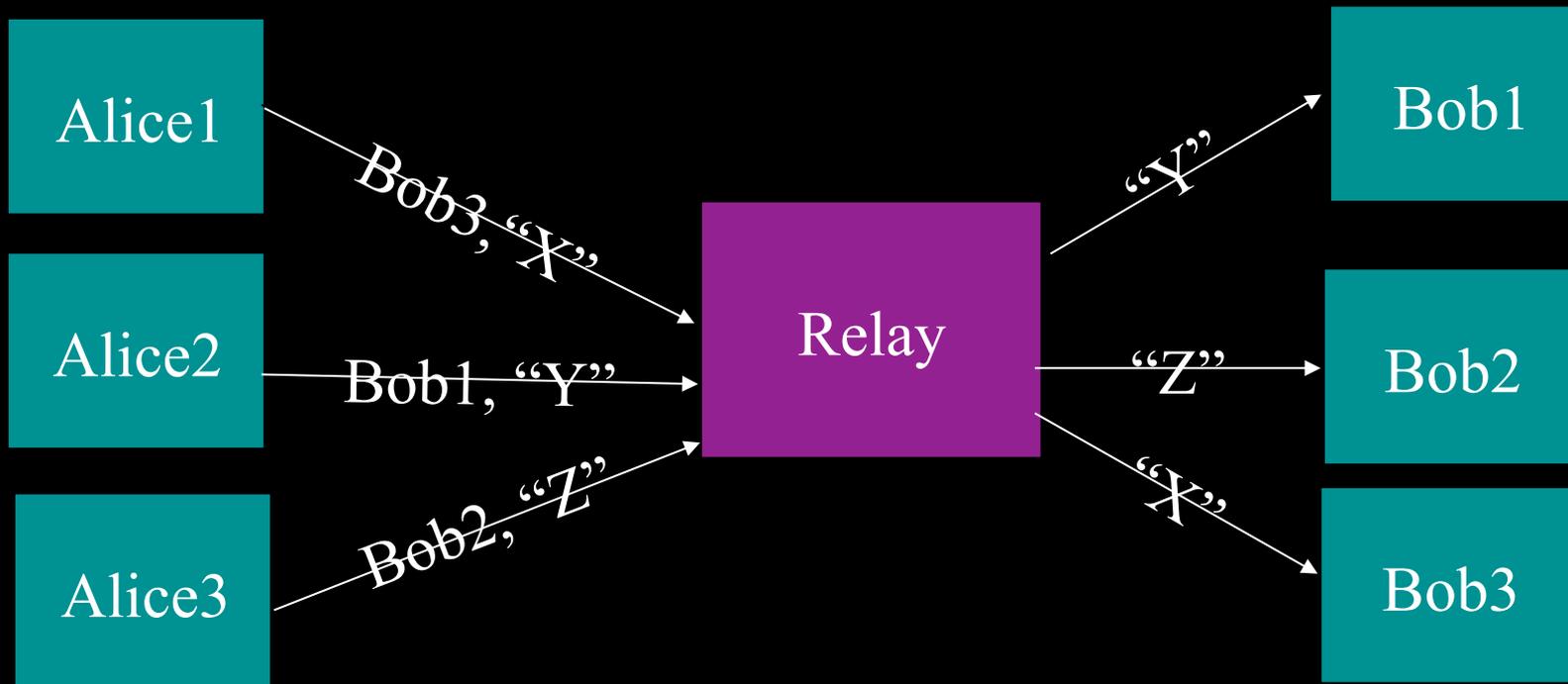
# You can't be anonymous by yourself: private solutions are ineffective...



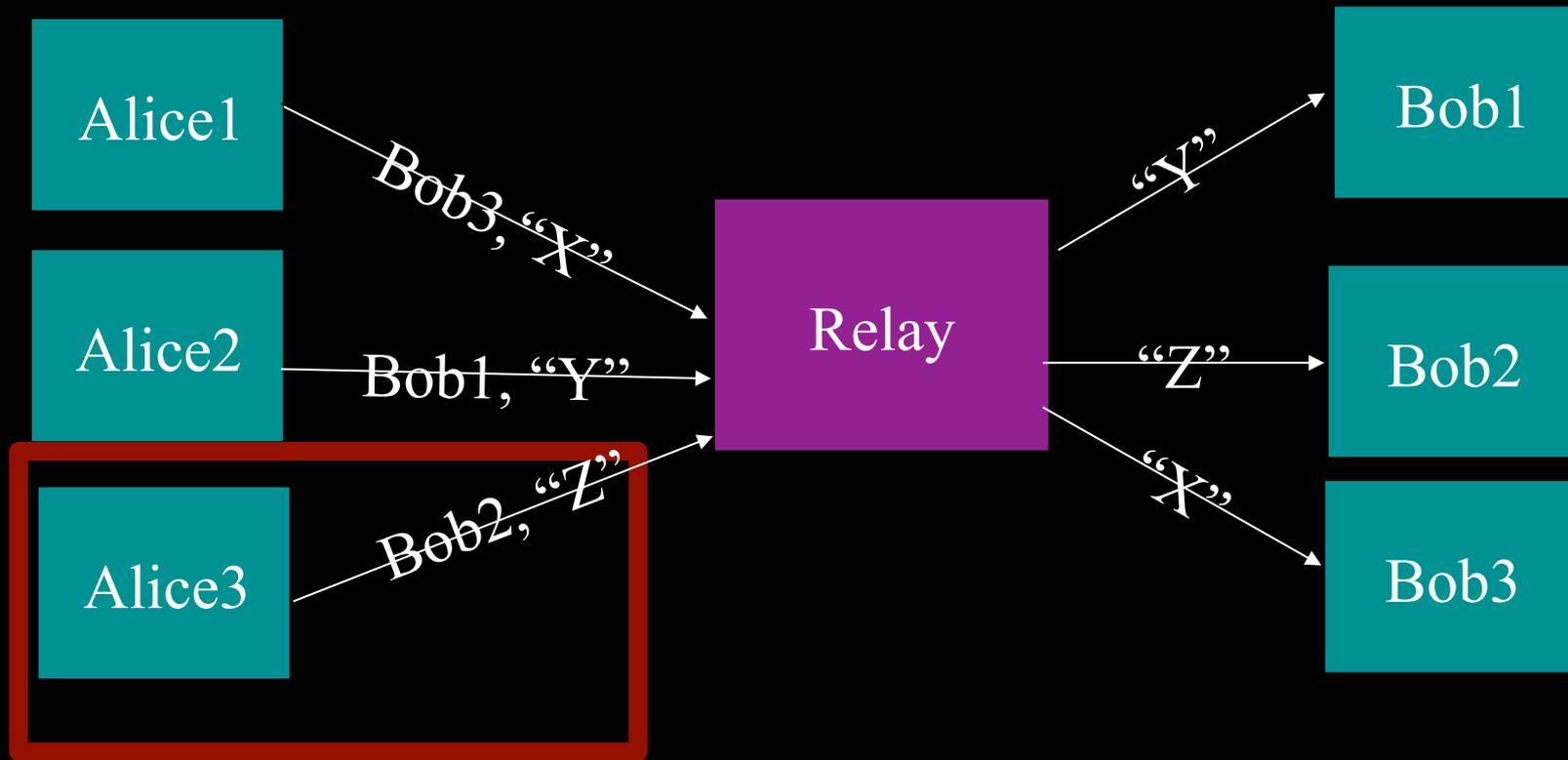
... so, anonymity loves company!



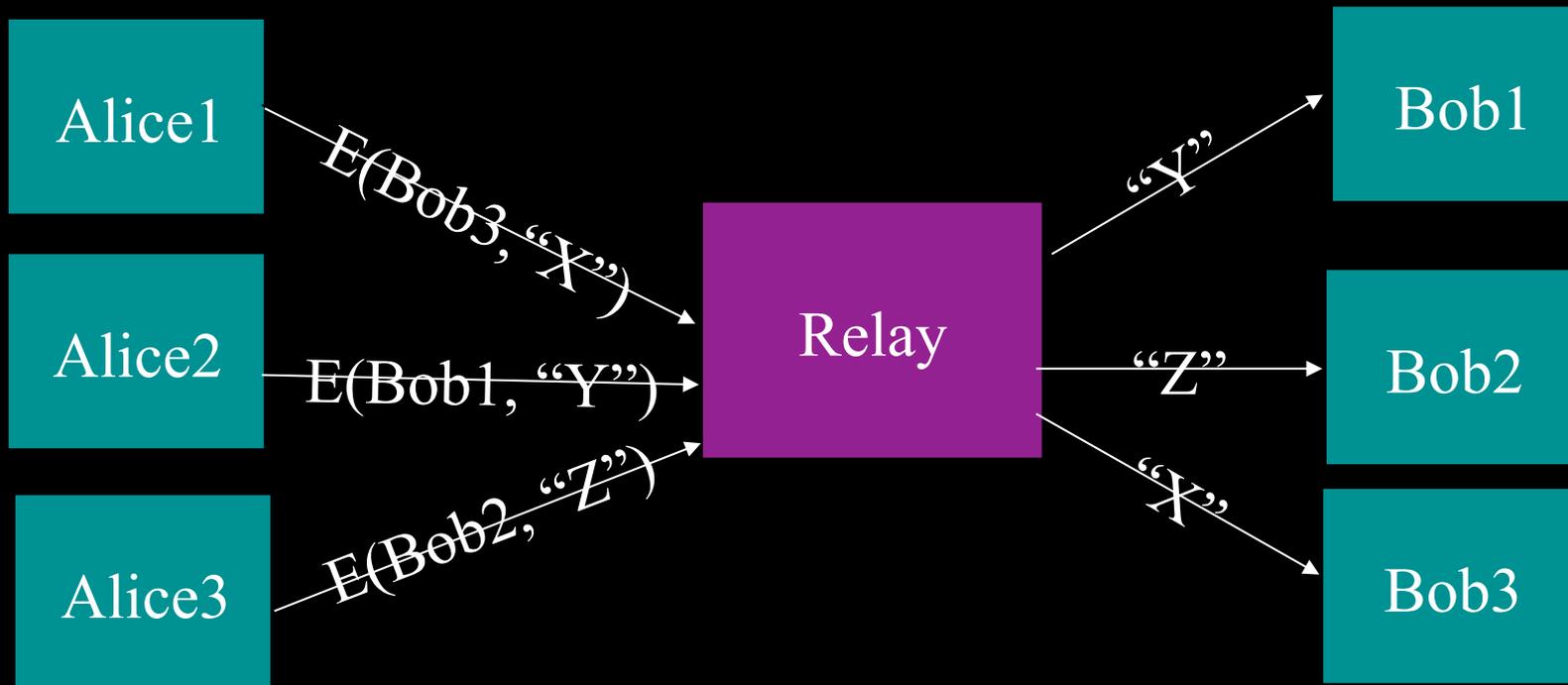
The simplest designs use a single relay to hide connections.



But an attacker who sees Alice can see who she's talking to.

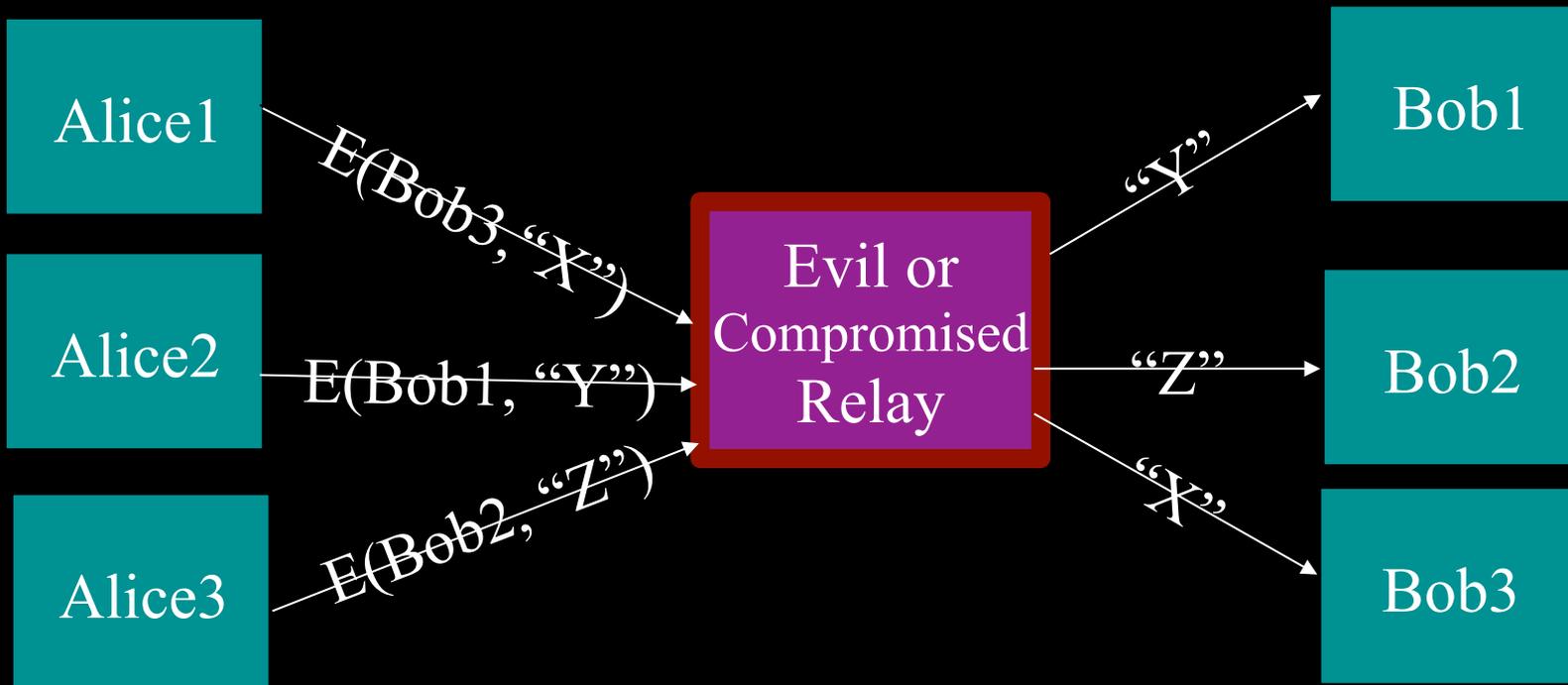


# Add encryption to stop attackers who eavesdrop on Alice.

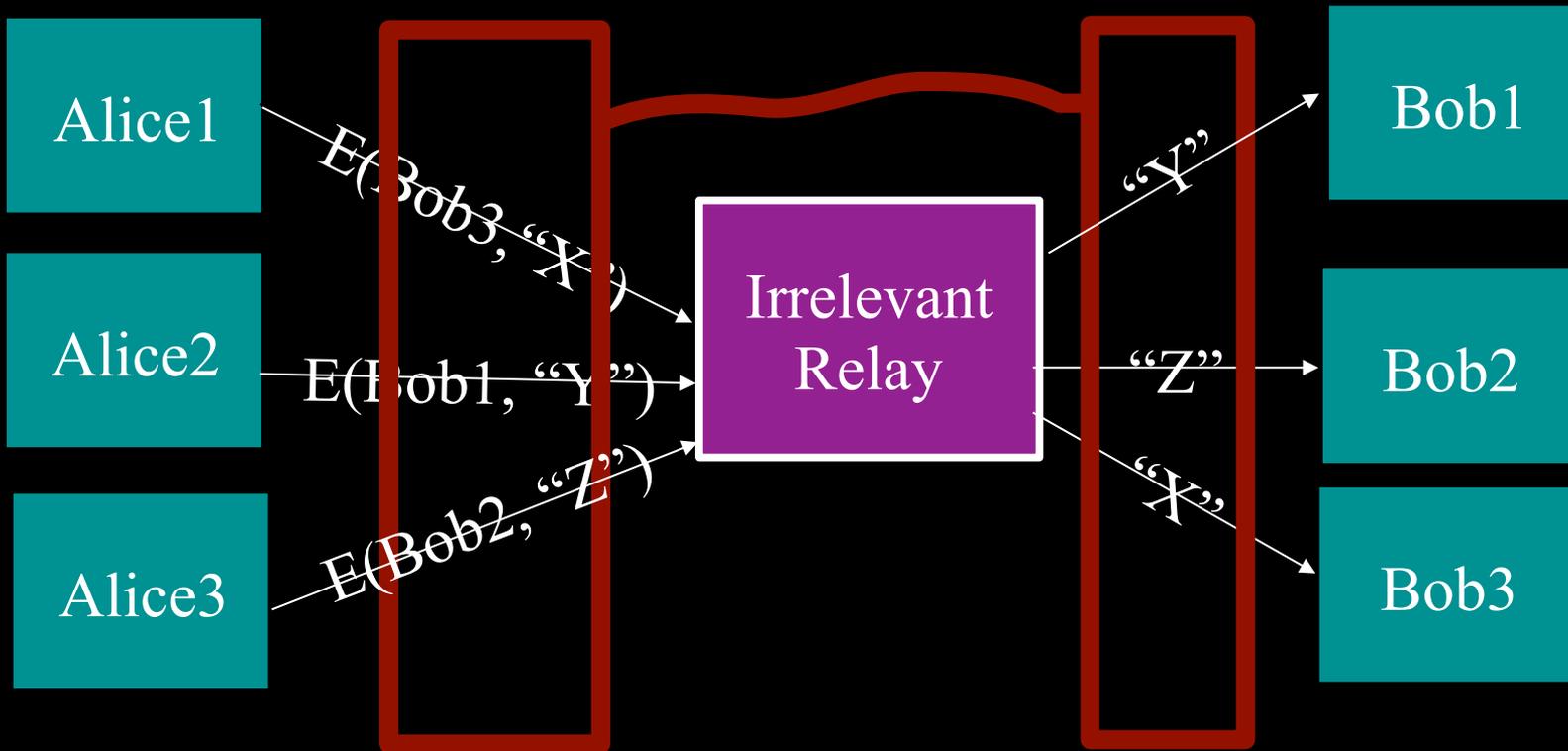


(e.g.: some commercial proxy providers, Anonymizer)

But a single relay is a single point of failure.

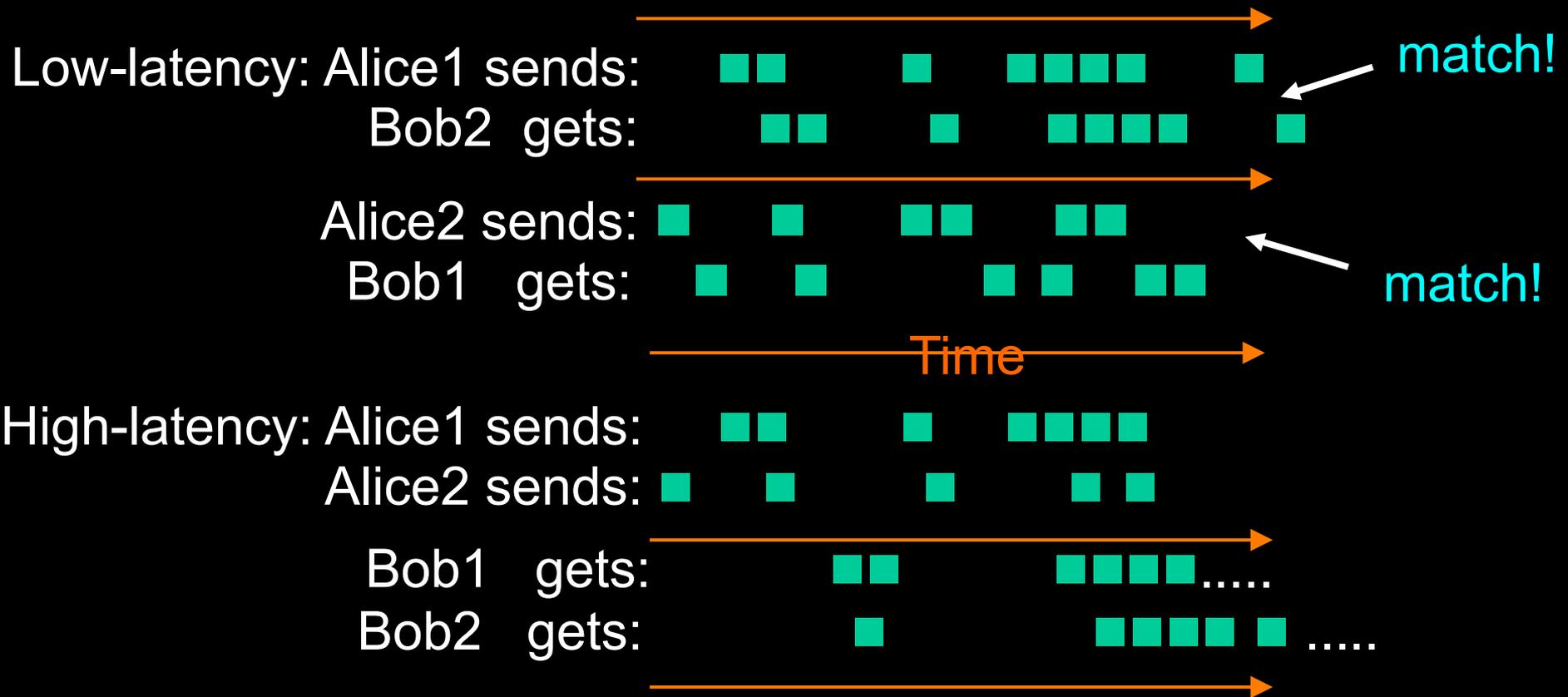


# But a single relay is a single point of bypass.



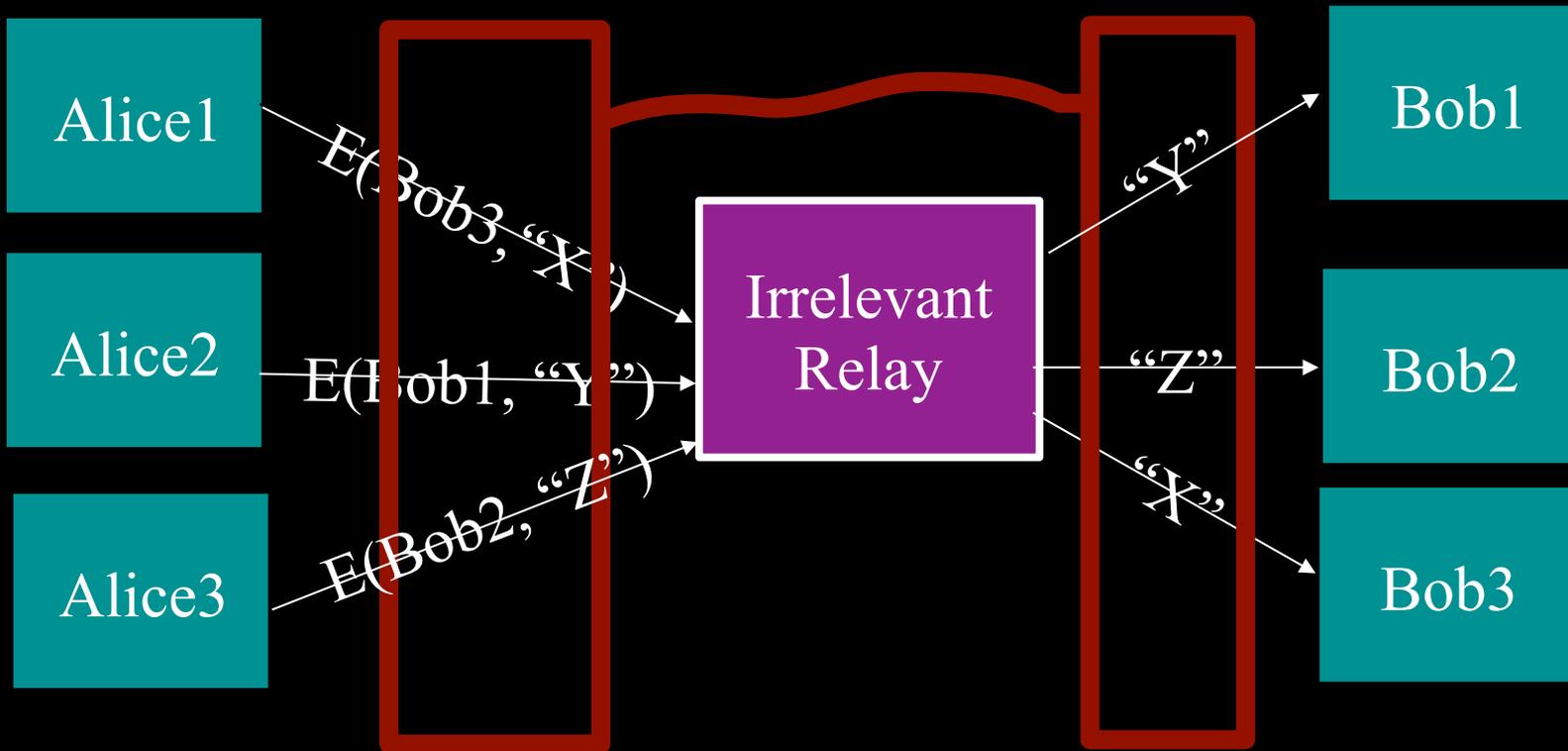
Timing analysis bridges all connections through relay  $\Rightarrow$  An attractive fat target

# Low-latency systems are vulnerable to end-to-end correlation attacks.



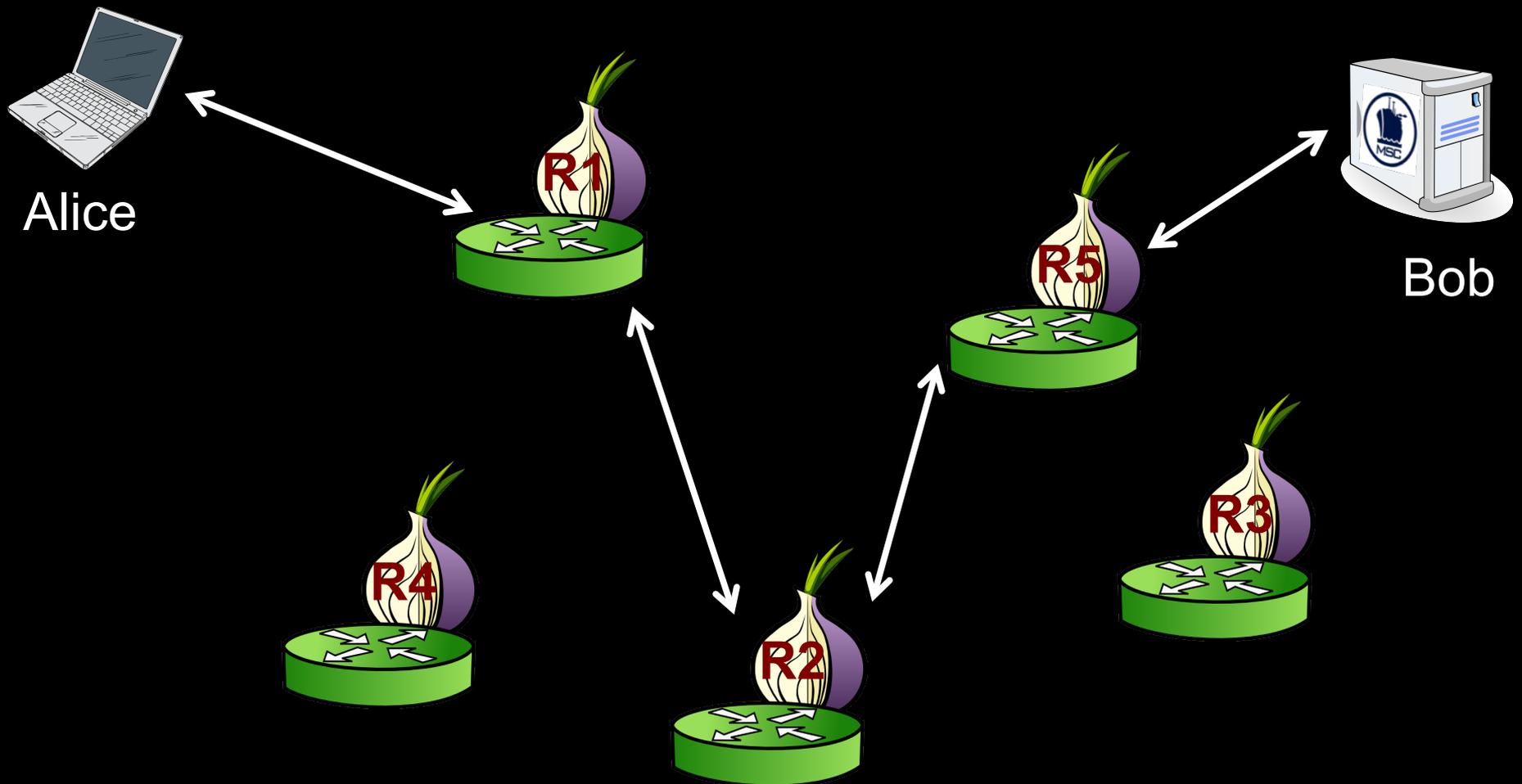
These attacks work in practice. The obvious defenses are expensive (like high-latency), useless, or both.

But a single relay is a single point of bypass.

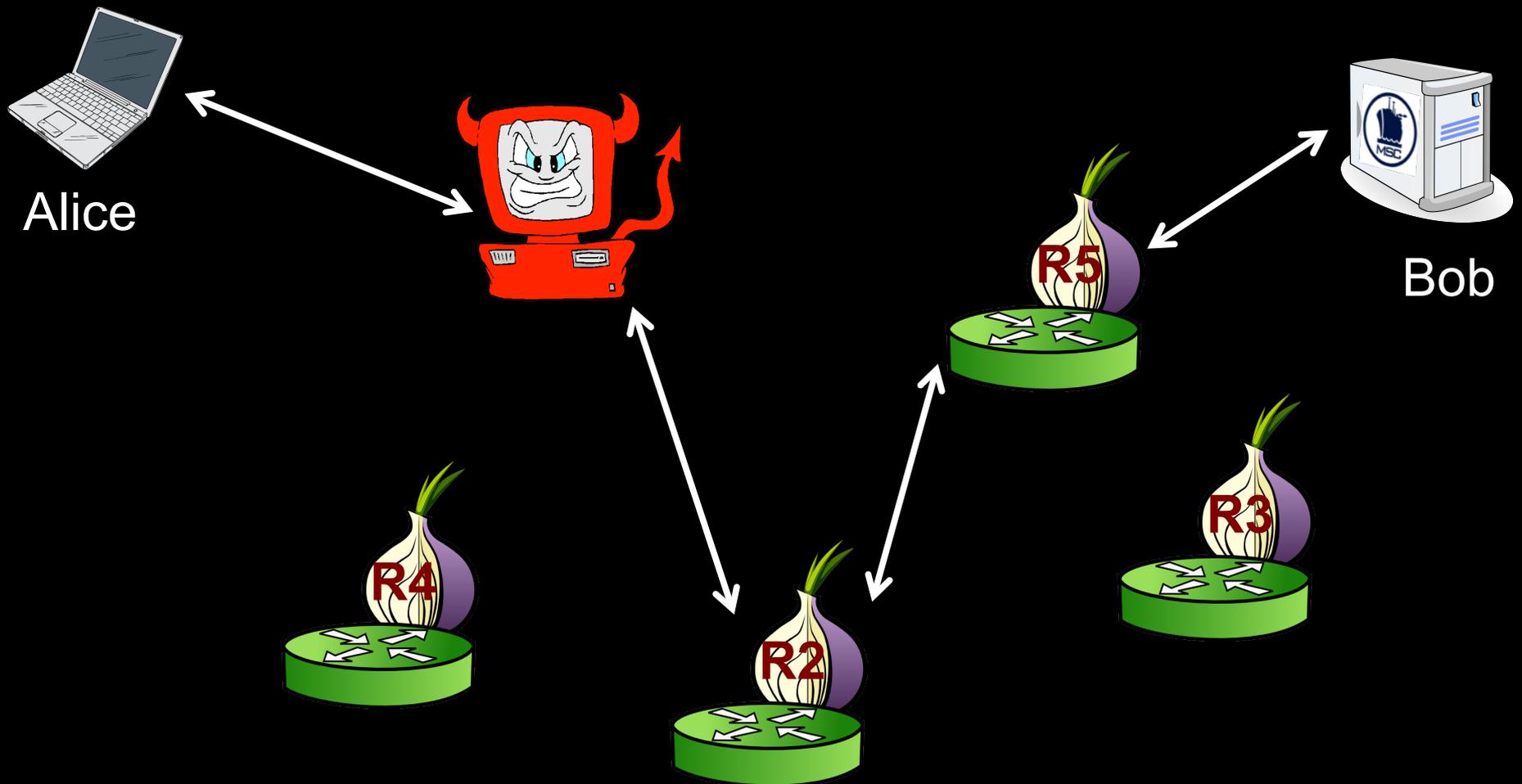


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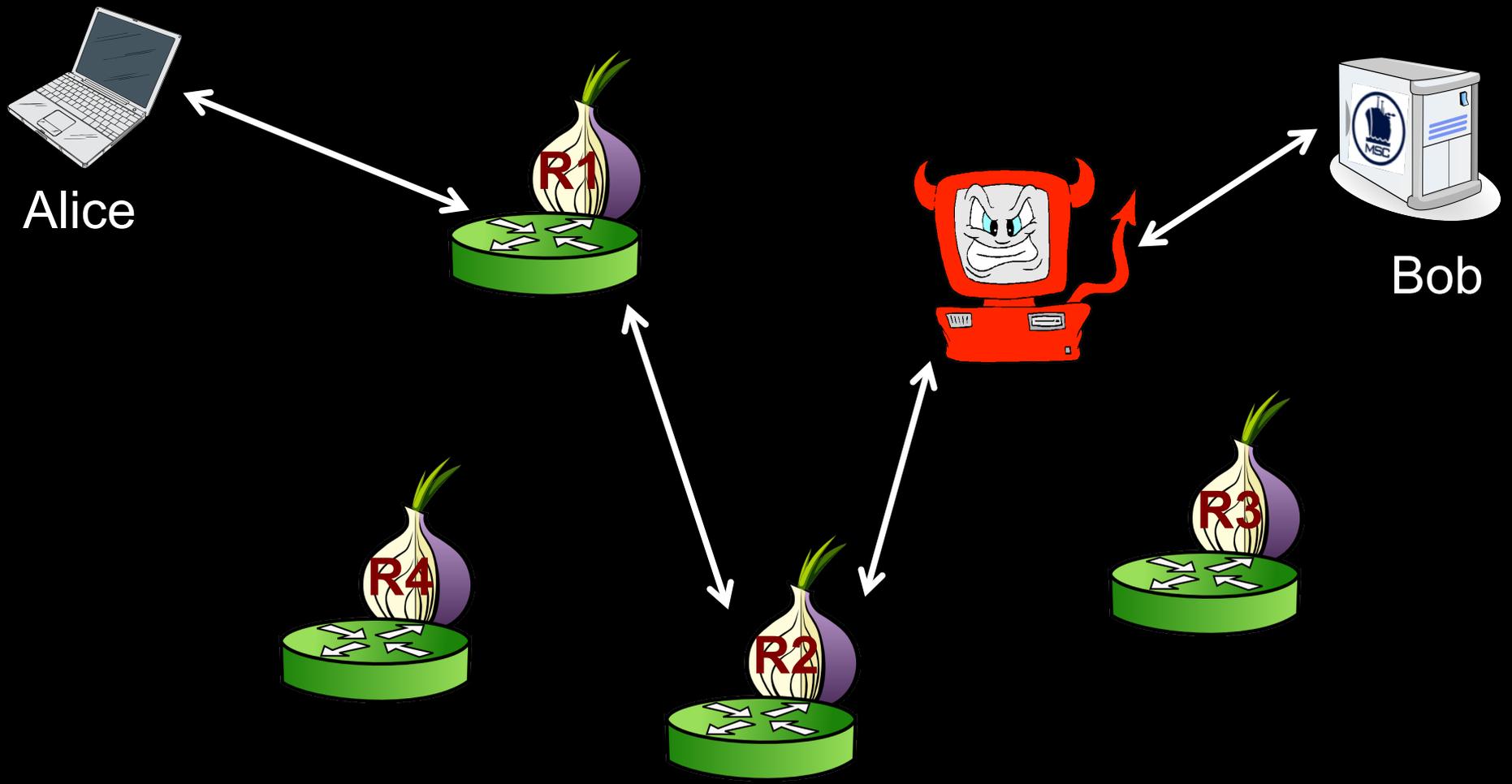
So, add multiple relays so that no single one can betray Alice.



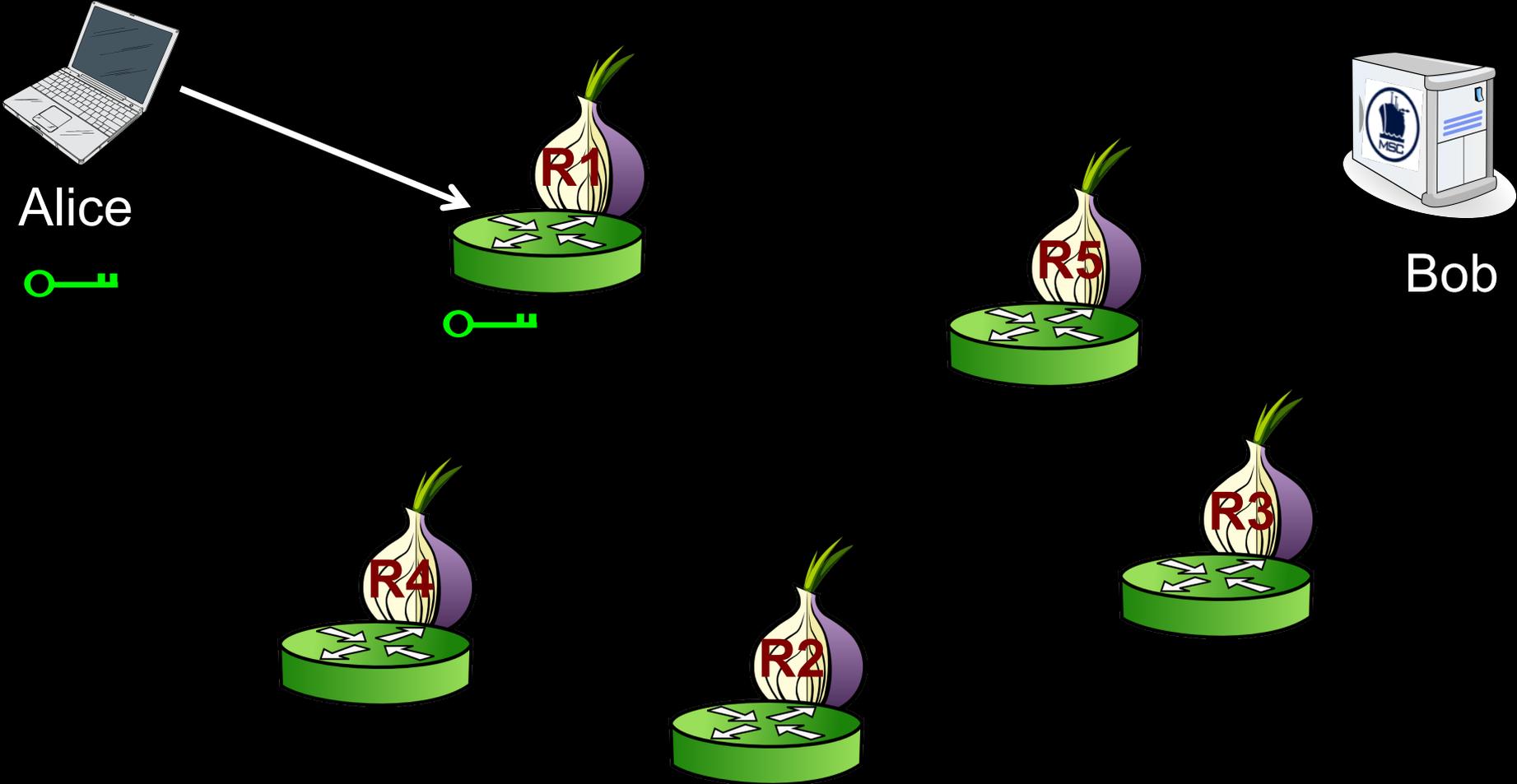
A corrupt first hop can tell that Alice is talking, but not to whom.



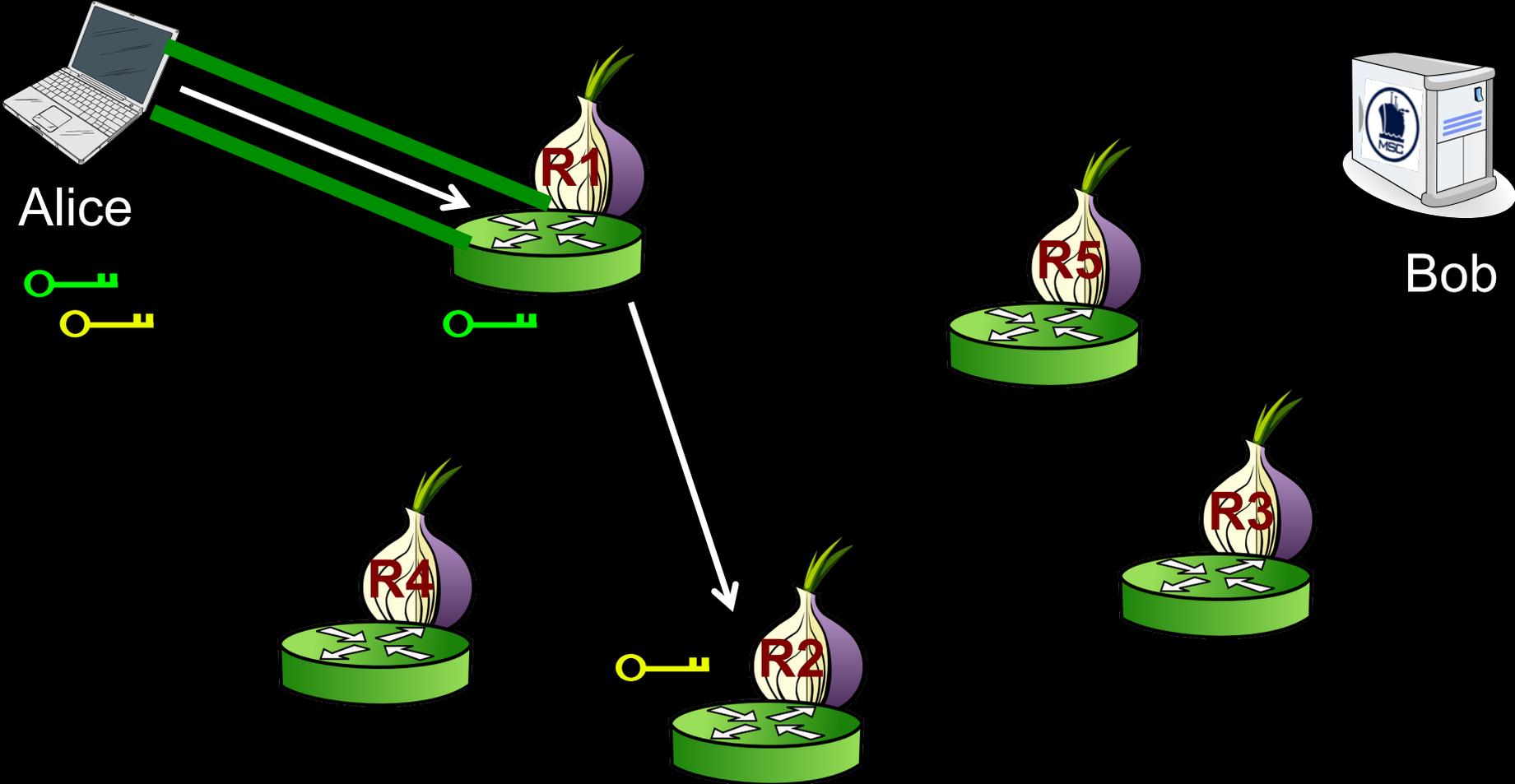
A corrupt last hop can tell someone is talking to Bob, but not who.



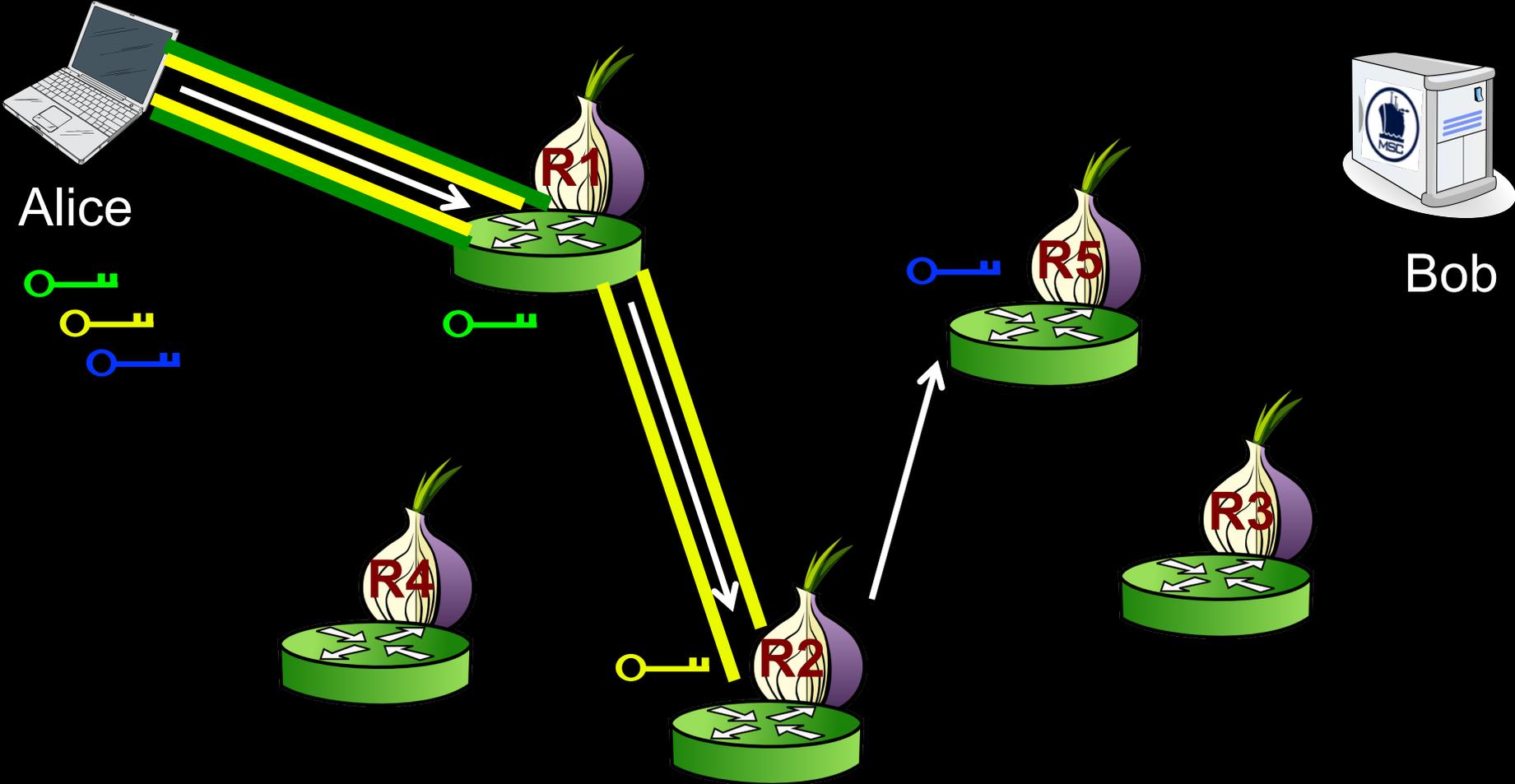
# Onion Routing: Circuit construction



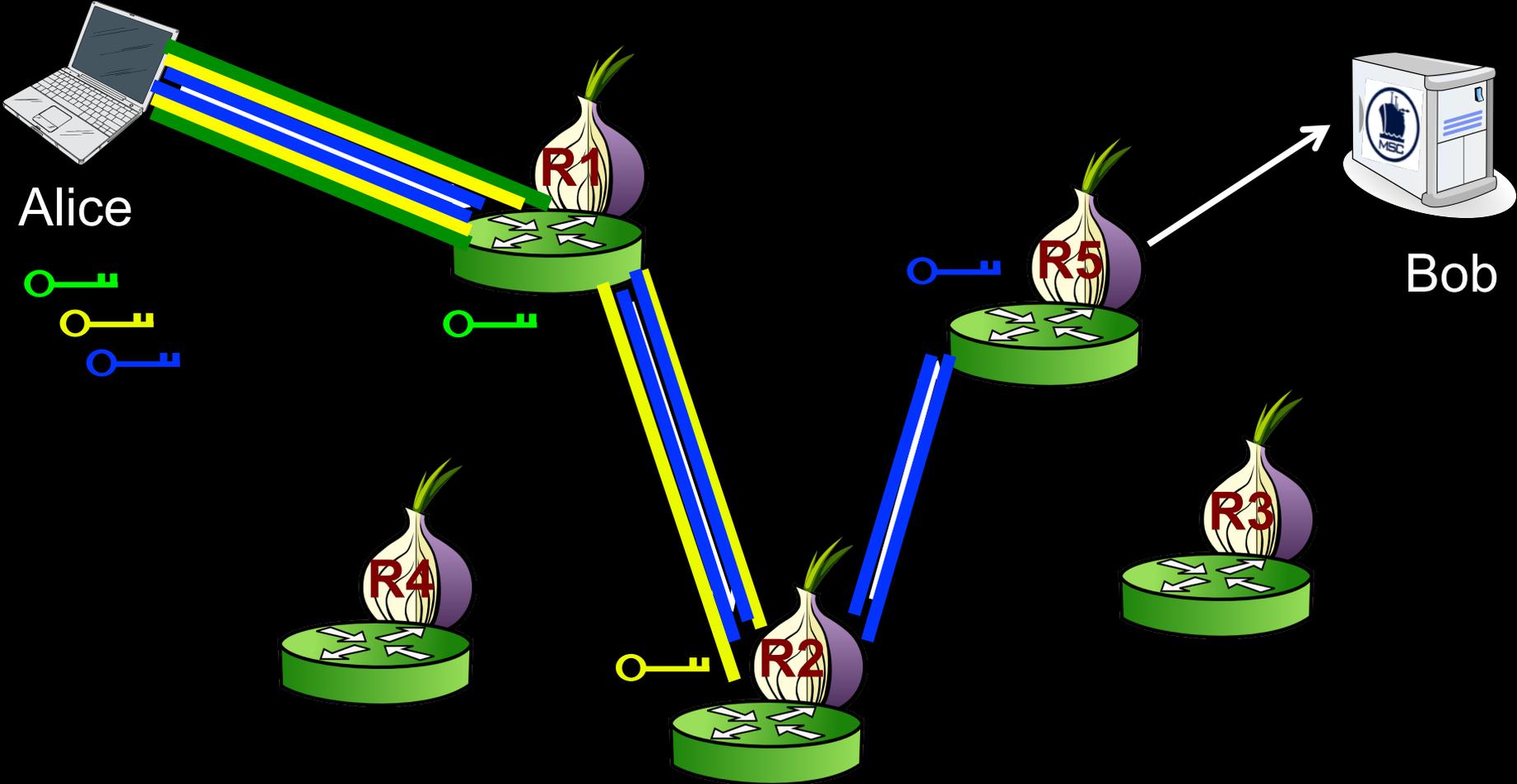
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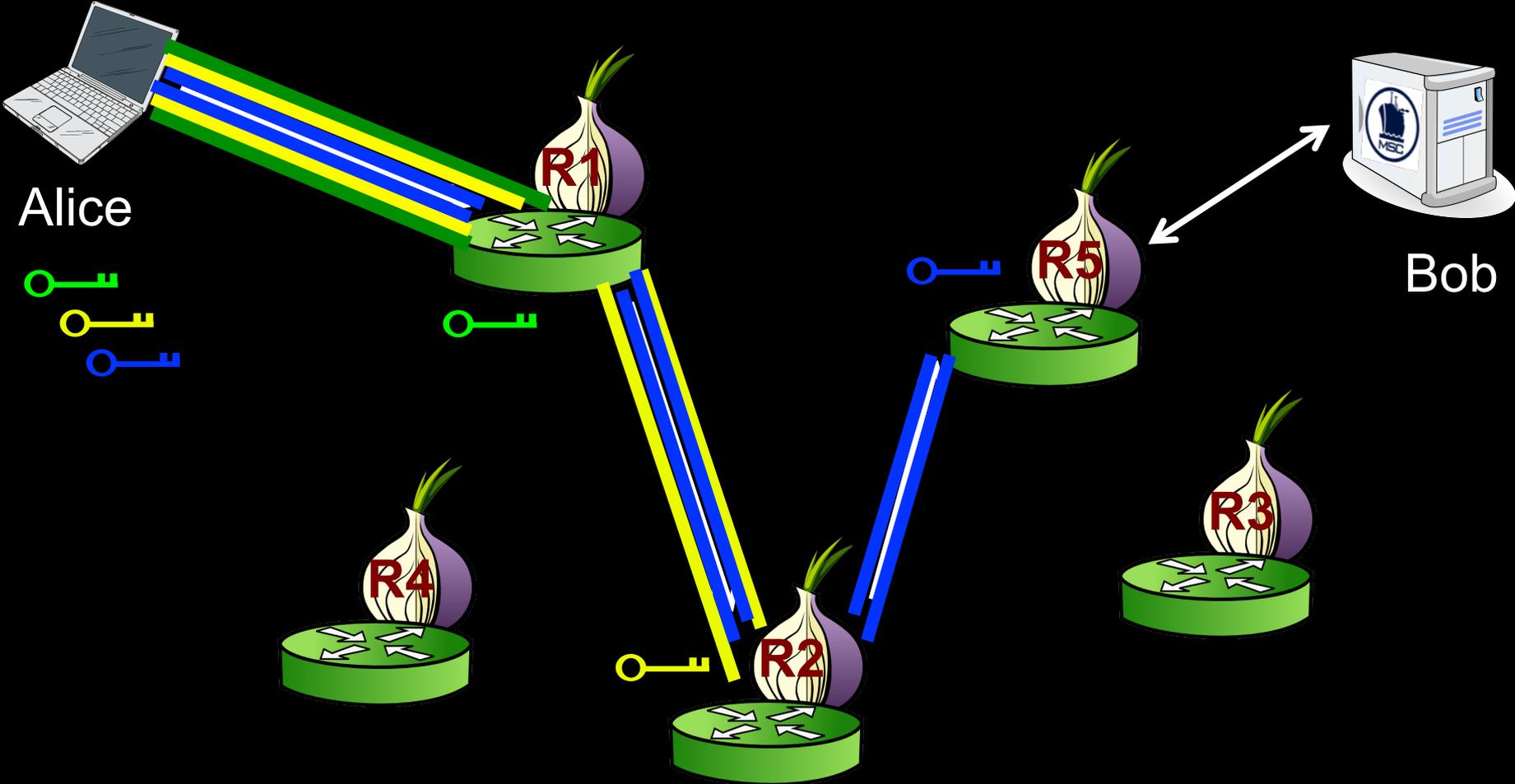
# Onion Routing: Circuit construction



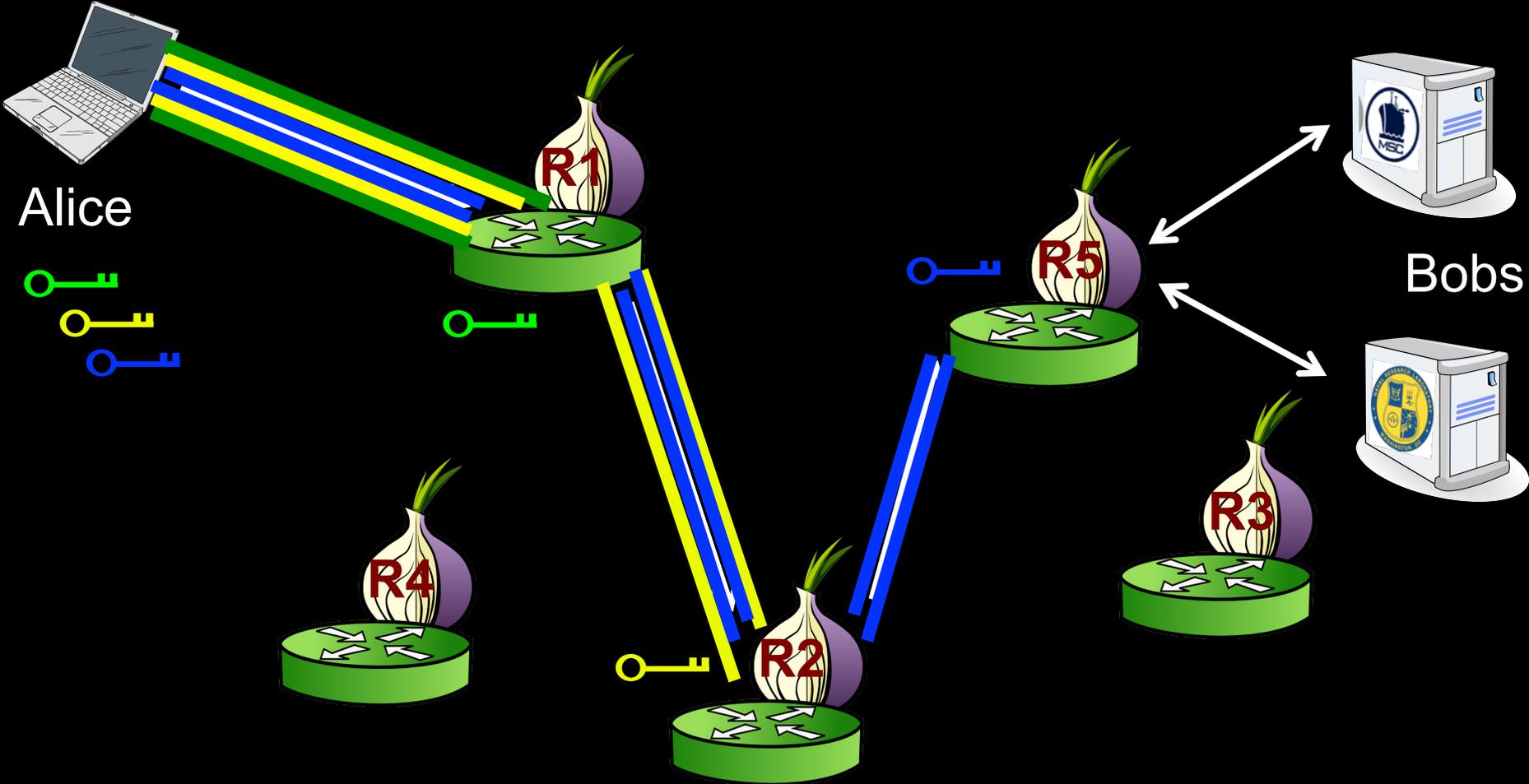
# Onion Routing: Connection creation



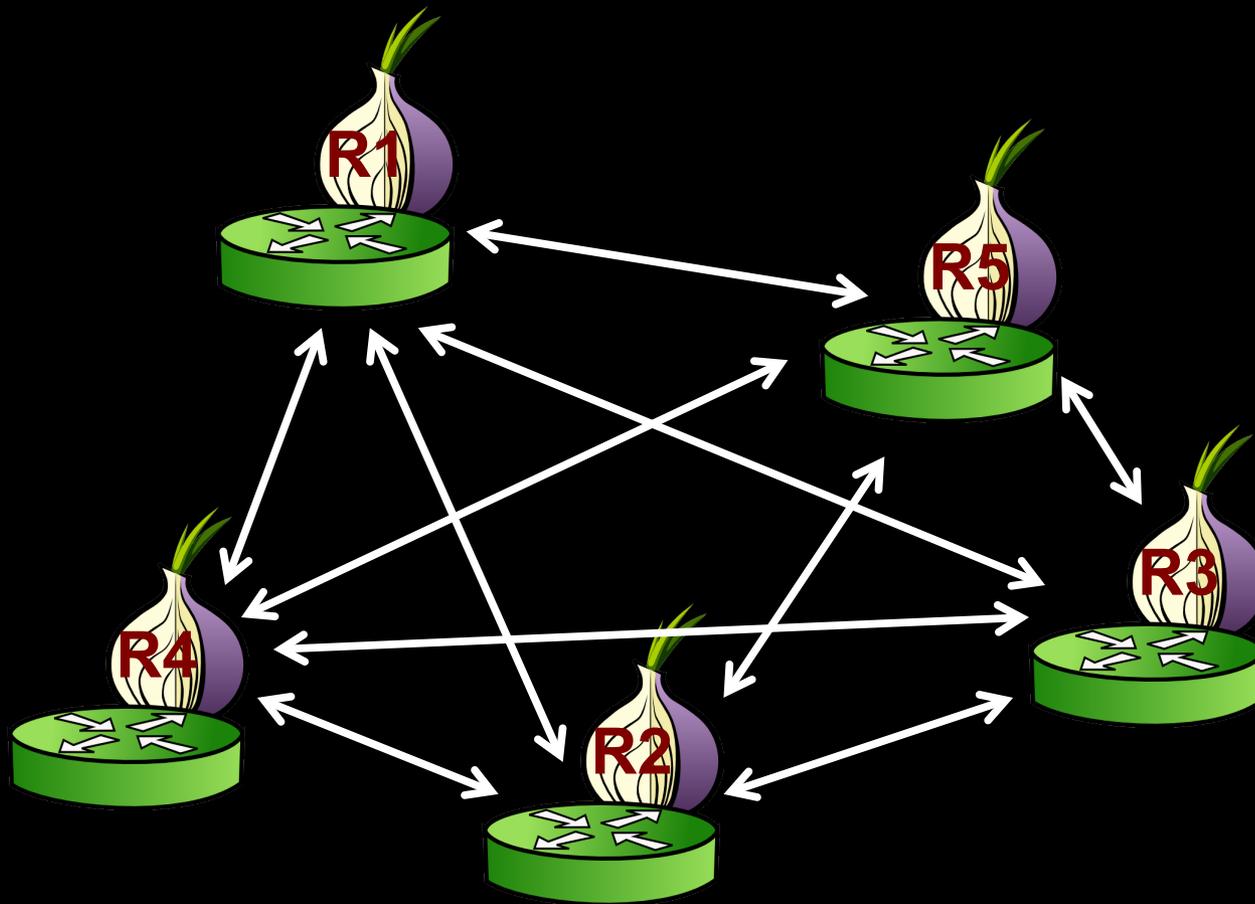
# Onion Routing: Data Exchange



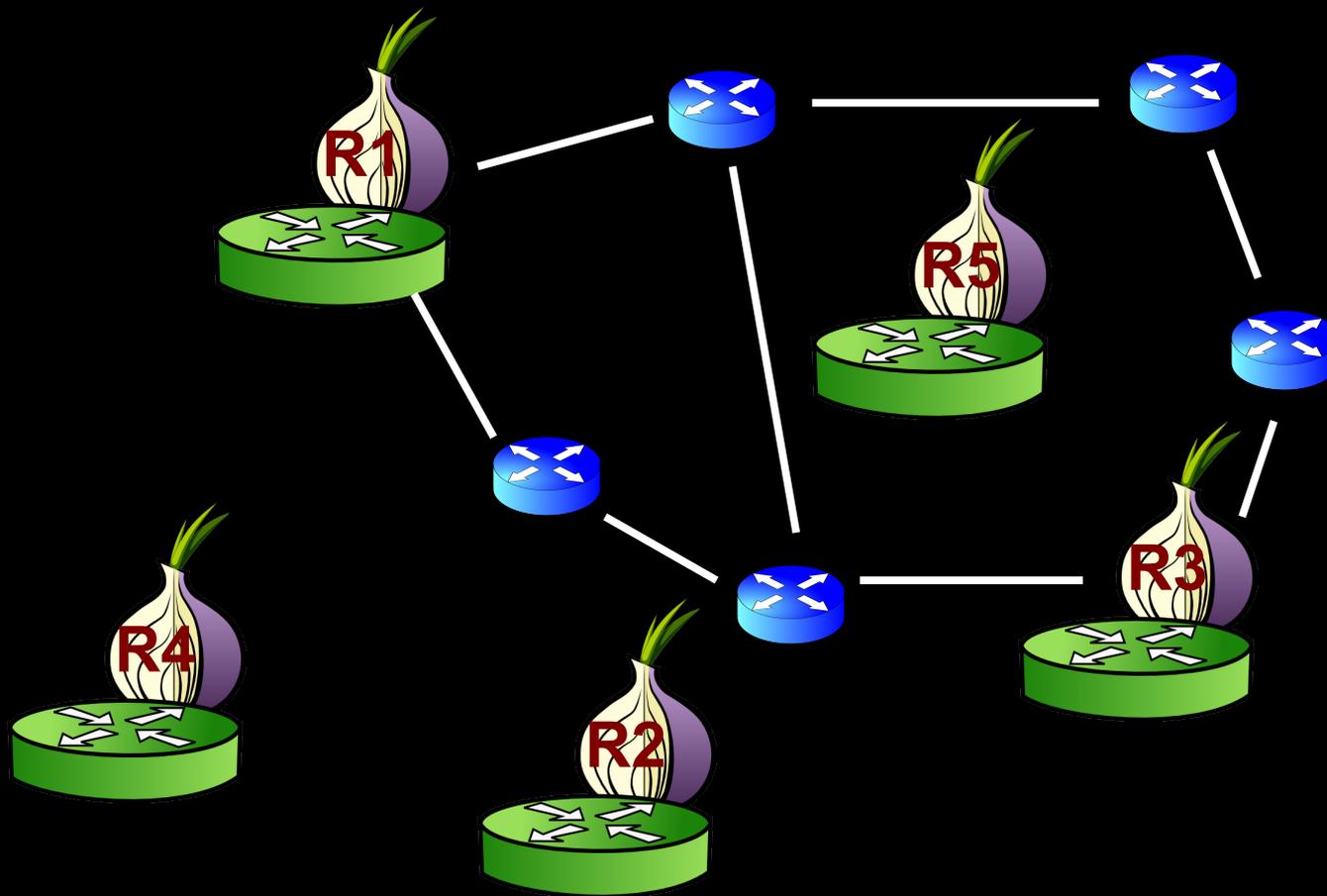
# Onion Routing: Data Exchange



# Onion Routers (Relays/Nodes): Clique topology



# Onion Routers (Relays/Nodes): Overlay network



That's onion routing in a nutshell

# Mix networks vs. Onion routing networks

Low-latency: Alice1 sends:

Bob2 gets:

Alice2 sends:

Bob1 gets:

High-latency: Alice1 sends:

Alice2 sends:

Bob1 gets:

Bob2 gets:

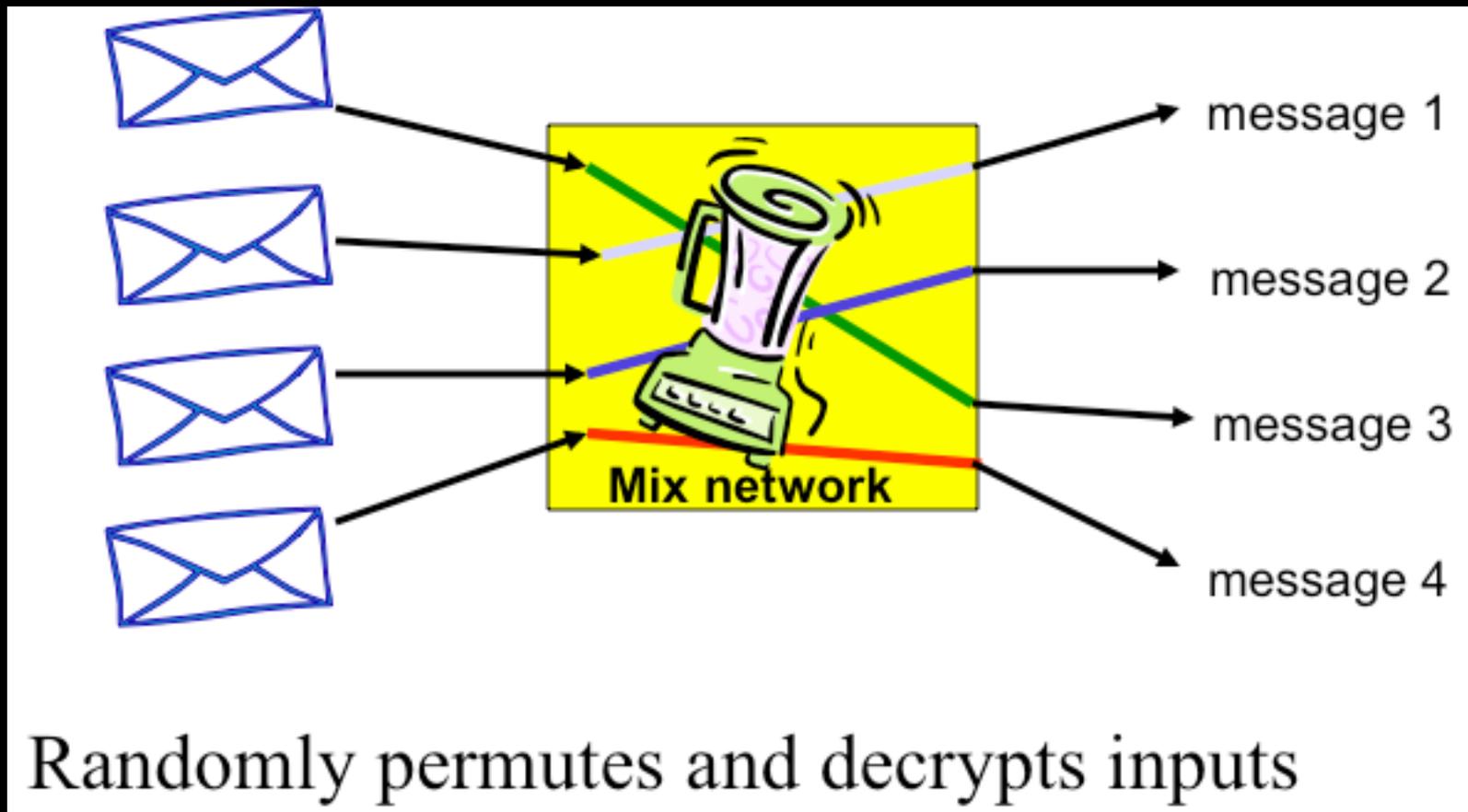


match!

match!

Time





# What onion routing is NOT: Mixes

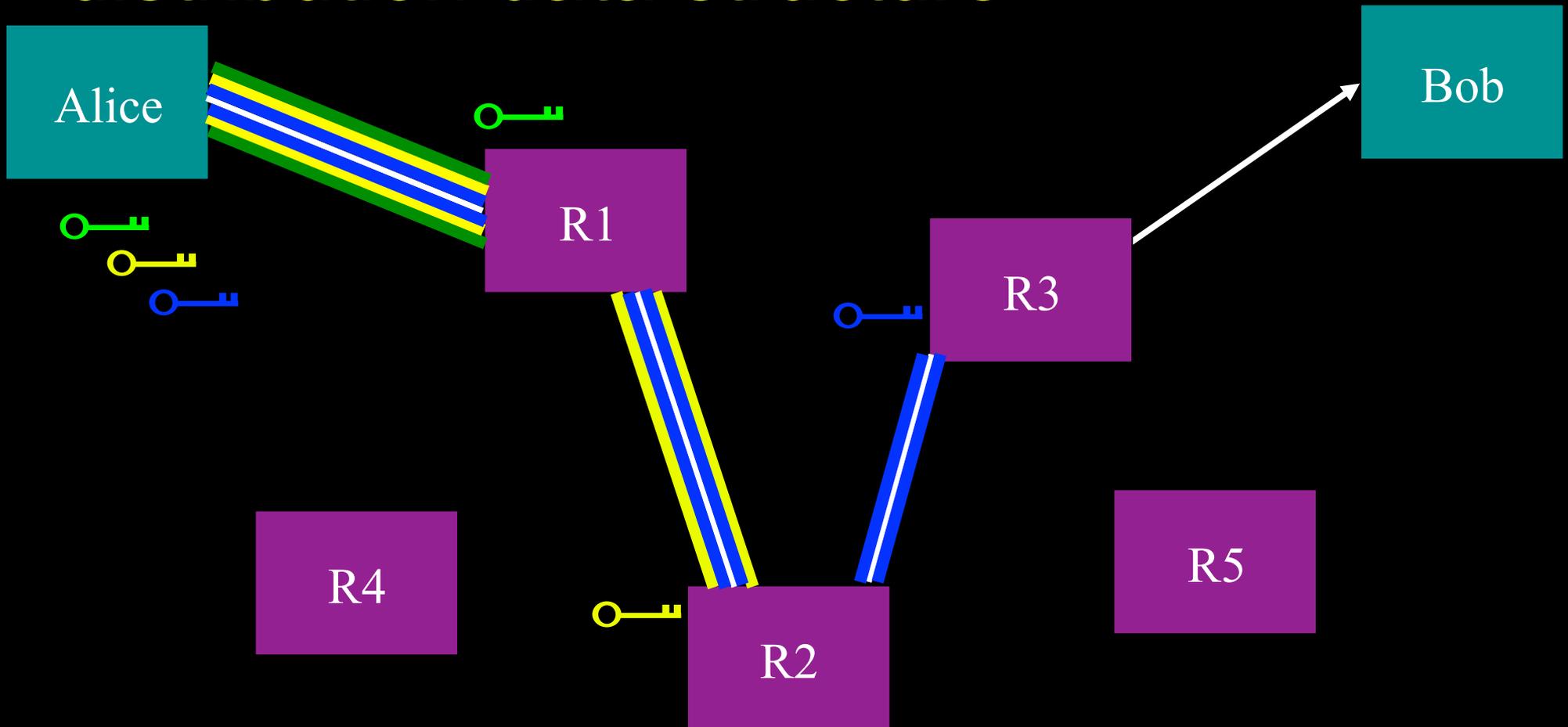
- Entirely different threat model
  - mixes are based on an adversary not being able to correlate inputs and outputs he sees
  - onion routing is based on an adversary not being able to see both inputs and outputs to correlate
  - mix networks more secure against global passive adversary
  - mix networks can be less secure vs. local active adversary
- Entirely different communications paradigm: Circuit based encryption vs. per message
  - onion routing supports bidirectional communication
  - onion routing supports low-latency communication
- Can be combined to make mixing onion routers, but not typically done or desired

# What onion routing is

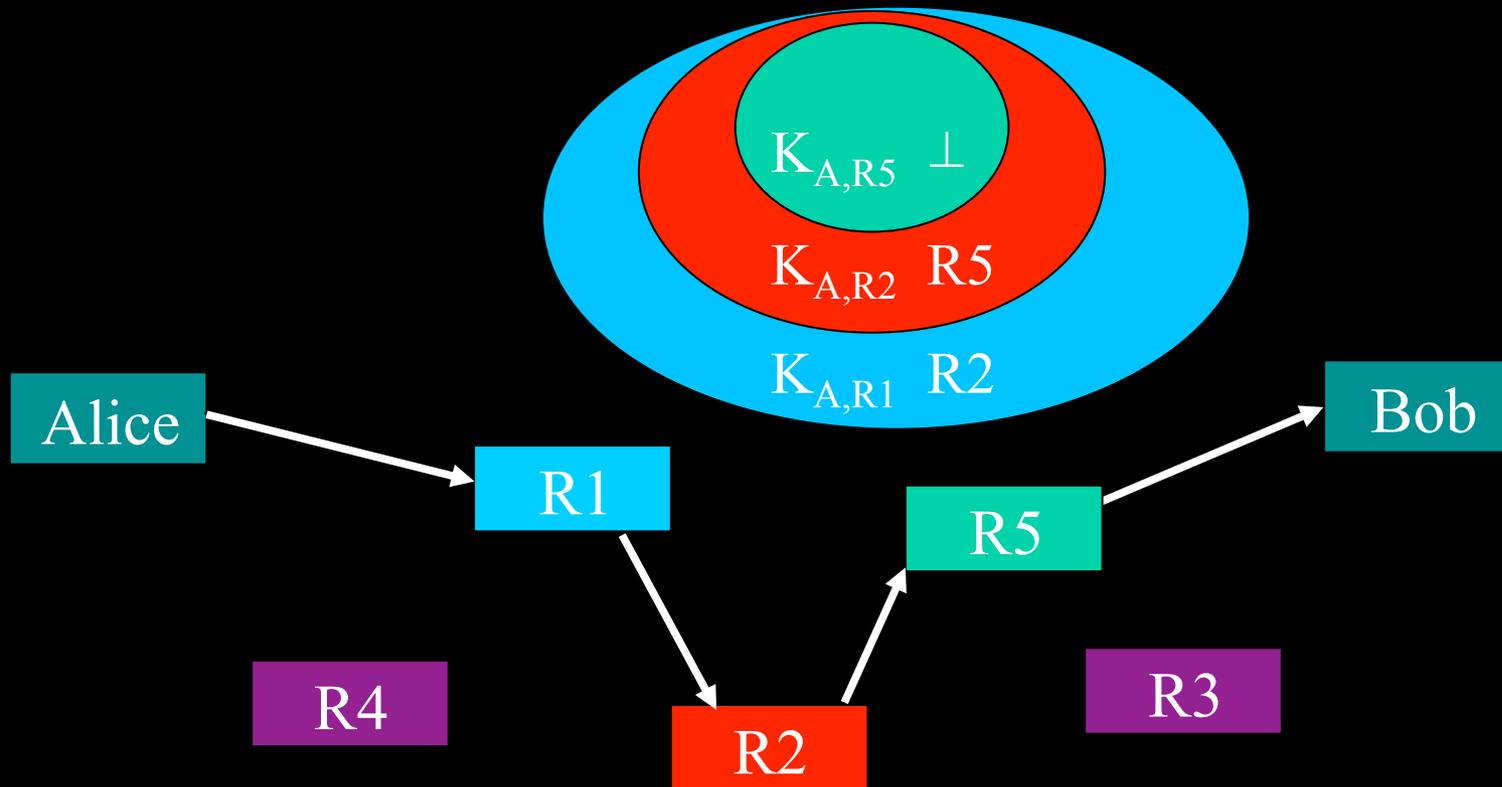
- Uses expensive crypto (public-key) to lay a cryptographic circuit over which data is passed
- Typically uses free-route circuit building to make location of circuit endpoints unpredictable

# Why call it “onion routing”?

Answer: Because of the original key distribution data structure

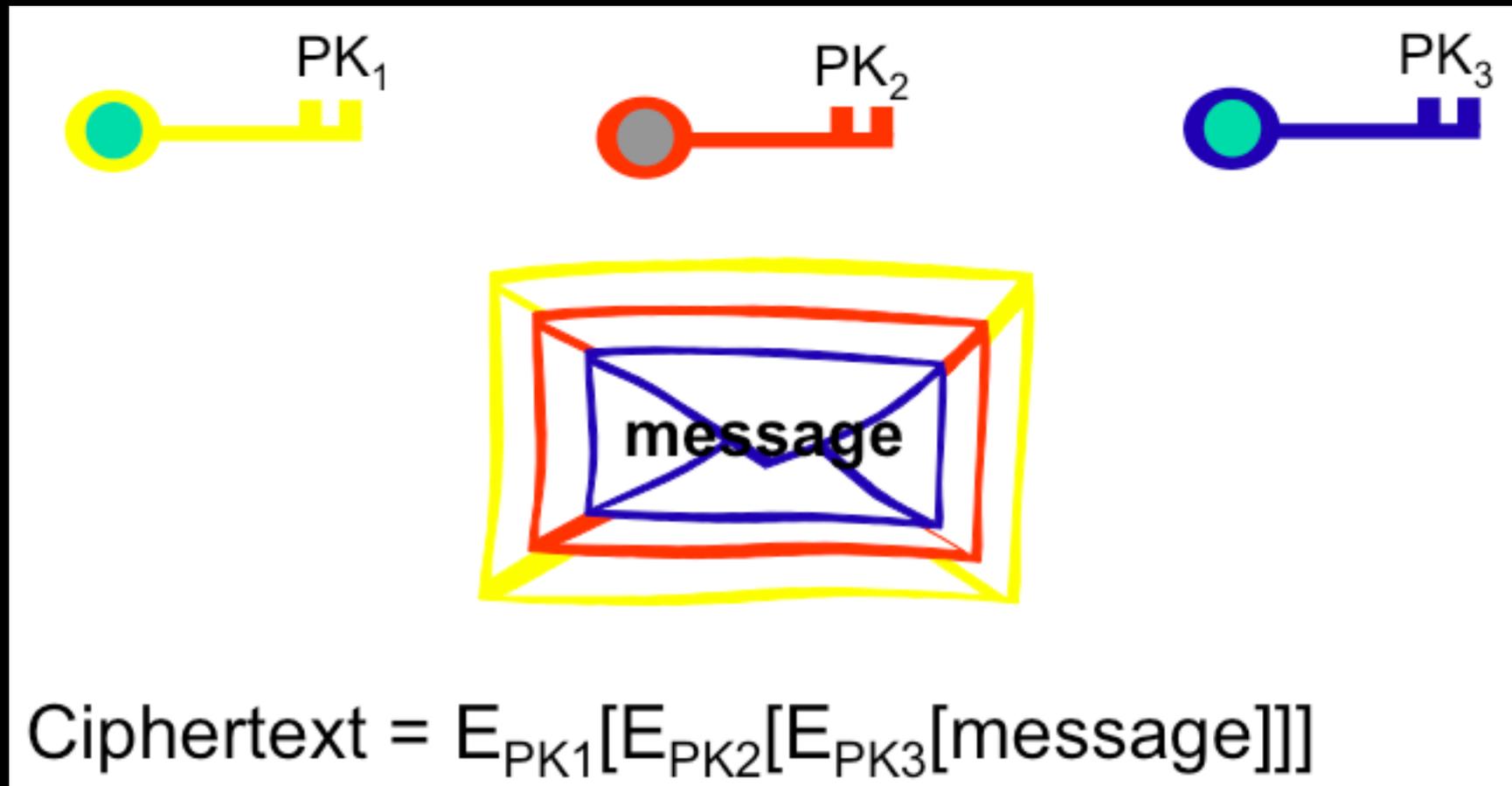


# Why is it called onion routing?

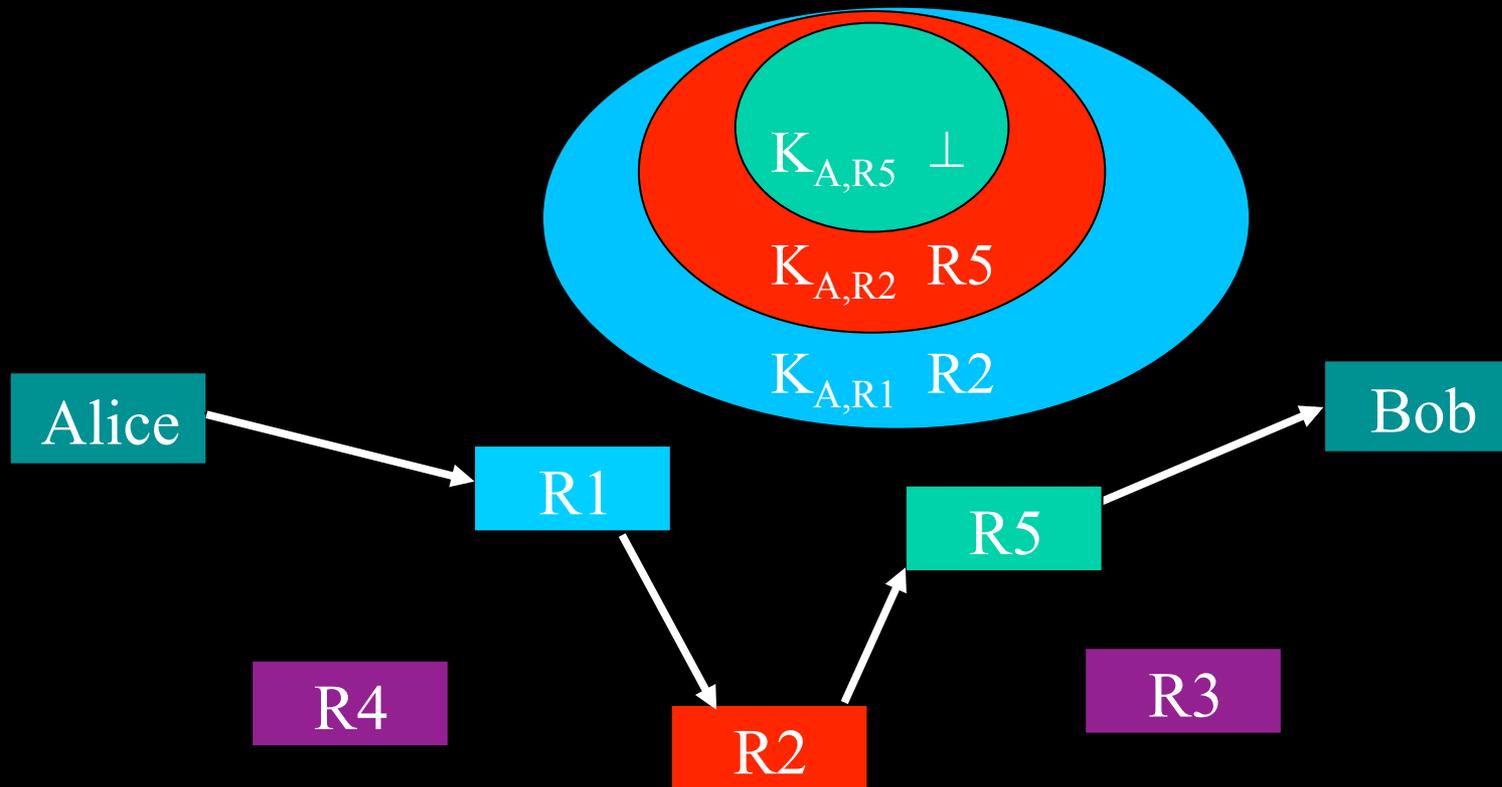


- Onion: Just layers of public-key crypto
  - Nothing in the center, just another layer

Mixi networks have a message in the middle of a public-key “onion”.

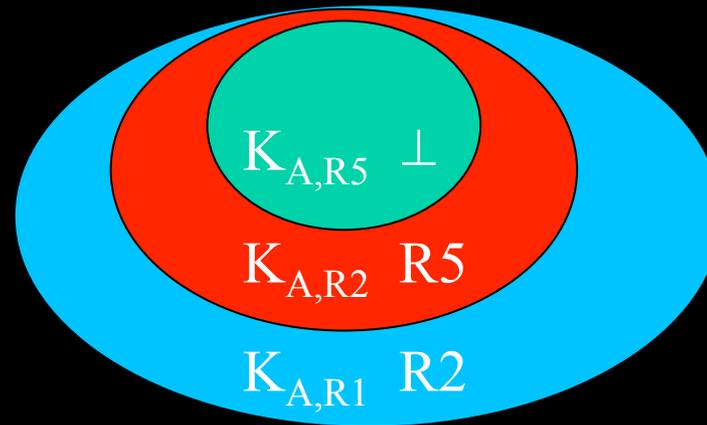


# Why is it called onion routing?



- Onion: Just layers of public-key crypto
  - Nothing in the center, just another layer

# Circuit setup



- NRL v0 and v1 onion routing and also ZKS Freedom network used onions to build circuits
  - Lacked Forward Secrecy
  - Required storing record of onions against replay
- Tor (NRL v2) uses one layer “onion skins”
  - ephemeral Diffie-Hellman yields forward secrecy
  - No need to record processed onions against replay
  - From suggestion out of Zack Brown’s Cebolla

# Aside: Why is it called 'Tor' and what does 'Tor' mean?

- Frequent question to Roger c. 2001-2: Oh you're working on onion routing... which one?
- Roger: *THE* onion routing. The original onion routing project from NRL.
- Rachel: That's a good acronym.
- Roger: And it's a good recursive acronym.
- Plus, as a word, it has a good meaning in German (door/gate/portal) and Turkish (fine-meshed net)

# Aside: Why is it called 'Tor' and what does 'Tor' mean?

- We foolishly called the first Tor paper “Tor: the second generation onion router”
- But this was very confusing
  - ‘Tor’ stands for “The onion routing” or “Tor’s onion routing”. It does not stand for “the onion router”
  - The paper is about the whole system, not just the onion routers
  - Tor is not the second generation

Aside: Why is it called 'Tor' and what does 'Tor' mean?



# Aside: Why is it called 'Tor' and what does 'Tor' mean?

- Tor: A (class of) onion routing design created at NRL starting c. 2001-2.
- Tor: A U.S. 501(c)3 nonprofit organization formed in 2006.
- Tor: A client software program that connects your computer to the Tor network.
- Tor: A volunteer network comprised of c. 5000 nodes serving c. 4 GiB/s data for c. 1M users (see [metrics.torproject.org](http://metrics.torproject.org) )
- Any amorphous combination of the above or other users

# Onion routing origins: Generation 0

- Fixed-length five-node circuits
- Integrated configuration
- Static topology
- Loose-source routing
- ★ Partial active adversary
- Rendezvous servers and reply onions

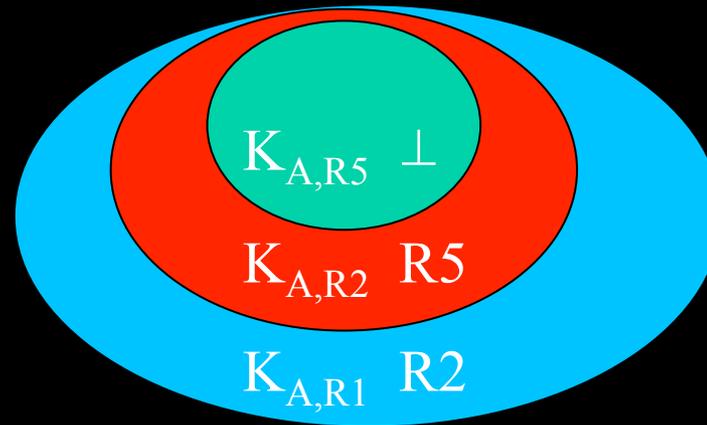
# Onion routing, the next generation

- ★ Running a client separated from running an OR
- Variable length circuits (up to 11 hops per onion---or tunnel for more)
- Application independent proxies (SOCKS) plus redirector
- ★ Entry policies and exit policies
- Dynamic network state, flat distribution of state info
- Multiplexing of multiple application connections in single onion routing circuit
- Mixing of cells from different circuits
- Padding and bandwidth limiting

# Third-generation onion routing (Tor)

- ★ Onion skins, not onions: Diffie-Hellman based circuit building
- Fixed-length three-hop circuits
- Rendezvous circuits and hidden servers
- Directory servers, caching (evolved w/in Tor)
- Most application specific proxies no longer needed (still need e.g. for DNS)
- Congestion control
- End-to-end integrity checking
- No mixing and no padding

# Circuit setup

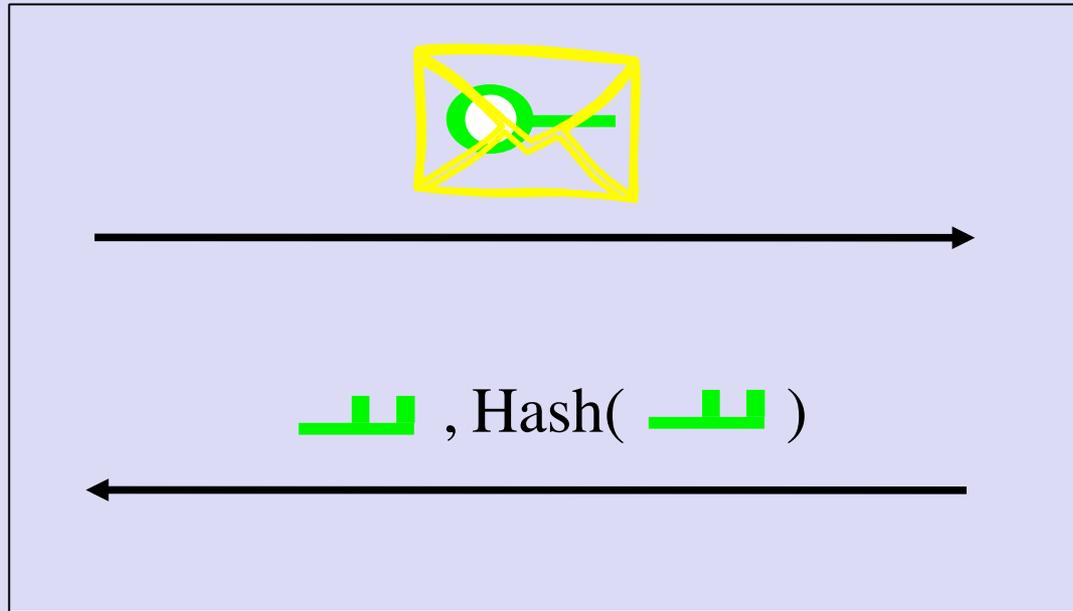


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# Tor Circuit Setup (Create)

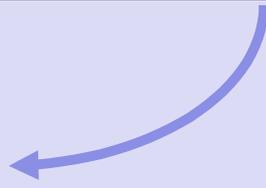


Client Initiator



Onion Router

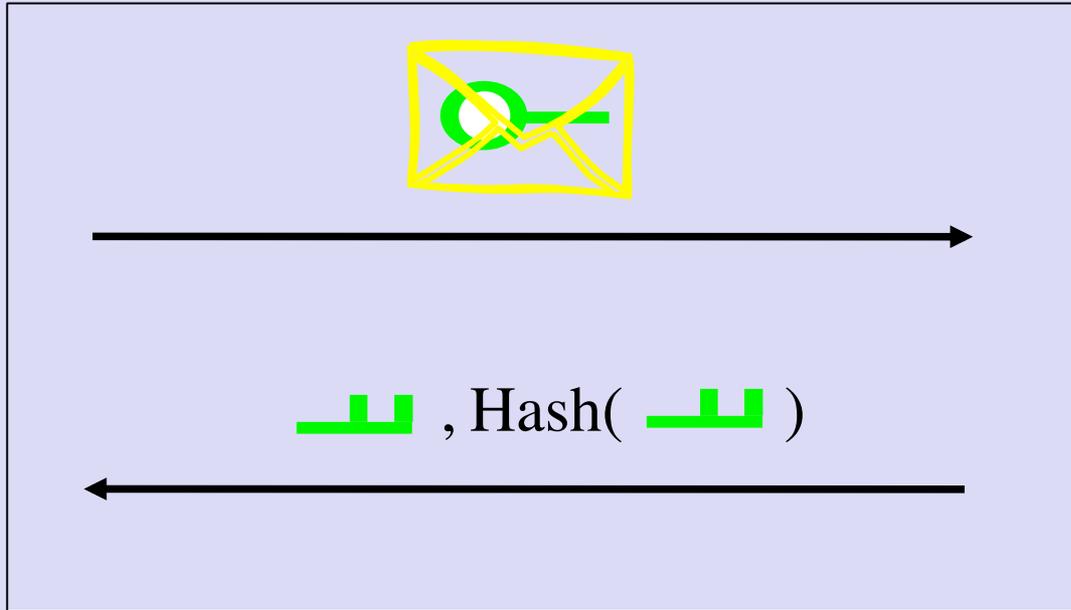
TLS connection



# Tor Circuit Setup (Create)



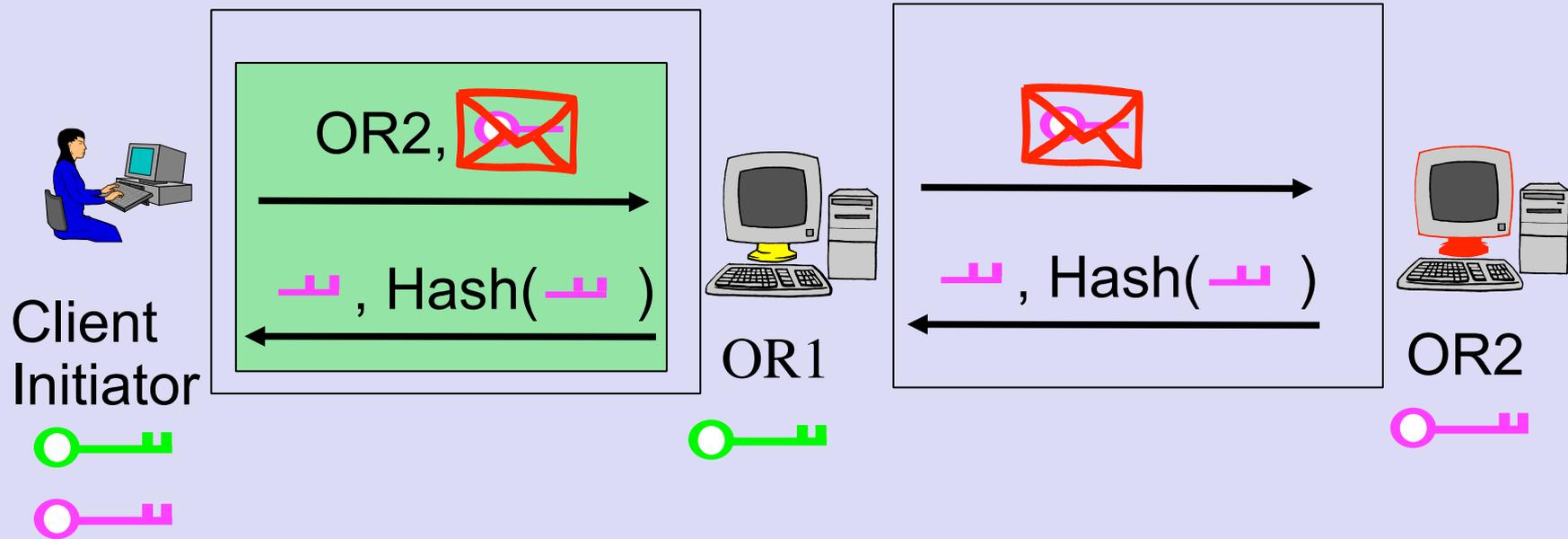
Client  
Initiator



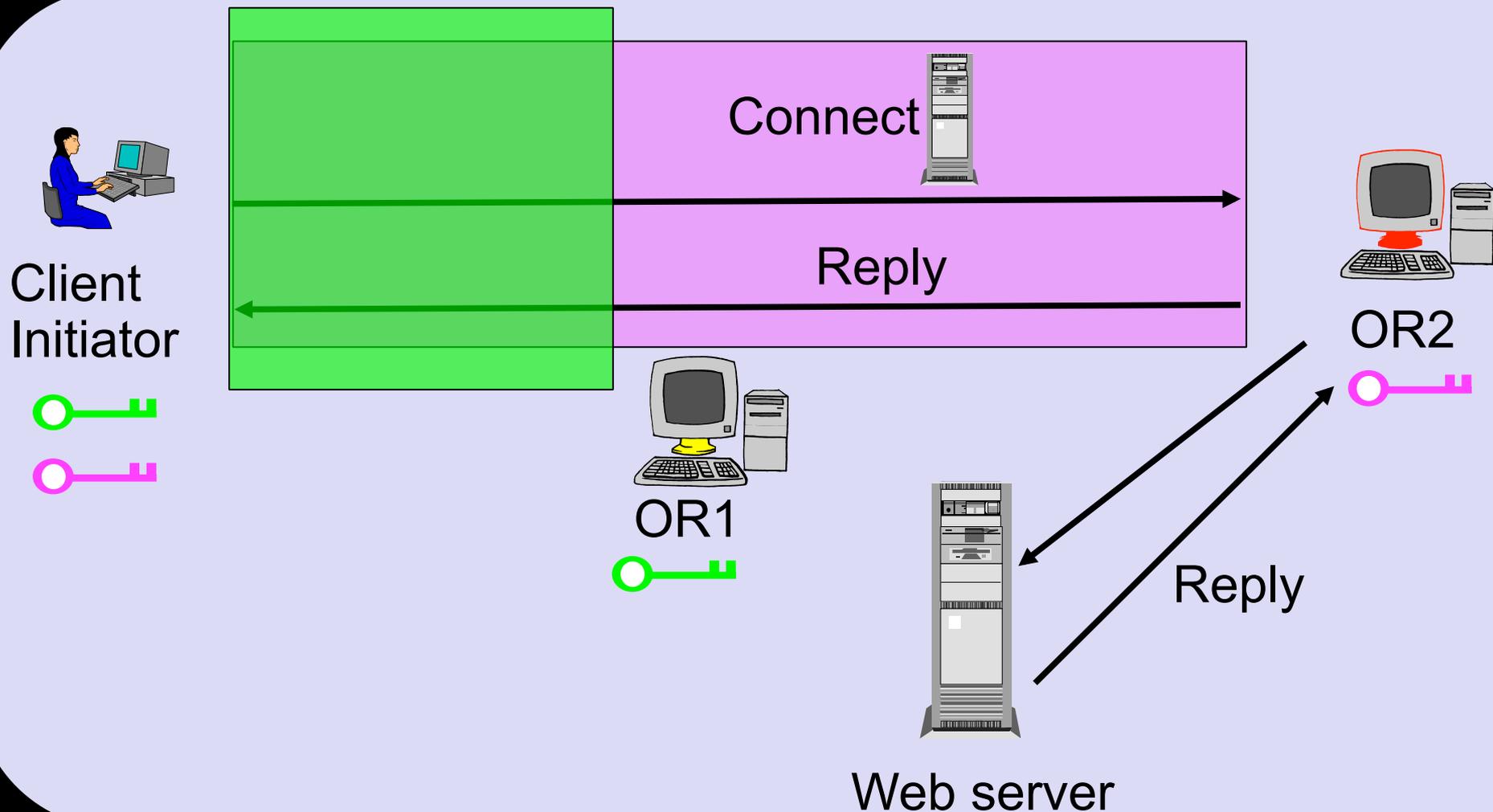
Onion Router



# Tor Circuit Setup (Extend)



# Tor Circuit Setup (Begin) and Data Flow



# How do we know where to build a circuit? Network discovery.

- Flat flooding of network state: complex, tricky, scales in principal but ?
- Tor has a directory system
- Originally a single directory signing information about network nodes. Then a multiple redundant directory with mirrors. Then a majority vote system. Then a consensus document system. Then separate things that need to be signed and updated frequently. Then...

# Onion routing was invented to separate identification from routing

- What if onion-routing-network-user is the identification you want to avoid?
- Bridges are proxies into the Tor network that are not publicly listed.
- Tricky to get bridge info out to potential users without giving it to the network blockers.
- Flash Proxy plugin on volunteer's browser connects to both censored client and Tor relay
- Can also use obfuscated transport to hide Tor protocols from DPI.

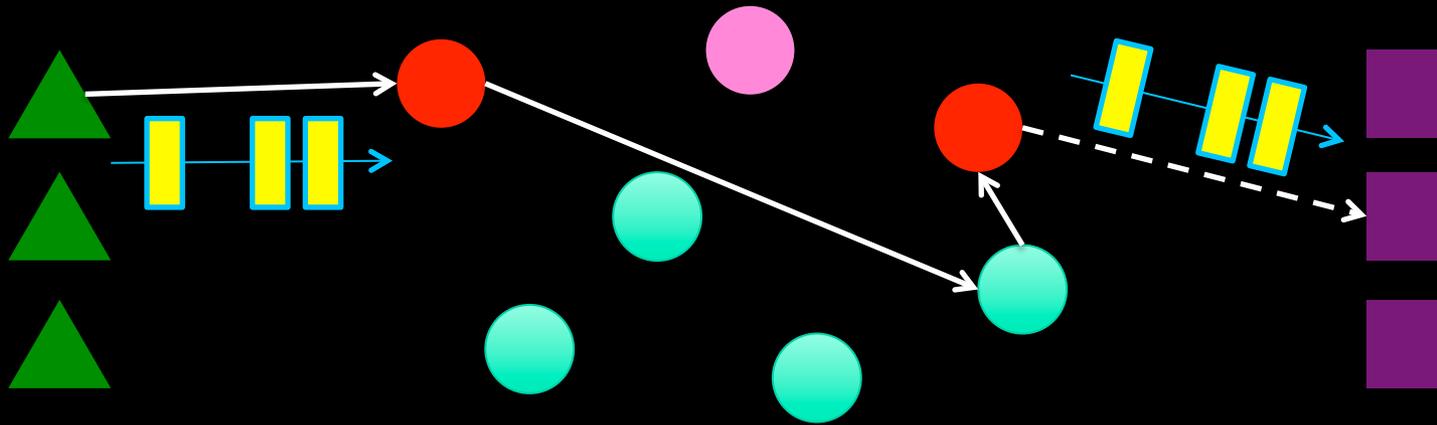
# What if adversary owns a botnet or has nation level resources?

- Consumer Alice, abuse/disease victim Alice, local law enforcement Alice, etc. probably OK
- Intelligence analyst Alice, DoD road warrior Alice, etc. ?

# Network diversity environment

- Government comms sometimes must use public internet
  - Open source intelligence gathering
  - Traveling employees communicating back home
  - Interacting with untrusted/semitrusted parties
- Need a network with diversely run infrastructure
- Economic and usage feasibility implies a free-to-use network with infrastructure open to any contributors
- Cannot preclude adversaries running a significant portion of your network

# First-Last Correlation Problem



## What?

- Adversary observes first and last routers.
- Traffic patterns link first and last routers.

## Why?

- Attack completely breaks anon regardless of number of users.
- Attack possible with moderate resources.
  - 17MB/s compromises random 1% of current Tor users (100 or so home Internet accounts needed for attack)
- Padding, etc. too expensive and will never work anyway.

# Key Idea: Trust

- Users may know how likely a router is to be under observation.

## *Tor Routers with Possible Trust Factors*

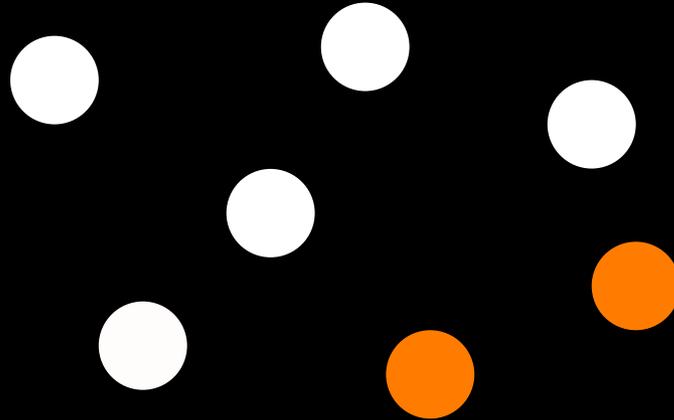
Name	Hostname	Bandwidth	Uptime	Location	Tor version	OS
moria	nexico.ediscom.de	4 KB/s	67 days	Germany	0.2.1.26	Linux
Republic	xvm-107.mit.edu	121 KB/s	49 days	USA	0.2.1.29	Linux
Unnamed	static- ip-166-154-142-114. rev.dyxnet.com	58 KB/s	58 days	Hong Kong	0.2.1.29	Windows Server 2003 SP2

Source: <http://torstatus.blutmagie.de>, 10/12/2011

# Basic Adversary Model

Routers  $R$

Users



Destinations



Adversary  $A$

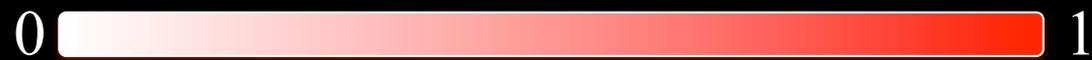
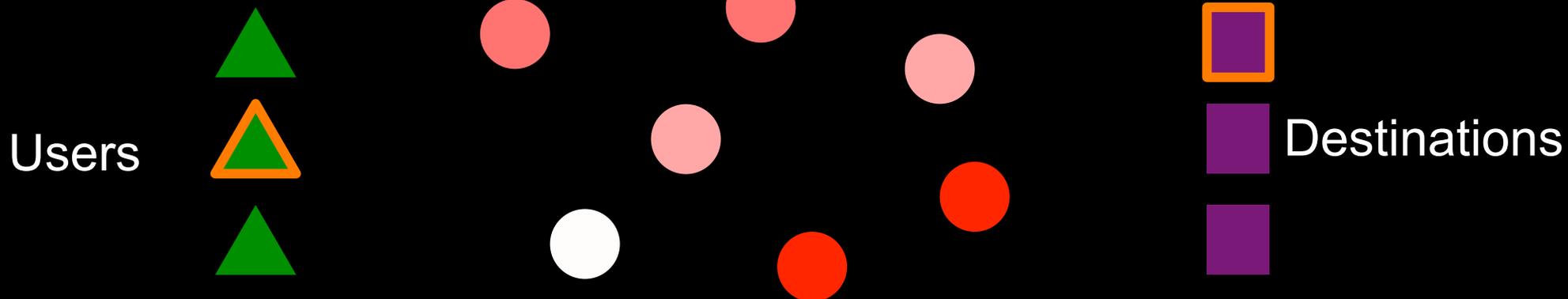
# Basic *Trust* Model

Routers  $R$



# Trust Model 1: Limited Adversary

Routers  $R$

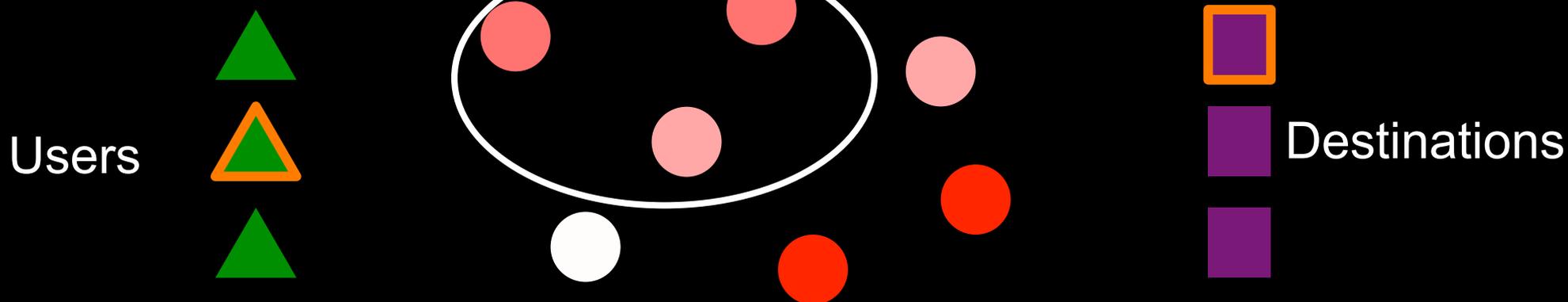


Probability of Compromise:  $c$

◆ Adversary  $A$   
 $A \subseteq R, |A| \leq k$

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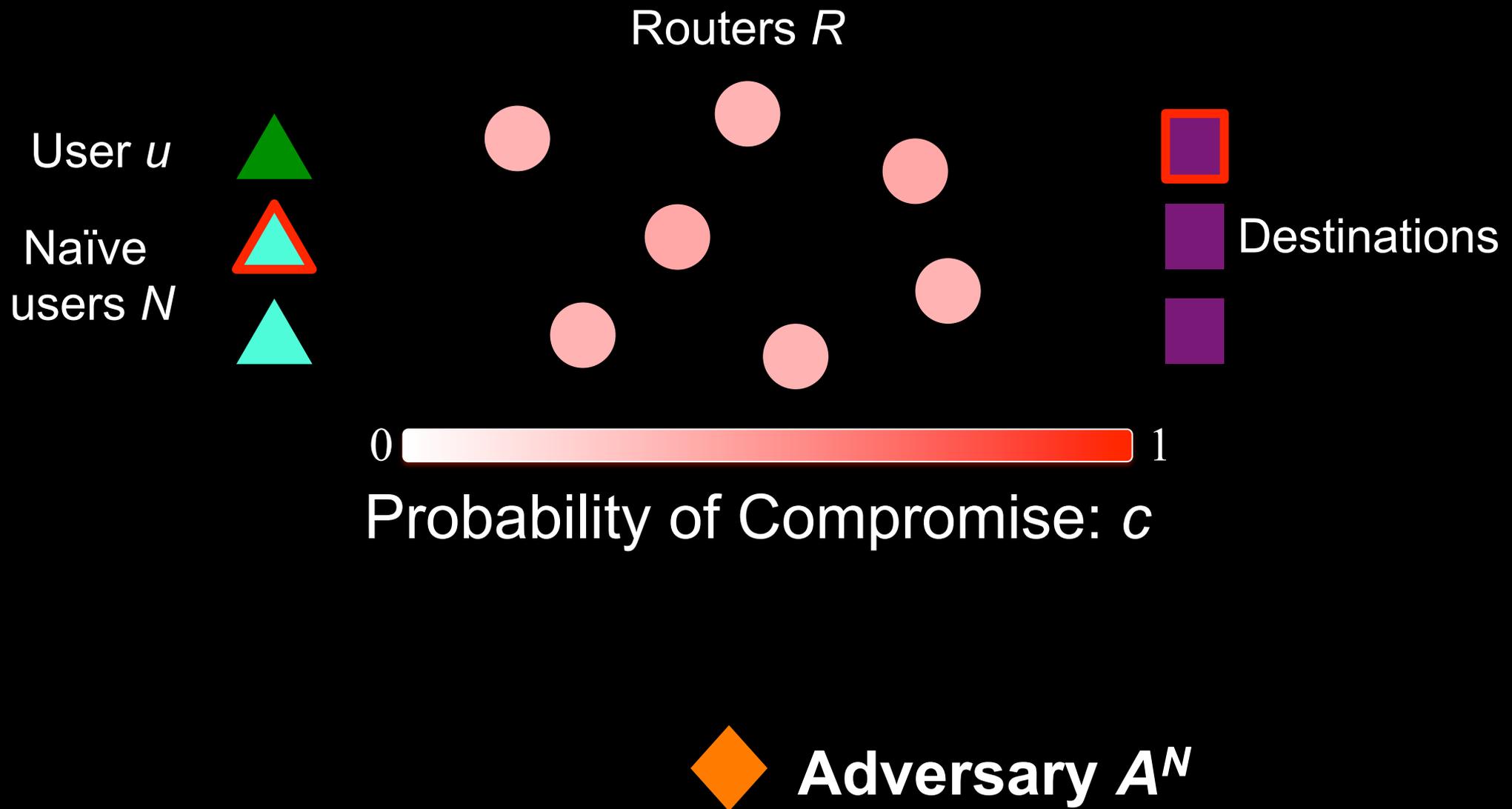


0 1

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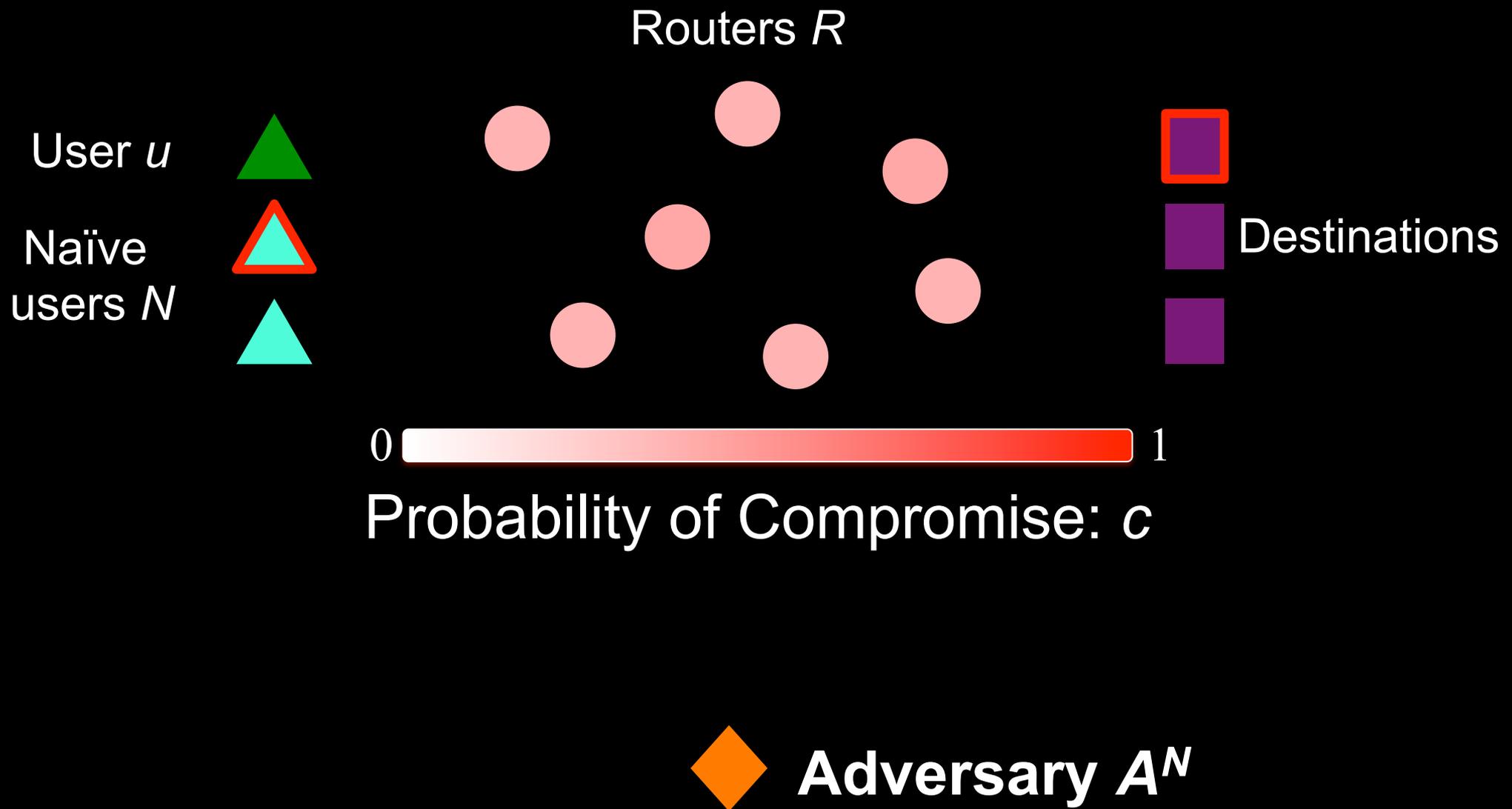
# Trust Model 2: Per-User Adversary



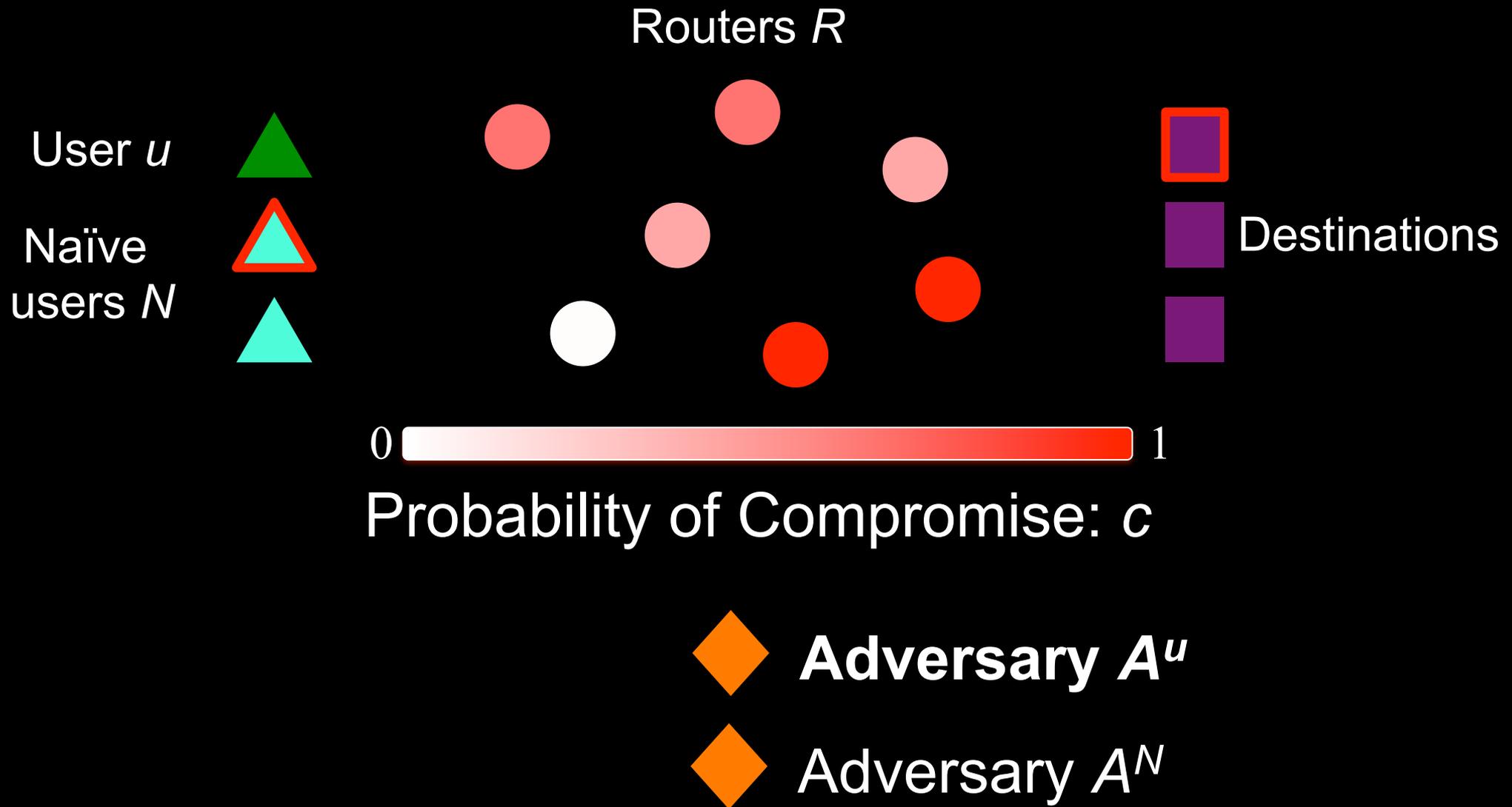
# The Man



# Trust Model 2: Per-User Adversary

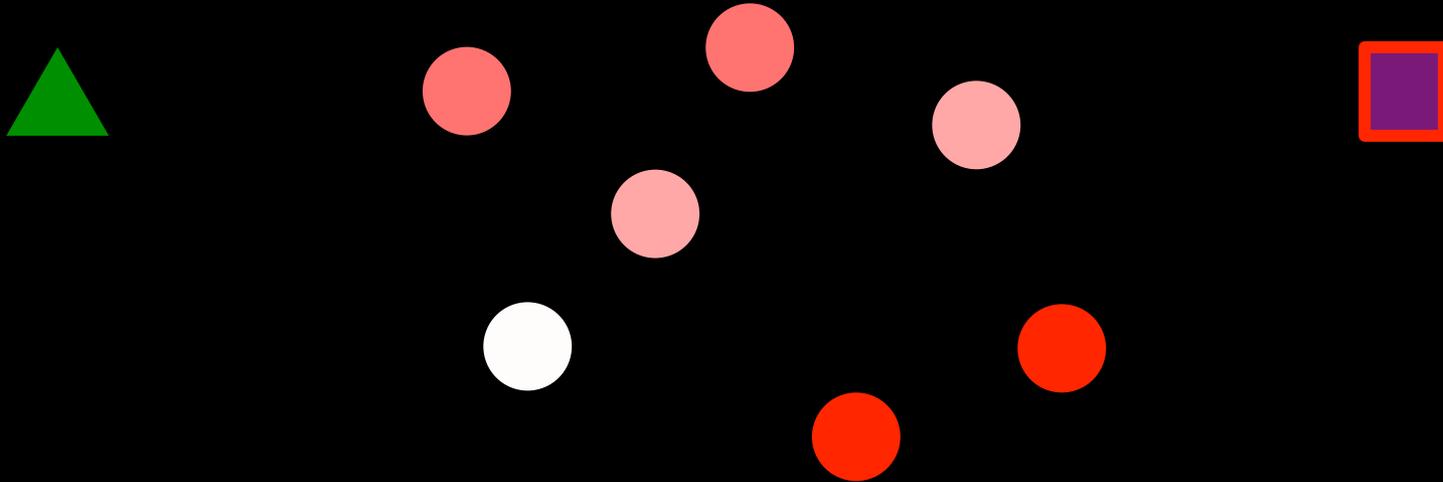


# Trust Model 2: Per-User Adversary



# Downhill Algorithm

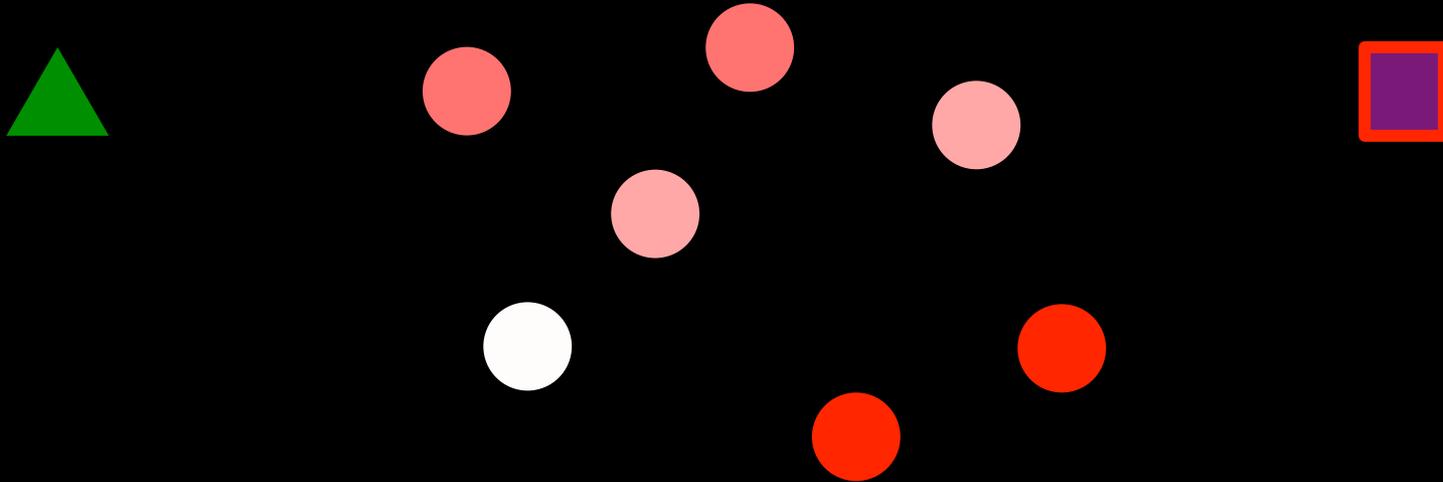
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1. Set path length  $l$  and trust levels  $\lambda_1, \dots, \lambda_l$  to optimize anonymity metric.

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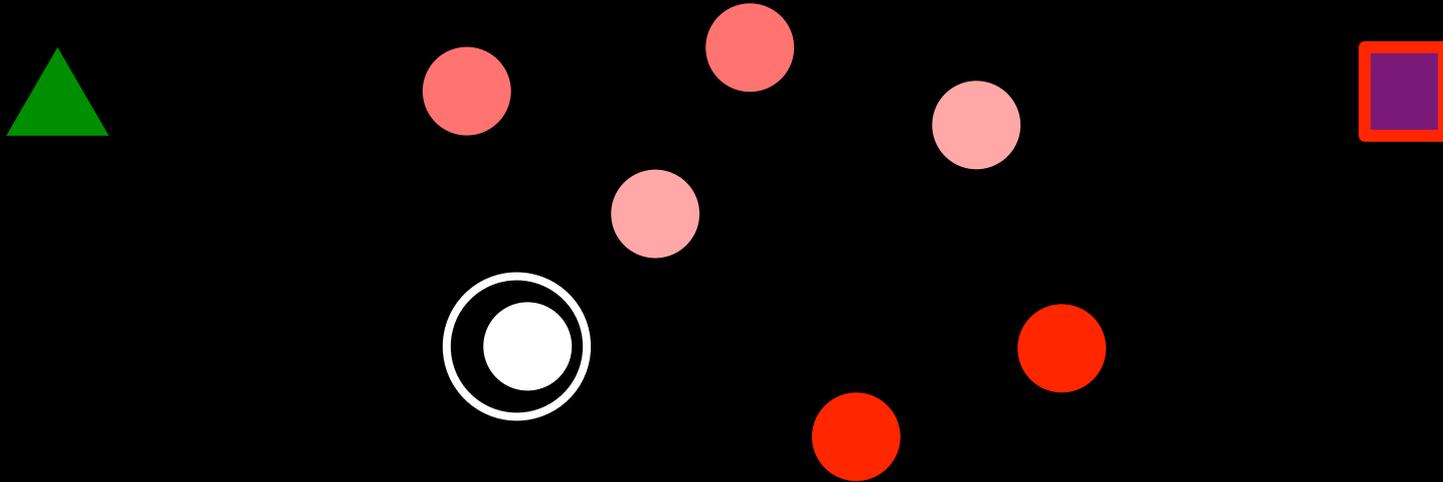
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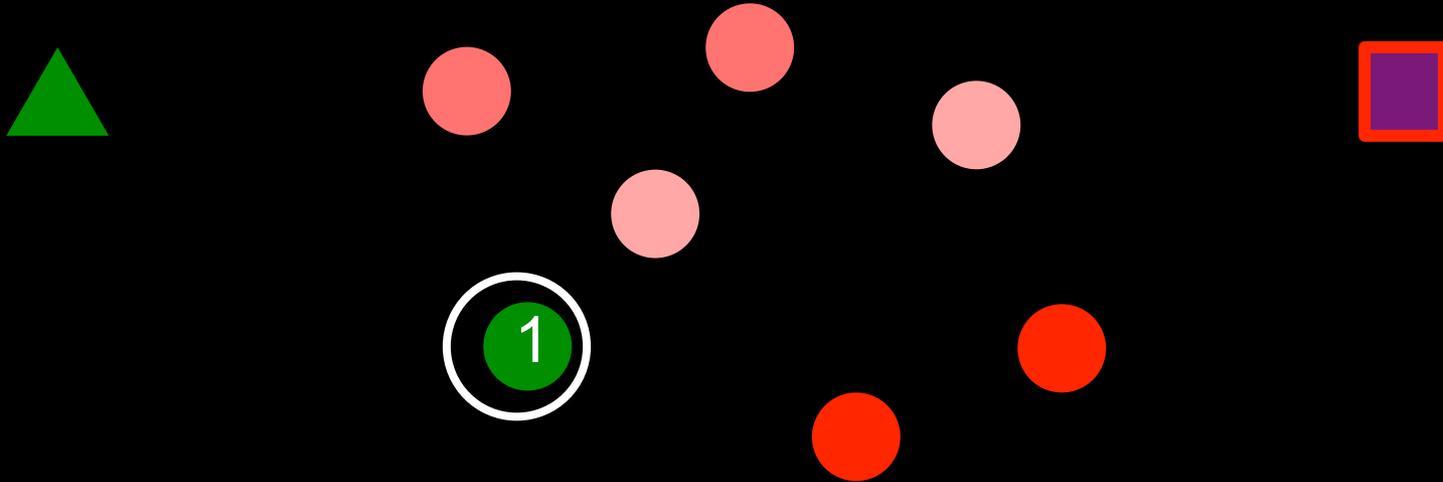
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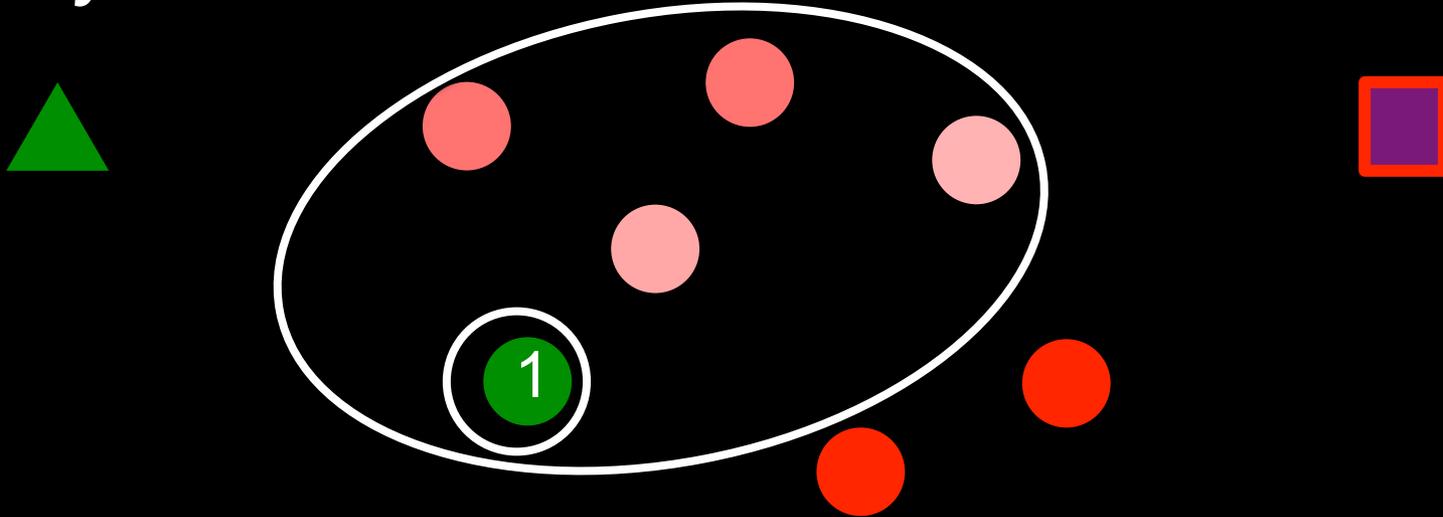
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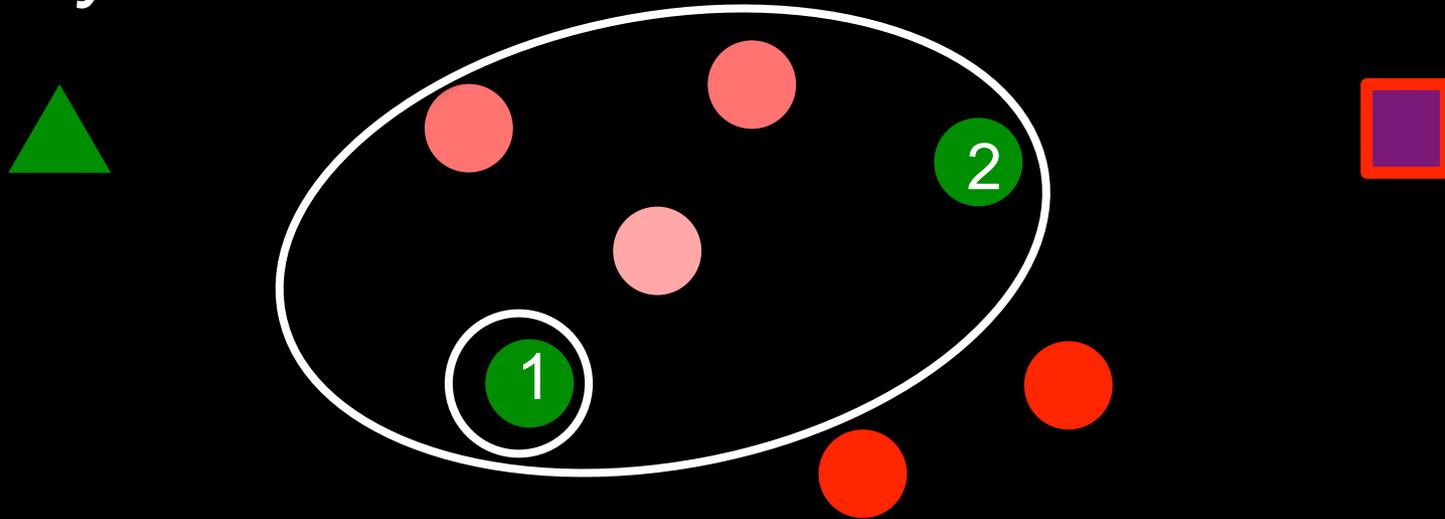
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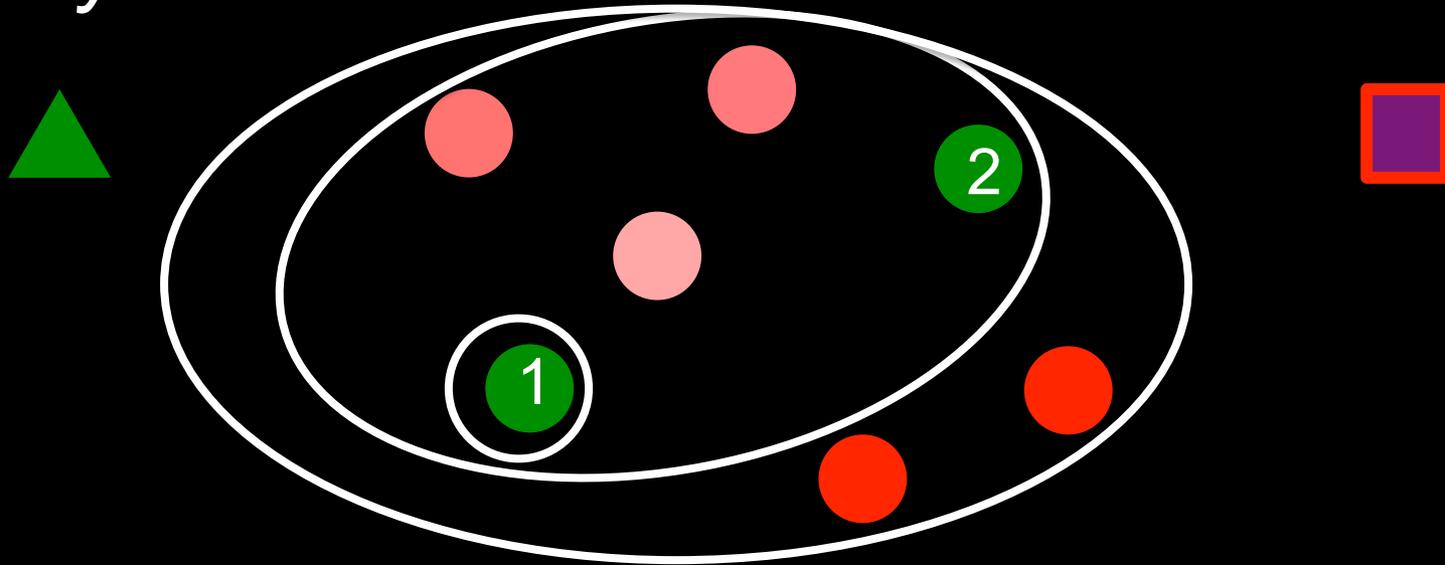
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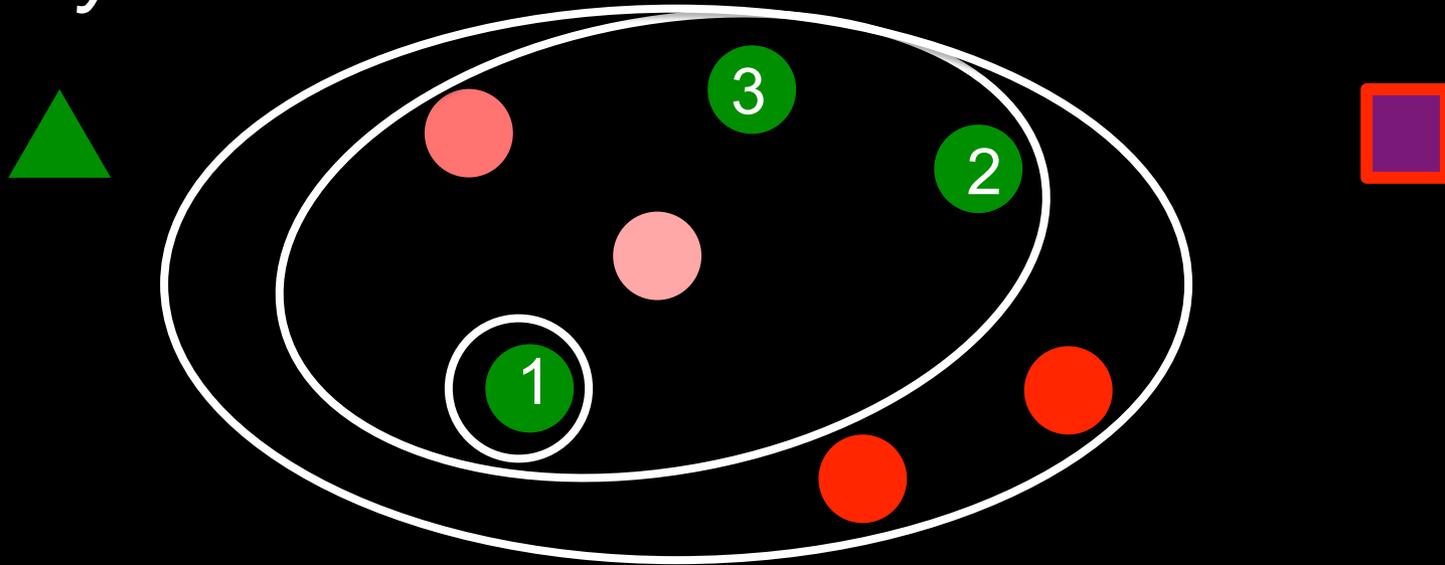
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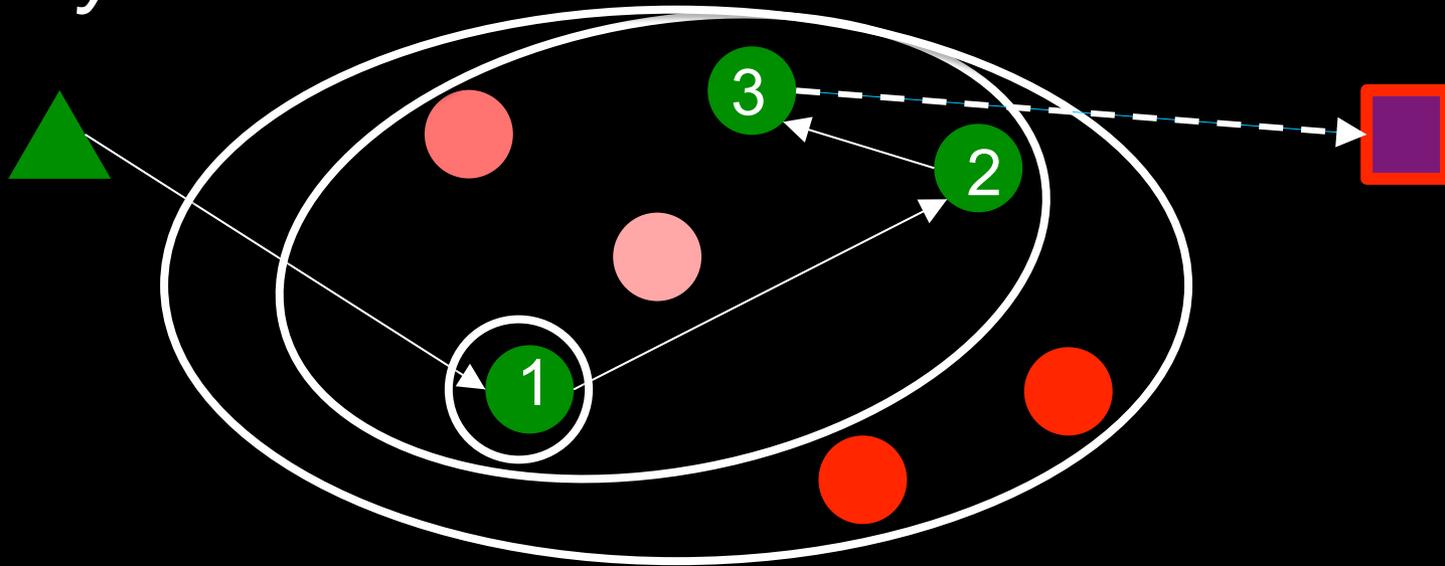
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3. For each connection,  
Create circuit through selected routers to the destination.

# Anonymity Analysis of Downhill Algorithm

Metric: Posterior probability of actual source of a given connection.

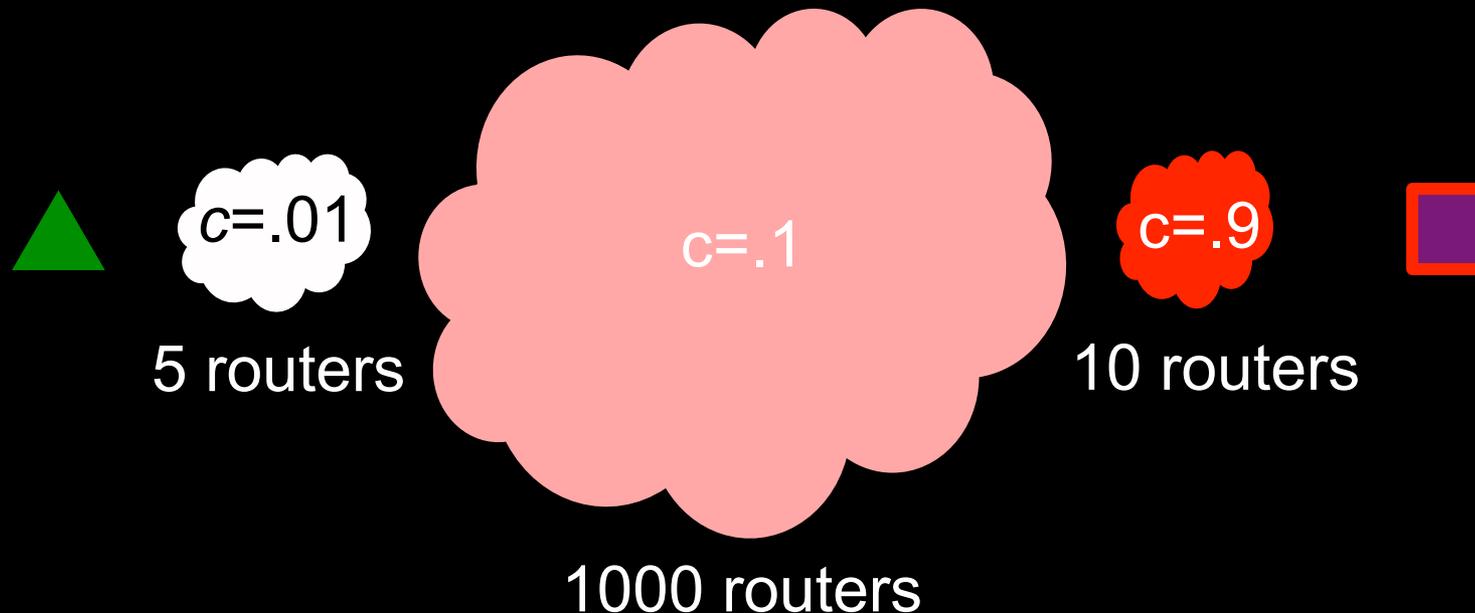
Expected anonymity	Downhill	Most trusted	Random	Lower bound
Many @ medium trust	0.0274	0.2519	0.1088	0.01
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*Scenario 1:* User has some limited information.



# Anonymity Analysis

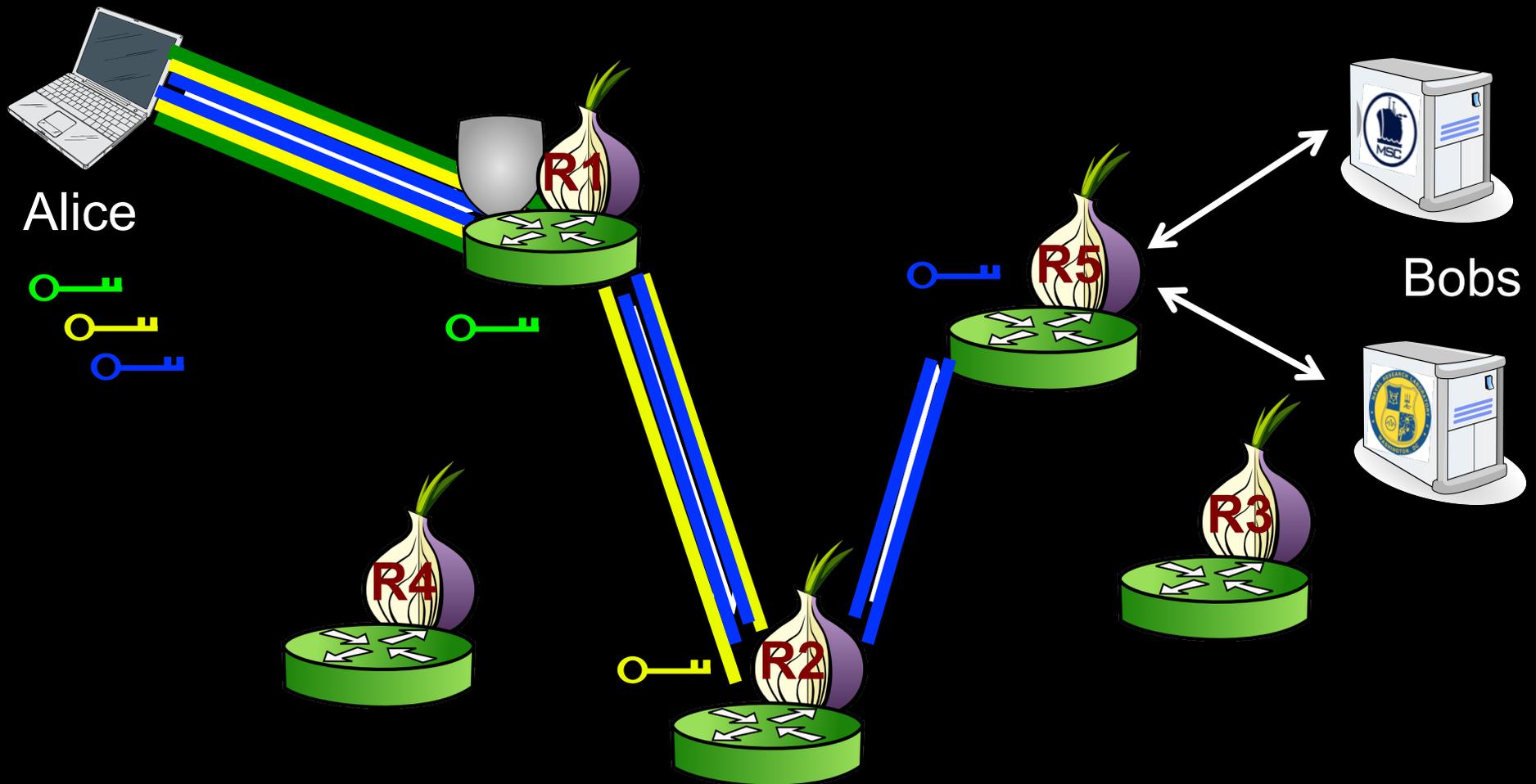
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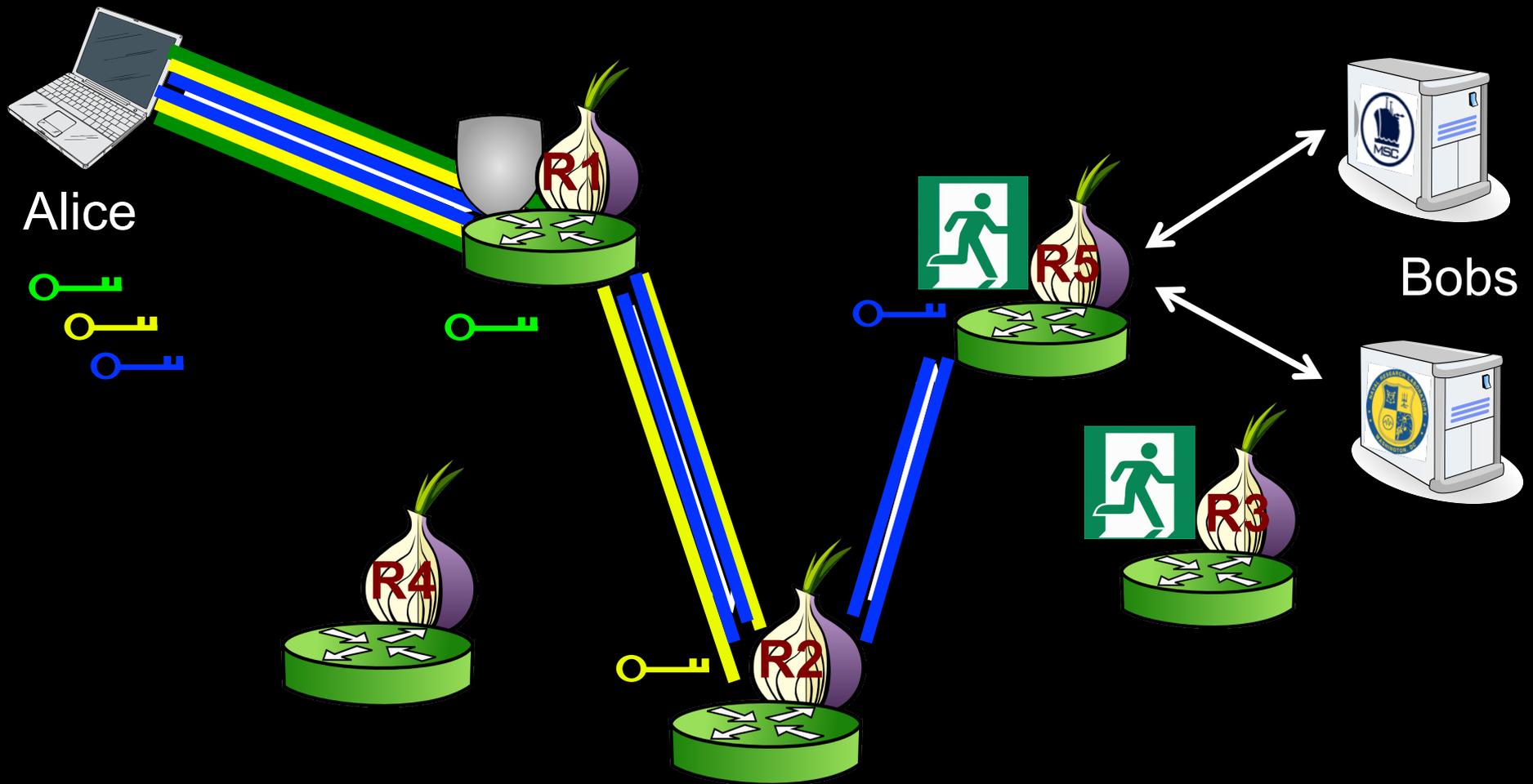
*Scenario 2:* User and friends run routers. Adversary is strong.



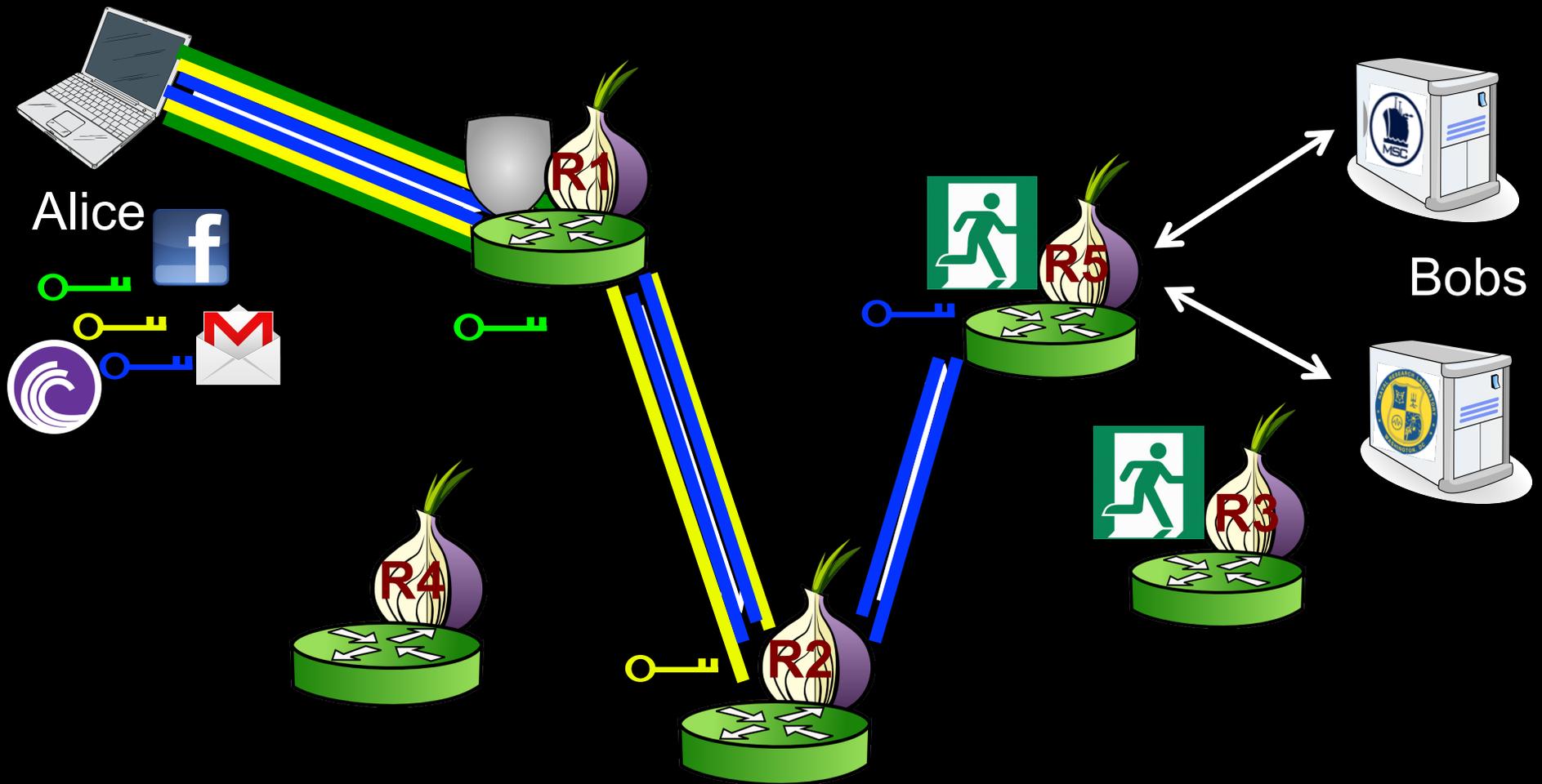
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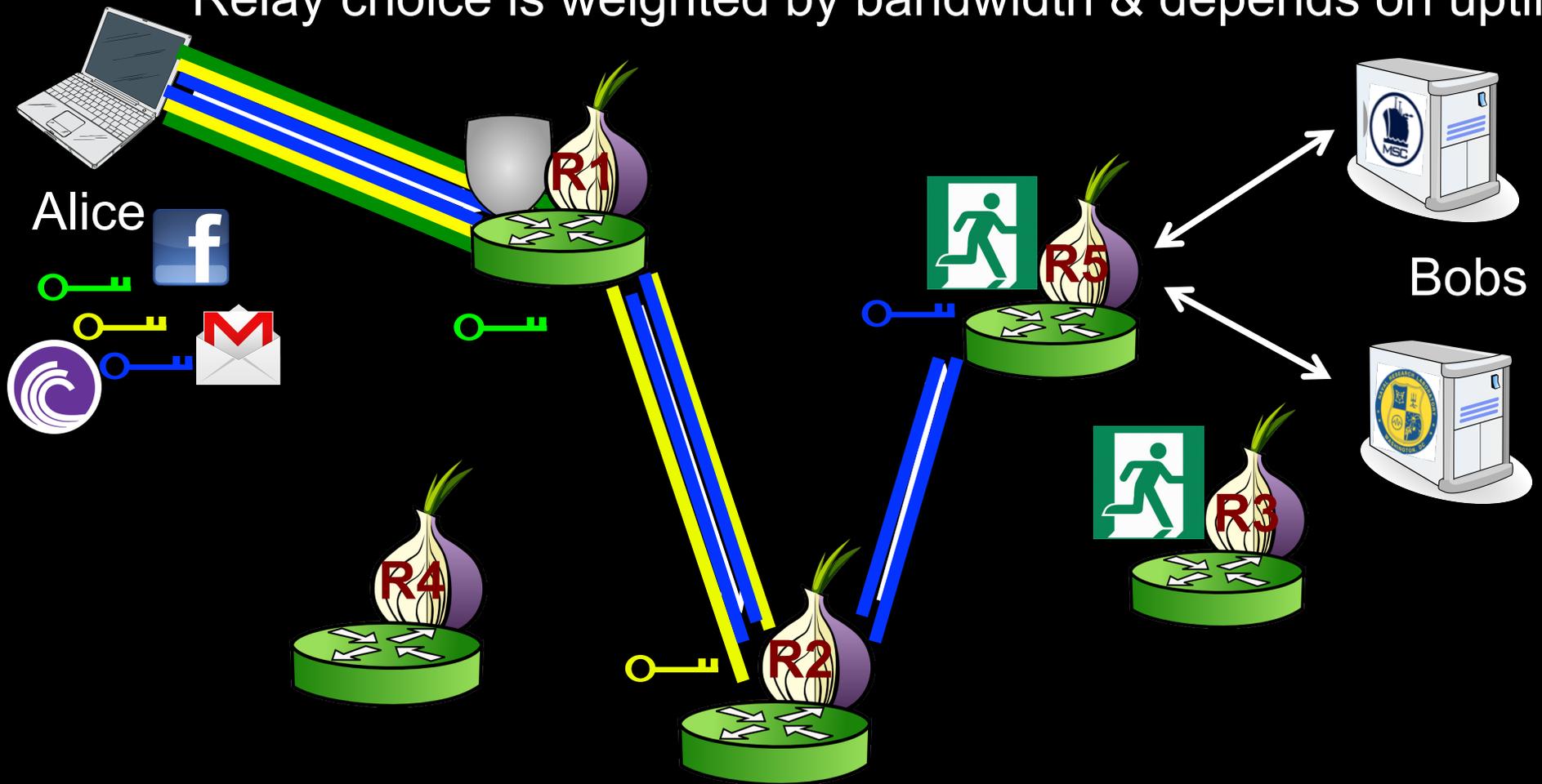


# Tor: Actual path selection



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Relay choice is weighted by bandwidth & depends on uptime

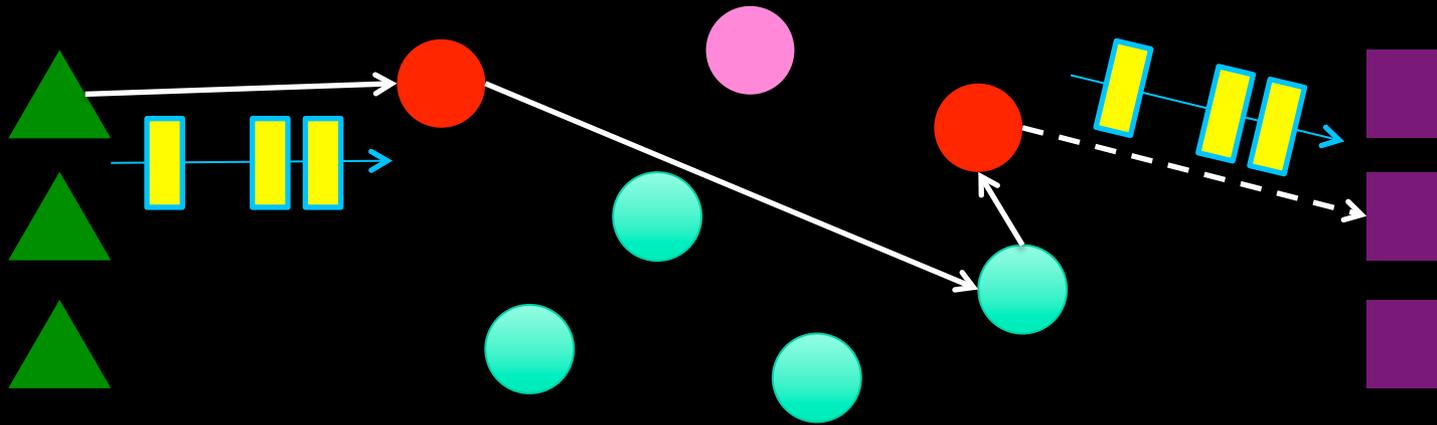


# Users get routed

(ACM CCS'13 NRL/Georgetown collaboration)

- 80% of all types of users may be deanonymized by moderate Tor-relay adversary within 6 months

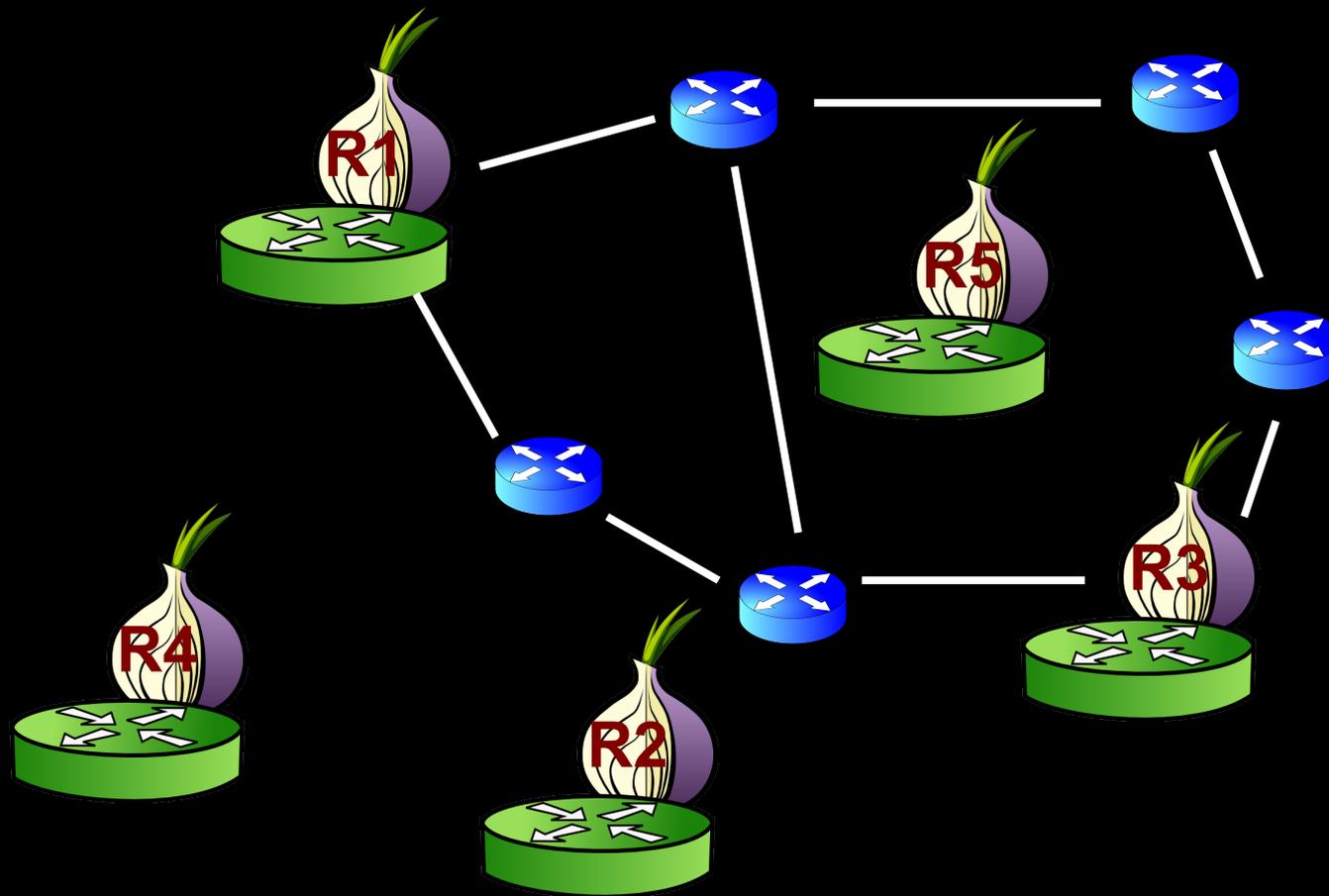
# First-Last Correlation Problem



What?

- Adversary observes first and last routers.
- Traffic patterns link first and last routers.

# Onion Routers (Relays/Nodes): Overlay network



# Users get routed

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- 80% of all types of users may be deanonymized by moderate Tor-relay adversary within 6 months
- Against a single-AS adversary roughly 100% of users in some common locations are deanonymized within three months
- (or 95% in 3 months for a single IXP)
- 2-AS adversary reduces median time to the first client deanonymization by an order of magnitude:
  - from over 3 months to only 1 day for typical web user
  - from over 3 months to c. 1 month for a BitTorrent user

Using Trust is first approach to protect traffic even if adversary owns a large chunk of the network.

Not yet (or much) mentioned/future work:

- Datagram transport
- Links
- Performance/congestion/throttling/incentives
- Hidden services
- Trust propagation
- Better security models

Questions?

