A SIMPLE INTRODUCTION TO TOR

The Onion Router

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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

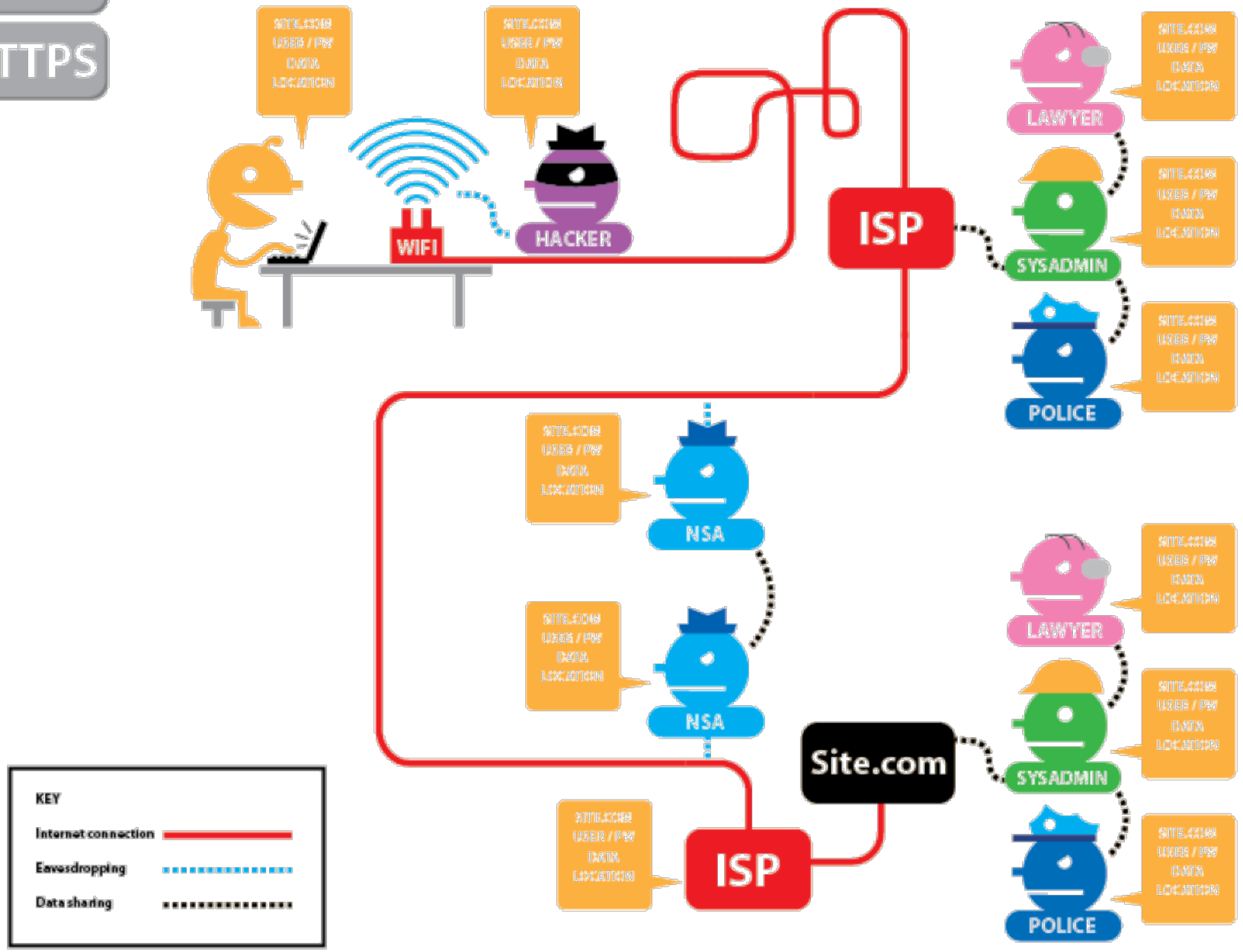
- Passive traffic analysis
  - Infer from network traffic who is talking to whom
- Active traffic analysis
  - Inject packets or put a timing signature on packet flow
- Compromise of network nodes
  - Attacker may compromise some routers
  - It is not obvious which nodes have been compromised
    - Attacker 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

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 is a distributed anonymous communication service using an overlay network that allows people and groups to improve their privacy and security on the Internet.
- Individuals use Tor to keep websites from tracking them, or to connect to those internet services blocked by their local Internet providers.
- Tor's hidden services let users publish web sites and other services without needing to reveal the location of the site.

Tor

HTTPS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KEY
Internet connection
Eavesdropping
Data sharing

Tor

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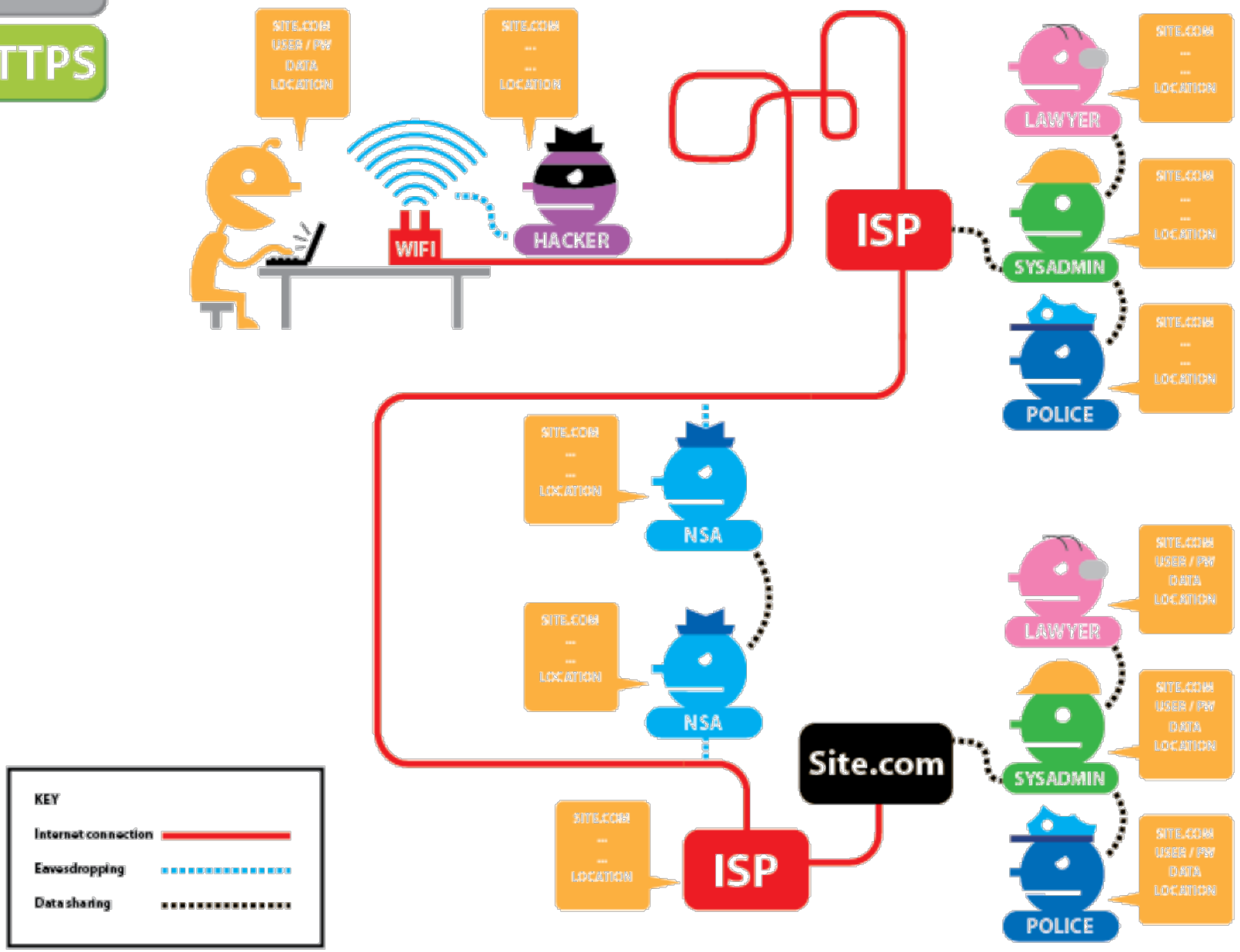
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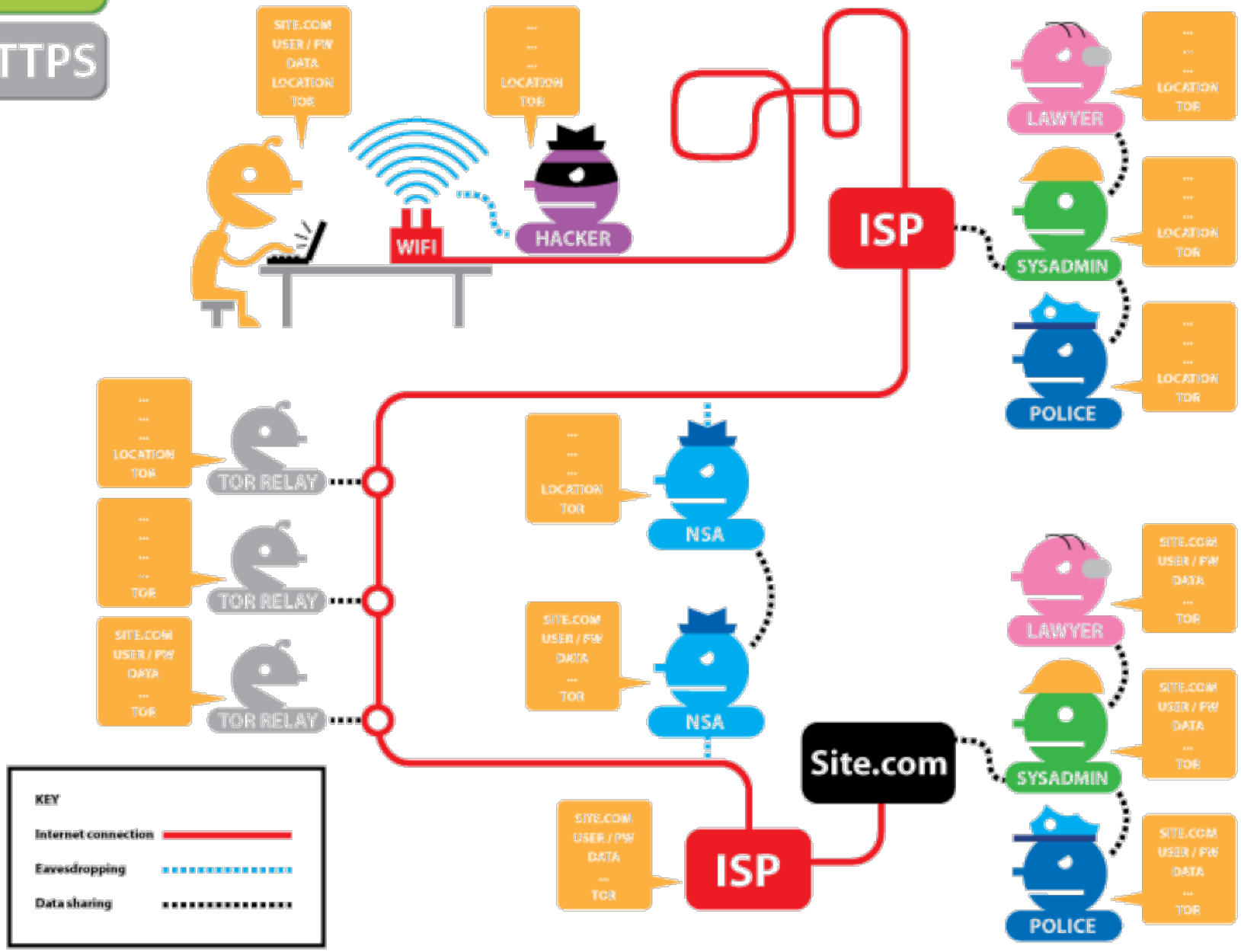
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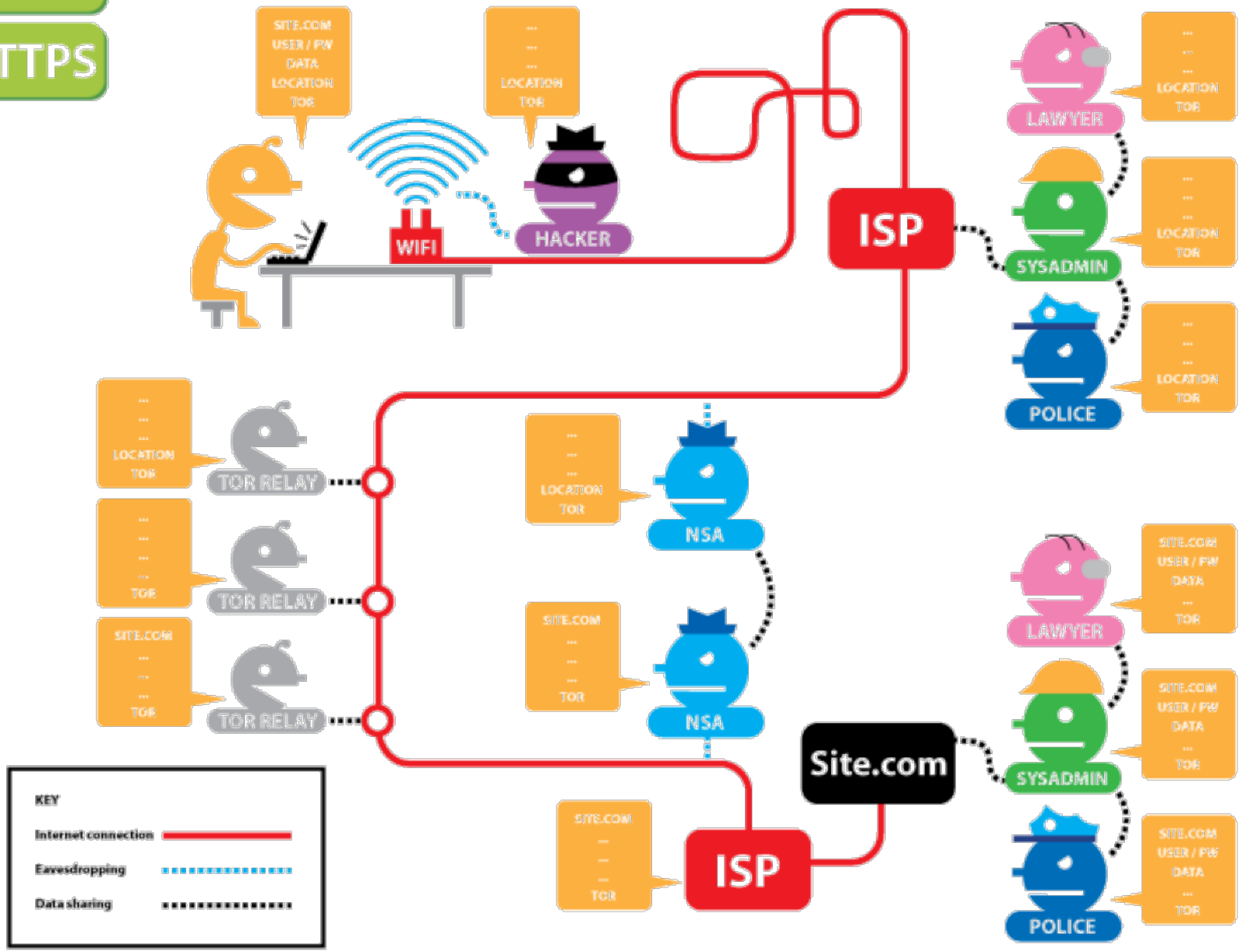
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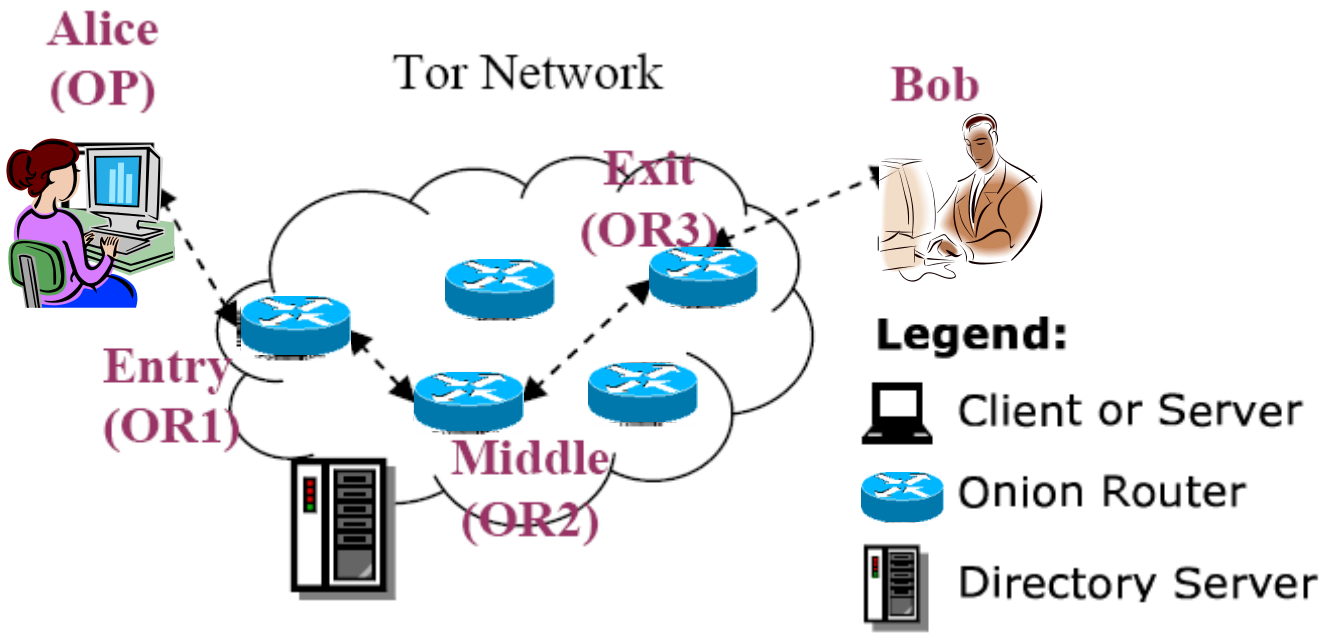
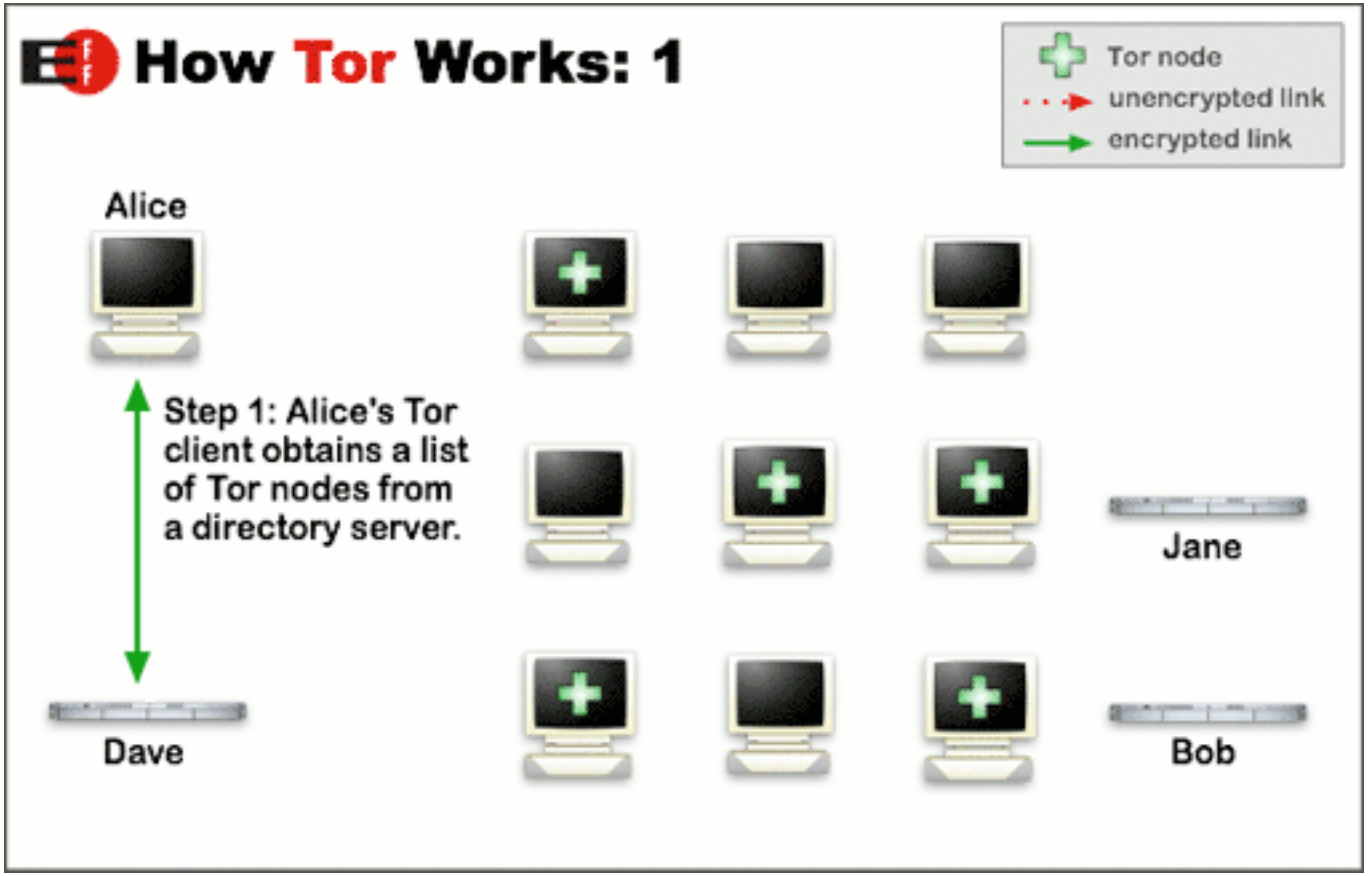
Components of Tor

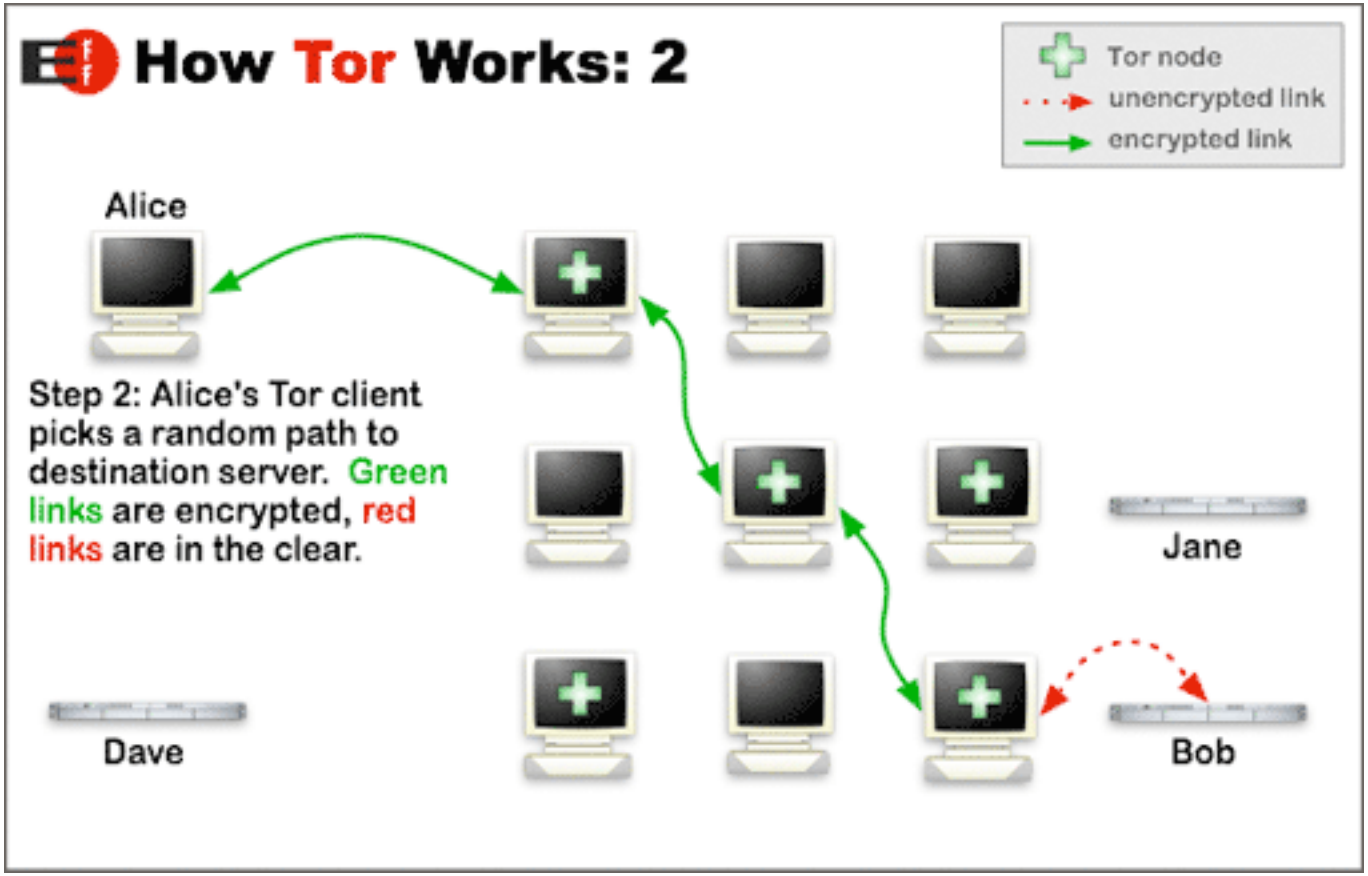


- **Client**: the user of the Tor network
- **Server**: the target TCP applications such as web servers
- **Tor (onion) router**: the special proxy relays the application data
- **Directory server**: servers holding Tor router information

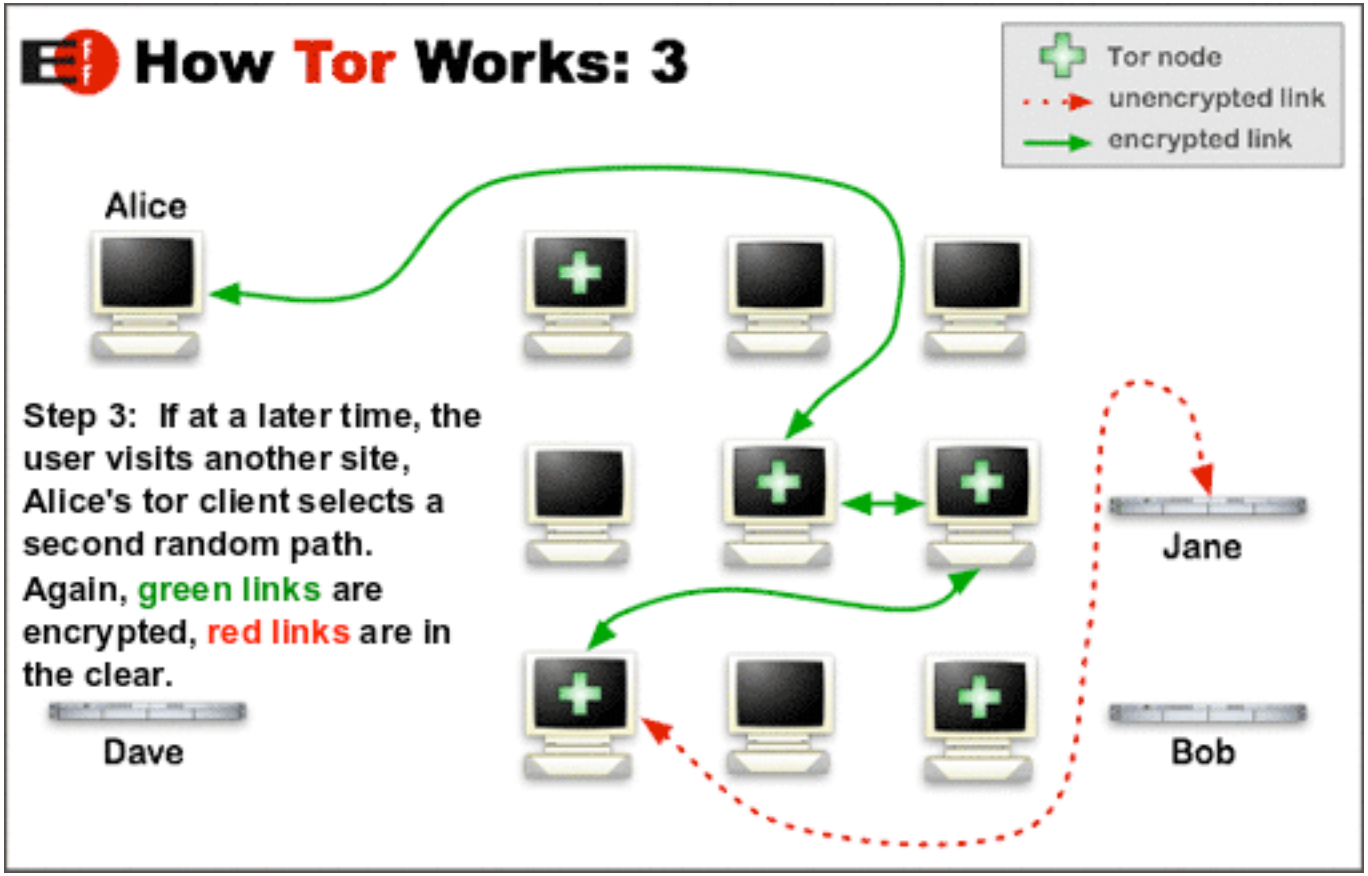
Tor operations 1



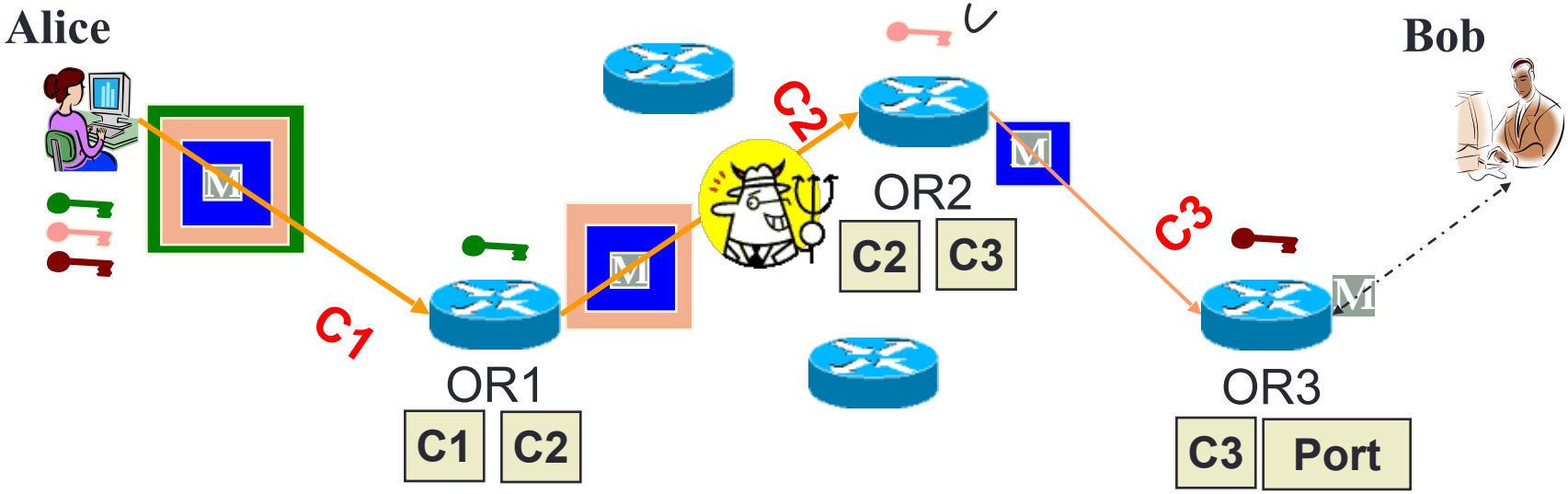
Tor operations 2



Tor operations 3

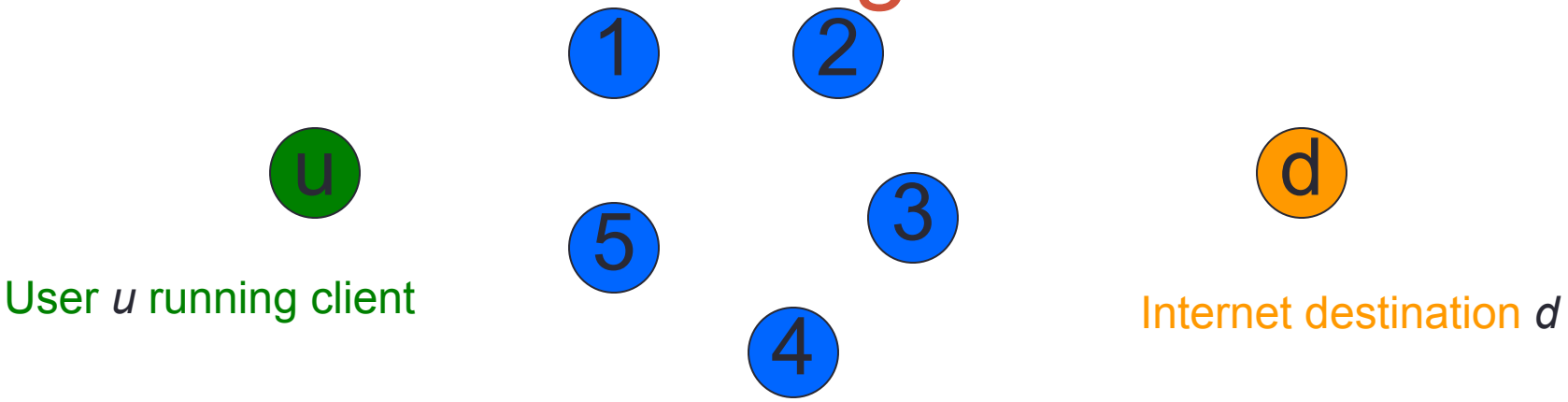


How Tor Works? --- Onion Routing



- A circuit is built incrementally one hop by one hop
- Onion-like encryption
  - Alice negotiates an AES key with each router
  - Messages are divided into equal sized cells
  - Each router knows only its predecessor and successor
  - Only the Exit router (OR3) can see the message, however it does not know where the message is from

How Onion Routing Works



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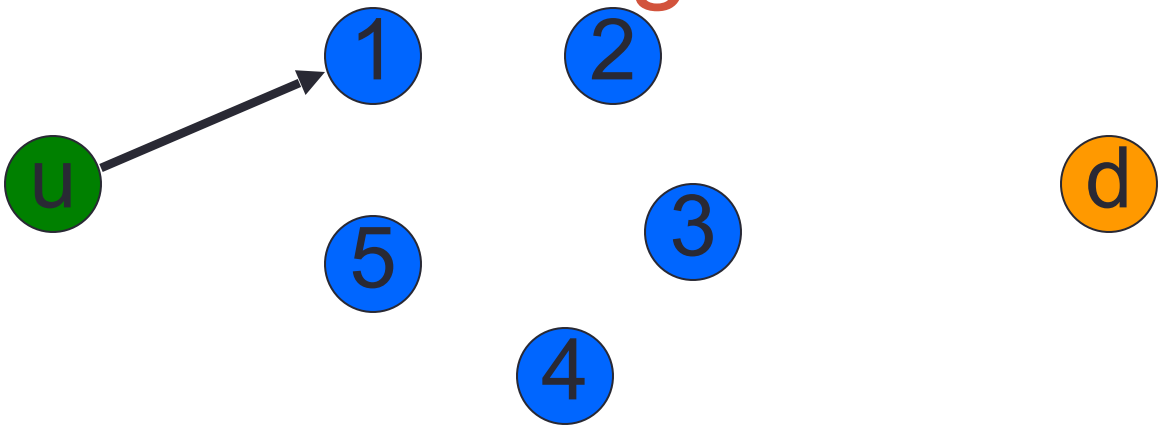

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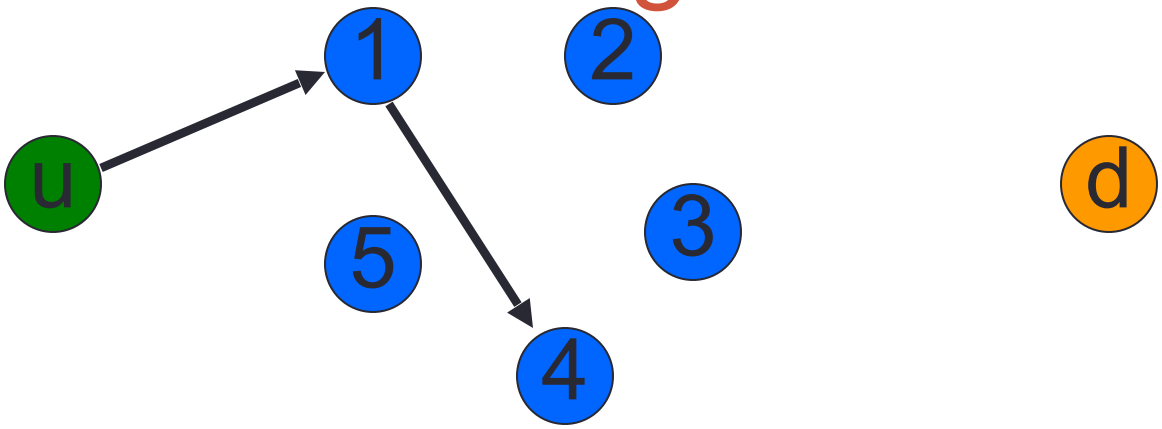

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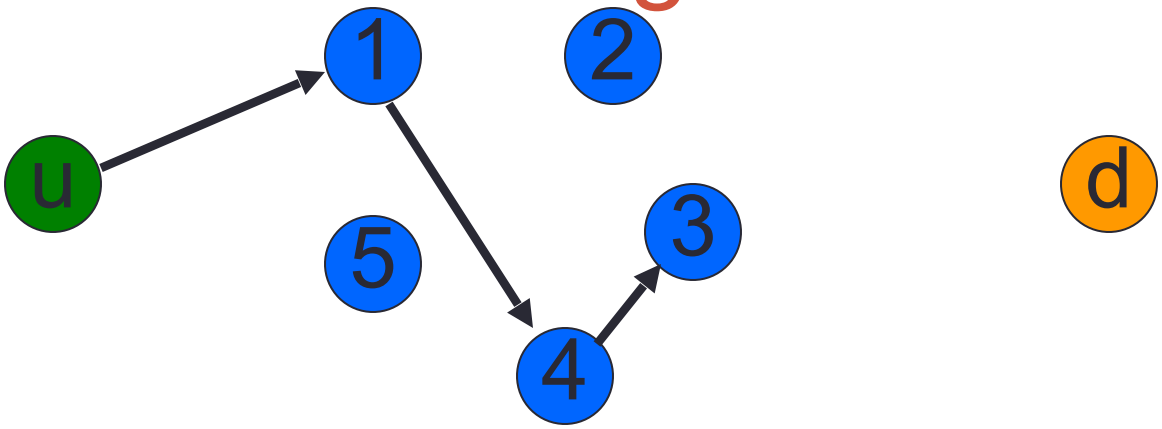

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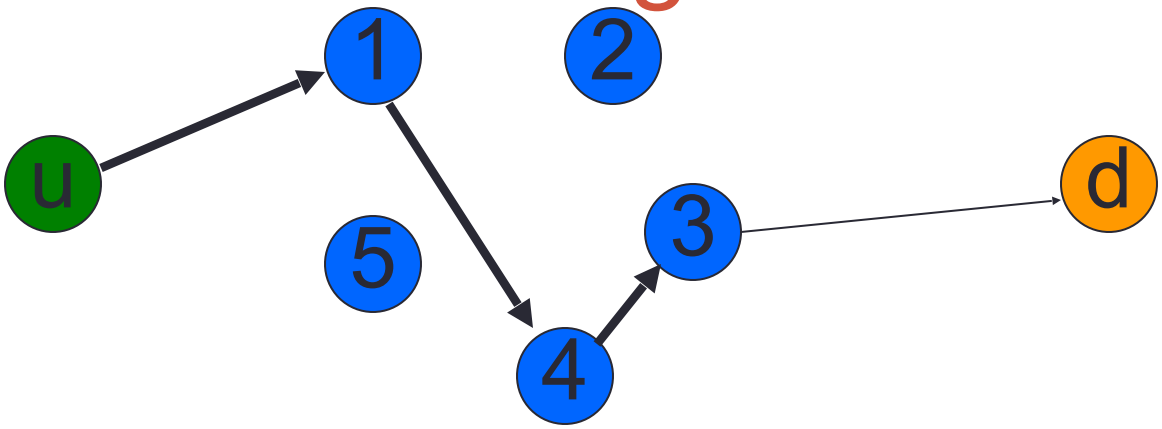

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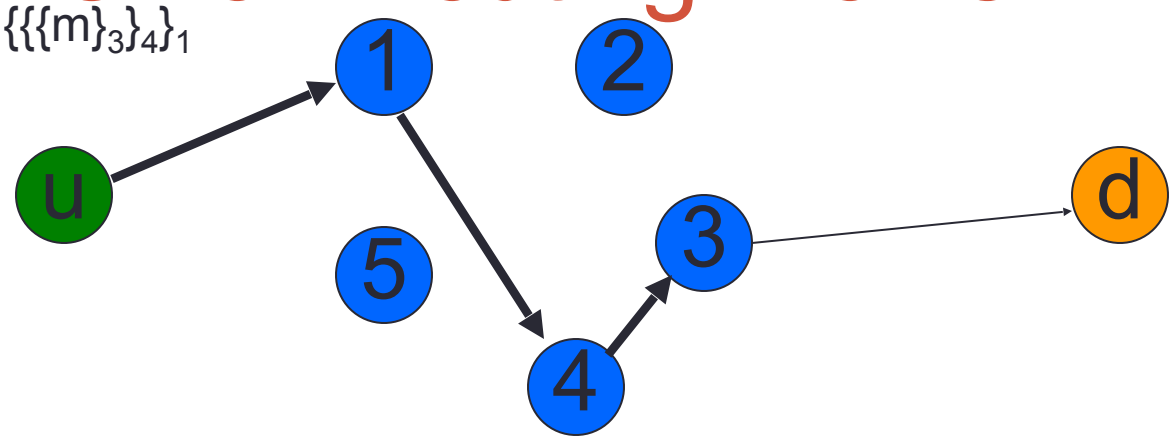

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3. Data are exchanged

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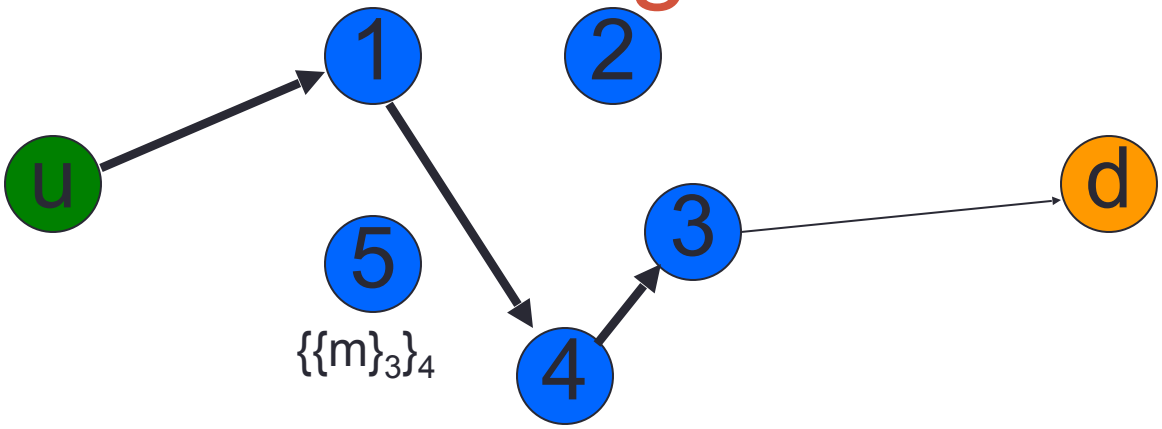

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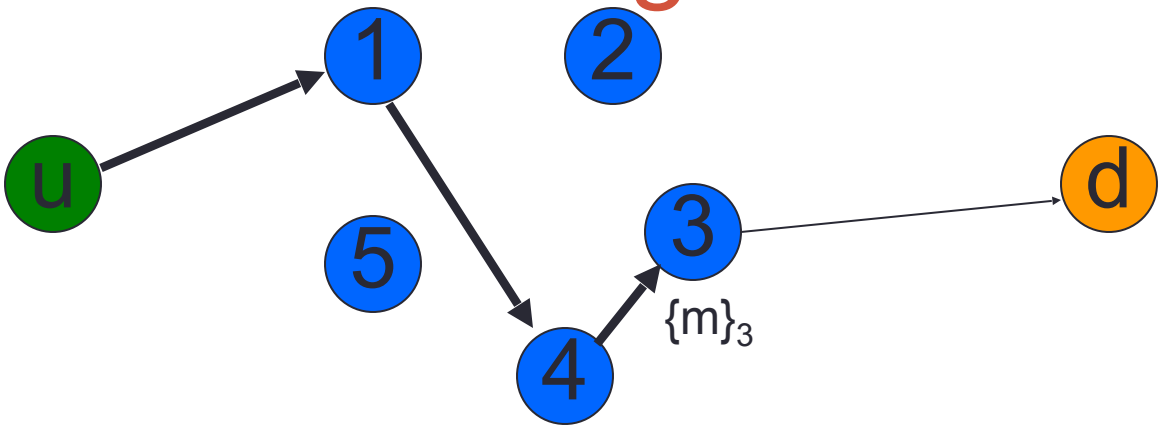

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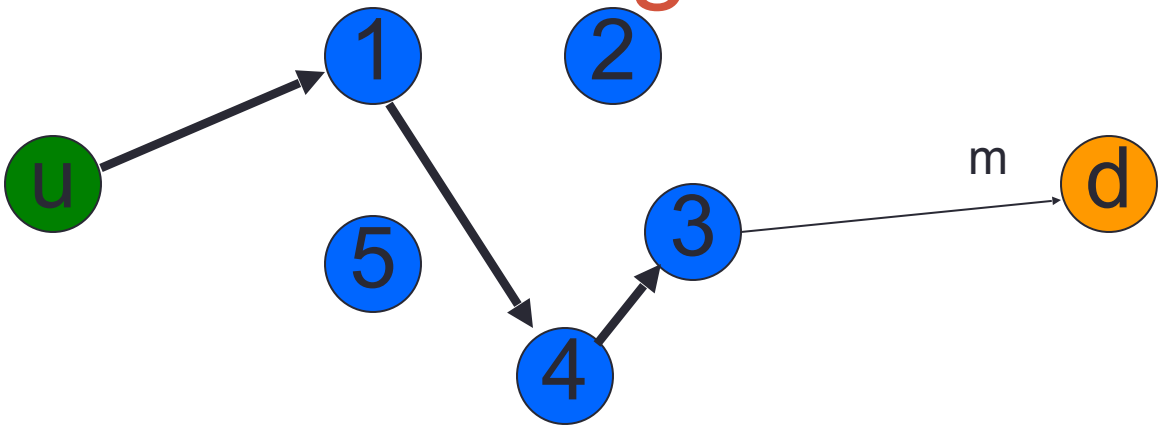

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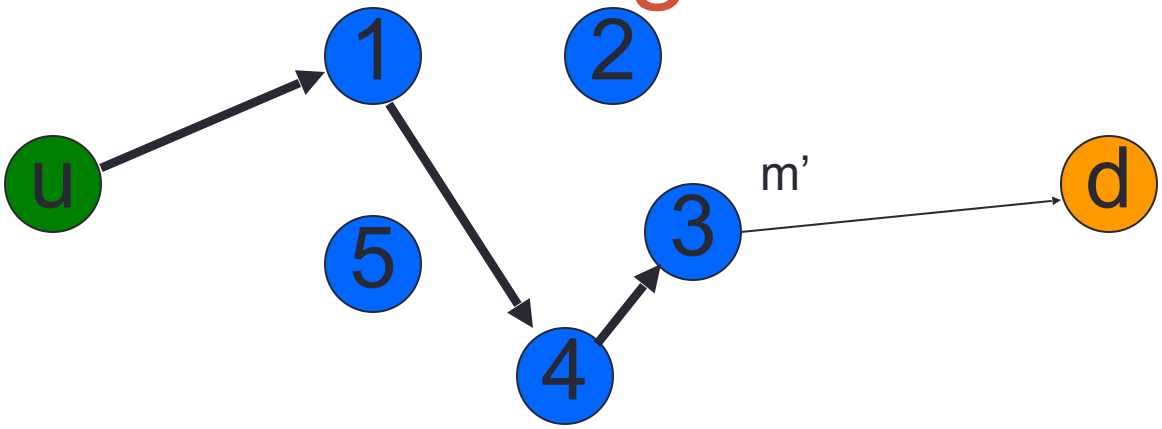

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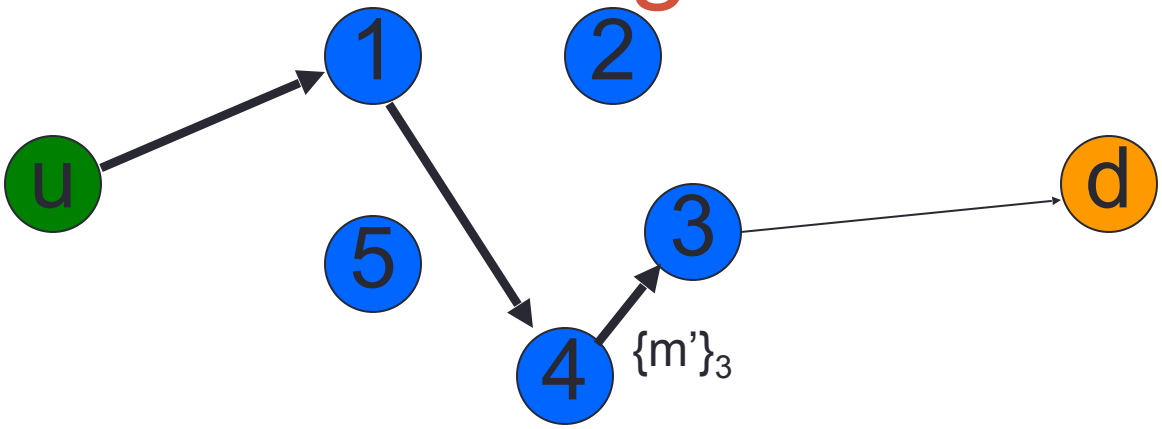

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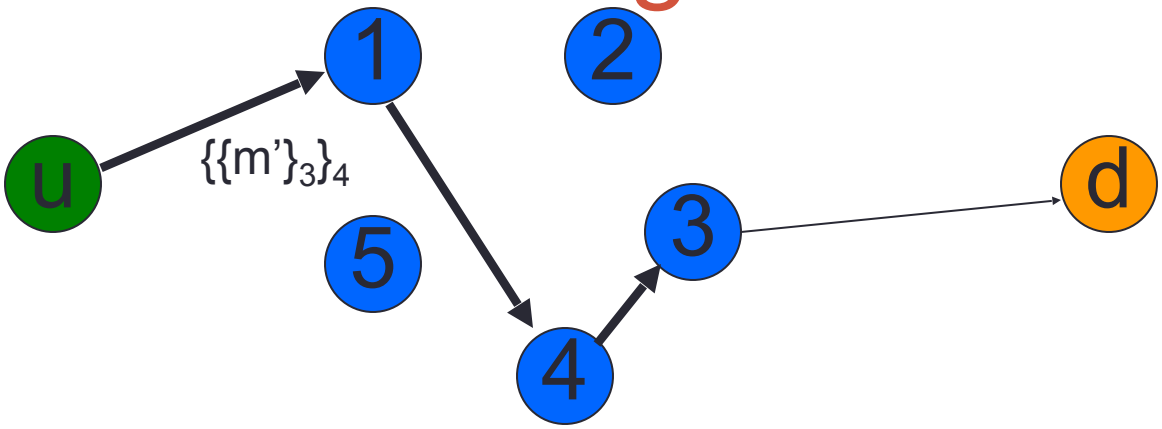

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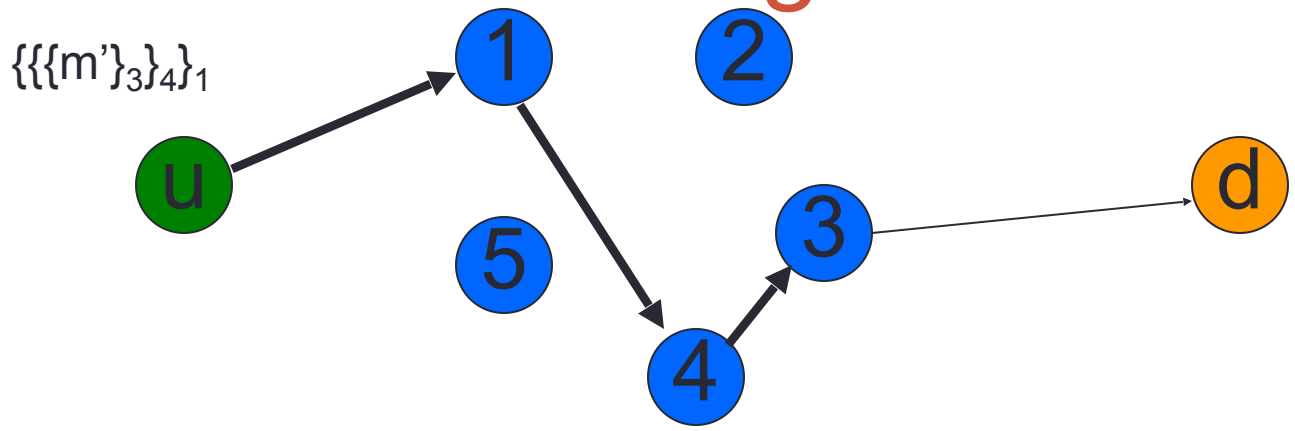

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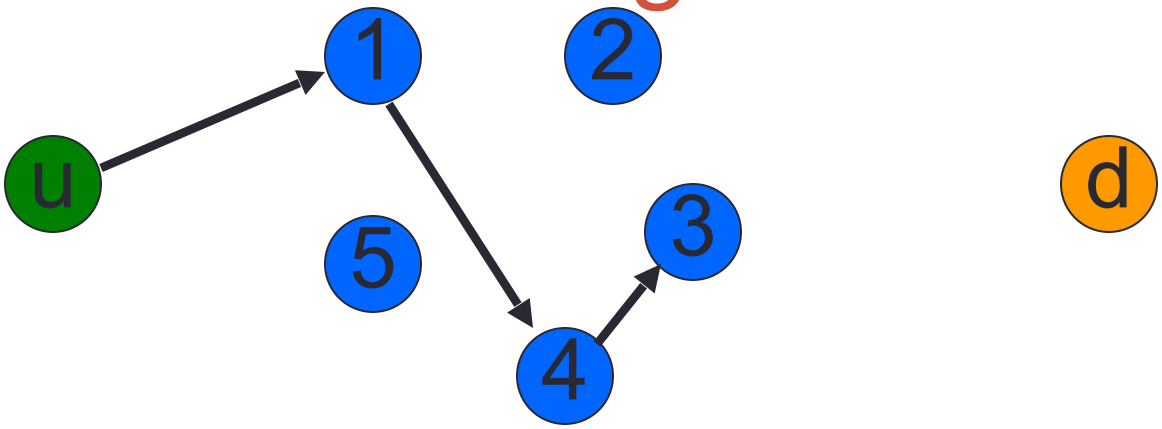

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4. Stream is closed.

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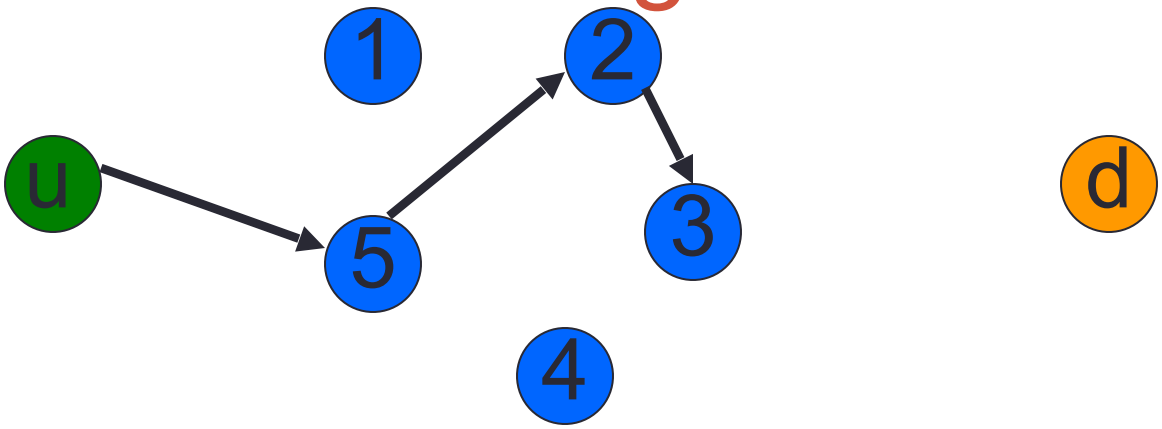
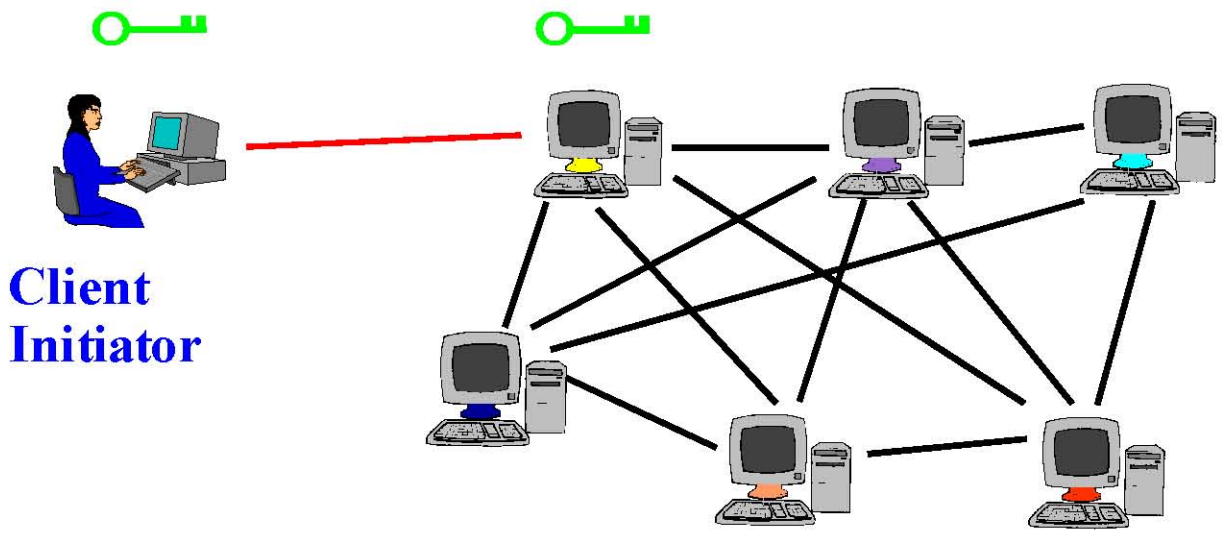


1. *u* creates *l*-hop circuit through routers
2. *u* opens a stream in the circuit to *d*
3. Data are exchanged.
4. Stream is closed.
5. Circuit is changed every few minutes.

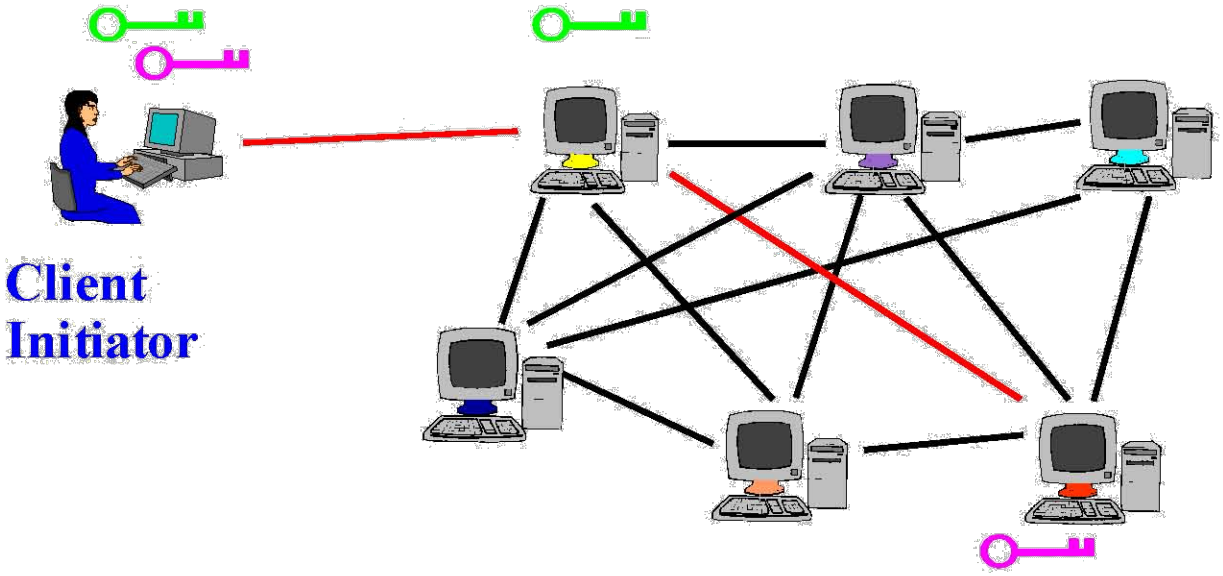
Tor Circuit Setup (1)

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



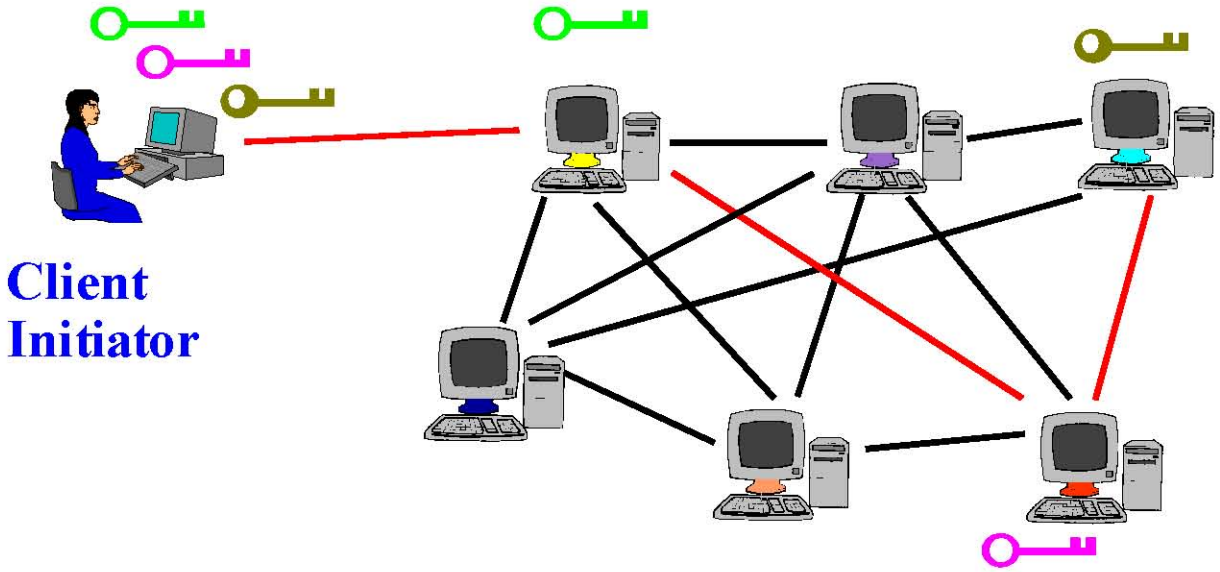
Tor Circuit Setup (2)

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



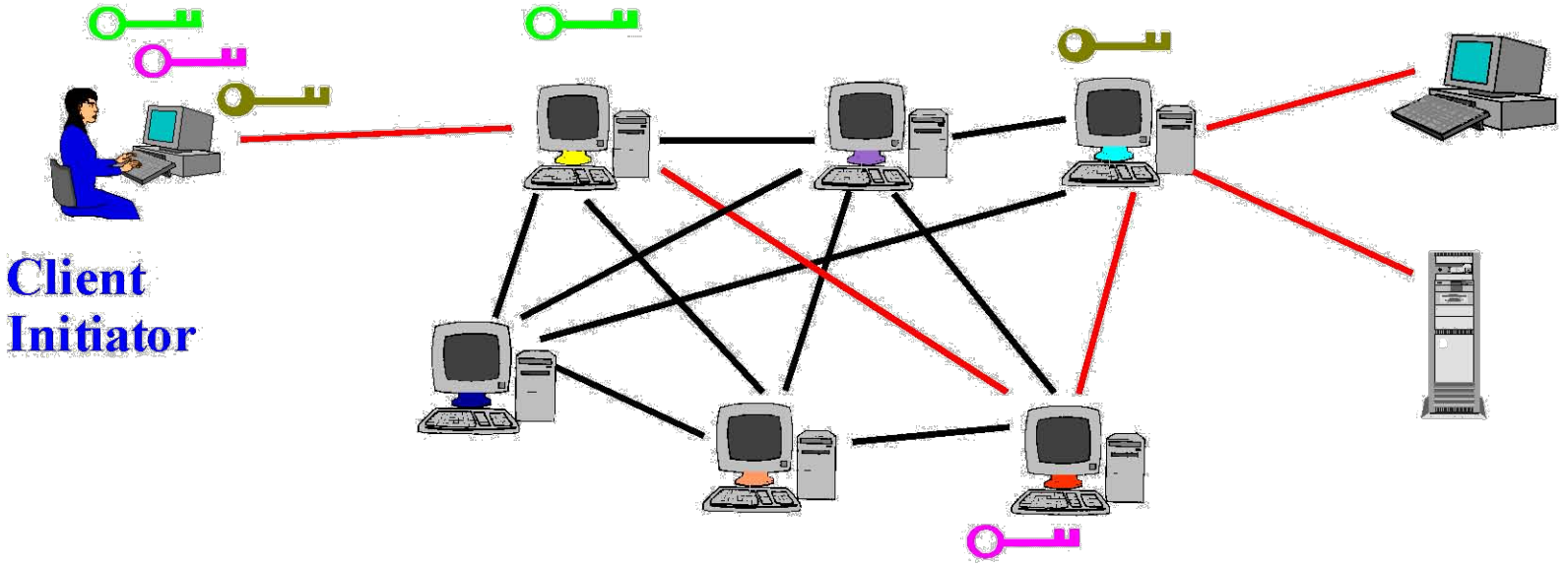
Tor Circuit Setup (3)

- 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



Additional functionality

- Integrity checking
  - Only done at the edges of a stream
  - SHA-1 digest of data sent and received
  - First 4 bytes of digest are sent with each message for verification
- OR-to-OR congestion might happen if too many users choose the same OR-to-OR connection.
- Circuit Level throttling
  - 2 windows keep track of relay data to be transmitted to other ORs (packaging window) and data transmitted out of the network (delivery window)
  - Windows are decremented after forwarding packets and increments on a relay sendme message towards OP with streamID zero.
  - When a window reaches 0, no messages are forwarded

Design

- Overlay network on the user level
- Onion Routers (OR) route traffic
- Onion Proxy (OP) fetches directories and creates virtual circuits on the network on behalf of users.
- Uses TCP with TLS
- All data is sent in fixed size (bytes) cells

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

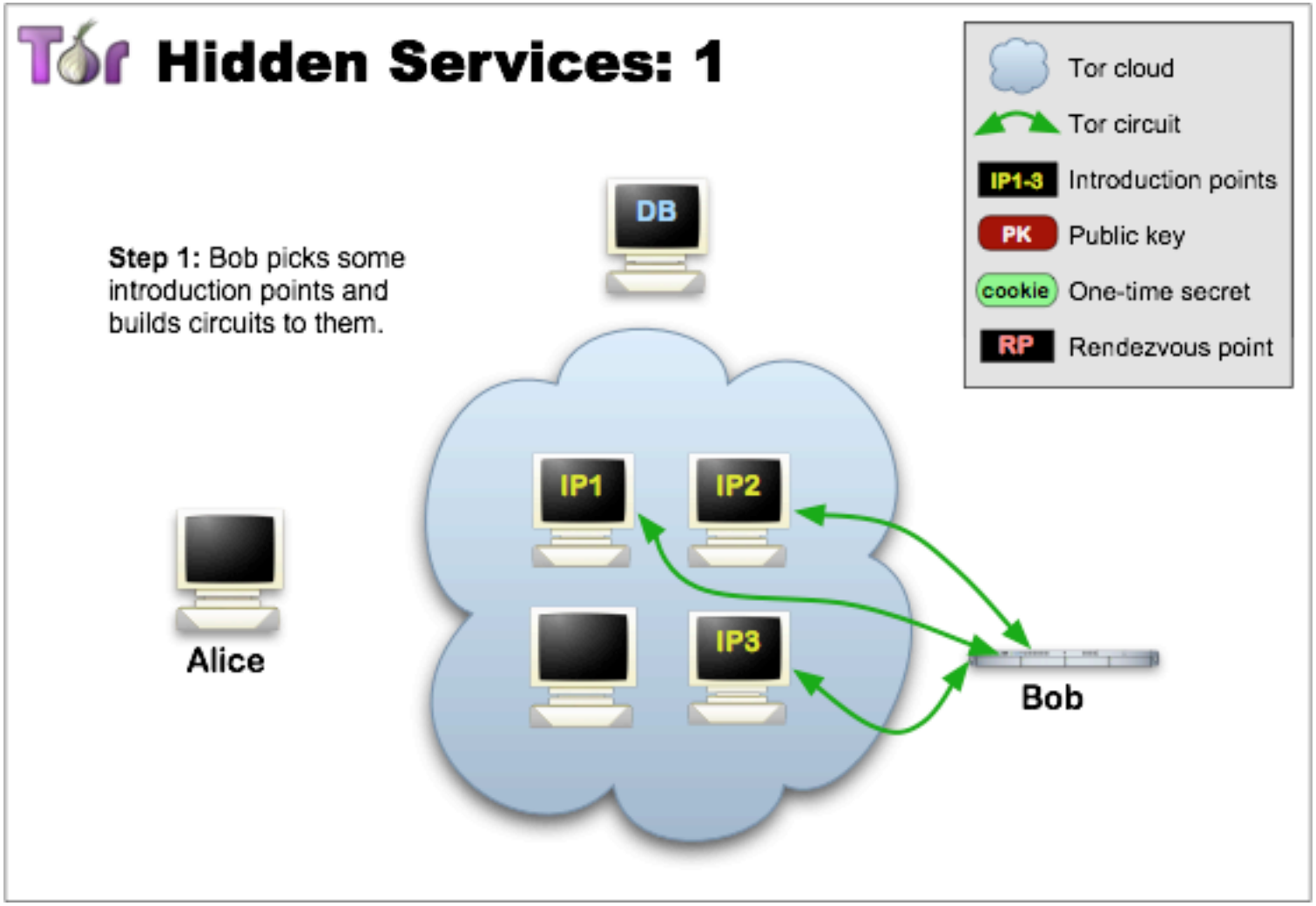
Hidden Services

- 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

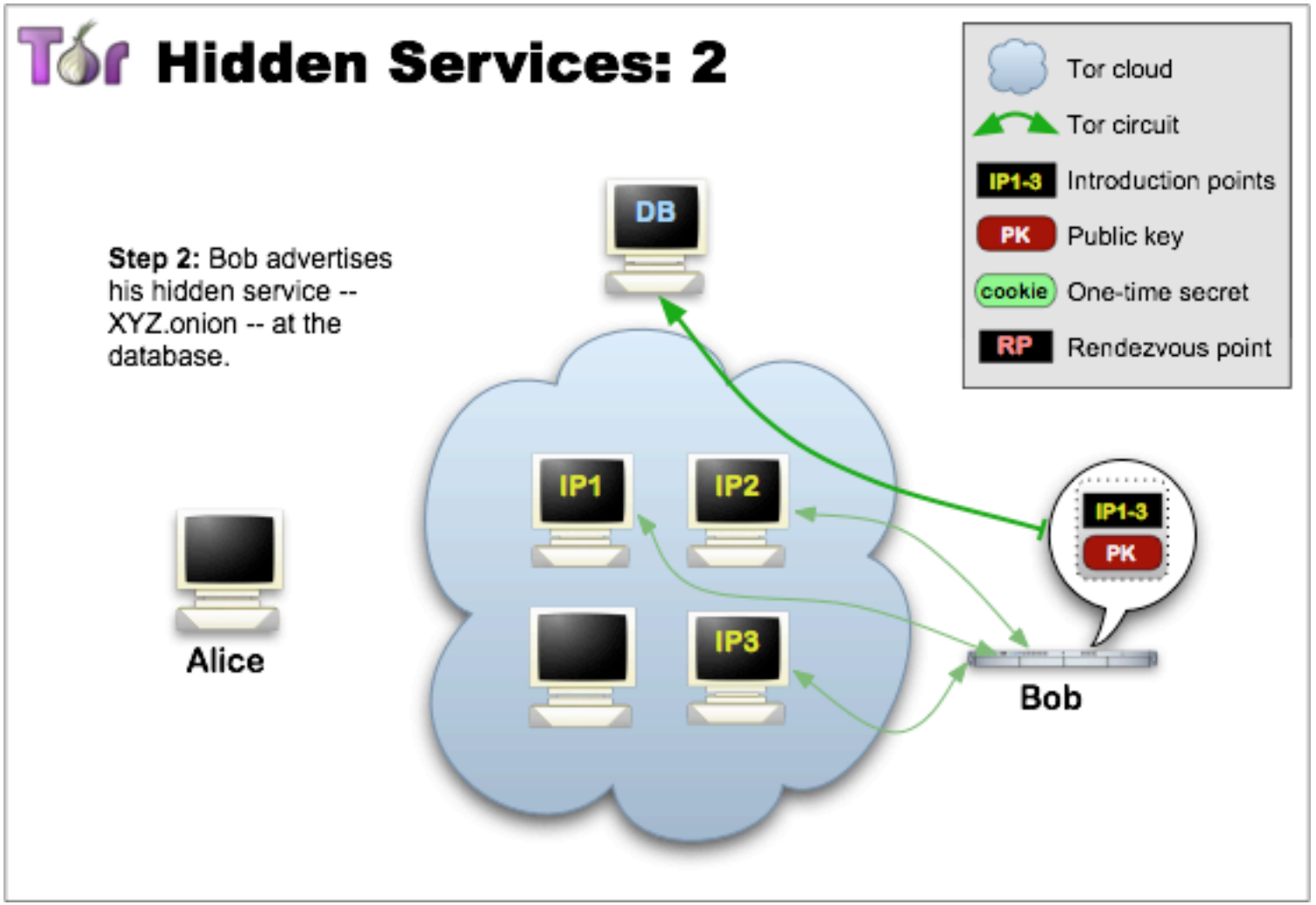
Hidden Service and Rendezvous Points

- Location-hidden services allow Bob to offer a TCP service without revealing his IP address.
- Tor accommodates receiver anonymity by allowing location hidden services
- Design goals for location hidden services
  - Access Control: filtering incoming requests (against flooding)
  - Robustness: maintain a long-term pseudonymous identity (ability to migrate service across Ors)
  - Smear-resistance: social attacker should not be able to “frame” a rendezvous router by offering an illegal location-hidden service and making observers believe the router created that service
  - Application transparency: same unmodified application
- Location hidden service leverage rendezvous points

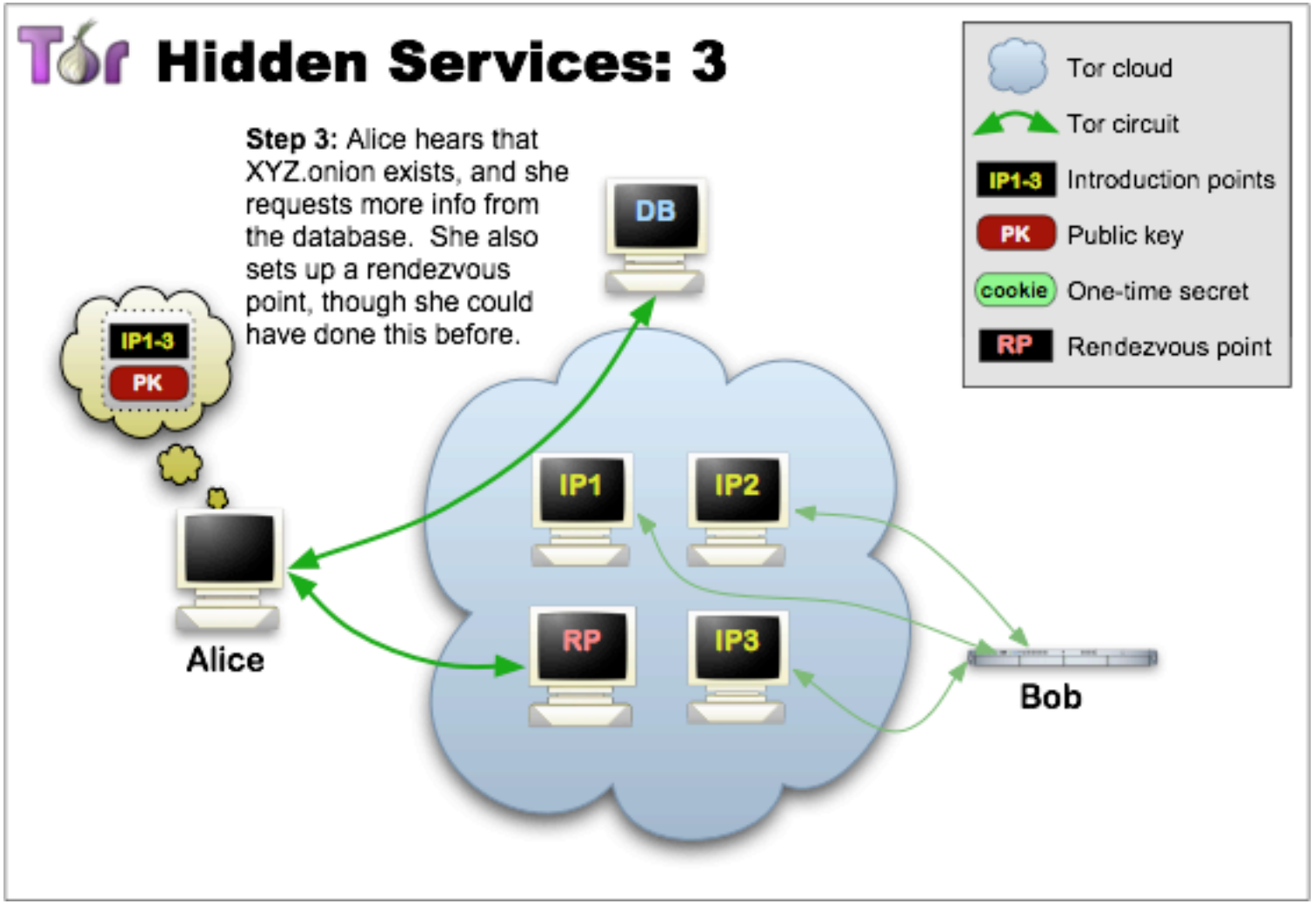
Setting up a hidden service 1



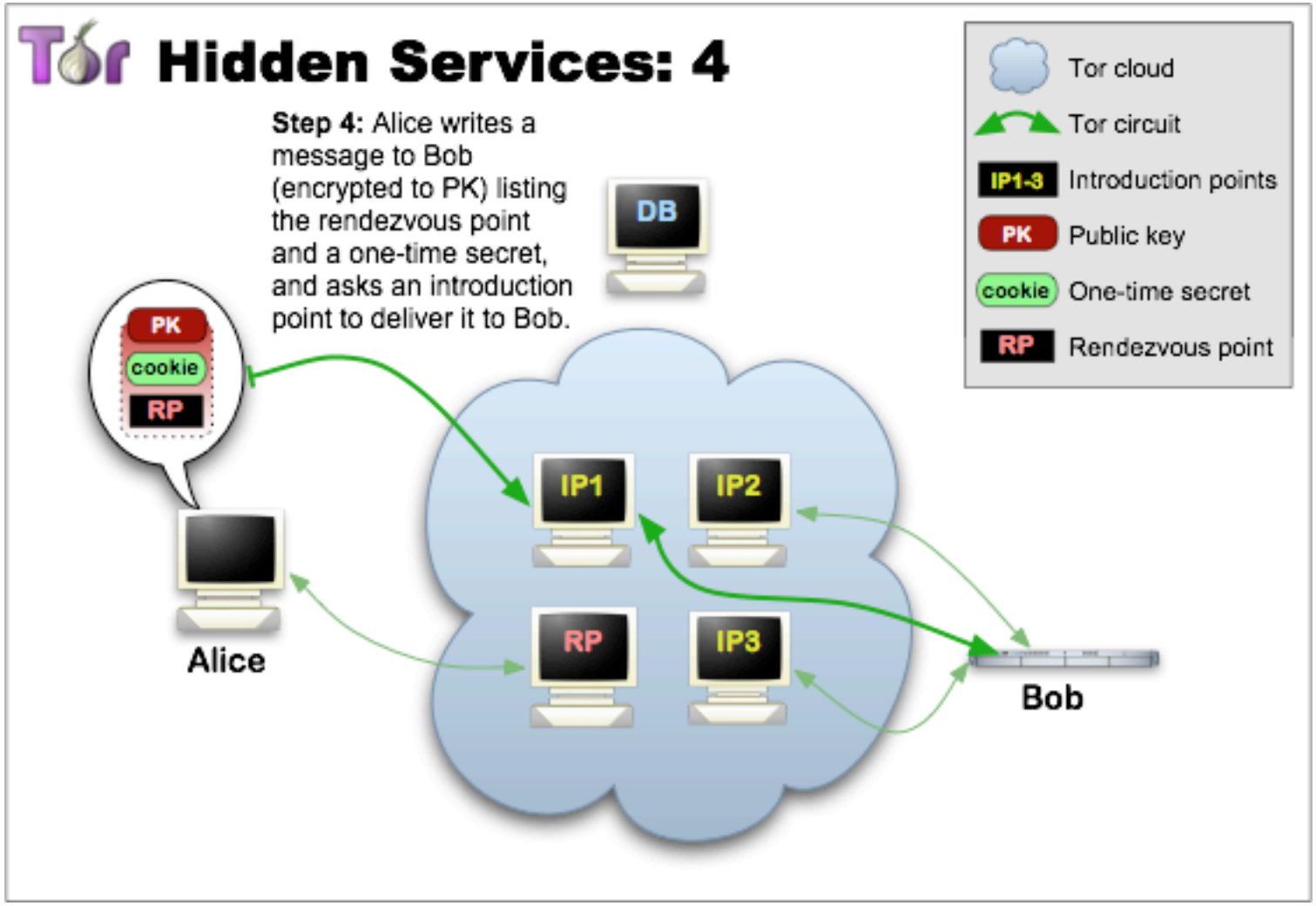
Setting up a hidden service 2



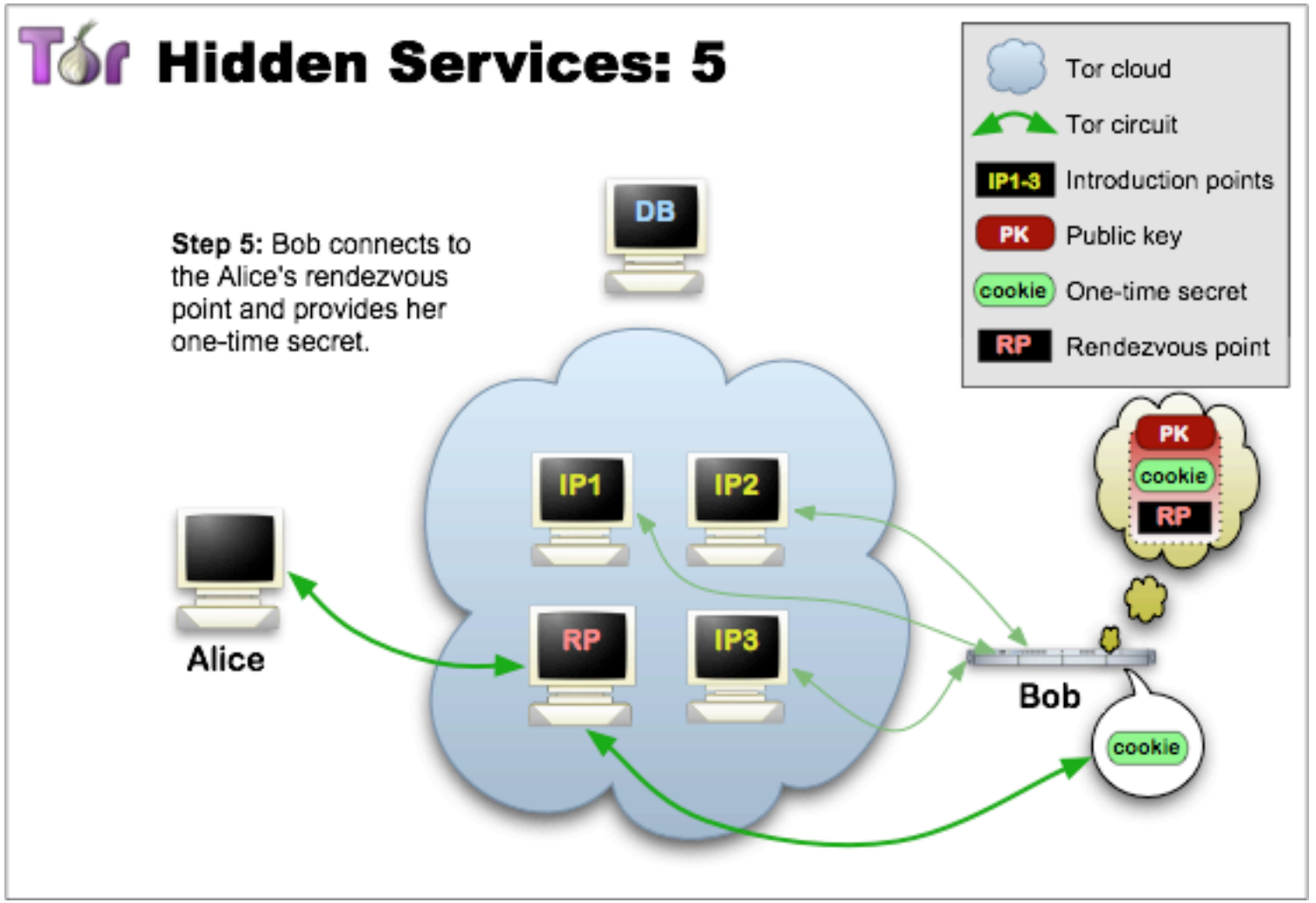
Setting up a hidden service 3



Setting up a hidden service 4



Setting up a hidden service 5



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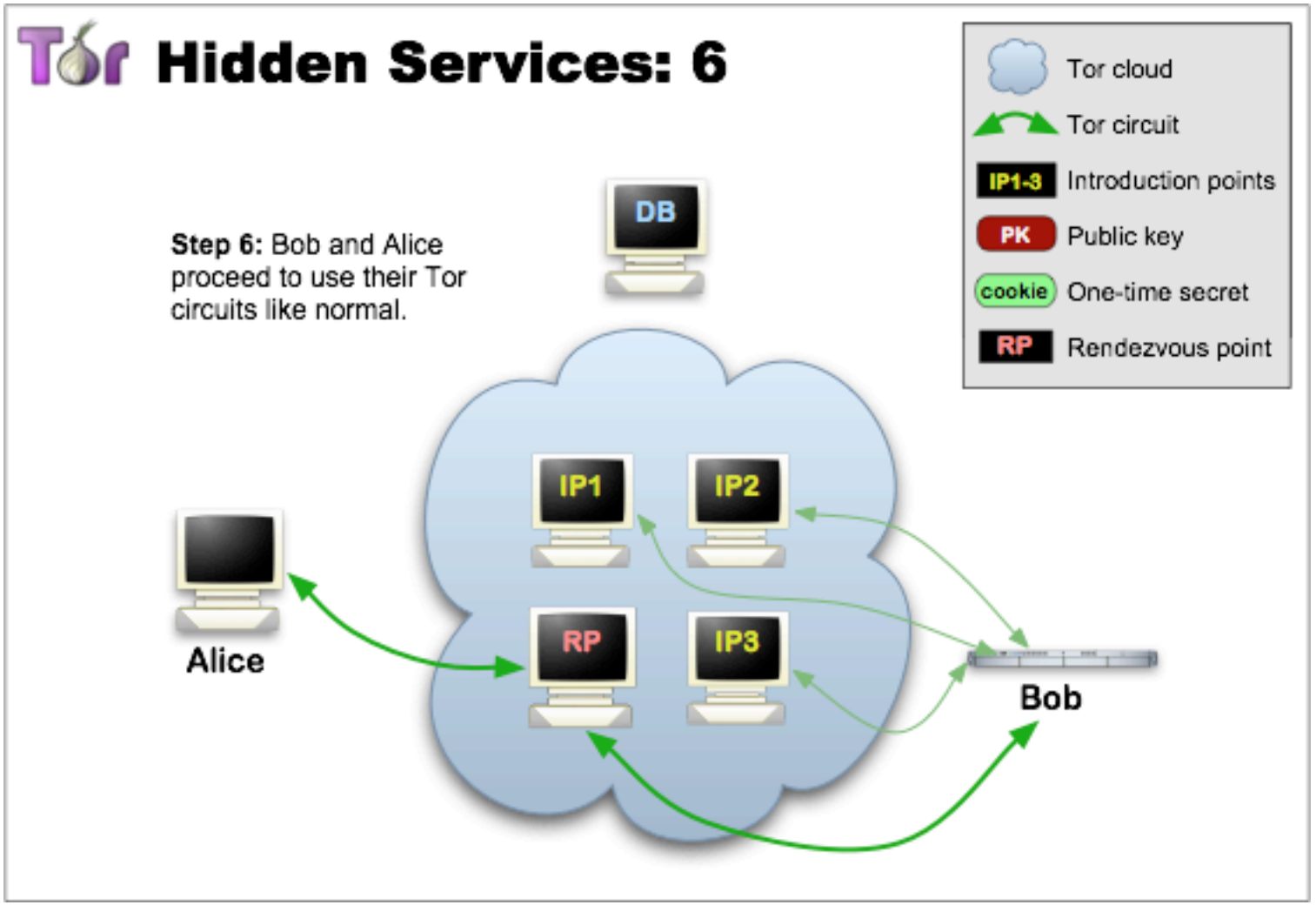
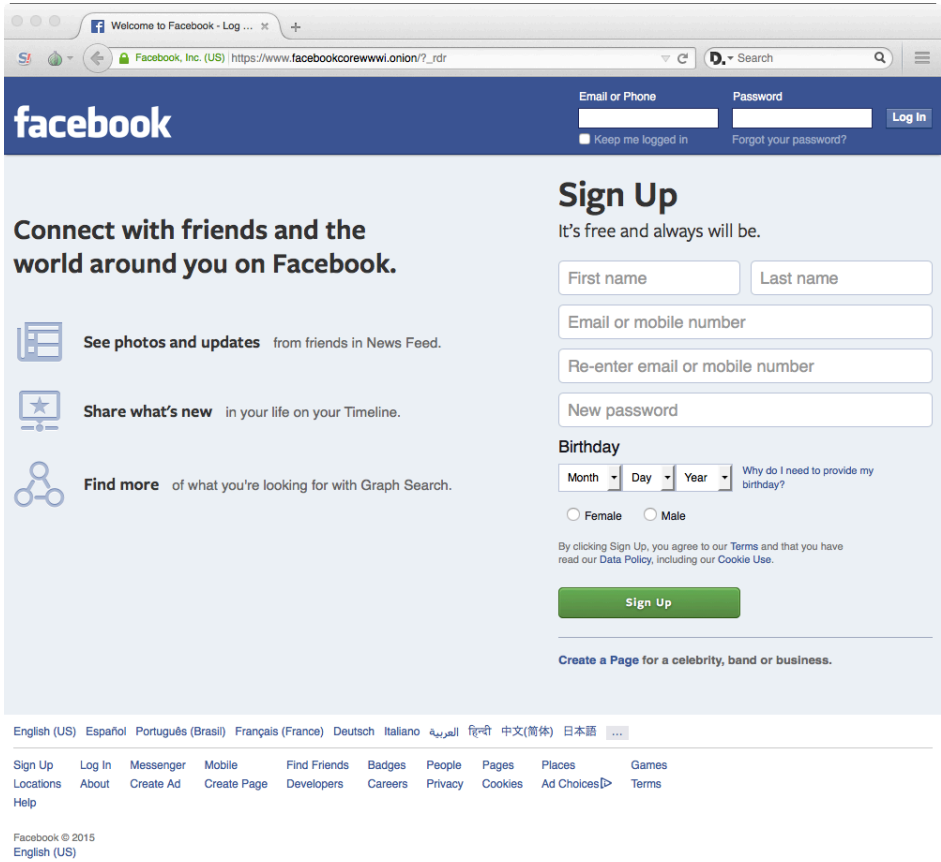


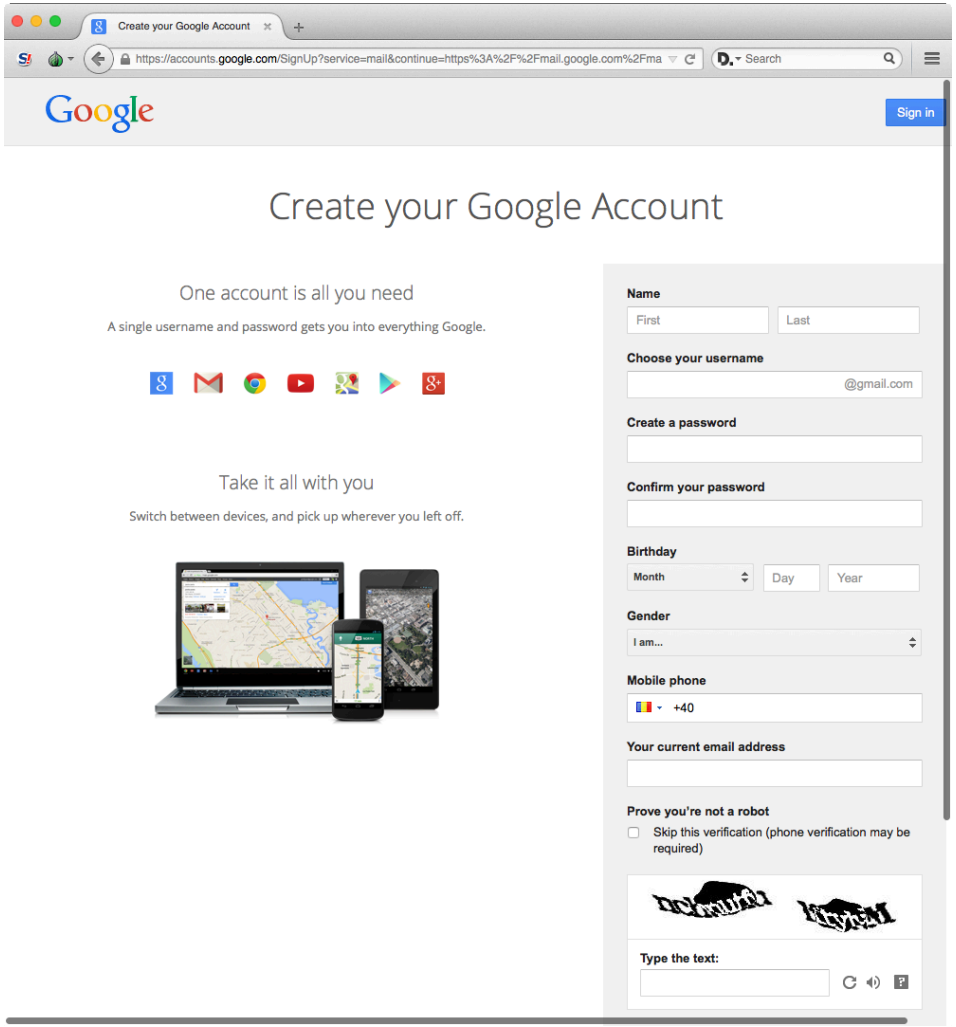
operations

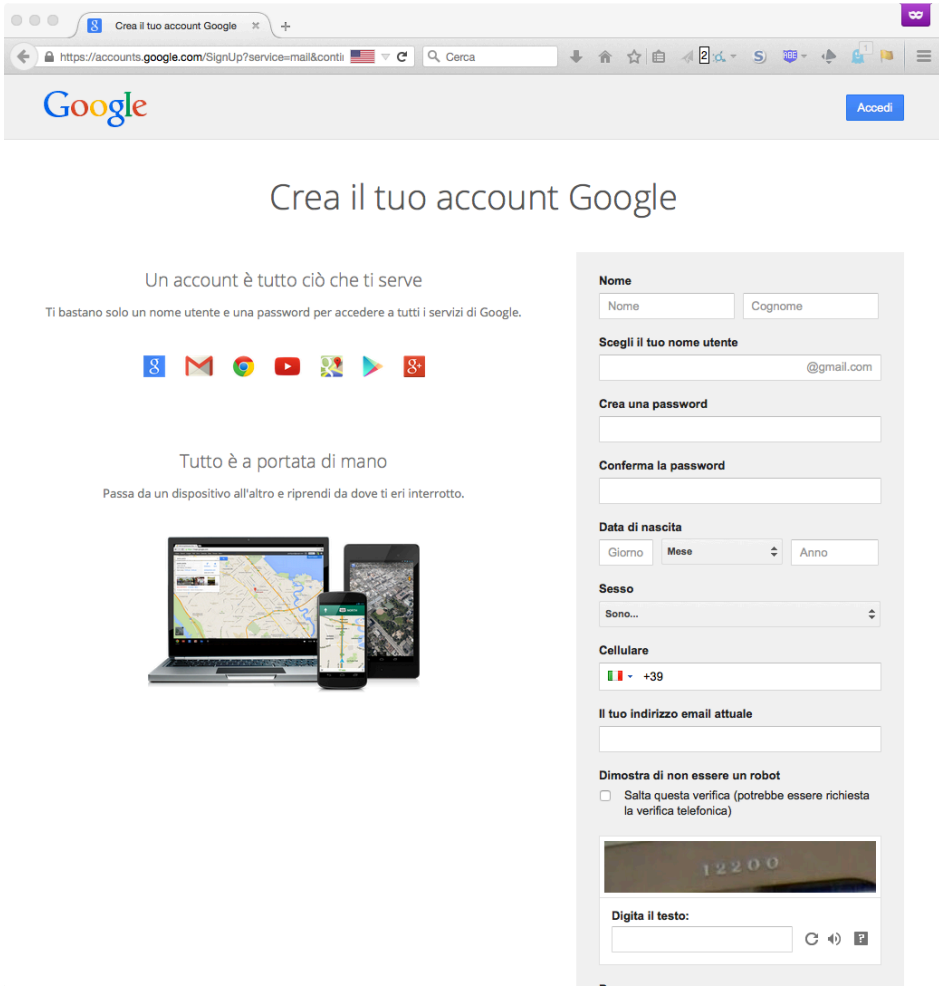
- Bob generates a long-term public key pair to identify his service
- Bob chooses some introduction points, and advertises them on the lookup service, also providing his public key
- Bob builds a circuit to each of his introduction points, and tells them to wait for requests.
- Alice learns about Bob's service out of band, retrieves the details of Bob's service from the lookup service
- Alice chooses an OR as the rendezvous point (RP) for her connection to Bob's service. She builds a circuit to the RP, and gives it a randomly chosen "rendezvous cookie" to recognize Bob.
- Alice opens an anonymous stream to one of Bob's introduction points, and gives it a message (encrypted with Bob's public key) telling it about herself, her RP and rendezvous cookie, and the start of a DH handshake. The introduction point sends the message to Bob.
- If Bob wants to talk to Alice, he builds a circuit to Alice's RP and sends the rendezvous cookie, the second half of the DH handshake, and a hash of the session key they now share.
- The RP connects the two circuits. Note that RP can't recognize Alice, Bob, or data they transmit.
- Alice sends a *relay begin* cell along the circuit. It arrives at Bob's OP, which connects to Bob's webserver.
- An anonymous stream has been established, and Alice and Bob communicate as normal.

hidden services examples

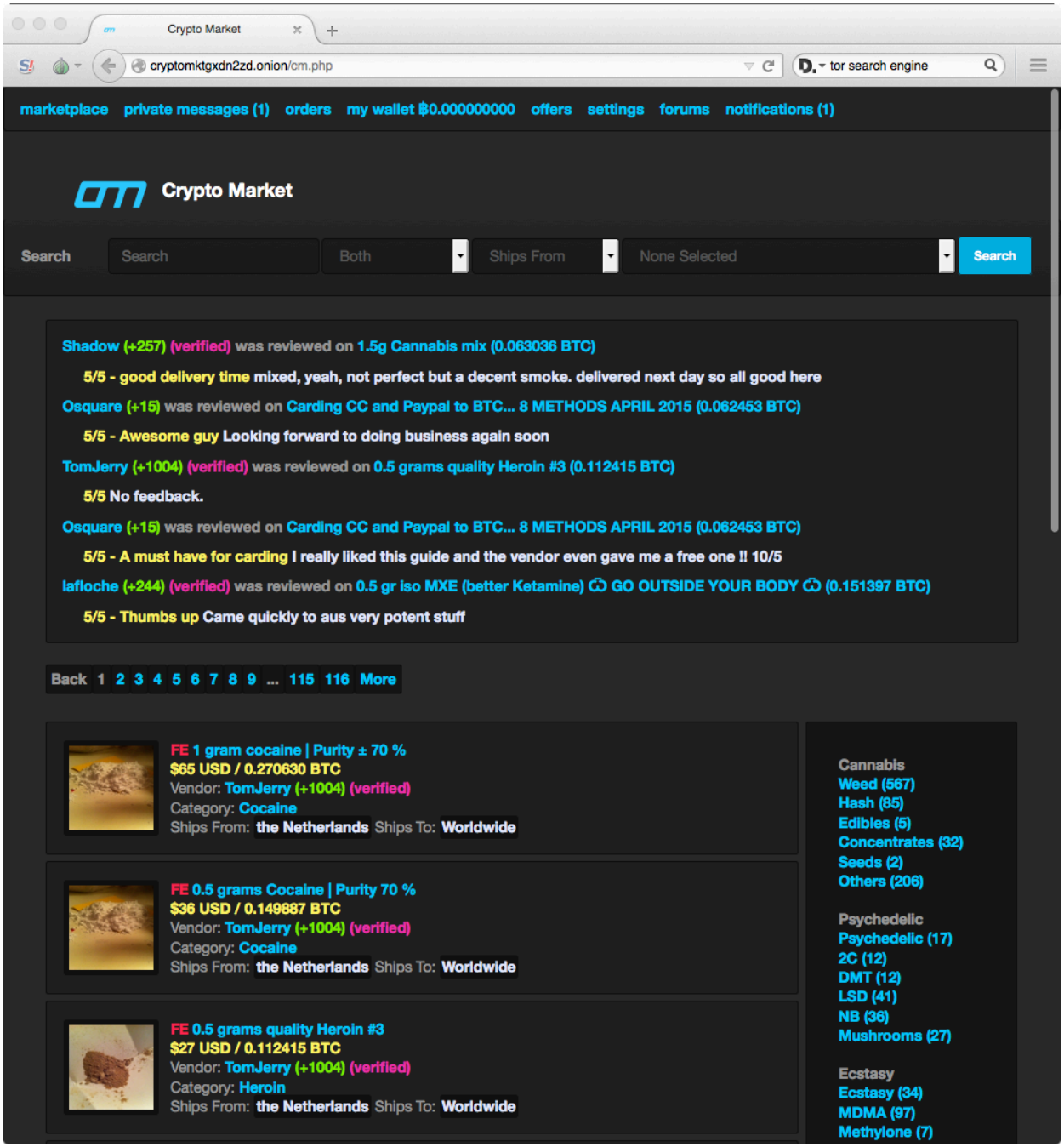


how Google treats Tor





crypto market



more insight

- https://svn.torproject.org/svn/projects/design-paper/tor-design.pdf
- http://freehaven.net/anonbib/
- https://www.torproject.org/docs/hidden-services.html.en
- https://gitweb.torproject.org/torspec.git/tree/tor-spec.txt