ΥΣ13 - Computer Security

Anonymous Communication

Κώστας Χατζηκοκολάκης

Anonymous communication

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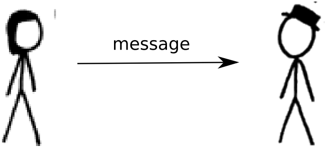

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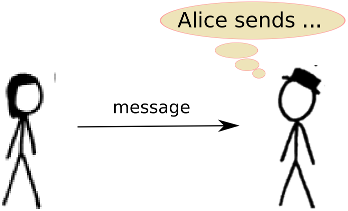

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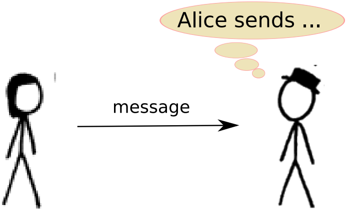

- Alice does not want Bob to know that she is the sender.

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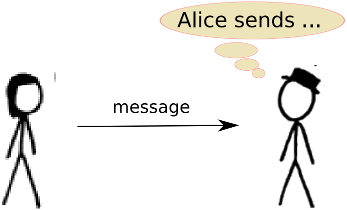

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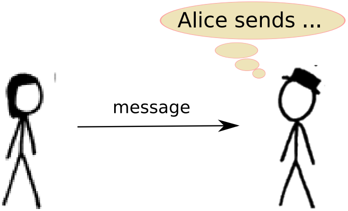

- Alice does not want Bob to know that she is the sender.
- Other properties?
- Adversary model?

Why?

- Accessing censitive content
- Censorship resistance (eg. Great Firewall of China)
- Electronic voting
- Whistleblowing
- File sharing
- Profiling resistance
- Auctions / stock market

Why anonymity is difficult?

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- Sender’s IP address included in all IP packets
- Already enough to trace someone to ISP/region level
- Can be traced down to individuals using ISP’s logs
  (obtained with ISP’s co-operation, subpoenas, …)
- Similarly for ethernet (MAC address) and other protocols

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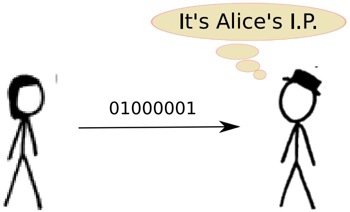
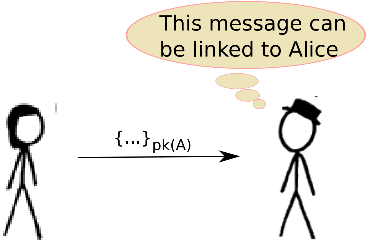
- Identity leakage via other means (eg cookies)

Communication level vs application level

Communication level (our focus)



Application level



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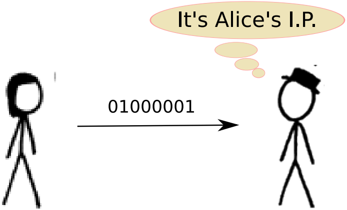
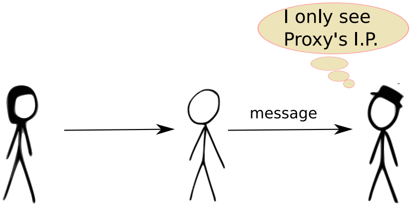


How can we approach this problem?

First approach

- Use an anonymous proxy



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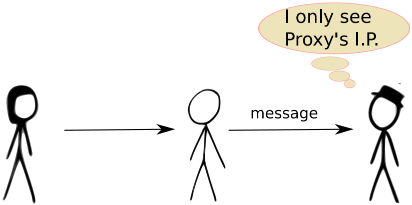

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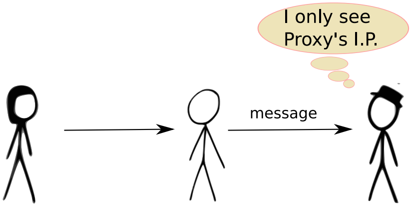

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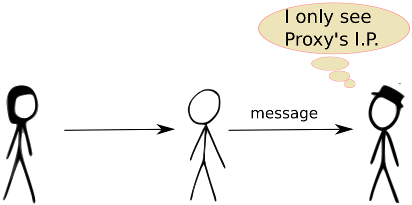

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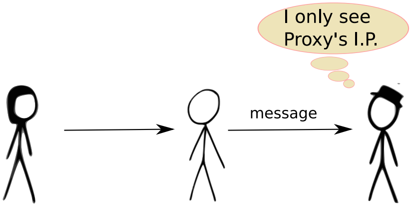

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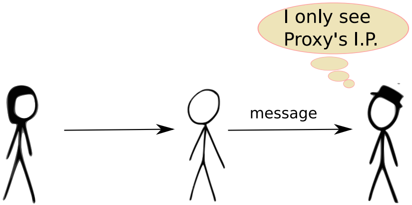

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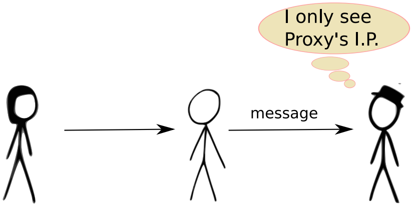

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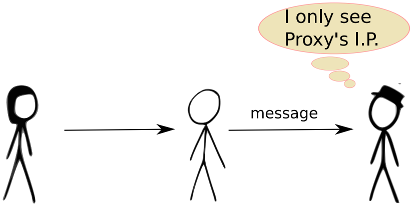

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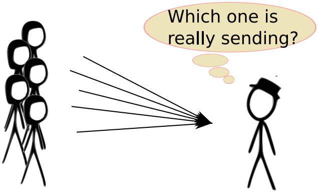
- Problems
  - We need to trust the proxy
  - Easy to block

Approaches without a trusted party

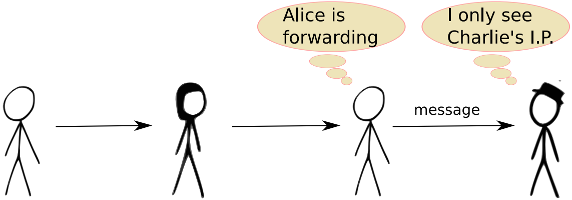
1. Hide message in other traffic



- Alice's traffic should look indistinguishable from everyone else's
- Possible to achieve "strong" anonymity
  - Dining Cryptographers protocol
- But too costly in bandwidth

Approaches without a trusted party

2. Forward message through other users



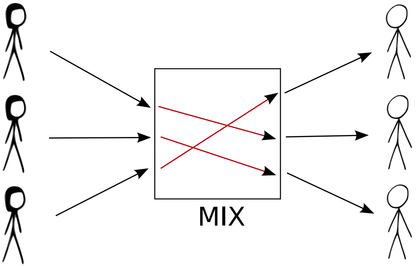
- More efficient
- But challening to deal with an adversary controlling the whole network
- Mixes and Onion routing protocols

Mix neworks

- Stronger adversary
  - Controls the whole network
- But weaker property
  - Hide only the link between a sender and a receiver

Mix

- Users send messages to the Mix
- The Mix waits until a certain number of messages is received
- Then outputs the messages in some order that is independent from the incoming order (eg random)



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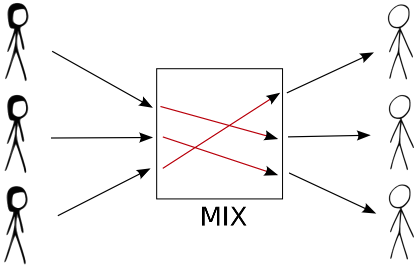

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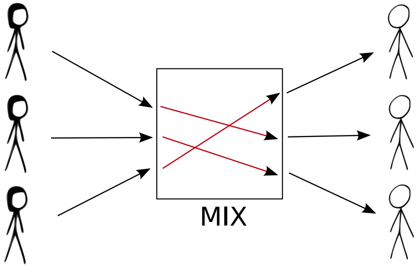

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- Prevent against tagging attacks

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- the order of messages (timing) or other meta-data should not allow to link the sender and receiver

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Mixing strategies:

- Threshold Mix: receive N messages, output them in random order
- Pool Mix: keep a pool of M messages. Receive N messages, output N out of $N + M$
- Insufficient traffic $\Rightarrow$ generate dummy messages

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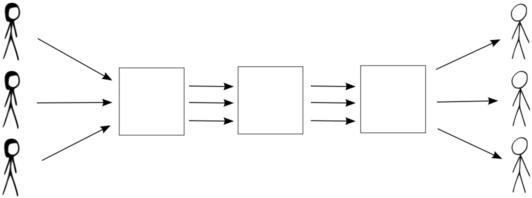
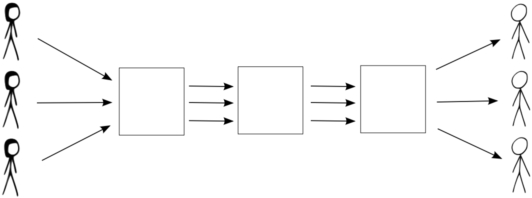


Mix: first problem

- We have to trust the Mix
- Solution: multiple mixes
- Messages are encrypted with the keys of the mixes in reverse order



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- Cascade mixes: messages pass through all mixes in fixed order
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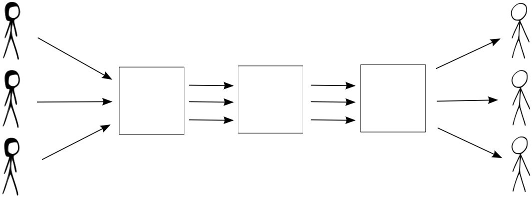
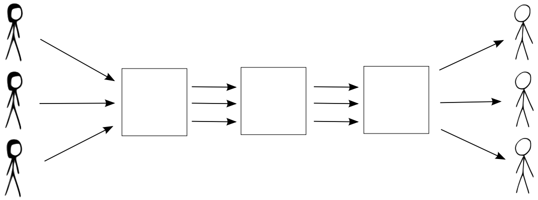


Mix: first problem

Various approaches:

- Cascade mixes: messages pass through all mixes in fixed order
  - A single honest Mix is enough
- Free routing: mixes are fully connected, messages are routed through random paths
  - Less anonymity, better load balancing



Mix: anonymity analysis

- Does the Mix provide ”strong” sender-receiver unlinkability?
- Adversary goal
  - Distinguish ($A \rightarrow C$, $B \rightarrow D$)
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- Anonymity depends on the behaviour of the other users
  - (prior knowledge)

Mix: anonymity analysis

- Extreme case: $(n-1)$ attack
  - the attacker blocks all senders except Alice
  - waits until the mix is flushed
  - sends $n-1$ messages of his own
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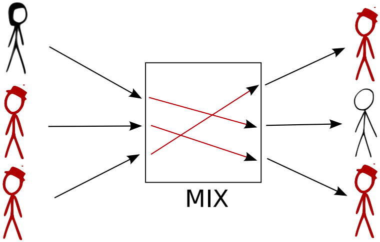

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- Delaying-expiring messages
  - Random delay is added by each mix
  - Messages have expiration time
  - Harder for the attacker to flush the mix
- Heartbeat traffic
  - The attacker needs to block other users to flush the mix
  - The mix sends a test message to itself on a certain interval
  - If the message is blocked, inject dummy traffic

Inferring patterns

- Repetitive usage creates patterns that can be observed
- Assume a Mix protocol with n users (one of which is Alice)
- All users are honest and select a receiver with uniform probability $1/n$
- On the i-th run we only observe the set R_i of receivers

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- On the i-th run we only observe the set R_i of receivers
- Extreme case: Alice always sends messages to the same receiver r
- With high probability: $\bigcap_i R_i = \{r\}$

Inferring patterns

- Now assume that Alice sends messages to a small set of users { Bob, Paul, Tom }
- We can still infer this set with high probability by simply counting the messages
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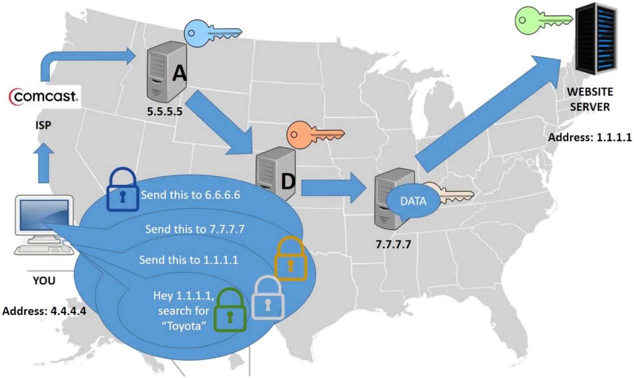
- Alice's friends will have a higher number of received messages
- This probabilistic knowledge can be now used to further de-anonymize other users

Onion routing

- Real-world communication, eg web browsing
- low latency, 1-2 secs round-trip max
- Frequent repeated use
- No time for mixing, delays, etc
- Trade a weaker adversary model for practicality

Onion routing

- Alice selects a short path (3 hops), relays are known
- Encrypt in reverse order (as with mixes)
- Bi-directional channel



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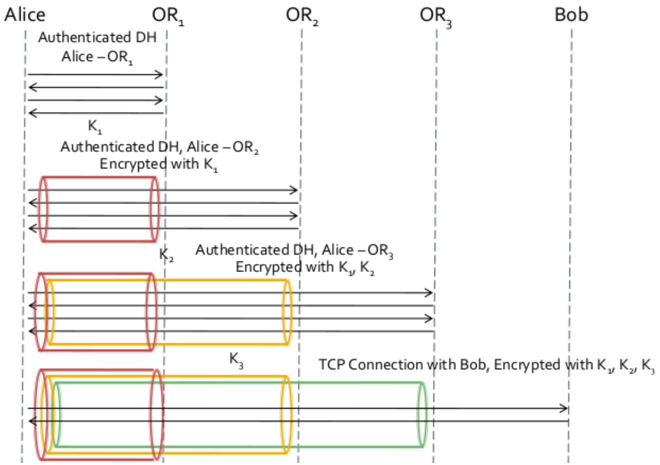
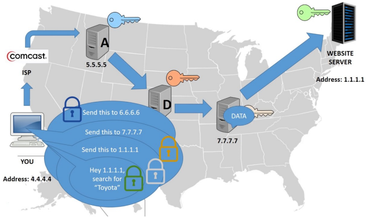
- Extend the route via Diffie-Hellman



Onion routing, anonymity

- Global adversary?



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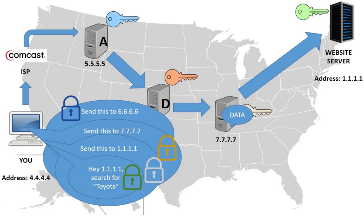

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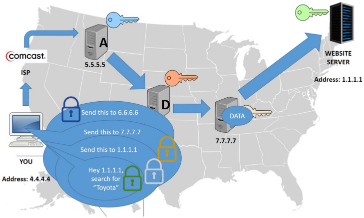

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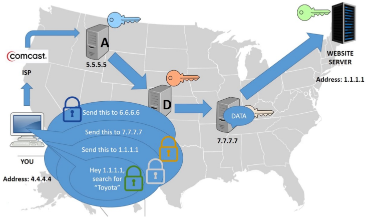

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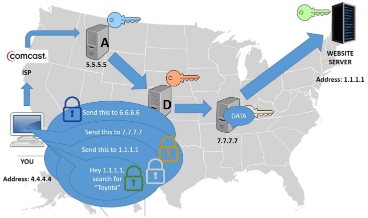

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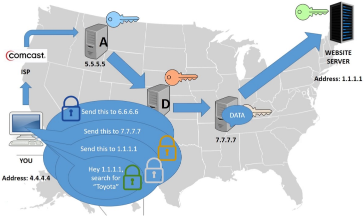
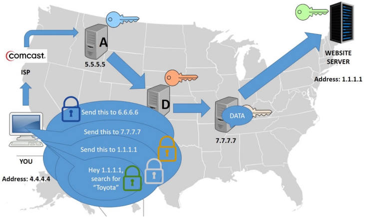
- Useful to have longer routes?



Onion routing, anonymity

- Profiling : detect that Alice communicated with Bob at least once



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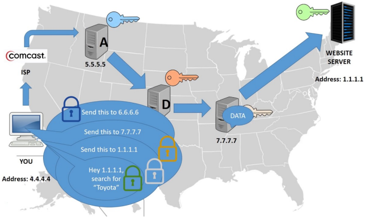

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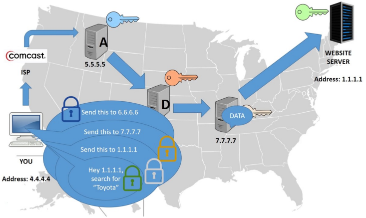

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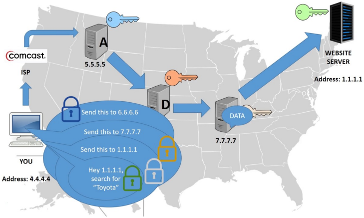

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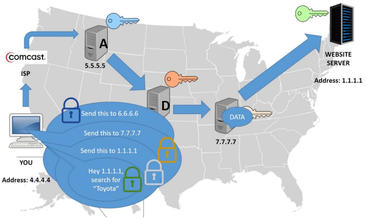

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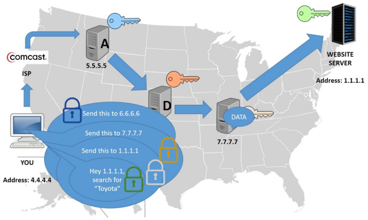
- Solution : fixed entry guard
  - if honest, profiling/tracing never happens
  - if compromised, higher chances of being traced $\frac{c}{n}$



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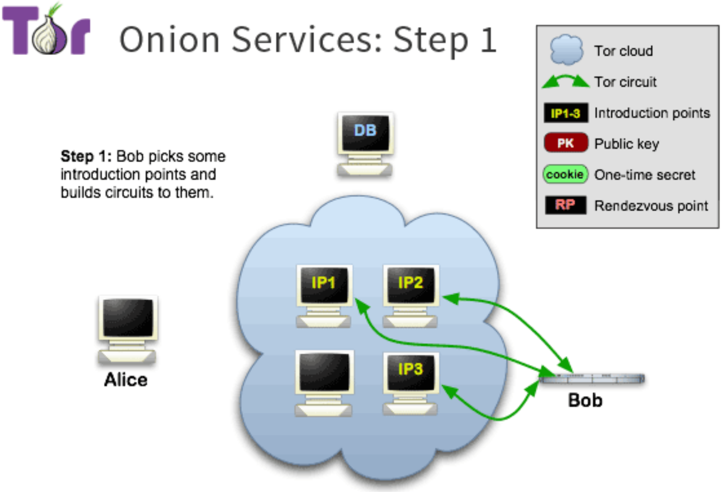
- Easy to block
- Exit node sees traffic
- Exit node might be identified with illegal behaviour
- No anonymity is provided to the server
  - Solution: onion services

Onion services



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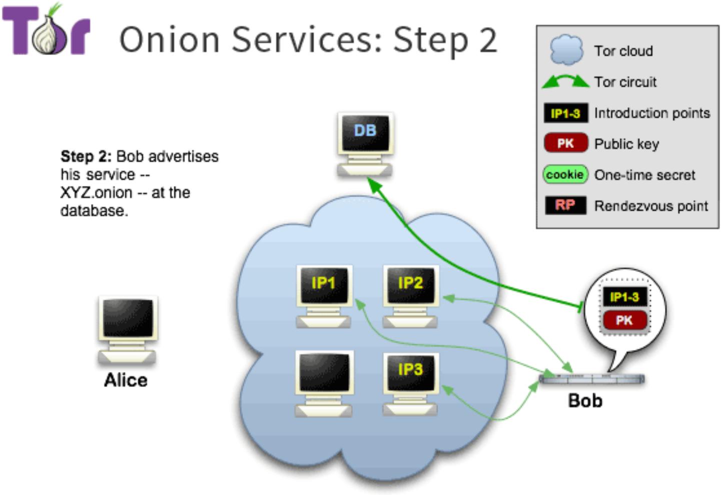

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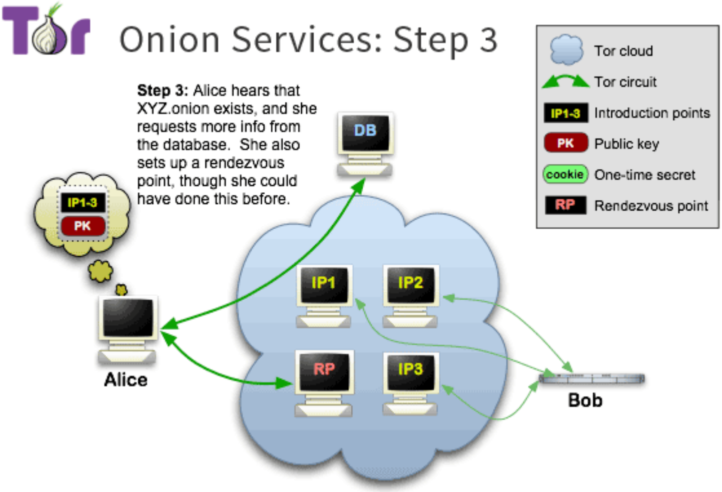

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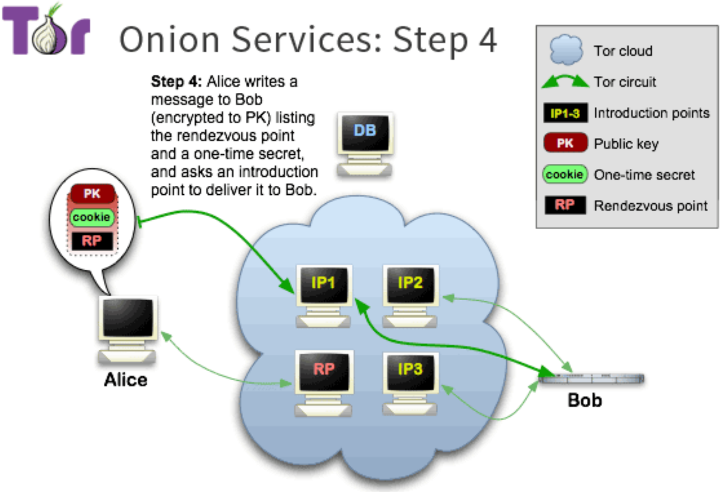

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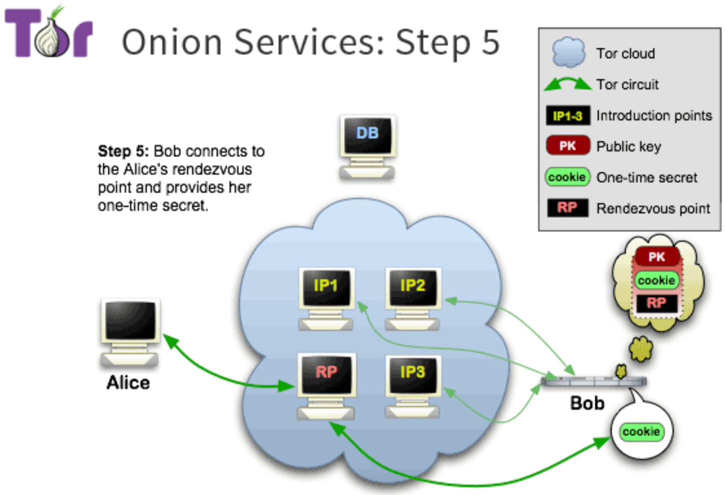
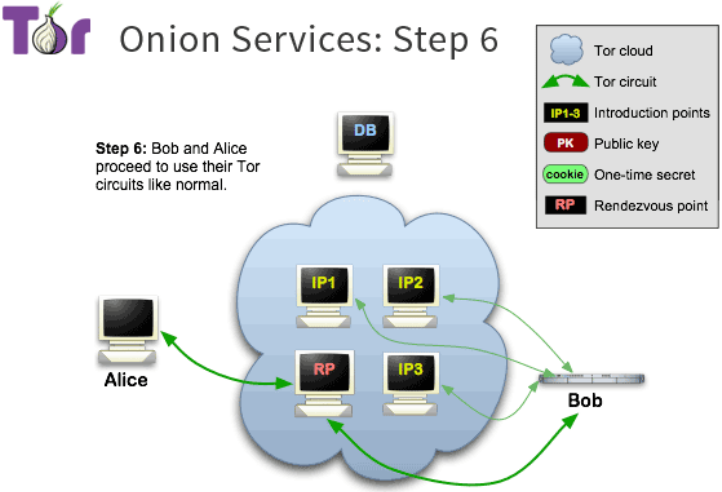


Onion services



Onion services

- Eg.
  - BBC: `https://www.bbcnewsv2vjtpsuy.onion/`
  - DuckDuckGo: `http://3g2upl4pq6kufc4m.onion/`
  - Facebook: `https://www.facebookcorewwwi.onion/`
  - Riseup: `http://vww6ybal4bd7szmgncyruucpgfkqahzddi37ktceo3ah7ngmcopnpyyd.onion`
- Accessible via the Tor browser