Why is anonymity so hard?

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Talk overview

- In-depth example: Mixminion

- Other systems, including Onion Routing

- Economic perspectives, some open problems

Many people need anonymity

- Political dissidents in oppressive countries
- Governments want to do operations secretly.
- Corporations are vulnerable to traffic analysis, corporate espionage – VPNs, encryption don't help
- Individuals are tracked and profiled daily. Imagine what they'll have in your dossier in twenty years.
- (If that doesn't scare you, think of your kids.)

Adversary characteristics

- External (wires) or Internal (participants)
- Passive or Active
- Local or Global
- Static or Adaptive

First example system
Mixminion:

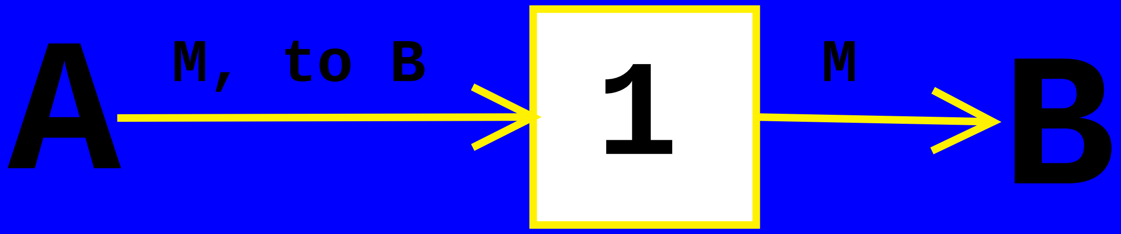
Design of a Type III Anonymous Remailer Protocol

Threat Model (what we aim to defend against)

- Global passive adversary – can observe *everything*
- Owns some of the nodes

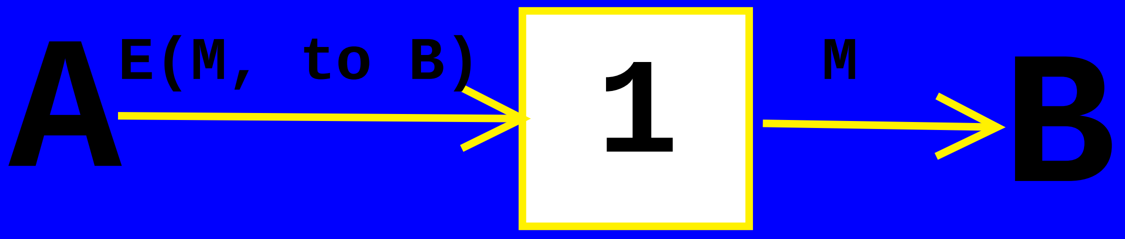
We are not real-time, packet-based, or steganographic

Direct Forwarder



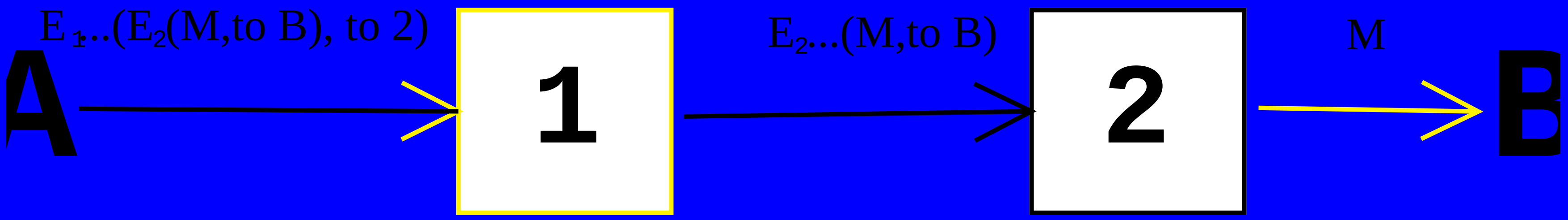
But: an observer of Alice can just read M and know it's going to Bob

Add Encryption



But: **1** still knows Alice sent **M** to Bob

Multiple Hops



Assume: Not all hops will collude and reveal **A**

But: How do you know what the servers are?

Statistics servers

(directory servers)

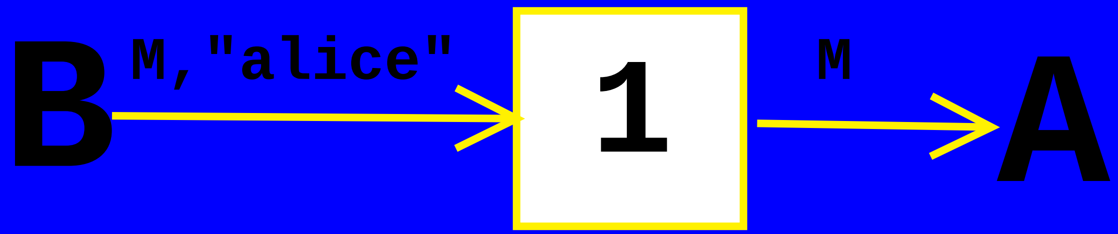
```
Mixmaster    Latent-Hist   Latent  Uptime-Hist   Uptime  Options
----------------------------------------------------------------
winter       111032010010    :42   ++++++++++++  100.0%   PR  O
xganon       000000000000    :03   ++++++++++++  100.0%   PR
green        00000000000?    :09   +++++++++++0   97.8%    2  O
lcs          151231221221   1:30   +++++++++7++   97.8%    M
```

- Have several servers to avoid single point of failure

- They can send test messages and tell users which nodes are up

Direct Reply

(Trying to hide A's location)



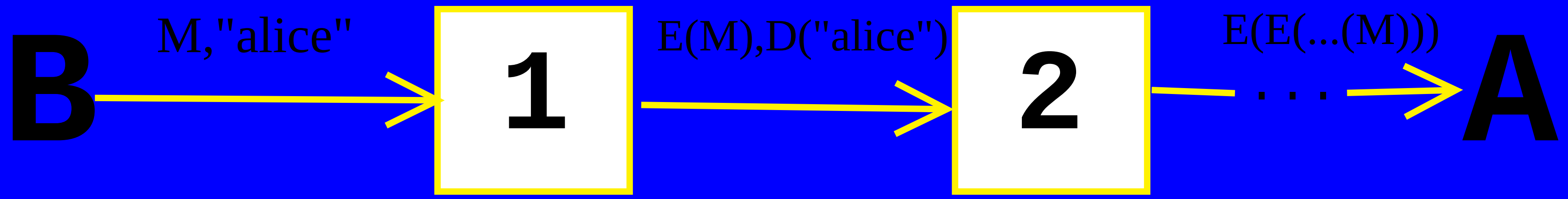
"alice"=an4691@anon.penet.fi (**A** has told **1** her location.)

This and the direct forward gets you type 0 remailers (anon.penet.fi)

But: observers still know it goes to **A**.

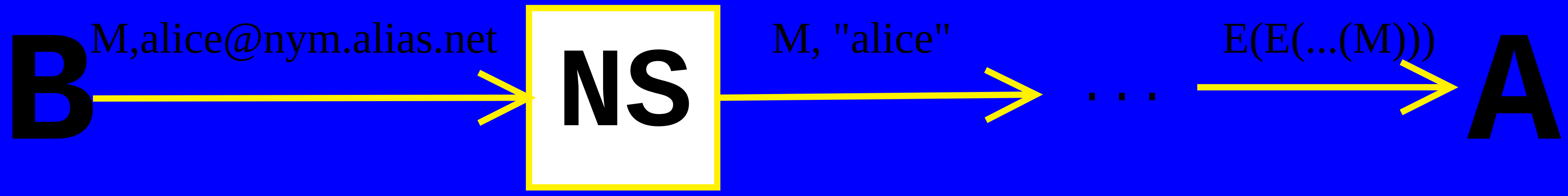
And **1** knows where **A** lives.

Reply Blocks



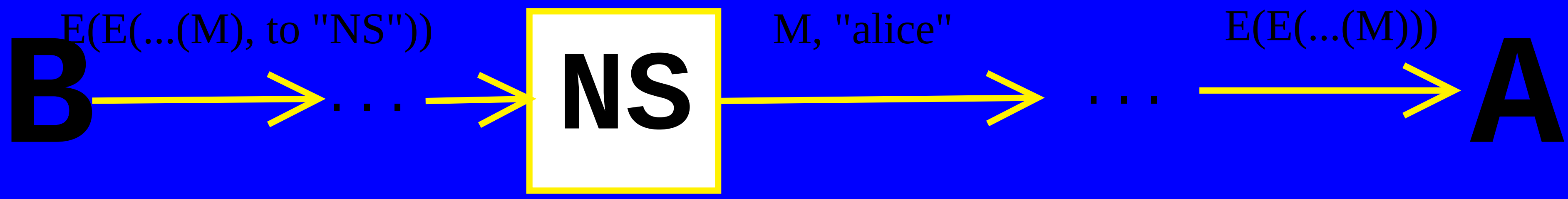
- "alice" $= 1, E_1(2, ...E_n(A))$
- Hard for B to get a reply block from A.

Nymserver



NS knows **A**'s reply block but not her location.

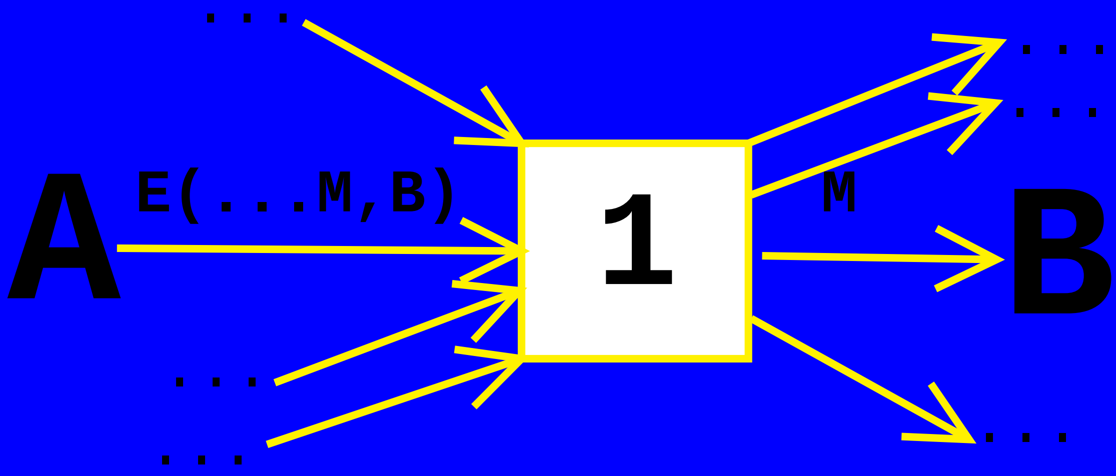
Anonymized Reply



- **NS** doesn't know **A** or **B**
- If you stop here you get type 1 (cypherpunk) remailers.

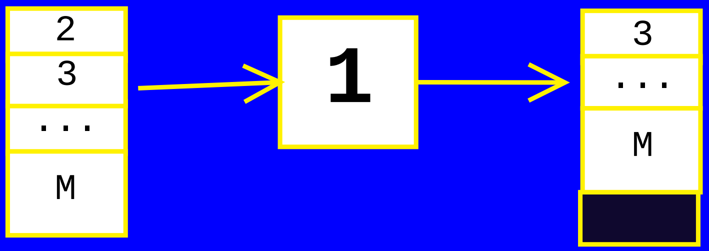
Batching and Mixing

Encryption doesn't matter if there's only one message.



But: Different-sized messages can still be distinguished.

Fixed length messages by re-padding



- Add random junk to the bottom to replace the header you strip off
- Everything's encrypted, so it looks ok.

But: Replay attacks – a given message always decrypts the same way!

Replay cache

- When a message comes in, hash it and add it to the replay cache.

- If it's already in the cache, drop it.

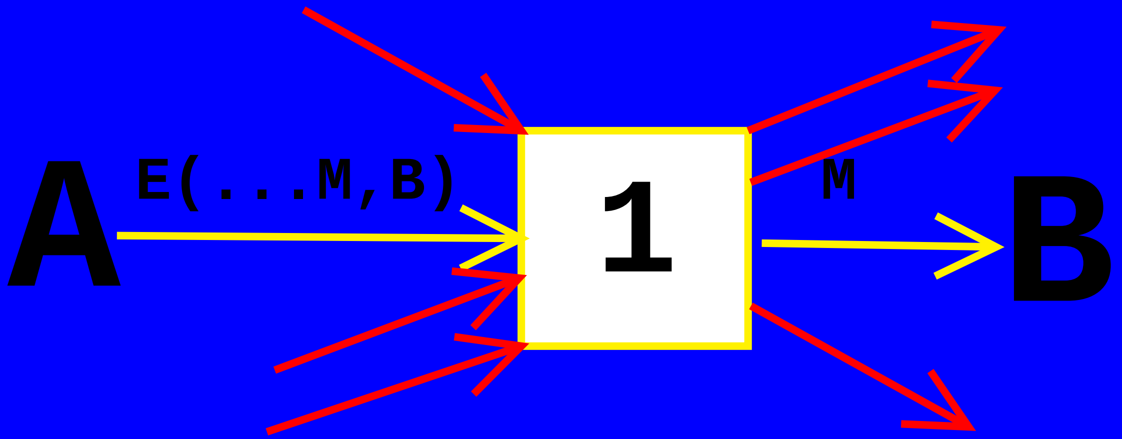
But: you have to remember all the hashes forever!

Expiration dates

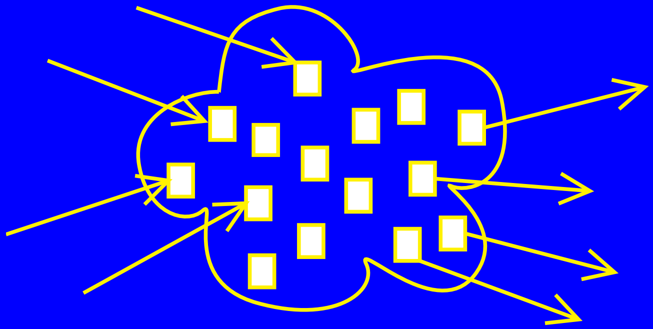
- Exp date is chosen randomly between 3 days ago and 3 days from now.
- Each node checks exp date; if more than 7 days old, drop.
- Now adversary can't tell when the message was sent from its exp date; and servers can forget hashes that are $>$ 7 days old.

Flooding attack

But you can flood a node so you know all but one message in the batch.



Pooling



- Not all messages come out at each flush. Keep a minimum number in the pool, always.
- Now it's harder to target an individual message.

- But: Trickle attack – what if you're the only one who sends a message into the node in a given interval?

- More broadly, what if you're the only one who sends a message into the whole network, in that interval?

Dummy messages

- Users sometimes send decoy messages even if they have nothing to send.
- Hopefully there will be enough messages that the adversary will be confused.
- Dummies go several hops and stop (hard to decide convincing destinations).
- If you stop here, you get type 2 (Mixmaster) remailers.

Passive subpoena attack

- Eve can record messages for later subpoena
  She can also recognize her own messages, which helps with flooding attacks

- Fix: Link encryption with ephemeral keys
  (rekeyed every message / few minutes)

Active subpoena attack

- Mallory can still record messages from the node she runs, and arrive later with a subpoena.
- Fix: Periodic key rotation

Partition attack on client knowledge (1)

- Adversary can distinguish between clients that use static node lists and clients that frequently update from the directory servers.

- Fix: Clients must all use the same algorithm for updating from the directory servers. Directory servers must be part of the spec!

Partition attack on client knowledge (2)

- Directory servers can be out of sync; evil directory servers can give out rigged subsets to trace clients.
- Fix: DSs must successively sign directory bundles; a threshold of servers is assumed good.
- What do users do if the DSs can't agree?

Partition attack on message expiration date

- Delaying a message a few days will push its exp date to one end of the valid window – so they won't be uniformly distributed.

- Fix: No expiration dates. Keep all hashes until key rotates.

Tagging attack on headers

- Mixmaster headers have a hash to integrity-check the fields for that hop. But it doesn't check the rest of the header.
- So we can flip some bits later in the header, and if we own the node later in the path that corresponds to the header we just broke, we can recognize the message.
- We must make the hash cover the entire header.

Tagging attack on payload

- Flip some bits in the payload, and try to recognize altered messages when they're delivered.

- Fix: Make the hash cover the payload too.

We're still using Cypherpunk replies

- No replay detection, no batching, messages change length at each hop, etc.
- Fix: Do all this stuff for replies too.

Since we want to *encrypt* replies at each hop, use a cryptosystem where decrypt is as strong as encrypt.

But you can't write a reply block without knowing the payload!

- Since the author of the reply block can't guess the right hashes for the payload, we've reintroduced the payload tagging attack.

- Actually, that's ok. Since we're *encrypting* at each hop, only the recipient can recognize the tag.

But forward messages and replies must now be distinguishable

- Forward messages need hashes, and replies can't have them.

- Assuming replies are rare relative to forwards, replies are easy to track.

We support three delivery types

- Forward messages, only Alice remains anonymous
- Direct replies, only Bob remains anonymous
- Anonymized reply messages where Alice *and* Bob remain anonymous

Parties that get anonymity must run our software.

Messages have two headers and a payload

Divide the path into two legs, one for each header

- For forward messages, Alice chooses both legs
- For direct replies, Alice can use the reply block directly
- For anonymized replies, Alice chooses the first leg and uses Bob's reply block for the second.

Legs are connected by the Crossover Point

- One of the hops in the first header is marked as a *crossover point*

- At the crossover point, we decrypt the second header with a hash of the payload, and then swap the headers.

Forward messages are anonymous:

- If the second header or the payload are tagged in the first leg, then the second header is unrecoverable.
- If tagged in the second leg, we've already gotten anonymity from the first.

Replies are anonymous:

- The adversary can never recognize his tag.

Multiple-message tagging attacks

- If Alice sends multiple messages along the same path, Mallory can tag some, recognize the pattern at the crossover point, and follow the rest.

- Only works if Mallory owns the crossover point.

- Fix: Alice picks k crossover points
(and hopes Mallory doesn't own most of them)

Nymservers and single-use reply blocks

- Work like pop/imap servers
- User anonymously sends a bunch of reply blocks to receive the mail that's waiting for him.

If you stop here, you get the current Mixminion remailer design.

Open problem: reputation on the directory servers

How do we let clients learn which nodes are good, without:

Letting the adversary do partitioning attacks on clients

Letting the adversary get more traffic by behaving well

Open problem: trickle attack on directory servers

- Malicious nodes can hold a message and release it later, when circumstances are different.
- More broadly, we're still in an arms race against flooding and trickle attacks

Open problem: long-term intersection attack

- The fact that not all users are sending messages all the time leaks information.
- By observing these patterns over time, we can learn more and more confidently who is sending mail, to whom, when, etc.
- Major unsolved problem in anonymity systems.

Play with our code

http://mixminion.net/

(Short break)

Next: *Other systems, including Onion Routing*