Advanced Networking

Privacy defense on the Internet

Csaba Kiraly

Topics

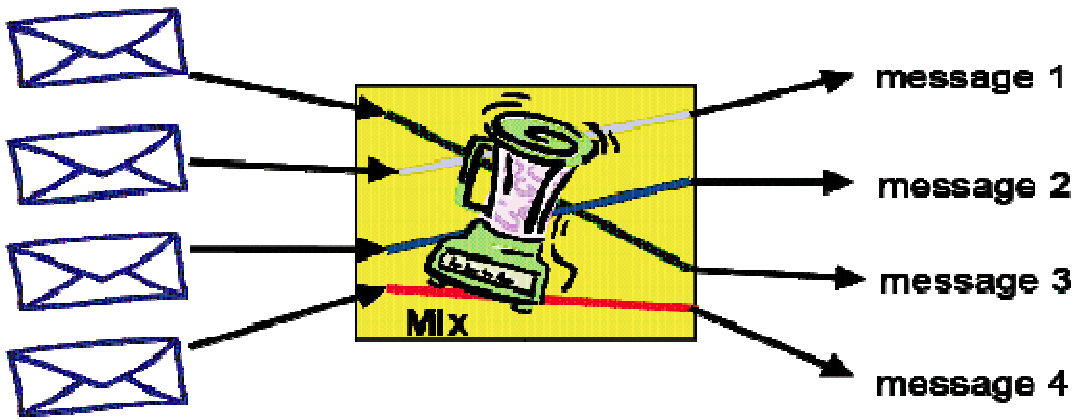
- ➔ **Anonymity on the Internet**
  - ⇨ Chaum Mix
  - ⇨ Mix network & Onion Routing
  - ⇨ Low-latency anonymous routing

Anonymity: Chaum mix

- ➔ **David L. Chaum (1981):**
  - ⇨ How to send anonymous e-mail …
  - ⇨ with return path
- ➔ **Designed for e-mail**
  - ⇨ Most of the concepts can be reused at packet level!
- ➔ **What anonymous means here:**
  - ⇨ Protect from external attacker
    - → Someone eavesdropping on the communication should not understand who is communicating
  - ⇨ From internal attacker
    - → A mail server should not know who is communicating to whom
  - ⇨ From other side
    - → The recipient should not know who was sending the mail

Chaum mix: tricks

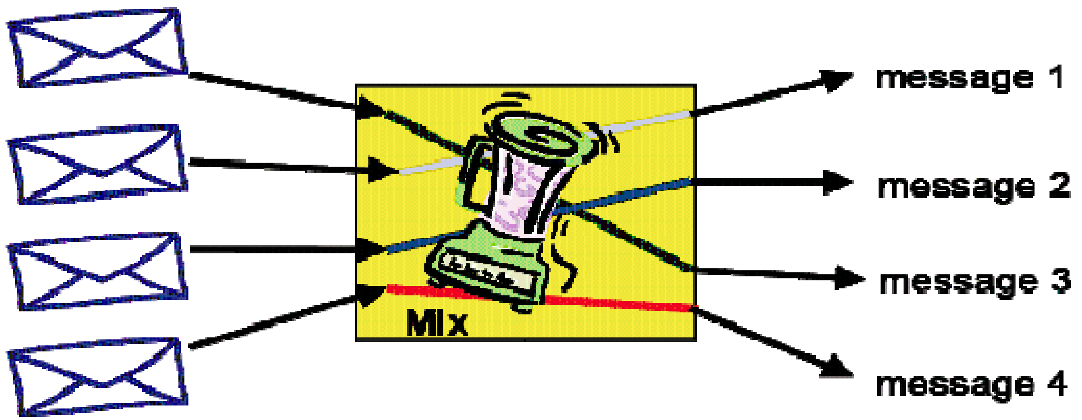
1. **What if someone can eavesdrop on the communication?**
   - ⇨ Solution: not sending directly
     - → Proxy (**mix**) removes/changes source
   - ⇨ Solution: use encryption
     - → Send message to mix encrypted (with its public key)
     - → Mix sends out message decrypted



Chaum mix: tricks

2. What if someone can inspect links of the mix?

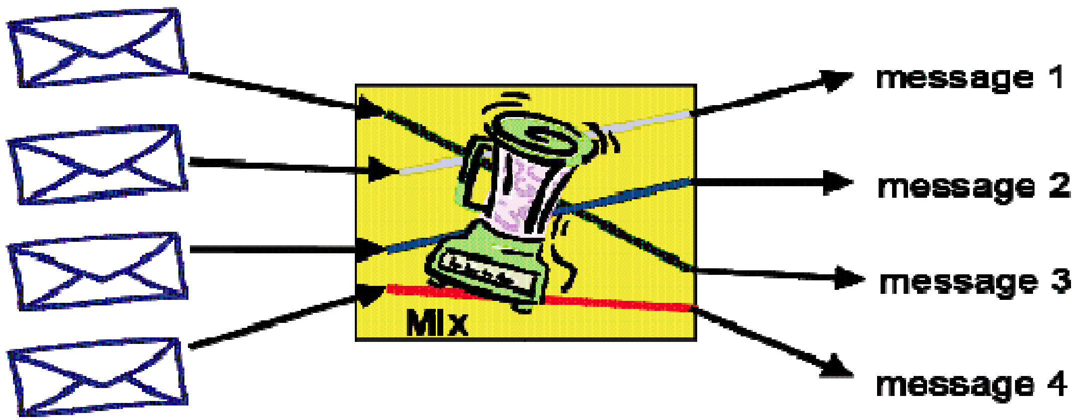
- ⇨ Can see incoming and outgoing message right after each other
- ⇨ Solution: delay messages
  - → Form batches of messages
  - → Send them out in random (or lexicographical) order



Chaum mix: tricks

3. What if someone can inspect links of the mix?

- ⇨ Can see the identical sized incoming and outgoing messaged -> linkage
- ⇨ Solution: pad messages to fixed size



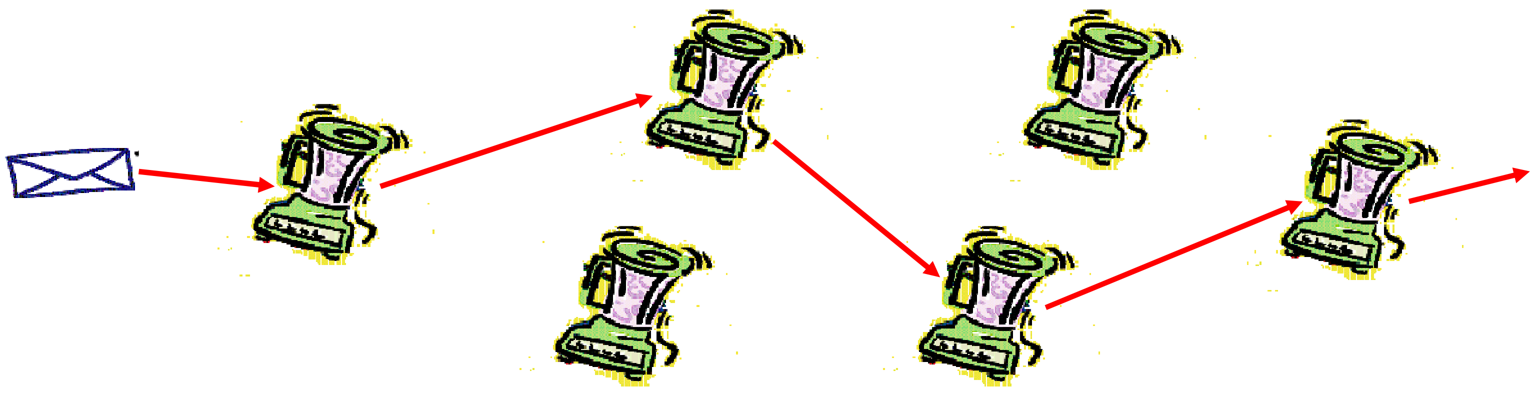
Topics

- **Anonymity on the Internet**
  - Chaum Mix
  - Mix network & Onion Routing
  - Low-latency anonymous routing

Chaum mix: tricks

4. What if the mix is the attacker?

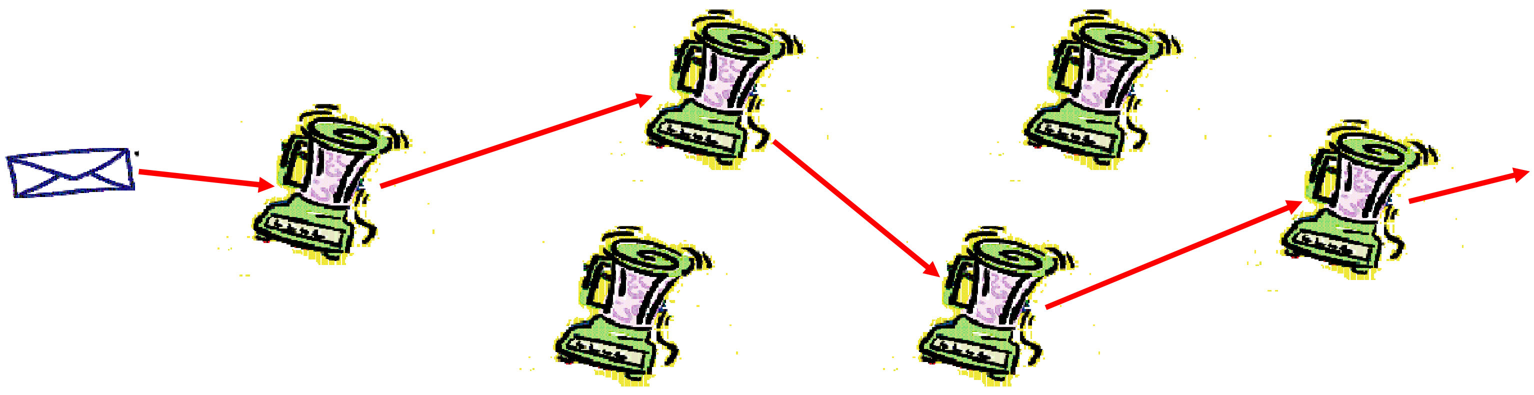
- ⇨ Solution: cascade mixes
- ⇨ Solution: use onion encryption
  - → 1st mix only knows source and 2nd mix …
  - → Nth mix only knows N-1th mix and N+1th mix



Chaum mix: tricks

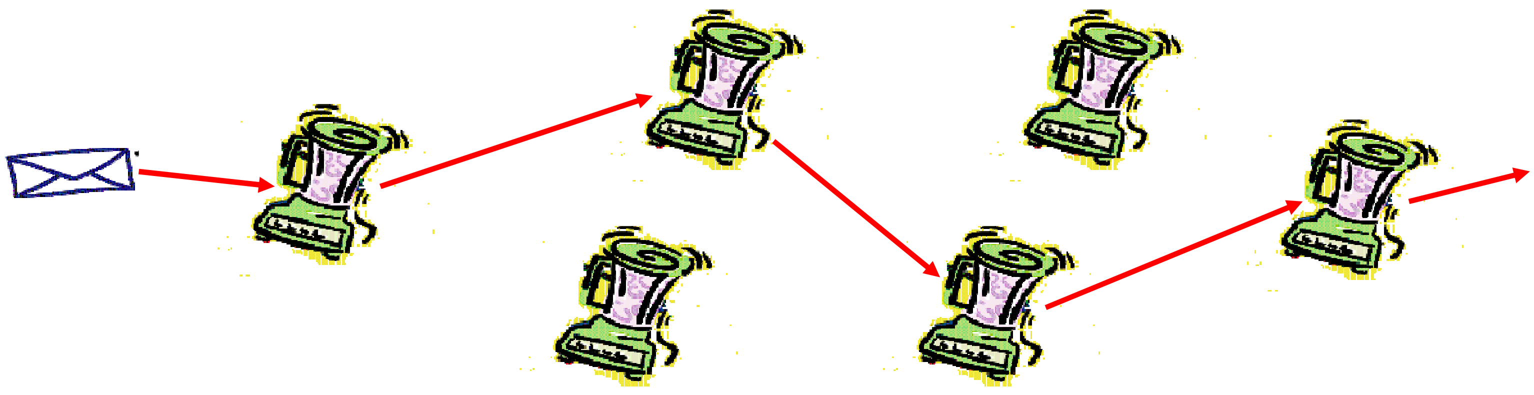
Onion routing, steps

1. Source downloads list of Mix nodes & their public keys
2. Select route (source routing): S->M1->M2->M3->D
3. Construct **onion** message
    1. D, K_D(Message)
    2. M3, K_{M3}(D, K_D(Message))
    3. M1,K_{M1}(M2,K_{M2}(M3, K_{M3}(D, K_D(Message)))))



Chaum mix: tricks

3. Construct **onion** message
   1. D, K_D(Message)
   2. M3, K_{M3}(D, K_D(Message))
   3. M1,K_{M1}(M2,K_{M2}(M3, K_{M3}(D, K_D(Message)))))
4. Onion travels
   1. S->M1: M1, cyphertext
   2. M1: M1,K_{M1}(M2, cyphertext) -> M2, cyphertext
   3. M1->M2: M2, cyphertext, …



Chaum mix: reply

➔ **Omitted for lack of time ☹**

Topics

- ➔ **Anonymity on the Internet**
  - ⇨ Chaum Mix
  - ⇨ Mix network & Onion Routing
  - ⇨ Low-latency anonymous routing

Low-latency anonymous routing

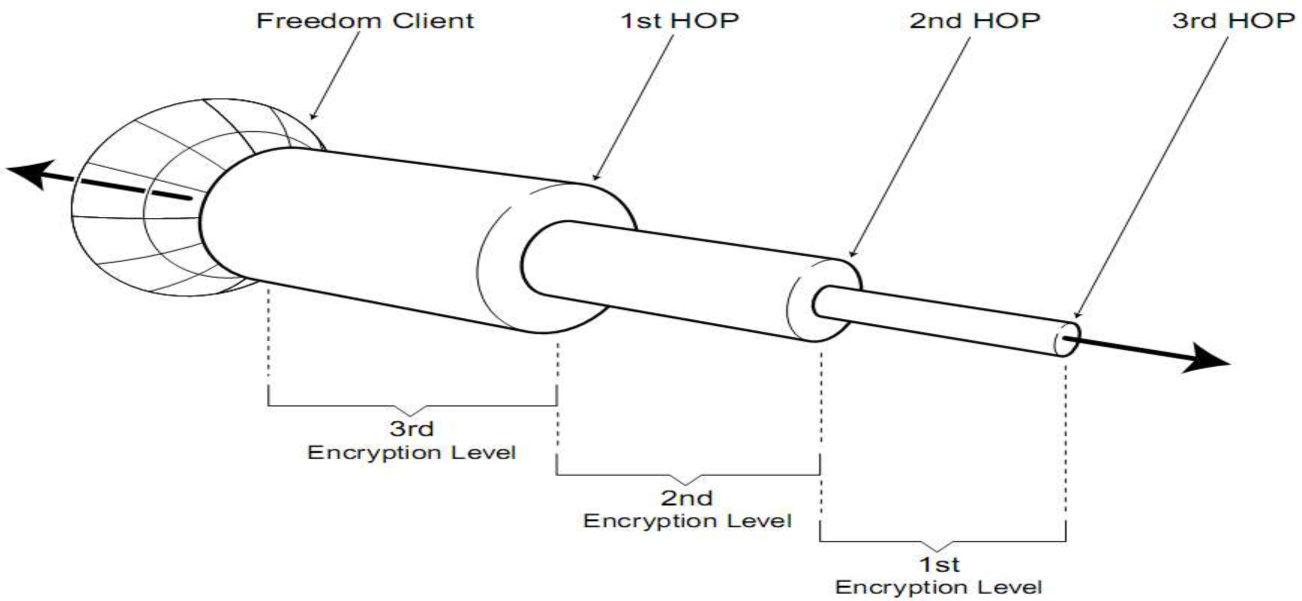
- ➔**Chaum mix works for**
  - ⇨large messages, high latency applications
  - ⇨E.g. e-mail
- ➔**What can be done for low latency applications (like web browser)?**
  - ⇨Messages (e-mail) -> packets
- ➔**Why can't it work the same way?**
  - ⇨Asymmetric (public/private key) encryption too slow, not feasible
  - ⇨Delaying in batches introduces too much latency

Low-latency anonymous routing: Circuit

- ➔ **Circuit: Why needed?**
  - ⇨ Public key cryptography too slow to encrypt each packet in an onion
  - ⇨ Use public key cryptography (slow) only at the beginning, to negotiate symmetric keys (fast)
    - → once with each node on the path
  - ⇨ Use these symmetric keys for the whole flow of packets
- ➔ **Consequences:**
  - ⇨ 2 phases of communication
    - → Circuit setup phase
    - → Data communication phase

Circuit setup phase

- ➔ **Problem: When negotiating with the 2nd mix, the source must be anonymous**
- ➔ **Idea: incremental circuit setup**
  - ⇨ Negotiate circuit with the 1st mix
  - ⇨ Use this circuit to speak to the 2nd anonymously and extend the circuit
- ➔ **Circuit implemented like a Telescope**



Data on the Circuit

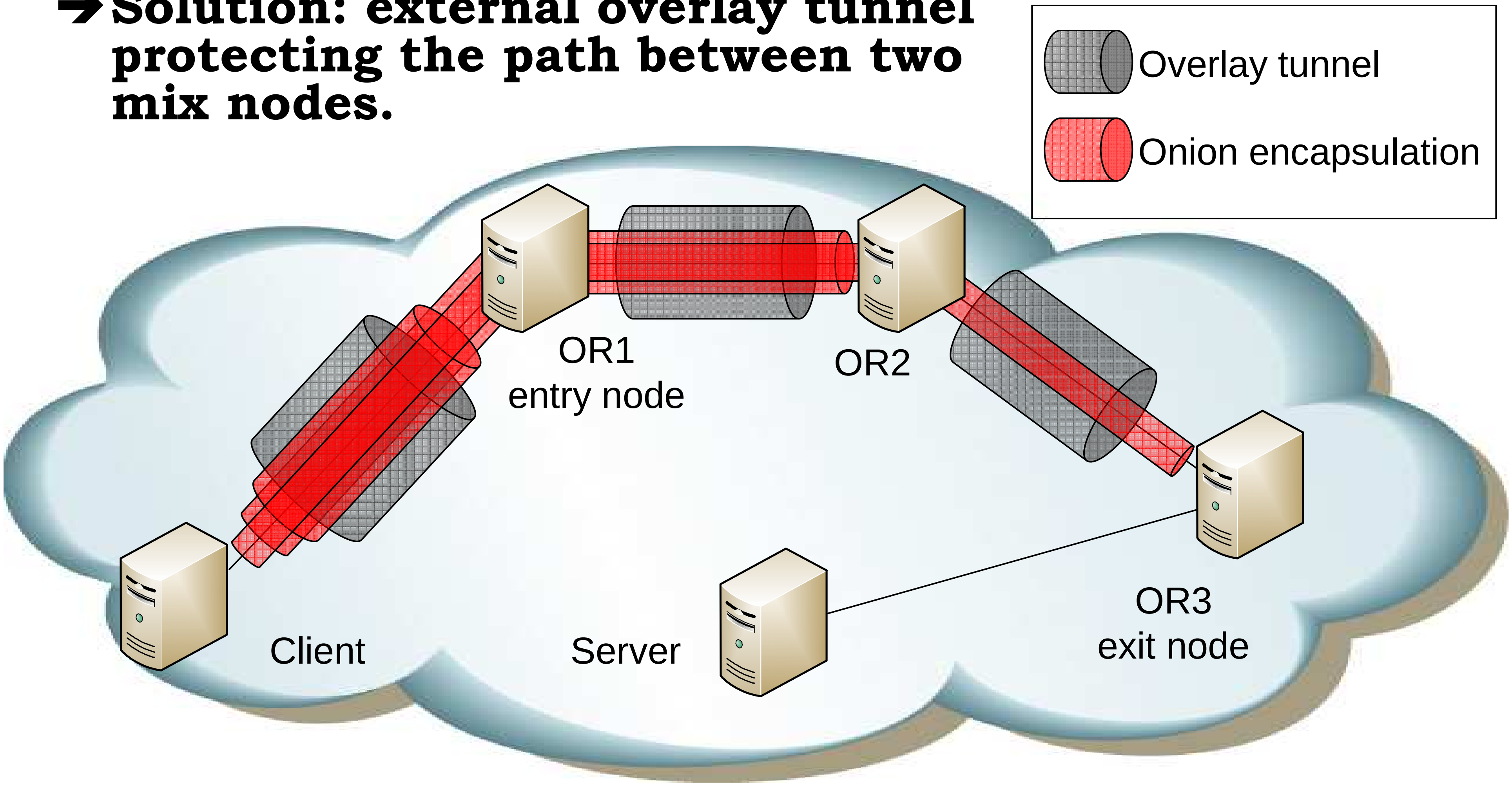
- ➔ **Label (circuit ID) switching**
  - ⇨ Circuit ID in each packet
  - ⇨ ID swapped in each mix
    - → Why?
      - » ID can't be same, otherwise the path would be easily uncovered
      - » ID must be unique in the mix
- ➔ **Re-encryption**
  - ⇨ Similar to Chaum, but now with symmetric keys.

Data return path

- **In case of Chaum, it was cumbersome (not discussed)**
- **With circuit:**
  - The same circuit can be used
  - In each hop
    - Swap ID back
    - Re-encrypt using the symmetric key
    - Send it to “previous” node
  - Source knows all the keys, so it can decrypt at the end

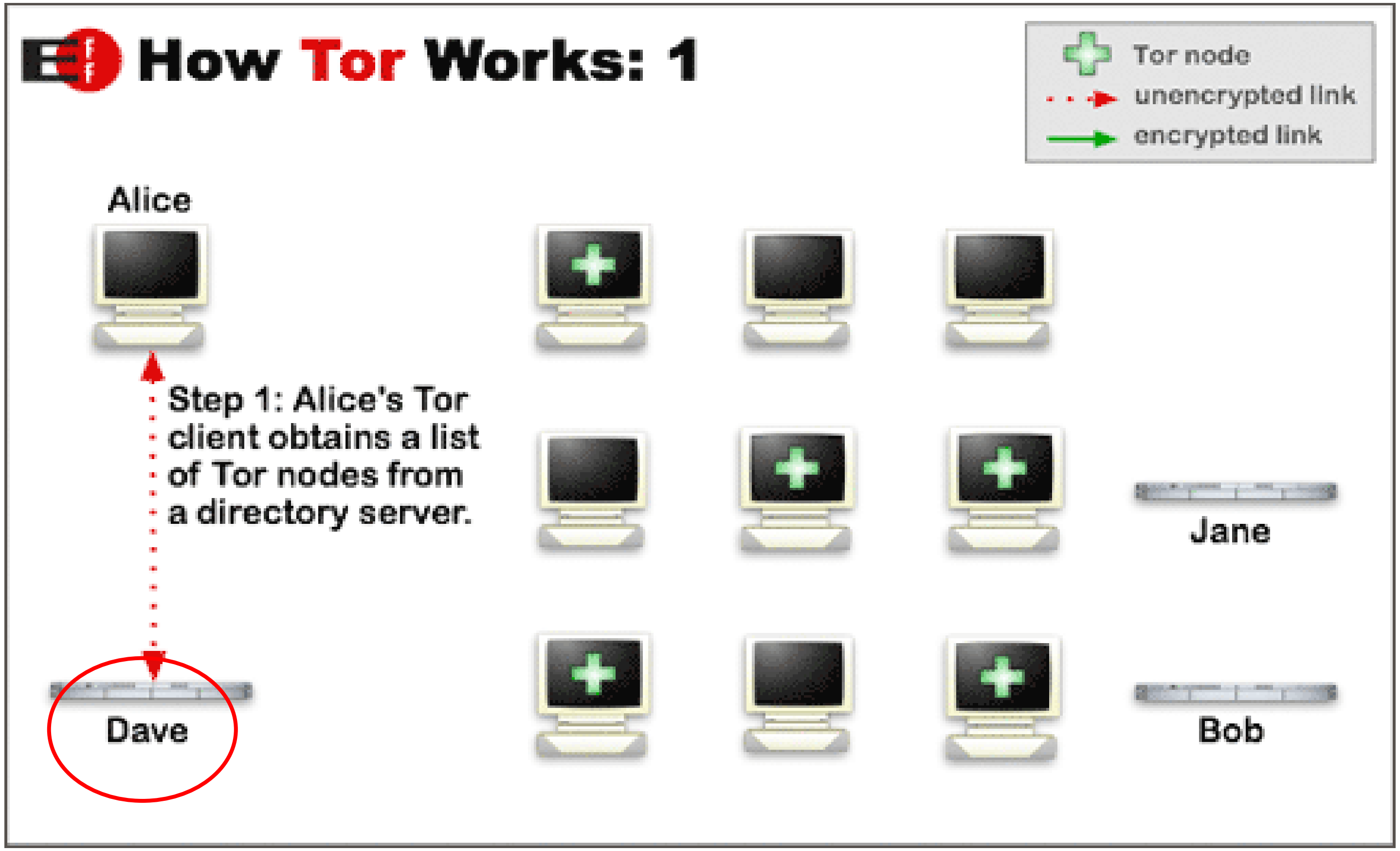
Protecting the circuit

- ➔ **Problem: circuit ID seen on the path between two mix nodes**
- ➔ **Solution: external overlay tunnel protecting the path between two mix nodes.**



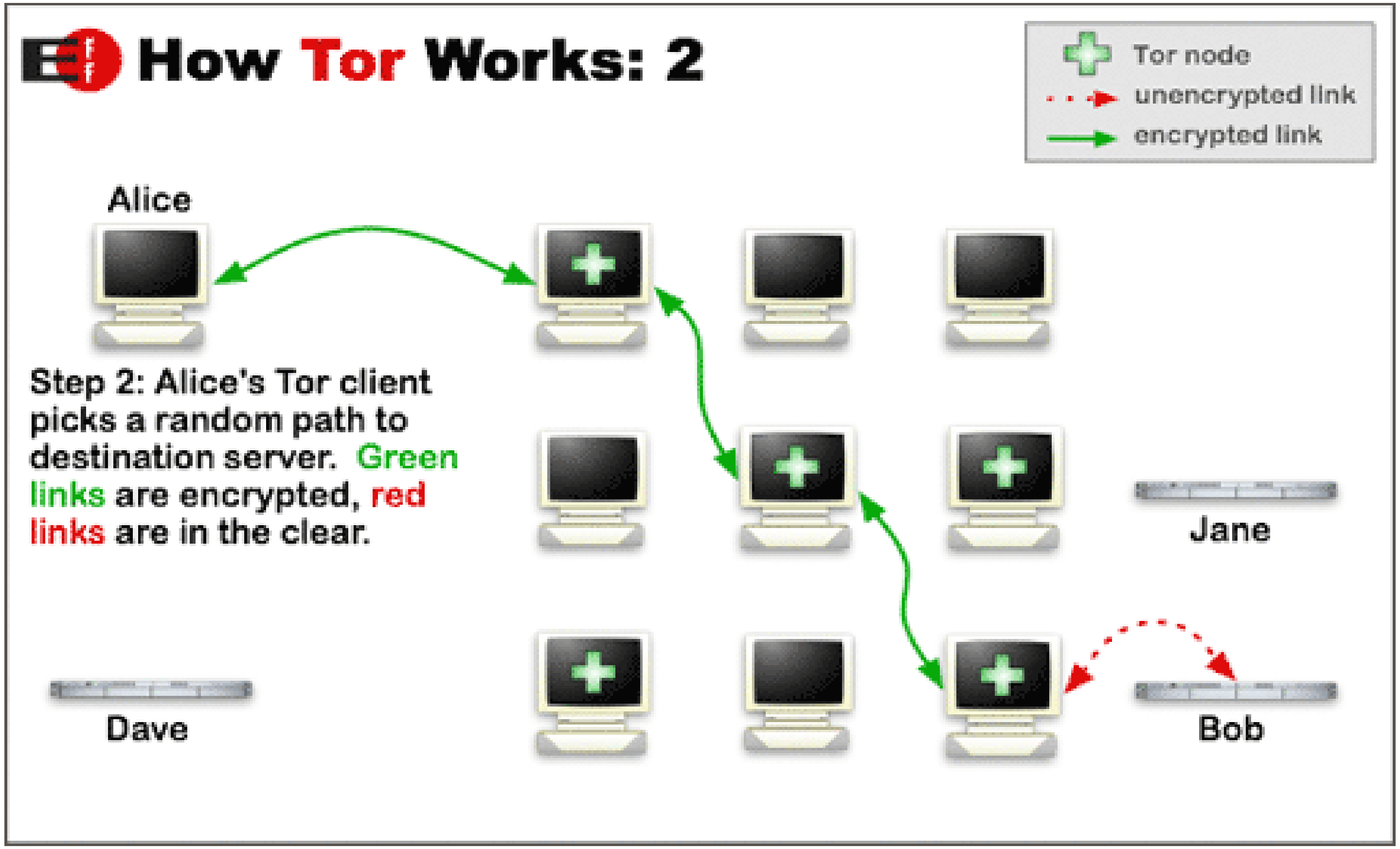
Steps: download list of mix nodes

- ➔ **The same as with e-mail**
- ➔ **List of overlay routers (mix nodes)**
  - ⇨ Their IP address and Public Key



Steps: Routing with Circuits

- ➔ **Decide about route**
- ➔ **Set up circuit for the whole connection!**
- ➔ **Send data through the circuit**



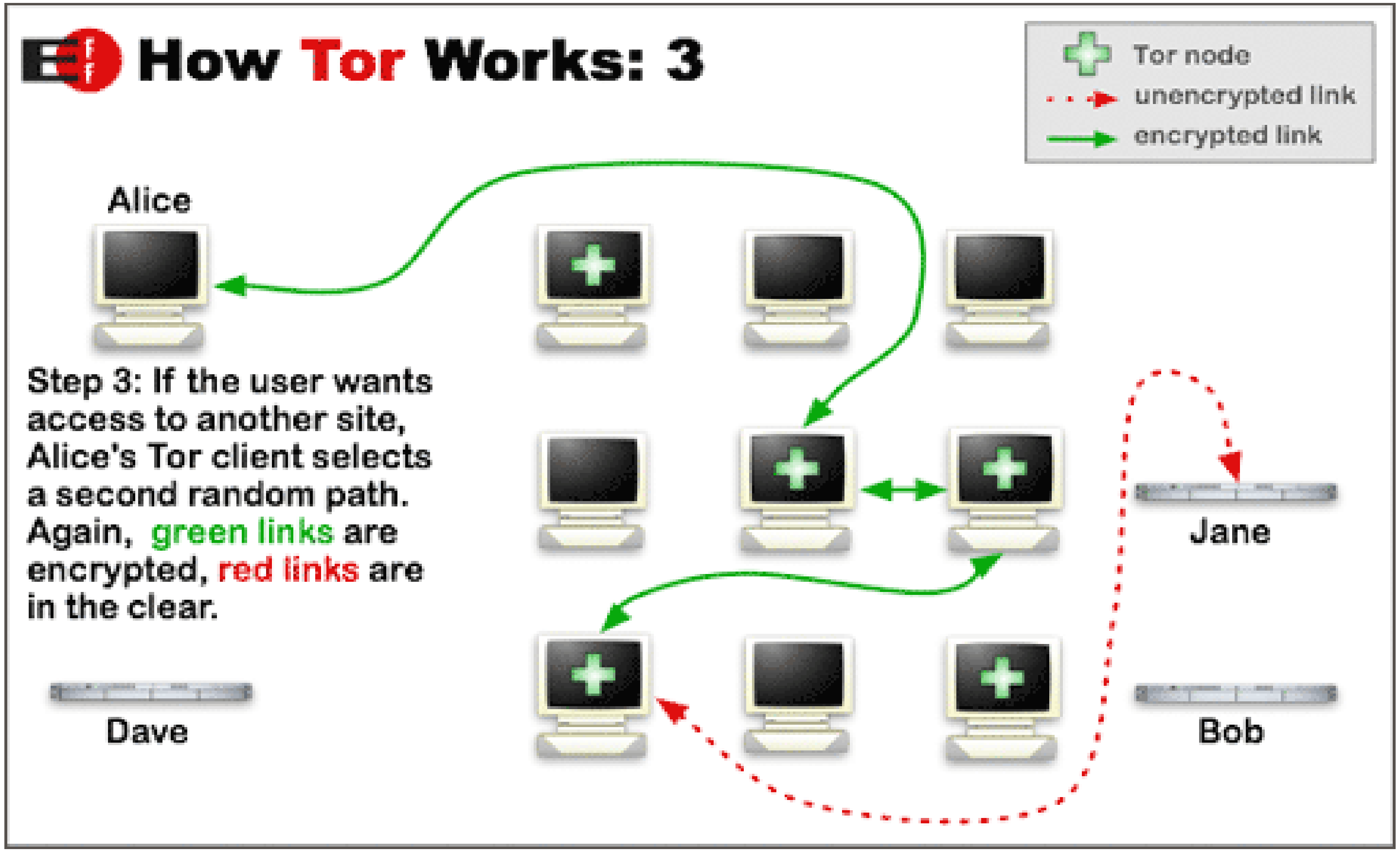
Source routing

Decide about route

- ➔ **Our goal**
  - ⇨ Whole route known only by the source
  - ⇨ A mix node knows only part of it
    - → Previous mix
    - → Next mix
- ➔ **Consequences**
  - ⇨ Mix shuoldn`t know the destination! => only source routing feasible
  - ⇨ Route selection should be random
    - → Otherwise easy to figure out the route
    - → Theoretical optimum: uniform random selection
    - → Practical considerations:
      - » In Tor: bandwidth weighted route selection

Steps: Changing circuits

- ➔ **Following comunications might use different path**
  - ⇨ to avoid linkage with old data exchanges
  - ⇨ to replace broken circuit

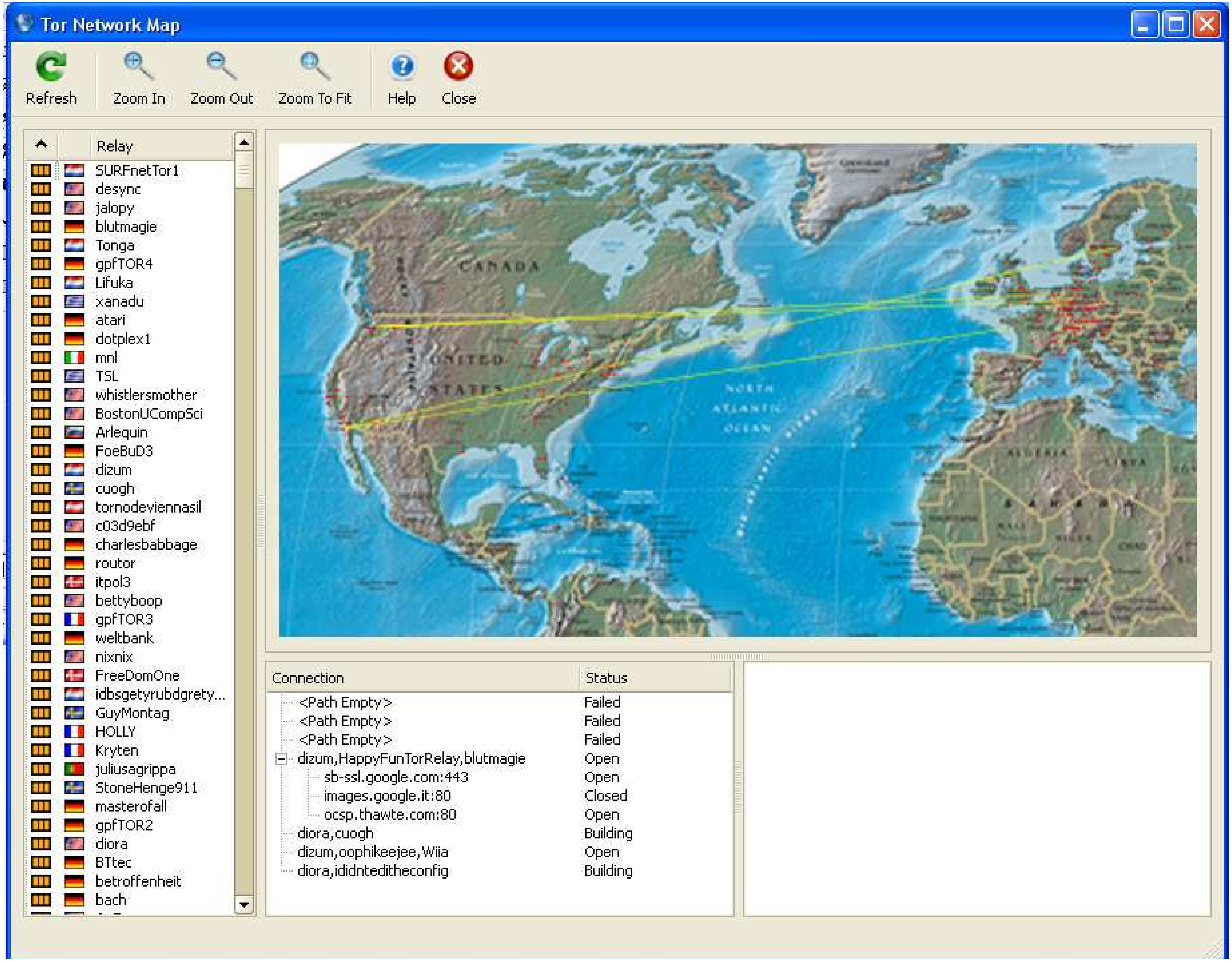


Circuit (dis)advantages

- **Circuit**
  - Pros:
    - Fast encryption
    - Easy return path routing
  - Cons:
    - Two phase communications
    - External overlay tunnel to protect circuit ID
    - State information in each mix node for each circuit!

A working example: Tor

- ➔ **Deployed in the Internet**
  - ⇨ More than 2000 mix nodes, run by volunteers
  - ⇨ Much more users
- ➔ **The infrastructure**
  - ⇨ Clients (called Onion Proxies, OP)
  - ⇨ Mix nodes (called Onion Routers, OR)
    - → Allow OP-OR and OR-OR traffic
  - ⇨ Exit nodes
    - → Special ORs that also allow traffic towards any server
  - ⇨ Directory servers
    - → Keep list of available OR nodes


Tor Network Map
Refresh
Zoom In
Zoom Out
Zoom To Fit
Help
Close
Relay
SURFnetTor1
desync
jalopy
blutmagie
Tonga
gpfTOR4
Lifuka
xanadu
atari
dotplex1
mnl
TSL
whistlersmother
BostonUCompSci
Arlequin
FoeBuD3
dizum
cuogh
tornodeviennasil
c03d9ebf
charlesbabbage
routor
itpol3
bettyboop
gpfTOR3
weltbank
nixnix
FreeDomOne
idbsgetyrubdgrety...
GuyMontag
HOLLY
Kryten
juliusagrippa
StoneHenge911
masterofall
gpfTOR2
diora
BTtec
betroffenheit
bach
CANADA
UNITED STATES
NORTH ATLANTIC OCEAN
ALGERIA
Connection
Status
<Path Empty> Failed
<Path Empty> Failed
<Path Empty> Failed
dizum,HappyFunTorRelay,blutmagie Open
sb-ssl.google.com:443 Open
images.google.it:80 Closed
ocsp.thawte.com:80 Open
diora,cuogh Building
dizum,oophikeejee,Wiia Open
diora,ididnteditheconfig Building

A working example: Tor

- **Tor works on L7**
  - It does not work on IP packets, but on “cells” of TCP connection of an application
  - There is nothing like a TCP cell, but Tor splits up the application data to small cells (502 bytes)
  - These cells are onion encrypted individually, the circuit ID is set, and the cell is routed on the overlay network
- **Integration with the application**
  - SOCKS proxy
- **Onion encryption**
  - Tor uses AES encryption on each cell, re-encrypting for each OR
- **Tunnel between OR nodes**
  - TLS/TCP tunnel
    - Multiplex several circuits going between the same 2 ORs
    - hide circuit IDs
    - send stream of cells
- **In each OR hop TLS/TCP is terminated -> L7 operation**

Tor in itself is not enough

- **HTTP query contains information too**

```
GET /spec.html HTTP/1.1
Host: www.example.org
User-Agent: Mozilla/5.0 (Macintosh; U; PPC Mac
  OS X Mach-O; en-US; rv:1.8) Gecko/20051130
  Firefox/1.5
Referer: http://comingfrom.com/
Accept: …
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 300 Connection: keep-alive
Cookie: yourtrackingid=123412
```

  - Leaks data or allows linkage
- ***Solution: remove these***
  - *e.g. use Privoxy*

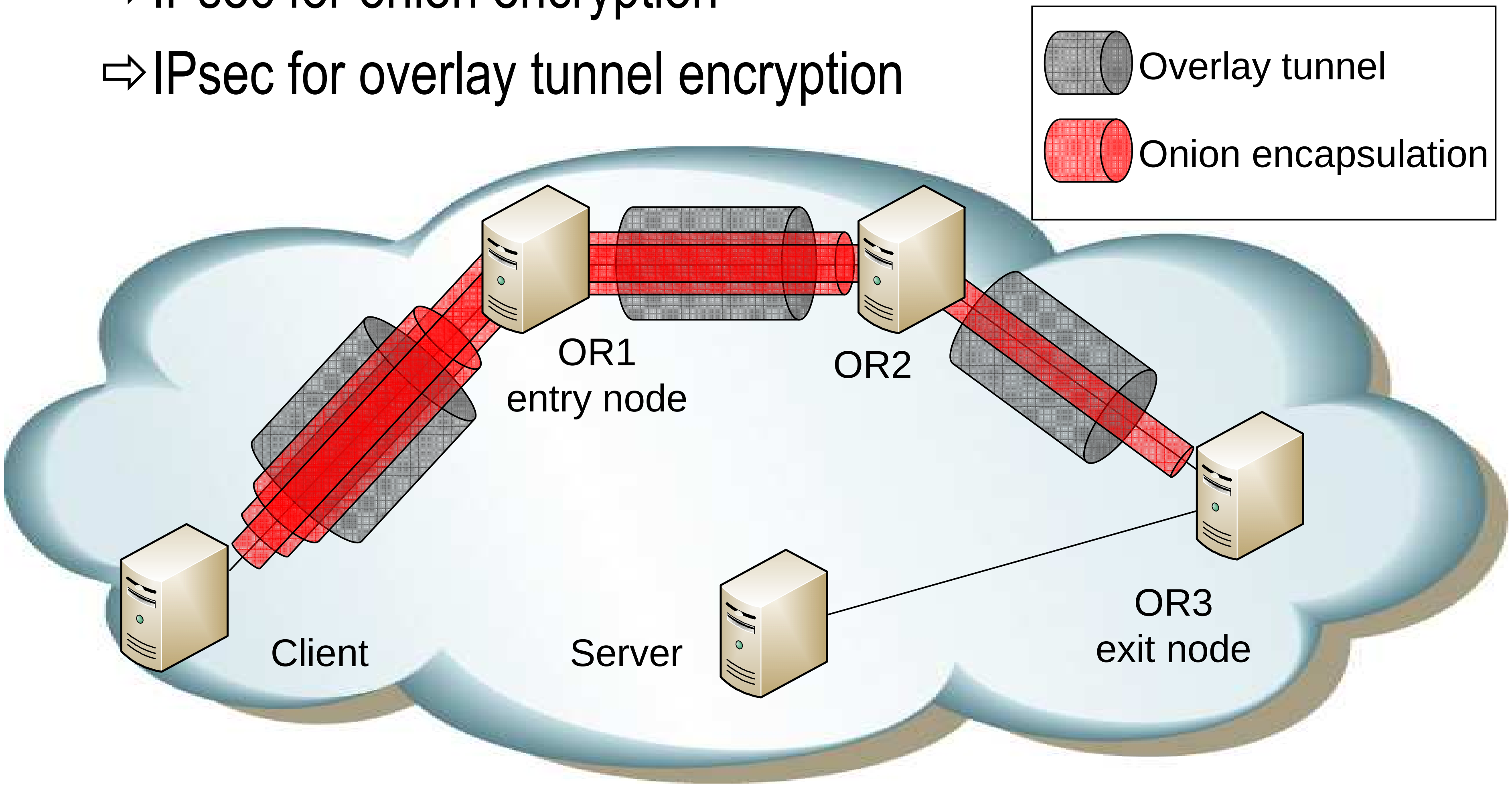
Tor in itself is not enough

- ➔**DNS query contains information as well**
  - ⇨Tor hides the destination IP address from Mix nodes and eavesdroppers
  - ⇨But, DNS query to figure out the IP address is in clear -> eavesdroppers see ot
- ➔***Solution: force the DNS query through Tor as well***
  - ⇨*Using a special version of SOCKS*

Another example: IPpriv

IPpriv works on L3, using IPsec

- ⇨IPsec for onion encryption
- ⇨IPsec for overlay tunnel encryption



L7 (Tor) vs. L3 (IPpriv)

L7 solution

- **Integration with the application: SOCKS proxy**
  - Only TCP supported
  - application support (or wrapper) needed
- **Tunnel between mix nodes: TLS/TCP**
  - TCP congestion control and reliable transmission on each tunnel
- **In each hop TLS/TCP is terminated**
  - Application level processing
- **Deployment: application**
  - Easy to install anywhere
- **Mix operates at: L7**
  - L3 and L4 characteristics hidden

L3 solution

- **Integration with the application: IP**
  - Not needed
  -
- **Tunnel between mix nodes: IPsec tunnel**
  - Best effort delivery
- **In each hop IPsec decription and routing**
  - Kernel processing with lower delays
- **Deployment: IPsec SP and SA**
  - Root priviledges neeed
- **Mix operates at: L3**
  - L3 and L4 characteristics are not hidden