Advanced Networking

Privacy defense on the Internet

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Topics

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

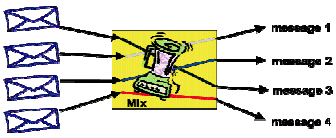
Anonymity: Chaum mix

- **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?

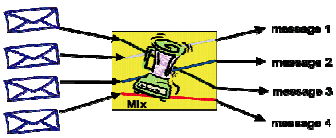
- ⇨ Solution: not sending directly
  - → Proxy (**mix**) removes/changes source
- ⇨ Solution: use encryption
  - → Send message to mix encrypted (with its public key)
  - → Mix sends out message decrypted



Chaum mix: tricks

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

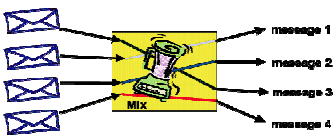
- ⇨ Can see incoming and outgoing message right after each other
- ⇨ Solution: delay messages
  - → Form batches of messages
  - → Send them out in random (or lexicographical) order



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

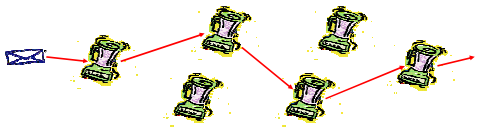
➔**Anonymity on the Internet**

- ⇨Chaum Mix
- ⇨Mix network & Onion Routing
- ⇨Low-latency anonymous routing

Chaum mix: tricks

4. What if the mix is the attacker?

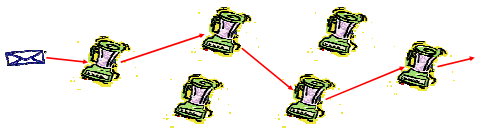
- ⇨ Solution: cascade mixes
- ⇨ Solution: use onion encryption
  - → 1st mix only knows source and 2nd mix …
  - → Nth mix only knows N-1th mix and N+1th mix



Chaum mix: tricks

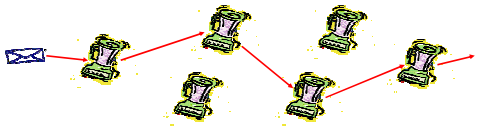
Onion routing, steps

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
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- ⇨Low-latency anonymous routing

Low-latency anonymous routing

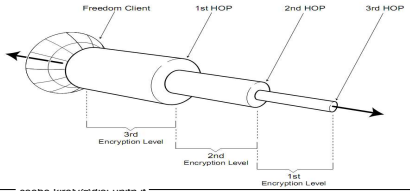
- **Chaum mix works for**
  - large messages, high latency applications
  - E.g. e-mail
- **What can be done for low latency applications (like web browser)?**
  - Messages (e-mail) -> packets
- **Why can't it work the same way?**
  - Asymmetric (public/private key) encryption too slow, not feasible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

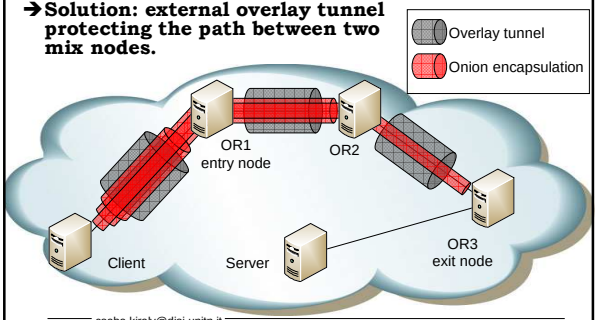
- **Label (circuit ID) switching**
  - Circuit ID in each packet
  - ID swapped in each mix
    - Why?
      - » ID can't be same, otherwise the path would be easily uncovered
      - » ID must be unique in the mix
- **Re-encryption**
  - Similar to Chaum, but now with symmetric keys.

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

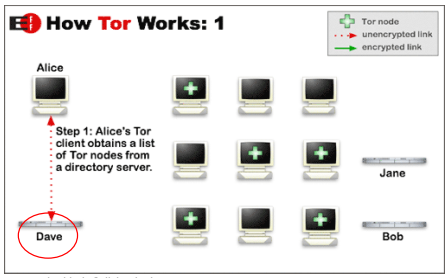
Protecting the circuit

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



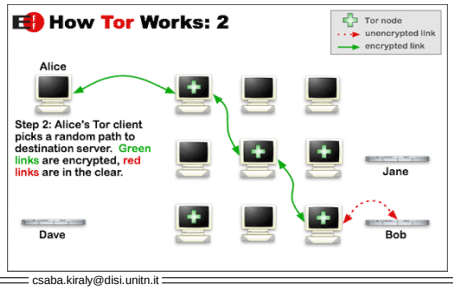
Steps: download list of mix nodes

➔**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**

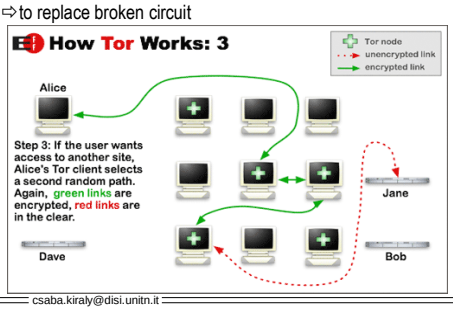


Source routing

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



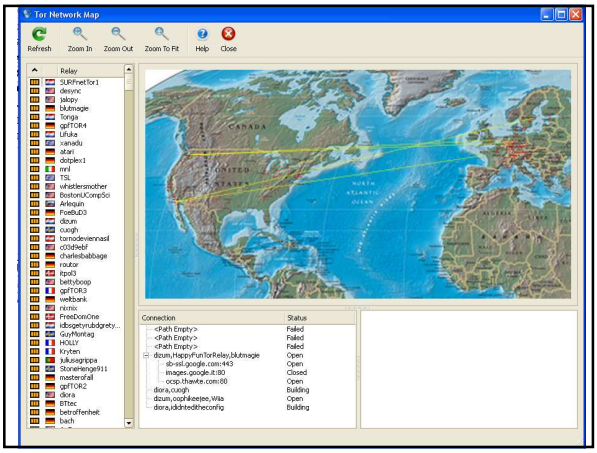
Circuit (dis)advantages

➔**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



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***

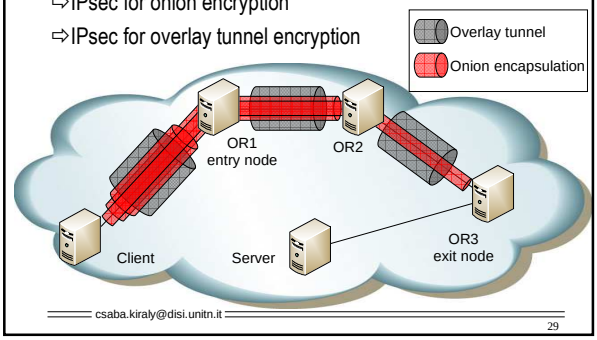
⇨*Using a special version of SOCKS*

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	*L3 solution*
➔ **Integration with the application: SOCKS proxy**	➔ **Integration with the application: IP**
⇨ Only TCP supported	⇨ Not needed
⇨ application support (or wrapper) needed	⇨
➔ **Tunnel between mix nodes: TLS/TCP**	➔ **Tunnel between mix nodes: IPsec tunnel**
⇨ TCP congestion control and reliable transmission on each tunnel	⇨ Best effort delivery
➔ **In each hop TLS/TCP is terminated**	➔ **In each hop IPsec decription and routing**
⇨ Application level processing	⇨ Kernel processing with lower delays
➔ **Deployment: application**	➔ **Deployment: IPsec SP and SA**
⇨ Easy to install anywhere	⇨ Root priviledges neeed
➔ **Mix operates at: L7**	➔ **Mix operates at: L3**
⇨ L3 and L4 characteristics hidden	⇨ L3 and L4 characteristics are not hidden