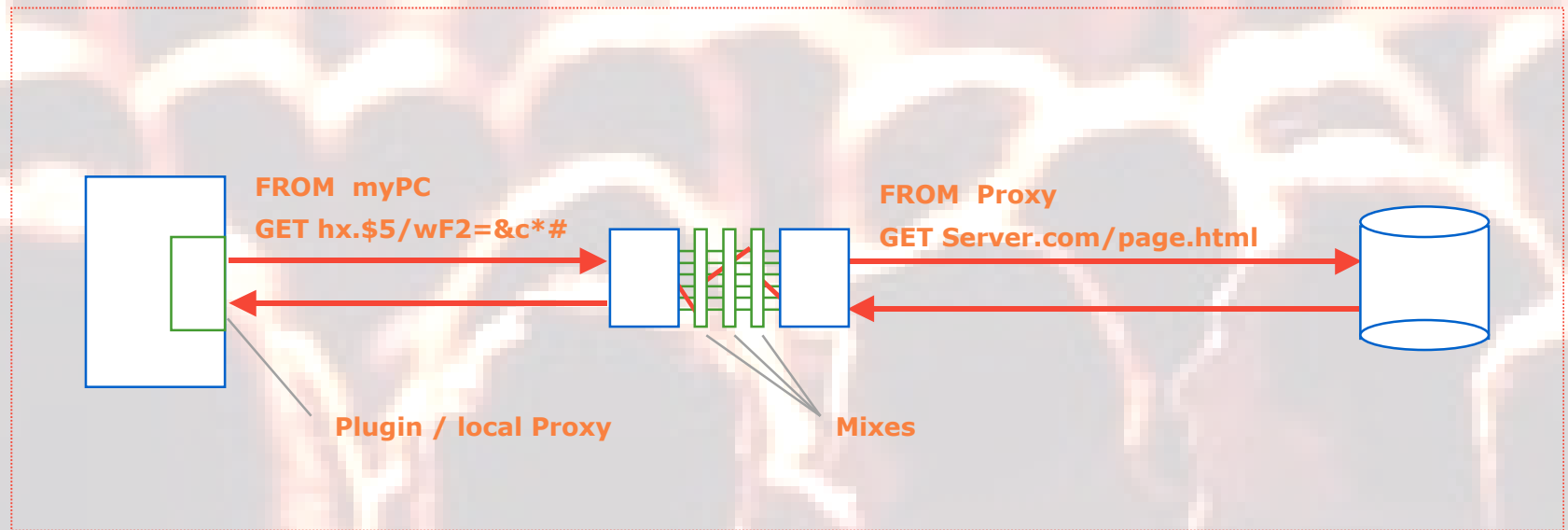


GET http://anon.nowhere.com/  
>please type in your name  
>set cookie

# > Privacy enhancing technologies in the Internet

Hannes Federrath



## > Logging and Observation of user actions

### Logging of e-mail communication

```
>tail syslog
Oct 15 16:32:06 from=<feder@tcs.inf.tu-dresden.de>, size=1150
Oct 15 16:32:06 to=<hf2@irz.inf.tu-dresden.de>
```

### Logging of web access

```
wwwtcs.inf.tu-dresden.de>tail access_log
amadeus.inf.tu-dresden.de - - [15/Oct/1997:11:50:01] "GET
/lvbeschr/winter/TechnDS.html HTTP/1.0" - "http://wwwtcs.inf.tu-
dresden.de/IKT/" "Mozilla/3.01 (X11; I; SunOS 5.5.1 sun4u)"
```

### Linkage of user actions

```
ithif19 logs 17 >finger @amadeus.inf.tu-dresden.de
[amadeus.inf.tu-dresden.de]
Login      Name                TTY      Idle      When
feder      Hannes Federrath    console  Wed 11:56
```

## > Logging and Observation of user actions

Log

>tail  
Oct  
Oct

Log

wwwto  
amade  
/lvbe  
dres

Lin

ithis  
[ama  
Login  
fede

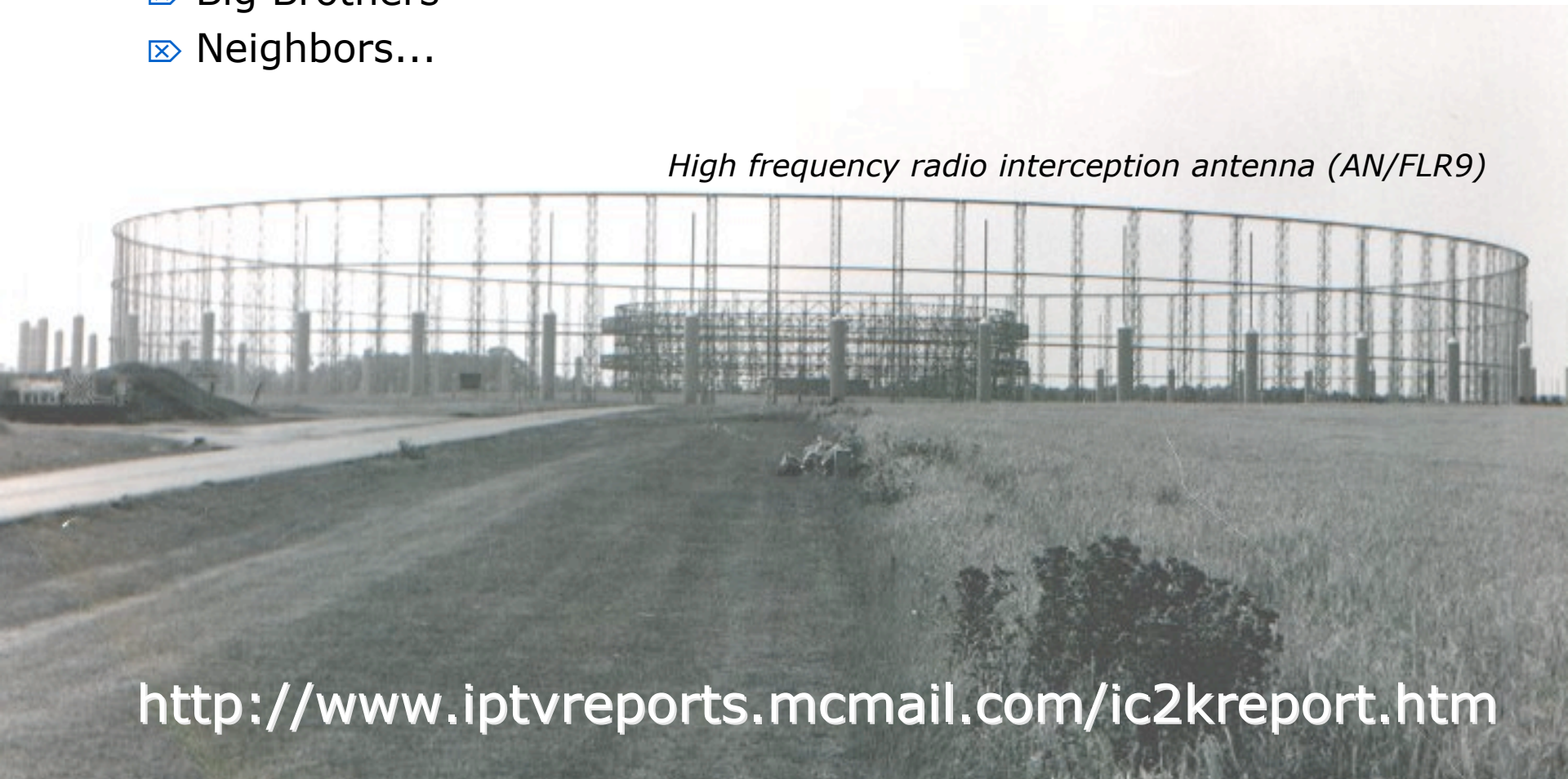
(213.68.175.4)	...	Heute 16:17 Uhr
p3e9baca6.dip.t-dialin.net (62.155.172.166)	...	Heute 13:41 Uhr
voss.mat.tu-harburg.de (134.28.61.22)	...	Gestern 14:13 Uhr
pec-120-252.tnt10.me2.uunet.de (149.225.120.252)	...	Gestern 13:50 Uhr
(212.100.36.50)	...	Gestern 13:35 Uhr
gw3.telekom.de (194.94.109.2)	...	Gestern 9:32 Uhr
wzl214.wzl.rwth-aachen.de (137.226.193.214)	...	Gestern 9:09 Uhr
n2-146-189.dhcp.mcphu.edu (144.118.146.189)	...	Gestern 4:04 Uhr
acb08d7f.ipt.aol.com (172.176.141.127)	...	04.06.2001 16:46 Uhr
pd9009416.dip.t-dialin.net (217.0.148.22)	...	04.06.2001 13:44 Uhr
dialppp-7-56.rz.ruhr-uni-bochum.de (134.147.7.56)	...	04.06.2001 8:24 Uhr
(194.64.244.18)	...	03.06.2001 23:19 Uhr
(62.2.58.8)	...	03.06.2001 20:25 Uhr
f-226-182.bielefeld.ipdial.viaginterkom.de (62.180.182.226)	...	03.06.2001 10:30 Uhr

# > Anonymity in the Internet is an illusion

## ⌘ Know your enemy!

- ⊠ Competitors
- ⊠ Security Agencies of foreign countries
- ⊠ Big Brothers
- ⊠ Neighbors...

*High frequency radio interception antenna (AN/FLR9)*



<http://www.iptvreports.mcmail.com/ic2kreport.htm>



# > Anonymity in the Internet is an illusion

## ⌘ Know your enemy!

- ⊠ Competitors
- ⊠ Security Agencies of foreign countries
- ⊠ Big Brothers
- ⊠ Neighbors...

*Bad Aibling Interception  
facility of the ECHELON  
system*

Source: <http://ig.cs.tu-berlin.de/w2000/ir1/referate2/b-1a/>



## > Protection Goals

Subject of communication  
**WHAT?**

**Confidentiality**

**Contents**

Circumstances of comm.  
**WHEN?, WHERE?, WHO?**

**Anonymity**  
**Unobservability**

**Sender**

**Location**

**Recipient**

**Integrity**

**Contents**

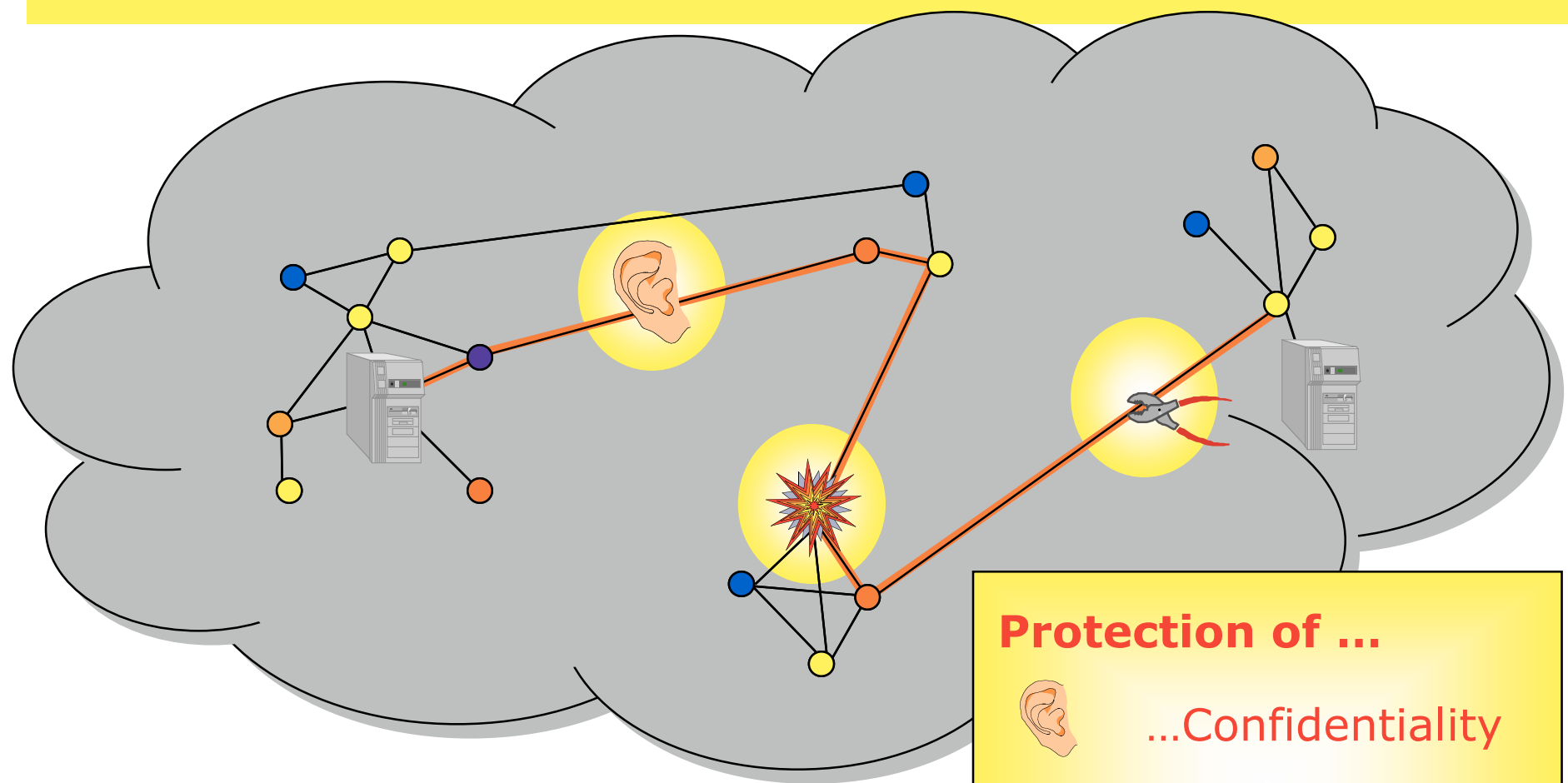
**Accountability**  
**Legal Enforcement**

**Sender**

**Billing**

**Recipient**

# The Internet



⌘ Telecommunication networks:

- ⌘ many operators
- ⌘ many users

## Protection of ...



...Confidentiality



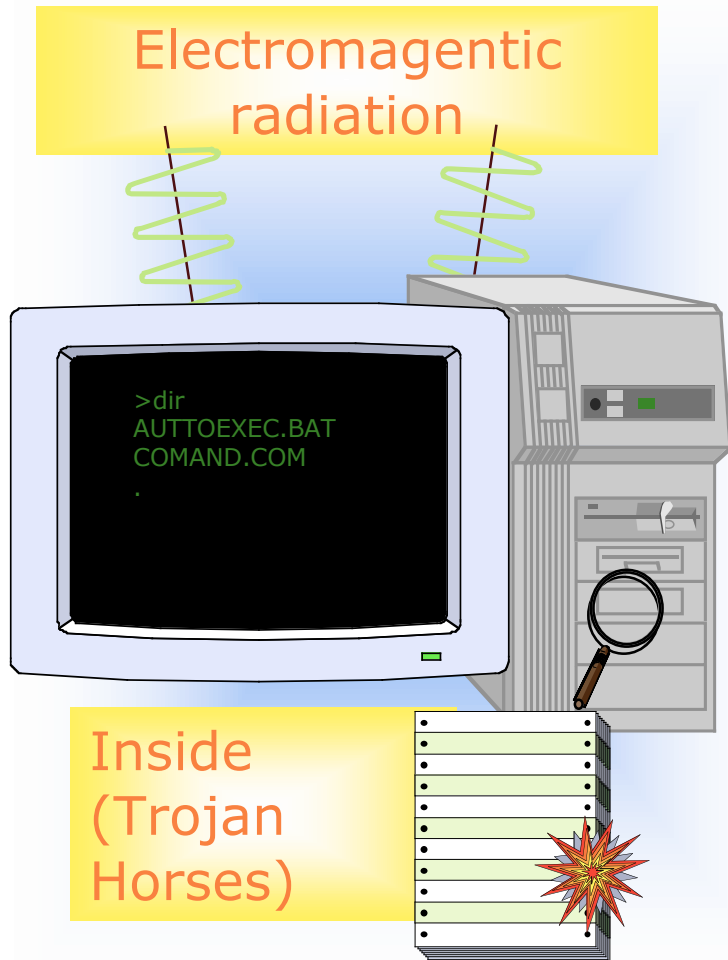
...Integrity



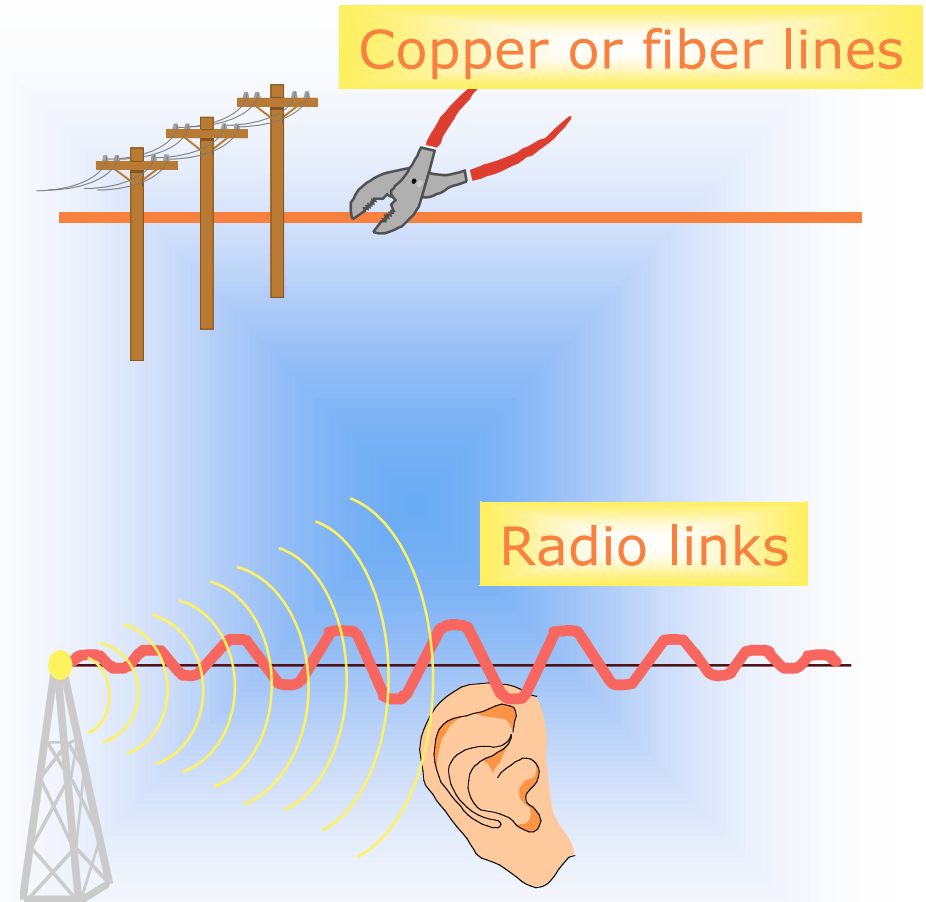
...Availability

> "Access points"

## Computer

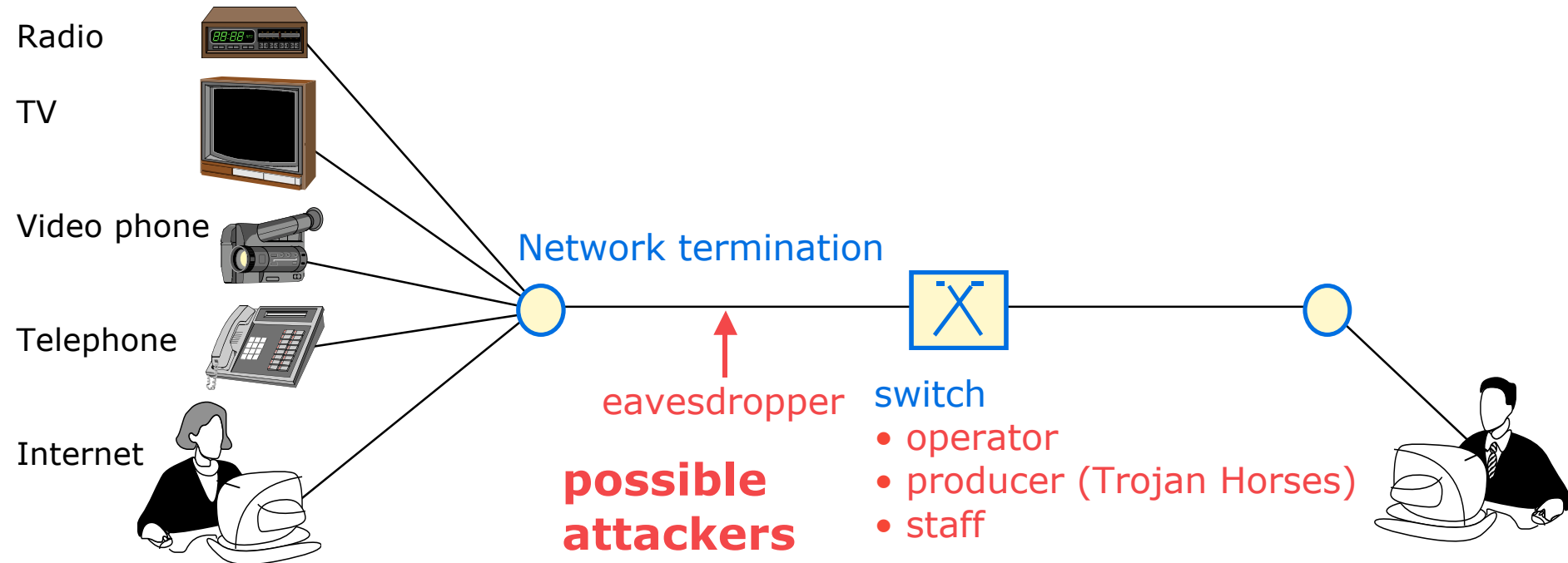


## Transmission

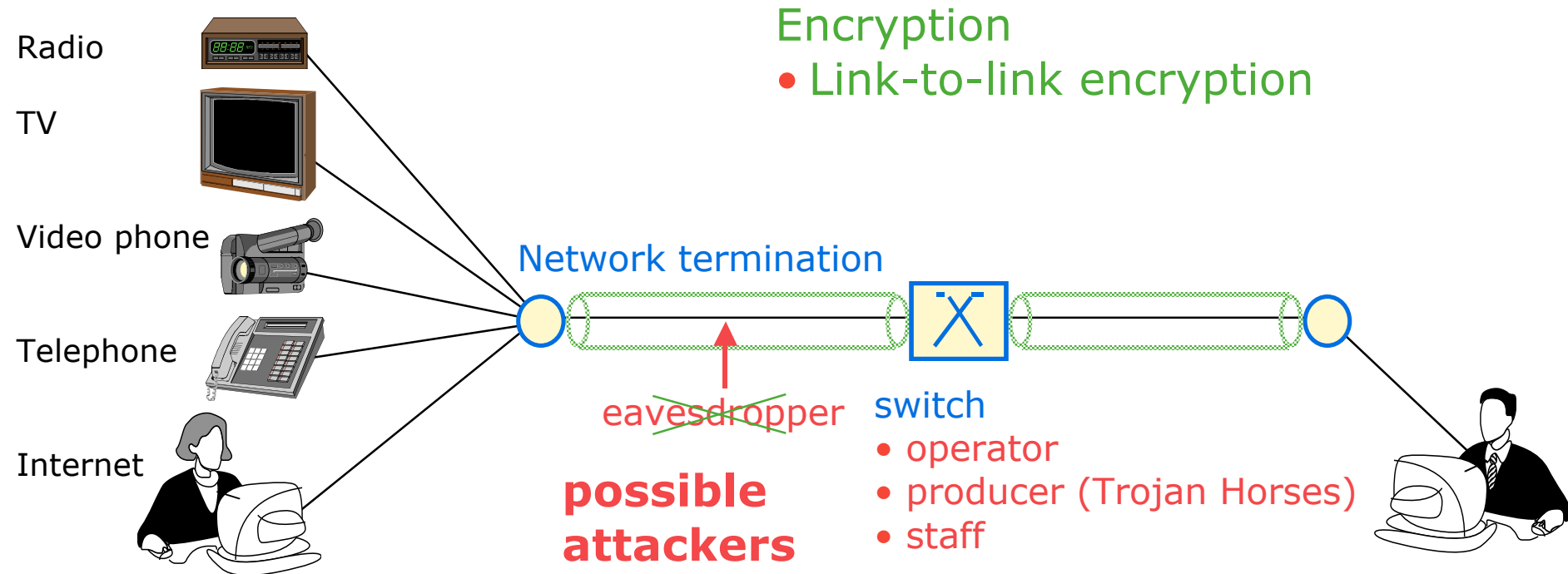




## > Observation of users in switched networks



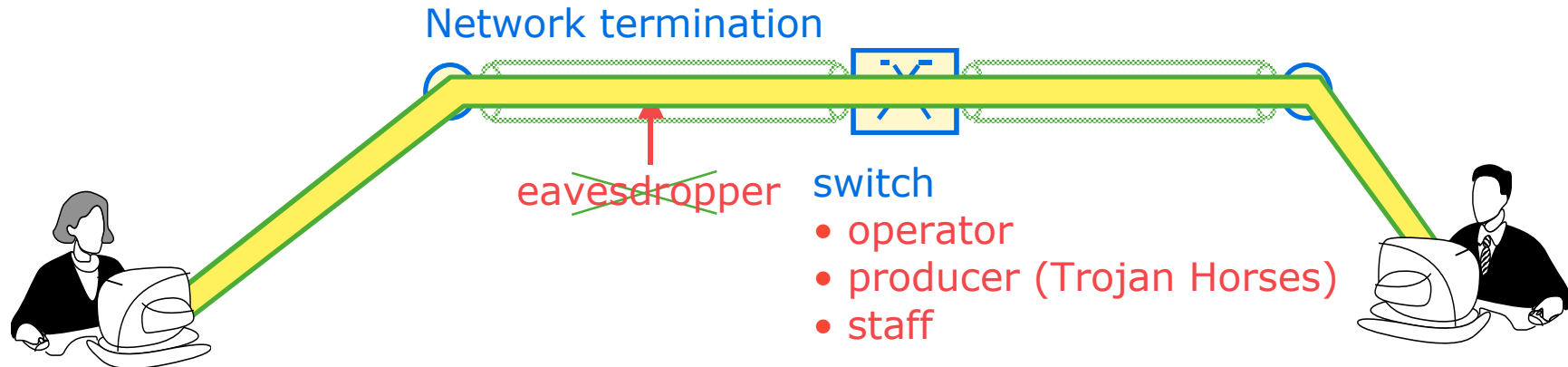
# >> Observation of users in switched networks



# >>> Observation of users in switched networks

## Encryption

- Link-to-link encryption
- End-to-end encryption of contents



## Problem – Traffic data:

Who communicates with whom, how long, where?  
Who is interested in which contents?

We need concepts that hide traffic data (or avoid it).

# Confidentiality of content by means of Encryption

## ⌘ Symmetric Encryption, e.g. DES, IDEA, AES

- ⊠ Both communication partners share a *secret* key for encryption and decryption
- ⊠ Security is based on a „chaos machine“
- ⊠ Key length approx 128 bits

## ⌘ Asymmetric Encryption (Public Key Encryption), e.g. RSA

- ⊠ Each user generates a key pair:
  - ⊕ *public* encryption key
  - ⊕ *private* (and secret) decryption key
- ⊠ Security is based on hard problems in number theory
- ⊠ Key length > 1024 bits  
new: elliptic curve cryptography approx. 160 bits

## ⌘ Well-known encryption software:

- ⊠ Pretty Good Privacy
- ⊠ <http://www.pgp.com>

# > Pretty Good Privacy (PGP)

<http://www.pgp.com>

The screenshot displays the PGP software interface with three main windows:

- PGPkeys**: A window showing a list of public keys. The table below represents the data shown in this window.
- Secret E-Mail Message**: A window showing a decrypted email message from Hannes Federrath.
- Hannes Federrath <federrath@inf.tu-dresden.de> NO...**: A detailed view of a specific key, showing its ID, type, size, creation date, expiration, cipher, and fingerprint.

Name	Validity	Trust	Size	Description
Gerrit Bleumer <bleumer@acm.org>			2048/1024	DH/DSS Public Key
Gerrit Bleumer <bleumer@acm.org>			1024	RSA Legacy Public
Gregor Goessler <ukjn@rz.uni-karlsruhe.de>			1024	RSA Legacy Public
Gritta Wolf <wolf@ibdr.inf.tu-dresden.de>			2048	RSA Legacy Public
Guntram Wicke <gw3@irz.inf.tu-dresden.de>			1024	RSA Legacy Public
Guntram Wicke <g-wicke@itsec-debis.de>			2048/1024	DH/DSS Public Key
Hannes Federrath <federrath@inf.tu-dresden.de>			2048/1024	DH/DSS Key Pair
Hannes Federrath <federrath@inf.tu-dresden.de> NO LEGAL RELEVANCE			1024	RSA Legacy Key P
Helmut Kohl <kohl@saumagen.net>			2048/1024	DH/DSS Key Pair
Hendrik Tews <tews@tos.inf.tu-dresden.de>			512	RSA Legacy Public

**Secret E-Mail Message**

From: federrath@inf.tu-dresden.de (Hannes Federrath)

An: Helmut.Lampshade@domain.com

Cc:

Betreff: Secret E-Mail Message

Anlagen: keine

-----BEGIN PGP MESSAGE-----  
Version: PGPfreeware 7.0.3 for non-commercial use <<http://www.pgp.com>>  
hQCMABodjdHYRExAP /v6M/hBj0m3r5pXSzXlw31Ezvi1bGRVWuxPWKpDc8o7x  
dna99YSVPcT66gEhal2NjNUCDwKX/5VtxySSQgnKdHw4SQu85P+UDjTCUPLRsQ80  
QJaKSWOqDmrImGzbhV3Lrevumiq7p4bTqCDwmto tC0vYdo3AGezmqAGMdxF21U0L  
ARcTUK6YAB8fB4NjlvbwlsyKKj0sRH986hySKKCGQF+3pAq0oqlvTCo0fTRMKTcu  
Jn2RETOnGDmqj/hyKlzuHv8oPSknGVN+Qa0nUD4ImSAx+VLYJbKlYKra+ixR8Fds  
zP6d99SAXg1EnZ4BmmS09o36zVmo6Zo5gjLFwHdGxdSRvRa60X9jzdl4azXlojU  
V30p38714V6ae+4nomRAImtxPr4wm2B5L+s9P0wThzV6rbPkw/Crm61hCZdrnzEe  
yAw10u3bhRmDh5vQzmVU2BgEJhZ0jkNyBP07fh+r3tnxn017ybpUdR46ZGafJ  
MWGJnJqts2B3fgtQinINRNCIMXDxQMvaxl t81ZDMcd1qky3lkKEB4bk=  
=4Wxr  
-----END PGP MESSAGE-----

**Hannes Federrath <federrath@inf.tu-dresden.de> NO...**

**General**

ID: 0x59B6FB01

Type: RSA Legacy

Size: 1024

Created: 18.08.1997

Expires: Never

Cipher: IDEA

Change Passphrase...

**Fingerprint**

skydive	hazardous	chairlift	inventive
peachy	determine	dreadful	October
surmount	bifocals	Burbank	direction
afflict	midsummer	offload	everyday

☐ Hexadecimal

**Trust Model**

Invalid ☐ Valid ☐ Untrusted ☐ Trusted ☐

☒ Implicit Trust

**PGPtools**

PGPkeys Encrypt Sign Encrypt & Sign Decrypt/Verify Wipe Wipe Free Space

## > Protection against observation?

### ⌘ New challenges:

- ⊠ Privacy in the Internet:
- ⊠ Protection against “Profiling” and commercial use of private data without consent.

### ⌘ Part of Privacy; here: confidentiality of traffic data

### ⌘ Encryption does not help against observation

- ⊠ Who is communicating with whom?

### ⌘ **Anonymity:**

- ⊠ The **sender** and/or **recipient** stay anonymous to each other.

### ⌘ **Unobservability:**

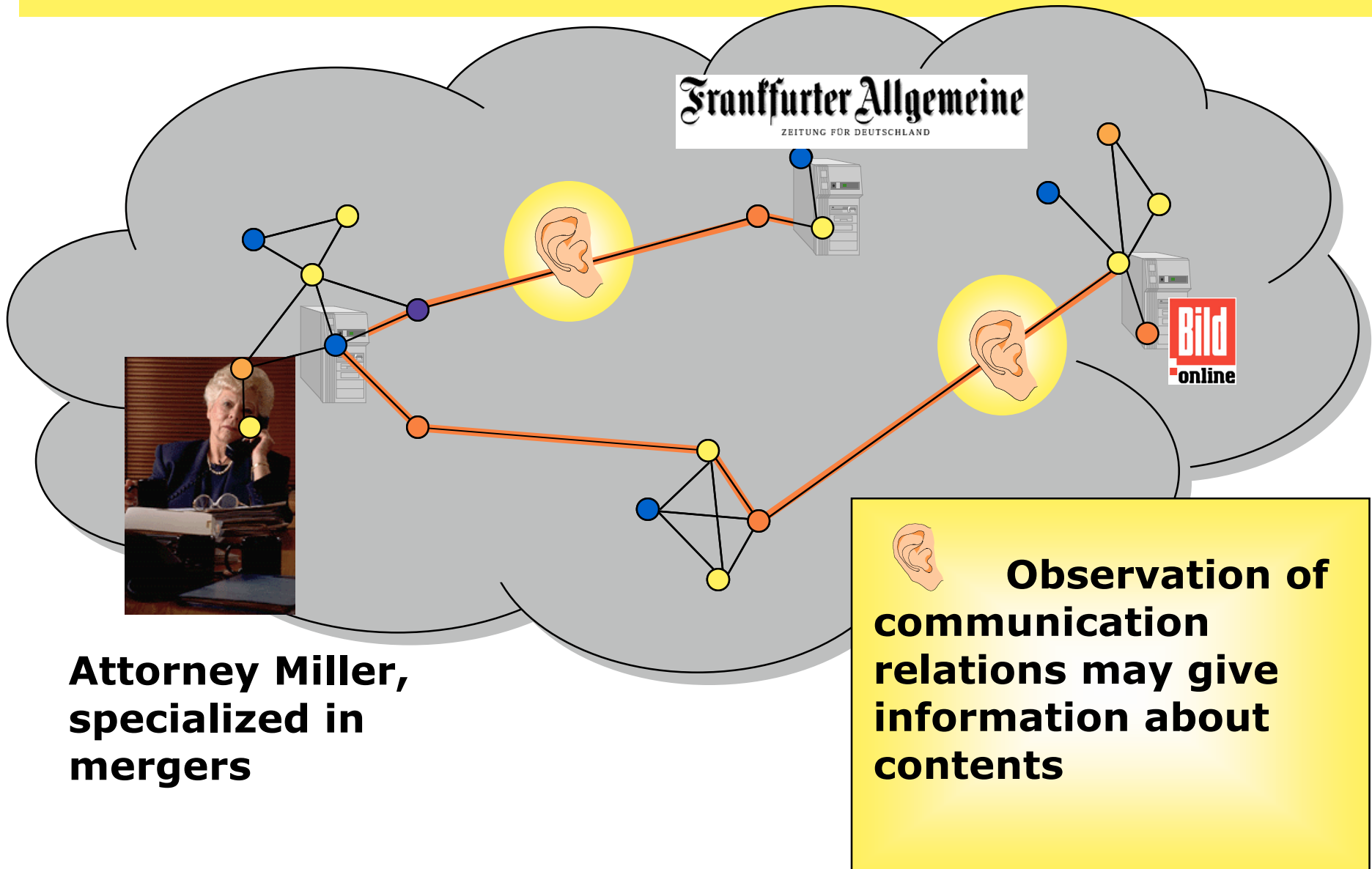
- ⊠ All parties (incl. network operators) cannot trace **communication relations**.
- ⊠ **Sending and/or receiving** of messages is unobservable

### ⌘ **Remarks:**

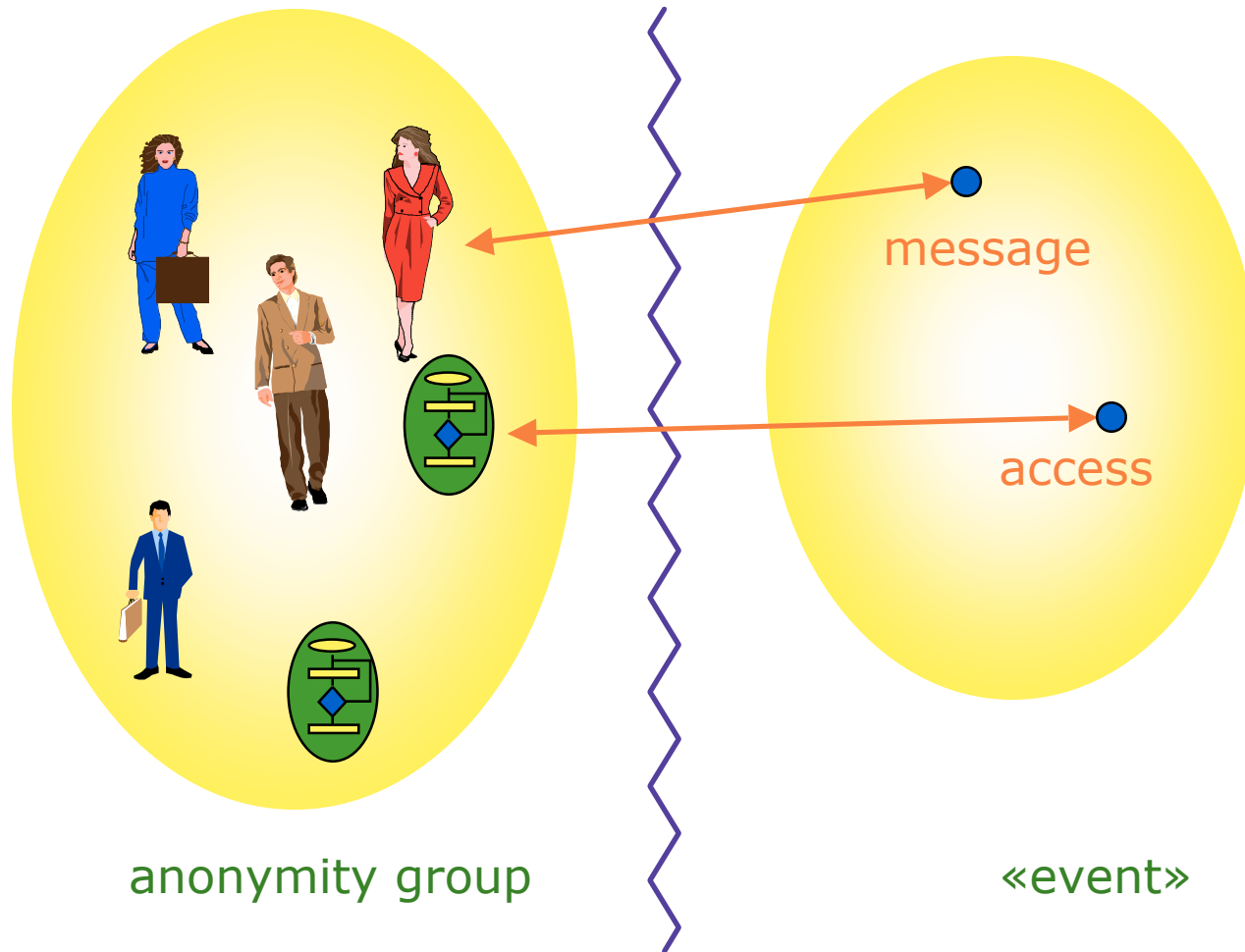
- ⊠ A single event caused by a single user cannot be anonymous or unobservable.
- ⊠ We need a group of users where all users behave similarly.



## > Why encryption is not enough



## > Anonymity and unobservability



Everybody can be the originator of an «event» with an equal likelihood

## > Our attacker model

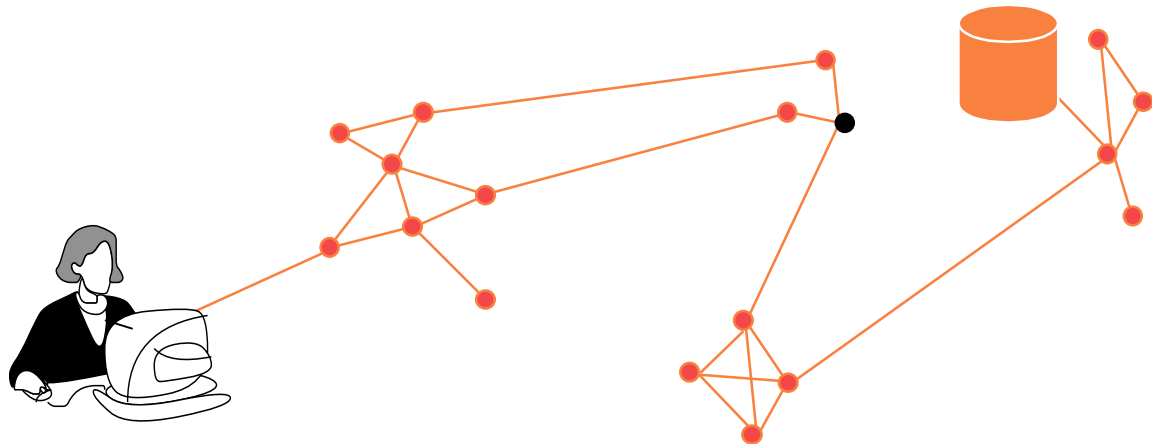
### ⌘ Attacker may:

- ⊠ observe all communication links,
- ⊠ send own messages,
- ⊠ operate anonymity services (all but one ...)
- ⊠ operate a server (web server)

### ⌘ Attacker cannot:

- ⊠ break into cryptographic systems,
- ⊠ attack the users personal machine,
- ⊠ has limited time and computing power

Assuming a very strong attacker is the best way to achieve real security.



# Existing systems for HTTP (real-time communication)

## ⌘ Simple Proxies (partly with filtering functions: Cookies, JavaScript, active content)

- ⊠ Anonymizer.com (Lance Cottrel)
- ⊠ Aixs.net
- ⊠ ProxyMate.com (Lucent Personal Web Assistant, Bell Labs)
- ⊠ Rewebber.com (Andreas Rieke, Thomas Demuth, FernUni Hagen)
- ⊠ Anon proxy (Hannes Federrath)
- ⊠ Each appropriate configured web server with proxy functions

## ⌘ Systems considering traffic analysis

- ⊠ Crowds (Mike Reiter, AT&T)
- ⊠ Onion-Routing (Naval Research Center)
- ⊠ Freedom (Ian Goldberg, Zero-Knowledge Inc.)
- ⊠ WebIncognito (Privada)
- ⊠ WebMixes (TU Dresden)

## > Simple Proxies

- ⌘ Server has no information about the real originator of request
- ⌘ **No protection against the operator**
- ⌘ **No protection against traffic analysis**

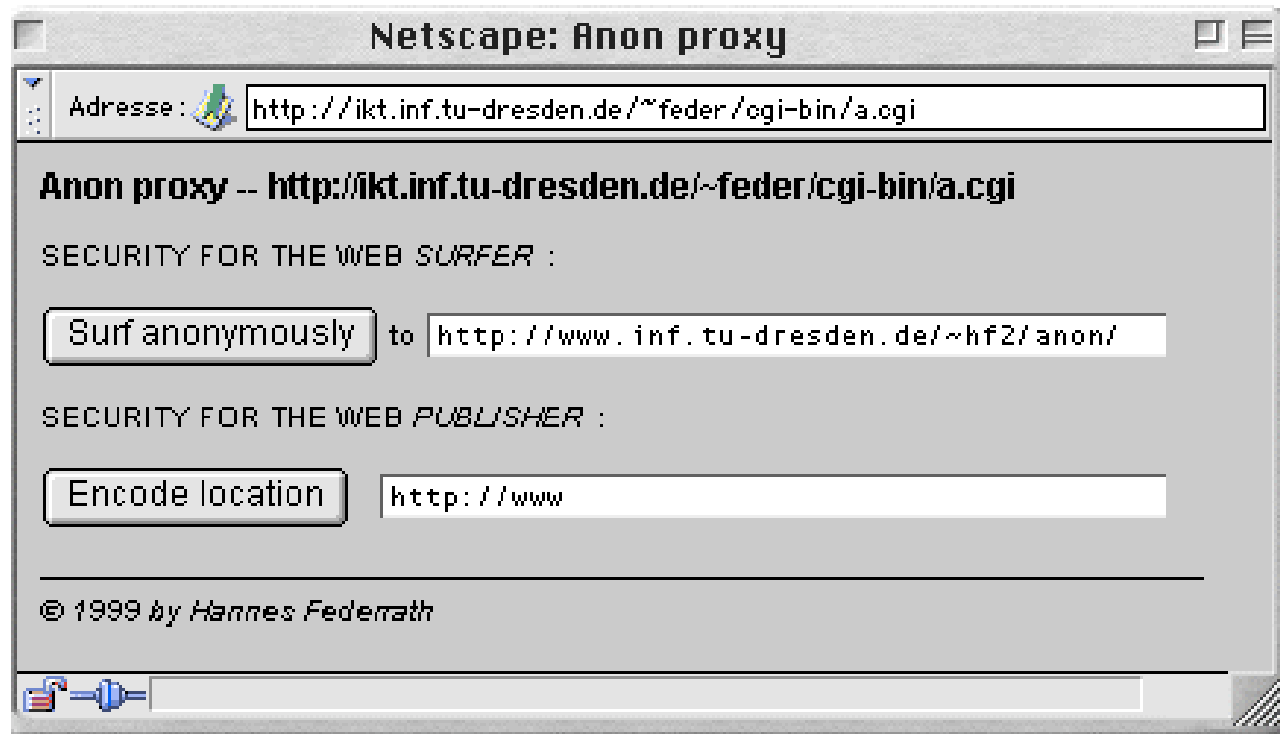
### ⌘ Principles for Web access:

#### 1. Form-based

- ⊗ Type in URL
- ⊗ Proxy gets the URL on behalf of user

#### 2. Change browser config

- ⊗ „use proxy“

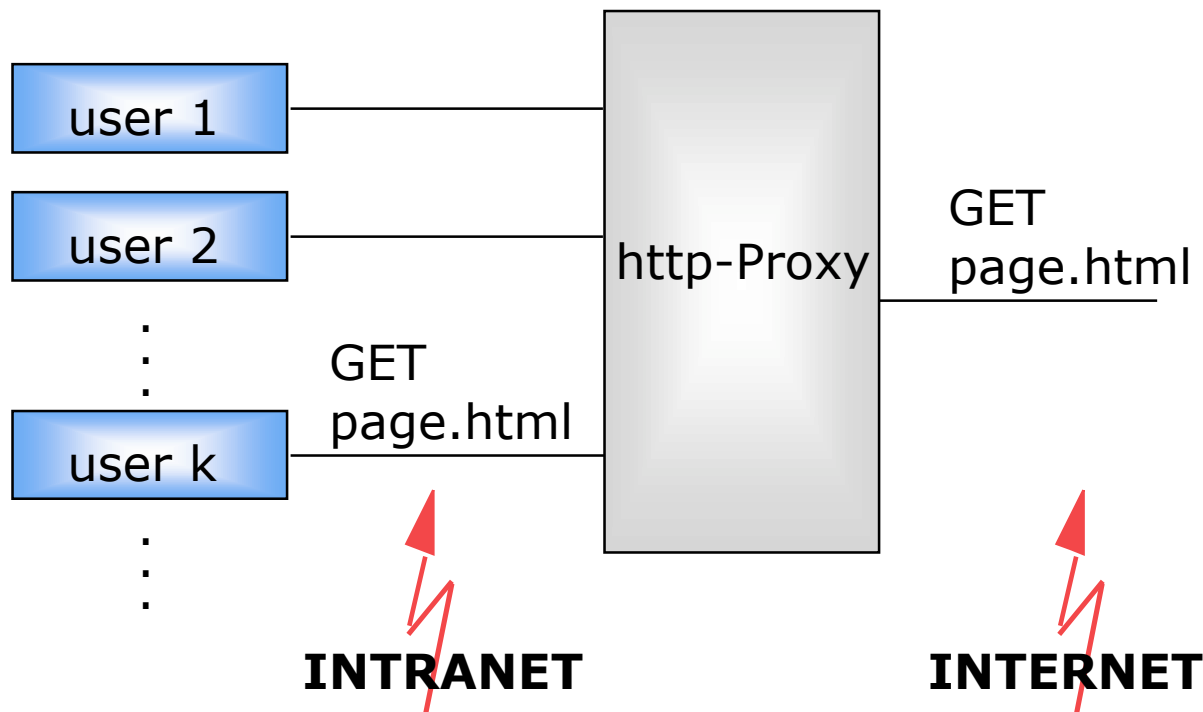


## >> Simple Proxies

⌘ Proxy gets to know all contents!!!

⌘ Observation is possible

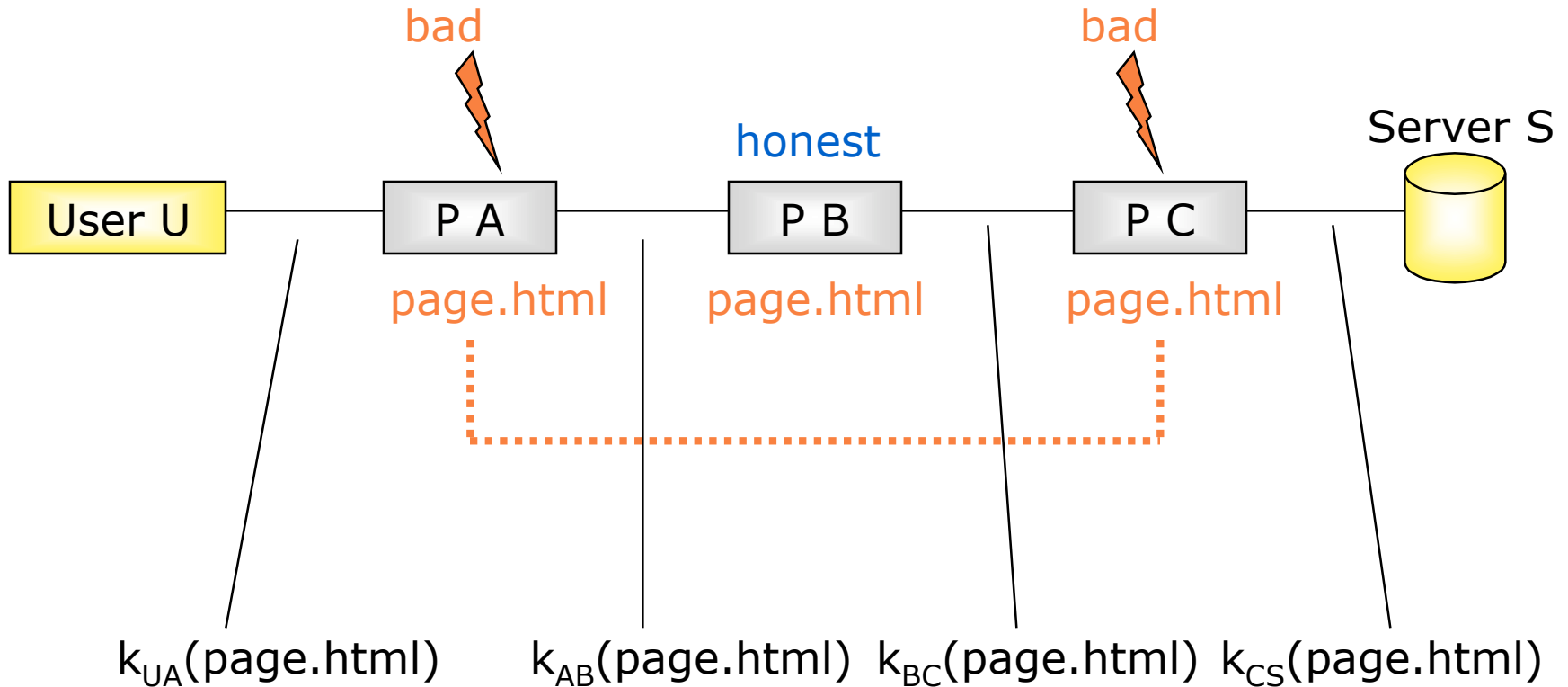
- ⊠ Timing correlation of incoming and outgoing requests
- ⊠ Correlation by message length and coding
- ⊠ Simple encryption between user and proxy is not sufficient because of the correlation of timing and length and it does not help against the operator



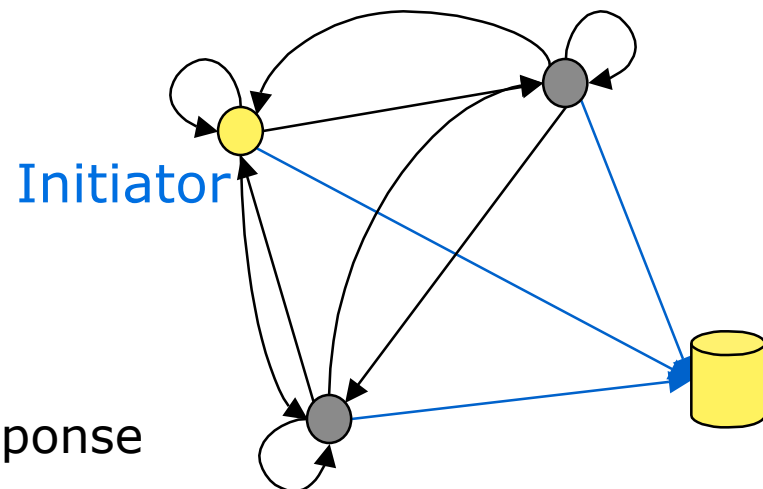


## > Cascading Simple Proxies

- ⌘ Link-to-link encryption between proxies
- ⌘ Does not help to avoid observation by operators



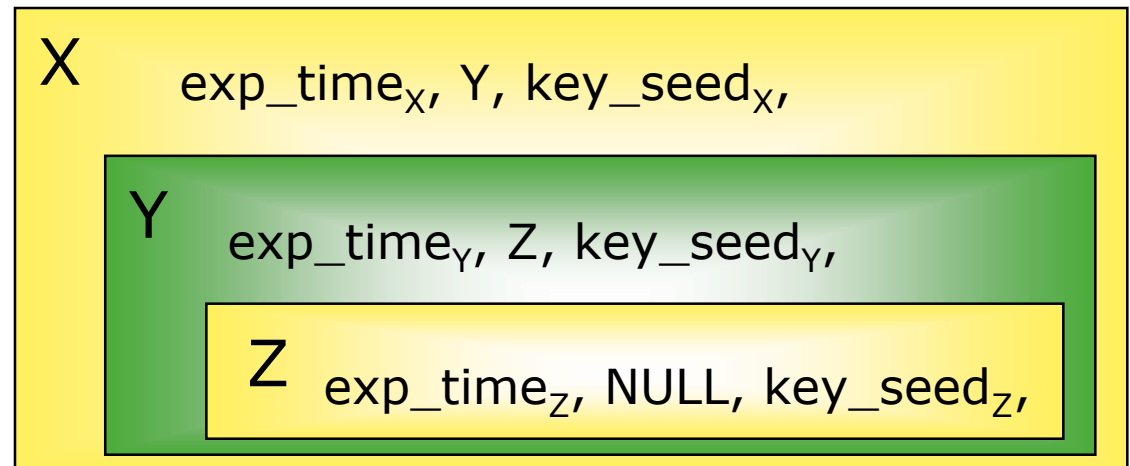
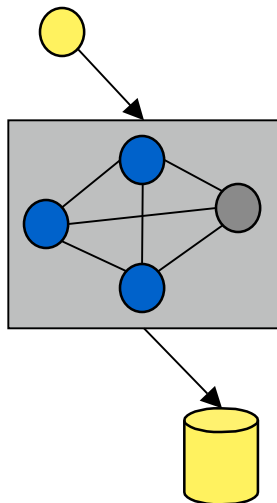
- ⌘ Each communication request is sent directly to the server with a probability of  $P$
- ⌘ Else the request is sent to another user (Jondo) of the crowd (with  $1-P$ )
- ⌘ Symmetric link-encryption between the users
  - ⊠ Avoid linkability
  - ⊠ However: timing coincidence
- ⌘ Embedded objects (images etc.) are requested by the last Jondo
  - ⊠ Suppress bursts of requests
- ⌘ Security goal:
  - ⊠ Every user can deny that he or she is the originator of a certain request
- ⌘ Problem:
  - ⊠ Jondos get to know about content of a request and response



# > Onion Routing

US Naval Research Center

- ⌘ Hiding of routing information in connection oriented communication relations
- ⌘ Nested public key encryption
- ⌘ Uses an expiration\_time field to reduce cost of replay detection
- ⌘ Dummy traffic between MIXes (Onion Routers)
- ⌘ First/Last-Hop-Attacks:
  - ⊠ Timing correlations
  - ⊠ Message length



⌘ Systems considering traffic analysis have to avoid all of the following possible attacks

**MIX** ☒ **Timing attacks:** Observe the duration of a communication by linking the possible endpoints of a communication and wait for a correlation between the creation and/or release event at all possible endpoints.

**MIX** ☒ **Message volume attacks:** Observe the amount of transmitted data (i.e. the message length) and correlate input and output.

**?** ☒ **Flooding attacks:** Each message can only be anonymous in a group of messages (batch). Under normal circumstances, each sender sends one message per batch. A good system has to avoid that the batch can be flooded by an attacker in order to separate a certain message.

**?** ☒ **Linking attacks:** Because of online/offline-periods of the users an attacker may create intersections of anonymity groups by observation over a long period.

⌘ At this time, no existing system withstands all attacks

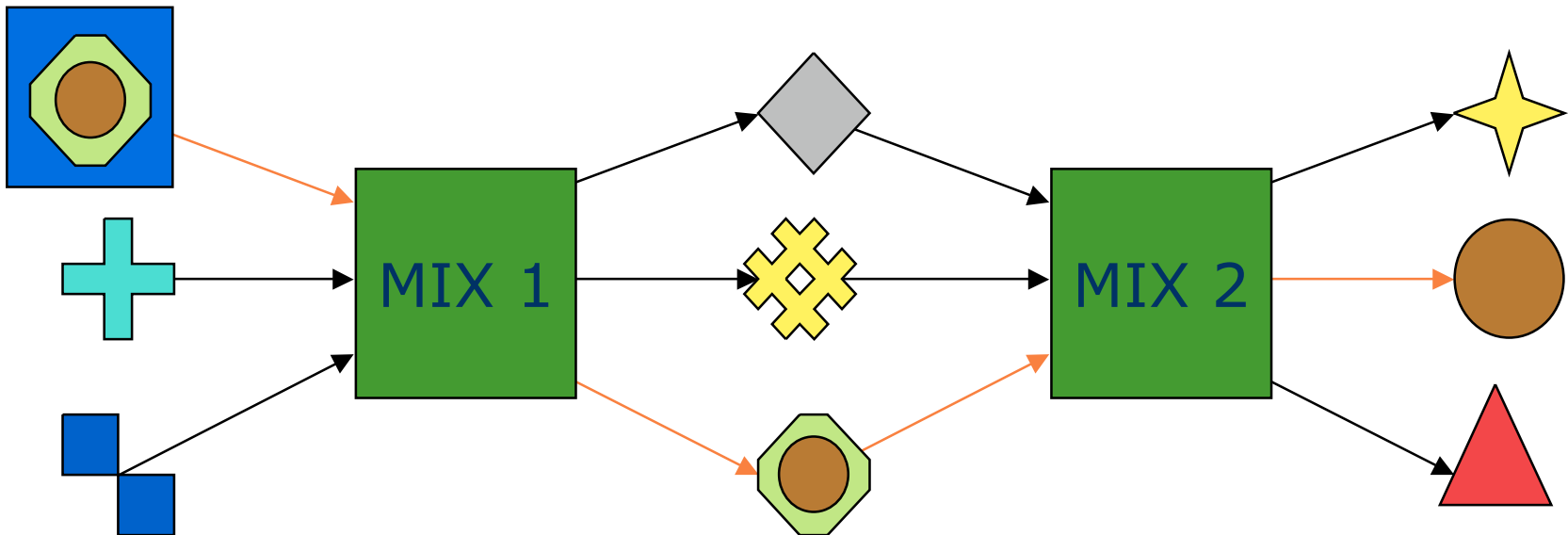
# Mixes (David Chaum, 1981)

## ⌘ Basic idea:

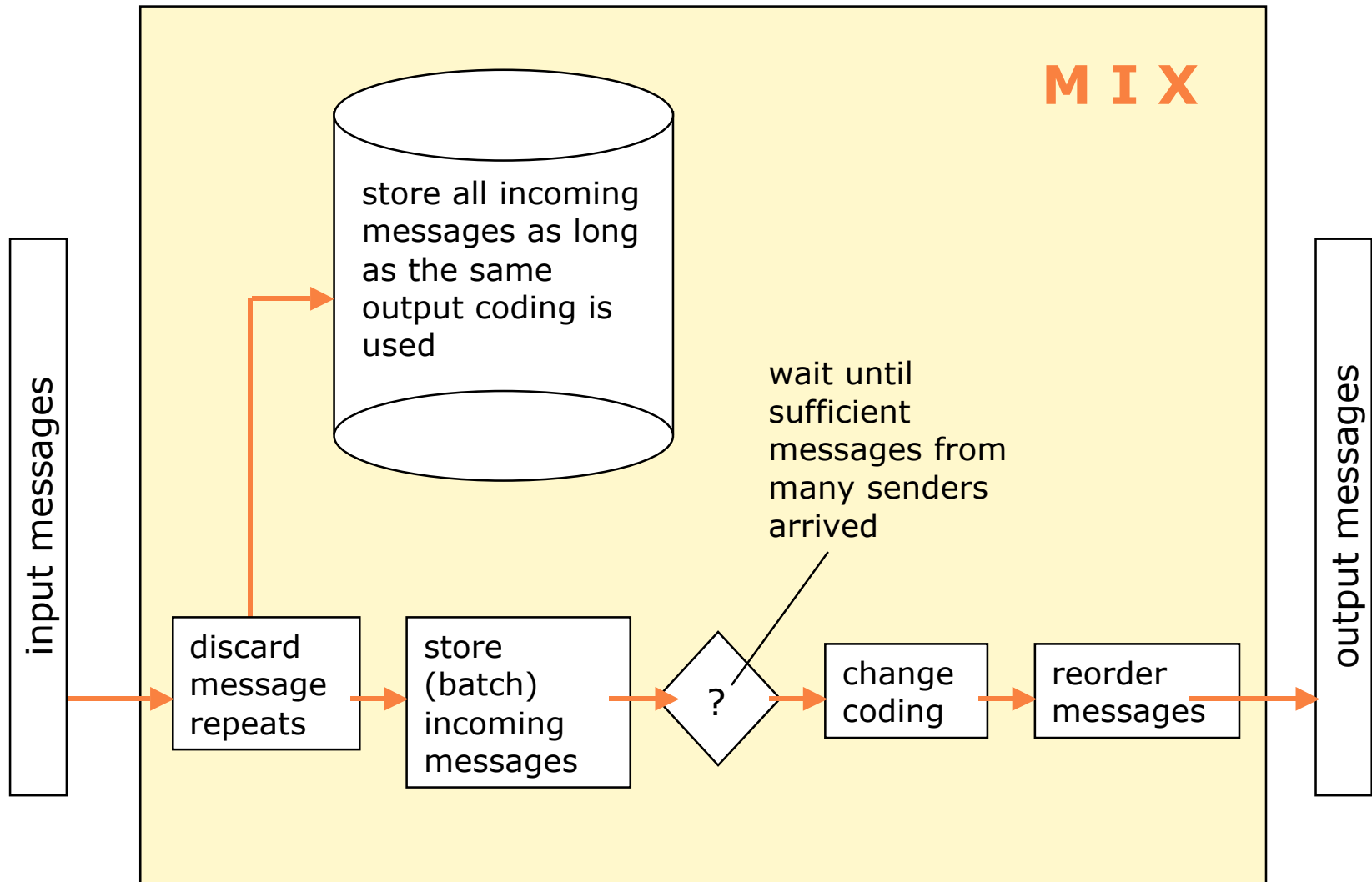
- ⊠ Sample messages in a batch, change their coding and forward them all at the same point of time but in a different order. All messages have the same length.
- ⊠ Use more than one Mix, operated by different operators.
- ⊠ At least one Mix should not be corrupt.

## ⌘ Then:

- ⊠ Perfect unlinkability of sender and recipient.



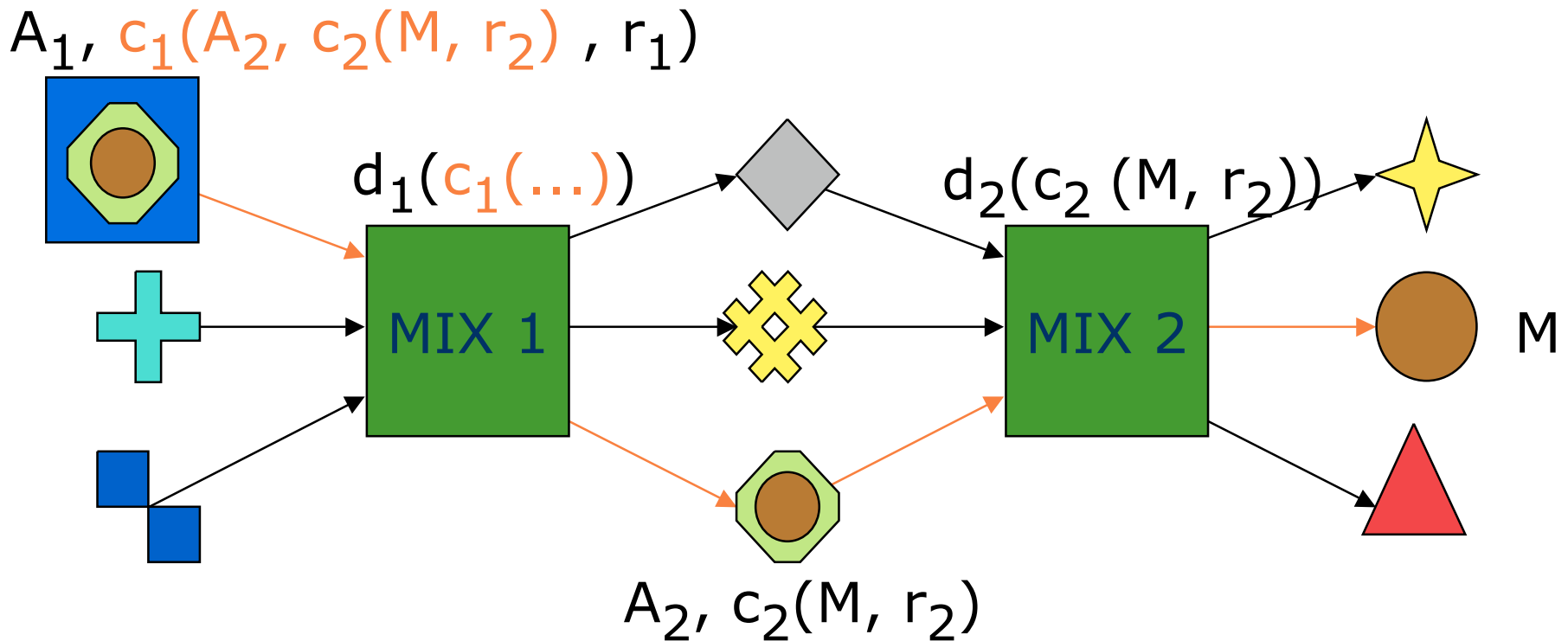
## > How a MIX works





# Mixes: some cryptography

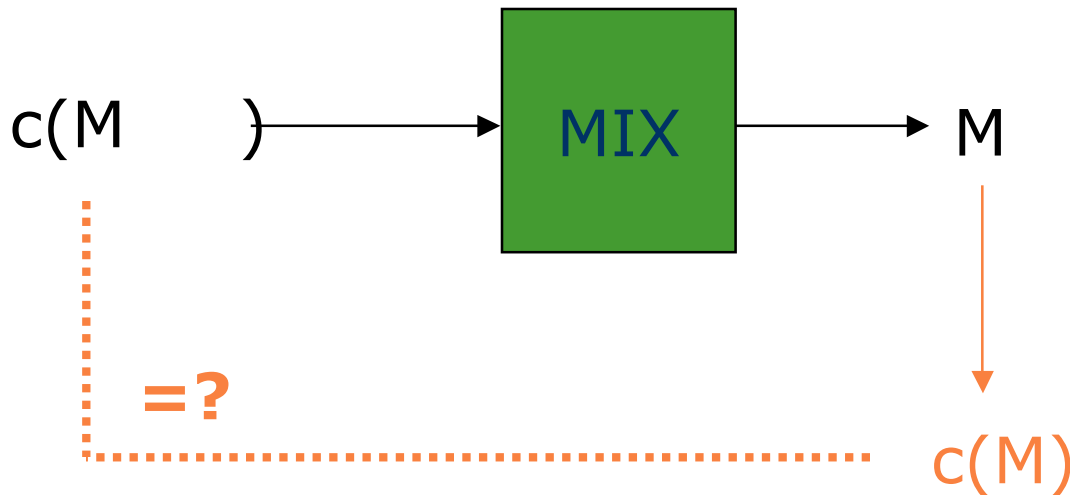
- ⊠ Use a public key cryptosystem:
- ⊠  $c_i(\dots)$  is an encrypted message for Mix  $i$  (everybody can encrypt messages for Mixes using this function)
- ⊠  $d_i(\dots)$  is the private function of Mix  $i$  to decrypt messages (only Mix  $i$  can decrypt his messages, nobody else)
- ⊠  $A_i$  is the address of Mix  $i$ ;  $r_i$  are random numbers (dropped by the Mix)
- ⊠  $M$  is the message for the recipient (including his address)



## > Mixes: Why do we need random numbers?

⌘ If no random numbers  $r$  used:

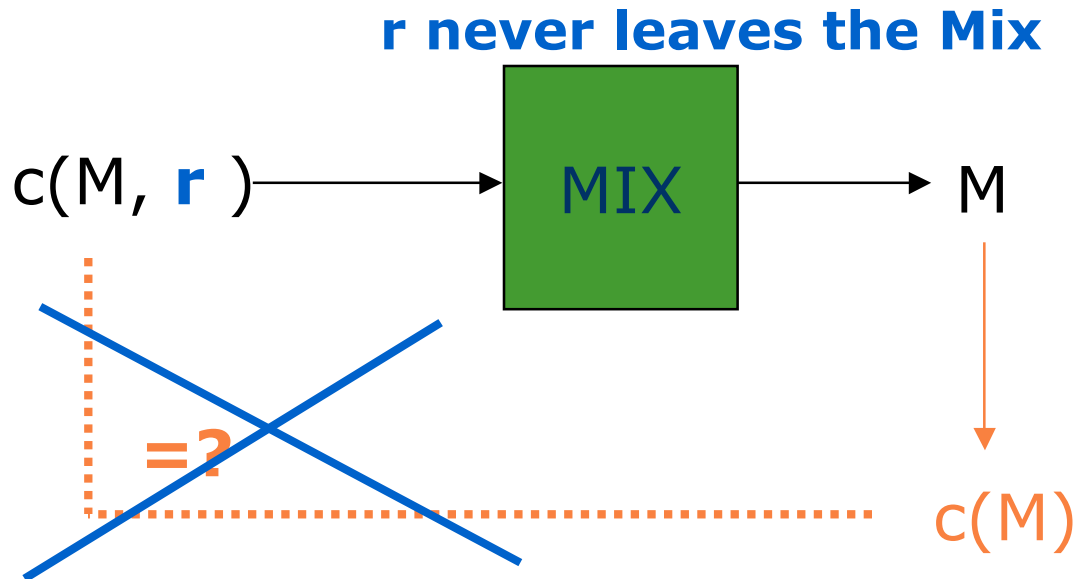
- ⊠ Everyone can encrypt the output messages of a Mix because  $c(\dots)$  is public
- ⊠ Compare results with all incoming messages
- ⊠ Need a indeterministic encryption scheme (or use random numbers)



## >> Mixes: Why do we need random numbers?

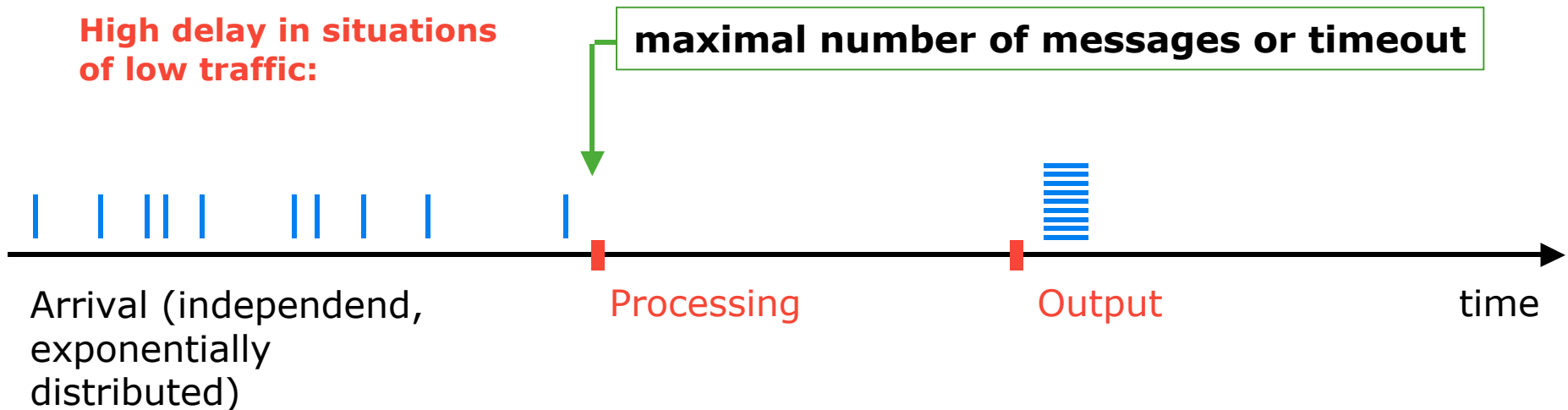
⌘ If no random numbers  $r$  used:

- ⊠ Everyone can encrypt the output messages of a Mix because  $c(\dots)$  is public
- ⊠ Compare results with all incoming messages
- ⊠ Need a **indeterministic encryption scheme** (or use random numbers)



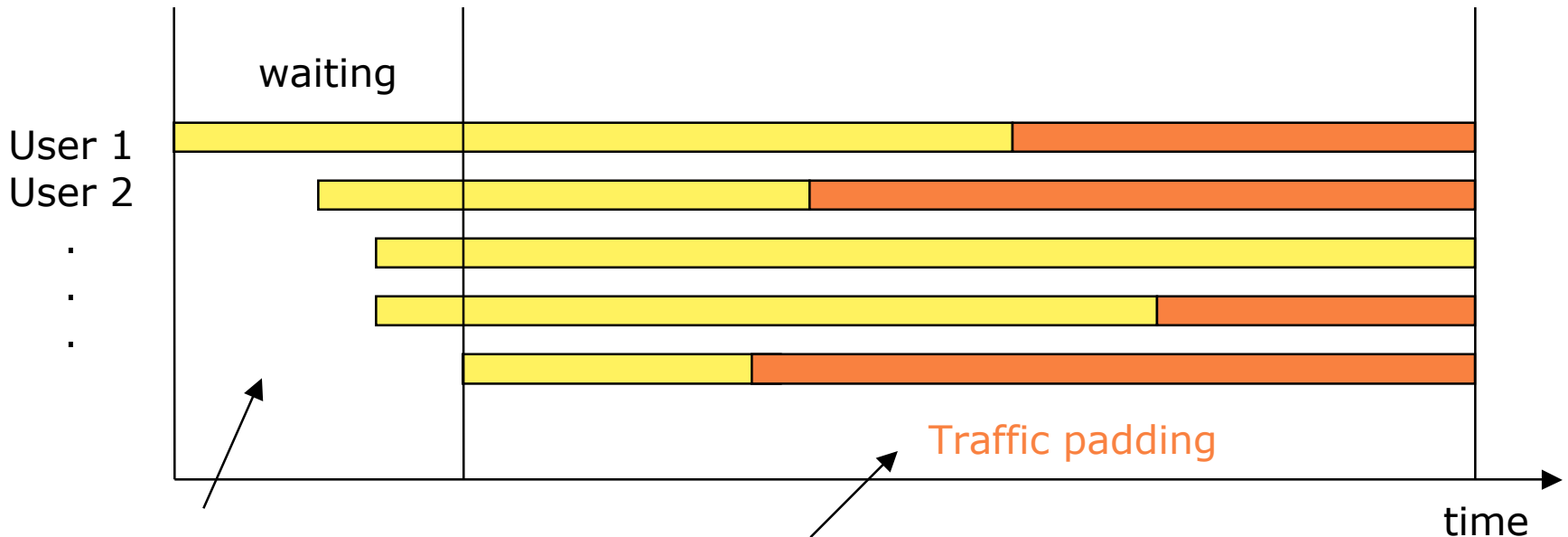
# The problem of anonymous real-time communication

- ⌘ Plain Mixes are good for non-real-time communication: E-Mail
- ⌘ But not sufficient for real-time communication: Web, Ftp, Internet Phone
  - ⊗ Sampling of messages means high delay, because a Mix is waits for (another) messages the most of time.
  - ⊗ Message lengths vary in a very large interval or no support of connection oriented services
- ⌘ We need a few improvements



## > Traffic padding

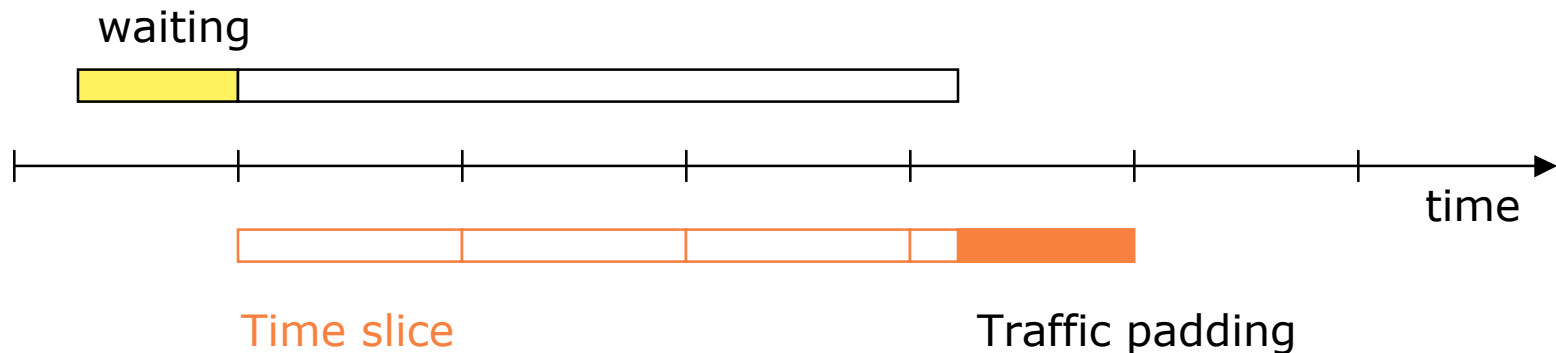
- ⌘ Hide from the attacker, when a certain communication ends
- ⌘ But: nobody knows, when the last user wants to end his communication



1. Users have to wait until enough users want to communicate (creation of the anonymity group)  
Example: 5 users
2. End of communication but users have to send random data until the last user has finished his connection
3. However: Nobody knows when the last user wants to end his communication – because nobody can distinguish real traffic from traffic padding

## > Time slices and traffic padding

- ⌘ Chopping of long communications into small pieces (connections or packet size)
  - ⊠ Unobservability in the group of all processed messages at one time slice
  - ⊠ Long communications consist of more than one time slice
  - ⊠ No linkability of time slices



## > Dummy traffic

- ⌘ Increase the amount of traffic in situations of low traffic



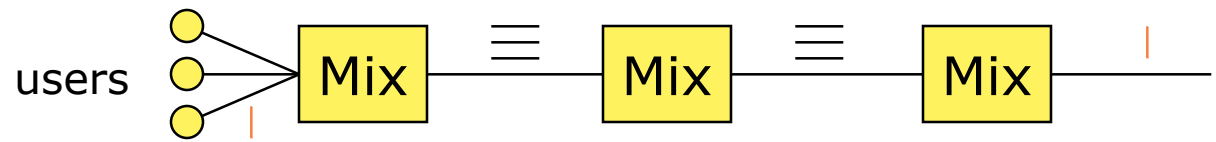
- ⌘ Sometimes the number of users is not sufficient to fill the batch.
- ⌘ This can happen in times of low traffic.
- ⌘ In that case,
  - ⊗ either the user has to wait until enough messages arrive (leads to likely high delay)
  - ⊗ or accepts, that he cannot remain anonymous,
  - ⊗ or other users send dummy traffic.
- ⌘ **Def.: Dummy traffic.** A user sends messages at all times. When he doesn't want to send messages, he sends random numbers. Nobody can make a distinction between real encrypted messages and the random numbers.

## >> Dummy traffic

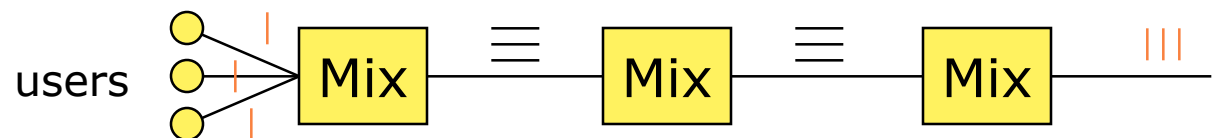
- ⌘ Increase the amount of traffic in situations of low traffic



- ⌘ Dummy traffic only between Mixes is not sufficient



- ⌘ Dummy traffic has to be generated by the users





## > Remaining attacks

⌘ Systems considering traffic analysis have to avoid all of the following possible attacks:

MIX

⊗ Timing attacks

⊗ Message volume attacks

MIX



?

⊗ **Flooding attacks:** Each message can only be anonymous in a group of messages (batch). Under normal circumstances, each sender sends one message per batch. Avoid that the batch can be flooded by an attacker in order to separate a certain message.

?

⊗ **Linking attacks:** Because of the online/offline-periods of the users an attacker may create intersections of anonymity groups by observation over a long period.

## > The Problem of flooding Mixes

- ⌘ Batch size  $n$
- ⌘ Flooding: Attacker tries to flood the Mix with his own  $(n-1)$  messages, except one message that he wants to observe
- ⌘ Attacker knows  $(n-1)$  outgoing messages. The only unknown message is the observed message.
- ⌘ In that case, the sender and recipient are uncovered.
  
- ⌘ Solution (first hack):
  - ⊠ All incoming messages need a ticket to be processed by a Mix.
  - ⊠ Now, the attacker needs help of the  $(n-1)$  other users. However, we assume the users will never harm themselves.
  - ⊠ Very similar to an anonymous payment system.
  - ⊠ Digital coin not traceable neither by the Mix nor the Bank.
  - ⊠ Additionally, solves the problem of payment for anonymity systems

## > The Problem of long-term observation of users

### ⌘ Supposed:

- ⊠ A user shows a nearly constant online-offline behavior (from 8 - 10 PM online everyday)
- ⊠ Requests certain contents (web pages, his e-mail account) during this time
- ⊠ A lot of other people are also online and use the anonymity service

⌘ Attacker observes all communication links and servers, except the anonymity service over a long time period.

⌘ Long-term observation leads to intersections of anonymity groups and uncovers the users behavior.

⌘ How long it takes that an attacker to link the user actions with a high probability depends on the size of the anonymity group and its behavior.

⌘ Simulation of that attack

⌘ No good solution at this time to defend this attack.

# > Web Mixes: Anonymous real-time communication

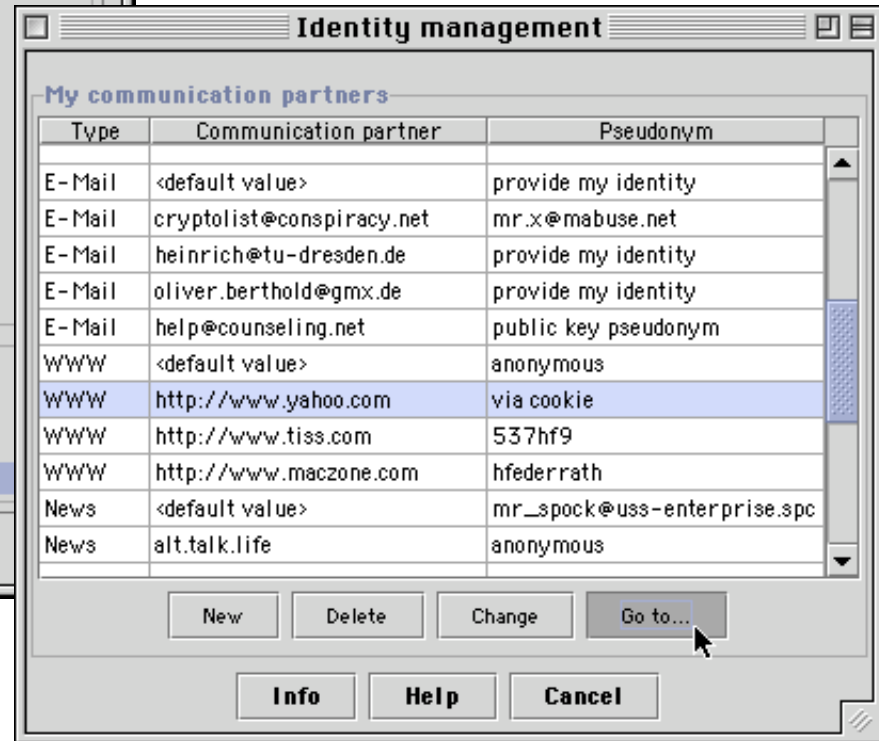
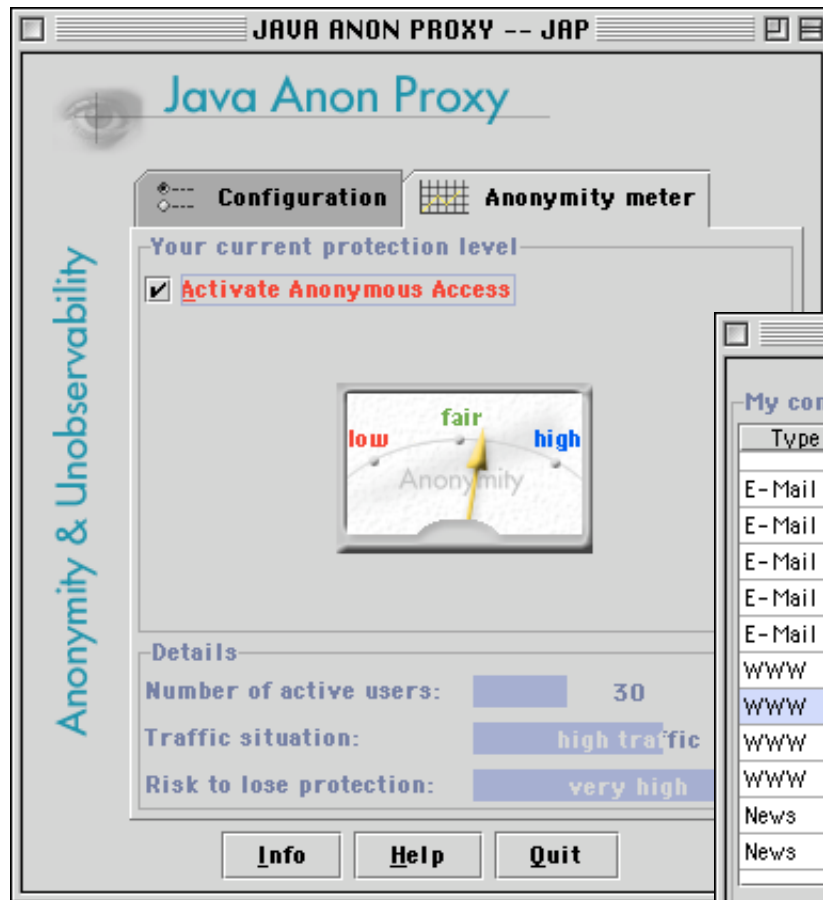
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- ⌘ Anonymous and unobservable transport system
  - ⊠ Mix-based proxies with additional functions to provide real-time communication
  - ⊠ Should withstand strong (big brother) attacks
- ⌘ Information service (impossible to operate a perfect Anon system)
  - ⊠ Current level of protection (Anonymity level)
  - ⊠ Trade-off between performance and protection should be decided by the user
- ⌘ Open source, as soon as core functions have been completely implemented
  - ⊠ Client software: Java (platform independent)
  - ⊠ Server software: C/C++ (Win/NT, Linux/Unix)
- ⌘ Technical and jurisdictional knowledge to serve legal issues
- ⌘ Test application:
  - ⊠ anonymous drug counseling site, supervised by an counselor, but without revealing identities

> Client software

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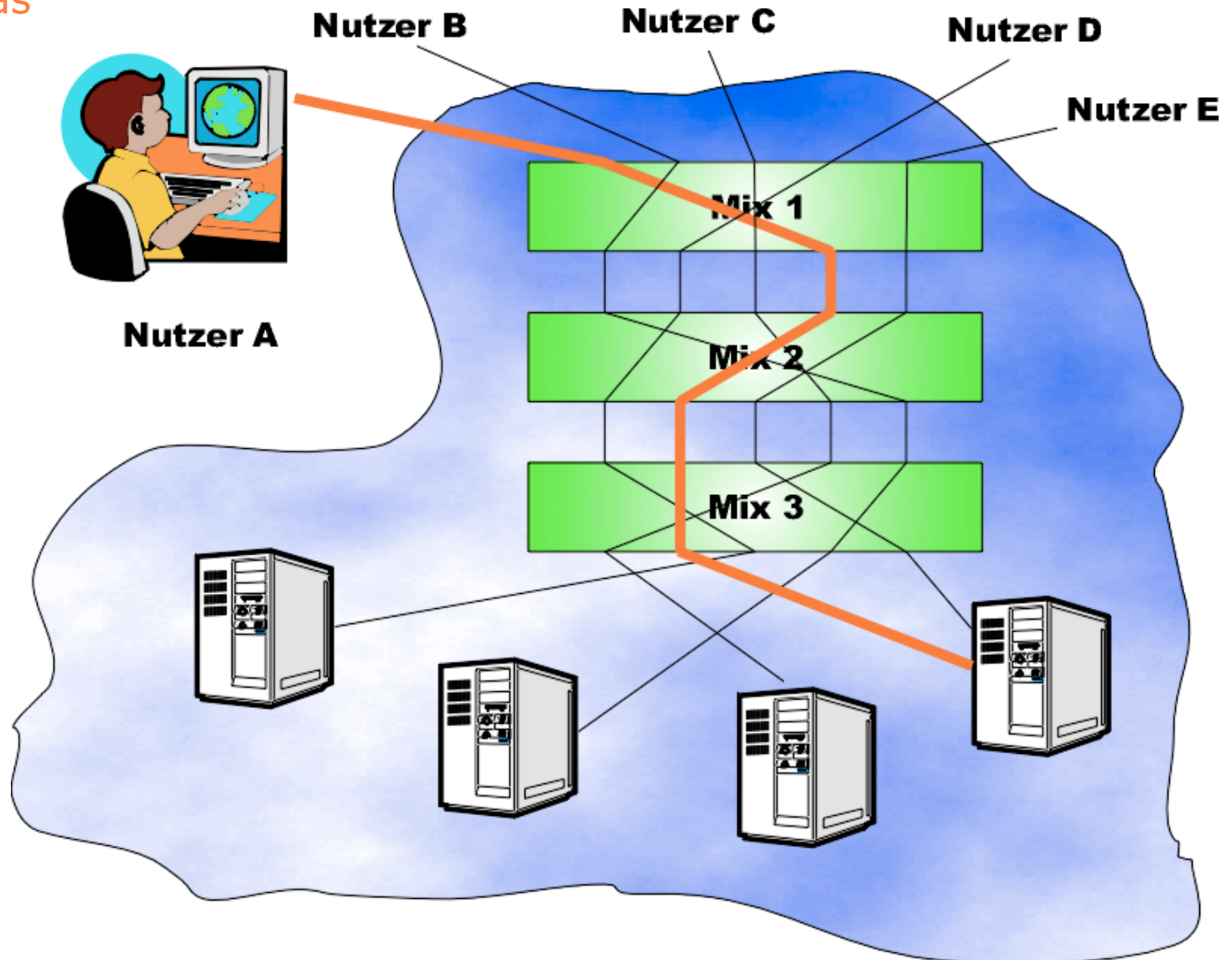
[JAP.inf.tu-dresden.de](http://JAP.inf.tu-dresden.de)



## > How does it work?

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- ⌘ JAP acts as a local proxy on the local machine

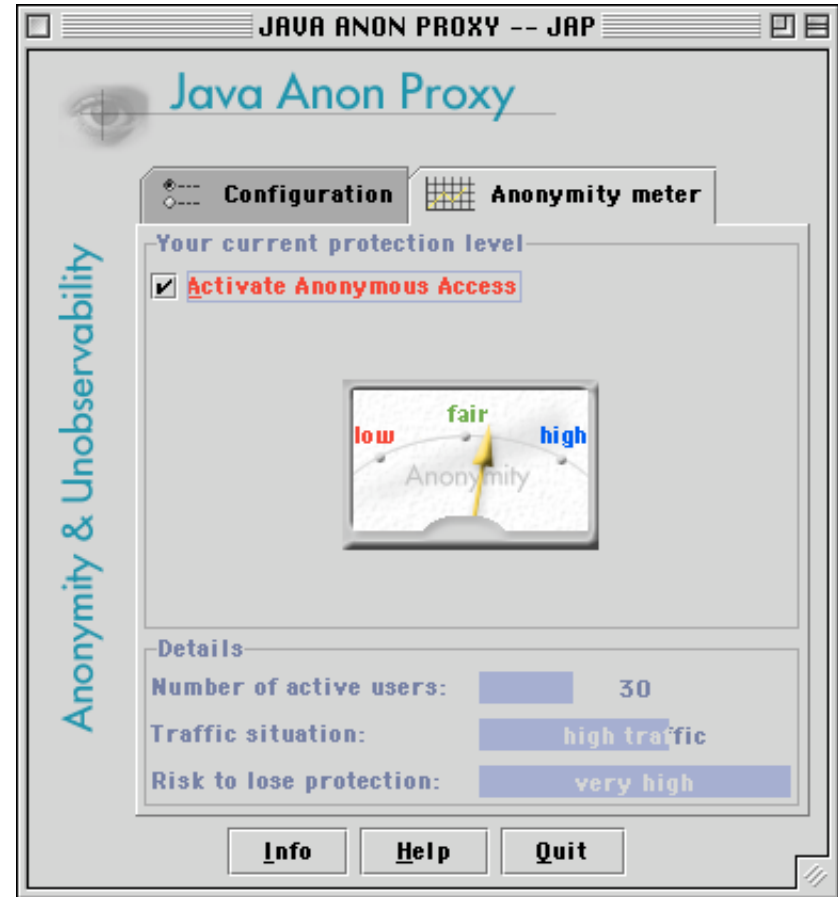


# Some practical experiences

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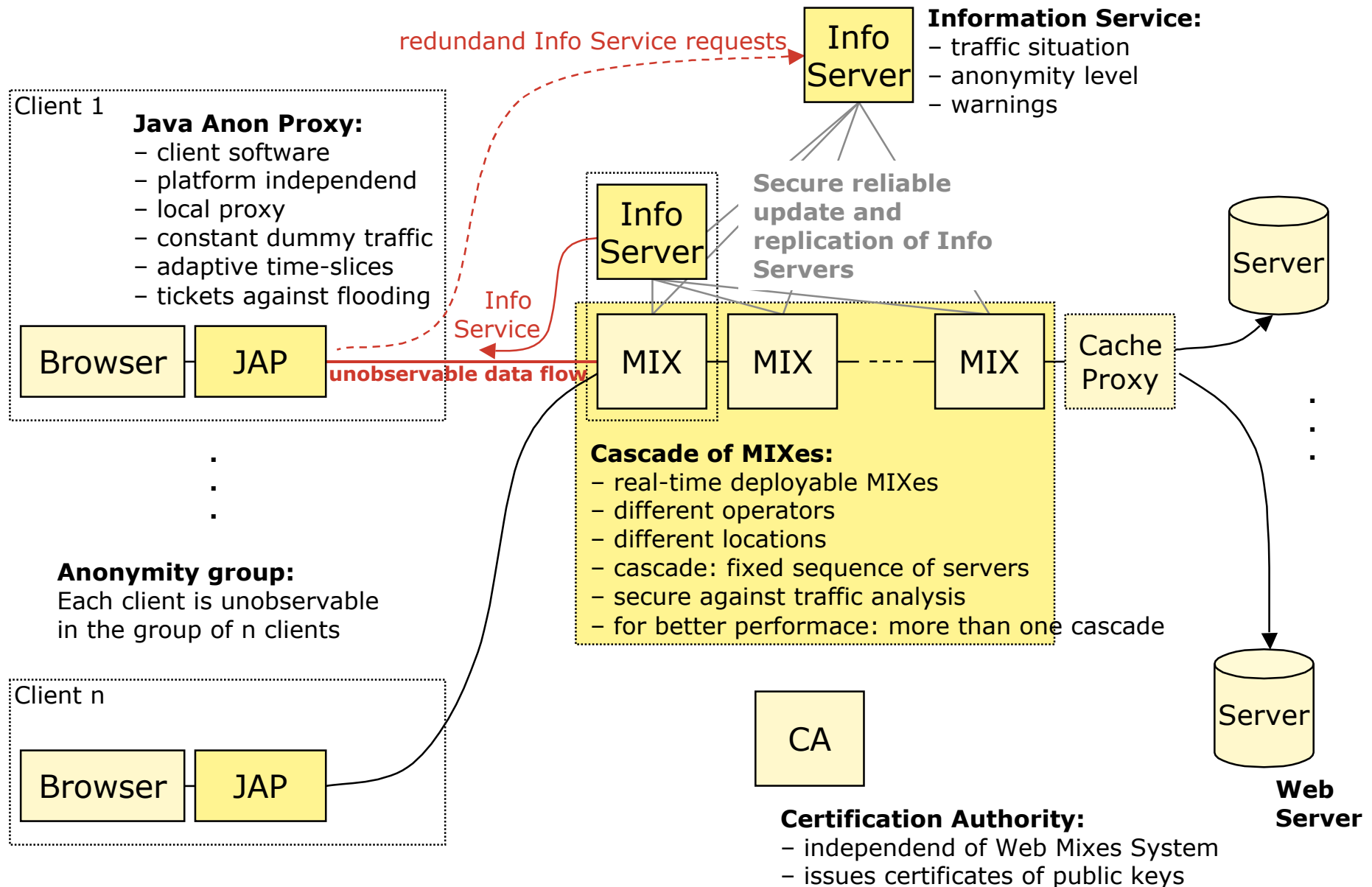
[JAP.inf.tu-dresden.de](http://JAP.inf.tu-dresden.de)

- ⌘ First test version has been launched in October 2000
- ⌘ Full service has been running since February 2001
- ⌘ Hybrid encryption system of 128 bit encryption by AES (Rijndael) and RSA/1024 bit public key encryption
- ⌘ 3 mix casades are running
- ⌘ Busy hour: 500 users at the same time are online
- ⌘ about 5000 – 8000 users
- ⌘ about 120 gigabyte troughput per week



# > Architecture of Web Mixes

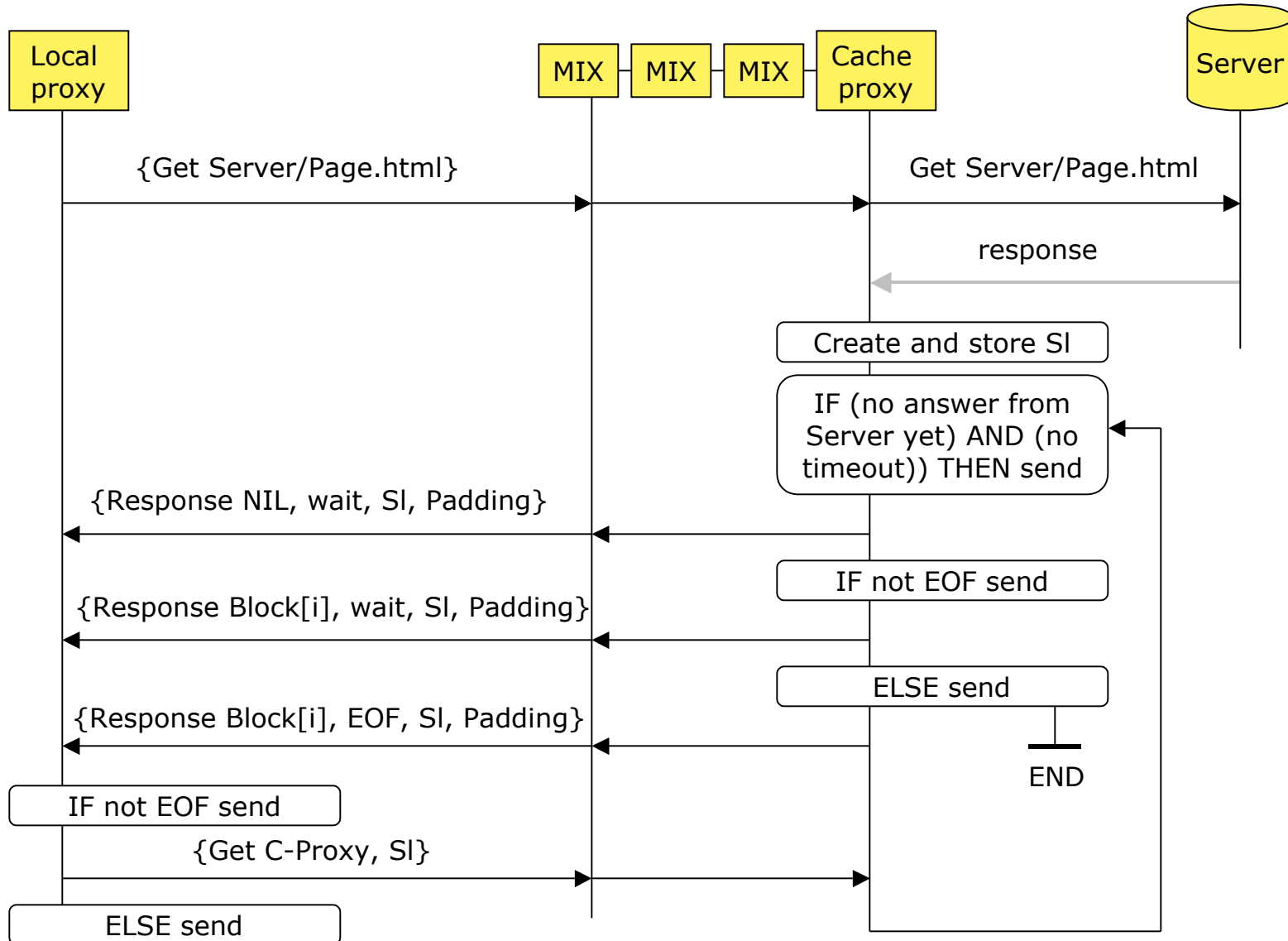
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# > Time Slice protocol

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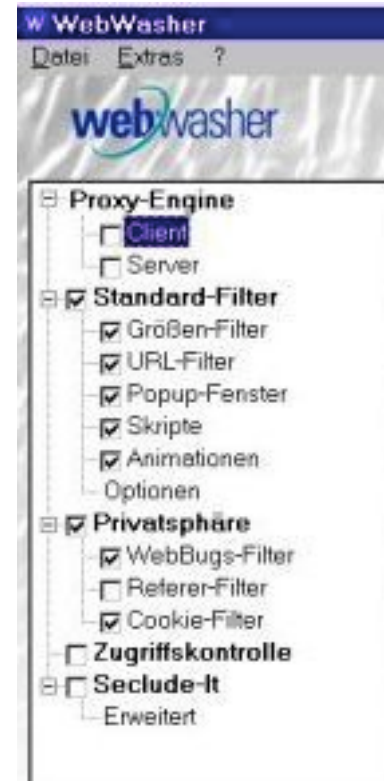
## > Some remarks about active content

### ⌘ Deactivate Cookies in your browser

- ⊠ Web server can track all activities of a user
- ⊠ Additional filter software is very useful
  - ⊕ <http://www.webwasher.com/>
  - ⊕ <http://www.junkbusters.com/ijb.html>
- ⊠ Filter additional "bugs" that reveal your behavior
- ⊠ Example: very small (1x1) transparent pictures on a website

### ⌘ Deactivate all sorts of active content in your browser

- ⊠ Java, JavaScript, ActiveX
- ⊠ IP-Address can be observed by an attacker
- ⊠ Unauthorized access to hard drive by ActiveX components



## > Concluding remarks

- ⌘ Anonymity and unobservability in the Internet is hard to realize.
- ⌘ All commercial systems like Anonymizer, Freedom etc. suppose a weaker attacker model. They base their model on the assumption, that the strong attacks are not realistic in the Internet.
- ⌘ In 95 or more percent of observation this assumption may be right, but not in the remaining 5 or less percent. Let's give an example of what we mean:
  - ✉ Assuming that an encryption tool sufficiently encrypts 99 of 100 messages, but in one case the message is sent in clear text. – Nobody will rely on that tool...
- ⌘ That is exactly the situation using one of the existing systems.
- ⌘ However, in some cases (or to defend some attacks) we do presently not know how a secure system has to be built.

# > Political and social context

## ⌘ Legal enforcement of communications

### ⊠ German Telekommunikationsüberwachungsverordnung (TKÜV)

⊕ [http://www.bmwi.de/Homepage/download/telekommunikation\\_post/TKUEV-Entwurf.pdf](http://www.bmwi.de/Homepage/download/telekommunikation_post/TKUEV-Entwurf.pdf)

### ⊠ European Cybercrime Convention

⊕ <http://conventions.coe.int/treaty/en/projets/cybercrime.htm>

## ⌘ Privacy laws

### ⊠ German (new) Bundesdatenschutzgesetz (BDSG)

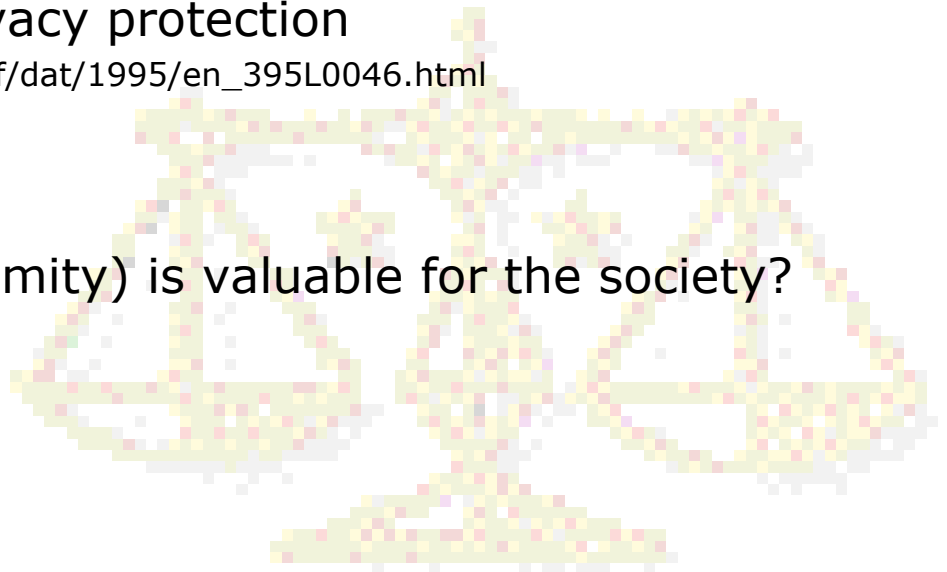
⊕ [http://www.bfd.bund.de/information/bdsg\\_hinweis.html](http://www.bfd.bund.de/information/bdsg_hinweis.html)

### ⊠ European directive on privacy protection

⊕ [http://europa.eu.int/eur-lex/en/lif/dat/1995/en\\_395L0046.html](http://europa.eu.int/eur-lex/en/lif/dat/1995/en_395L0046.html)

## ⌘ Open question

### ⊠ How much privacy (anonymity) is valuable for the society?



# >>> Privacy and Anonymity

**Anonymous communication secure against traffic analysis**

## INFORMATION ONLINE ?

<http://www.inf.tu-dresden.de/~hf2/anon/>

- ⊕ Demonstrations
- ⊕ Downloads
- ⊕ Links