

Computer Security (COM-301)

Privacy

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Goal of this lecture

Understanding:

- Privacy is not solely an individual-oriented problem. It is crucial for democratic societies
- There are different conceptions of privacy depending on the adversary model
- Depending on the adversary model one relies of different Privacy Enhancing Technologies: different protection degree
- Privacy requires to protect information beyond content: The need to protect meta-data

The context: Availability of data

Intelligent data-based applications

Recommendation systems

Movies (Netflix)

Products (Amazon)

Friends (Social networks)

Music (Spotify, iTunes)

Location based services

Friend finders

Maps

Points of interest

Health monitoring

Children/Elderly trackers

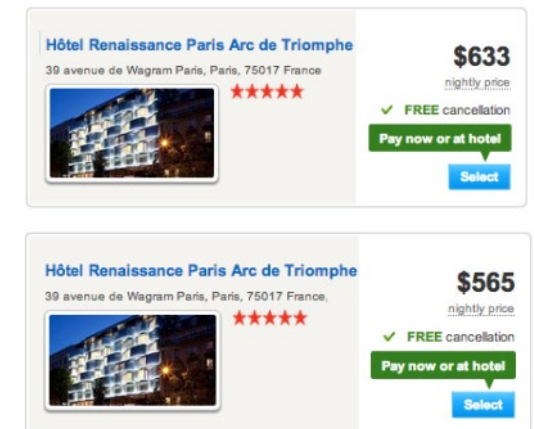
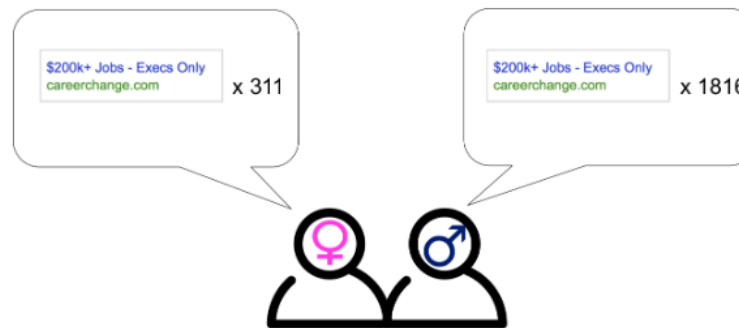
Smart metering

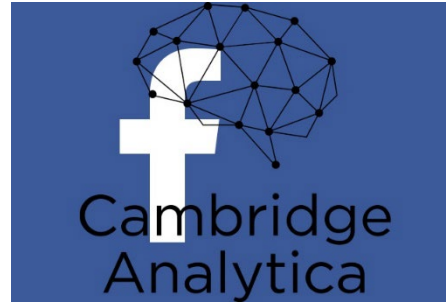
Intelligent buildings

Individual applications are legitimate



Together they become a cheap
SURVEILLANCE INFRASTRUCTURE





100K users installed CA Facebook App

enabled **COLLECTING PERSONAL DATA** of 87+ million

public profile, page likes, birthday and current city

creation of **PROFILES** of the subjects of the data

TARGETED ADVERTISEMENTS influenced the US elections

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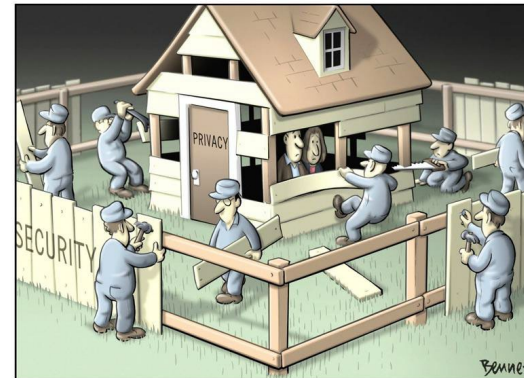
Intelligent buildings

Individual applications are legitimate



Together they become a cheap
SURVEILLANCE INFRASTRUCTURE

We need privacy!



**But what about
security!!?!?!?!?**

Privacy **IS** a security property

For individuals

protection against profiling and manipulation.
protection against crime / identity theft

For companies

protection of trade secrets, business strategy, internal operations, access to patents

For governments / military

protection of national secrets, confidentiality of law enforcement investigations, diplomatic activities,
political negotiations

Privacy IS a security property

INFRASTRUCTURE IS SHARED

Individuals, Industry, and Governments use the same applications

*Denying privacy to some is denying
privacy to all!!*



Directly

(Cloud-based services, Industry 4.0,
Blockchain)



Indirectly

(employers are users)

and Privacy is important for society



Daniel Solove,
Prof. of Law

“Part of what makes a society a good place in which to live is the extent to which it allows people freedom from the intrusiveness of others. **A society without privacy protection would be suffocation**”

Not so much Orwell’s “Big Brother” as Kafka’s “The Trial”:

“...a bureaucracy with inscrutable purposes that uses people’s information to make important decisions about them, yet denies the people the ability to participate in how their information is used”

“The problems captured by the Kafka metaphor are of a different sort than the problems caused by surveillance. They often do not result in inhibition or chilling. Instead, they are problems of information processing—the storage, use, or analysis of data—rather than information collection.”

“...not only frustrate the individual by creating a sense of helplessness and powerlessness, but they also affect social structure by altering the kind of relationships people have with the institutions that make important decisions about their lives.”



MAY
BECOME

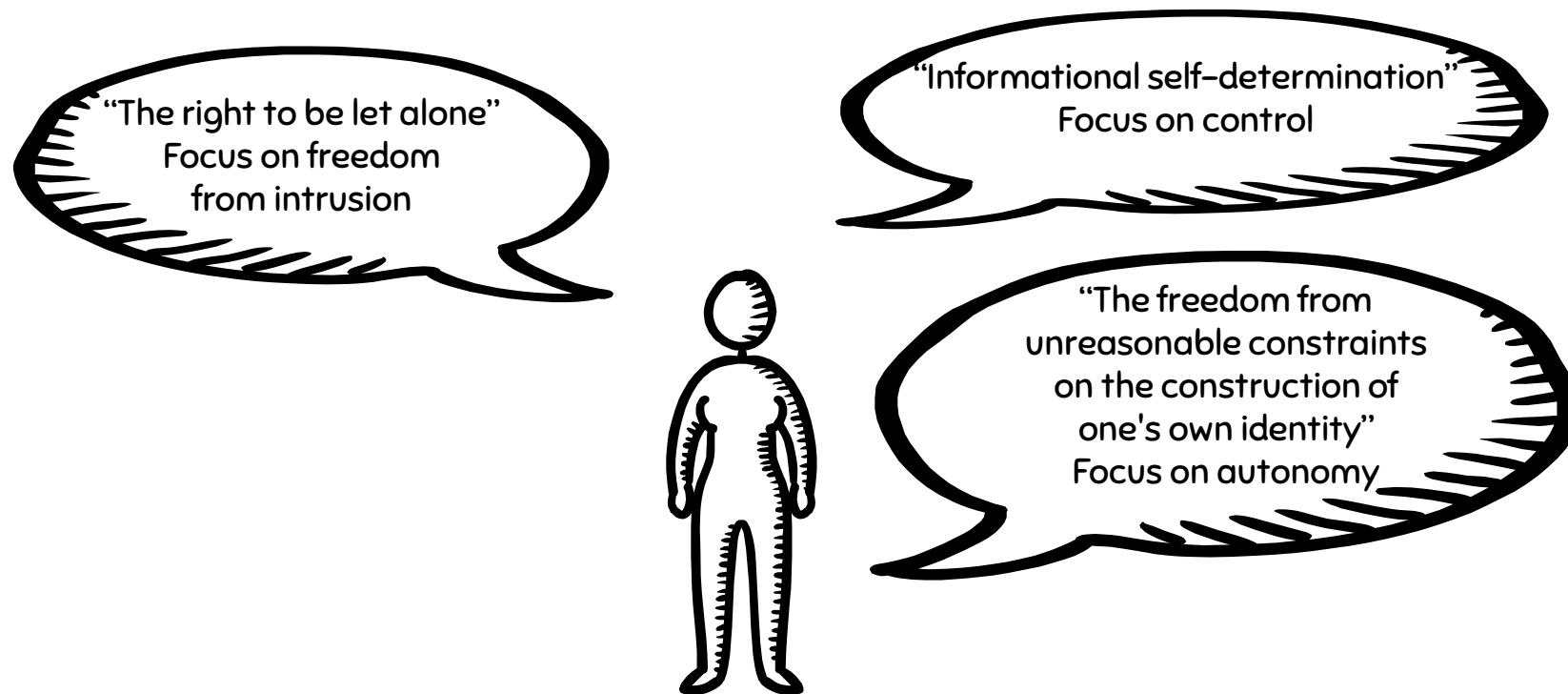


ONE RING TO RULE THEM ALL

What is privacy

Abstract and subjective concept, hard to define

Dependent on cultural issues, study discipline, stakeholder, context



What is privacy in Privacy Enhancing Technologies

PETs

3 different types of PETs depending on ...

the concerns they address

their goals

their challenges and limitations

1 – The adversary is in your **social** circle

CONCERNS - The privacy problem is defined by **Users**

Technology brings problems

“My parents discovered I'm gay”

“My boss knows I am looking for other job”

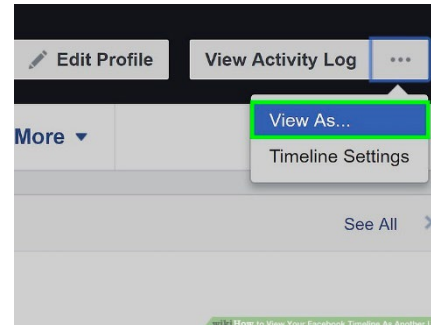
“My friends saw my naked pictures”

GOALS - Do not surprise the user

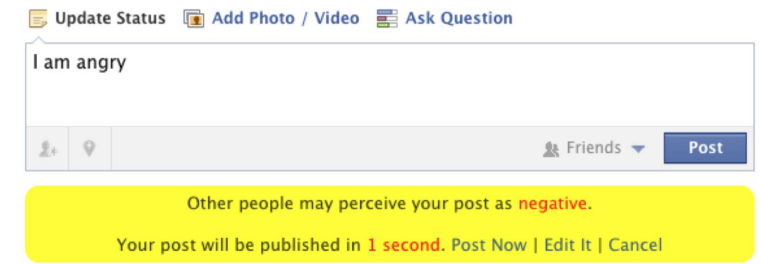
Two main approaches

Support decision making

Help identifying actions impact



Contextual feedback



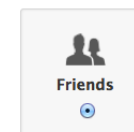
Privacy nudges

Control Your Default Privacy

This setting will apply to status updates and photos you post to your timeline from a Facebook app that doesn't have the inline audience selector, like Facebook for BlackBerry.



Public



Friends



Custom

Easy defaults

1 – The adversary is in your **social** circle

CONCERNS - The privacy problem is defined by **Users**

Technology brings problems

“My parents discovered I'm gay”

“My boss knows I am looking for other job”

“My friends saw my naked pictures”

GOALS - Do not surprise the user

Two main approaches

Support decision making

Help identifying actions impact

LIMITATIONS

Only protects from other users: **trusted service provider!**

Limited by users' capability to understand policies

Based on user expectations – What if the expectations are null?

1 – The adversary are others (Social Privacy)

CONCERNS - The privacy problem is defined by **Users**

Technology brings problems

“My parents discovered I'm gay”

“My boss knows I am looking for other job”

“My friends saw my naked pictures”

GOALS - Do not surprise the user

Two main approaches

Support decision making

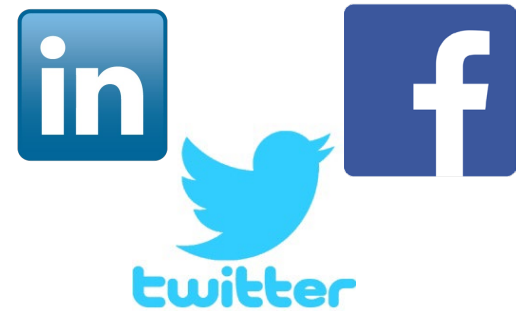
Help identifying actions impact

LIMITATIONS

Only protects from other users: **trusted service provider!**

Limited by users' capability to understand policies

Based on user expectations – What if the expectations are null?



Common Industry approach
Make users comfortable

2 – The provider may be adversarial (Institutional Privacy)



CONCERNS - The privacy problem is defined by **Legislation**

Data **should not** be collected without user consent or processed for illegitimate uses
Data **should** be secured: correct, integrity, deletion

Personal data

any information that relates to an identified or identifiable living individual.

2 – The provider may be adversarial (Institutional Privacy)



CONCERNS - The privacy problem is defined by **Legislation**

Data **should not** be collected without user consent or processed for illegitimate uses

Data **should** be secured: correct, integrity, deletion

GOALS — Compliance with data protection principles

informed consent

purpose limitation

data minimization

subject access rights

Preserving the security of data

Auditability and accountability

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GOALS — Compliance with data protection principles

informed consent
purpose limitation
data minimization
subject access rights

Preserving the security of data
Auditability and accountability

Access control
Logging
Anonymization??

Wouldn't it be nice if... you could take a dataset full of personal data, and transform it into one with no personal data – while keeping all the value of the data?



Magic does not exist!
this **cannot** happen in general!

2 – The provider may be adversarial (Institutional Privacy)



CONCERNS - The privacy problem is defined by **Legislation**

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Data should be secured: correct, integrity, deletion

GOALS — Compliance with data protection principles

informed consent

purpose limitation

data minimization

subject access rights

Preserving the security of data

Auditability and accountability

LIMITATIONS

Never questions collection – assumes it is necessary

Trusted service provider! No technical measures to protect data from them

Limits misuse, but not collection (seven legal basis)

Limited scope (personal data != all data)

3 – Everyone is the adversary (Anti-surveillance Privacy)

CONCERNS - The privacy problem is defined by **Security Experts**

Data is disclosed **by default** through the ICT infrastructure: **the adversary is anybody**

Concerned about: censorship, surveillance, freedom of speech,...

3 – Everyone is the adversary (Anti-surveillance Privacy)

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Data is disclosed **by default** through the ICT infrastructure: **the adversary is anybody**
Concerned about: censorship, surveillance, freedom of speech,...



GOALS — Minimize

Default disclosure of personal information to anyone - both explicit and implicit!

Minimize the need to trust others



3 – Everyone is the adversary

(Anti-surveillance Privacy)

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GOALS – Minimize

- Default disclosure of personal information to anyone - both explicit and implicit!
- Minimize the need to trust others

LIMITATIONS

Privacy-preserving designs are narrow – difficult to create “general purpose privacy”

Usability problems both for developers and users

- how the @\$%&#\$Ŷ& do I program this?

- performance hit

- unintuitive technologies

Industry lacks incentives

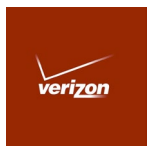
The adversary is anyone and VERY powerful



Intelligence agencies



The Boss



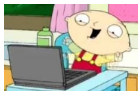
ISPs



SysAdmins



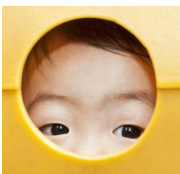
Your Parents



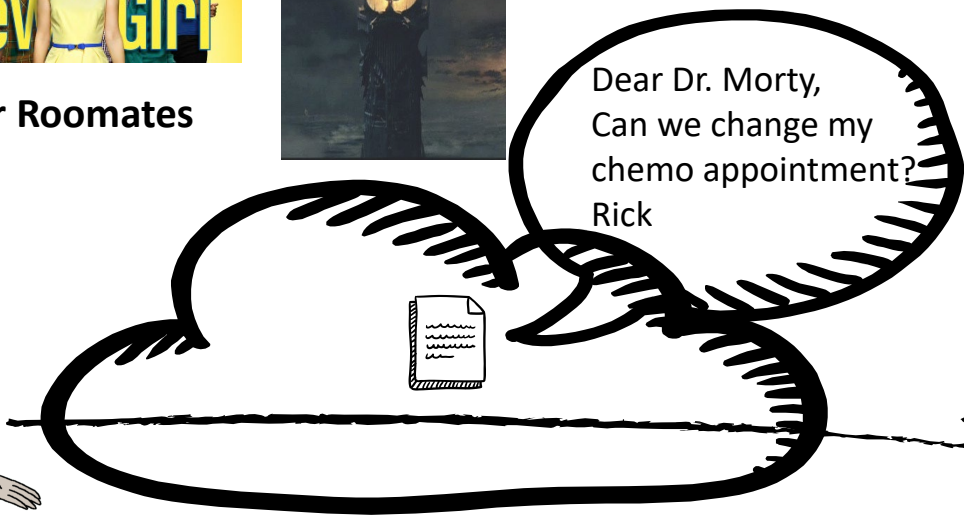
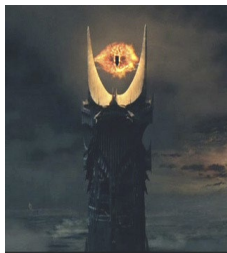
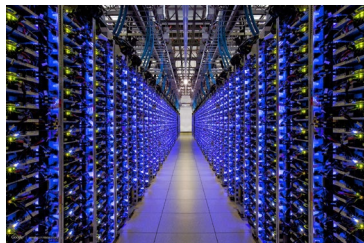
Your Children



Your Roomates



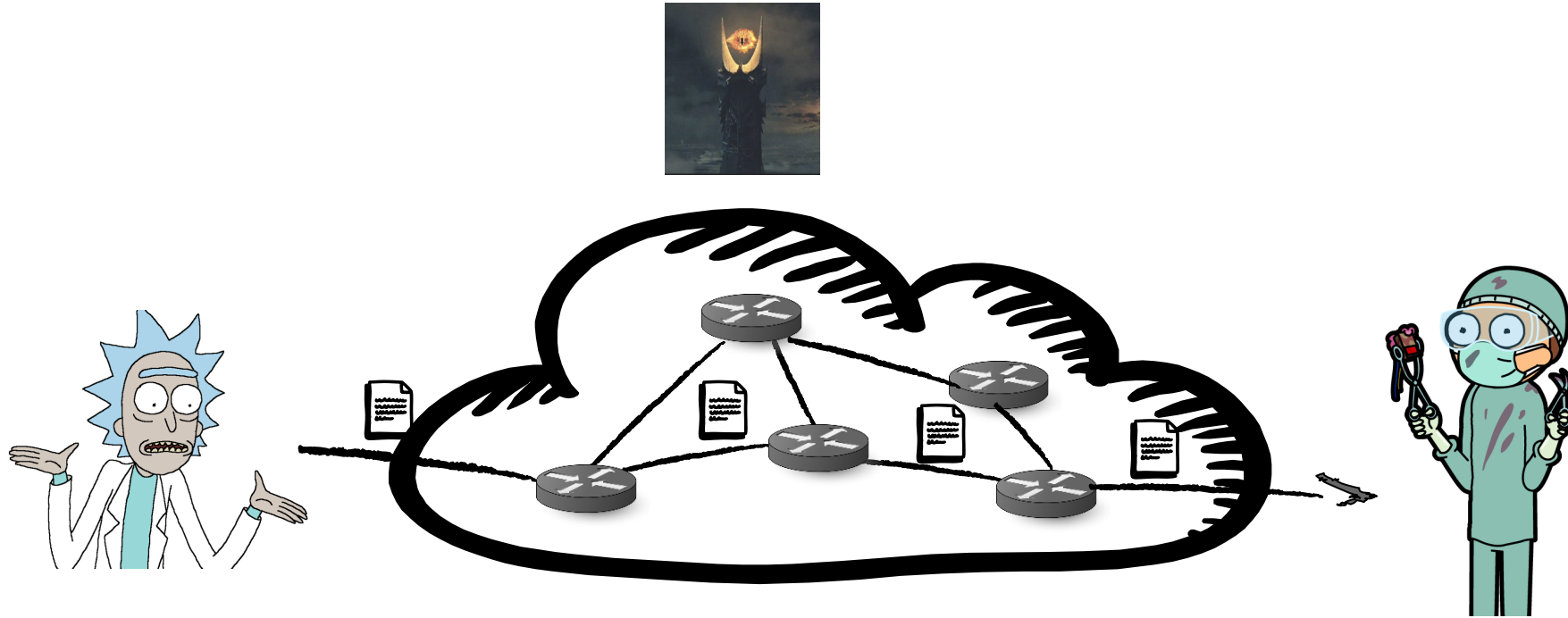
Anybody curious



Dear Dr. Morty,
Can we change my
chemo appointment?
Rick

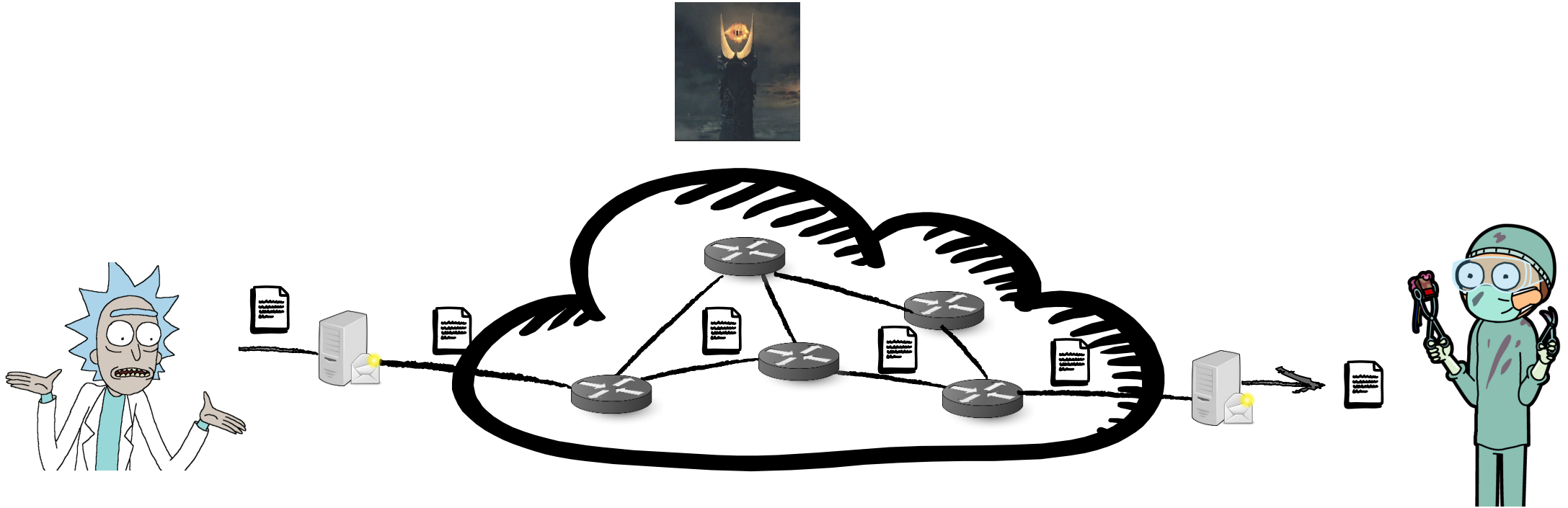


End to End Encryption



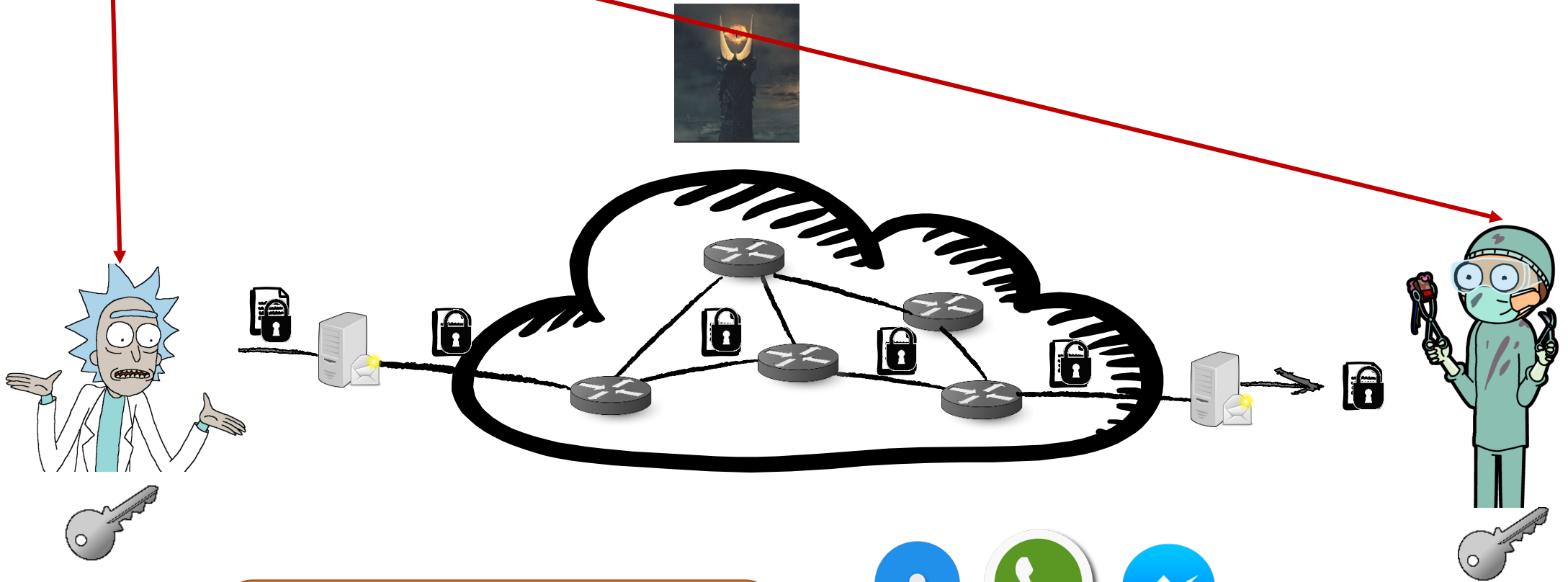
End to End Encryption

What is an End?



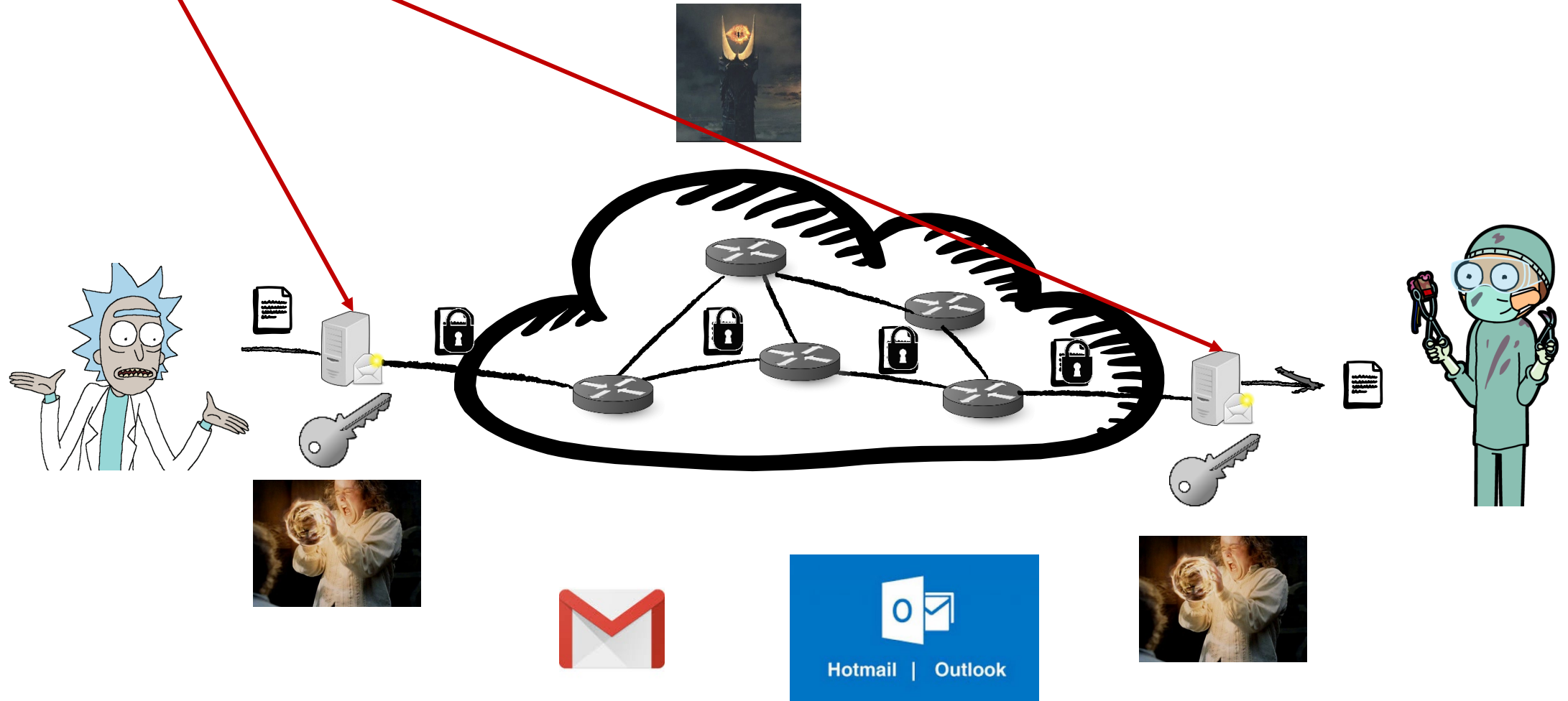
**Cryptography → Confidentiality!
(and integrity and authenticity)**

End to End Encryption



They also provide forward secrecy,
by using ephemeral keys.
How: advanced crypto

End to End Encryption



But we can encrypt! What is the problem?



0		4		8		16		24		31	
Version		IHL		Type of Service		Total Length					
Identification						Flags		Fragment Offset			
Time to Live				Protocol		Header Checksum					
Source IP Address											
Destination IP Address											
IP Options (optional)										Padding	
Data											

IPv4 Header (RFC 791, 1981)

Same for Ethernet, TCP, SMTP, IRC, HTTP, ...

The problem is Traffic Analysis



Bit Position: 0				4	8	16	24	31
Version	IHL	Type of Service		Total Length				
Identification				Flags	Fragment Offset			
Time to Live		Protocol		Header Checksum				
Source IP Address								
Destination IP Address								
IP Options (optional)							Padding	

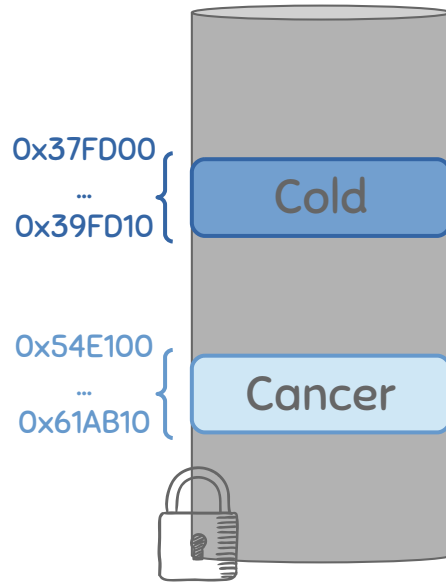
IPv4 Header (RFC 791, 1981)

Same for Ethernet, TCP, SMTP, IRC, HTTP, ...

Other metadata is also sensitive!!

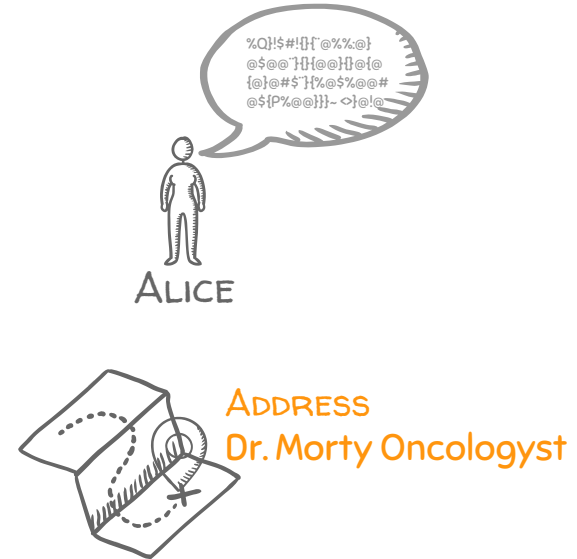


Implicit data is as
important as explicit data!



The address where data is stored may reveal information about the content.

Example: medical database with patients with mild and severe diseases in different locations



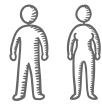
The address where an action happens may reveal information about the action / user.

Example: sending a message from an Oncologist clinic reveals information about the sender

Traffic analysis

Wikipedia: traffic analysis is the process of intercepting and examining messages in order to deduce information from patterns in communication

Making use of “just” traffic data of a communication (aka metadata) to extract information
(as opposed to analyzing content or perform cryptanalysis)



Identities of
communicating parties



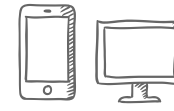
Timing, frequency,
duration



Location



Volume



Device

MILITARY ROOTS

M. Herman: “These non-textual techniques can establish **targets' locations**, order-of-battle and **movement**. Even when messages are not being deciphered, traffic analysis of the target's Command, Control, Communications and intelligence system and its patterns of behavior provides indications of his **intentions** and **states of mind**”

WWI: British troops finding German boats.

WWII: assessing size of German Air Force, fingerprinting of transmitters or operators (localization of troops).



NOWADAYS

Diffie&Landau: “Traffic analysis, not cryptanalysis, is the backbone of communications intelligence”

Stewart Baker (NSA): “metadata **absolutely tells you everything about somebody's life**. If you have enough metadata, you don't really need content.”

Tempora, MUSCULAR → XkeyScore, PRISM

We need to protect the communication layer!

Why anonymous communications?

If you are a cyber-criminal!

DRM infringement, hacker, spammer, terrorist, etc.

But, also if you are:

Journalist

Whistleblower

Human rights activist

Business executive

Military/intelligence personnel

Abuse victims

Or you want to...

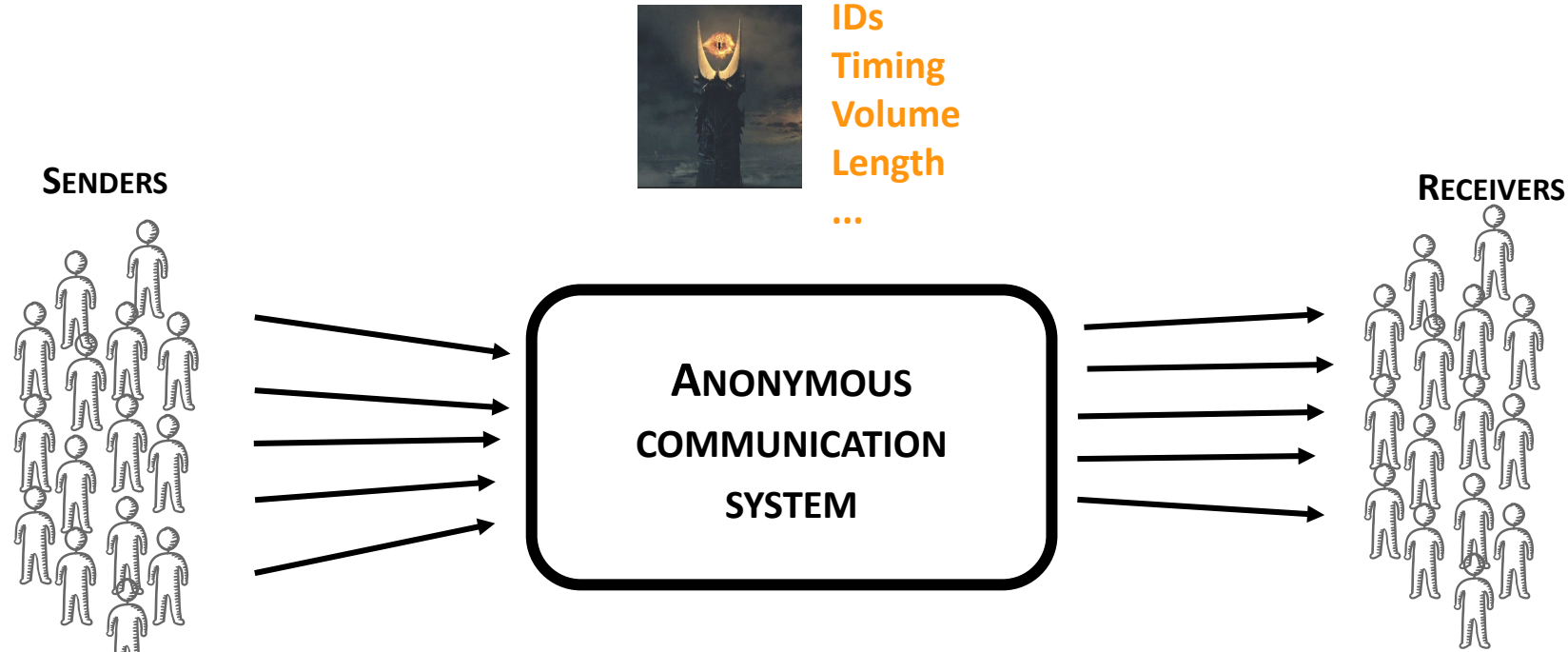
- Avoid tracking by advertising companies
- Protect sensitive personal information from businesses, like insurance companies, banks, etc.
- Express unpopular or controversial opinions
- Have a dual life

A professor who is a pro in LoL!

- Try uncommon things

...

Anonymous communications – Abstract model



Bitwise unlinkability

Use cryptography to make inputs and outputs to the anonymous communication systems appearance (bits) different

(re)packetizing + (re)schedule

Destroy patterns (traffic analysis resistance)

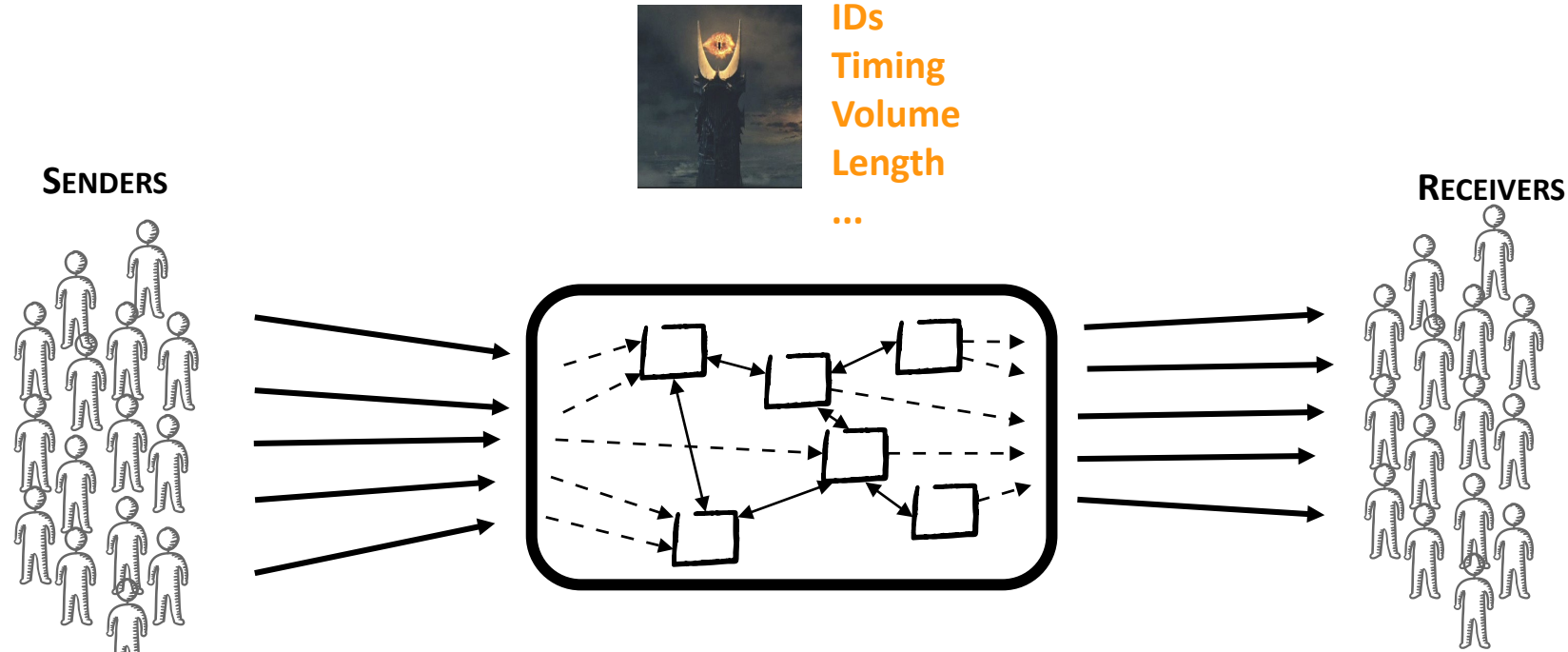
ONE-PROXY PROBLEMS

LOW THROUGHPUT

CORRUPT PROXY OR PROXY HACKED / COERCED

REAL CASE: PENET.FI VS THE CHURCH OF SCIENTOLOGY (1996)

Anonymous communications – Abstract model



Bitwise unlinkability

Use cryptography to make inputs and outputs to the anonymous communication systems appearance (bits) different

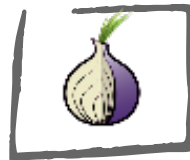
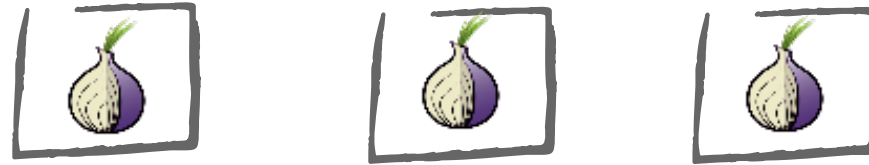
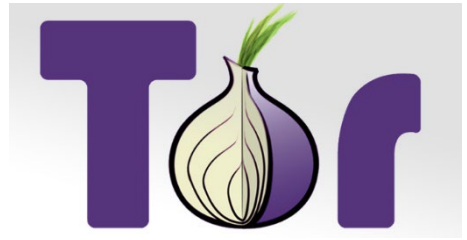
(re)packetizing + (re)schedule + (re)routing

Destroy patterns (traffic analysis resistance)

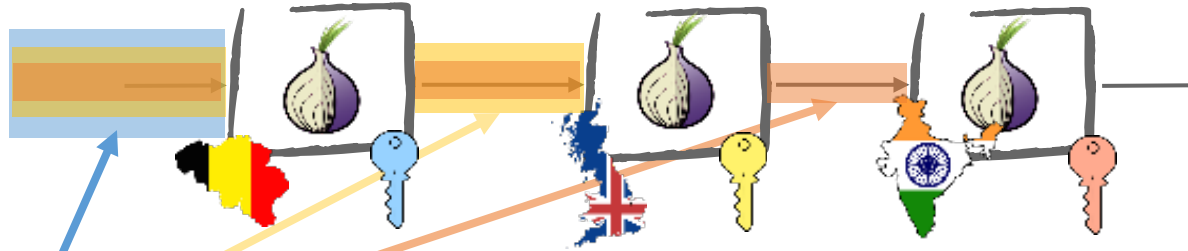
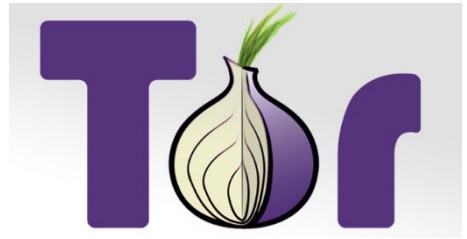
Load balancing

Distribute trust

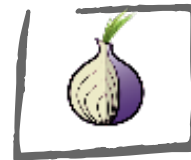
The Tor network – Onion routing



The Tor network – Onion routing

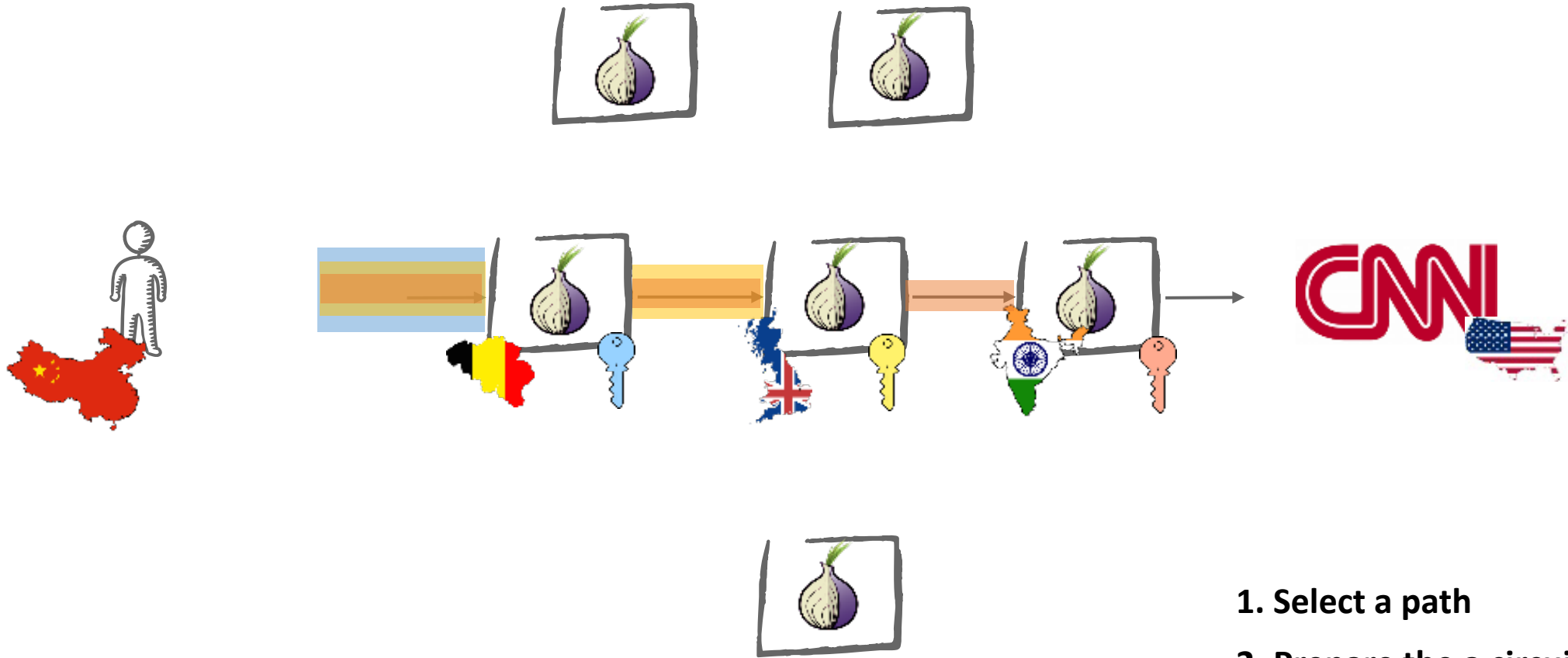
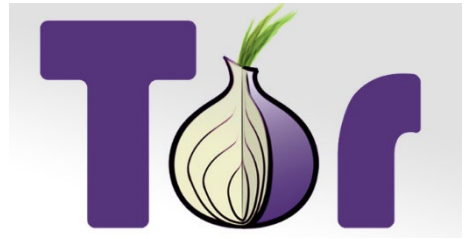


Authenticated Diffie Hellman to get a symmetric key



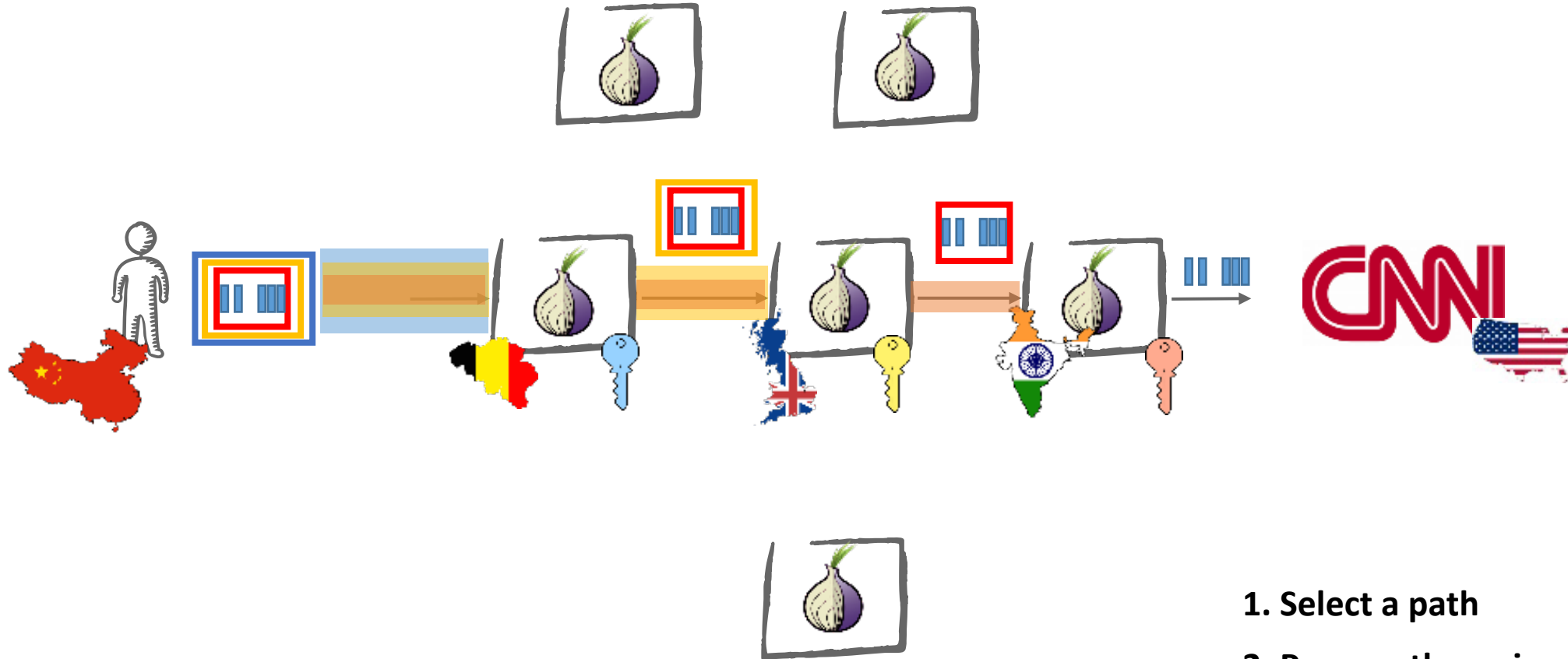
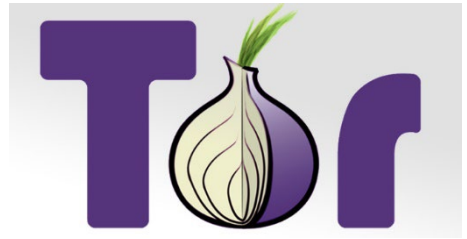
1. Select a path
2. Prepare the a circuit

The Tor network – Onion routing



1. Select a path
2. Prepare the a circuit
3. Send stream

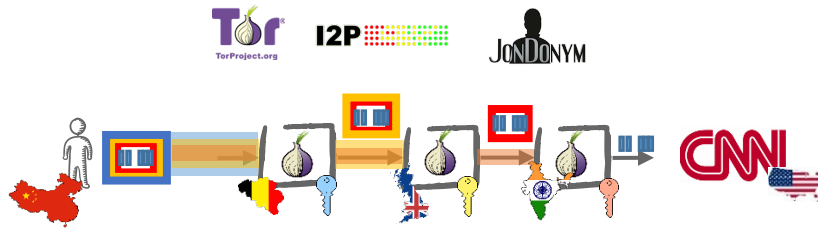
The Tor network – Onion routing



1. Select a path
2. Prepare the a circuit
3. Send stream

Anonymous communications out there

LOW LATENCY 

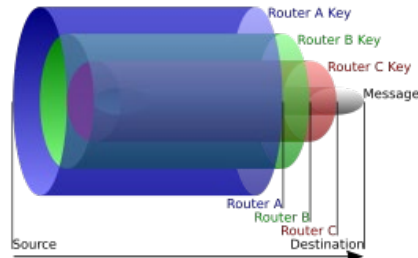


Web browsing, Instant Messaging, streaming

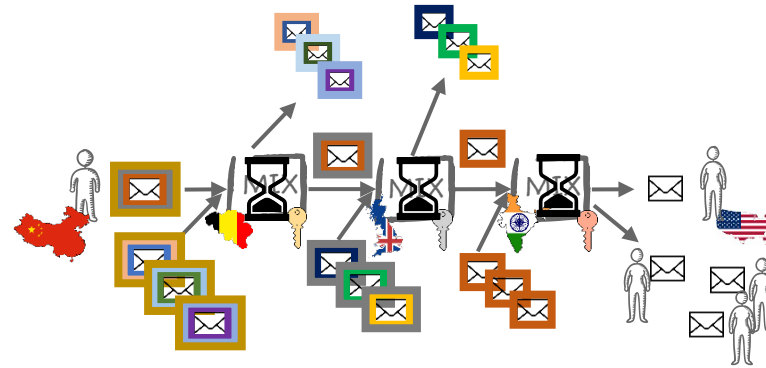
STREAM-based:



**fixed
for the
stream**

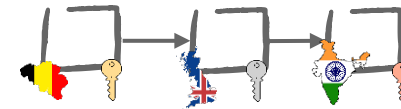


HIGH LATENCY 



Email, Voting, Bitcoin

MSG-based:

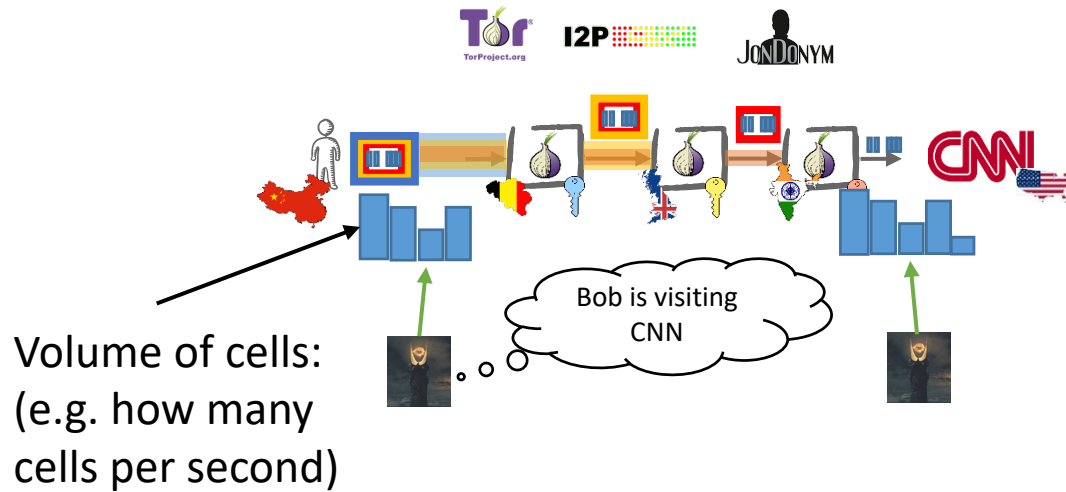


vary every message

One route per message + delays
(slower!)

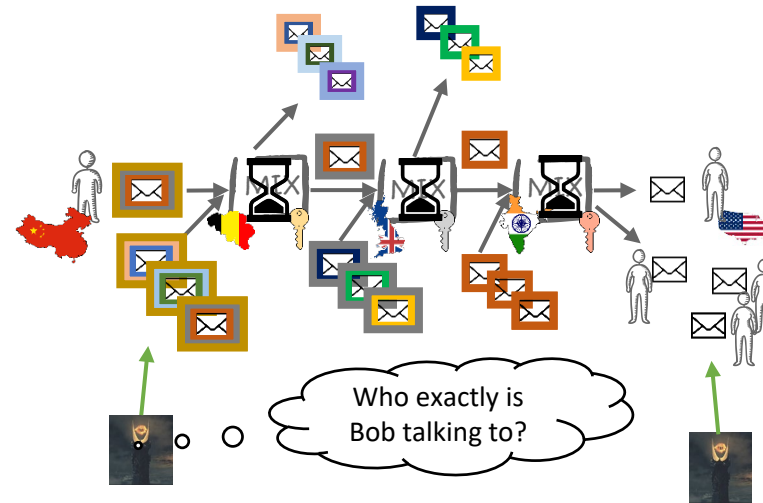
Anonymous communications out there

LOW LATENCY 



Cannot resist **Global** Adversary
(Tor assumes that the adversary cannot see both edges)

HIGH LATENCY 



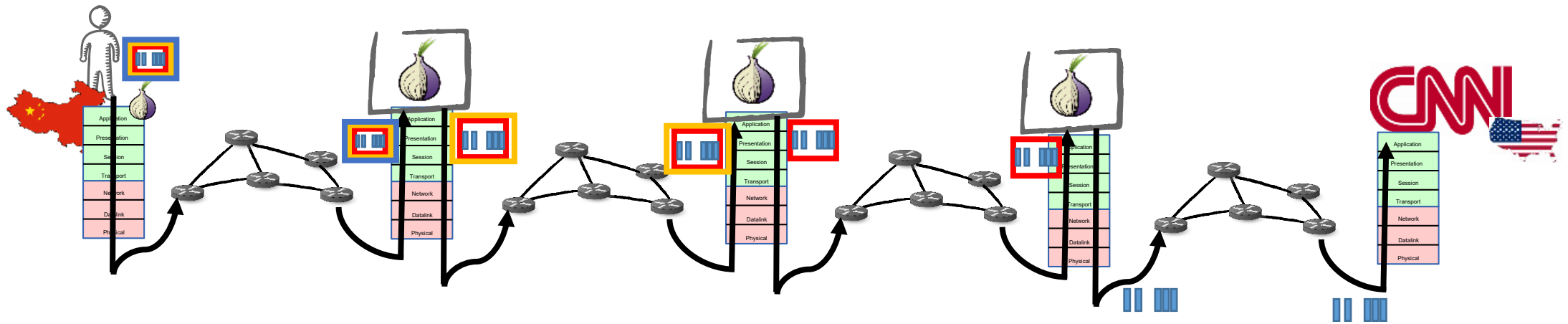
Global Adversary resistance
at the cost of latency
(and long term patterns revealed)

Anonymous communication networks are overlay networks

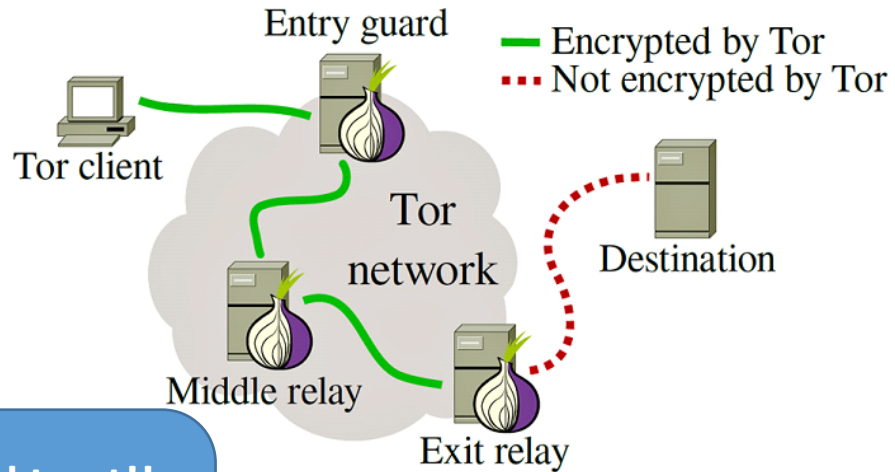
Nodes in anonymous communication networks (e.g., onion routers in Tor) are **not** internet routers. They work at the application layer!

(overlay network = a computer network that is built on top of another network)

A more realistic view of how Tor traffic travels would be this



Anonymous communications vs. VPN



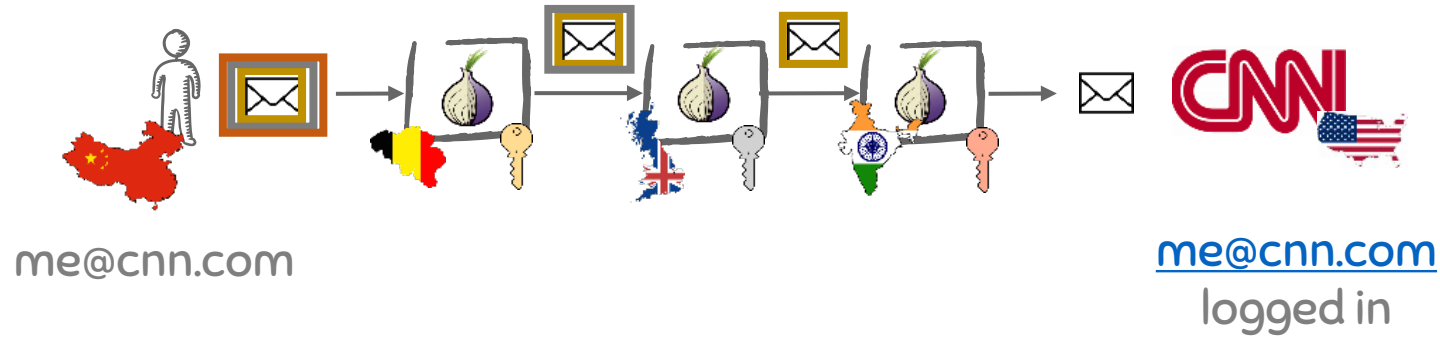
Different trust models!! Who is the adversary?

Decentralized trust!!
Provides privacy as long as the adversary cannot see both edges

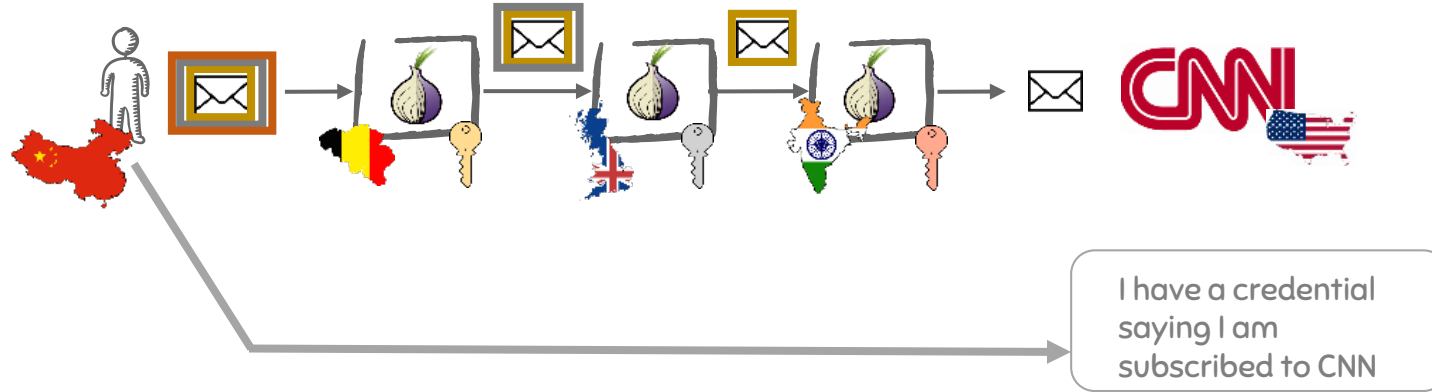
Centralized trust. No anonymity vs the VPN, or anyone seeing the VPN



Anonymous communications at network layer what about the application layer?



Anonymous communications at network layer what about the application layer?



Anonymous credentials
Attribute-based credentials

When shown the server **cannot**

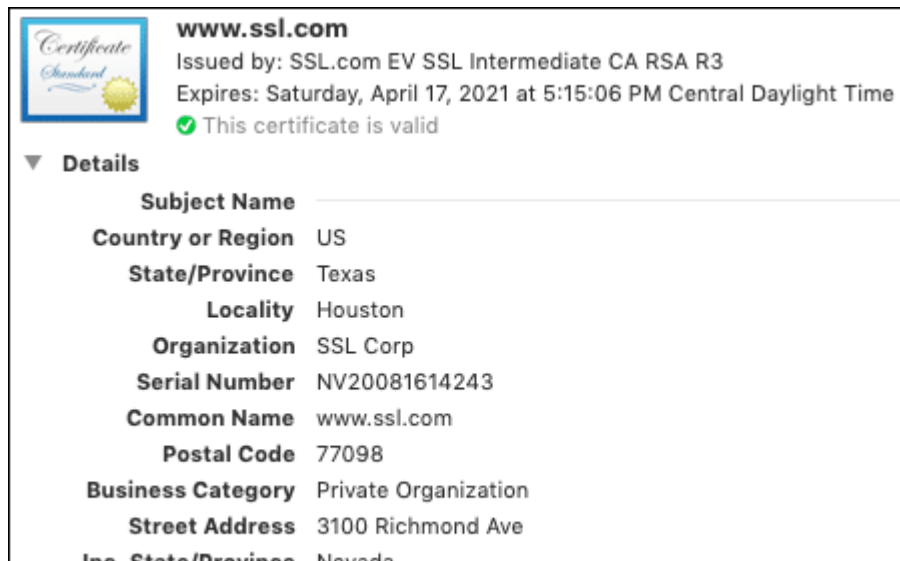
- Identify Alice (if her name is not provided)
- Learn anything beyond the info she gives (and what can be inferred)
- Distinguish two users with the same attributes
- Link multiple uses of the same credentials

Public Key Infrastructure

(usual internet authentication)

Signed by a trusted issuer
Certification of attributes
Authentication (secret key)

No data minimization
Users are identifiable
Users can be tracked
(Signature linkable to other contexts
where PK is used)



Attribute based credentials

Signed by a trusted issuer
Certification of attributes
Authentication (secret key)

Data minimization
Users are anonymous
Users are unlinkable across contexts

Other PETs examples

Private set intersection

a client and a server jointly compute the intersection of their private input sets in a manner that at the end the client learns the intersection and the server learns nothing (one-way PSI) or both learn the intersection (mutual PSI) -- private search

Blind Signatures

a server signs a message produced by a client without learning the content of the message -- eCash

Multiparty computation

parties to jointly compute a function over their inputs while keeping those inputs private -- compute total computations (statistics)

Want more? CS-523: Advanced Privacy Technologies