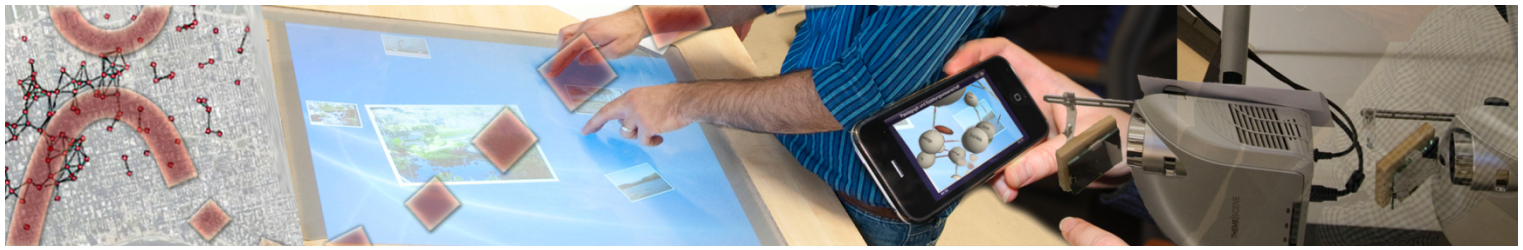
Technische Universität Darmstadt

Telecooperation Lab
Prof. Dr. Max Mühlhäuser

TK3: Ubiquitous (& Mobile) Computing

Chapter ?: Privacy

Lecturer: Jörg Daubert
(based on slides by Stefan Schiffner)



PRIVACY - OUTLINE

- An Introduction to Privacy:
  - Definitions and Terminology
  - Privacy Enhancing Technologies
  - Case study: Smart Meter Privacy

Privacy – Dictionary Definition

1

- a : the quality or state of being apart from company or observation : seclusion
- b : freedom from unauthorized intrusion <one's right to privacy>

2

- archaic : a place of seclusion

3

- a : secrecy
- b : a private matter : secret

From Merriam Webster Online Dictionary

Not Really a basis for technical solutions

Informational self-determination

"The claim of individuals, groups and institutions to determine themselves, when, how and to what extent information about them is communicated to the others"

Privacy and Freedom: Westin 1967

Information about the subject

Subj+ communicate +What? +ToWhom? +When?How?How much?

Verb | Direct Object | Indirect Object | Adverbial Adjuncts

What is Personal Data

EU Data Protection Directive (95/46/EC):

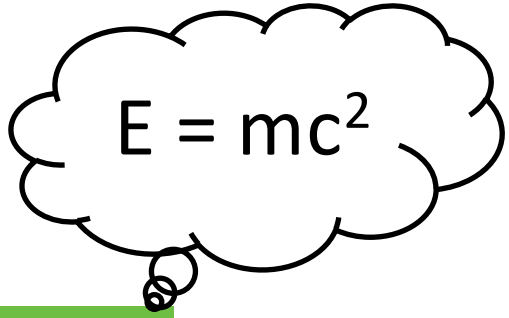
"personal data" shall mean any information relating to an **identified or identifiable** natural person ('Data Subject');

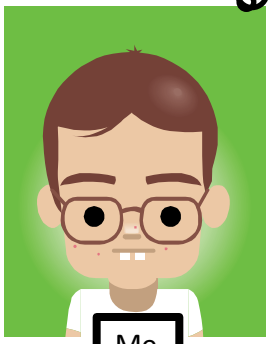
an identifiable person is one who can be **identified, directly or indirectly,** in particular by reference to an **identification number** or to one or more factors specific to his **physical, physiological, mental, economic, cultural or social** identity.

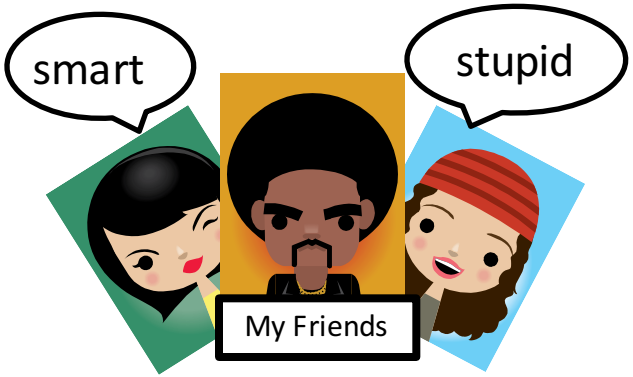
Personally Identifiable Information (PII)

Who I am?


My Car




Me



My Friends


I love Coffee


My Diploma

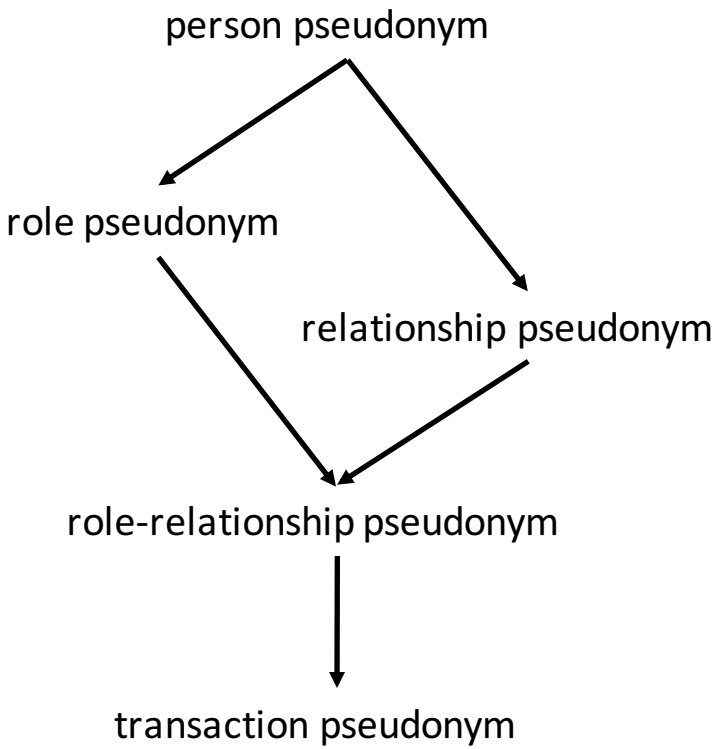
Privacy Enhancing Technologies (PETs)

How to enforce my right to informational self-determination?

- Protect legal privacy principles using technology
  - minimizing or **avoiding personal data**
  - safeguarding of **lawful data processing**

Pseudonyms

ID in a certain context



- **Increasing Anonymity support**
- **Linkability**
  - Separate pseudonyms might be linkable by context, e.g., used IP address
  - Can lead to re-identification, e.g., several linkable transaction pseudonyms can be seen as a role-relationship pseudonym

The internet is not made for unlinkable pseudonymous communication

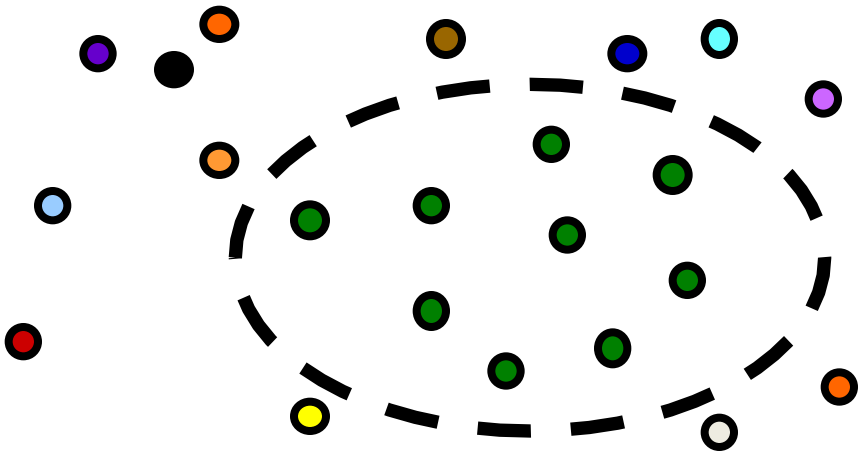
PETs for Data Minimization

- Anonymous Communication
  - MIXes
  - DC-Nets
- Controlled Disclosure
  - Anonymous credentials
  - Anonymous payment systems
  - Voting systems
- Privacy enhanced ID Management Systems
  - Ecosystems that use the above

Anonymity

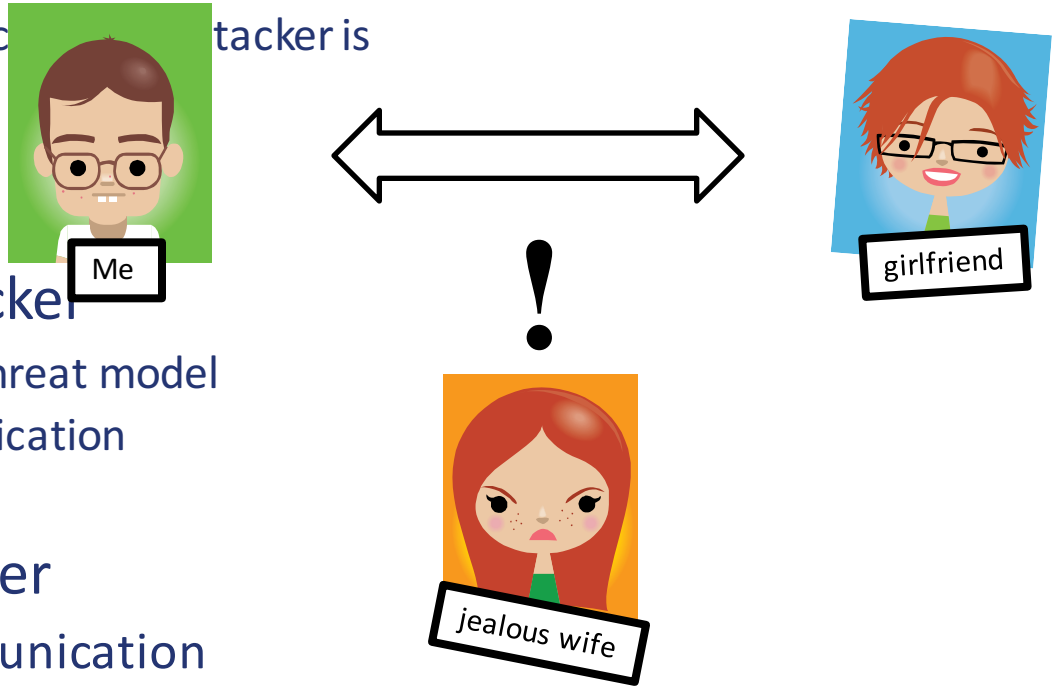
- Anonymity of a subject means that the subject is not identifiable within a set of subjects, the anonymity set

Pfitzmann 2000



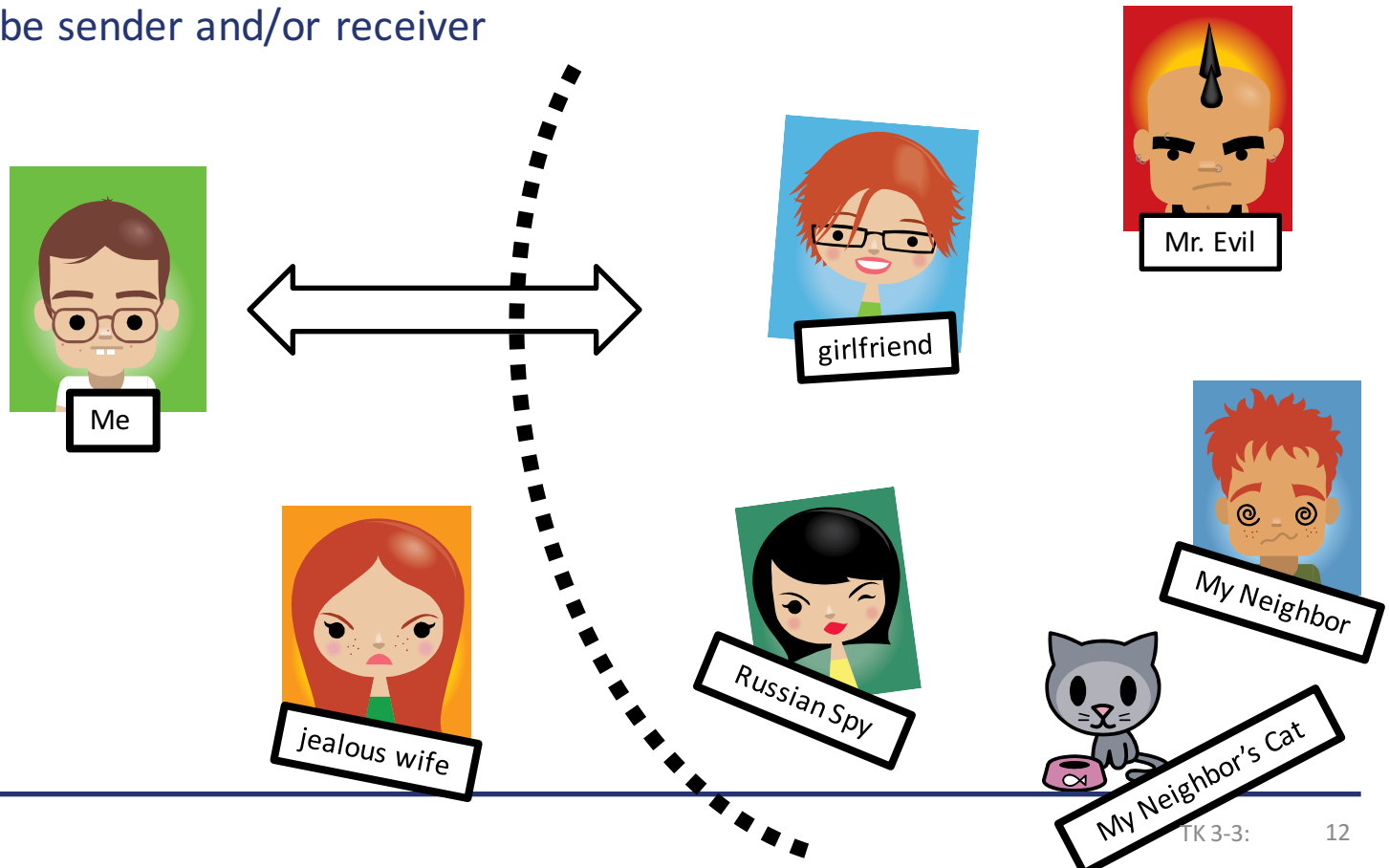
the anonymity set

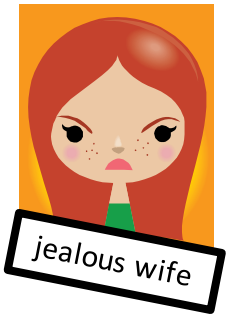
- Anonymous communication between peers
- Attacker Model
  - How resourc tacker is
  - Active
  - Passive
- Global Attacker
  - Dolev-Yao threat model
  - All communication
  - Some nodes
- Local Attacker
  - Some communication
  - Some nodes



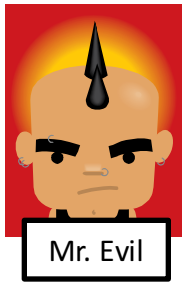
Anonymous Communication

- Basic Idea:
  - Every message can be sent by anyone
  - ~can be received by anyone
  - Attacker can be sender and/or receiver

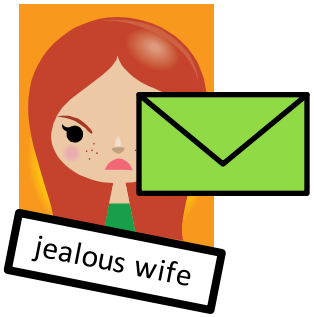




1. Collects messages
2. Deletes doublets
3. Re-Codes
4. Shuffles
5. Forwards

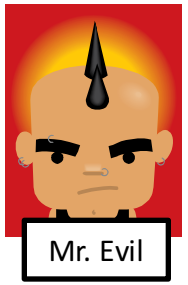


Replay attack (why step 2)



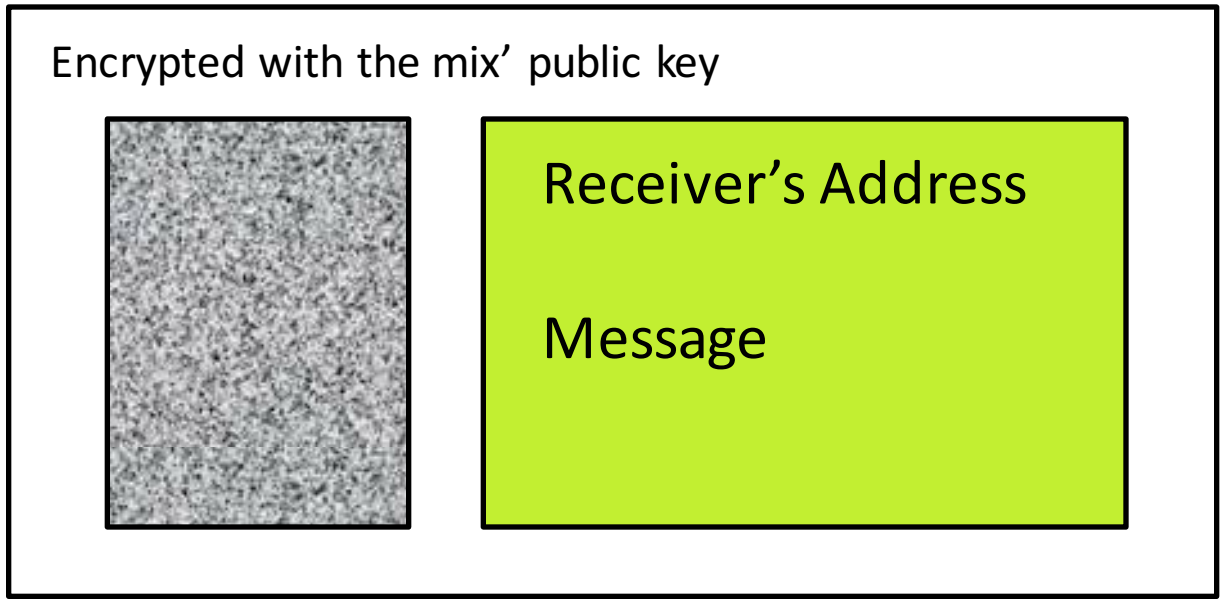
Repetitions need to be

dropped

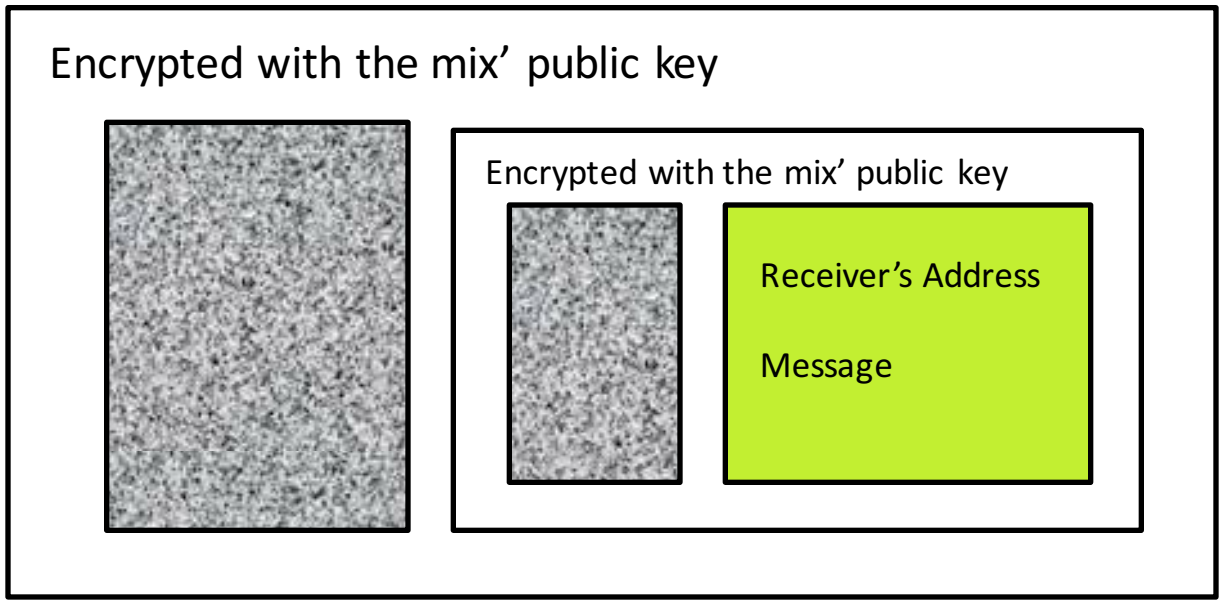


How to construct the messages?

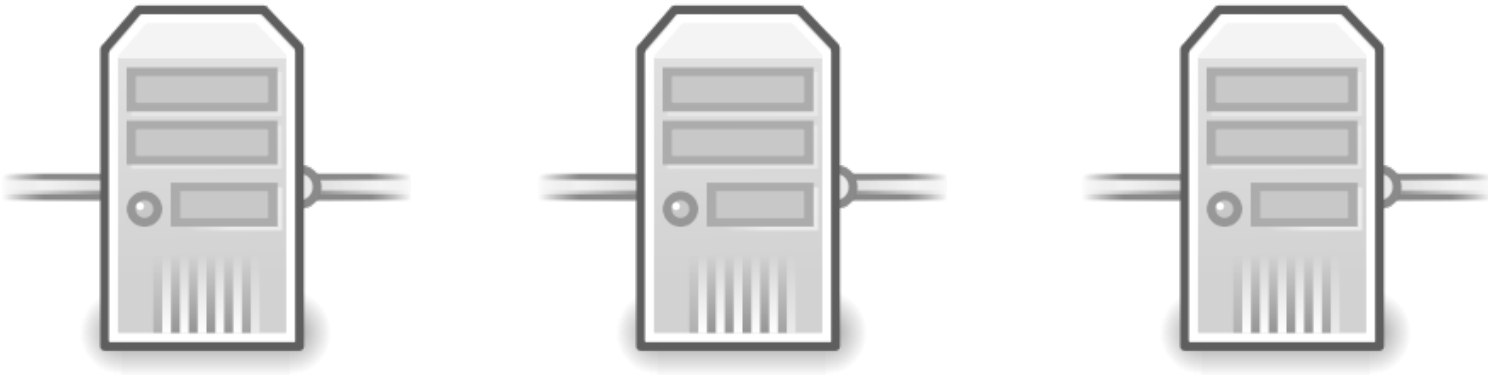
- Symmetric Encryption -> key distribution problem
- Hence Mix provides a public key
- Problem: The attacker knows the public key, can encrypt the forwarded messages



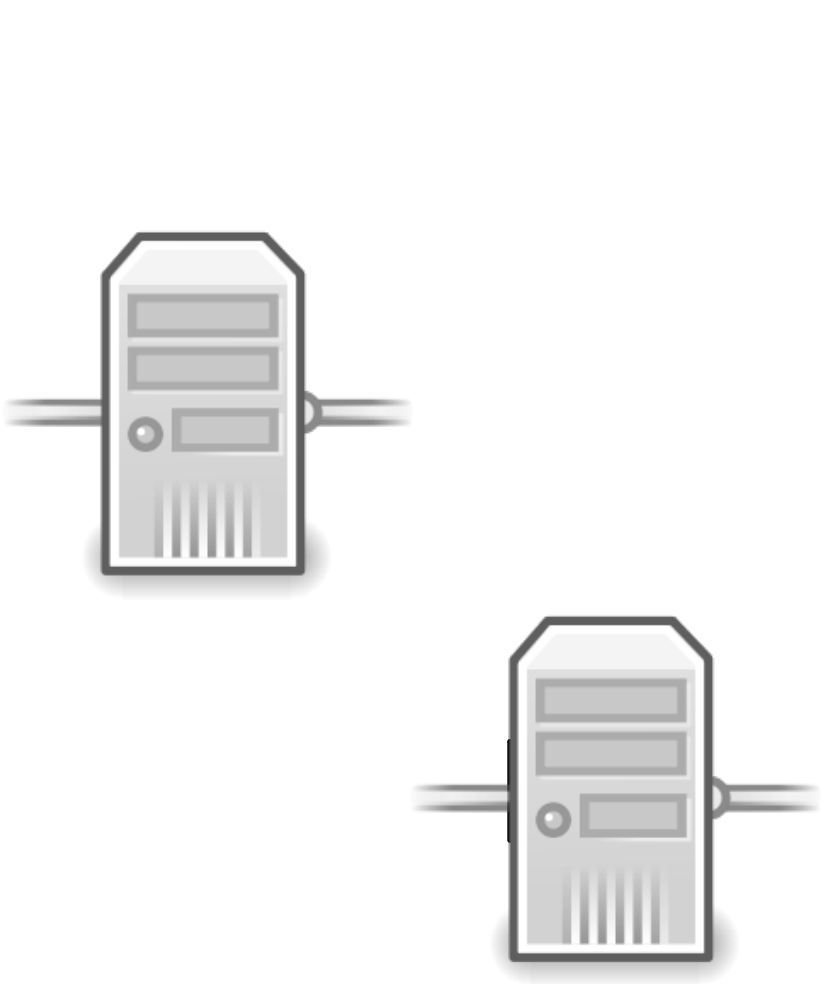
Don’t want to trust in 1 single MIX



MIX Cascades



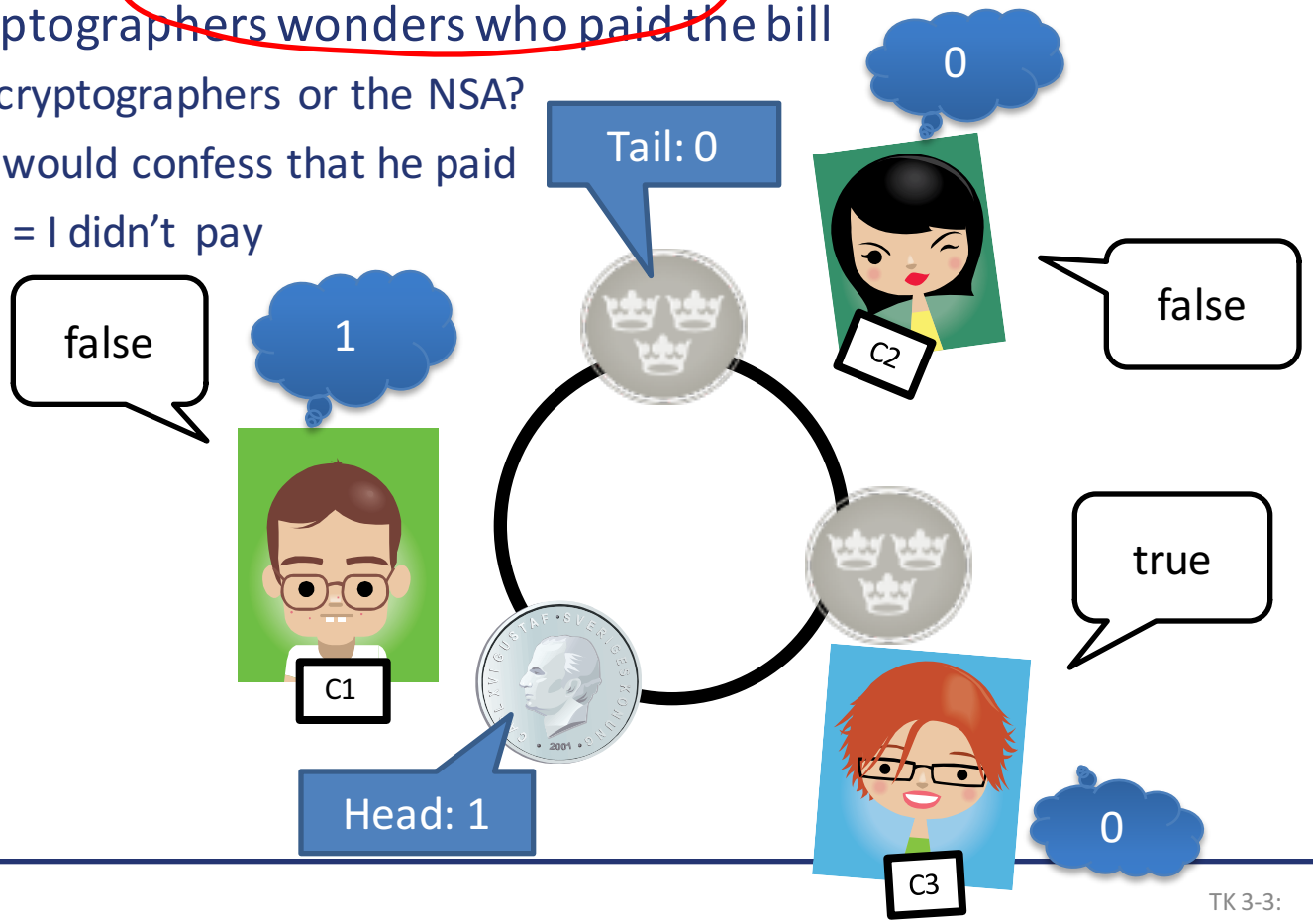
Free Routes



Which is better? – Cascades or free routes

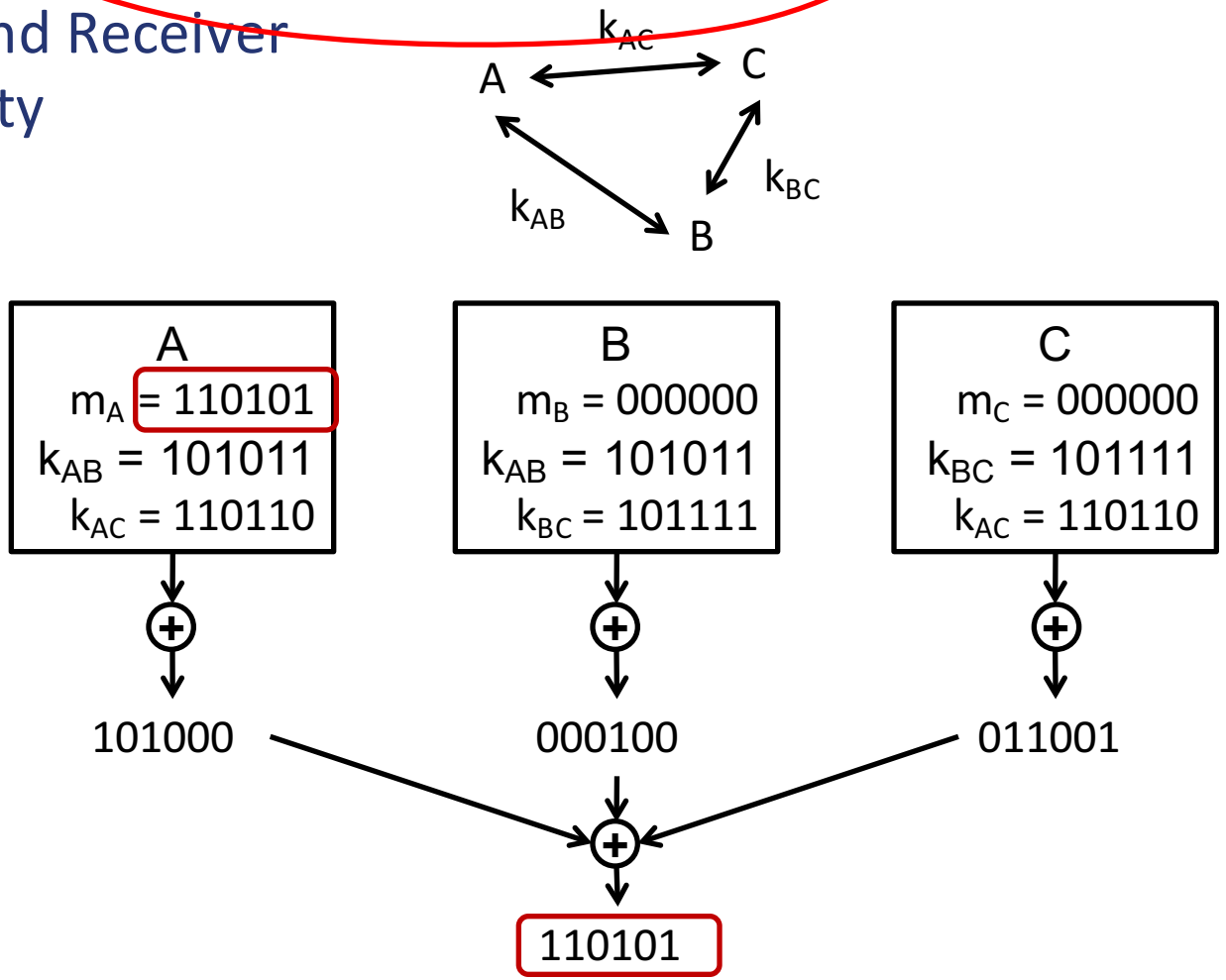
Is information theoretic anonymity possible

- DC-Nets
- A short tale about dining cryptographers
  - A group of cryptographers wonders who paid the bill
    - One of the cryptographers or the NSA?
    - But no one would confess that he paid
    - 1 = I paid, 0 = I didn't pay



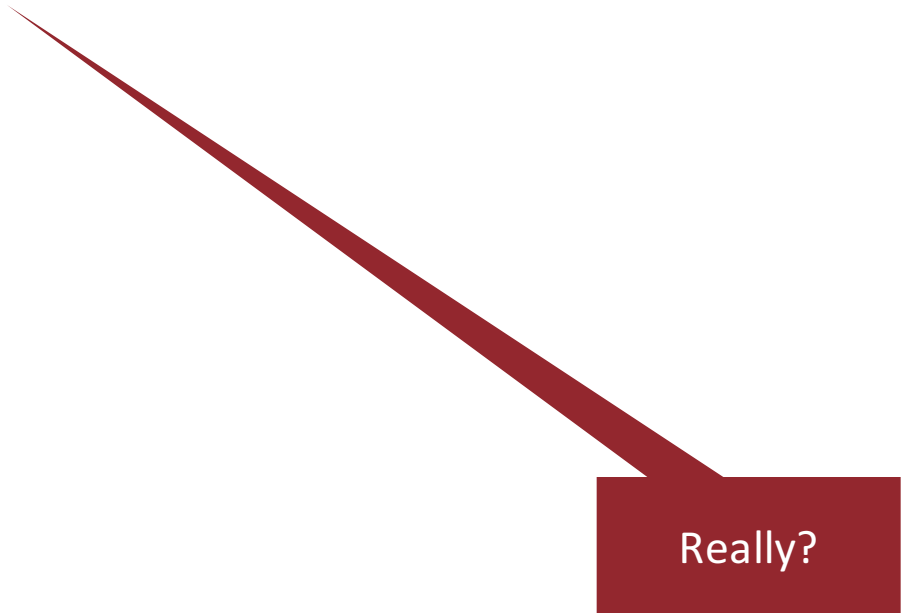
DC Nets – Binary Superposed

Sender and Receiver Anonymity



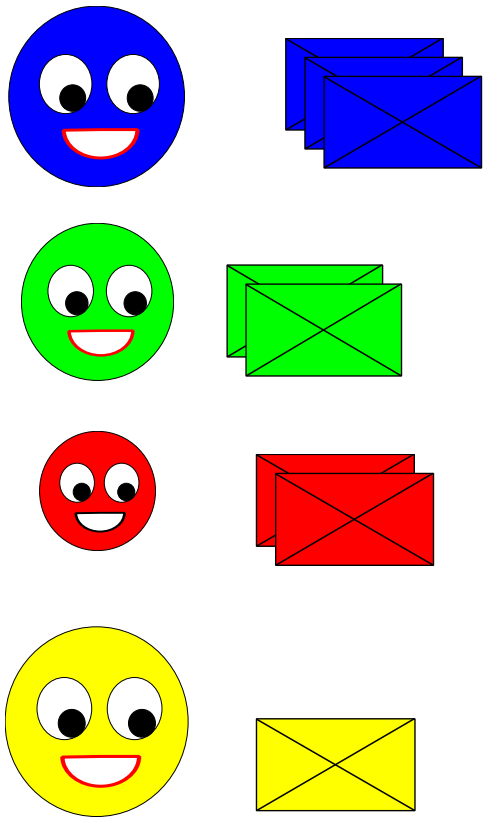
TECHNISCHE UNIVERSITÄT DARMSTADT

Anonymous Communication! We are Safe!

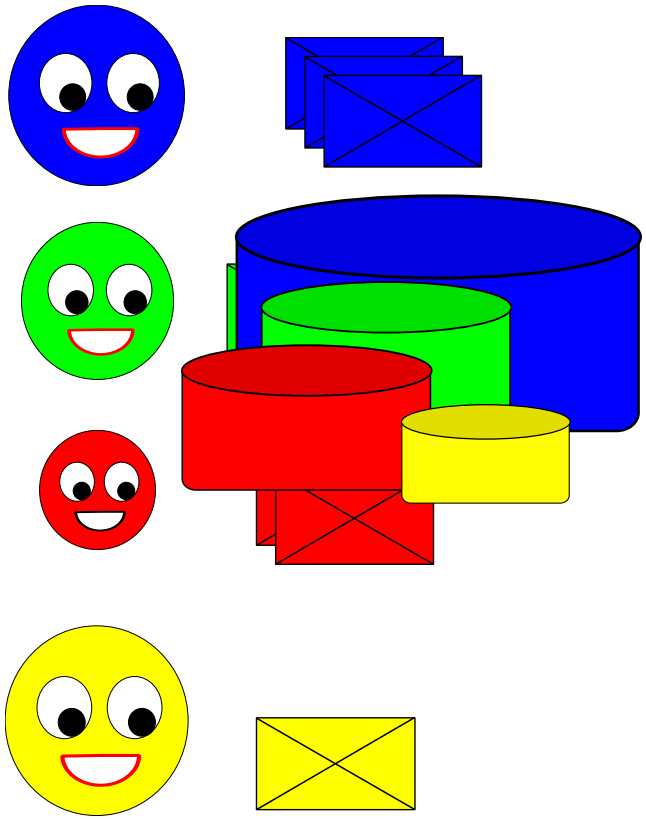


Application Layer Information

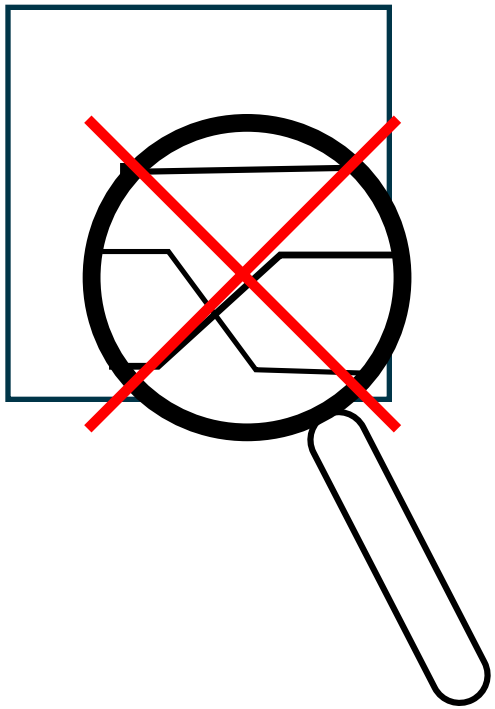
System Model

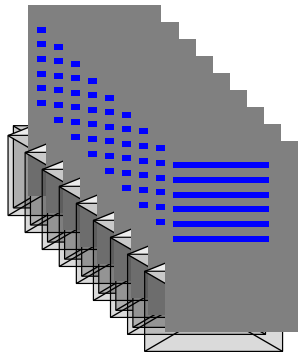


Attacker Knowledge



Traffic Data



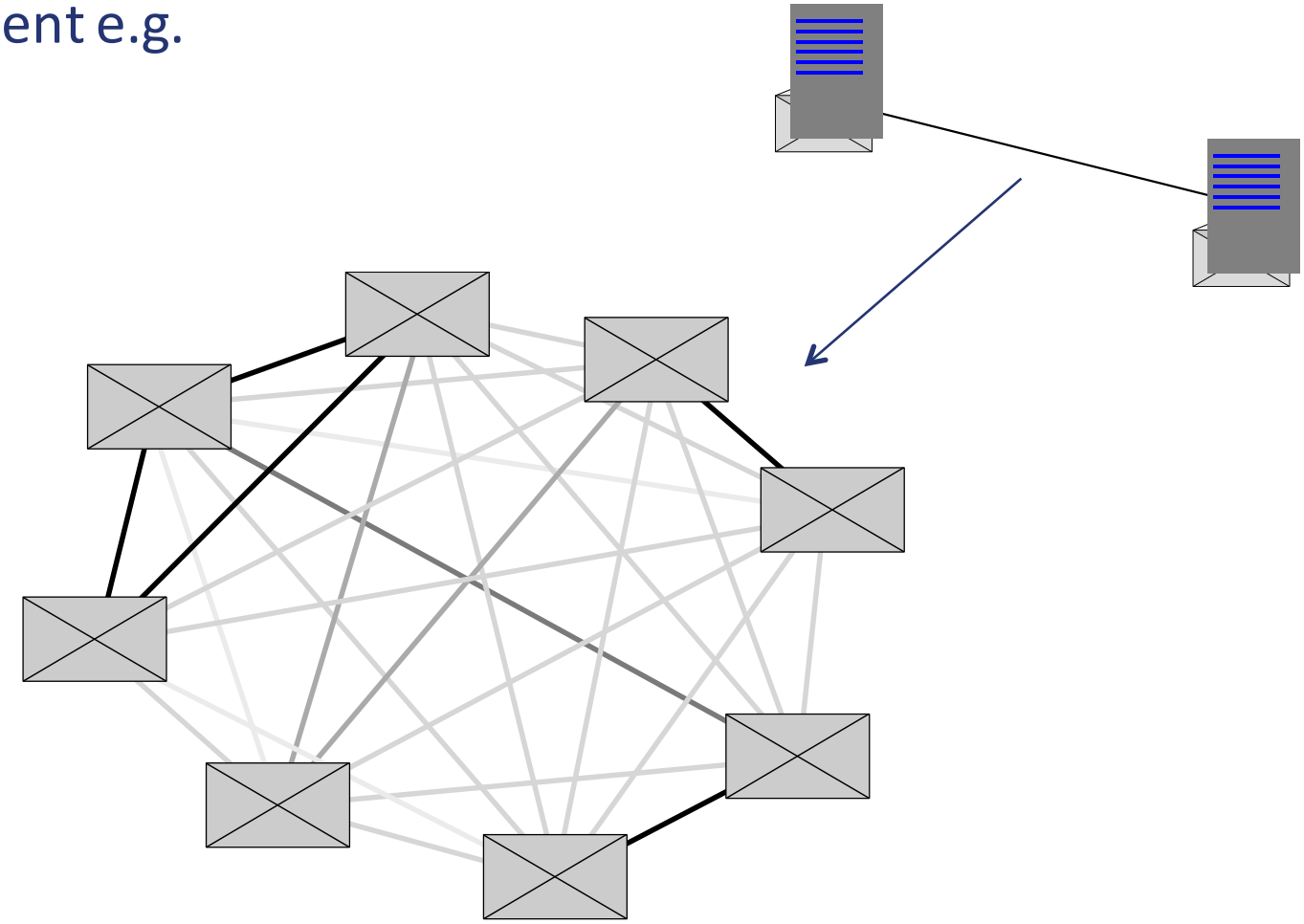


Application Data

Linkability Information

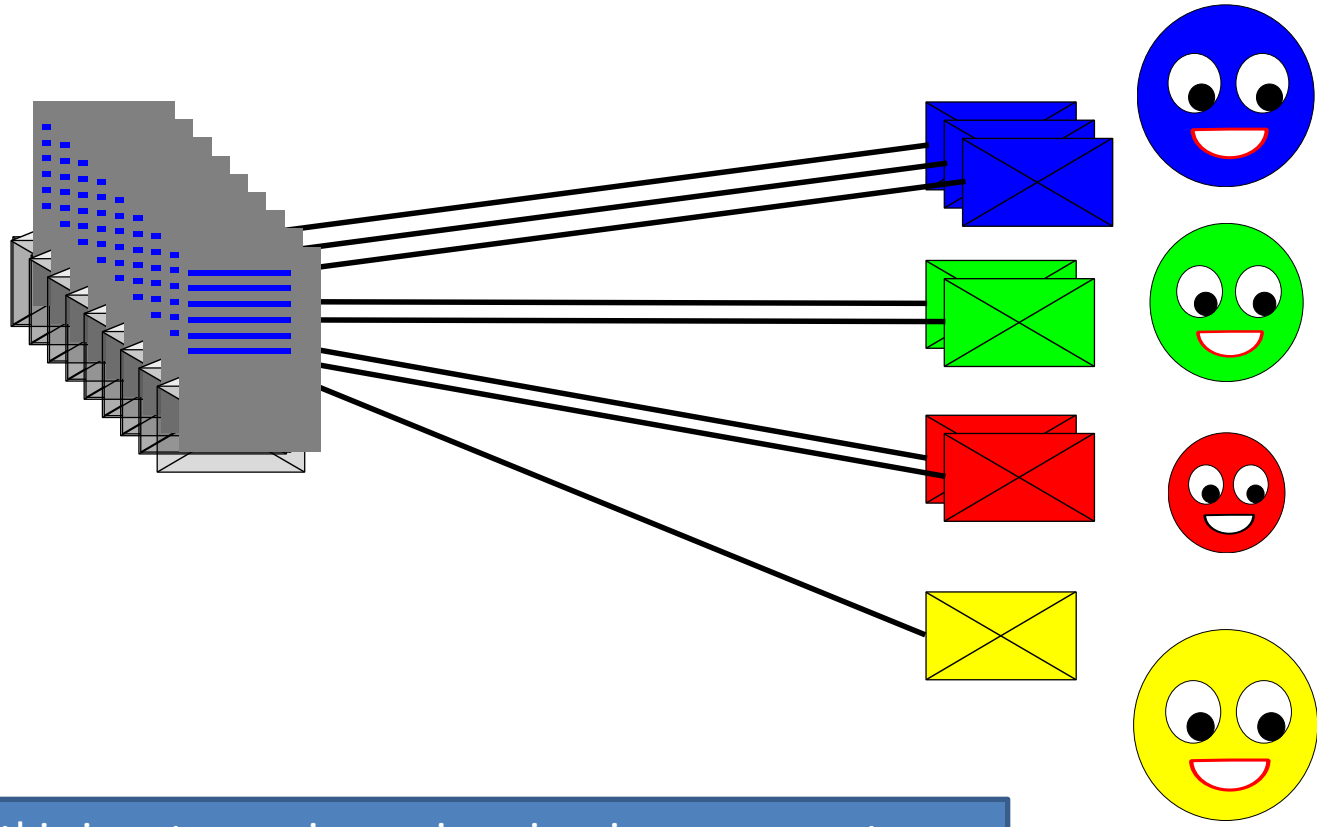
Message Content e.g.

- Language
- Context
- Style



Attacker Aim

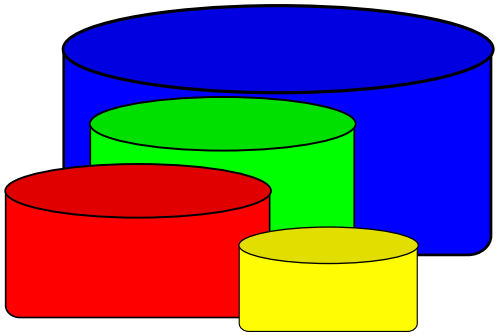
- To map anonymized messages to senders

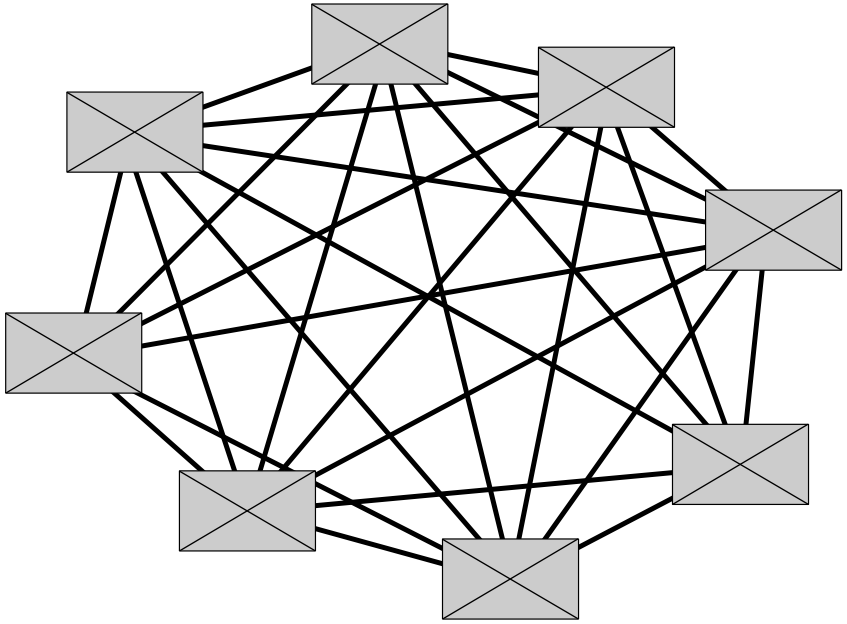


Note: this is not mapping a given ingoing message to a certain outgoing message!

Random Attacker

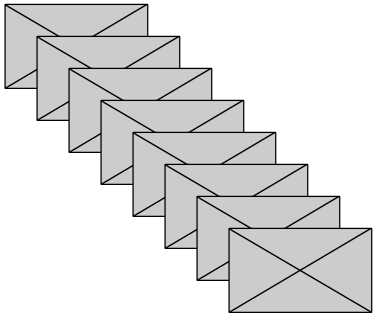
Number of messages

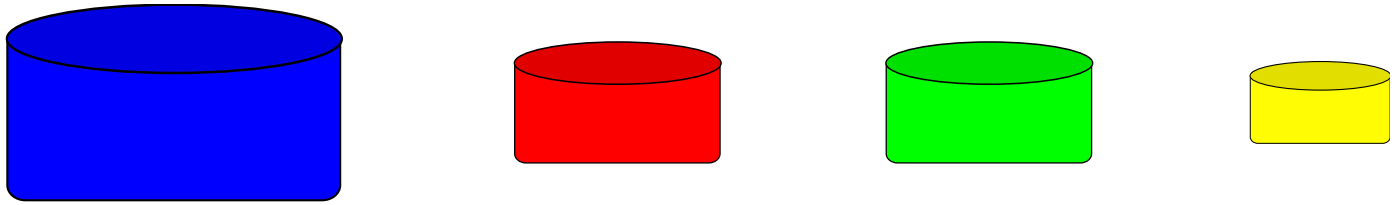




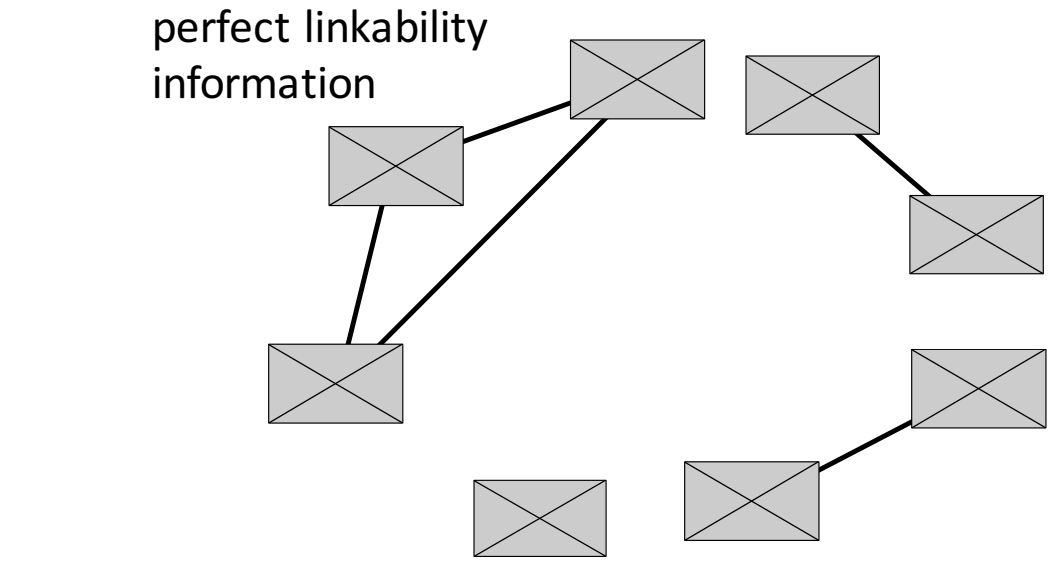
No linkability information

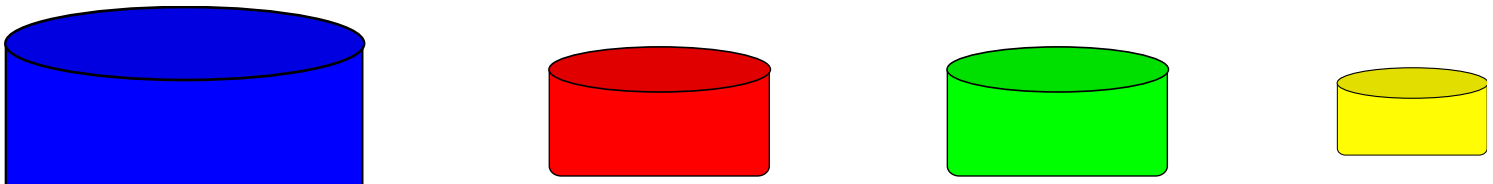
Random Attack





Perfect Attack

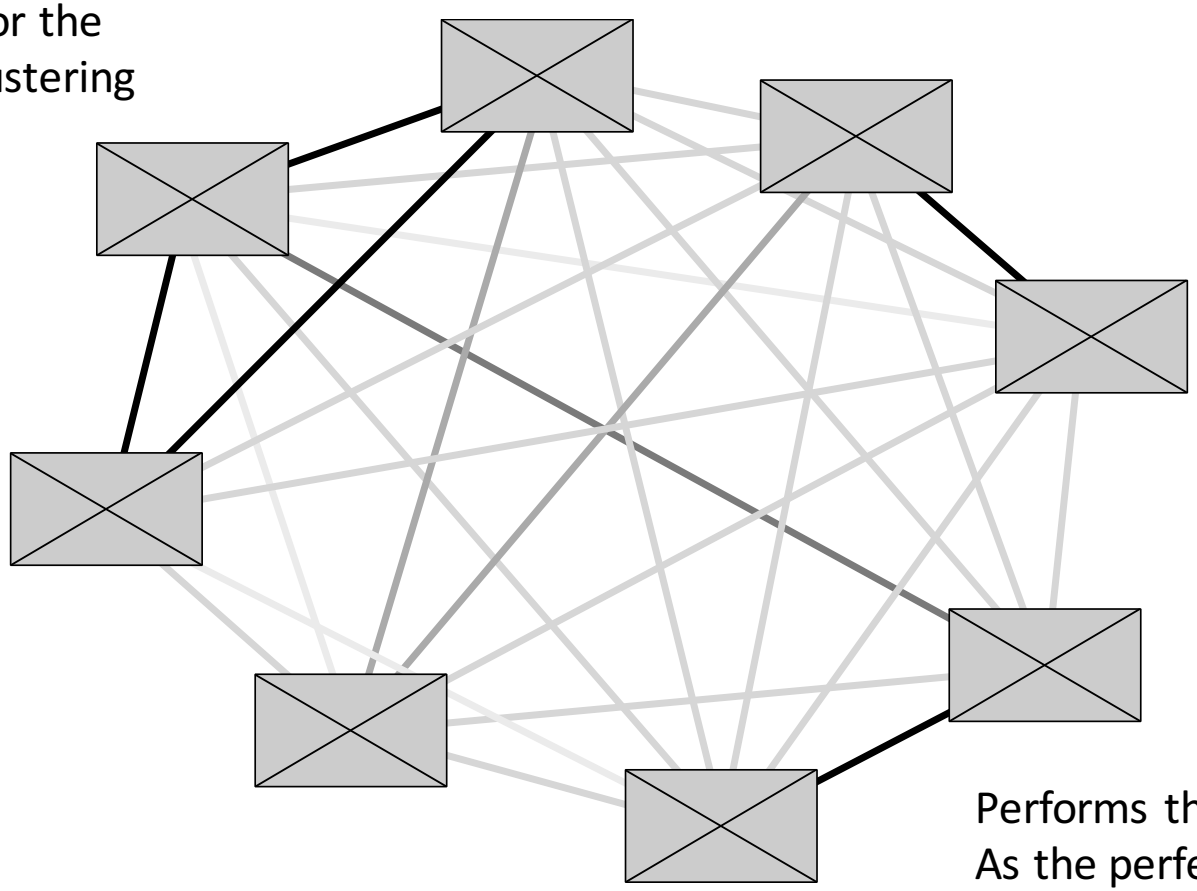




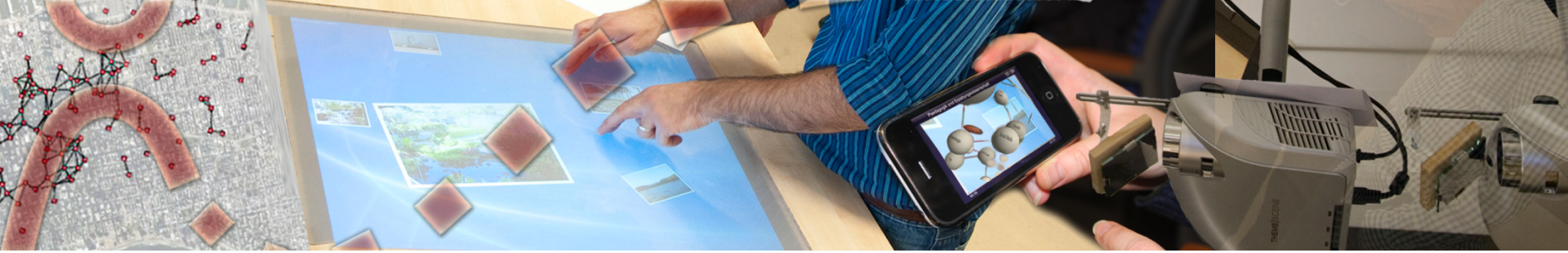
same # of messages

Noisy linkability information

Searches for the optimal clustering



Performs the same attack
As the perfect attacker



Smart Meter Privacy

Telecooperation Lab

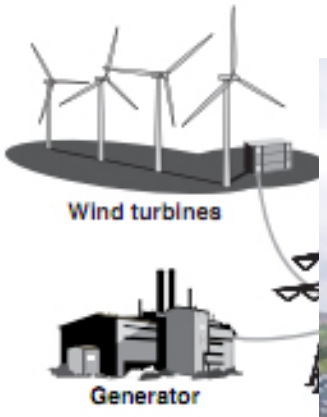
TECHNISCHE UNIVERSITÄT DARMSTADT

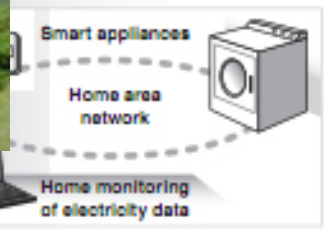
CASED

Smart Grid Anatomy

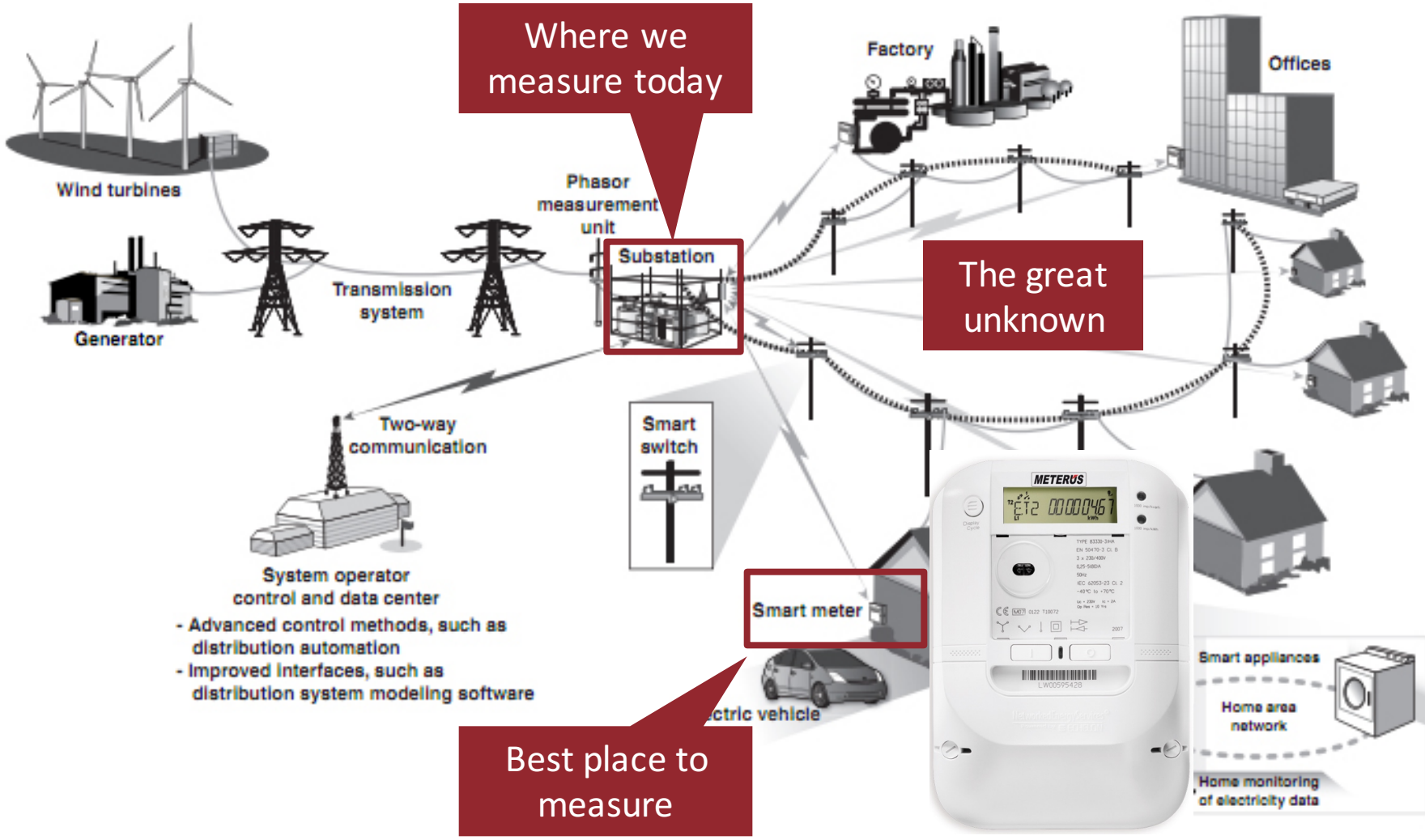
TECHNISCHE UNIVERSITÄT DARMSTADT

Where we





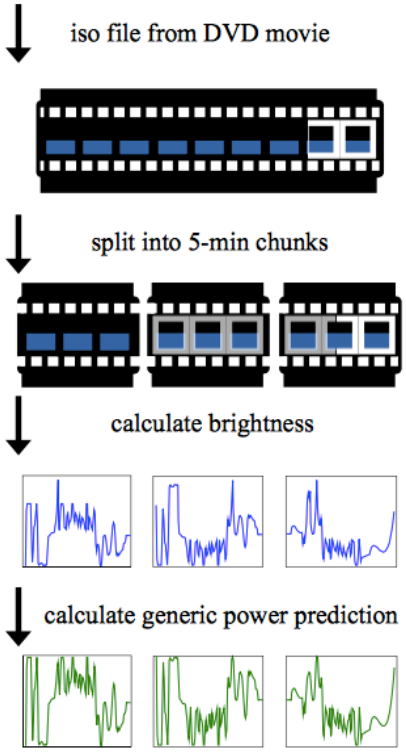
Smart Grid Anatomy

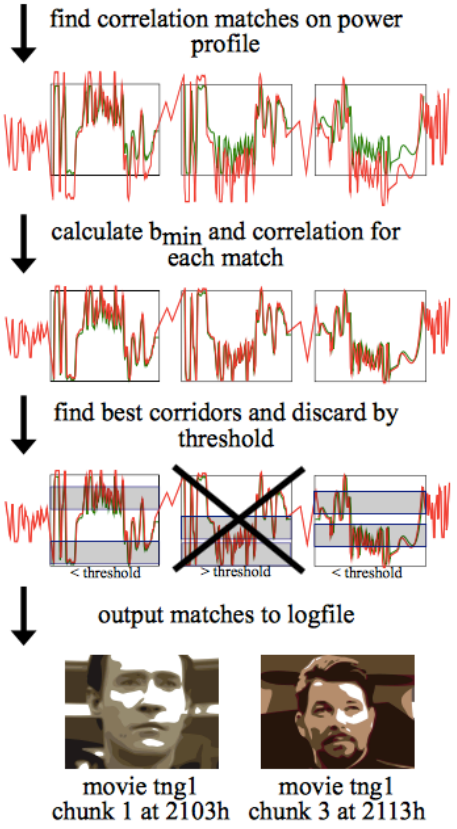


Smart Meter Privacy Issue

Greveler 2012
Smart Meter pilot project
Real meter
Real energy supplier
Real plain HTTP
2s intervals

Flat screen TV:
more white →
more power



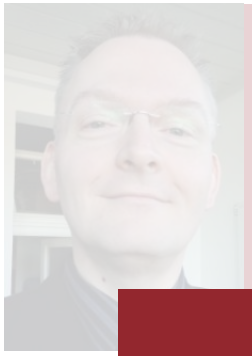



```
POST /api/w.html HTTP/1.1
Content-Type: application/
Host:85.214.93.99
Content-Length:851

version=0.9&identity=
{"meterdata":"00000285.982
{"meterdata":"00000285.9824793*k
{"meterdata":"00000285.9826075*kWh
{"meterdata":"00000285.9827358*kWh","tickdelta":"0000028
{"meterdata":"00000285.9828636*kWh","tickdelta":"00000285.9827358*kWh","seconds":"399511327.62"},
{"meterdata":"00000285.9829915*kWh","tickdelta":"00000285.9828636*kWh","seconds":"399511329.62"},
{"meterdata":"00000285.9831196*kWh","tickdelta":"00000285.9829915*kWh","seconds":"399511331.62"},
{"meterdata":"00000285.9832476*kWh","tickdelta":"00000285.9831196*kWh","seconds":"399511333.62"}]
&now=399511335.65
```


00000285.9822239*kWh","seconds":"399511319.61"},
00000285.9823514*kWh","seconds":"399511321.61"},

Smart Meter Privacy Issue



Greveler 2012
Smart Meter pilot project
Real meter
Real energy supplier
Real plain HTTP

- **No privacy!**
- **Energy supplies learns absolutely everything!**
- **Noise (fridge, etc) does NOT help!**
- **80% of EU households with smart meter until 2020**

- **Clear need for technical privacy protection**

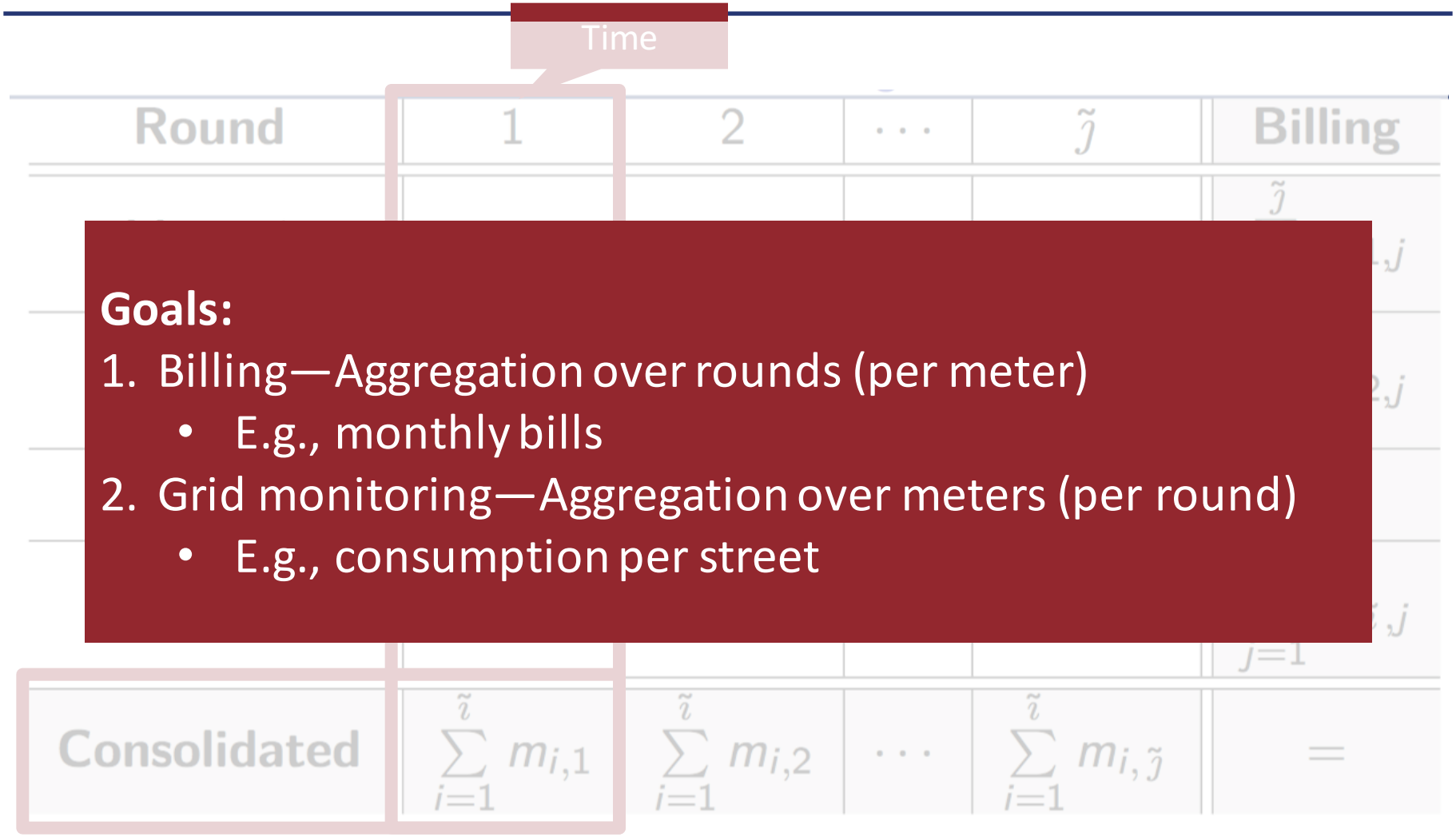
Smart Metering Goals

TECHNISCHE UNIVERSITÄT DARMSTADT

Time

Round	1	2	$\cdots$	$\tilde{j}$	Billing
Meter 1	$m_{1,1}$	$m_{1,2}$	$\cdots$	$m_{1,\tilde{j}}$	$\sum_{j=1}^{\tilde{j}} m_{1,j}$
Meter 2	$m_{2,1}$	$m_{2,2}$	$\cdots$	$m_{2,\tilde{j}}$	$\sum_{j=1}^{\tilde{j}} m_{2,j}$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
Meter $\tilde{i}$	$m_{\tilde{i},1}$	$m_{\tilde{i},2}$	$\cdots$	$m_{\tilde{i},\tilde{j}}$	$\sum_{j=1}^{\tilde{j}} m_{\tilde{i},j}$
Consolidated	$\sum_{i=1}^{\tilde{i}} m_{i,1}$	$\sum_{i=1}^{\tilde{i}} m_{i,2}$	$\cdots$	$\sum_{i=1}^{\tilde{i}} m_{i,\tilde{j}}$	$=$

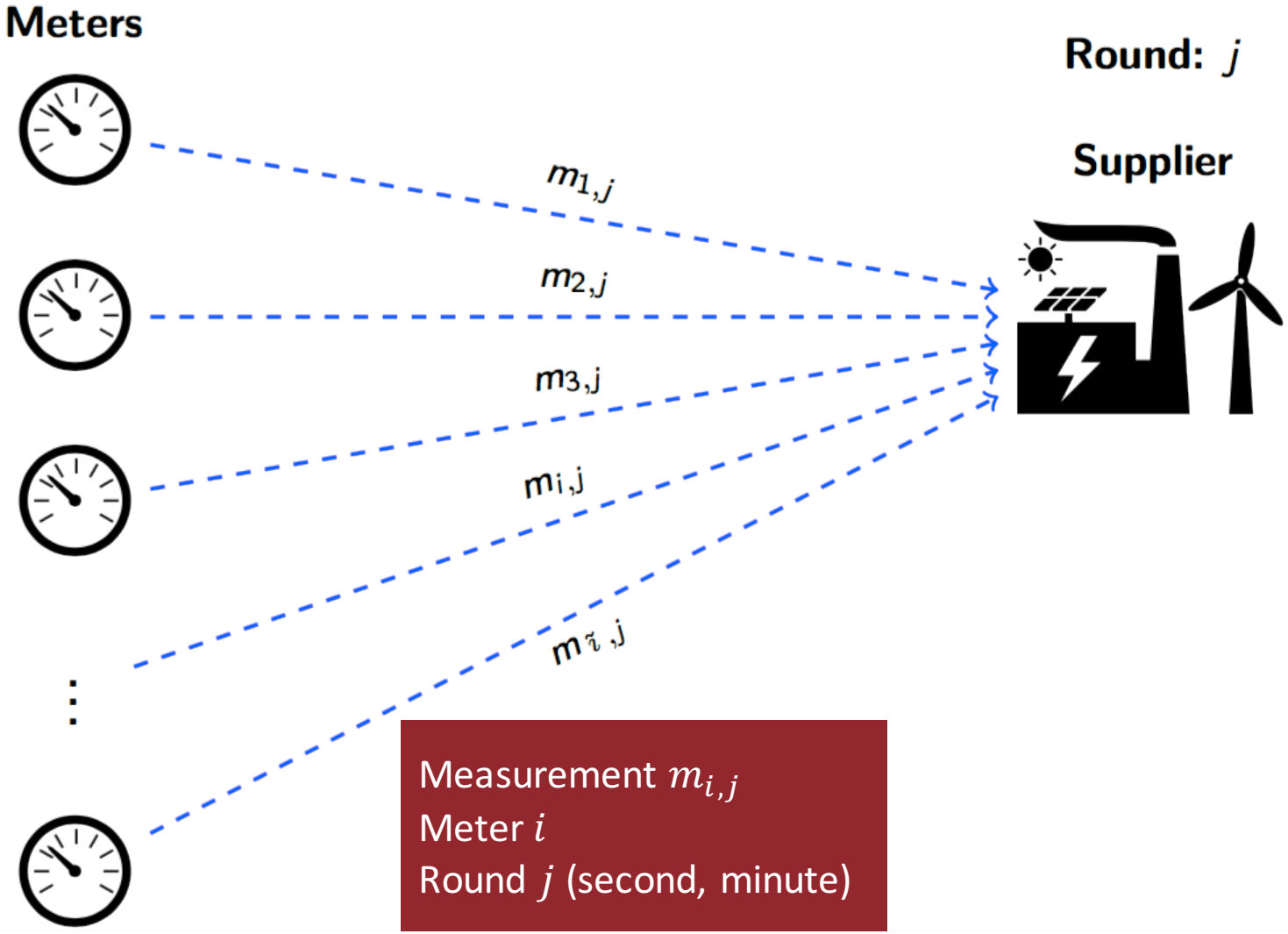
Smart Metering Goals



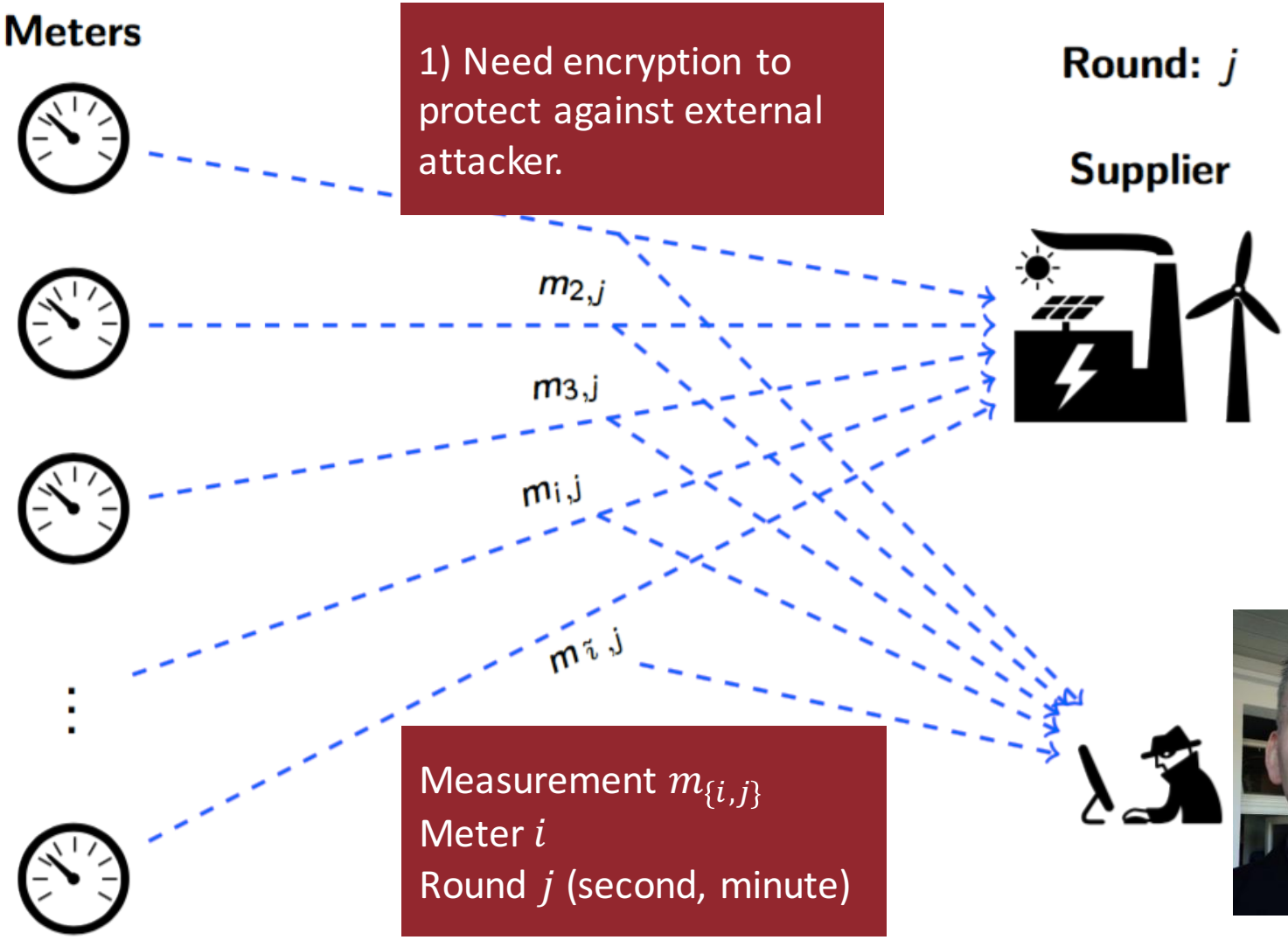
Goals:

1. Billing—Aggregation over rounds (per meter)
   - E.g., monthly bills
2. Grid monitoring—Aggregation over meters (per round)
   - E.g., consumption per street

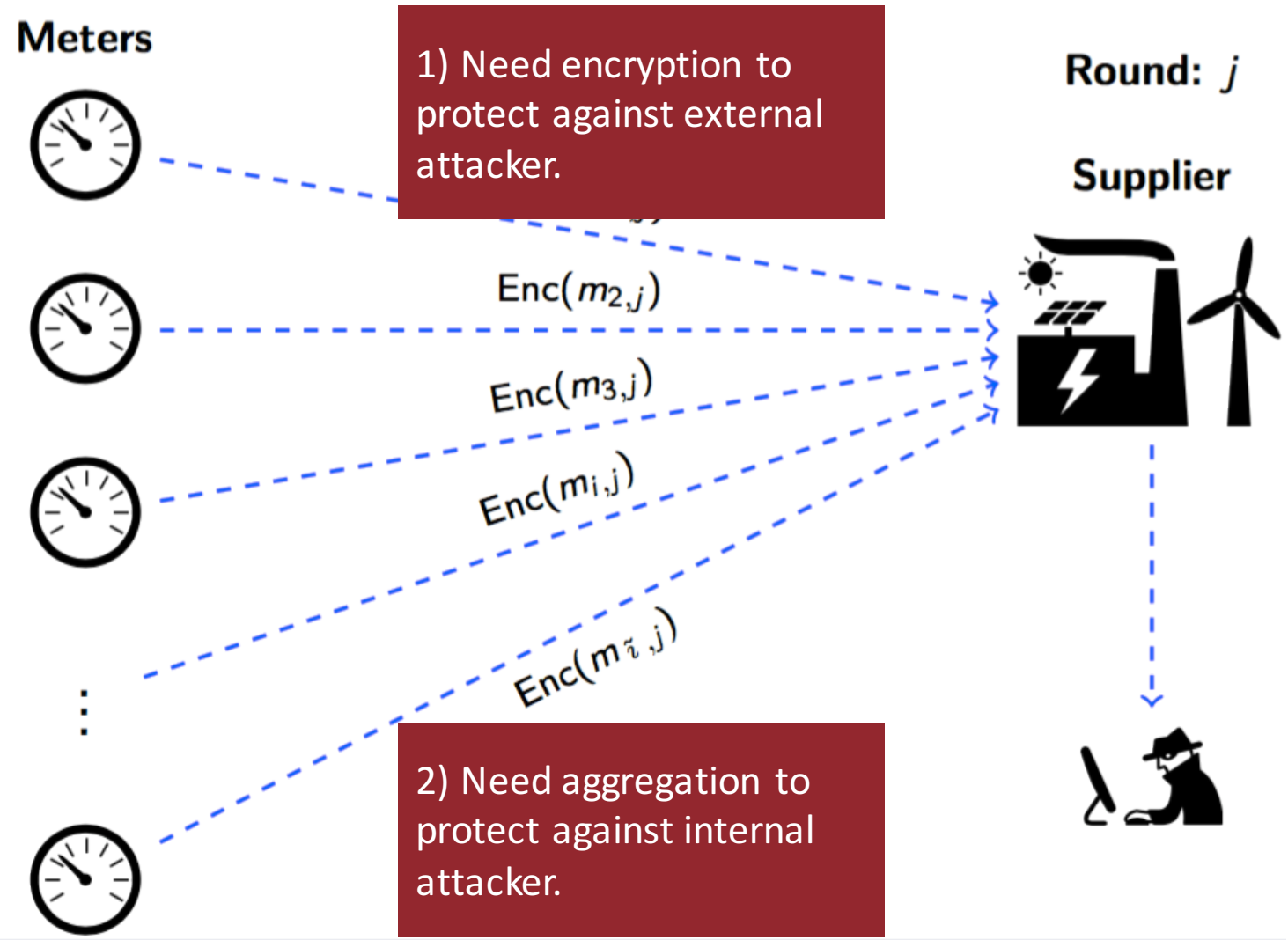
Smart Metering Protocol (1)



Smart Metering Protocol (2)



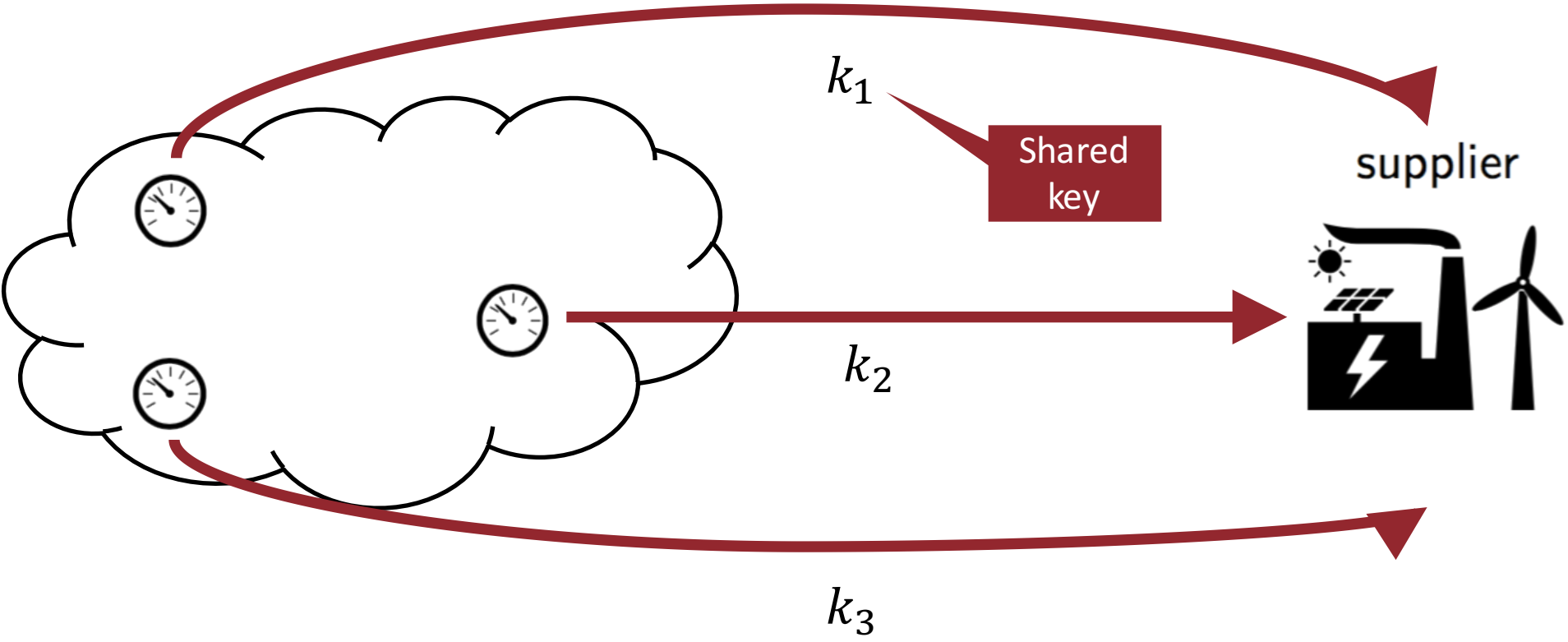
Smart Metering Protocol (3)



In Network Aggregation (PPP1)

TECHNISCHE UNIVERSITÄT DARMSTADT

Step 0 (setup)

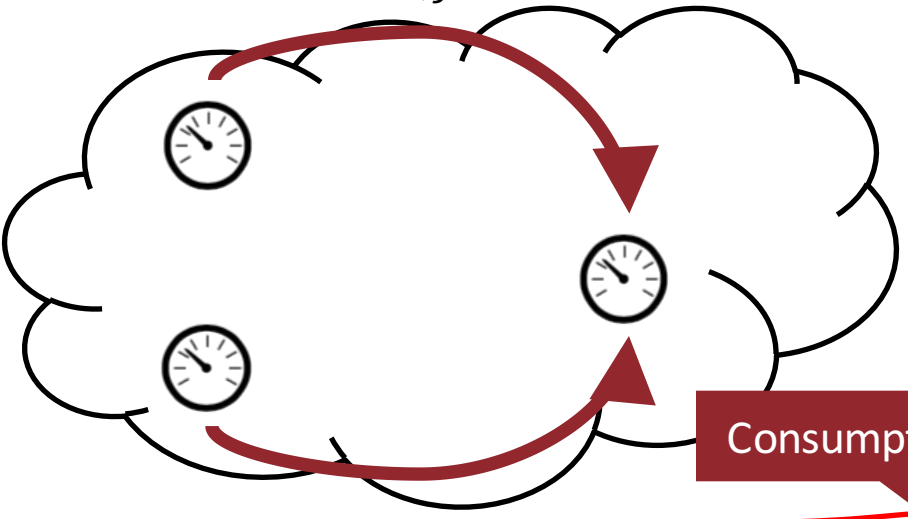


In Network Aggregation (PPP1)

TECHNISCHE UNIVERSITÄT DARMSTADT

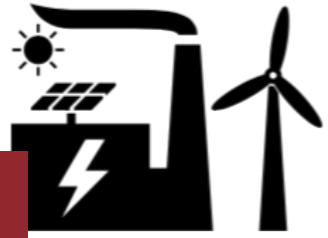
Step 1

$Enc(m_{1,j})$



$Enc(m_{3,j})$

supplier



Consumption

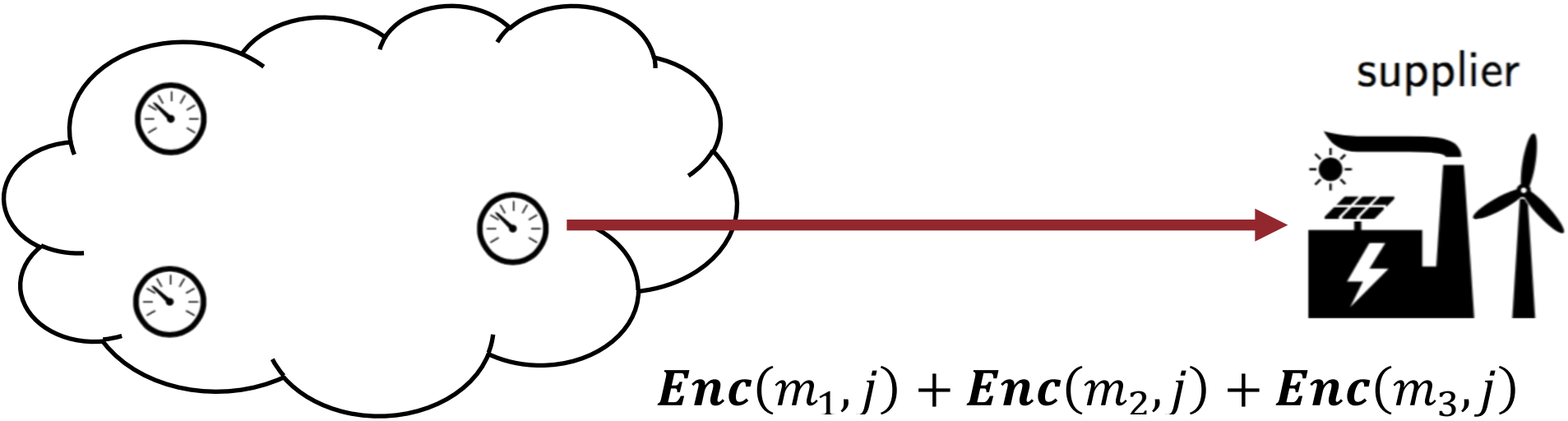
Hash that differs for every meter and every round.

$$Enc(m_{i,j}) = m_{i,j} + H(k_i||j)$$

In Network Aggregation (PPP1)

TECHNISCHE UNIVERSITÄT DARMSTADT

Step 2

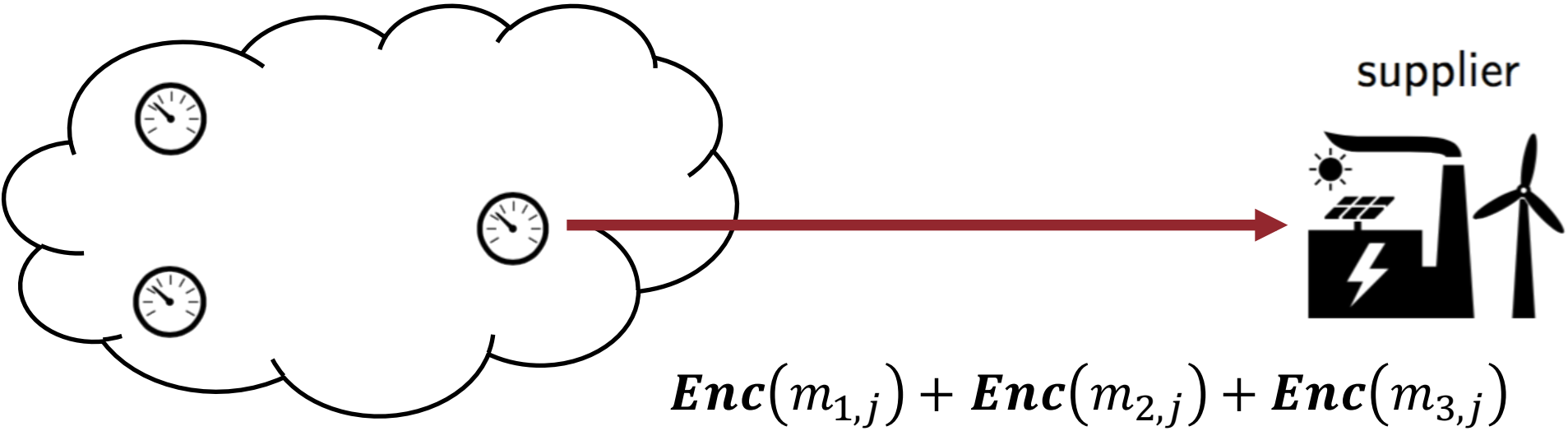


$$\boldsymbol{Enc}(m_1, j) + \boldsymbol{Enc}(m_2, j) + \boldsymbol{Enc}(m_3, j)$$

In Network Aggregation (PPP1)

TECHNISCHE UNIVERSITÄT DARMSTADT

Step 2



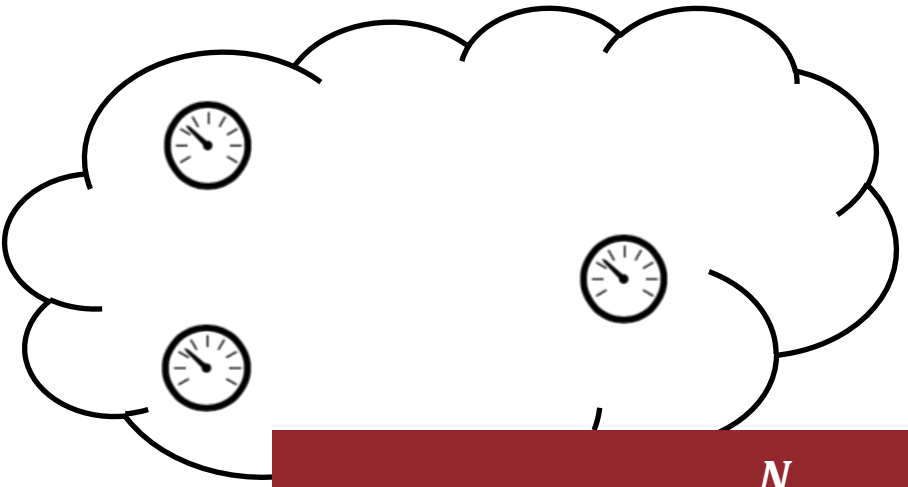
$$\boldsymbol{Enc}(m_{1,j}) + \boldsymbol{Enc}(m_{2,j}) + \boldsymbol{Enc}(m_{3,j}) = \mathbf{Enc}(\mathrm{m_{1,j}} + \mathrm{m_{2,j}} + \mathrm{m_{3,j}}) = \boldsymbol{C}$$

In Network Aggregation (PPP1)

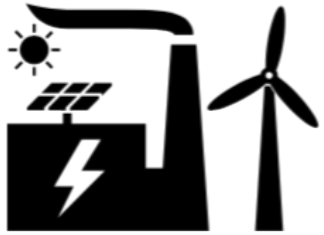
TECHNISCHE UNIVERSITÄT DARMSTADT

Step 3

$$\mathbf{C} = \mathbf{Enc}\left(m_{1,j} + m_{2,j} + m_{3,j}\right)$$



supplier



$$Dec(C) = C - \sum_{i=1}^{N} H(k_i||j) = \sum_{i=1}^{N} m_{i,j}$$

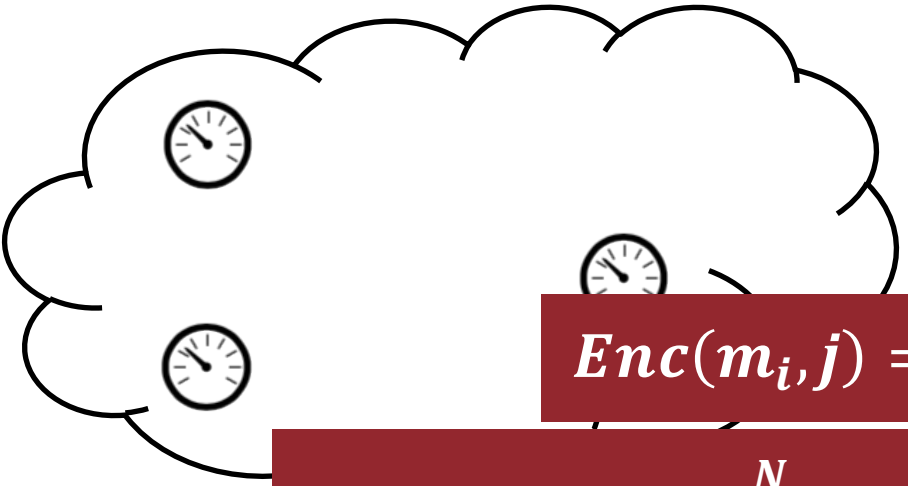
Aggregate over meters

In Network Aggregation (PPP1)

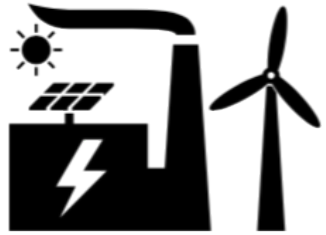
Borges 2014
DC-Net

Step 3

$$\mathbf{C} = \mathbf{Enc}\left(\mathrm{m}_{1,\mathrm{j}} + \mathrm{m}_{2,\mathrm{j}} + \mathrm{m}_{3,\mathrm{j}}\right)$$



supplier



$$\boldsymbol{Enc(m_i, j) = m_{i,j} + H(k_i || j)}$$

$$\boldsymbol{Dec(C) = C - \sum_{i=1}^{N} H(k_1 || j) = \sum_{i=1}^{N} m_{i,j}}$$

Aggregate over meters

Take home message

TECHNISCHE UNIVERSITÄT DARMSTADT

- Privacy protection is a legal requirement
- Data minimization is the technical mean to protect privacy
- Anonymous communication is the basis
  - MIX (practical)
  - DC-Net (theoretical bounds)
- Application layer info can be used for attacks
- Smart Metering as application of DC-Nets
- **Do not try this at home**

Further Reads

TECHNISCHE UNIVERSITÄT DARMSTADT

- Terminology
  - Anonymity, Unobservability, and Pseudonymity - A Proposal for Terminology
    http://dx.doi.org/10.1007/3-540-44702-4_1
- For General understanding of anonymous communication
  - Untraceable electronic mail, return addresses, and digital pseudonyms
    http://dl.acm.org/citation.cfm?id=358563
  - The dining cryptographers problem: *Unconditional sender and recipient untraceability*
    http://link.springer.com/article/10.1007/BF00206326
- *For Application Layer Privacy*
  - Using Linkability Information to Attack Mix-Based Anonymity Services
    https://www.cosic.esat.kuleuven.be/publications/article-1215.pdf
- For Smart Metering Privacy
  - iKUP keeps users' privacy in the Smart Grid
    http://dx.doi.org/10.1109/CNS.2014.6997499