PRIVACY THREAT MODELING

LINDDUN in Action

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Privacy Threat Modeling

OUTLINE

PRIVACY

- Why?
- What?
- *Hands-on exercise (15min)*

PRIVACY THREAT MODELING

- How?
  - LINDDUN / LINDDUN GO
  - Best practices
- *Hands-on exercise (15min)*

TAKE AWAYS

LINDDUN

PRIVACY THREAT MODELING APPROACH

- CREATED 10+ YEARS AGO
  AT DISTRINET/COSIC (KU LEUVEN)
  TOPIC OF **ONGOING DEVELOPMENT**
- INSPIRED BY AND **ALIGNED** WITH MICROSOFT'S STRIDE
- SYSTEMATIC IDENTIFICATION OF **PRIVACY** ISSUES

PRIVACY

WHY PRIVACY MATTERS?

I HAVE DONE NOTHING WRONG, SO I HAVE NOTHING TO HIDE

MISCONCEPTION

WHY PRIVACY MATTERS?

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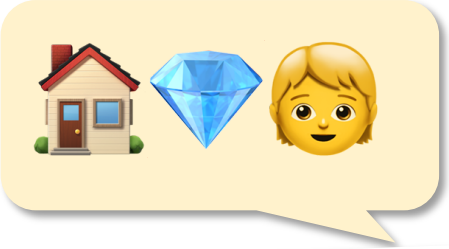
I HAVE DONE NOTHING WRONG, SO I HAVE NOTHING TO HIDE

MISCONCEPTION



Roomba testers feel misled after intimate images ended up on Facebook

Researchers find smart meters could reveal favorite TV shows

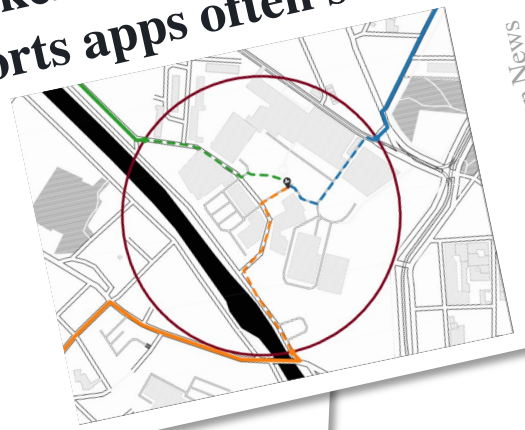
CNET Jan 2012

The Strava the End of

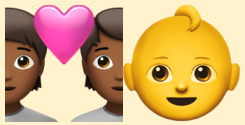
The US military security policies data shared on soc bases and patrol ro

Wired Jan 2018

A run a day won't keep the hacker away: privacy in sports apps often subpar



KU Leuven News Nov 2022



How Target Figured Out A Teen Girl Was Pregnant Before Her Father Did

Forbes Feb 2012

'Gaydar' on Faces Your Friends Reveal Sexual Orientation?

ABCnews Sept 2009

Sex toy company admits to recording users' remote sex sessions, calls it a 'minor bug'

The Verge, Nov 2017

WHY SHOULD PRIVACY MATTER FOR COMPANIES?

WE DO NOT PROCESS PERSONAL DATA!

MISCONCEPTION

PERSONAL DATA:

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

social security number

name

IP address

Cookie ID

address

date of birth

browser fingerprint

location data

SECURITY vs. PRIVACY

MISCONCEPTION

NO WORRIES! WE ALREADY HAVE SECURITY MEASURES IN PLACE.

MISCONCEPTION

WE VALUE SECURITY SO WE CAN'T SUPPORT PRIVACY!

PRIVACY ENGINEERING

INTERVENABILITY
MANAGEABILITY

TRANSPARENCY
PREDICTABILITY

UNLINKABILITY
DISASSOCIABILITY

M. Hansen, M. Jensen and M. Rost, "Protection Goals for Privacy Engineering," *2015 IEEE Security and Privacy Workshops*, 2015

NISTIR 8062 An Introduction to Privacy Engineering and Risk Management in Federal Systems, 2017

UNLINKABILITY

LINKING

IDENTIFYING

DATA DISCLOSURE

DETECTING

NON-REPUDIATION

LINDDUN

LINKING

IDENTIFYING

NON-REPUDIATION

DETECTING

DATA DISCLOSURE

UNAWARENESS

NON-COMPLIANCE

DistriNet

LINKING

PLAYING "GUESS WHO"

Linking multiple properties to the same individual

VS.

IDENTIFYING

WINNING "GUESS WHO"

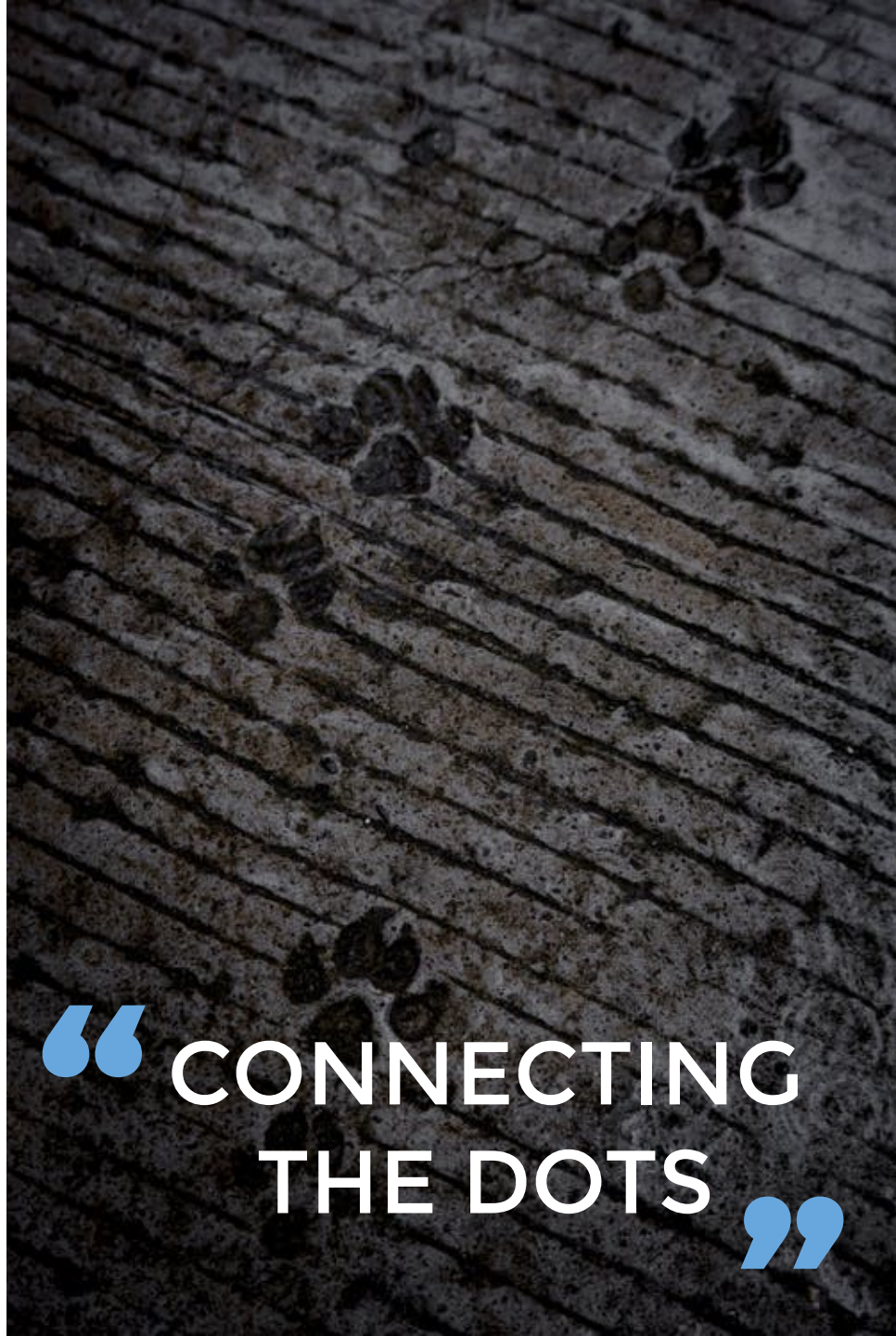
Reducing the set of individuals to one.

DistriNet

LINKING

LEARNING MORE ABOUT AN INDIVIDUAL (OR GROUP) BY MATCHING DATA ITEMS TOGETHER

- Through identifiers
- Through combination
- Through profiling/derivation/inference



IDENTIFYING

LEARNING

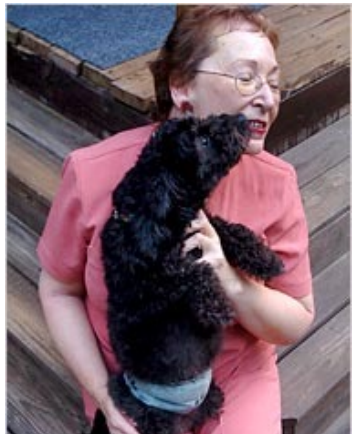
THE IDENTITY

- Through direct identifiers
- Through identifiable information
  - Pseudonyms
  - Revealing content
  - Small anonymity set (set of individuals)

EXAMPLE
Identifying

Aol.

- Clothes for age 60
- 60 single men
- Best retirement city
- Jarrett arnold
- Jack t. arnold
- Jaylene and jarrett arnold
- Gwinnett county yellow pages
- Rescue of older dogs
- Movies for dogs
- Sinus infection



Thelma Arnold
62 year old widow
Lilburn, Georgia

DistriNet

NON-REPUDIATION

PROOF OF A CLAIM ABOUT AN INDIVIDUAL

- Evidence of the claim / action
- Attribution to the individual

PERIOD TRACKING APPS

EXAMPLE
Non-repudiation

ROE VS. WADE

DETECTING

DEDUCING SUBJECT INVOLVEMENT BY OBSERVING EXISTENCE OF RELEVANT INFORMATION

- Observed communication
- Application side-effects
- System responses

DATA DISCLOSURE

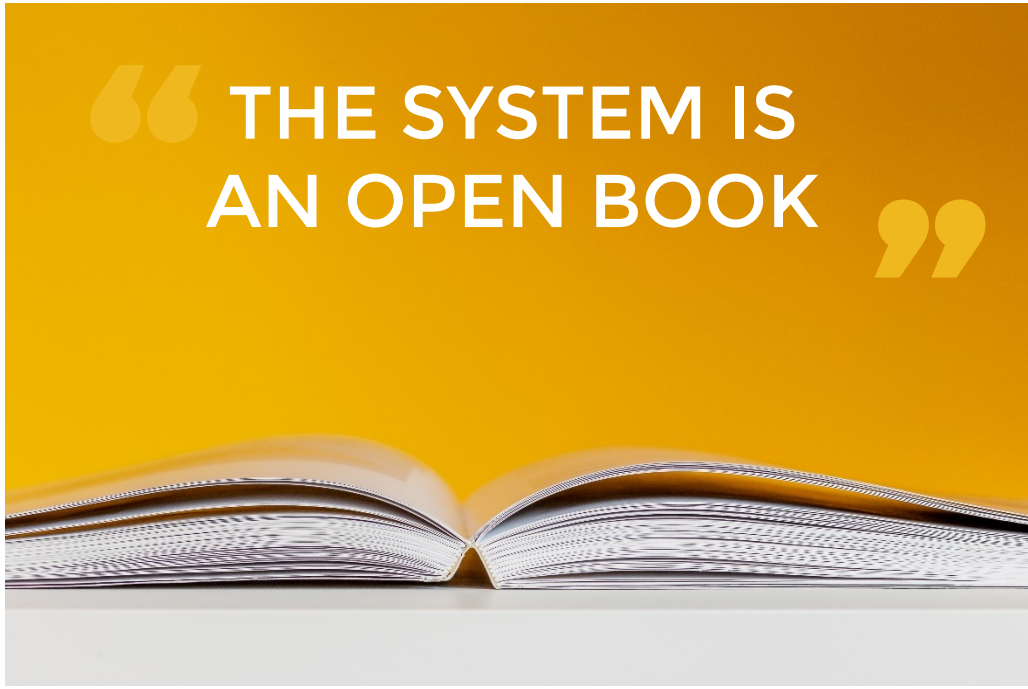
UNNECESSARY USE OF DATA

- Excessive data types
- Excessive volume
- Excessive processing
- Excessive exposure

- collection
- storage
- processing
- sharing

- Unawareness of data subject
- Unawareness of user sharing personal data (about others or themselves)

INSUFFICIENTLY INFORMING ABOUT THE PROCESSING OF PERSONAL DATA



UNAWARENESS

LACK OF DATA SUBJECT CONTROL

- Lack of preferences control
- Lack of access
- Lack of rectification/erasure

DARK PATTERNS

EXAMPLE
Unawareness

HIDING THE PRIVACY INFORMATION

WANT TO KNOW MORE?

and therefor do you allow us to collect and process all your personal data?

YES!
SHOW ME THE COOL STUFF

No, I don't consent

NUDGING TO SELECT THE LESS PRIVACY-FRIENDLY BUTTON

HIDING THE OPT-OUT

NON-COMPLIANCE

LACK OF ADHERENCE TO LEGISLATION, REGULATION, STANDARDS AND BEST PRACTICES

4

- Lawfulness
- Data lifecycle management
- Cybersecurity risk management

SECURITY AND PRIVACY

TRUTH

PRIVACY REQUIRES A DIFFERENT MINDSET

SECURITY	PRIVACY
• Protecting data	• Protecting personal data
• Company assets	• Data subject assets
• (External) attacker	• Attacker + (internal) 'misbehavior'

TRUTH

PRIVACY DOESN'T NEED TO CONFLICT SECURITY

HANDS-ON #1

- Threat Modeling Manifesto value

Doing threat modeling
over talking about it.

EXERCISE 1

HOLLYWOOD BLOCKBUSTER SCENARIO

1. DISCUSS AND LIST ALL MISACTORS THAT COULD VIOLATE YOUR MAIN CHARACTER'S PRIVACY.

2. DESCRIBE EACH SCENARIO. HOW COULD IT BE DONE? WHAT INFORMATION COULD BE USED/DEDUCED?

3. DISCUSS THE PARALLELS WITH THE ONLINE WORLD.

EXERCISE 1: READOUT

HOLLYWOOD BLOCKBUSTER SCENARIO

SHARE 1-2 SCENARIOS THAT YOU IDENTIFIED.

WHO WAS INVOLVED?

HOW DID THEY VIOLATE THE PRIVACY?

Privacy Threat Modeling

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- *Hands-on exercise (15min)*

PRIVACY THREAT MODELING

- How?
  - LINDDUN / LINDDUN GO
  - Best practices
- *Hands-on exercise (15min)*

TAKE AWAYS

THREAT MODELING

1. WHAT IS GOING ON?
2. WHAT CAN GO WRONG?
3. WHAT TO DO ABOUT IT?
4. WAIT A MINUTE?!

HOW TO THREAT MODEL?

1. MODEL THE SYSTEM

- Create DFD / white board sketch / …

2. ELICIT THREATS

- Map model components
- Identify threats

3. MITIGATE THREATS

- Assess & prioritize
- Mitigate

4. REFLECT

- Reflect & repeat

All models are wrong, some are useful *- G. Box*

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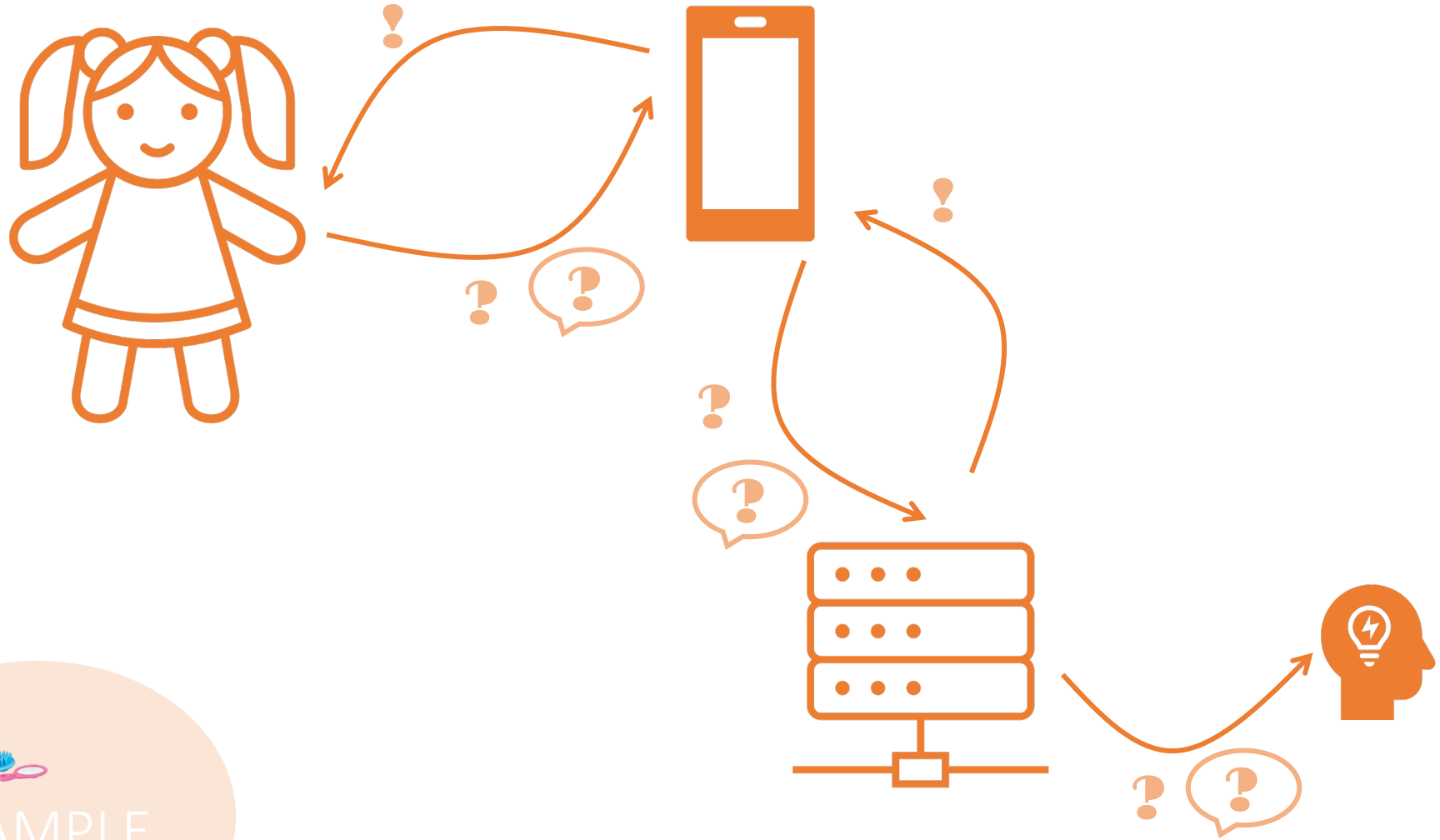

Question(s)

Voice recordings

Response

EXAMPLE

NOW WHAT?

PROCESS

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REUSABLE KNOWLEDGE

STRIDE

- SPOOFING
- TAMPERING
- REPUDIATION
- INFORMATION DISCLOSURE
- DENIAL OF SERVICE
- ELEVATION OF PRIVILEGE

LINDDUN

- LINKING
- IDENTIFYING
- NON-REPUDIATION
- DETECTING
- DATA DISCLOSURE
- UNAWARENESS
- NON-COMPLIANCE

PROCESS

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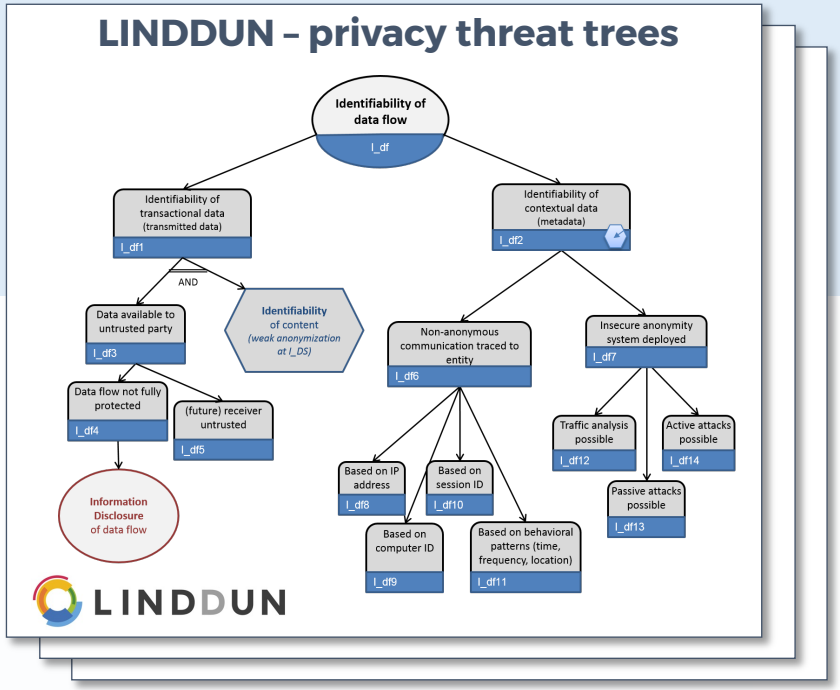
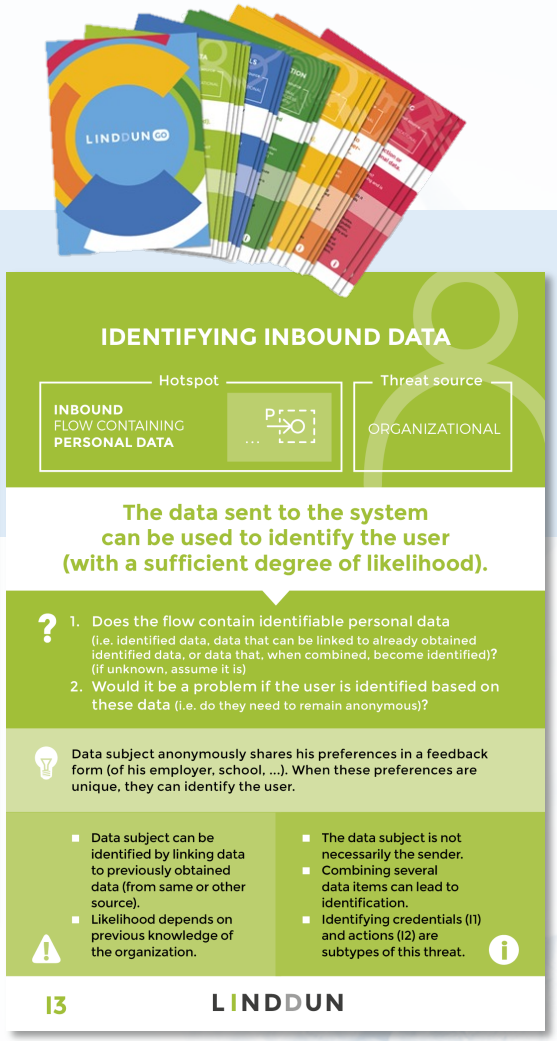


WWW.LINDDUN.ORG



LINDDUN GO cards

PROCESS

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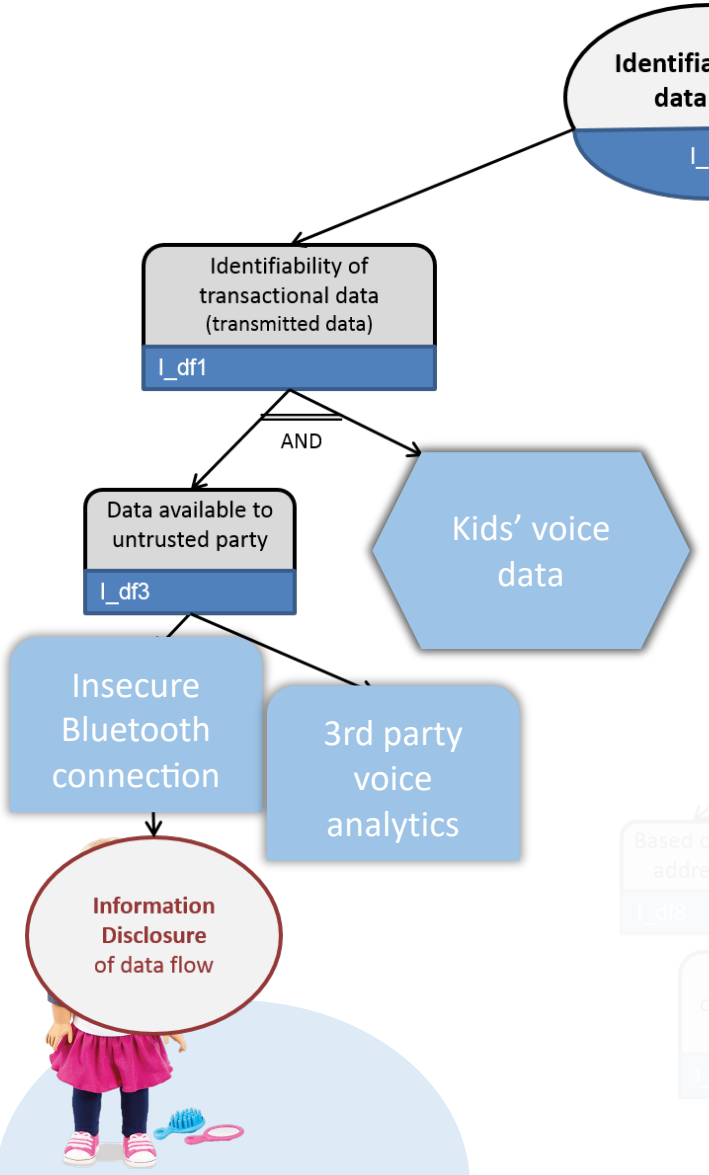


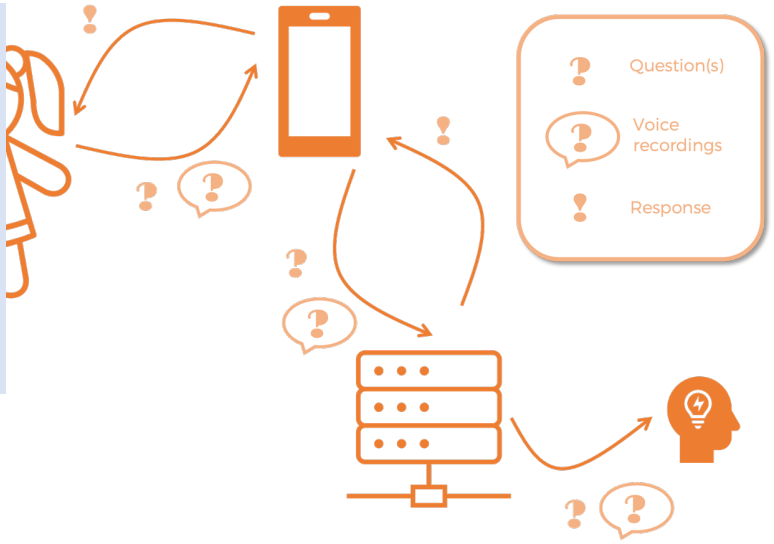
EXAMPLE

THREAT 01

Identifiable kids' voice data is being sent over an insecure communication channel

THREAT 02

Identifiable kids' voice data is being shared with an untrusted 3rd party



LINDDUN GO

LEAN APPROACH TO PRIVACY THREAT MODELING

DECK OF 34 **PRIVACY THREAT CARDS** DESCRIBING MOST COMMON THREATS FOR EACH LINDDUN CATEGORY

FACILITATE AND **STRUCTURE** DISCUSSION

COLLABORATIVE APPROACH TO ENGAGE ALL PARTICIPANTS

- Prioritize threats
  - assess risk (impact & likelihood)

- Mitigate threats
  - Tactics & strategies
  - Privacy patterns
  - PETs

THEN WHAT?

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THREAT 01

Identifiable kids' voice data is being sent over an insecure communication channel

THREAT 02

Identifiable kids' voice data is being shared with an untrusted 3rd party

Before sharing

- Hide – Restrict access. Secure communication between doll and phone.
- Separate – Distribute processing. Local speech to text translation (no sharing of voice to the back-end).

When shared to back-end

- Abstract – summarize/group/perturb recordings. When share to external party, aggregate data, scramble recordings, etc.
- Minimize – select/exclude/strip/destroy data. Don't store recordings. Delete once speech is translated to text. Don't link questions to user profiles.

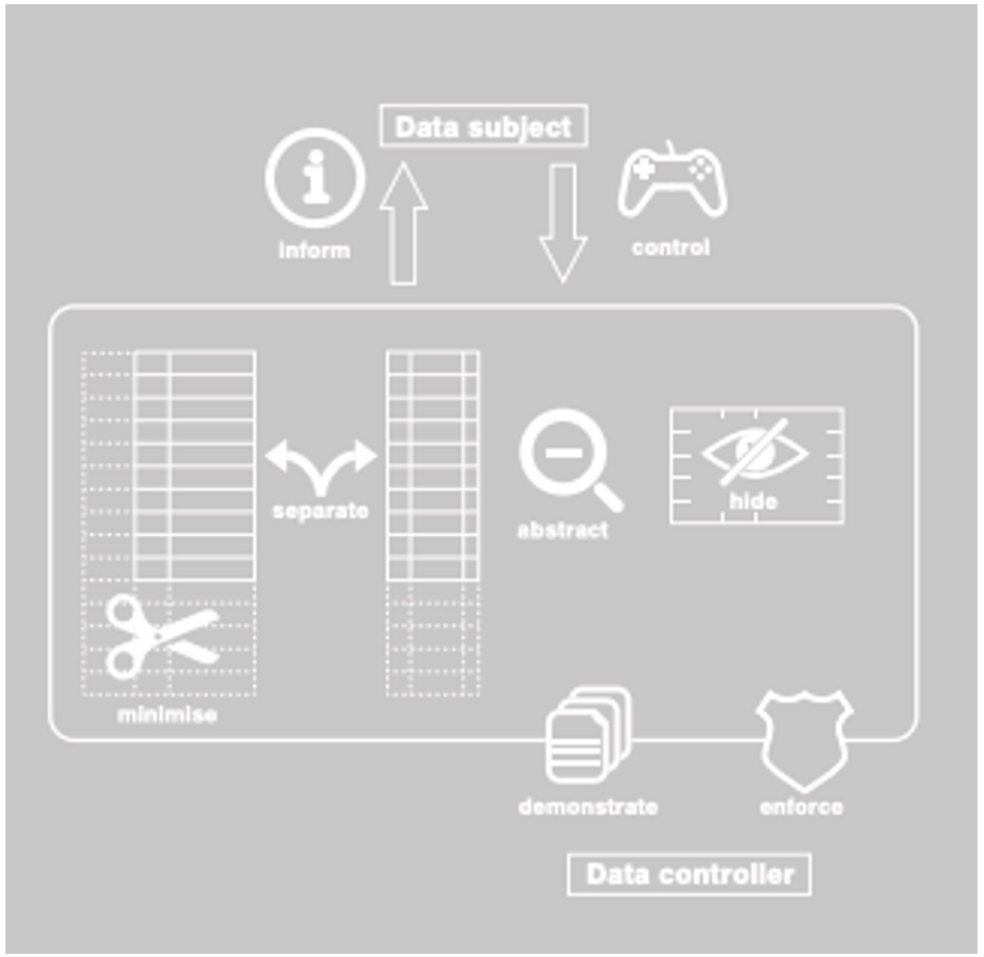
EXAMPLE

Strategies and tactics from:
Jaap-Henk Hoepman, Privacy design strategies (little blue book) https://www.cs.ru.nl/~jhh/publications/pds-booklet.pdf

Privacy design strategies

(Hoepman)

MITIGATING THREATS



- Minimise
  - Limit as much as possible the processing of personal data.
- Separate
  - Separate the processing of personal data as much as possible.
- Abstract
  - Limit as much as possible the detail in which personal data is processed.
- Hide
  - Protect personal data, or make it unlinkable or unobservable. Make sure it does not become public or known.
- Inform
  - Inform data subjects about the processing of their personal data in a timely and adequate manner.
- Control
  - Provide data subjects adequate control over the processing of their personal data.
- Enforce
  - Commit to processing personal data in a privacy-friendly way, and adequately enforce this.
- Demonstrate
  - Demonstrate you are processing personal data in a privacy-friendly way.

Jaap-Henk Hoepman, Privacy design strategies (little blue book)
https://www.cs.ru.nl/~jhh/publications/pds-booklet.pdf

MITIGATE THREATS

- LINDDUN privacy mitigation strategies and privacy solutions
  www.linddun.org/mitigation-strategies-and-solutions
- NIST SP 800-53 security and privacy controls
  https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-53r5.pdf
- Privacy design strategies (Hoepman)
  https://www.cs.ru.nl/~jhh/publications/pds-booklet.pdf
- Patterns
  - Security: https://securitypatterns.distrinet-research.be/
  - Privacy: privacypatterns.org privacypatterns.eu
- OWASP cheat sheets:
  https://cheatsheetseries.owasp.org/
- …

DID I DO A GOOD ENOUGH JOB?

PROCESS

1. MODEL THE SYSTEM

- Create DFD / white board sketch / …

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4. REFLECT

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USEFUL RESOURCES

- *Threat modeling. Designing for security.* By Adam Shostack, 2014.
- *Threat Modeling – A Practical Guide for Development Teams* by Izar Tarandach & Matthew J. Coles, 2020
- *Securing systems. Applied security architectures and threat models* by Brook Schoenfield, 2015.
- Threat Modeling Manifesto *www.threatmodelingmanifesto.org*
- Threat Modeling Connect community *www.threatmodelingconnect.com*

THREAT MODELING APPROACHES

- **STRIDE**
- **LINDDUN** PRIVACY

- EoP
- PASTA
- TRIKE
- TARA
- Continuous Threat Modeling

- INCLUDES NO DIRT PRIVACY
- PLOT4AI PRIVACY
- TRIM PRIVACY
- STRIPED PRIVACY

https://insights.sei.cmu.edu/blog/threat-modeling-12-available-methods/

PRIVACY THREAT MODELING

BEST PRACTICES

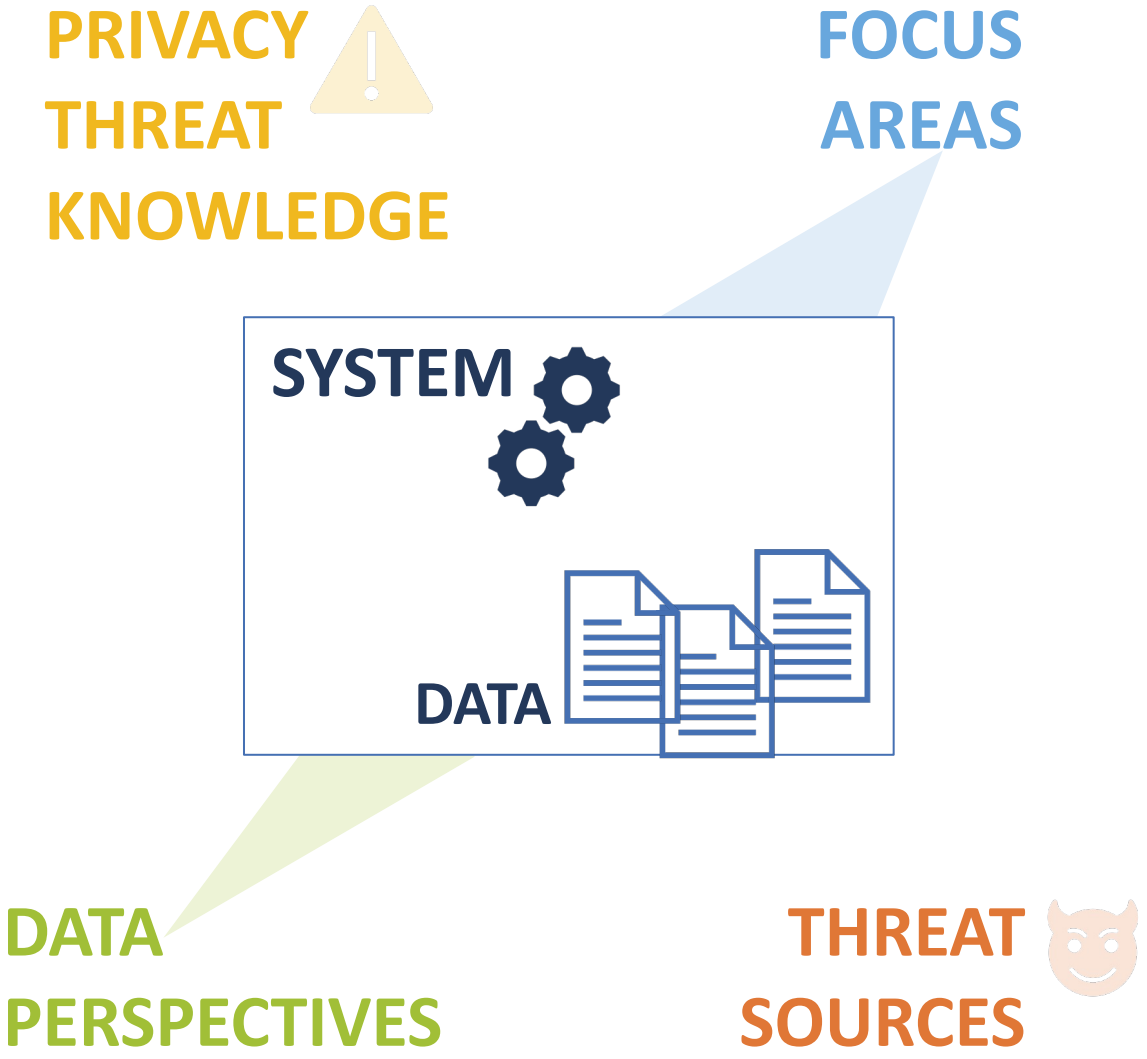
PRIVACY THREAT MODELING

What you need?

Understanding of the system & data (dfd, whiteboard sketch, …)

What you do?

Analyze the **privacy threats** that are posed by the different **threat sources** at play to the individuals associated with the **data** that are being processed by the **system**



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PRIVACY THREAT KNOWLEDGE

LINDDUN

- Threat trees
- GO cards
- Threat categories

Use **knowledge** as

- ❑ Structured guidance
- ❑ Facilitation of discussion
- ❑ Gap analysis
- ❑ …

Privacy threat categories

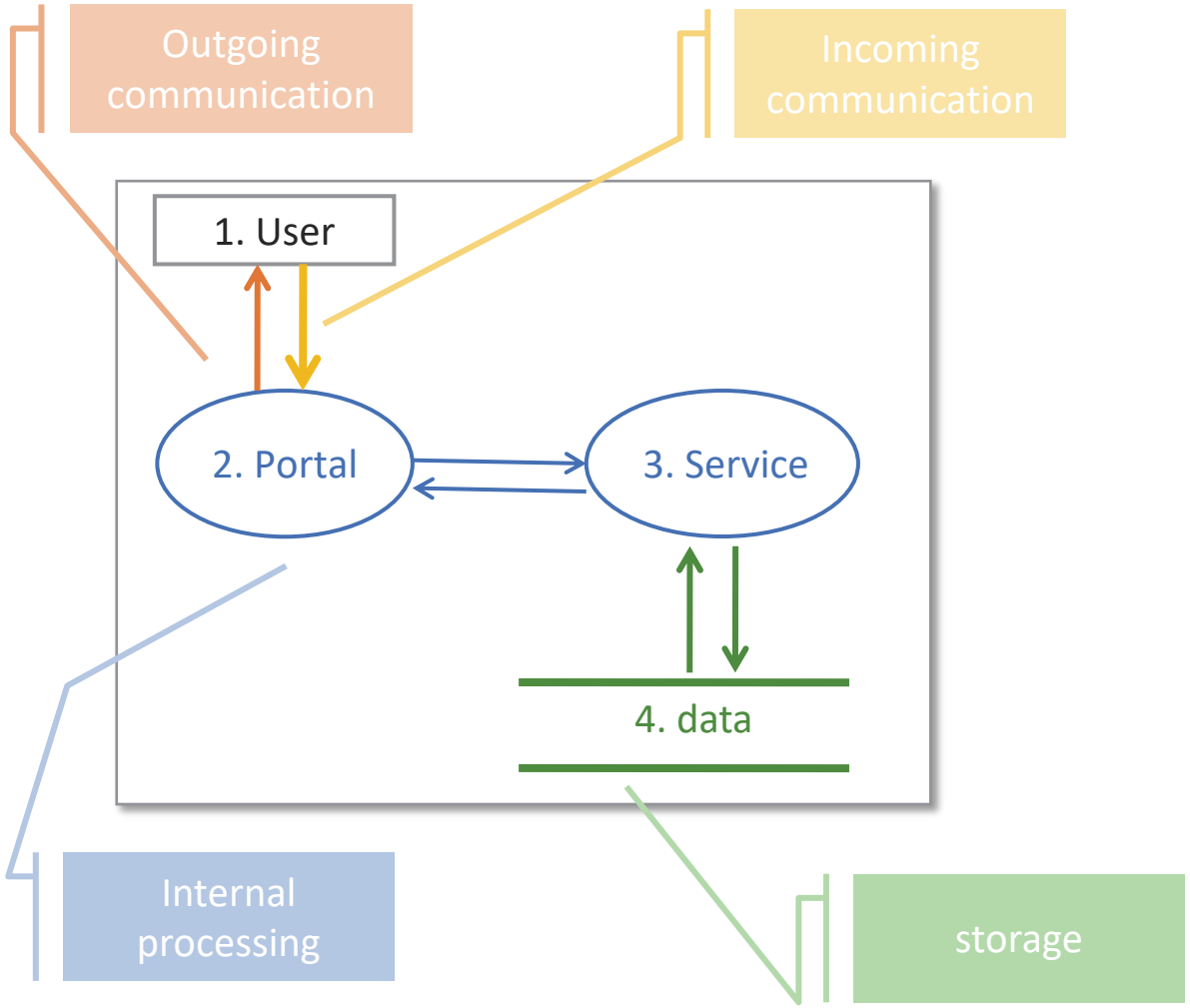
Classification of known privacy issues.

- Data disclosure
- Linking
- Identifying
- Detecting *
- Non-repudiation *
- Unawareness
- Non-compliance *

1

FOCUS AREAS

WHAT PART OF THE SYSTEM ARE WE ASSESSING?



Focus areas

Parts of the system model that require a detailed privacy analysis.

- Incoming communication
- Outgoing communication
- Storage
- Internal processing *

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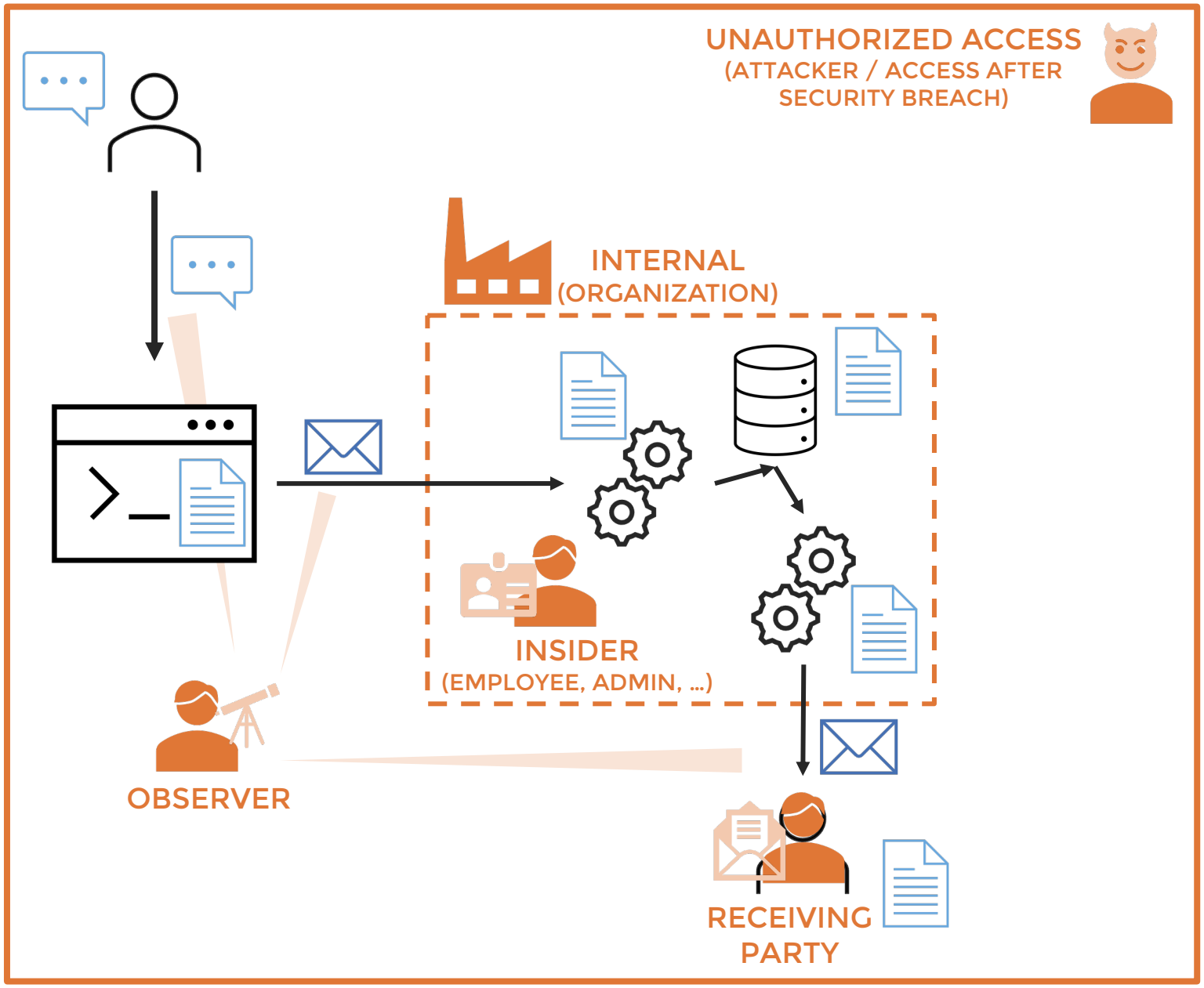
THREAT SOURCES



INTERACTIONS WITH THE SYSTEM
OR ACTIONS THAT INDIRECTLY TRIGGER THE SYSTEM

- IPHONE PICTURES ARE AUTOMATICALLY SAVED TO THE CLOUD

- PEOPLE TAGGED
- PLACES TAGGED
- LOCATION COORDINATES SAVED BY CAMERA
- DATE OF PICTURE SAVED BY CAMERA
- CAMERA SPECIFICATIONS SAVED BY CAMERA

- BOB TAGGED BY ALICE
- AT RESTAURANT *R*
- IN BRUSSELS
- ON FEBRUARY 14, 2022 AT 20h
- PICTURE TAKEN WITH IPHONE 13

PICTURES OF ALICE

- BOB IS IN A RELATIONSHIP WITH ALICE
- A & B HAD DINNER AT RESTAURANT *R*
- BOB WAS WITH ALICE ON *FEB14 2022*
- ALICE OWNS AN IPHONE 13

INFORMATION DEDUCED FROM EXPLICIT AND IMPLICIT DATA.

DATA PERSPECTIVES

EXPLICIT DATA + IMPLICIT METADATA → IMPLICIT INFERRED DATA

OWN OR EXTERNAL SOURCES

PROFILING OF INDIVIDUAL OR GROUP

ACTIONS

PRIVACY

NOT A BLACK/WHITE CONCEPT

INSPIRATION

not LIMITATION

“Allow for creativity by including both craft and science.”

- Threat Modeling Manifesto pattern Informed Creativity

HANDS-ON #2

- Threat Modeling Manifesto value

Doing threat modeling
over talking about it.

EXERCISE 2: LINDDUN GO

VOICE ASSISTANTS

Siri Privacy Whistleblower Unmasks to Urge Stricter Voice Assistant Privacy Regulation

ERIC HAL SCHWARTZ on May 20, 2020 at 3:30 pm

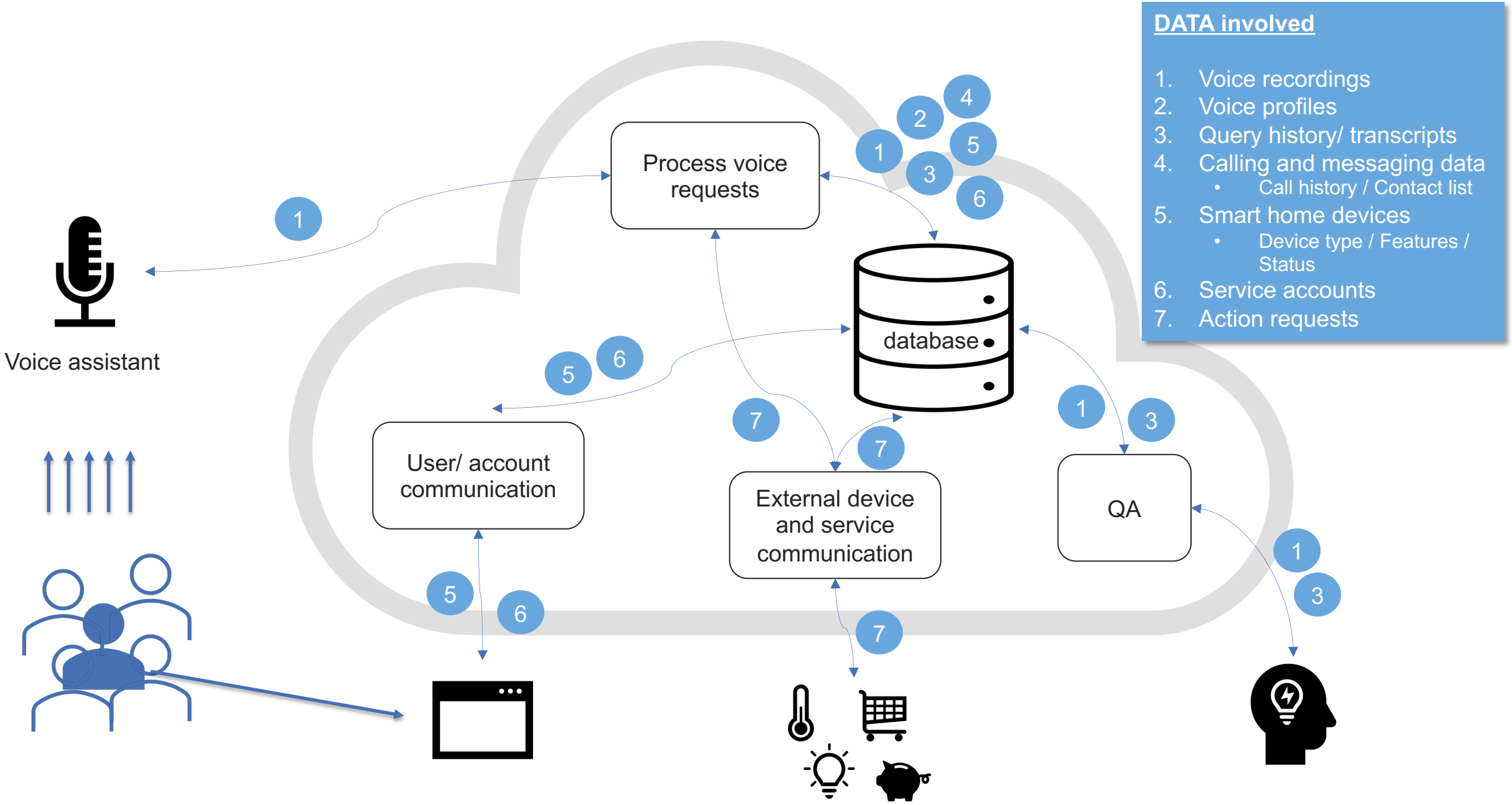
Alexa has been eavesdropping on you this whole time

When Alexa runs your home, Amazon tracks you in more ways than you might want.

Alexa has so many recordings of me, I made a song out of them.

amazon

'Alexa, are you invading my privacy?' – the dark side of our voice assistants


DATA involved
1. Voice recordings
2. Voice profiles
3. Query history/ transcripts
4. Calling and messaging data
• Call history / Contact list
5. Smart home devices
• Device type / Features / Status
6. Service accounts
7. Action requests
Voice assistant
Process voice requests
database
User/ account communication
External device and service communication
QA

LINKABILITY OF INBOUND DATA

Hotspot

INBOUND FLOW CONTAINING **PERSONAL DATA**

Threat source

ORGANIZATIONAL

The data sent to the system are linked to already collected data of the same or other data subjects (from same or other source).

1. Does the flow contain personal data?
2. Does (or can) the system link these data (i.e. are data items sufficiently unique to link to each other) in a privacy-violating way?

- Data subject shares minimal set of information (e.g. city instead of full address), yet given the information already available (e.g. only 1 person of that city in the system), the data can be easily linked.

- Information can be deduced based on the linked data (inference).
- Threat depends on the knowledge of the organization.

- The data subject is not necessarily the sender of the data.
- Linkability of credentials (L1) and actions (L2) are subtypes of this threat.

L3

LINDDUN

#1

DATA involved

1. Voice recordings
2. Voice profiles
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   - Call history / Contact list
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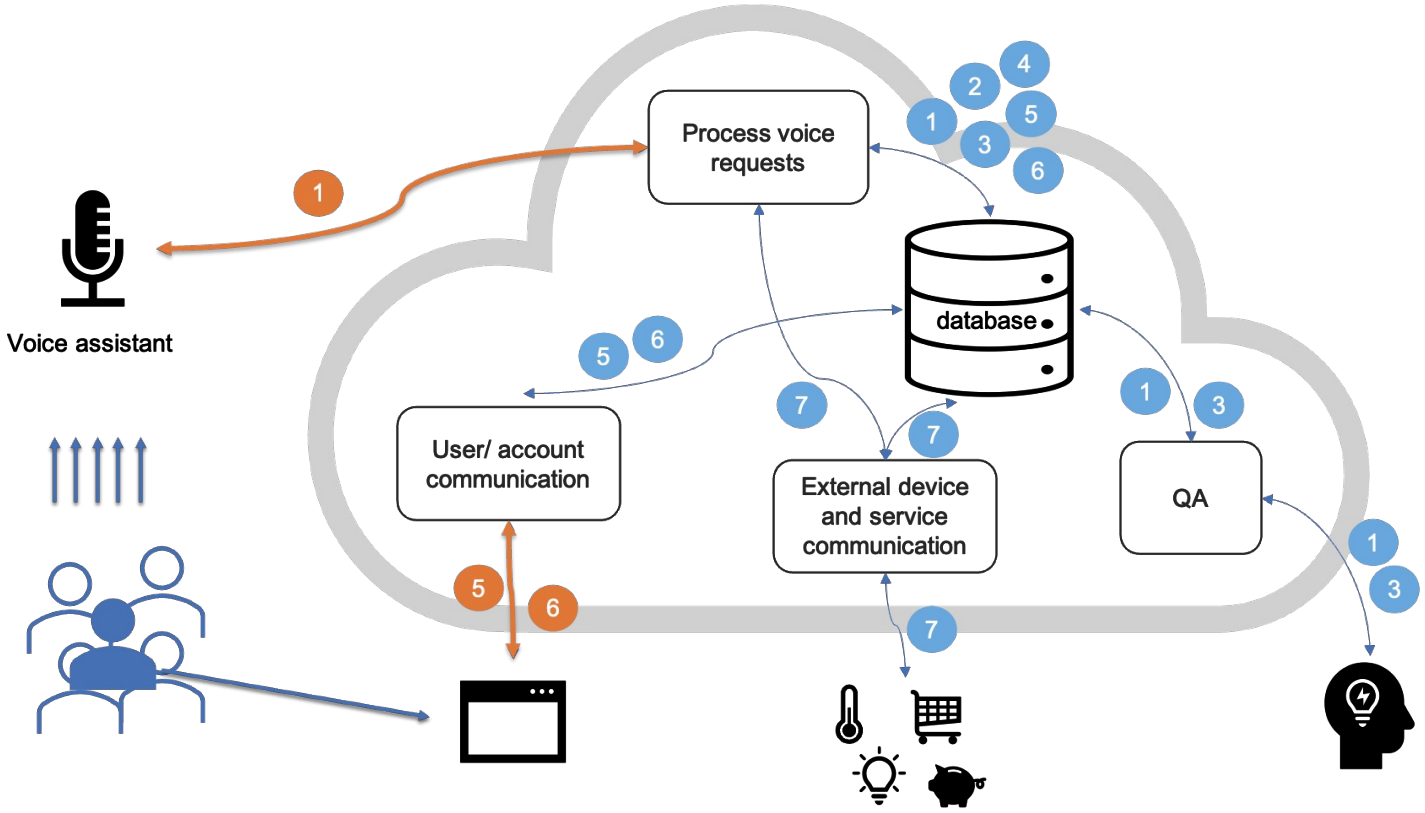

EXERCISE 2: LINDDUN GO

VOICE ASSISTANTS

1 ITERATE OVER THE LINDDUN GO CARDS (SUBSET IN SLIDES). DISCUSS AND LIST ALL POTENTIAL PRIVACY THREATS RELATED TO THE LINDDUN GO CARD(S) FOR THE SYSTEM COMPONENTS INVOLVED.

START WITH THE # OF YOUR BREAKOUT GROUP

TAKE TURNS DISCUSSING POTENTIAL THREATS


LET'S DO THIS
IDENTIFYING CONTEXT
DISPROPORTIONATE PROCESSING
DETECTABLE AT RETRIEVAL
NO USER-FRIENDLY PRIVACY
NON-REPUDIATION OF SENDING
IDENTIFYING CREDENTIALS
LINKABILITY OF SHARED DATA
NON-REPUDIATION OF RECEIPT
DISPROPORTIONATE STORAGE
NO ACCESS OR PORTABILITY
LINDDUN

LINKABILITY OF INBOUND DATA

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LINDDUN

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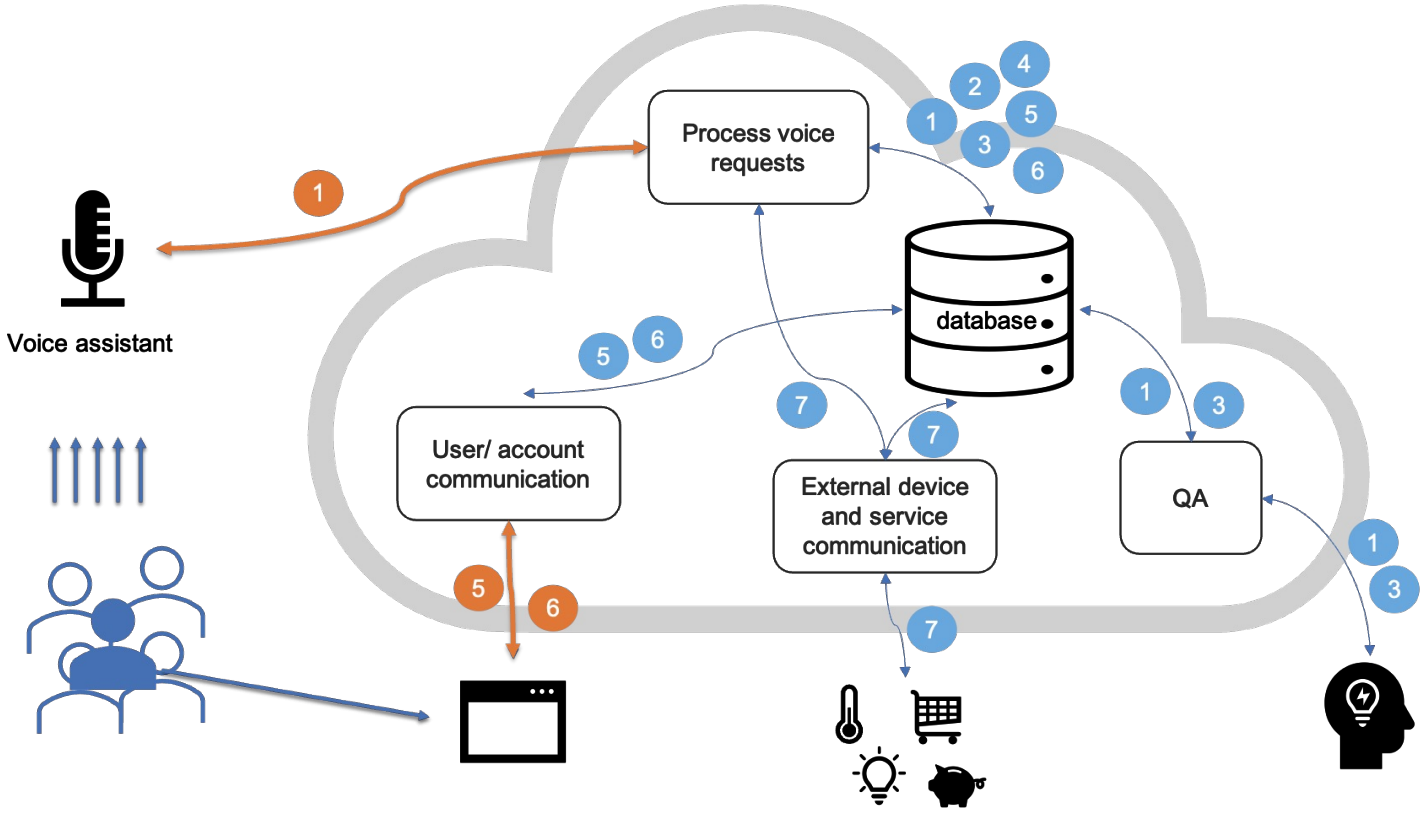


NON-REPUDIATION OF SENDING

Hotspot

INBOUND USER INTERACTION

Threat source

ORGANIZATIONAL

The user cannot deny having sent a message.

1. Is the origin of incoming communication known and traceable to the sender? (e.g. sender logged, digital signature,...)
2. Is it a problem if a trace of this information is kept (i.e. does the sender require deniability afterwards)? (This threat is not likely to be applicable as it only applies when sensitive actions or data are being communicated that require deniability)

An employee shares gossip among his co-workers via a digitally signed email.. When his boss received the forwarded message, it is difficult for the employee to deny having spread the gossip. (level of deniability depends on the likelihood of spoofing the message).

- Mainly applies when the receiving end requires a proof of authenticity during communication, but the sender wants to be able to deny to external parties (afterwards).

- Not only applies to messages, but also to 'requests' to the system (e.g. logging of access to a process, logging of database queries, etc.).
- Credential non-repudiation (Nr1) is a subtype of this threat.

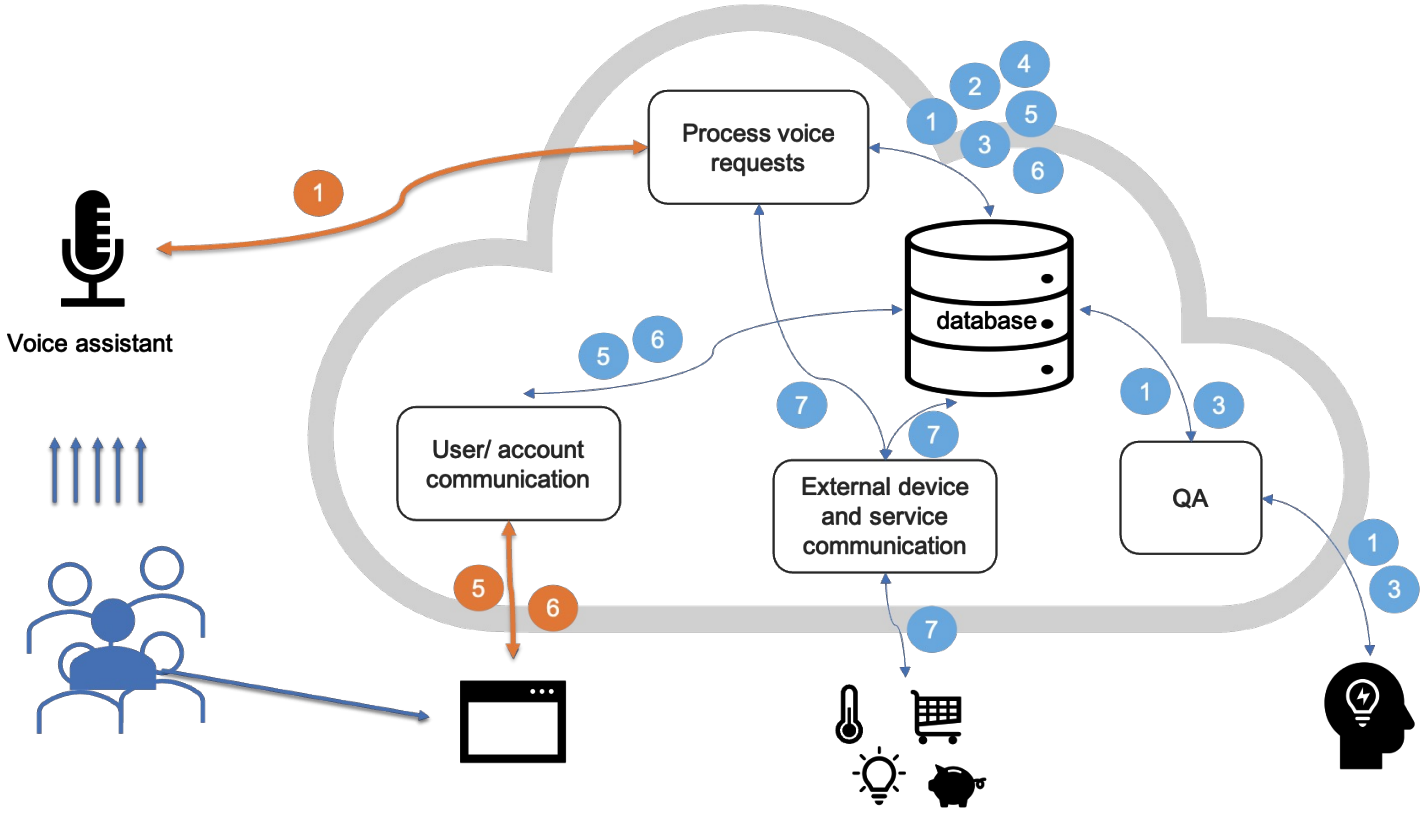
Nr2

LINDDUN

#2

DATA involved

1. Voice recordings
2. Voice profiles
3. Query history/ transcripts
4. Calling and messaging data
   - Call history / Contact list
5. Smart home devices
   - Device type / Features / Status
6. Service accounts
7. Action requests



LINKABILITY OF SHARED DATA

Hotspot

OUTBOUND FLOW CONTAINING **PERSONAL DATA** (RECEIVER IS NOT DATA SUBJECT)

Threat source

RECEIVING PARTY

Content communicated to external party can be linked by receiving party.

1. Are the shared data expected to be anonymous or unlinkable?
2. Can shared data be linked to previously obtained data? (if unknown, assume it is possible.)

A third party service is used as expert knowledge base. To easily forward asynchronous responses to the correct user, the system provides the user's internal identifier which allows the third party service to link all requests of the same user.

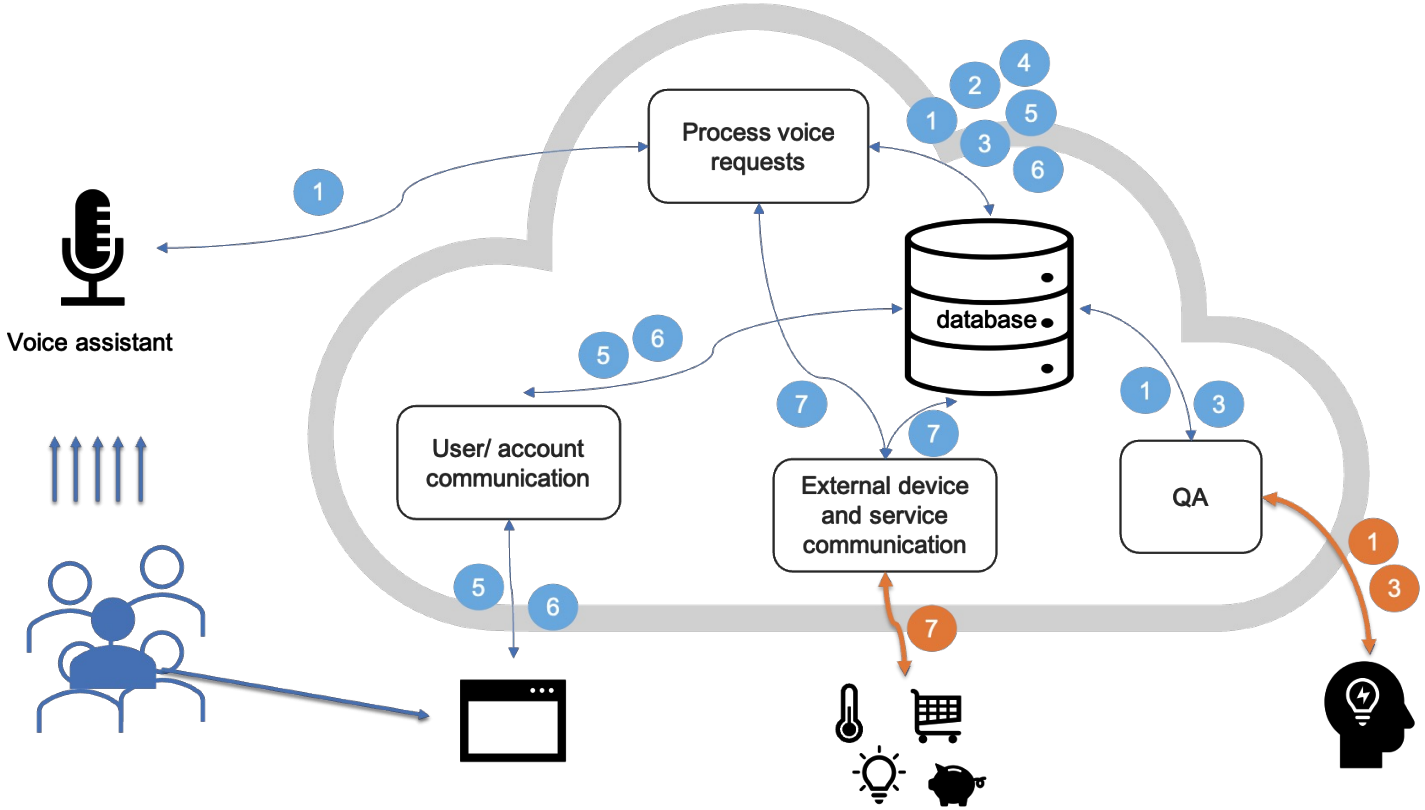
- Linkability can lead to profiling and identifiability (I4)
- Depends on knowledge of the receiving party.
- The more shared attributes, the higher the risk.

- When assuming data were fully de-identified, also non-compliance (Nc3) and unawareness (U1) threats will arise.
- If the shared data originate from a database, the threat can also be categorized as 'linkability of retrieved data (L7)'.

#3

DATA involved

1. Voice recordings
2. Voice profiles
3. Query history/ transcripts
4. Calling and messaging data
   - Call history / Contact list
5. Smart home devices
   - Device type / Features / Status
6. Service accounts
7. Action requests



IDENTIFYING CREDENTIALS

Hotspot

INBOUND
USER INTERACTION
SENDING CREDENTIALS
(AUTHENTICATED USER)

Threat source

ORGANIZATIONAL

The use of (non-anonymous) credentials allows identification of the user.

1. Do the credentials contain identifiable info?
   (e.g. e-ID, company email address, biometrics)
2. Is it a problem if the user is identified (i.e. should credentials only be used to gain access to the system)?

A user is required to register with his full name and address to access a newspaperwebsite allowing identification of webpage views.
Examples of identifying credentials include: email address with full name, e-ID, biometrics, too specific attributes of (anonymous) credentials, etc.

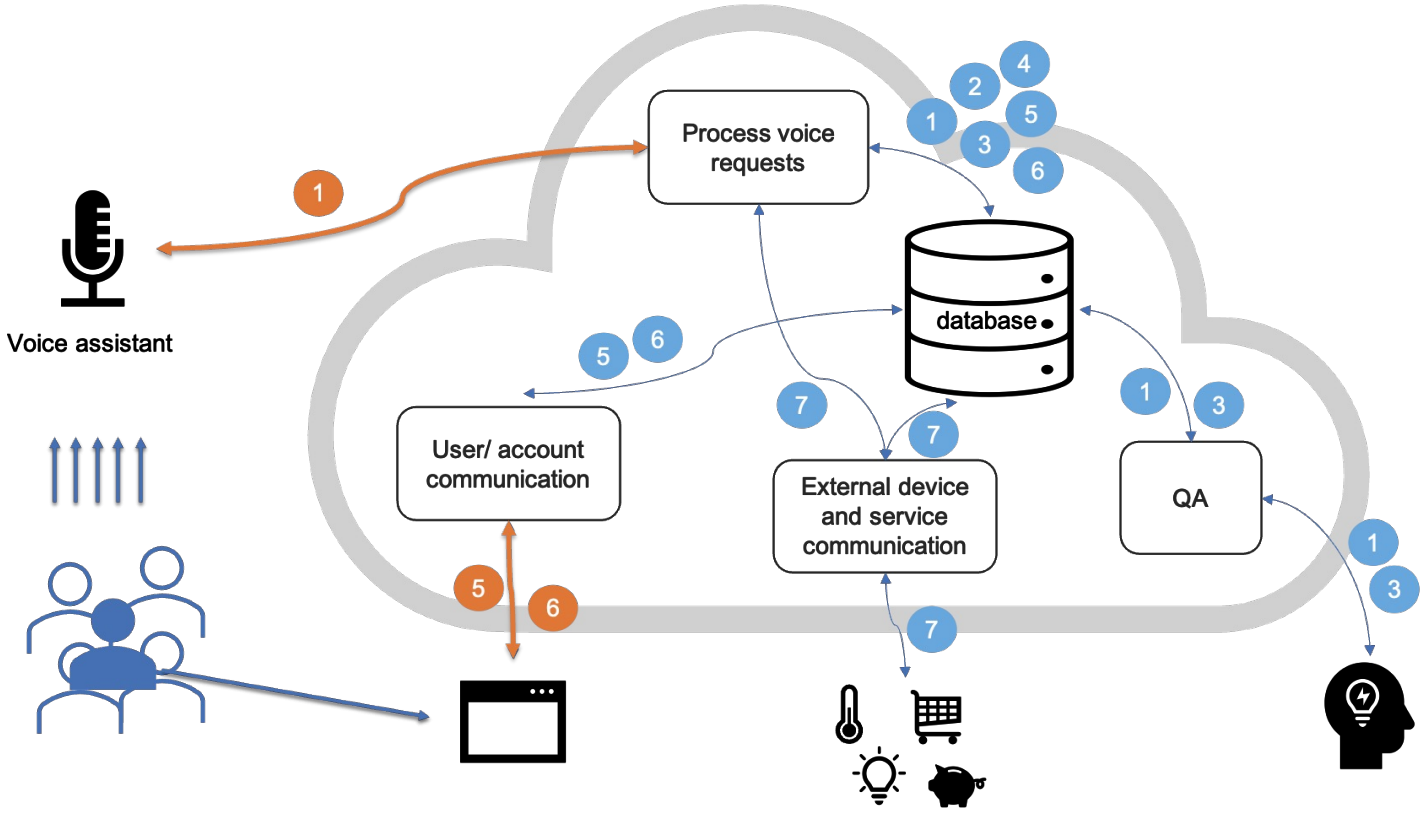
- When data are identified rather than identifiable, stronger security measures need to be in place.
- Relates to non-compliance (Nc1) and unawareness (U1).

LINDDUN

#4

DATA involved

1. Voice recordings
2. Voice profiles
3. Query history/ transcripts
4. Calling and messaging data
   - Call history / Contact list
5. Smart home devices
   - Device type / Features / Status
6. Service accounts
7. Action requests



NO TRANSPARENCY

Hotspot

INBOUND FLOW/ ...
PROCESS WITH
PERSONAL DATA

Threat source

ORGANIZATIONAL

The data subject is insufficiently informed about the collection and further processing of their personal data.

1. Are personal data being collected and/or processed?
2. Is the data subject insufficiently informed about this collection or further processing activities?

- It is unclear to the data subject with which third parties their data will be shared because no notice is provided.
- The data subject was not informed at collection time about the purpose or the retention period of their personal data.
- The notice provided to the data subject was not written in clear and plain language.

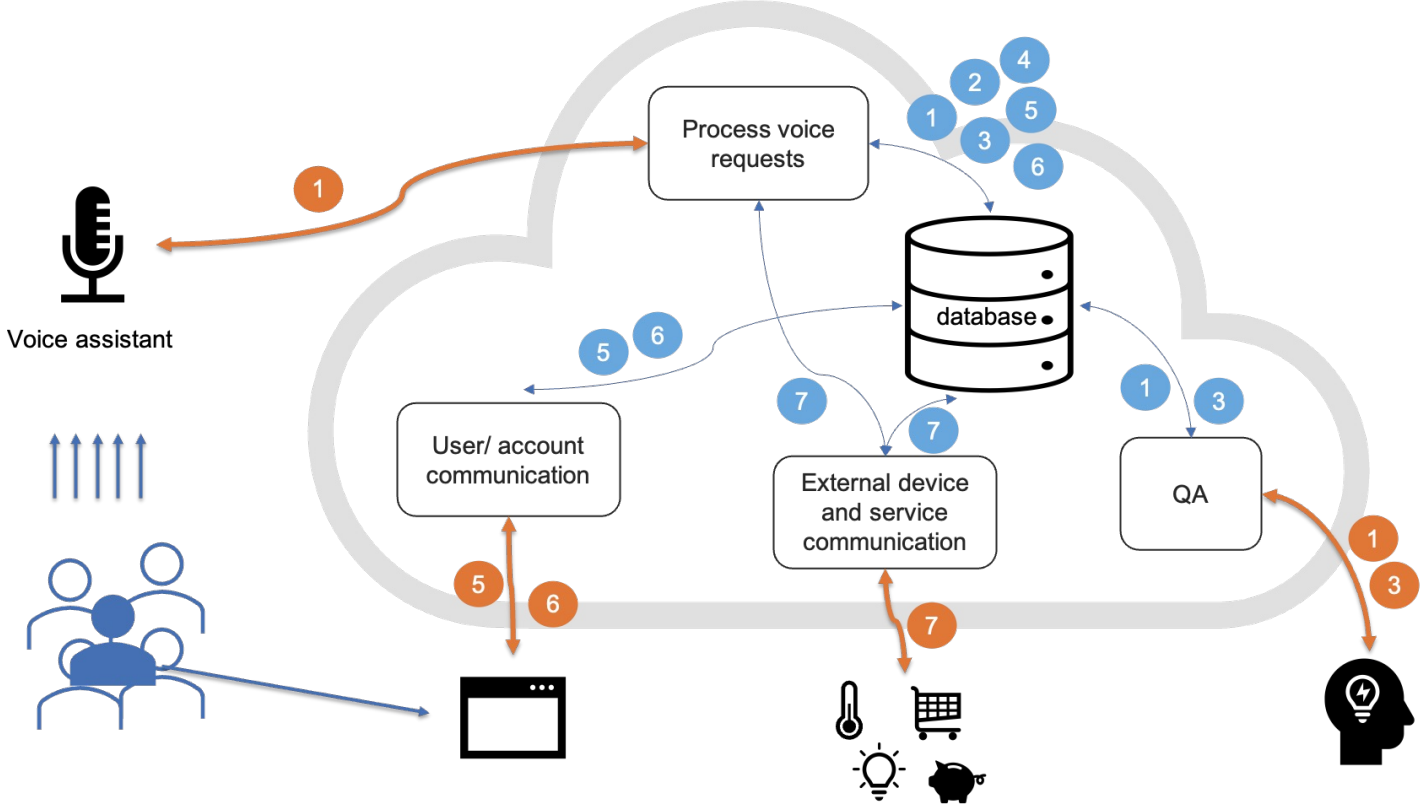
- Transparency (notice) is a data subject right [GDPR].
- This threat can be triggered at collection time, but applies to all further processing activities.

- Both collection directly from the data subject and collection from a third party should be communicated to the data subject.

#5

DATA involved

1. Voice recordings
2. Voice profiles
3. Query history/ transcripts
4. Calling and messaging data
   - Call history / Contact list
5. Smart home devices
   - Device type / Features / Status
6. Service accounts
7. Action requests



EXERCISE 2: READOUT

LINDDUN GO – VOICE ASSISTANTS

SHARE 1-2 SCENARIOS THAT YOU IDENTIFIED.

HOW WAS THE INDIVIDUAL'S PRIVACY VIOLATED?

HOW WOULD YOU MITIGATE THIS?

Siri Privacy Whistleblower Unmasks to Urge Stricter Voice Assistant Privacy Regulation

ERIC HAL SCHWARTZ on May 20, 2020 at 3:30 pm

Alexa has been eavesdropping on you this whole time

When Alexa runs your home, Amazon tracks you in more ways than you might want.

Alexa has so many recordings of me, I made a song out of them.

'Alexa, are you invading my privacy?' – the dark side of our voice assistants

Take aways

- Privacy matters
- Security practices, such as threat modeling, are equally applicable to privacy
- Privacy requires a different mindset than security
- LINDDUN threat trees or LINDDUN GO cards can facilitate privacy threat discussions

LINDDUN FEEDBACK? LET US KNOW!

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PRIVACY THREAT MODELING

LINDDUN in Action

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