Security/Privacy Models for "Internet of things": What should be studied from RFID-schemes?

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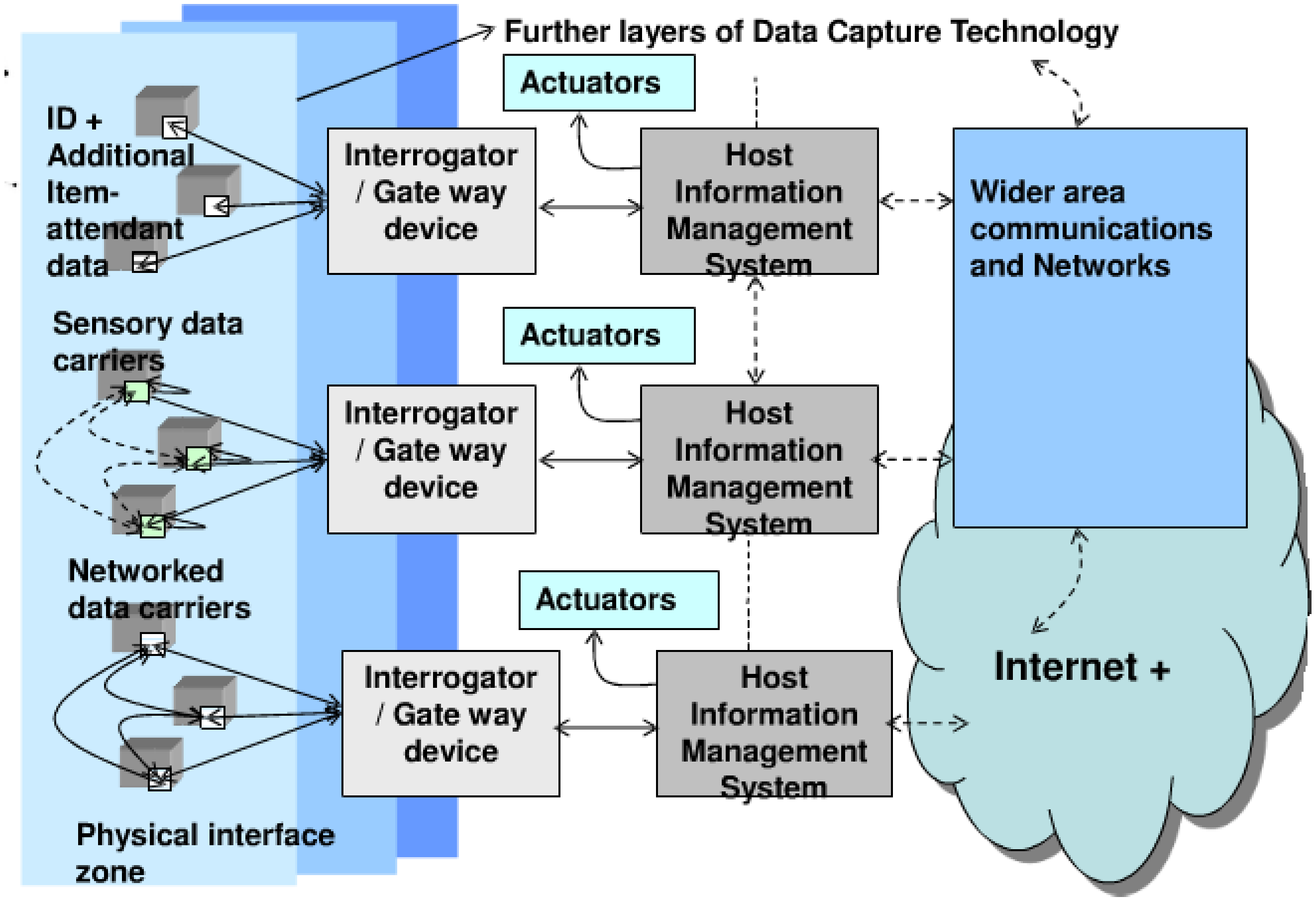
Internet of Things (IoT)

CASAGRAS defined that:

A global network infrastructure, linking physical and virtual objects
through the exploitation of data capture and communication capabilities.
This infrastructure includes existing and evolving Internet and network developments.
It will offer specific object-identification, sensor and connection capability as
the basis for the development of independent federated services and applications.
These will be characterised by a high degree of autonomous data capture,
transfer event network connectivity and interoperability.

Source: CASAGRAS Meeting

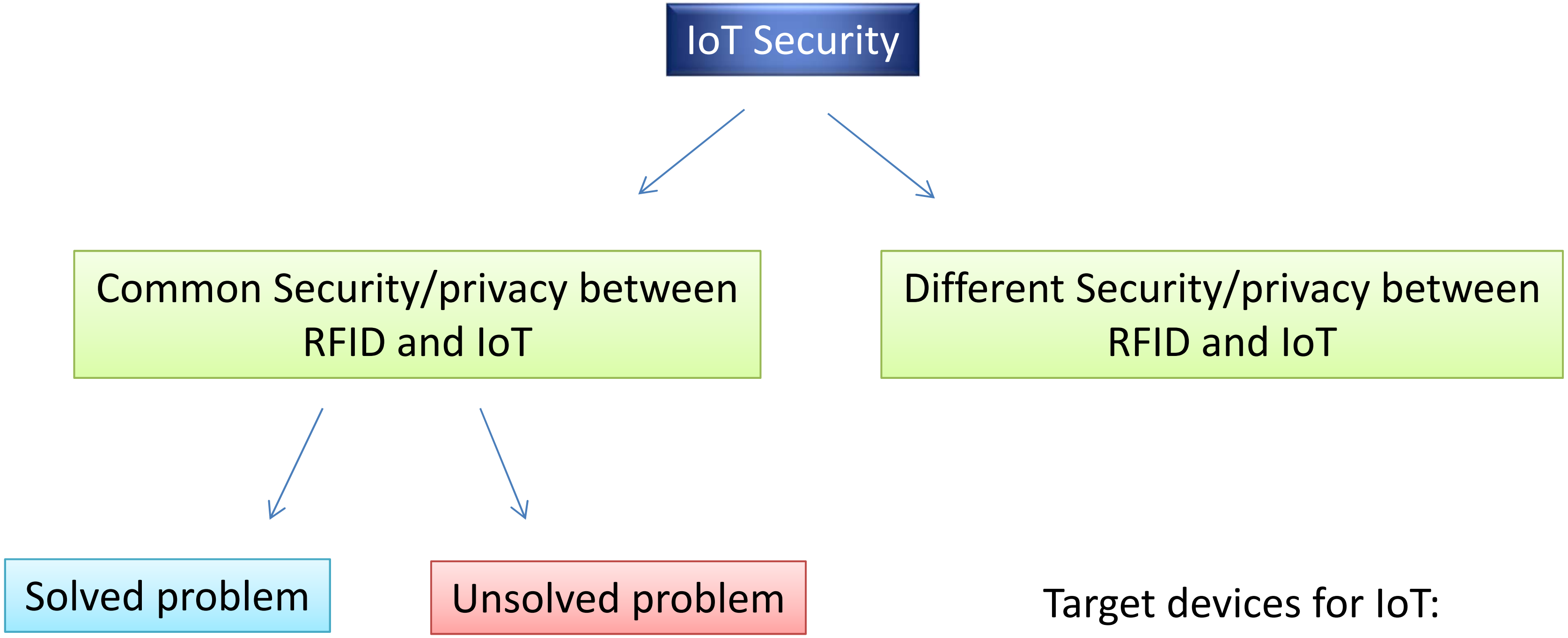
Internet of Things (IoT)


Further layers of Data Capture Technology
ID + Additional Item-attendant data
Sensory data carriers
Networked data carriers
Physical interface zone
Actuators
Interrogator / Gate way device
Host Information Management System
Actuators
Interrogator / Gate way device
Host Information Management System
Actuators
Interrogator / Gate way device
Host Information Management System
Wider area communications and Networks
Internet +

CASAGRAS's inclusive model

Source: "The CASAGRAS Goal"

My talk



IoT Security

Common Security/privacy between RFID and IoT

Different Security/privacy between RFID and IoT

Solved problem

Unsolved problem

Target devices for IoT:

- RFIDs
- Sensors
- Smart Phones
- (future devices, etc.)

The existing effort in cryptography

Internet of Things consists of

- RFIDs
- Sensors
- Smart Phones
- (future devices, etc.)

Number of papers in IACR ePrint Archive:

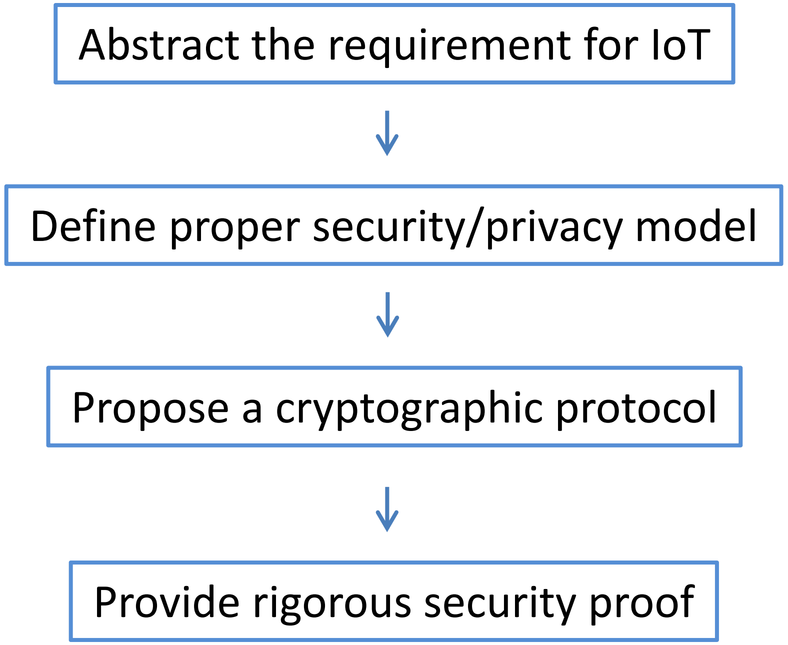
“Internet of Things”, “IoT” – 0 hit

“RFID” – 52 hit

“Sensor” – 23 hit

“Mobile phone”, “Mobile device”, “Mobile (ad-hoc) network” – 12 hit

How to construct secure protocols for IoT



Abstract the requirement for IoT

↓

Define proper security/privacy model

↓

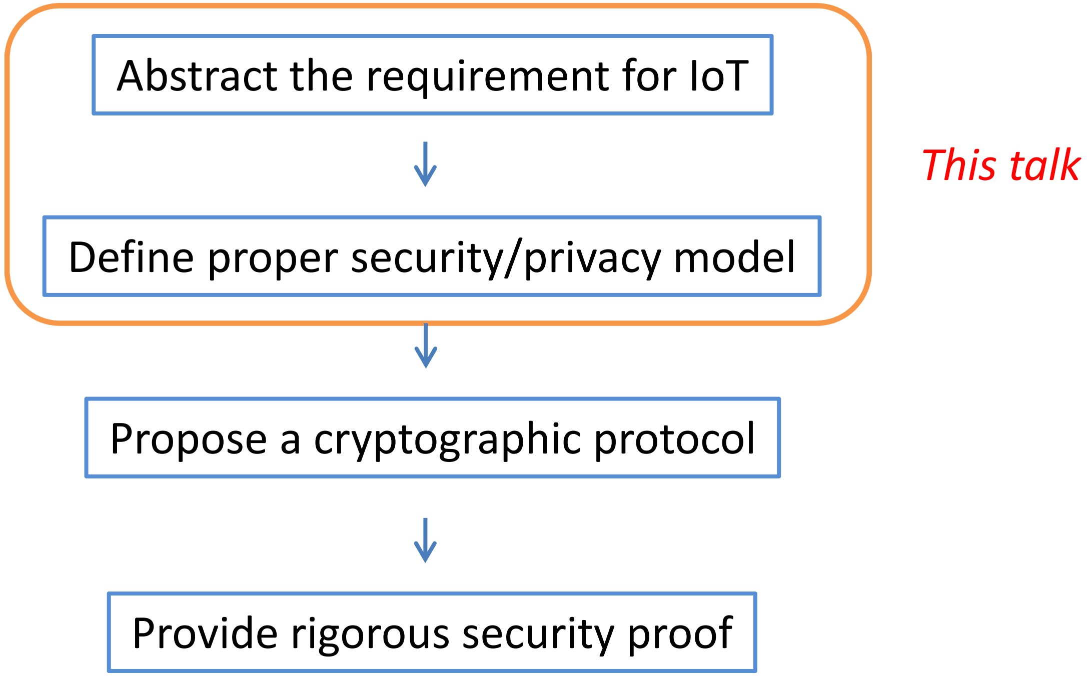
Propose a cryptographic protocol

↓

Provide rigorous security proof

This flow has been used in any cryptographic schemes and protocols.

How to construct secure protocols for IoT



Abstract the requirement for IoT

Define proper security/privacy model

This talk

Propose a cryptographic protocol

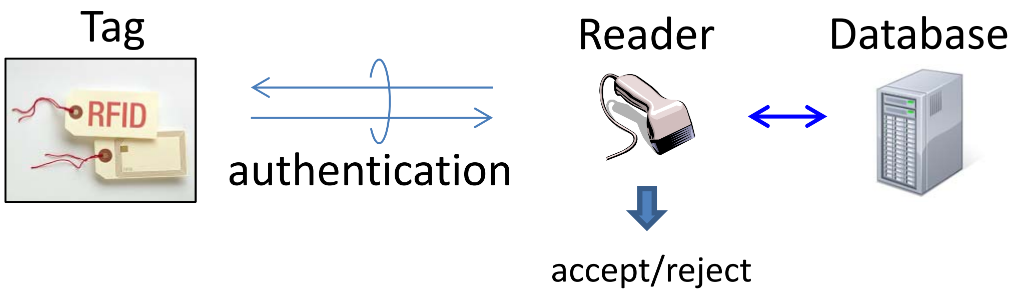
Provide rigorous security proof

Object identification in IoT is mainly solved by RFID technology, and there are many results for RFID authentication protocol

Let’s refer and compare them to construct the security model for IoT !

The existing RFID research in cryptography

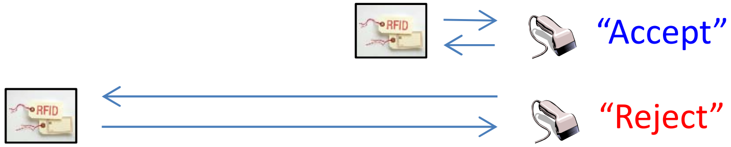
Cryptographers concentrate on RFID authentication protocol



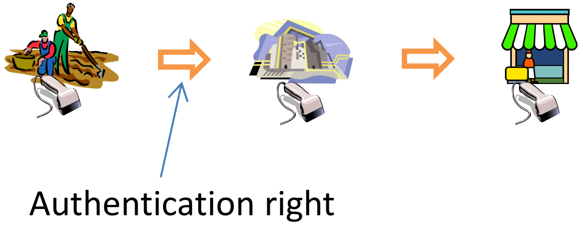
RFID authentication protocol provides:
tag’s authentication and tag’s privacy (reader’s authentication as optional)

Several researcher consider additional properties

- Distance-Bounding protocol



- Ownership transfer protocol



Several unsolved problems

1. Suitable security model

We analyzed the relationship among the security models

2. Identification vs. authentication

3. Real-Life Requirements for RFID

Problem 1: suitable security model

There are several security models for RFID authentication

- Juels-Weis (PerCom 2007, ACM TISSEC 2009) ***major***

  Indistinguishability based

- Vaudenay (ASIACRYPT 2007), Paise-Vaudenay (ACMCCS 2008) ***major***

  Simulation based

- Deng-Li-Yung-Zhao (ESORICS 2010)

  Zero-knowlege based

- Burmester-Li-Medeiros-Tsudik (ACM TISSEC 2009)

  Universal composability based

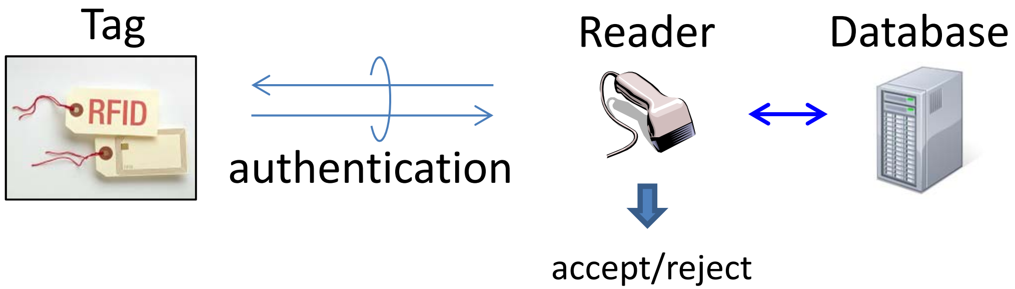
- Ha-Moon-Zhou-Ha (ESORICS 2008)

  Unpredictability based

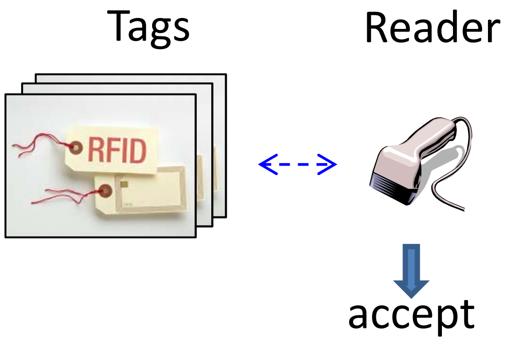
…and many minor variants

Problem 1: suitable security model

Juels-Weis security model:

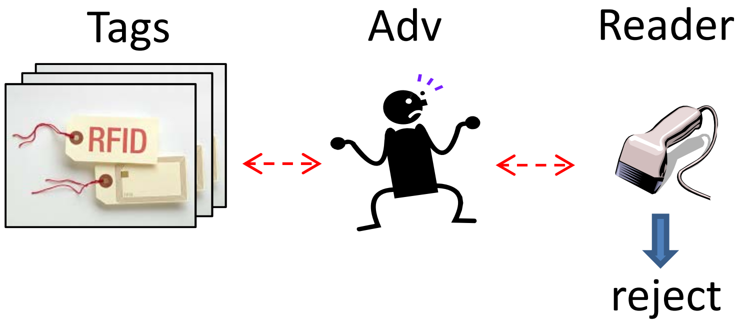


Correctness:



When the protocol is honestly executed, the reader accepts the tags

Security:



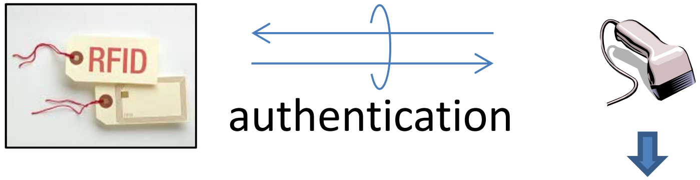
Except the relay attack and corrupt tags, the reader does not accept the tags when an adversary interferes the message

Problem 1: suitable security model

Juels-Weis security model:

Tag

Reader



authentication

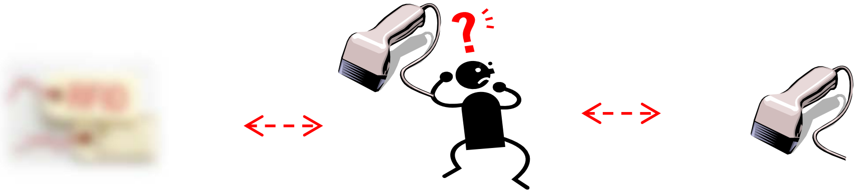
accept/reject

Privacy:

Tag t_0 or t_1

Adv

Reader



The adversary cannot distinguish whether he interacts with tag t_0 or t_1 .

Problem 1: suitable security model

Juels-Weis security model:

$$\begin{array}{l}
\underline{\mathsf{Exp}_{\mathcal{A}}^{\mathsf{IND}\text{-}b}(k)} \\
\quad (pk, sk) \overset{\mathsf{R}}{\leftarrow} \mathsf{Setup}(1^k) \\
\quad (t_0, t_1, st_1) \overset{\mathsf{R}}{\leftarrow} \mathcal{A}_1^{\mathsf{ReaderInit}, \mathsf{Send}, \mathsf{Corrupt}, \mathsf{Result}}(pk, \mathcal{R}, \mathcal{T}) \\
\quad b \overset{\mathsf{U}}{\leftarrow} \{0,1\}, \mathcal{T}' := \mathcal{T} \setminus \{t_0, t_1\} \\
\quad b' \overset{\mathsf{R}}{\leftarrow} \mathcal{A}_2^{\mathsf{ReaderInit}, \mathsf{Send}, \mathsf{Corrupt}, \mathsf{Result}}(\mathcal{R}, \mathcal{T}', \mathcal{I}(t_b), st_1) \\
\quad \text{Output} \quad b'
\end{array}$$

(Reveal(t_0) and Reveal(t_1) are prohibited)

$\mathcal{A}_2$ anonymously interacts with t_b

$$\mathsf{Adv}_{\mathcal{A}}^{\mathsf{IND}}(k) := \left| \Pr\left[\mathsf{Exp}_{\mathcal{A}}^{\mathsf{IND}\text{-}0}(k) \to 1\right] - \Pr\left[\mathsf{Exp}_{\mathcal{A}}^{\mathsf{IND}\text{-}1}(k) \to 1\right] \right|$$

This is a slight variant proposed by Deng-Li-Yung-Zhao (ESORICS 2010)

This definition is based on [IND-CCA security for PKE] / [anonymity for IBE] as a reference

If we allow $\mathcal{A}_1$ to issue Reveal queries to t_0 and t_1, we need public key cryptography to satisfy the modified model

Problem 1: suitable security model

Indistinguishability-based formal privacy definition is useful to provide the security proof. However, only few (rigorous) relationship among the security models is proved.

Ma-Li-Deng-Li (ACMCCS 2009) proved that

$$\begin{tikzcd} \text{Indistinguishability based privacy} \arrow[r, shift right, "/" marking] & \text{Unpredictability based privacy} \arrow[l, shift right] \end{tikzcd}$$

We analyzed the other security models based on the several results for public key encryption. We recently found that

$$\begin{tikzcd} \text{Indistinguishability based privacy} \arrow[r, shift right, "/" marking] \arrow[d, shift right] & \text{Simulation based privacy} \arrow[l, shift right] \\ \text{Zero-knowledge based privacy} \arrow[u, shift right] & \end{tikzcd}$$

Problem 2: identification vs. authentication

Many researcher describe “authentication” protocol for RF “Identification”

The reader outputs accept or reject
(for Result query)

$<$

The reader outputs identity or $\perp$
(for Result query)

(The adversary can obtain information more than one bit if we actually treat it as identification)

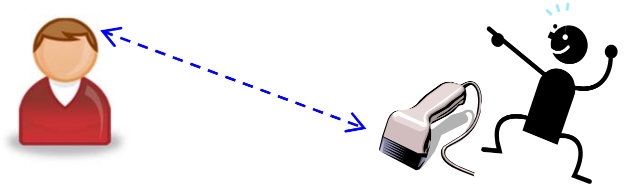
Only authentication is necessary ? Why ?

I think the existing protocols are “Radio Frequency Authentication (RFAU)”!

It may cause a problem when the protocol is embedded in IoT

Problem 3: real-life requirements for RFID

- On-off control



"I don't know the identity, but he is wearing a wig !"
(because my reader received a response)

Cryptographic solution:

Reader authentication is needed before the tag responds a message,
but digital signature is too expensive to compute.

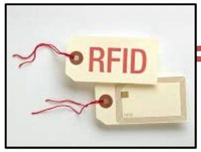
Another solutions:

Breaking the RFID tag's circuit is not good solution
since the tag cannot be reused.

Physically protection (e.g. foil-wrapping) may be difficult in some cases.

Problem 3: real-life requirements for RFID

- Secrecy/integrity/availability of stored data



Several types of Tags can contain the Identity, secret key for authentication and usable data

Utilizing the data in RFID tag (in addition to Identity) is one of the attractive point (manufacturer, production date, expiration data)

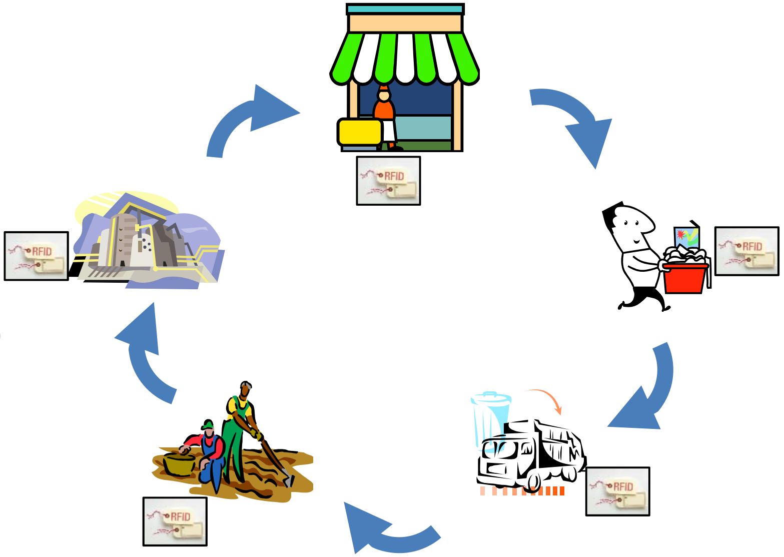
Several data should be protected or verified, however cryptographers only study RFID authentication protocol now…

For the resource constraint, some kinds of merged scheme/protocol will be valuable

-- Example in public key crypto: Signcryption (faster than “Encrypt + Sign”)

Problem 3: real-life requirements for RFID

- Life-cycle of the tag



Some data on RFID tag (e.g. indication of origin) should be declared and not be modified

However, special commands for (partially) erasure is useful to reuse the tag

In addition to the transmission of the ownership (ownership transfer protocol), how to manage the tag's data/identity/ownership respectively is important in the realistic setting

What are the additional requirements in IoT ?

- Data integrity <-- it is necessary in sensor network
- Data secrecy <-- it is also necessary in sensor network
- Primary sender <-- who generates the data should be specified
- Key Management <-- how to keep/update/recover a secret is one of the main issue in all protocols

⋮

We should abstract the realistic requirement to the cryptographic-oriented notion as possible as we can. We can refer many types of security model in public key cryptography

Anonymous IBE --- indistinguishability of data and identity

Forward signature --- unforgeability, forward security

Group signature --- unforgeability, anonymity, unlinkability, traceability

Key exchange --- impersonation, unknown key share, key leakage…

What are the additional requirements in IoT ?

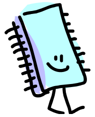
In RFID authentication, researchers assume that the reader (and the background database) has enough computation resources

⇧

However, it may be smart phone in IoT ! This gap is not considered …

⇨ It is important to define the actual roll (tag, reader, sensor, etc.) of the "Things"

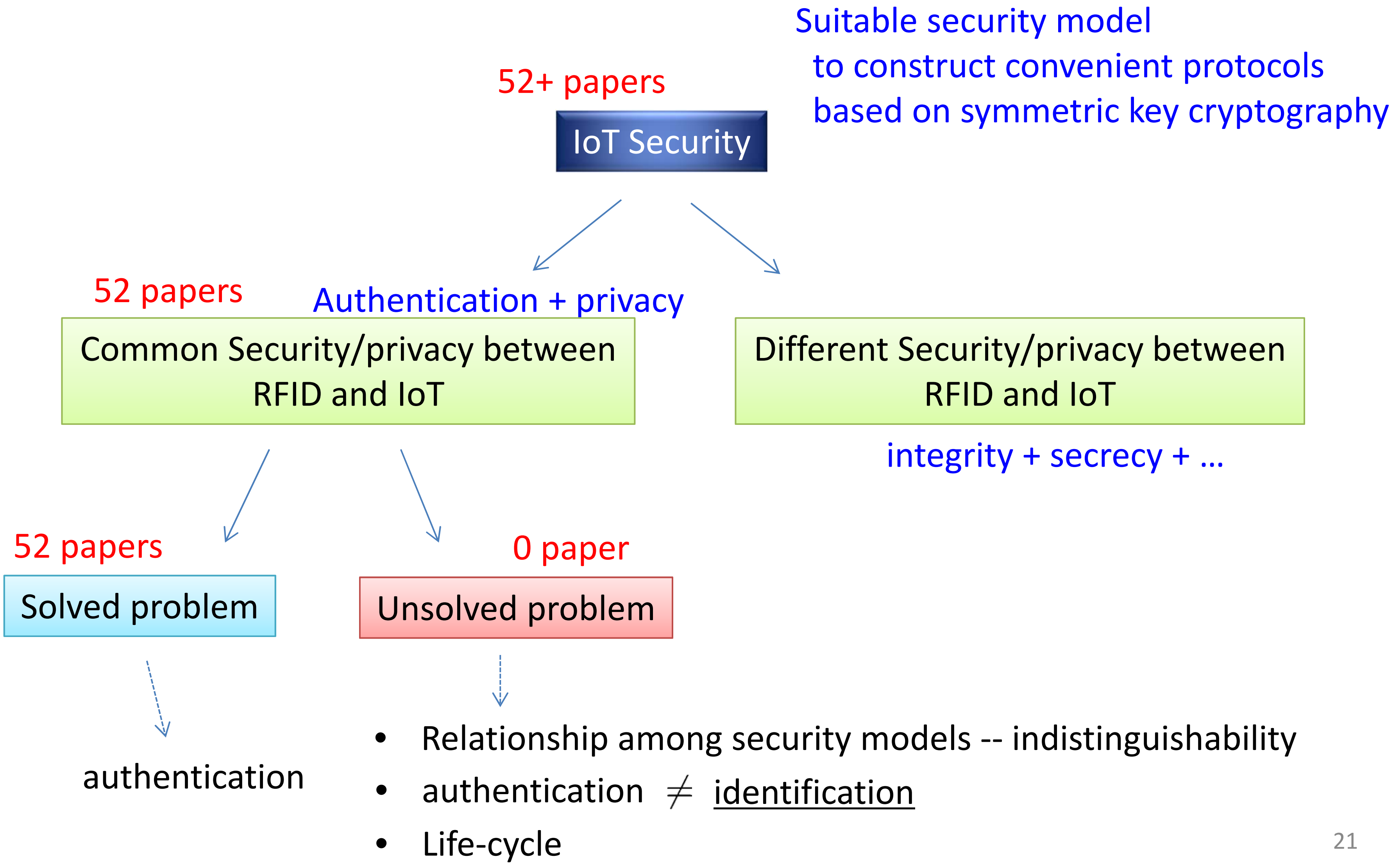
It should also be discussed in the IoT environment



"I will send you the weekly data I obtained.
I am now computing fully homomorphic encryption.
Please wait 1 year ! "

Depending on the specific wide environment, we should organize the security requirement, choose the security model and propose an efficient protocol to spread the world of IoT !

Conclusion



Suitable security model
to construct convenient protocols
based on symmetric key cryptography

52+ papers

IoT Security

52 papers

Authentication + privacy

Common Security/privacy between RFID and IoT

Different Security/privacy between RFID and IoT

integrity + secrecy + …

52 papers

Solved problem

0 paper

Unsolved problem

authentication

- Relationship among security models -- indistinguishability
- authentication $\neq$ identification
- Life-cycle

Thank you for your attention !