



Automated Security and Risk Analysis of Strong Customer Authentication Solutions for the PSD2

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Recent Security Advances in the Finance Sector
January 14, 2021

| Agenda

- Overview of Security Vulnerabilities Affecting the Financial Scenario
- Payment Services Directive 2 (PSD2)
- Automated Analysis of Security Protocols for the PSD2



| Agenda

- **Overview of Security Vulnerabilities Affecting the Financial Scenario**
- Payment Services Directive 2 (PSD2)
- Automated Analysis of Security Protocols for the PSD2



| Security Vulnerabilities

Android malware can steal Google Authenticator tokens

A new version of the "Google Authenticator" app and

**Android Malware Gains
2FA Tokens, Screen
Cerberus banking Trojan source code
released for free to cyberattackers**

An auction designed to net the developer of the Android malware \$100,000 failed.

TrickMo bypassing 2FA

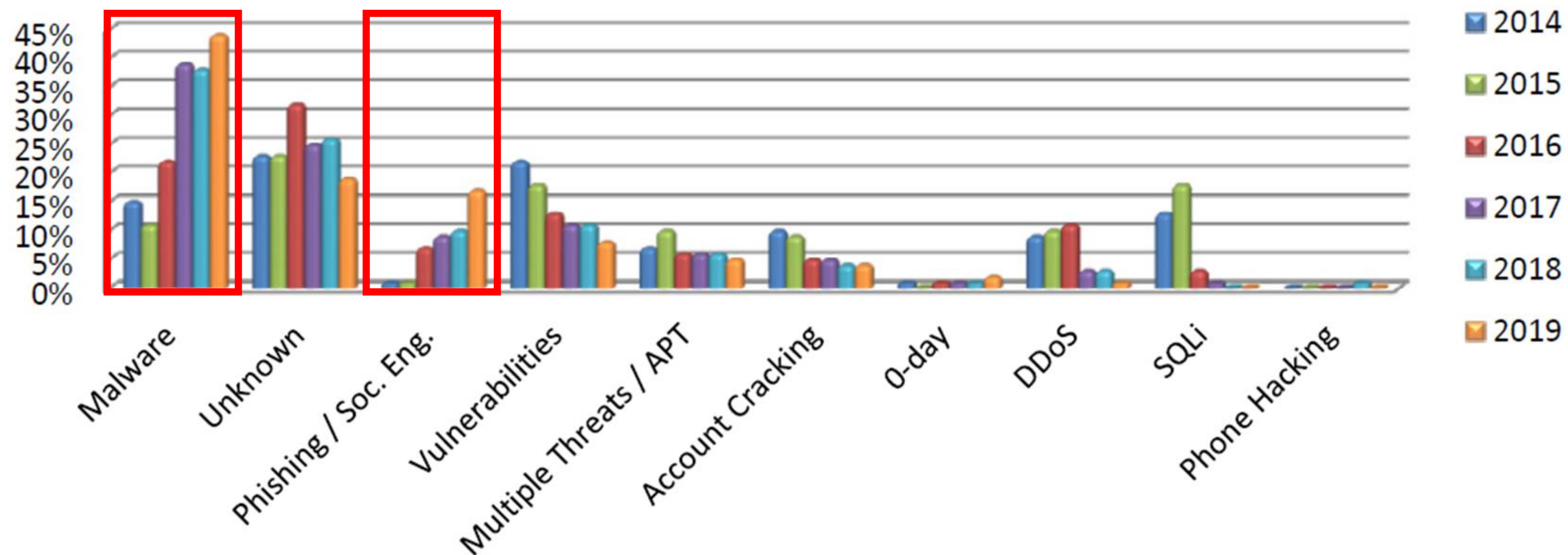
Malicious TrickMo app seen deployed in Germany for now, but broader use is

New 'Alien' malware can steal passwords from 226 Android apps

Most targets are banking apps, but Alien can also show phishing pages for social, instant messaging, and cryptocurrency apps.

Malware steals passwords and two-factor codes

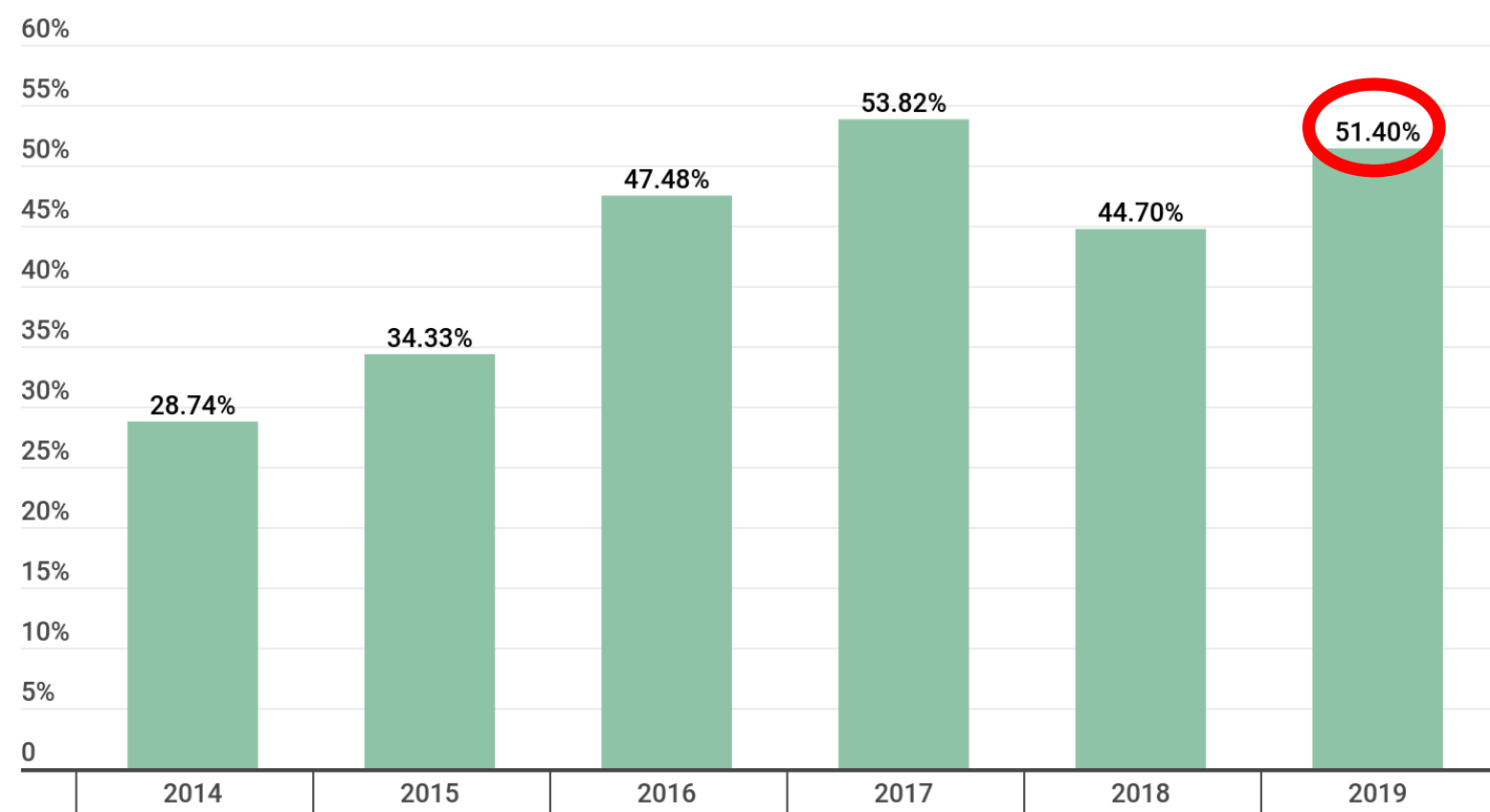
Security Vulnerabilities Techniques



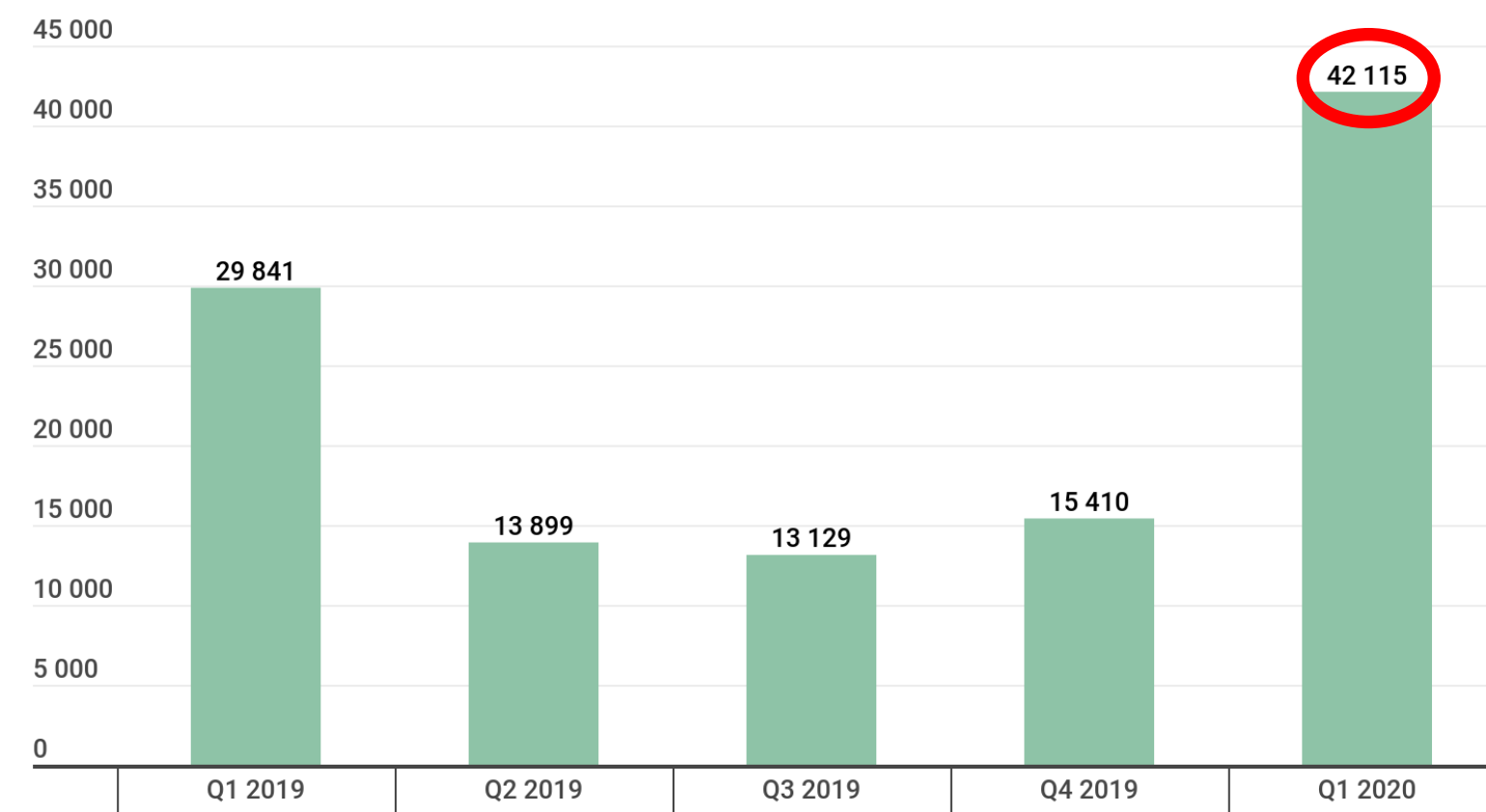
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Security Vulnerabilities

Financial Phishing and Malware



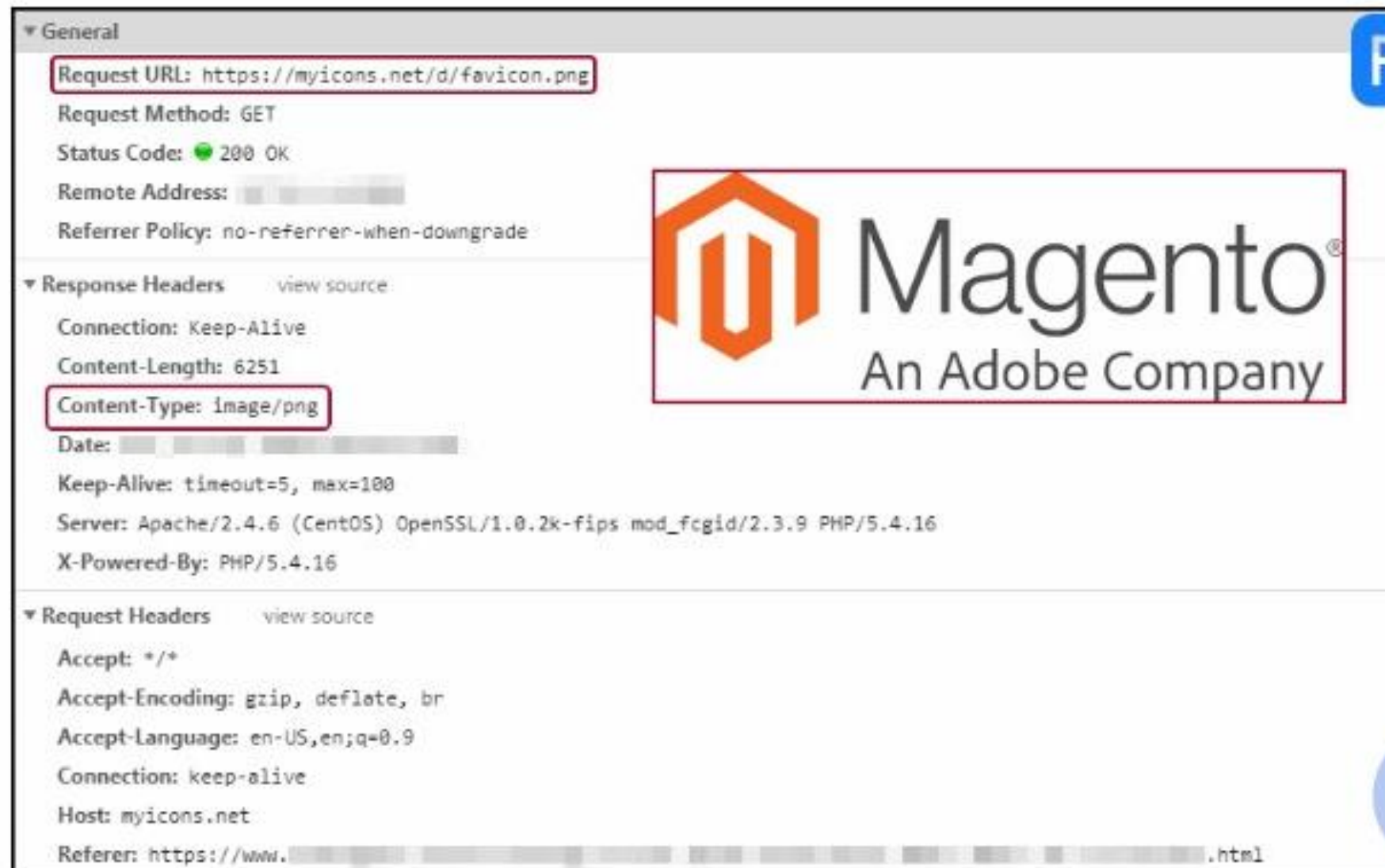
The percentage of financial phishing attacks (from overall phishing attacks) detected by Kaspersky, 2014-2019



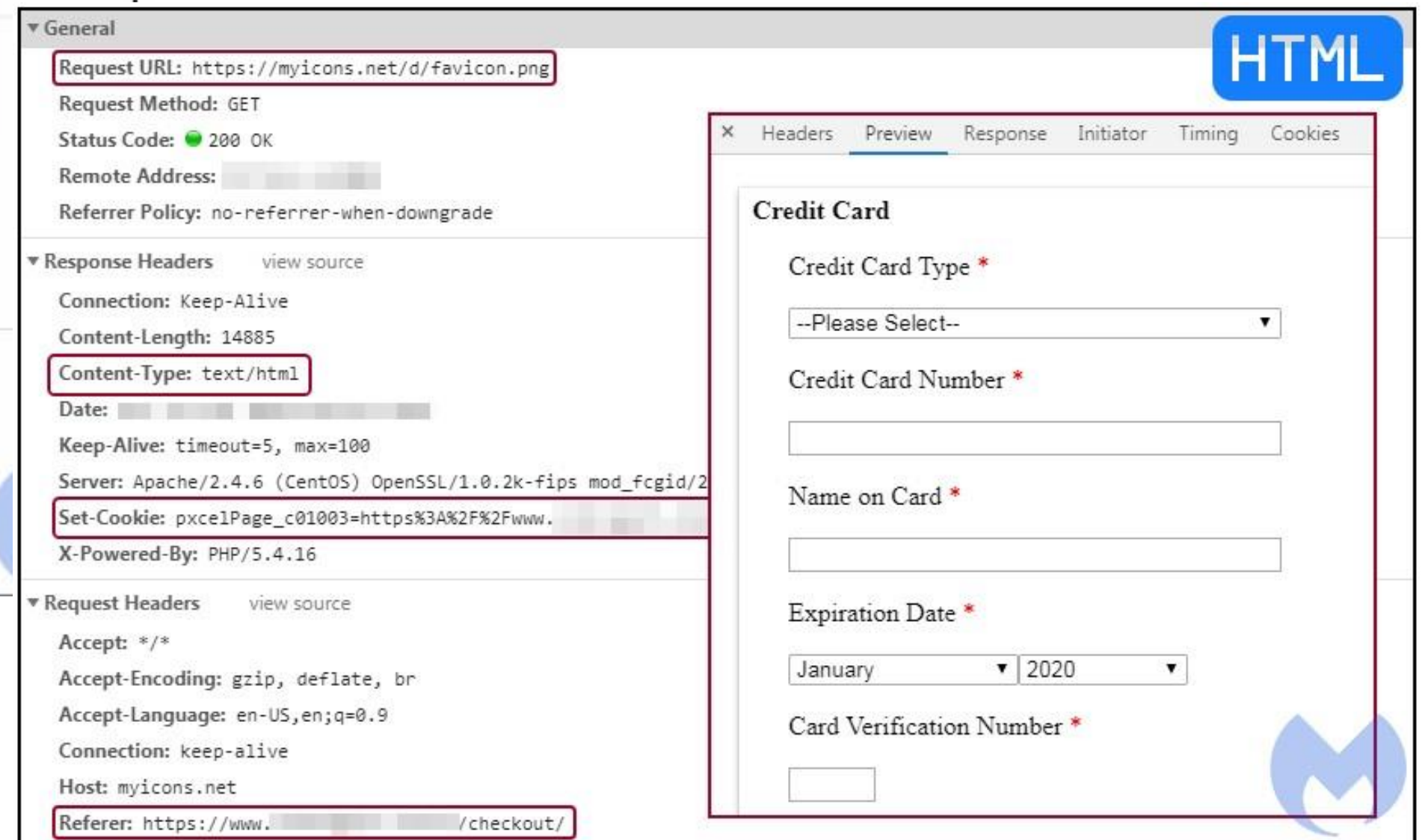
Number of installation packages of mobile banking trojans detected by Kaspersky, Q1 2019 – Q1 2020

Security Vulnerabilities

Skimming

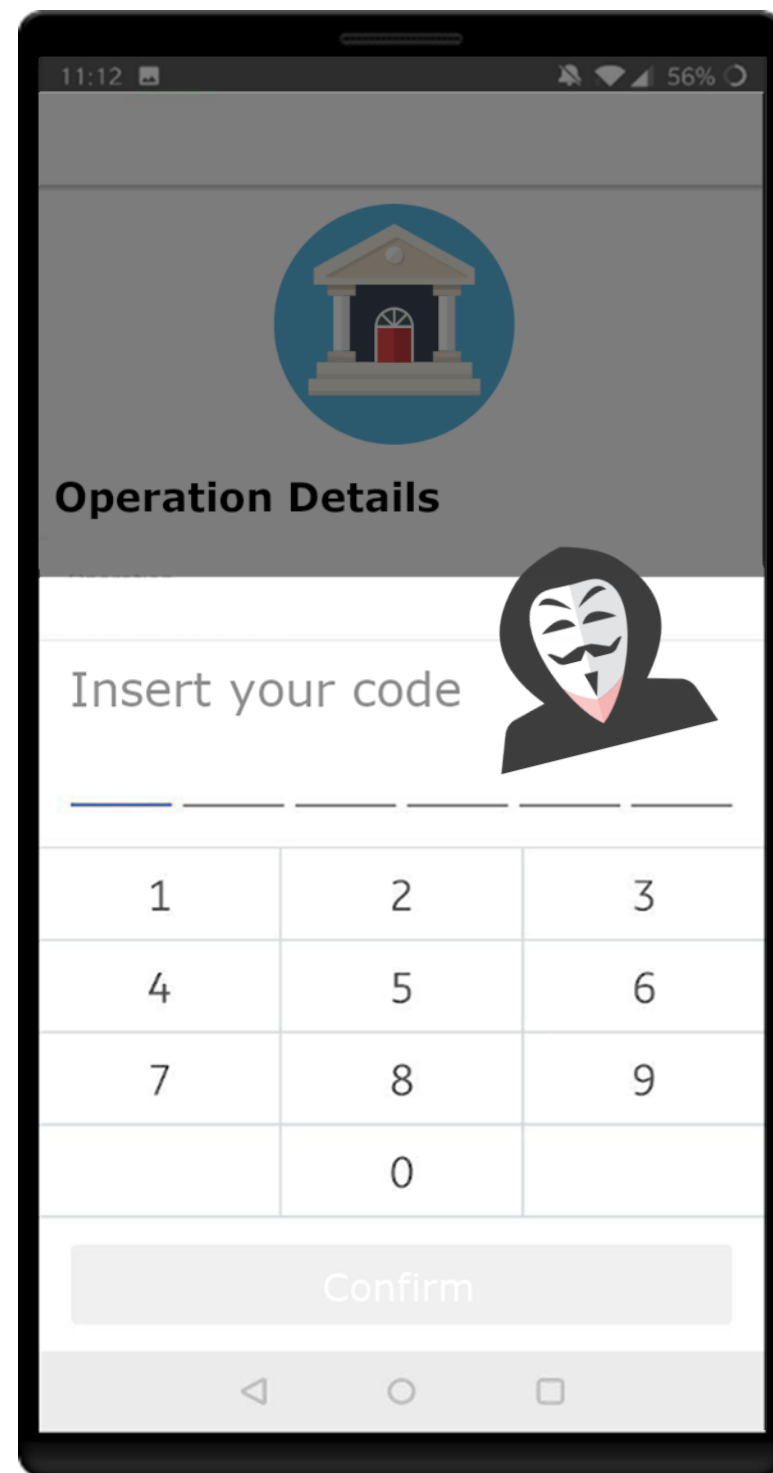


PNG



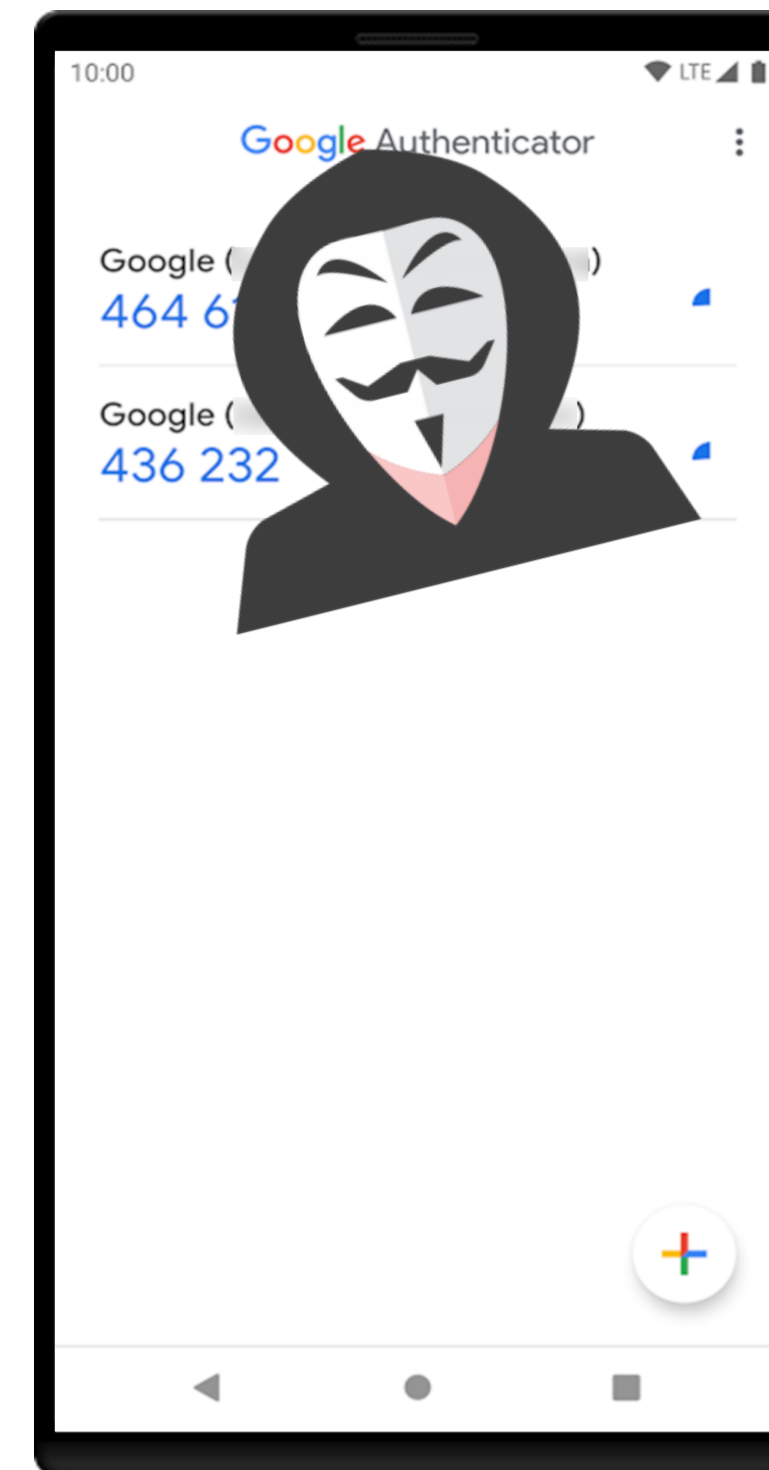
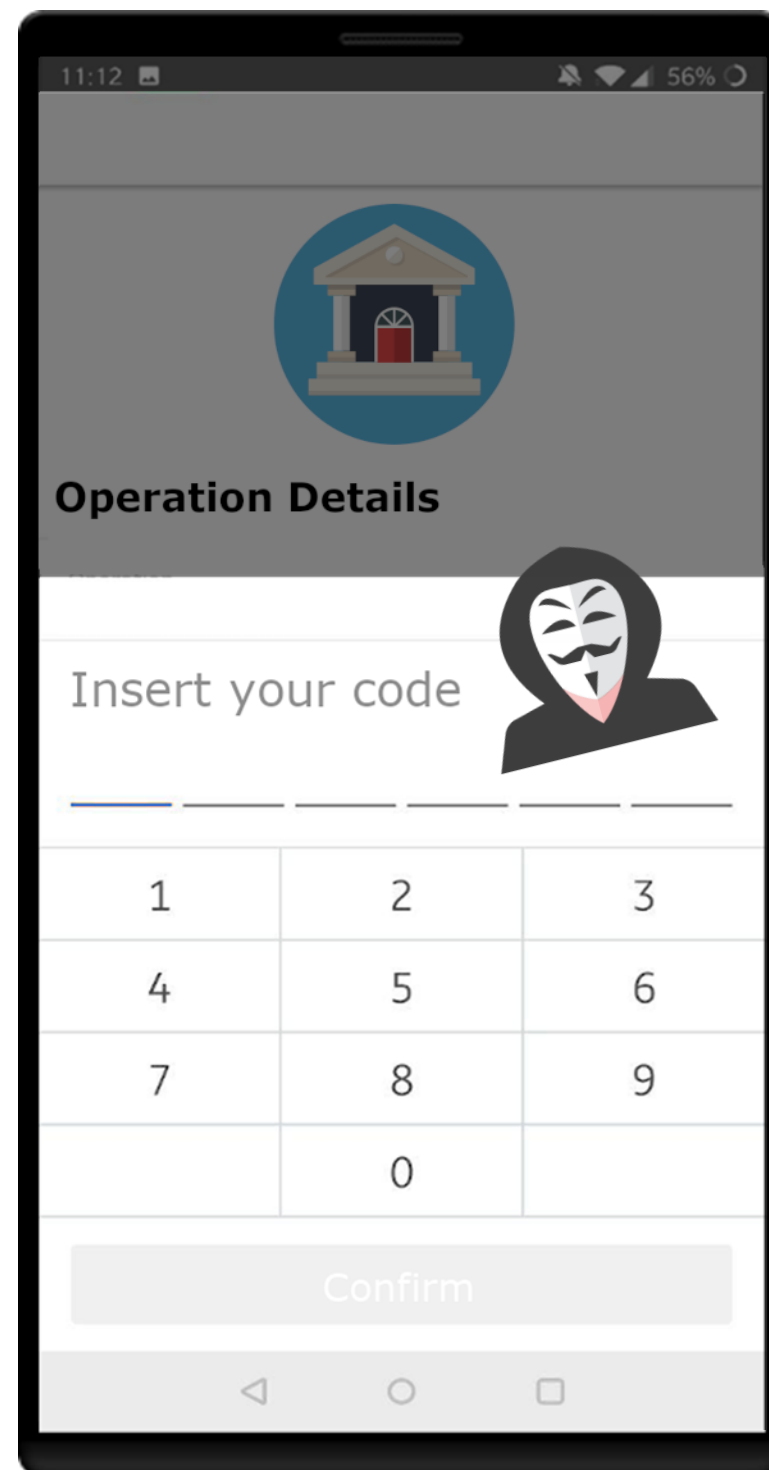
Security Vulnerabilities

TrickBot



Security Vulnerabilities

TrickBot



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- Overview of Security Vulnerabilities Affecting the Financial Scenario
- **Payment Services Directive 2 (PSD2)**
- Automated Analysis of Security Protocols for the PSD2



| Payment Services Directive (PSD2)



Directive (EU) 2015/2366 regarding payment services in the internal market.



Open Banking

Fostering the birth of new innovative solutions built around financial institutions



Security

Improving the security of e-banking protocols

| Payment Services Directive (PSD2)

Directive (EU) 2015/2366 regarding payment service



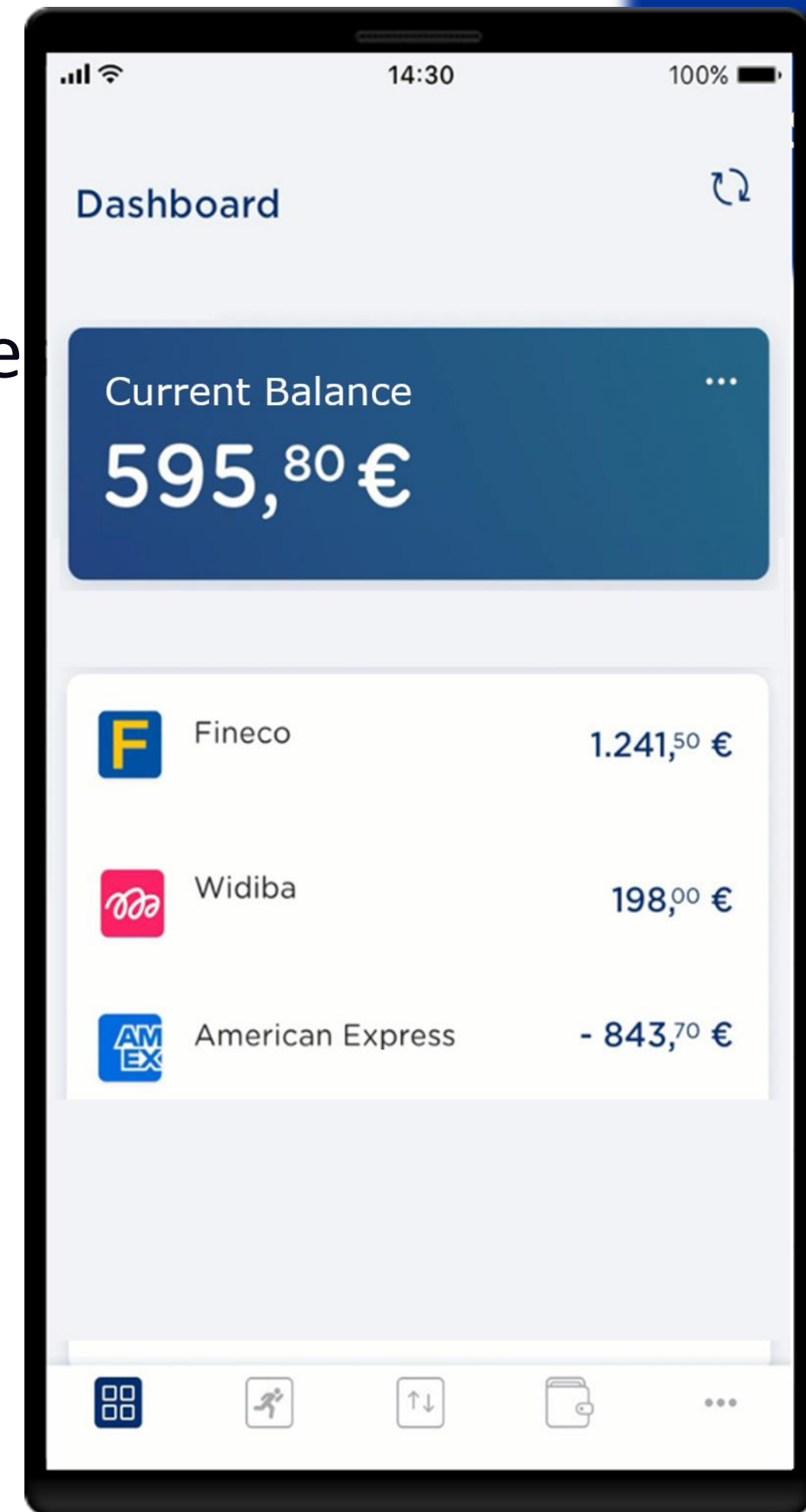
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| Payment Services Directive (PSD2)



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Open Banking

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Strong Customer Authentication (SCA)



Security

Improving the security of e-banking protocols



Dynamic Linking

Payment Services Directive (PSD2)

Strong Customer Authentication (SCA)

Authentication relying on more than a single *authentication factor*:

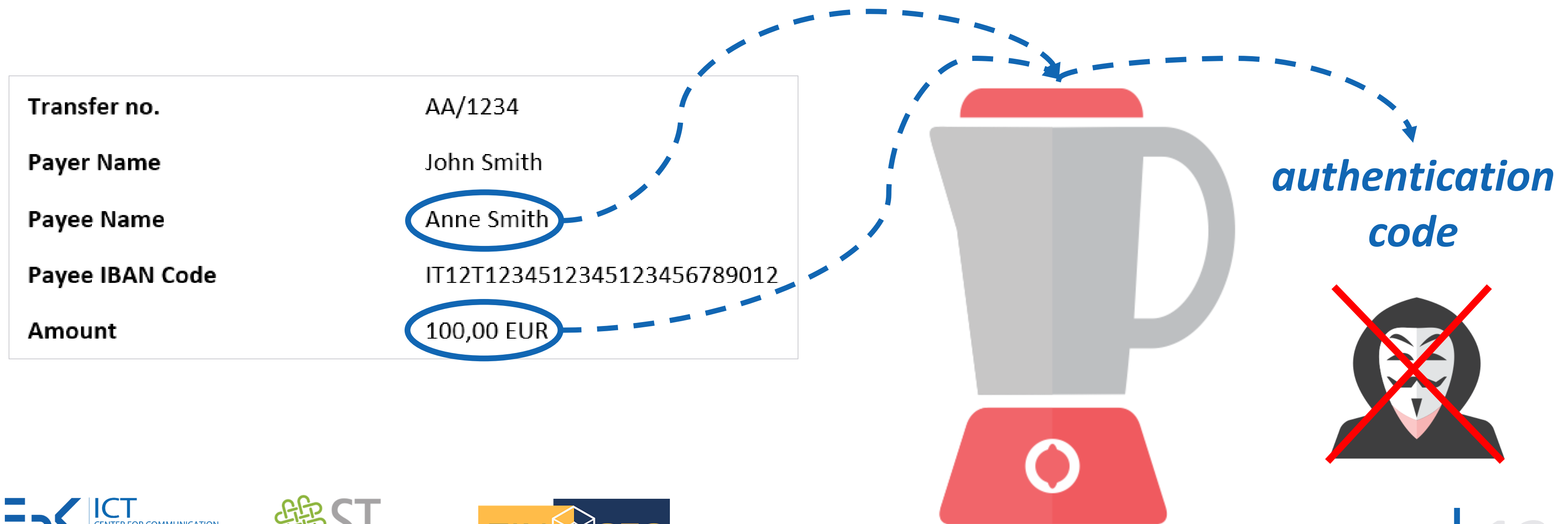


Actions	SCA required?
Balance inquiry	Depends on the case
Consultation of payment history of past 90 days	Depends on the case
Payments to trusted beneficiaries	Depends on the case
Recurrent payments with same amount and same payee	Depends on the case
Payments not exceeding € 30	Depends on the case
Payments exceeding € 30	Always

Payment Services Directive (PSD2)

Dynamic Linking

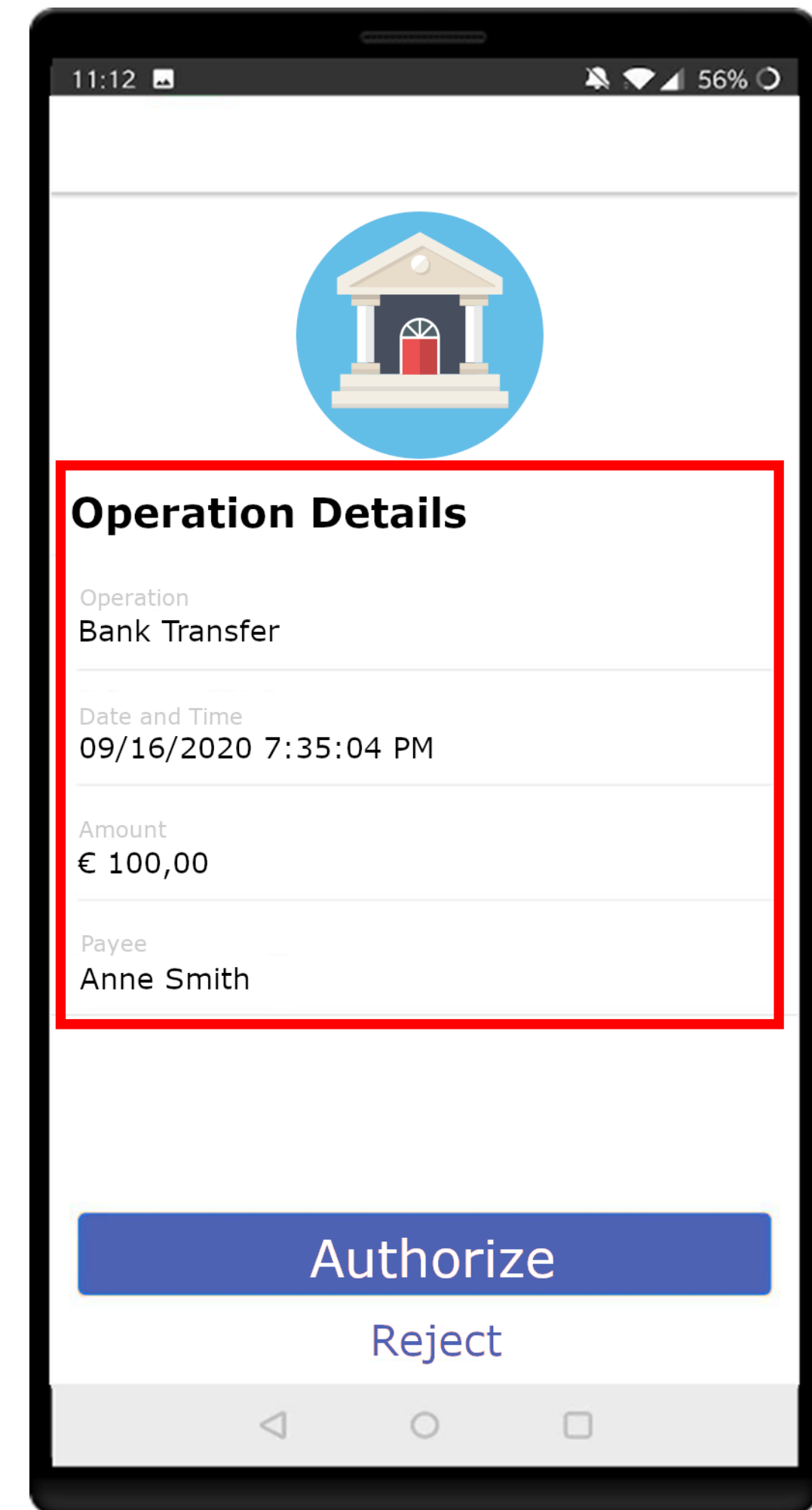
During a transaction, the *authentication code* must be strongly connected with the ongoing operation.



Payment Services Directive (PSD2)

Dynamic Linking

Moreover, the user is always displayed the operations' details before the authorization.



Use Case Before PSD2

Before
PSD2

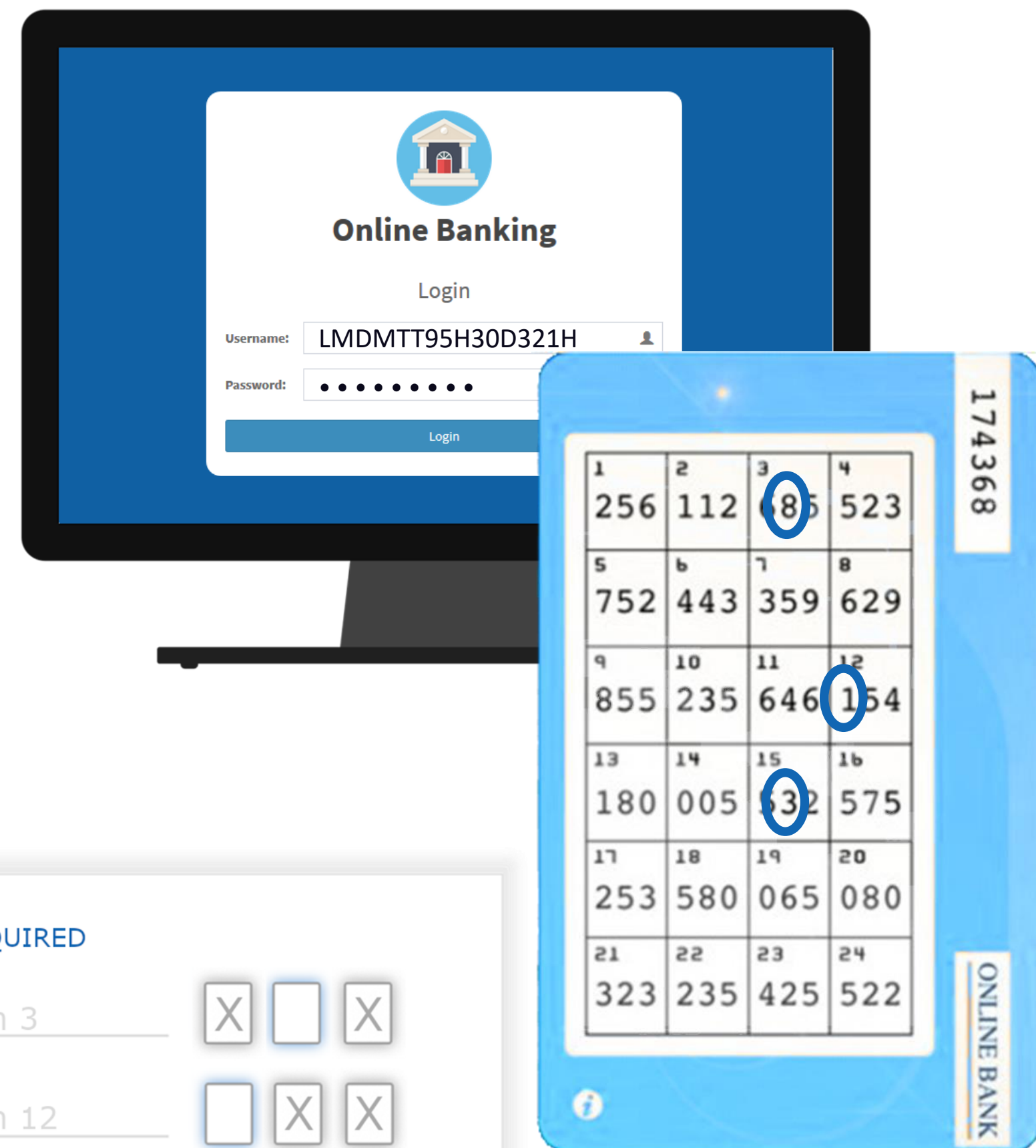
1. The user authenticates on the online banking through credentials and performs an operation.



Use Case Before PSD2

Before
PSD2

1. The user authenticates on the online banking through credentials and performs an operation.
2. The user generates a code through the matrix.



OTP REQUIRED

Position 3

Position 12

Position 15

Use Case Before PSD2

Before
PSD2

1. The user authenticates on the online banking through credentials and performs an operation.
2. The user generates a code through the matrix.
3. The user inserts the code in the online page to authorize the operation.



Payment Services Directive (PSD2)

Not Compliant Solutions

1. The authentication code is not connected with the ongoing operation.



2. Users cannot be aware of which operation they are about to authorize.



Use Case After PSD2

After
PSD2

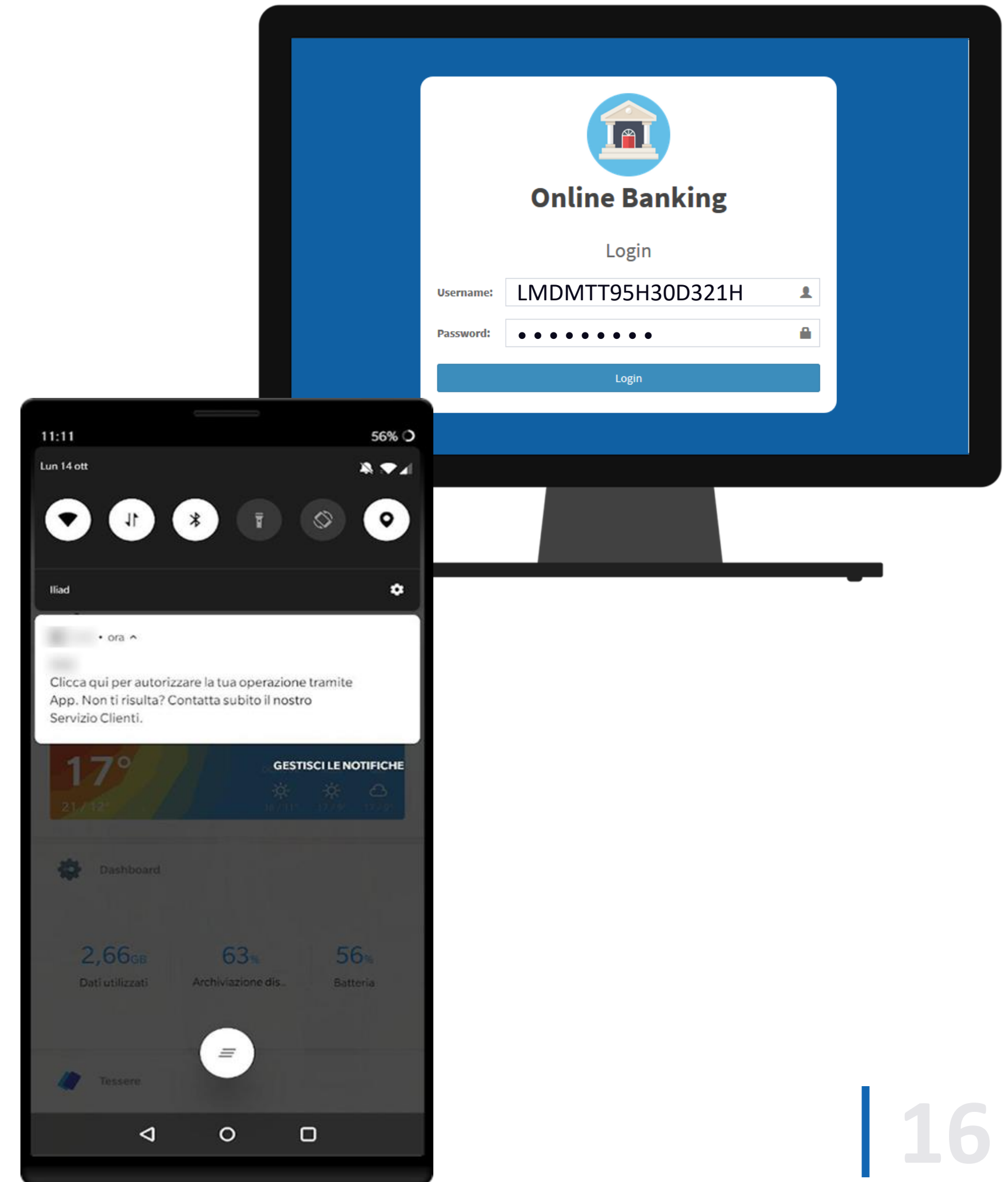
1. The user authenticates on the online banking through credentials and performs an operation.



Use Case After PSD2

After
PSD2

1. The user authenticates on the online banking through credentials and performs an operation.
2. The user receives a *push notification* that, once opened, details the ongoing operation.



Use Case After PSD2

After
PSD2

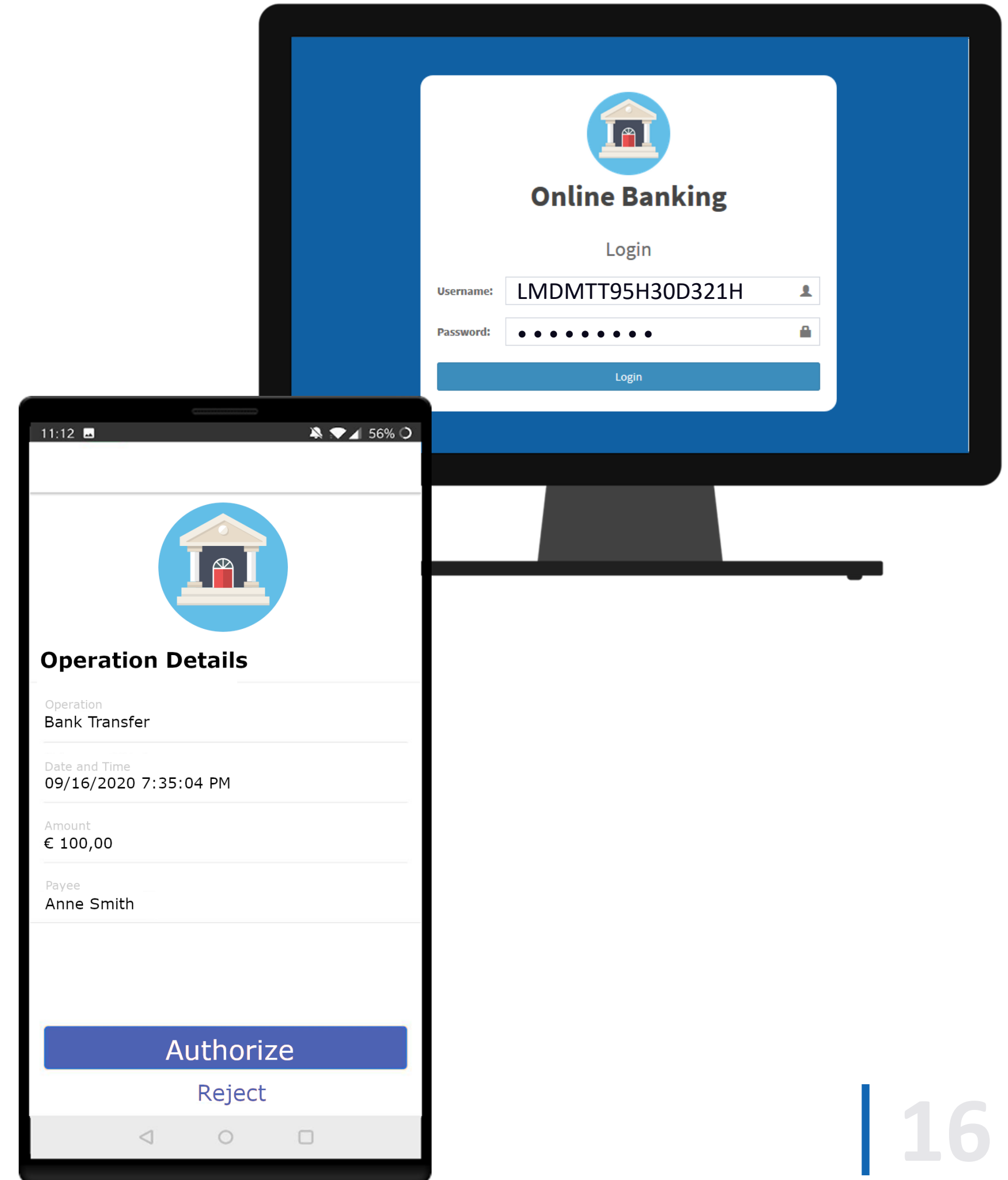
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Use Case After PSD2

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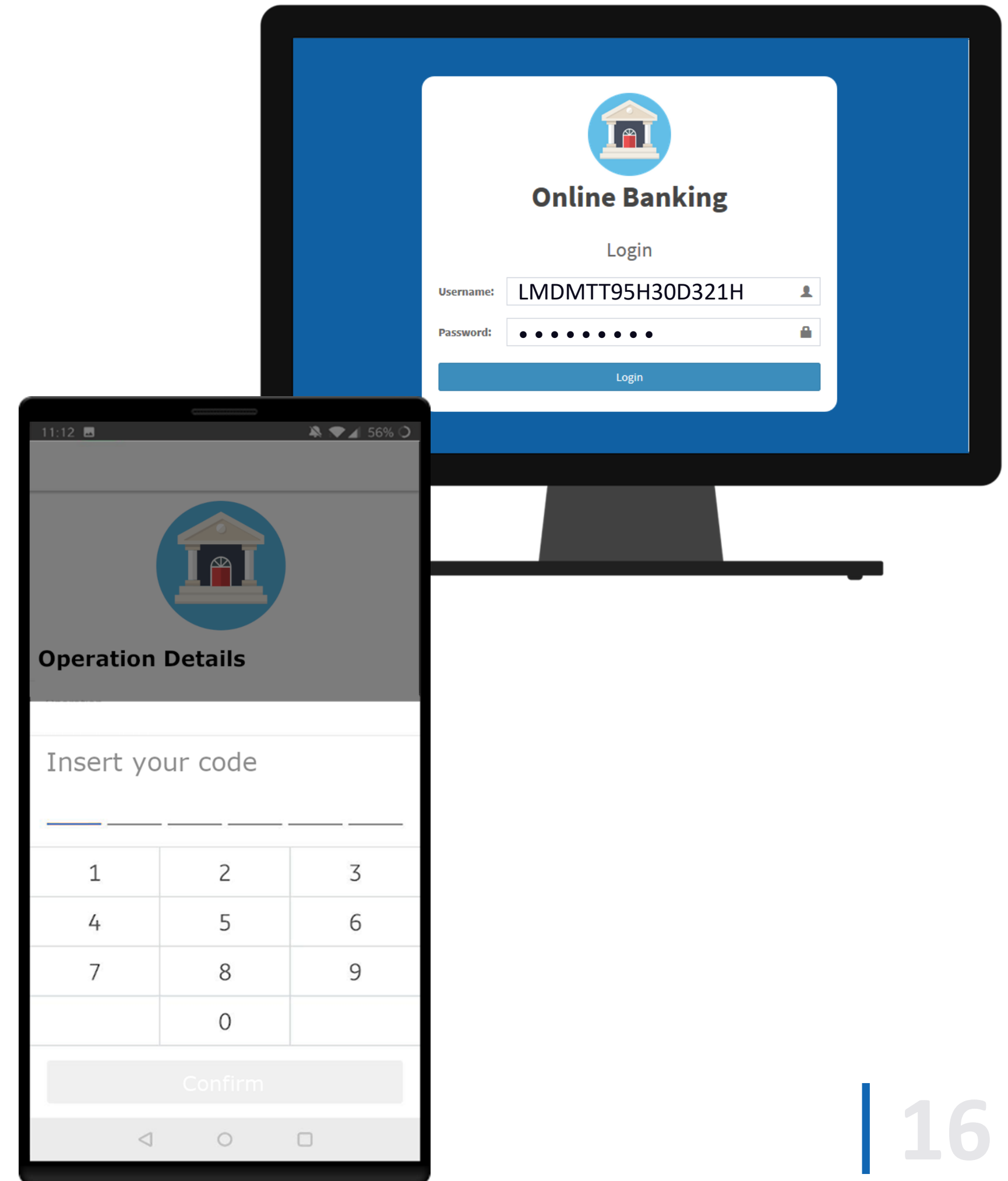
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Use Case After PSD2







After
PSD2

1. The user authenticates on the online banking through credentials and performs an operation.
2. The user receives a *push notification* that, once opened, details the ongoing operation.
3. By inserting a specific PIN, the user can authorize the operation.



Use Case

Compliance with the PSD2

Requirement	Before PSD2	After PSD2
Strong Customer Authentication	 Factors: credentials (K) matrix (P)	 Factors: credentials (K) smartphone (P)
Dynamic Linking (link between authentication code and operation)	 Matrices cannot generate codes linked to the ongoing operation	 Authentication code is bound to the ongoing operation
Dynamic Linking (information on the operation displayed to the user)	 Matrices cannot display any information about the ongoing operation	 Details on the ongoing operation are displayed after clicking on the notification

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- **Automated Analysis of Security Protocols for the PSD2**



Automated Analysis of Security Protocols for the PSD2

A Two-Levels Approach

1

Security Analysis

To detect the attackers that manage to compromise the protocol

2

Risk Analysis

To evaluate the risks connected with the successful attackers detected

Automated Analysis of Security Protocols for the PSD2

A Two-Levels Approach

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Security Analysis

To detect the attackers that manage to compromise the protocol

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Risk Analysis

To evaluate the risks connected with the successful attackers detected

Automated Analysis of Security Protocols for the PSD2

Security Analysis

To detect the attackers that manage to compromise the protocol, we perform two different kinds of analysis:

1. **Combinatorial Analysis:** relying on attackers' capabilities on the authentication factors. It is fast and thus helps prune the set of attackers to test, but may not detect some advanced attacks.
2. **Formal Analysis:** relying on formal methods (a specification language and a model checker). It can be computationally expensive, but manages to find even more complex categories of attacks.

Automated Analysis of Security Protocols for the PSD2

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Automated Analysis of Security Protocols for the PSD2

MuFASA



Secret

Device

App

Authentication factors

It requires a secret code (e.g., a PIN)?

yes

It requires a biometric scan (e.g., fingerprints)?

no

It requires an object you own (e.g., a smart card)?

yes

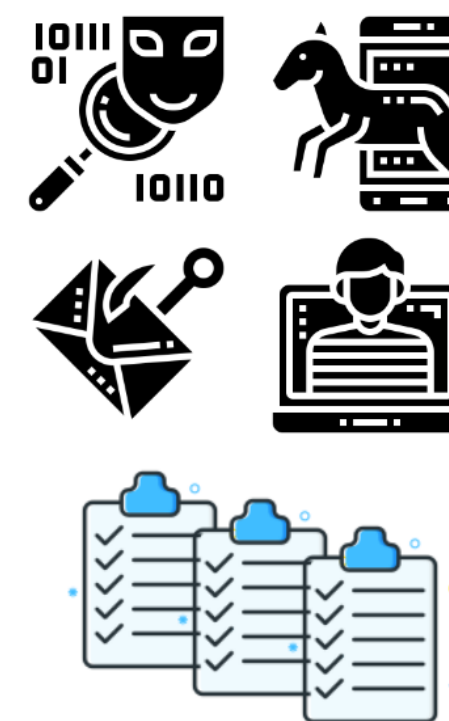
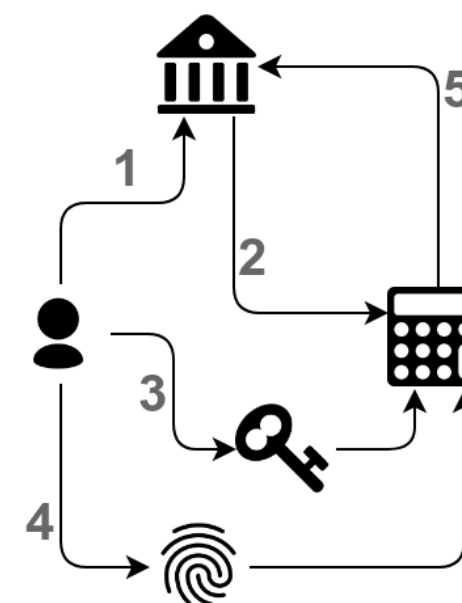
Input/output

I have to manually input a code

yes

I receive the code via

sms



Usage

Users acquire experience by running the MFA protocols

Translation

Users describe the MFA protocol through a questionnaire

Modeling

Forms are translated to a MFA ML specification

Analysis

Models are validated against adversaries and other specifications

Reporting

Risk profile, compliance and other metrics

Automated Analysis of Security Protocols for the PSD2



MuFASA

MuFASA – Translation



From which endpoint do you start the protocol?

☒ I start the protocol from a desktop computer

☐ I start the protocol from my smartphone

What kind of data does your service process?

☐ anonymous data

☐ personal data

☐ sensitive data

☒ financial data

[Previous](#) [Next](#)



Automated Analysis of Security Protocols for the PSD2



MuFASA

MuFASA – Translation



Endpoint: Desktop

Protocol specified so far:

What is your next operation?

- ☒ I insert some secret credentials (e.g., a password on a website)
- ☐ I read a value from a list
- ☐ I use a device (e.g., a card reader)
- ☐ I use a software (e.g., an app on my smartphone)
- ☐ I send/receive something on my mobile phone (e.g., an SMS, a Push notification)

Reset Next

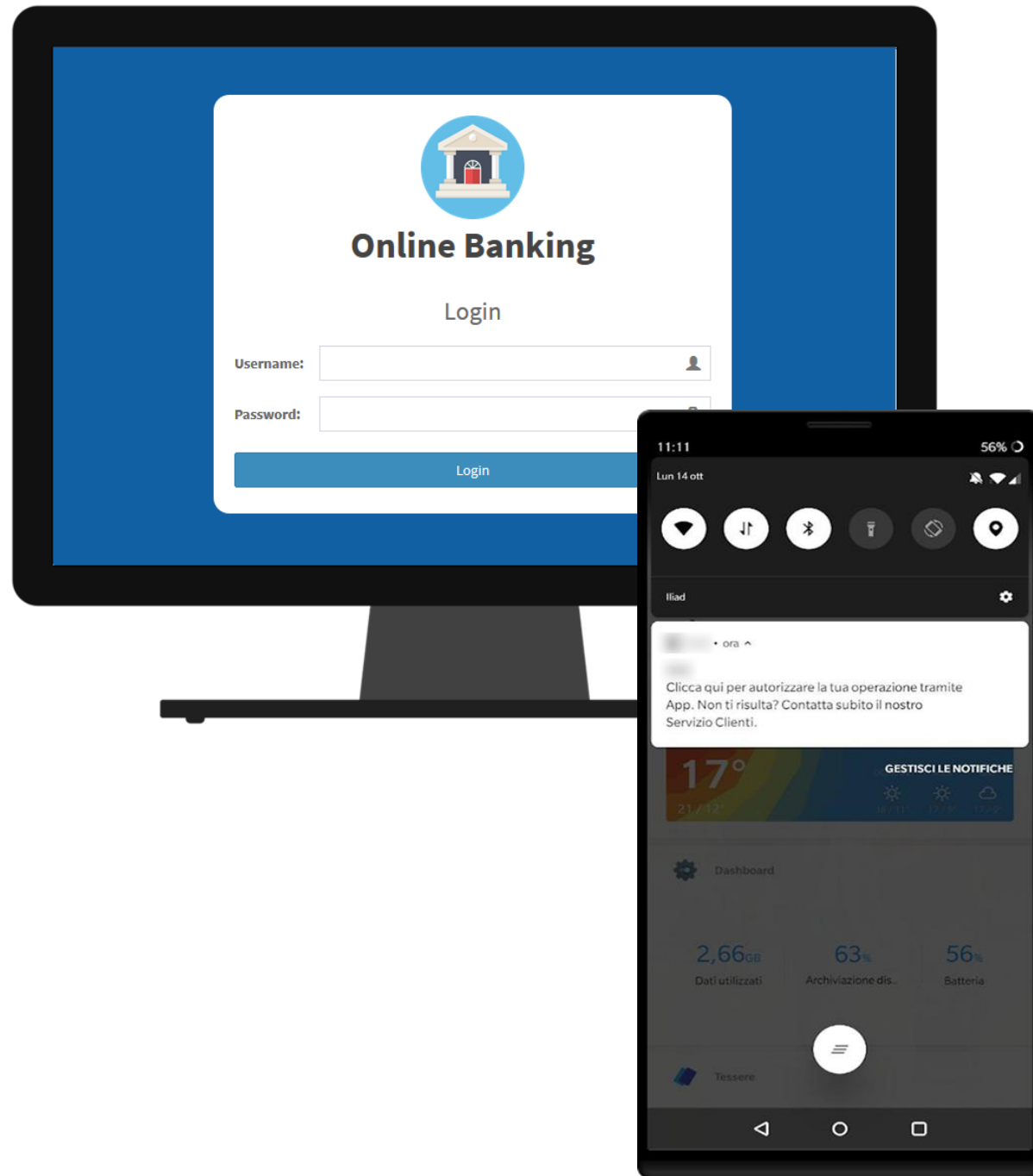


Automated Analysis of Security Protocols for the PSD2




MuFASA

MuFASA – Translation



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Protocol specified so far:



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- ☐ None, I'm authenticated

How do you receive information?

- ☐ I receive an SMS
- ☐ I make a phone call
- ☒ I receive a push notification on my smartphone

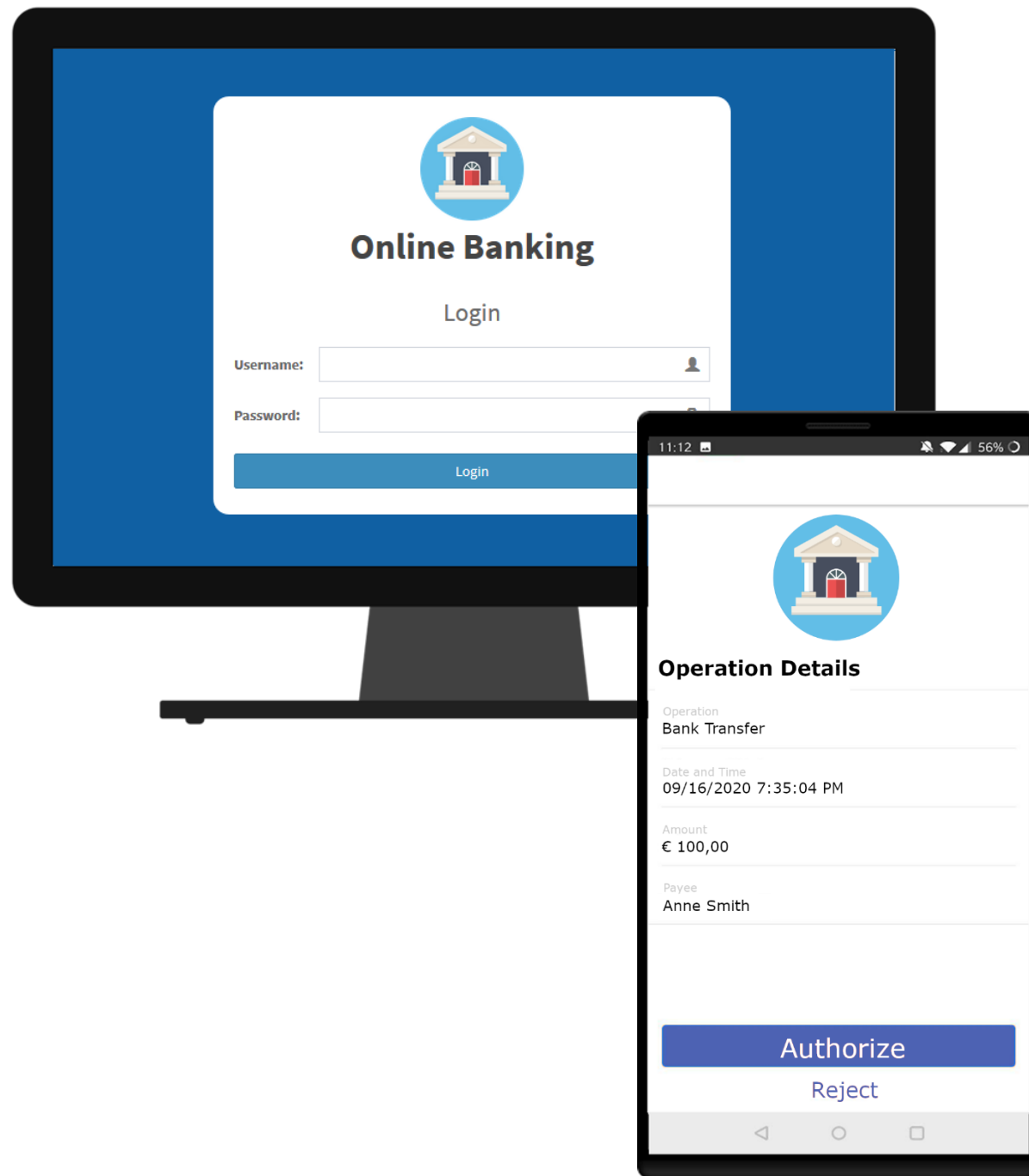


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How do you receive information?

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- ☐ I make a phone call
- ☒ I receive a push notification on my smartphone

Does it recap the ongoing operation and ask for your confirmation?

- ☐ No
- ☒ Yes (e.g. You are paying x\$ to y. Confirm?)
- ☐ Yes (e.g. You are signing in as ... Confirm?)

Reset Next

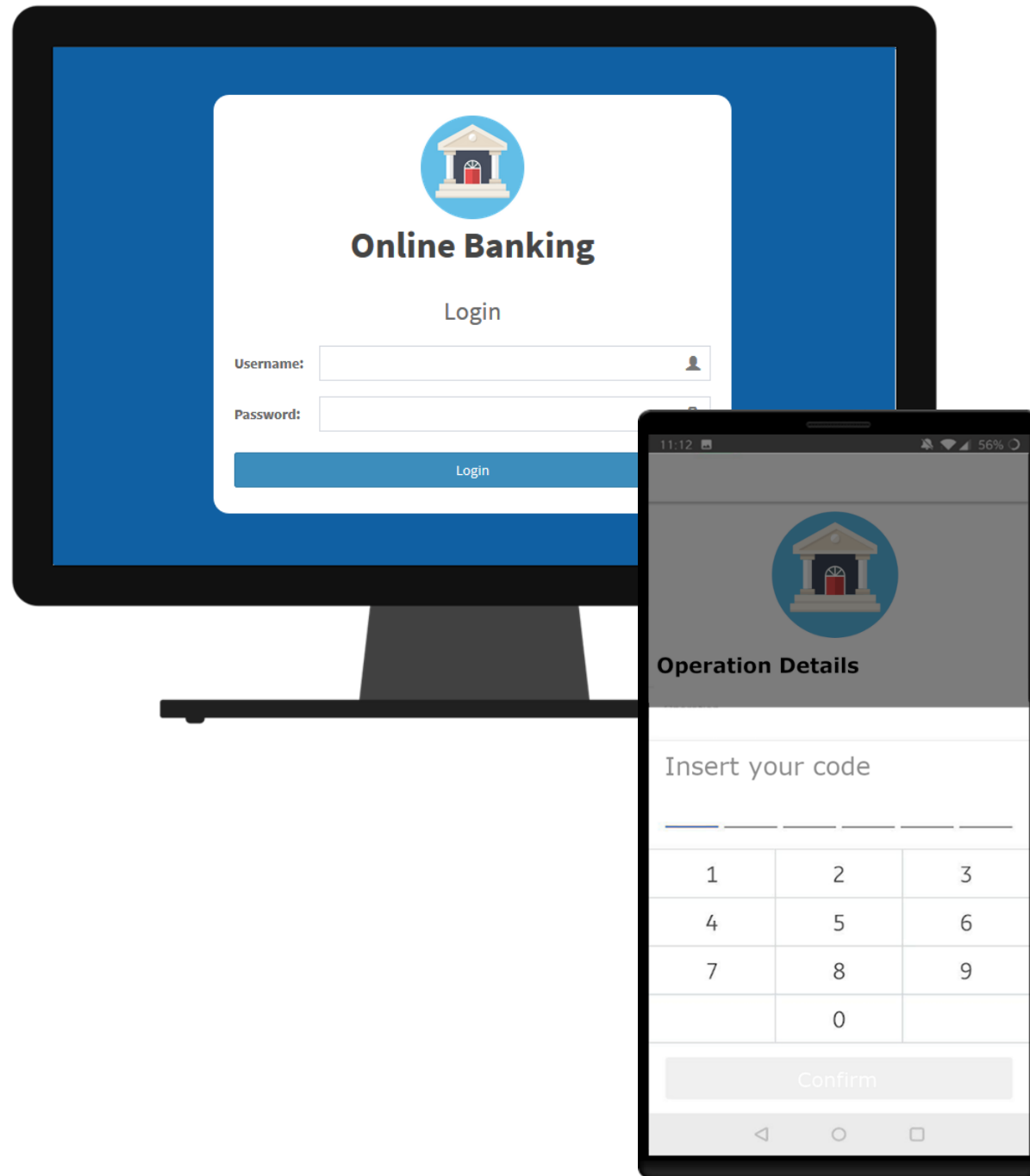


Automated Analysis of Security Protocols for the PSD2




MuFASA

MuFASA – Translation



Endpoint: Desktop
Protocol specified so far:



Among the followings, what do you need to use the authenticator?

☐ Nothing

☒ I must insert a secret code/pin

☐ I must scan a part of my body (e.g., my fingerprint)

Does it return some code that you have to copy somewhere?

☒ No

☐ Yes

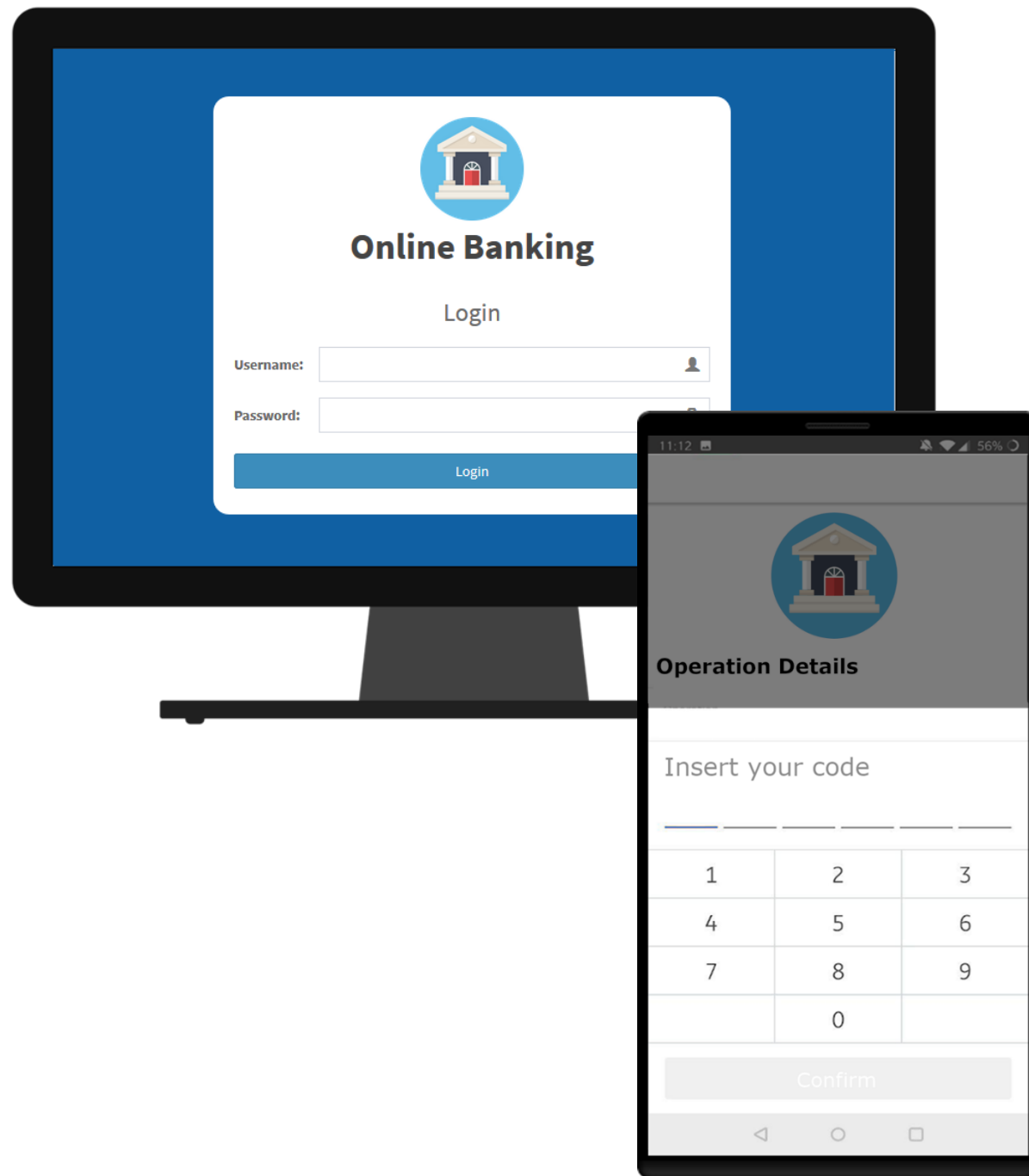
Reset Next



Automated Analysis of Security Protocols for the PSD2



MuFASA – Translation



Endpoint: Desktop
Protocol specified so far:

$$K; opid \gg_n \text{phone}^? [O, K] \gg_n otp_c$$

What is your next operation?

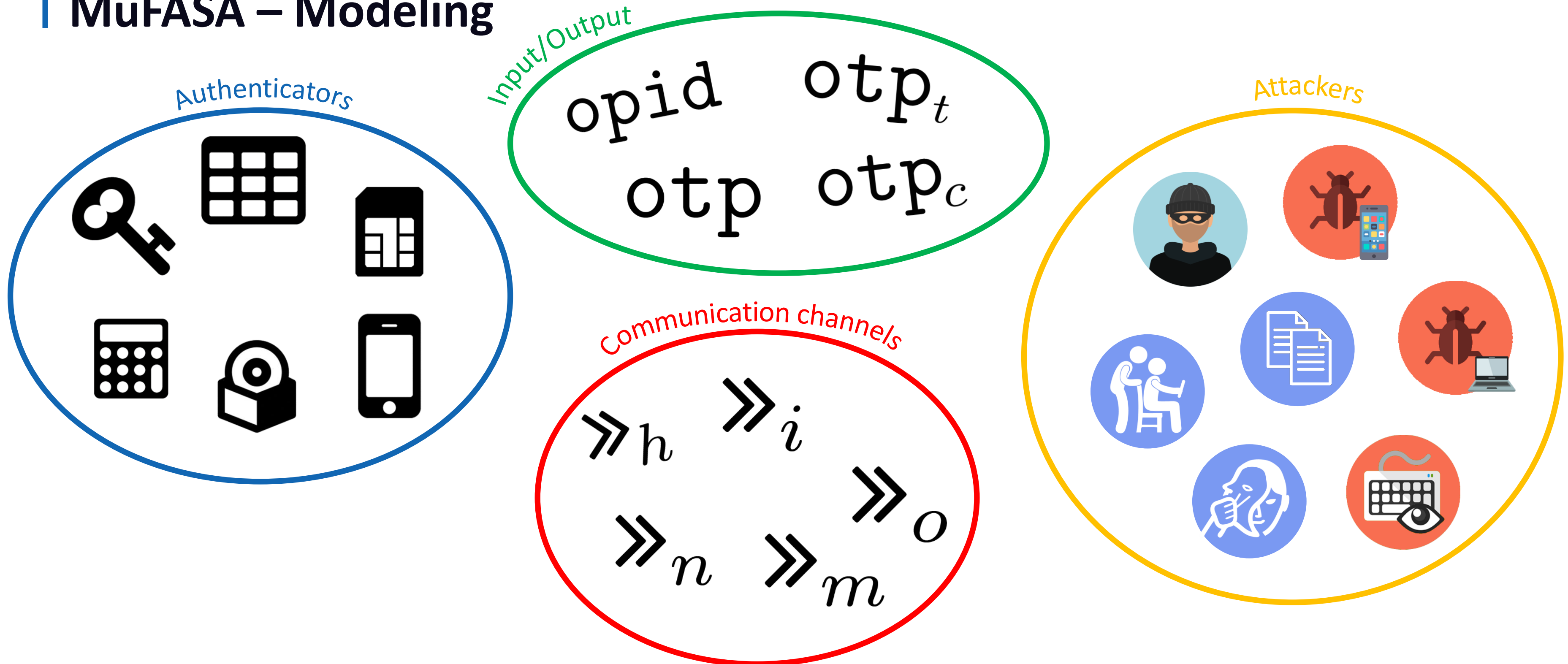
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- ☒ None, I'm authenticated

Reset Next

Automated Analysis of Security Protocols for the PSD2



MuFASA – Modeling



Shoulder Surfer: compromises secrets by looking at the victim while typing



Social Engineer: deceives the victim into revealing secrets or performing operations



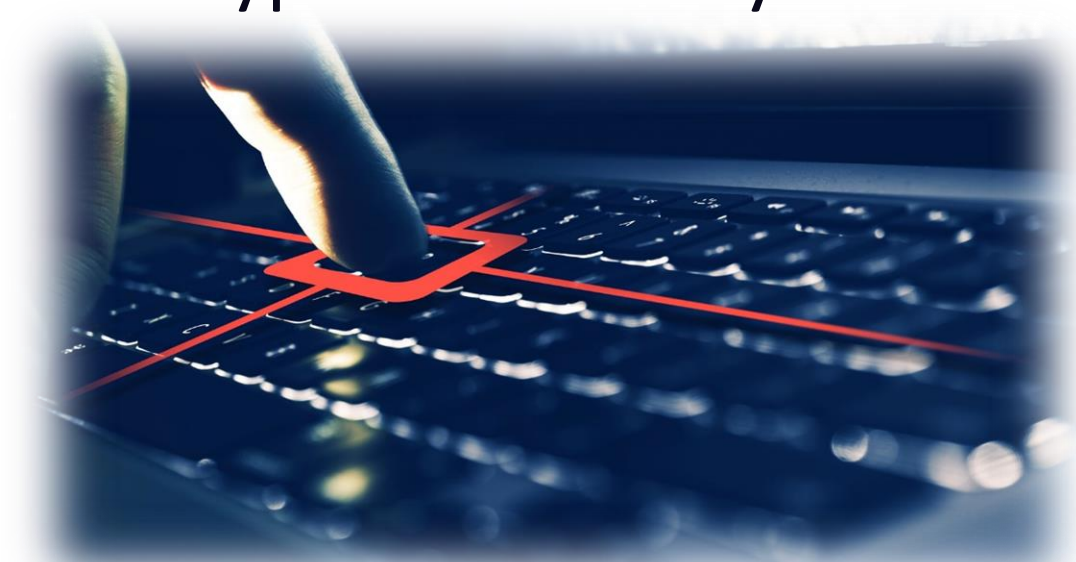
Attackers



Man in the Browser: malicious application lying on the victim's browser, manages to tamper with any window or transaction



Eavesdropping Software: malicious application intercepting everything is typed on the keyboard



Automated Analysis of Security Protocols for the PSD2



MuFASA – Analysis

Before
PSD2

4 single attackers



After
PSD2

0 single attackers

Automated Analysis of Security Protocols for the PSD2



MuFASA – Analysis

Before
PSD2

After
PSD2

4 single attackers

0 single attackers

Advantages:

Security:

Dynamic Linking

- the user is aware of the ongoing operation
- the authentication code is connected with the ongoing operation and session, therefore it cannot be used anywhere nor for any other operation
- the authentication code is sent directly through the network, without requiring the user to manually enter it → attackers that intercept the code while the user is typing are mitigated

Usability: common devices are leveraged (smartphone)

Automated Analysis of Security Protocols for the PSD2



MuFASA

MuFASA – Reporting

Analysis of MFA Protocol

$Q; \text{opid} \gg_n \text{phone}^? [O, K] \gg_n \text{otp}_c$

Info on the Analyzed Protocol:

- Starting Endpoint: Desktop
- Number of authenticators: 2
- Employed authentication factors: [K, K, O]

Protocol Complexity

- Memory: 2
- Manual Operations: 0
- Extra Devices: 0
- **Complexity Score: 2**

Compliance with security requirements

- Requirement 1: true
- Requirement 2: true
- Requirement 3: true
- Requirement 4: true

Result of the resistance analysis

Base attackers: DT, AD, SS, ES, SE, MB, MM

Max number of attackers in combination: 3

Considered attackers: 63

Combinations of attackers
DT SS
ES MM
MM MB
ES DT
SS AD
ES AD
SS MM
MM SE

Automated Analysis of Security Protocols for the PSD2

Security Analysis

To detect the attackers that manage to compromise the protocol, we perform two different kinds of analysis:

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Automated Analysis of Security Protocols for the PSD2

Formal Analysis with ASLan++ and SATMC

```
entity IdPServer(Actor, FCMServer, EICApp, User, SPServer, Browser, EIC: agent, Ch_B2IdPS, Ch_IdPS2FCMSrv, Ch_EICApp2IdPS, Ch_IdPS2EICApp: channel) {
```

```
symbols
```

```
IdPCookie: cookie;
OpId: opid;
Request: userrequest;
```

```
body { % of IdPServer
```

```
select {
```

```
on(Browser -Ch_B2IdPS-> Actor: ?Request):{
  Actor -Ch_IdPS2B-> Browser: Actor;
```

```
select {
```

```
on(Browser -Ch_B2IdPS-> Actor: User.?IdPCookie &
  enrollmentDB(Actor)->contains((User,?IdPCookie))):{
  OpId := fresh();
  Actor -Ch_IdPS2FCMSrv-> FCMServer: OpId.Request;
```

```
select {
```

```
on(EICApp -Ch_EICApp2IdPS-> Actor: OpId):{
  Actor -Ch_IdPS2EICApp-> EICApp: OpId.Actor.SPServer;
```

```
select {
```

```
on(EICApp -Ch_EICApp2IdPS-> Actor: OpId.{OpId.Actor.SPServer}_inv(pk(EIC))):{
  Actor -Ch_IdPS2B-> Browser: {Actor.User.SPServer}_inv(pk(Actor));
```

```
}
```

```
}
```

```
}
```

```
}
```

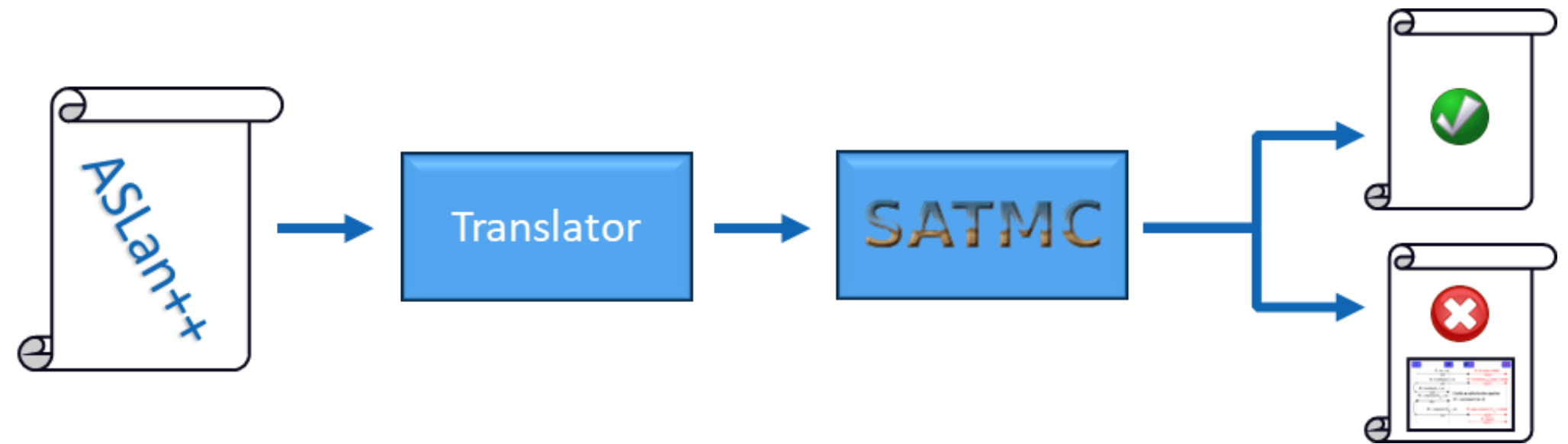
```
}
```

```
}
```

```
}
```

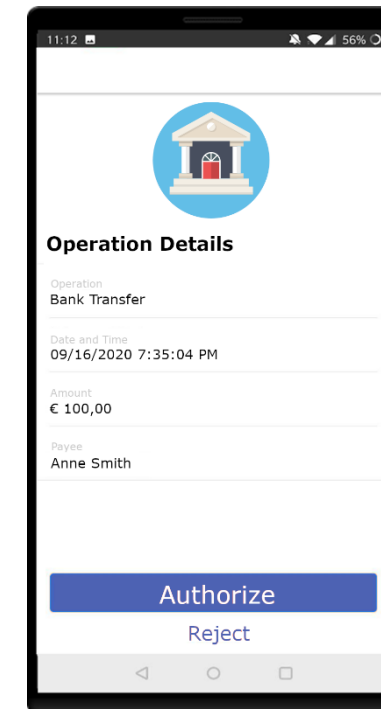
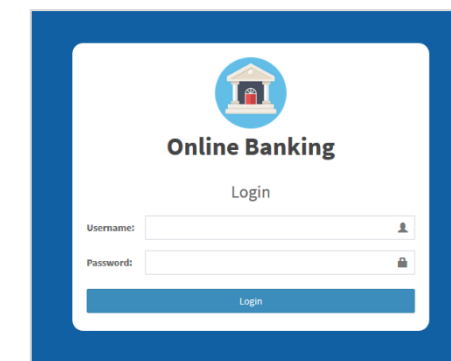
```
}
```

```
}
```



Advanced Vulnerabilities

Man in the Browser (Login)



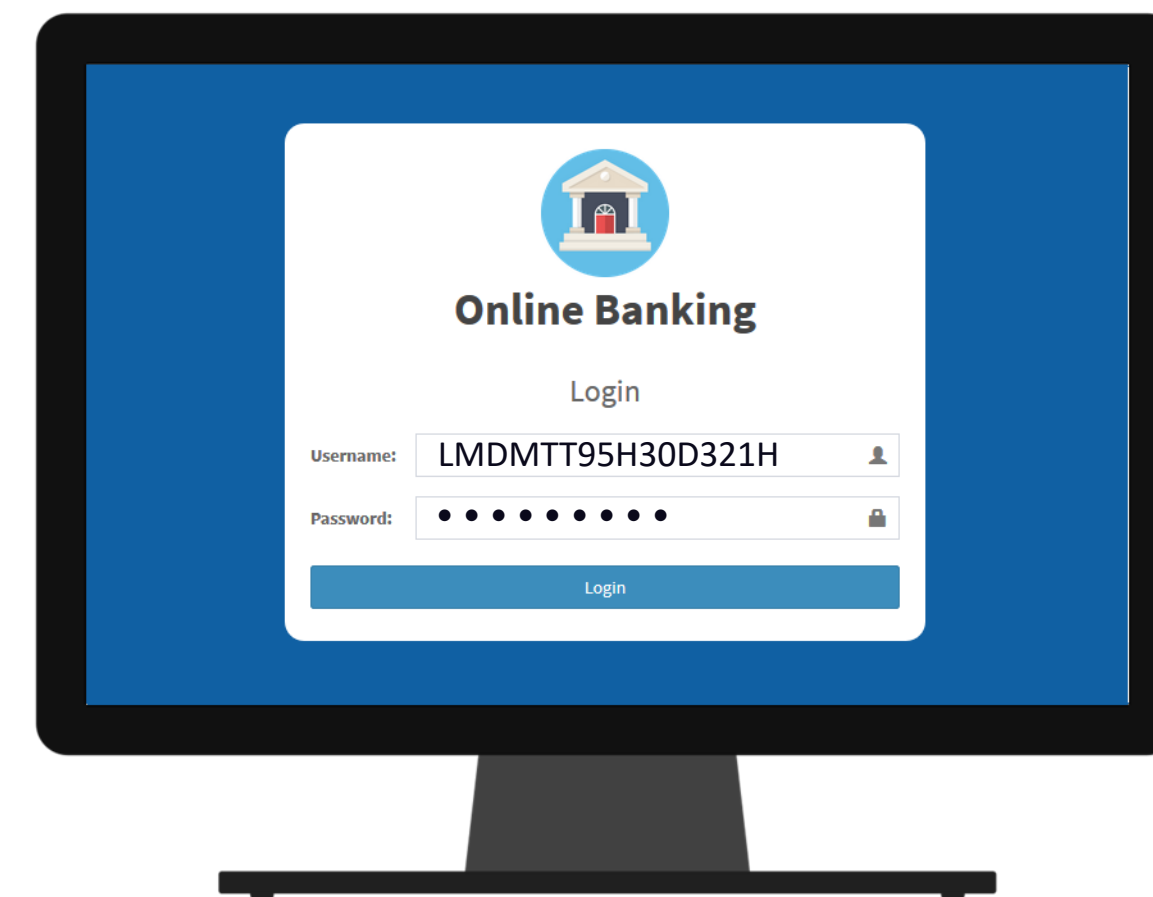
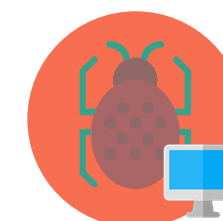
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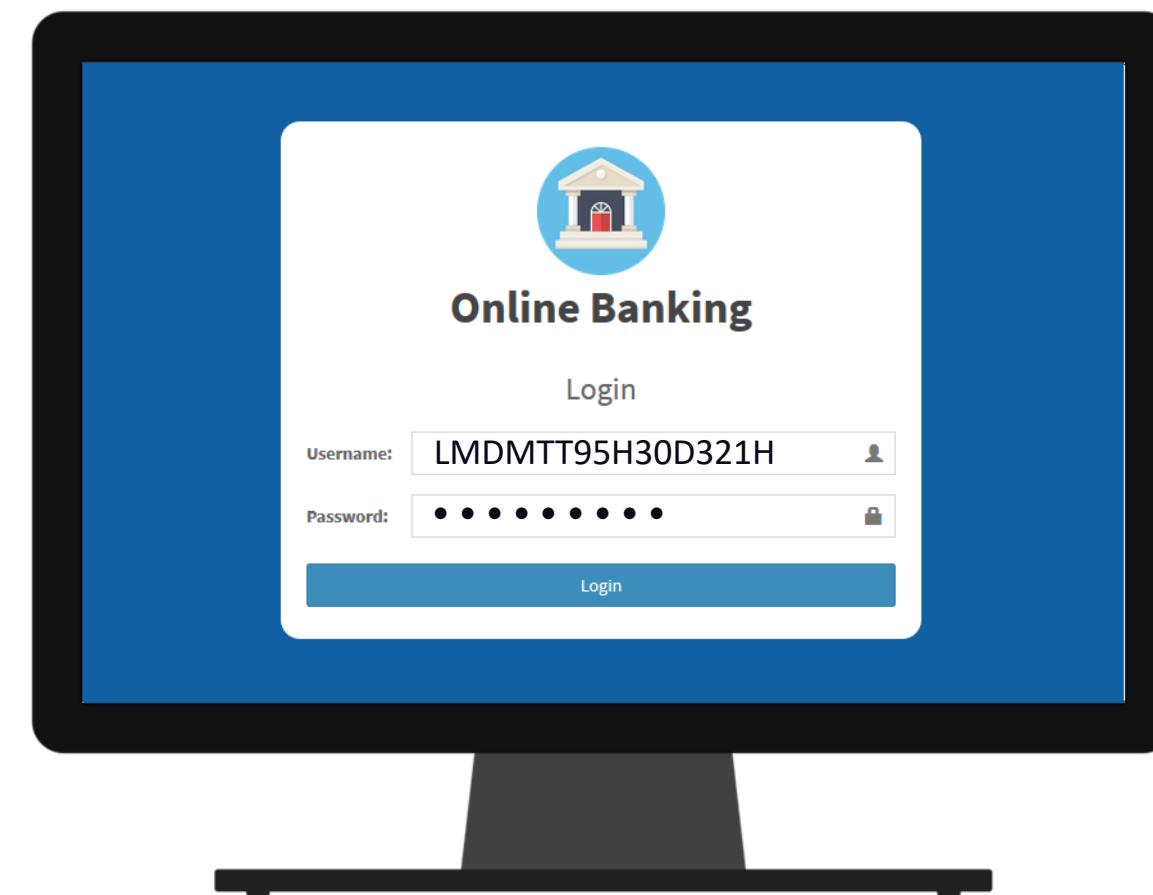
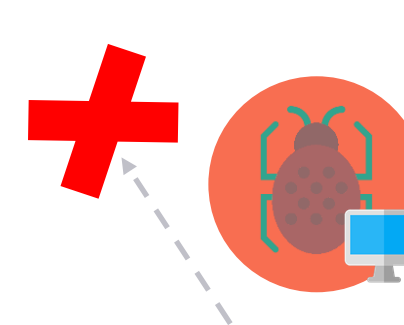
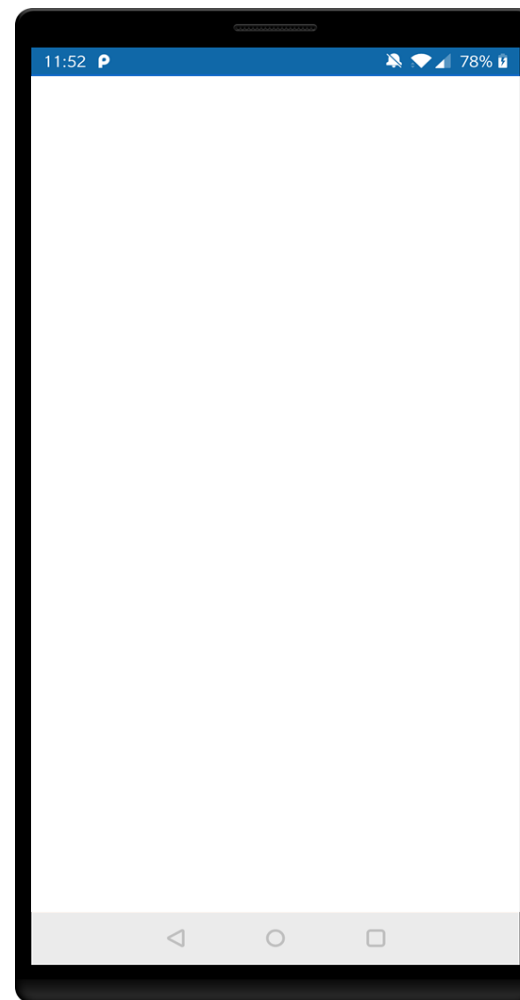
Advanced Vulnerabilities

Man in the Browser (Login)



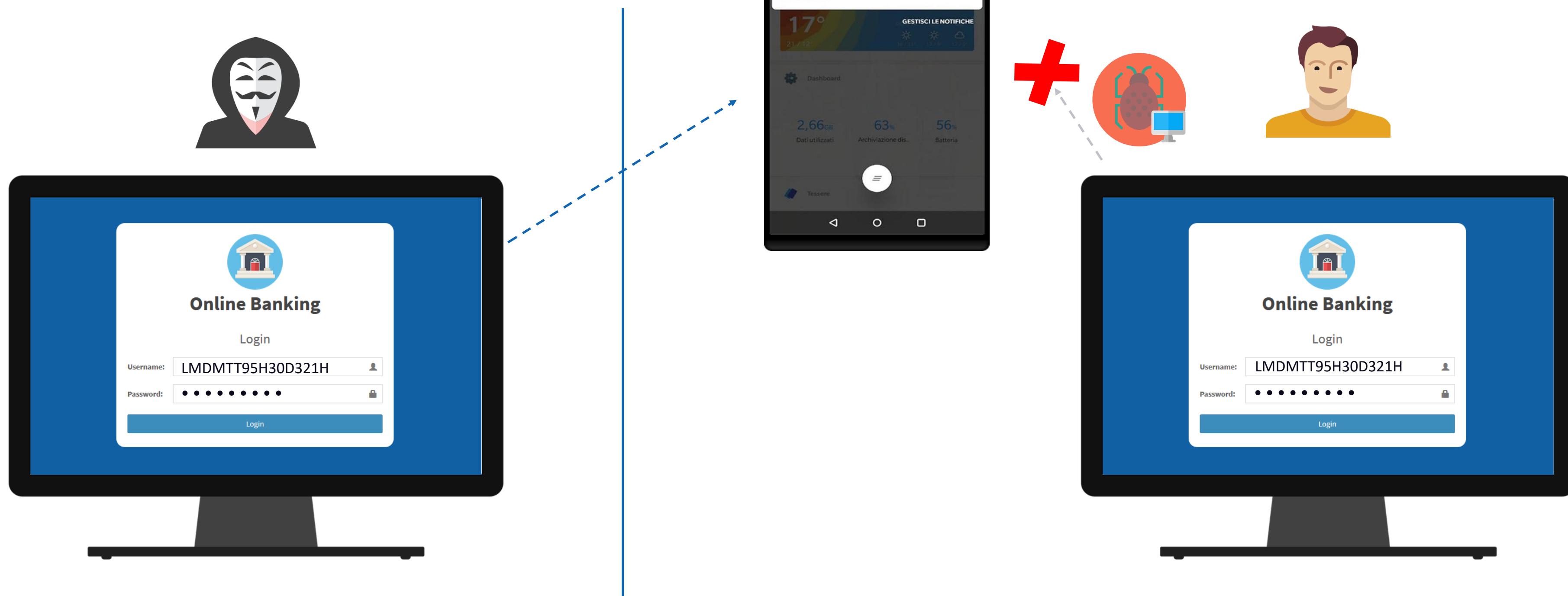
Advanced Vulnerabilities

Man in the Browser (Login)



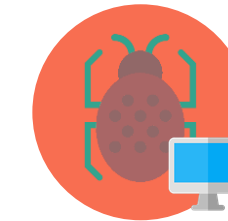
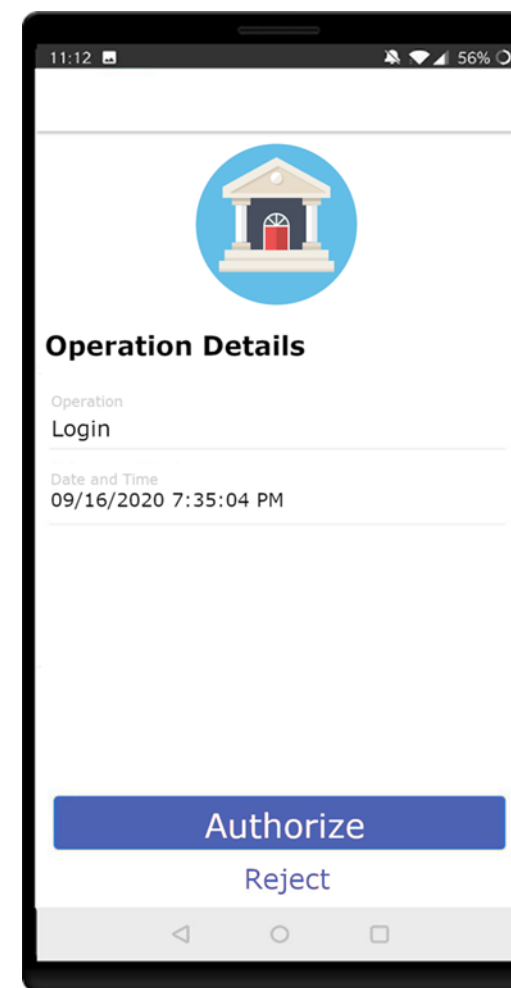
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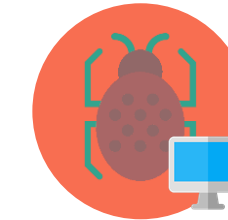
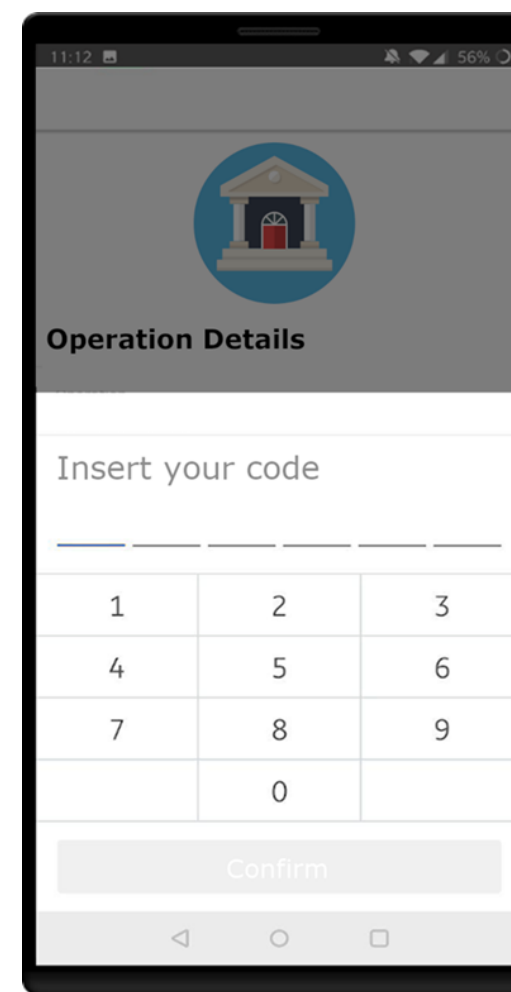
Advanced Vulnerabilities

Man in the Browser (Login)



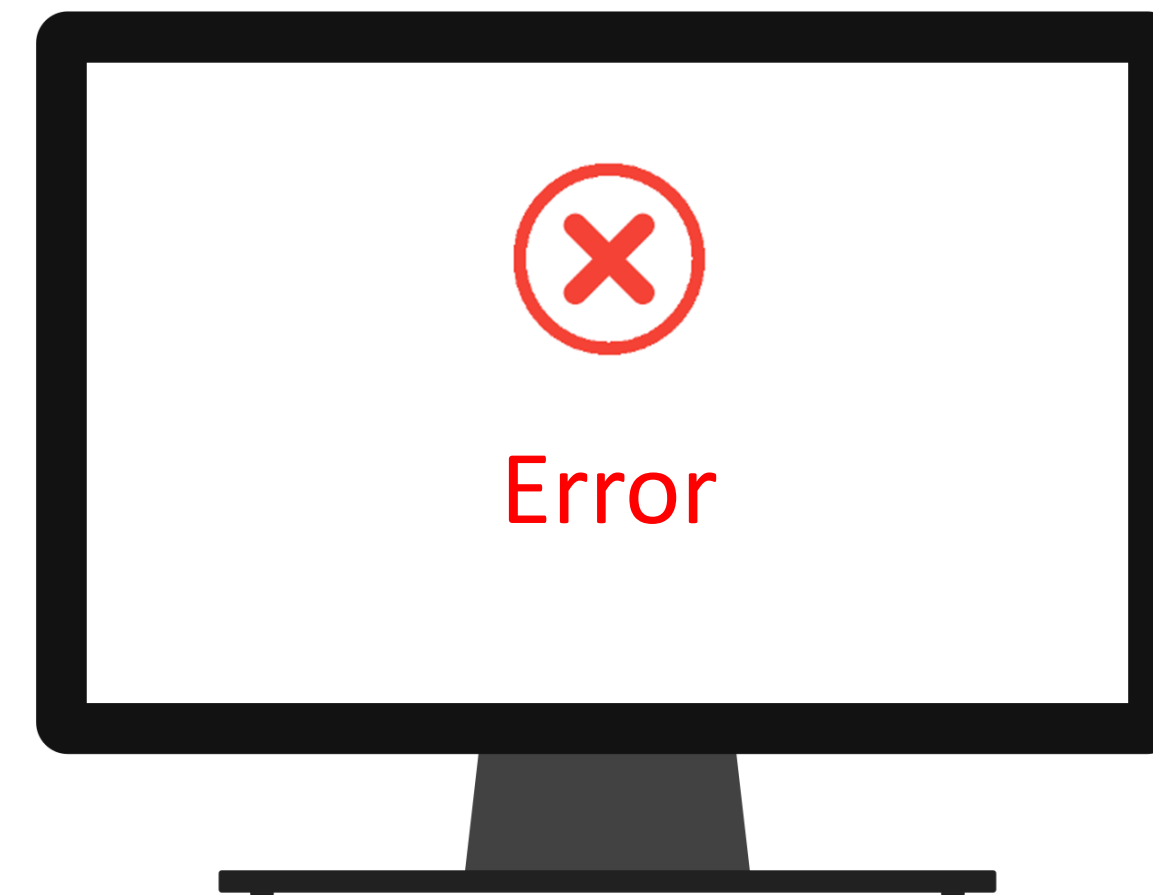
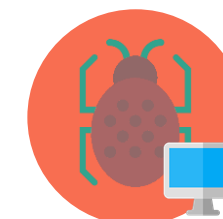
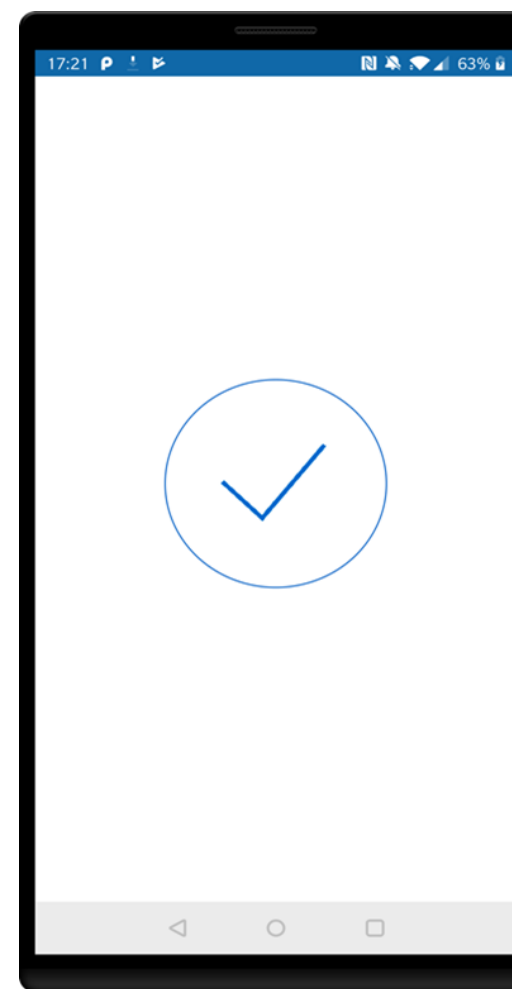
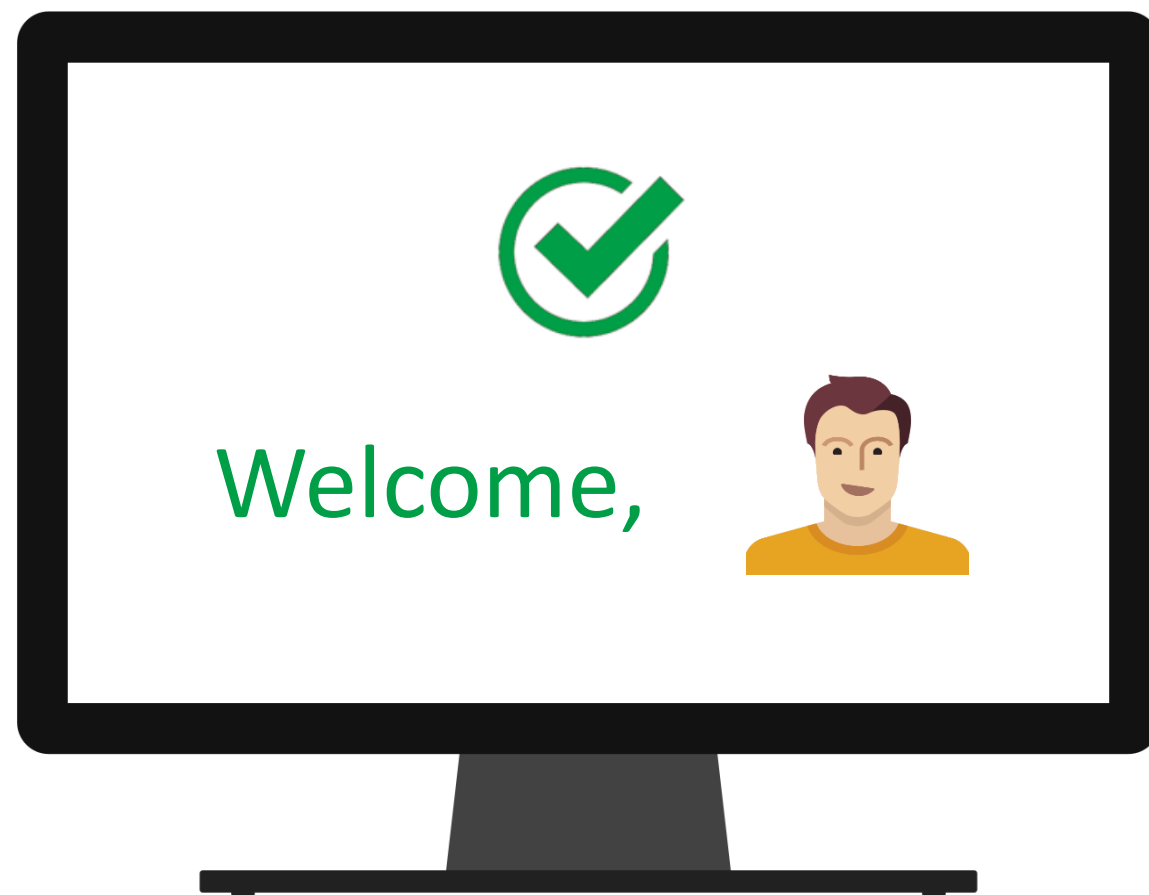
Advanced Vulnerabilities

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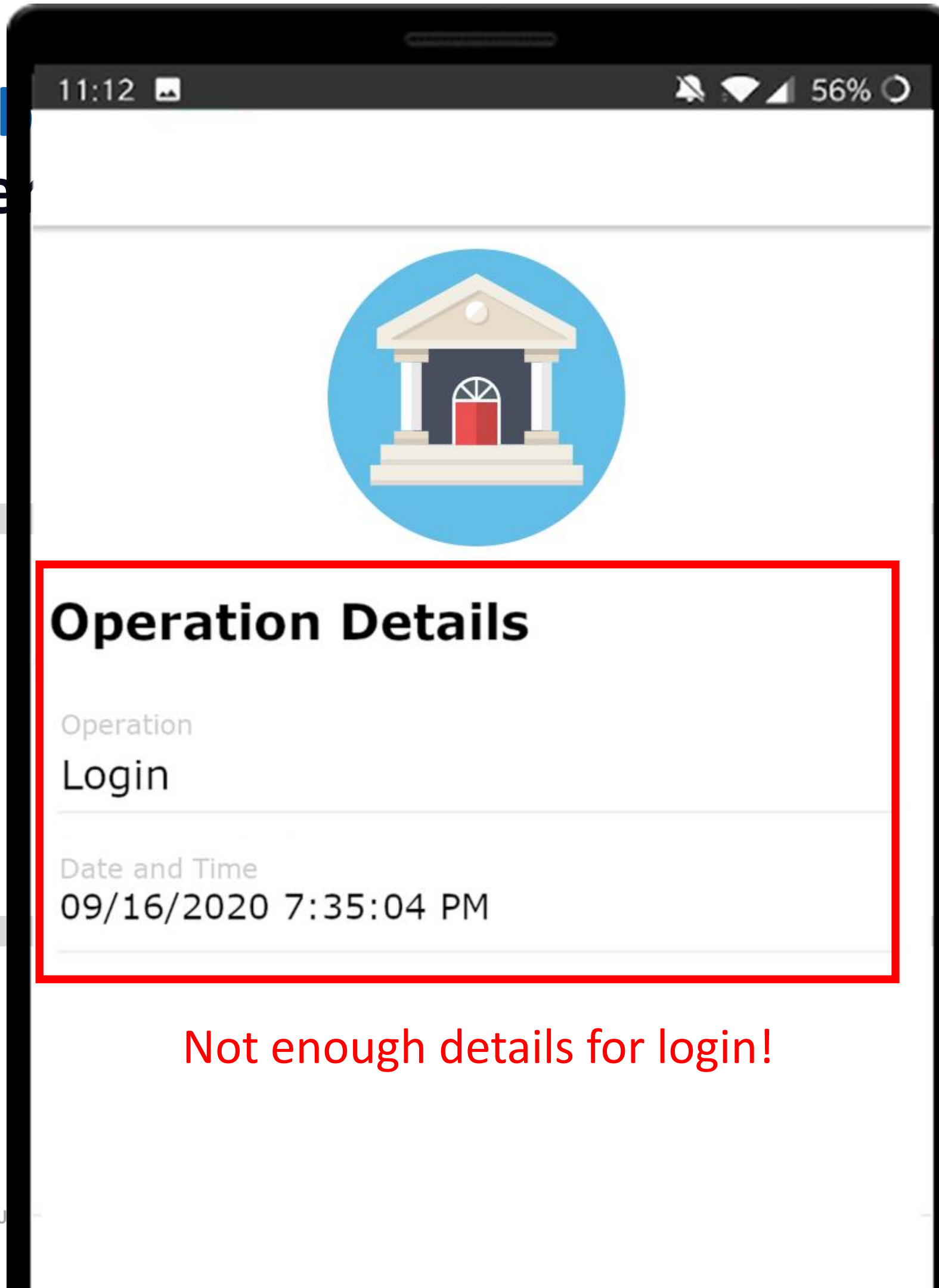


Advanced Vulnerabilities

Man in the Browser (Login)



Advanced Vulnerability Man in the Browser



Not enough details for login!

Advanced Vulnerability Man in the Browser



Welcome,



Operation Details

Operation
Login

Date and Time
09/16/2020 7:35:04 PM

Not enough details for login!

Operation Details

Operation
Bank Transfer

Date and Time
09/16/2020 7:35:04 PM

Amount
€ 100,00

Payee
Anne Smith

Enough information for
operation authorization!

Error

Automated Analysis of Security Protocols for the PSD2

A Two-Levels Approach

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Security Analysis

To detect the attackers that manage to compromise the protocol

2

Risk Analysis

To evaluate the risks connected with the successful attackers detected

Automated Analysis of Security Protocols for the PSD2

Risk Analysis with OWASP Risk Rating Methodology



Likelihood

Impact

$$\text{Risk} = \text{Likelihood} \times \text{Impact}$$

Probability of an
attack happening

Consequences in case of
the attack was successful

Automated Analysis of Security Protocols for the PSD2

Risk Analysis with OWASP Risk Rating Methodology

		Likelihood		
		<i>Low</i>	<i>Medium</i>	<i>High</i>
Impact	<i>Low</i>	Note	Low	Medium
	<i>Medium</i>	Low	Medium	High
	<i>High</i>	Medium	High	Critical

$$\text{Risk} = \text{Likelihood} \times \text{Impact}$$

Automated Analysis of Security Protocols for the PSD2

Risk Analysis with OWASP Risk Rating Methodology

Result of the resistance analysis

Base attackers: DT, AD, SS, ES, SE, MB, MM

Max number of attackers in combination: 3

Considered attackers: 63

Combinations of attackers	Likelihood	Impact	Risk
DT SS	MEDIUM	MEDIUM	MEDIUM
ES MM	LOW	HIGH	MEDIUM
MM MB	LOW	HIGH	MEDIUM
ES DT	LOW	MEDIUM	LOW
SS AD	LOW	MEDIUM	LOW
ES AD	LOW	MEDIUM	LOW
SS MM	LOW	MEDIUM	LOW
MM SE	LOW	MEDIUM	LOW



Questions?

Thank you for the attention!



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