Detecting (Absent) App-to-app Authentication on Cross-device Short-distance Channels

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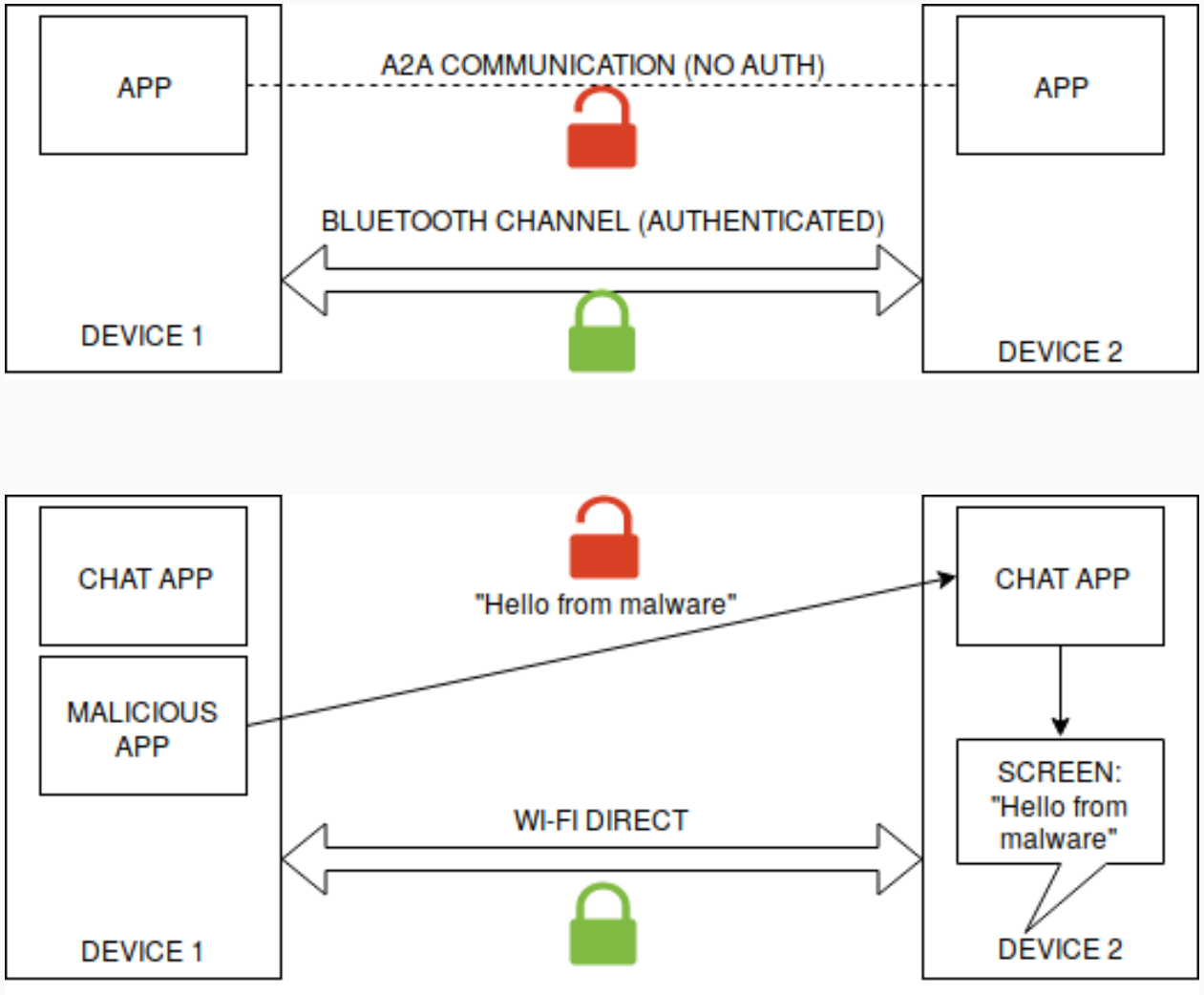
Outline

Introduction

Context

- Cross-device communications allow nearby devices to directly communicate bypassing cellular base stations (BSs) or access points (APs) (e.g. **spectral efficiency improvement, energy saving, and delay reduction**, etc.)
- Without the need for infrastructure, **such a technology enables mobile users (e.g., Android) to instantly share information (e.g., pictures and videos)**
- Such technology is also predominat in **IoT environment** where a mobile device is direct connected to the embedded system.

Cross-device Authentication Scheme



Threat Model & Attack

- The attacker is able to install a malicious app on the mobile's victim phone.
- The malicious app can therefore craft custom messages to send to the other device, which are displayed as if they were sent from the original app.
- Depending on the particular context, there are some scenarios in which the attack can become very dangerous: **Phishing, Malware delivery, Exploitation**.

Current Solutions

- Several solutions exist for securing cross-device communication. In the Android environment, they allow **authentication of devices and communication channels**.
- Others solutions **restricts apps' access to external resources, such as Bluetooth, SMS and NFC**, by defining new SEAndroid types to represent the resources.
- Moroever such **solutions are not able to address several communication channels such as: SMS, Audio, Wi-Fi and NFC** due to of missing important information for the detection purpose.

Contributions

- We identify a security problem called **cross-device app-to-app communication hijacking (CATCH)**, which commonly exists in Android apps that use short-distance channels, and afflicts all the tested Android version.
- We provide a solution to the CATCH problem by **designing and developing an authentication scheme detector** that analyzes Android apps to discover potential vulnerabilities

CATCH Detection

Authentication Scheme Definitions

- Such form of authentication proposes authenticated information exchange between devices. **These are called out-of-band, side-channels or location-limited channels (LLCs).**
- Then the apps can share a secret and they can start sending data, **using the secret as authenticator**, appending the secret as a form of nounce to protect the messagge.
- When the messagge has been received the app needs to perform authentication checks. **These checks must occur before any critical use of the data, otherwise the communication is not authenticated.**

Challenges

- We need to define a **generic scheme that captures the essential logic of app-to-app authentication**.
- We need to define a strategy for differentiating between an if-statement that does not operate on security critical data and an **if-statement that is a part of the authentication scheme**.
- Additionally, the authentication scheme **can be implemented in several ways according to the developer experience**. This adds an additional layer of difficulty for our analysis (e.g., obfuscation).

Detection Strategy

We define two main check points for our algorithm:

- An **entry point** is an instruction in the code that indicates the start of the communication over the analyzed channel (e.g., data receiving)
- An **exit point** is represented by the first authenticated use of the data coming from the monitored channel.

Detection Algorithm

Algorithm 3.1: Authentication detection

```
1  | input: APK app
2  | output: NO AUTH NEEDED |
3  |         NO AUTH FOUND |
4  |         POSSIBLE AUTH FOUND
5  |
6  |   entry_points ← []
7  |   cfg ← computeCFG(app)
8  |   ddg ← computeDDG(app)
9  |  foreach node in cfg
10 |    if isEP(node) then entry_points.add(node)
11 |  end
12 |  if entry_points == [] then return NO AUTH NEEDED
13 |
14 |  foreach node in ddg
15 |    if isCondition(node) then
16 |      foreach ep in entry_points
17 |        path ← findPath(ep, node, ddg)
18 |        if path != null
19 |        then
20 |          if isCheckConstant(node, ddg) == false
21 |          then return POSSIBLE AUTH FOUND
22 |        endif
23 |      end
24 |    endif
25 |  end
26 |
27 |  return NO AUTH FOUND
```

Reducing False Positive

- In our context, the analyzed authentication model must be performed with some sort of **dynamically generated secret** that is usually stored in the dynamic memory (e.g., heap, stack).
- By using **constant propagation** we can discard all the conditions that use constant values in their comparison, and **we only consider comparison between the input and dynamic values.**
- Constant propagation is a very powerful technique for our analysis, and it helps to reduce the false positives to 0%

Experimental Evaluation

Experimental Evaluation

To test our system we divided the experiments into two main categories:

- A dataset analysis on APKs retrieved from a research repository, aiming at confirming the efficacy of the algorithm on negative samples;
- A targeted analysis on custom apps built by applying code transformation techniques (e.g. obfuscation) for proving that the authentication scheme is correctly detected by our algorithm.

Dataset Composition

- We ran tests on a large number of APKs collected from the **Androzoo repository**, crawled from **several Android markets: Google Play, Anzhi and AppChina**.
- We started analyzing a total of **210,425 APKs**, randomly chosen from the Androzoo repository. In order to select the appropriate Bluetooth APKs we applied the **Bluetooth filter** and we obtained a total of **2,739 APKs**.
- Obfuscation filter selected a total of **942 APKs from the initial set of 2,793**, which means that the majority of the apps in our dataset, almost **70%, use ProGuard for code obfuscation**.
- we discovered that 704 of the selected apps do not have any entry point for Bluetooth communication in the CFG. we obtained a number of **238 APKs, suitable for our analysis and evaluation**.

Dataset Composition

We analyzed the composition of our dataset to make sure that we did not run tests on sample/unused/abandoned apps.

- We sampled 200 APKs (containing permissions/classes for Bluetooth) from our dataset, and performed a manual analysis by searching them on Google Play.
  - **Game apps**, where Bluetooth is used for playing peer-to-peer
  - **IoT apps for specific devices**, where Bluetooth is used to send and receive data from the controlled device or sensors
  - **Business/health apps**, using Bluetooth to send data from smartphone to computer, or again smartphone to device

Results

- We run our algorithm on **238 Apps without constant propagation** we obtained 11% of false positive. With constant propagation enable we reach **0% of false positive**.
- We built a custom app using Bluetooth that use out-of-band authentication and we applied Proguard transformation on the app. **We found that our algorithm correctly predicts the possible presence of authentication**
- We decided to run our tool on ProGuard-obfuscated APKs from our dataset a total of 662 APKs. **100% of the APKs were identified as negative (i.e., not containing authentication) by our tool.**

Performance Analysis

To set up a correct time threshold we need to be sure that the constructed CFG and DDG include the Bluetooth entry points and the authentication checks. we set up three Threshold 30, 60, 120 sec.

- For any entry point, we found on average more than **10,000 instructions that are dominated by the entry point and the CFG reachability from a single entry point to any node in the graph**.
- The **variation of the results between the three runs is minimal**, that it means that we generally do not miss any important information.
- The average time spent for **modeling the APK in Argus-SAF is 5 minutes**, while the **average running time of our algorithm** on the generated graphs is **2 minutes**, giving a total average **time of 7 minutes**.

Case Studies

Data injection on BluetoothChat and Wifi-Direct

- We implement the attack vector against two real applications: (1) BluetoothChat that use Bluetooth technology, (2) Filesharing on Wi-Fi Direct.
- Two preliminaries requirements: (1) the malicious app needs to recognize the **presence of the target application**. (2) the malicious app needs to detect when the target **application is opened and run.**
- If the attacker has satisfied the previous two requirements the attack can be performed successfully.

Limitations

Impact & Limitations

- Our framework is not able to handle particular intra-component and inter-component transitions, such as ones performed with **reflection**, and it cannot correctly **model concurrency**.
- In case of authentication, we **expect to see controls on data read from the channel immediately after a read operation**, following our authentication model.
- We manually analyzed **20 Android apps from 662 dataset apps** and we check whether threads functions defined in the apps include any authentication scheme (**false negative results**).

Conclusion

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- We have shown the extension and potential impact of **CATCH vulnerabilities in Android apps**, providing a threat model and specific definitions for the problem,
- We design an automated system for APK analysis, is a first line of defense against human error, and could be used to identify vulnerable apps.
- We test the efficacy and efficiency of our system against a large number of android apps.

Thank you for attention

Questions?