Hiding Privacy Leaks in Android Applications Using Low-Attention Raising Covert Channels

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Privacy protection is one of the hot topics for smartphones:

- **Private data comprises:**
  - phone identifiers (IMEI)
  - contacts, phone numbers (MSISDN)
  - sms content
  - files, passwords, ...

- **Data leakages enable to:**
  - Sell collected information
  - Blackmail a user
  - Attack other targets using the collected information

- **Malware can use the phone’s capabilities (e.g., send SMS)**
Outline

1. Introduction
   - Covert Channels

2. Malware Based on Covert Channels
   - Malware Design
   - Improve Hiding Techniques

3. Conclusion and Future Work
What about security if the malware exploits covert channels?
Covert Channels

What about security if the malware exploits covert channels?

Covert channels are channels that:
- are unforeseen by a system’s design
- exploit application/OS/hardware capabilities
- ... in order to break a security policy
- escape classical detection solutions
- can be optimized to keep a low profile

... and can be found in local systems, networks, automation environments, business processes, smart cards, ...
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Our goal is to show that:
- covert channels can help to build an unnoticeable malware
- therefore, we improve the covert channel stealthiness
Our proposal, similar to Marforio et al. [?]:

- Data collector: accesses private data
- Data submitter: leaks collected data
- Covert channel: local hidden communication path

**Scenario:** Multiple smart home apps, workout apps, ...
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**Scenario**: Multiple smart home apps, workout apps, ...
The designed covert channel enables to leak private data and keeps a low profile by:

- minimizing and separating the required permissions
- leaking data correlated with the user interaction
- comprising a low energy footprint

**Goal:** User should not suspect presence of a malware.
Micro Protocols

We adapted a feature of network covert channel research: Micro Protocols (MP).
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- MPs enable reliable covert channels
- MPs enable adaptive covert channels

We split the covert channel into a separate control channel (simple MP) and a data channel.
Four Different Covert Channels

We developed four covert channels linked to different required permissions:

<table>
<thead>
<tr>
<th>Covert channel type</th>
<th>Control channel</th>
<th>Data channel</th>
<th>Required permission</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC#1: Task list / screen-based</td>
<td>screen state</td>
<td>task list process priority</td>
<td>GET_TASK</td>
</tr>
<tr>
<td>CC#2: Process priorities / screen-based</td>
<td>screen state</td>
<td>process priority screen based</td>
<td></td>
</tr>
<tr>
<td>CC#3: Process priorities</td>
<td>screen based</td>
<td>WAKE_LOCK</td>
<td></td>
</tr>
<tr>
<td>CC#4: Pure screen-based</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Control and data channels of our covert channel techniques.
Required permissions (CC#1)

- The user will not suspect each app independently.
- Automatic tools will miss the information flow.
- How works the CC?

Hiding Privacy Leaks in Android Applications Using Low-Attention Covert Channels

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Required permissions

INTERNET

GET_TASKS

READ_CONTACTS

CC receiver

Browser

Messaging

Covert Channel

Data collector

CC sender
Why GET_TASKS permission is needed?

Example: CC#1 is based on observable screen and task events:

- The screen turns off ⇒ starting transmission
- CC sender is killed: ⇒ ending transmission (GET_TASKS)
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![Diagram showing screen state and CC sender state](image-url)
Why `GET_TASKS` permission is needed?

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Eliminating the requirement for `GET_TASKS`

Synchronization realized like in case of CC#1 (screen state)

Data transfer based on **process priority** (receiver needs to scan for the priority) instead of process existence:

- Sender changes its priority to $p$ known by sender and receiver
- Receiver iterates over all process IDs to determine the presence of a process with priority $p$ (error-prone!)

Two variants: With a data channel using the screen state (CC#2) and without data channel (CC#3)
Architecture of CC#1 and CC#2

- **CC Sender**
  - **Is screen off?**
    - yes
    - Synchronizing event
  - **Starting data channel**
    - CC#1: scheduling auto-kill
    - CC#2: changing prio. to 4
  - **Data channel started**
    - CC#1: time to launch auto-kill
    - CC#2: time to return prio. to 0
  - **Is screen off?**
    - yes
    - Message sent
    - no: wait deltaT
  - **Message received**
  - Cancelling all tasks: sending failed

- **Covert Channel**
- **CC Receiver**
  - **Is screen off?**
    - yes
    - Synchronizing event
  - **Starting data channel**
    - CC#2: check one priority = 4
  - **Data channel started**
    - CC#1: check CC sender alive
    - CC#2: check priority = 4
  - **Is screen off?**
    - yes: wait deltaT/4
    - Message received
    - no
  - Cancelling all tasks: receiving failed
Energy Consumption

Energy consumption of CC#1 and CC#2 during 1 min of transmission (automatic fake user interactions) and of CC#3 during 1 min of runtime (measured using Power Tutor)
Throughput (Example CC#2)

Interruptions (screen interaction by the user after \( n \) sec). Low \( n \) interrupts CC transmission (the screen state changes), high \( n \) leads to long pause intervals between byte transmissions.
Countermeasures

- Applying the *fuzzy* time approach
- Applying machine learning
- Introducing barrier values, e.g. \( \geq n \) process priority requests/\( \text{sec} \)
- Introduce errors for process priority requests (CC#3); Fig. shows results for introduced errors (barrier size) per 1000 API requests using solely the process priority:

![Graph showing Good, Wrong, and Dropped bytes ratio against barrier size (int) for process priority requests.](image-url)
Conclusion

- Introduced covert channels with a low throughput
- ... but with a high data transmission quality (control channel),
- ... the need for only few privileges,
- ... and a low energy footprint and a behavior correlated to the user’s interaction (keeping a low profile)
Future Work

- Utilize multiple covert channels simultaneously
- Therefore: Introduce reliable covert channel protocols (sequence numbers and ARQ)
- Introduce adaptive covert channels (notice blocked communication means dynamically and switch to alternative channels on demand)
Questions