Trusted Execution Environment: what it is and what it is not

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Outline

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2. Dual-EE
   - The Trust Problem
   - Towards Dual-EE
   - Core Properties

3. Trusted Execution Environment
   - Design
   - Attacks
   - Small Survey

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“The time has come,” the Walrus said,
“To talk of many things;
Of shoes—and ships—and sealing wax—
Of cabbages—and kings—
And why the sea is boiling hot—
And whether pigs have wings.”

— Lewis Carroll, Through the Looking-Glass
Ubiquitous TEE

- Virtual TPM [Trust 2009];
- Privacy-Preserving Mobile Payment [TrustCom 2012];
- Sensors [MobiSys 2012];
- Two Factor Authentication [NDSS 2014];
- Introspection [CCS 2014];
- Software Obfuscation [ARES 2014];
- Mobile Advertisement [MobiSys 2015];
- Autonomic Systems [ICAC 2015].
Once upon a time
Introduction

From different directions
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Come, listen, my men, while I tell you again
The five unmistakable marks
By which you may know, wheresoever you go,
The warranted genuine Snarks.

— Lewis Carroll, The Hunting of the Snark
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Let’s start at the very beginning...

Practical Need

Execute a highly-sensitive app on an off the shelf smartphone.
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**Existing Solutions**
- special hardware processor: AEGIS and CHERI;
- micro-kernel: SeL4;
- separation kernel: TLR.
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State of the art
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Definitions

Separation Kernel

Security kernel that enables the coexistence of different systems requiring different levels of security on the same platform.
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Secure Execution Environment

Processing environment that guarantees the following properties:

- **authenticity**: the code under execution should not have been changed;
- **integrity**: runtime states should not have been tampered with;
- **confidentiality**: code, data and runtime states should not have been observable by unauthorized applications.
The Dual-Execution-Environment Approach

Definition

The Dual-Execution-Environment is a security architecture where both a Separation Kernel and a Secure Execution Environment play the role of Security Kernel. As its name indicated, only two processing environments run above the defined separation kernel.
Overview

M. Sabt al. (Orange Labs)

TEE: what it is and what it is not

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Dual-EE
Core Properties

Isolation

1. **Data separation**: Data within one partition cannot be read or modified by other partitions;
2. **Sanitization**: Shared resources cannot be used to leak information into other partitions;
3. **Control of information flow**: Communication between partitions cannot occur unless explicitly permitted;
4. **Fault isolation**: Security breach in one partition cannot spread to other partitions.
Inter-EE Communication

1. **Reliability**: memory/time isolation;
2. **Minimum overhead**: unnecessary data copies and context switches;
3. **Integrity**: protection of communication structures.
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**Attacks**
- message overload attacks;
- control data corruption attacks;
- memory faults caused by shared pages being removed.
Secure Scheduling

1. **Time-slicing**: balanced sharing of the hardware resources;
2. **Preemptive**: mixing the priority level of the GPOS and SEE activities.
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**Attacks**

- non-responsive event-driven operations;
- unbound waits caused by the non-cooperation of the untrusted part of the system.
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“When I use a word,” Humpty Dumpty said, in rather a scornful tone, “It means just what I choose it to mean—neither more nor less.”

— Lewis Carroll, Through the Looking-Glass
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The War of Terminologies

The Existential Question

Does the **TEE** exist before the existence of the **TEE**?
Building Blocks

- Normal OS
  - Inter-Environment Communication
- TEE
  - Trusted Applications
  - Trusted Kernel
    - Secure Provisioning
    - Secure Attestation
    - Secure Storage
    - Inter-Environment Communication
    - Trusted I/O Path
  - Information Flow Control
  - Secure Scheduling
- Separation Kernel
- Root Keys
- Secure Boot
- Root of Trust
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Adversary model

a powerful attacker who is able to execute an arbitrary code in the kernel privileges.

Attack Classes

- bypassing security features;
- executing arbitrary code in the secure zone;
- overwriting part of the secure region of the memory with certain values;
- Denial-of-service attacks are not included.
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## Small Survey

<table>
<thead>
<tr>
<th>TEE</th>
<th>License</th>
<th>Normal World</th>
<th>Hardware Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>ObC</td>
<td>Close</td>
<td>Symbian OS</td>
<td>300 MHz OMAP 2420</td>
</tr>
<tr>
<td>t-base</td>
<td>Close</td>
<td>Android</td>
<td>Samsung Exynos platforms</td>
</tr>
<tr>
<td>Andix OS</td>
<td>Open</td>
<td>Linux</td>
<td>iMX53 QSB</td>
</tr>
<tr>
<td>TLK</td>
<td>Open</td>
<td>Android</td>
<td>Tegra SoCs</td>
</tr>
<tr>
<td>TLR</td>
<td>Close</td>
<td>.NET CLR</td>
<td>Tegra 250 Dev Kit</td>
</tr>
<tr>
<td>SafeG</td>
<td>Open</td>
<td>TOPPERS/ASP</td>
<td>PB 1176 JZF-S board</td>
</tr>
</tbody>
</table>
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Summary

- TEE is a promising security technology;
- Formal model can be defined with the Dual-EE approach;
- TEE could be shown as a security architecture, rather than just a technology in order to have enough theoretical basis to answer basic issues related to TEE.
Thank you for your attention!