BASTION-SGX: Bluetooth and Architectural Support for Trusted I/O on SGX

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Dartmouth[1], Intel[2]

Hardware and Architectural Support for Security and Privacy (HASP)
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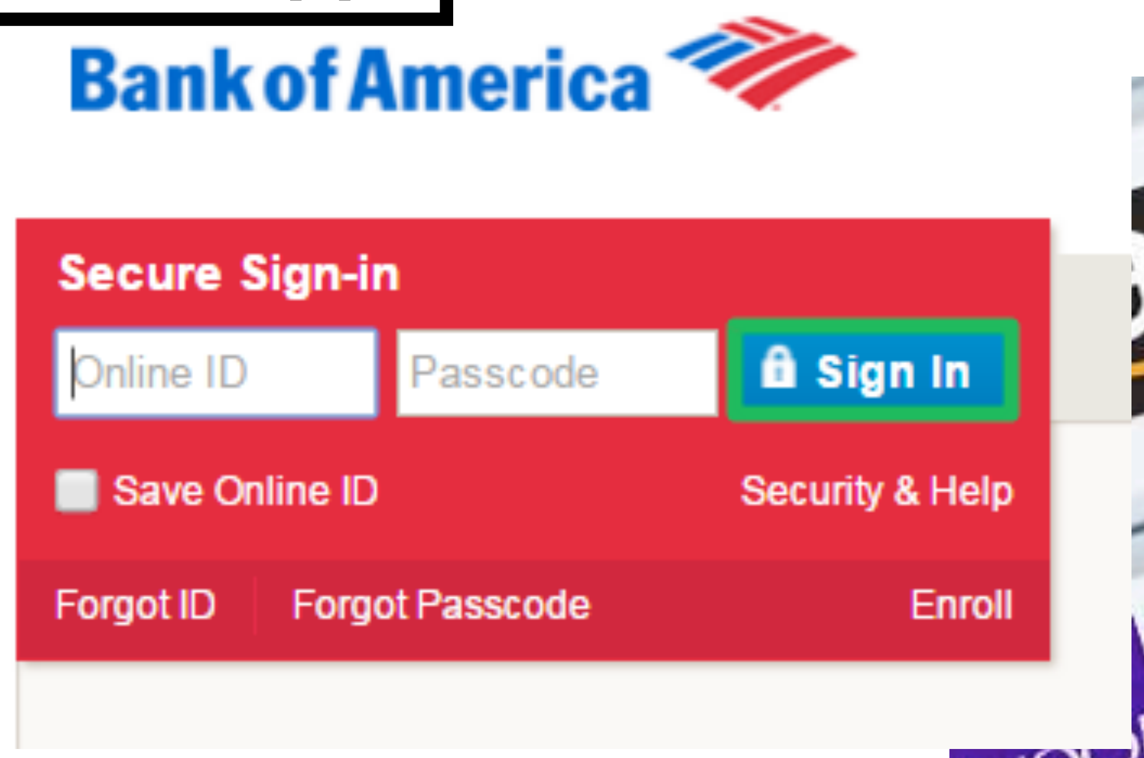
Outline

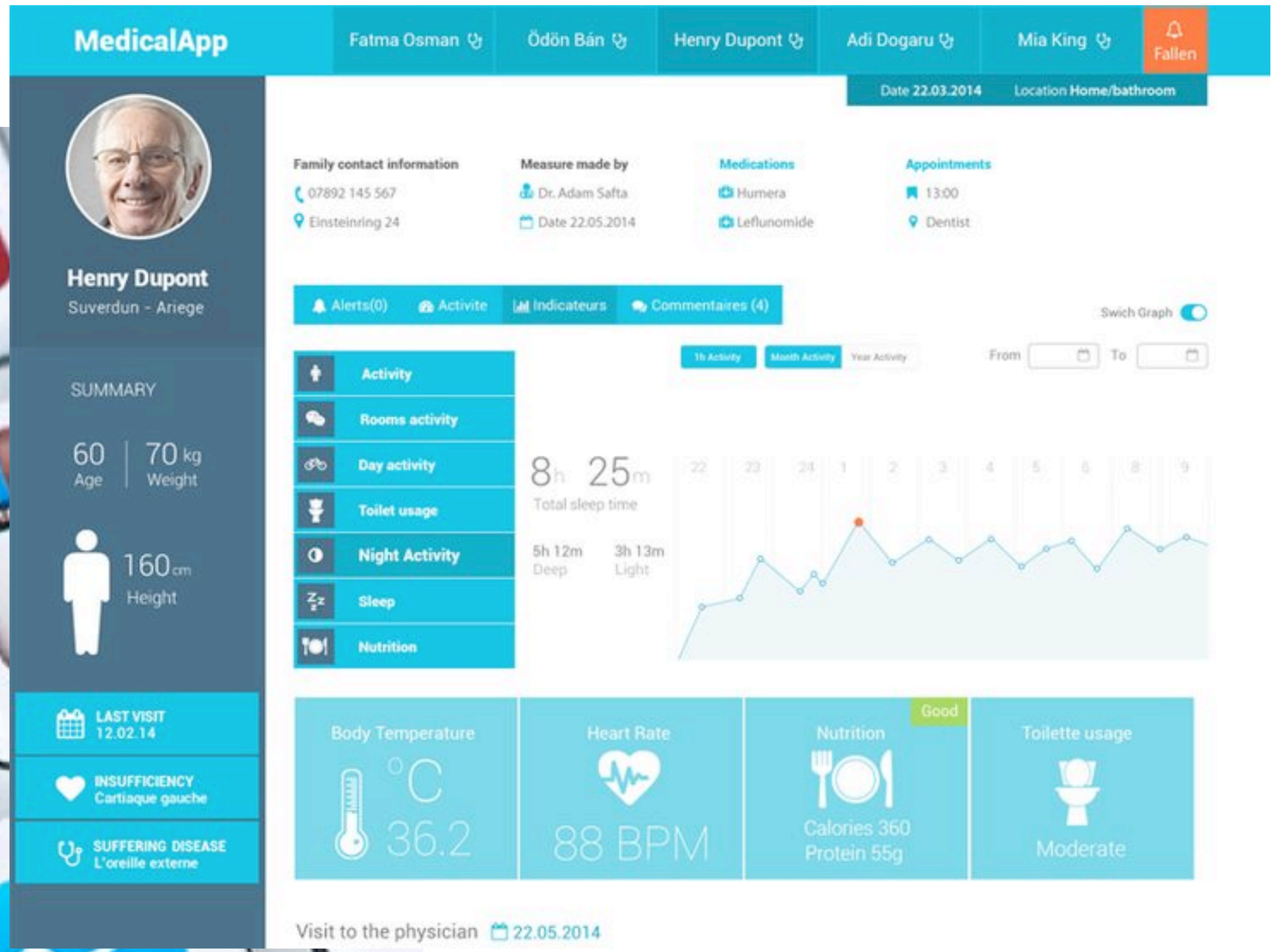
- Motivation
  App security & the insecurity of I/O — we need app security + I/O security!
- BASTION-SGX
  A novel Bluetooth Trusted I/O architecture
- Challenges
  Fine-grained channel selection & security policy enforcement
- Proof-of-Concept
  Delivering secure input from Bluetooth keyboards to SGX apps
- Conclusion
  Take-aways and future work

App Security is Imperative…

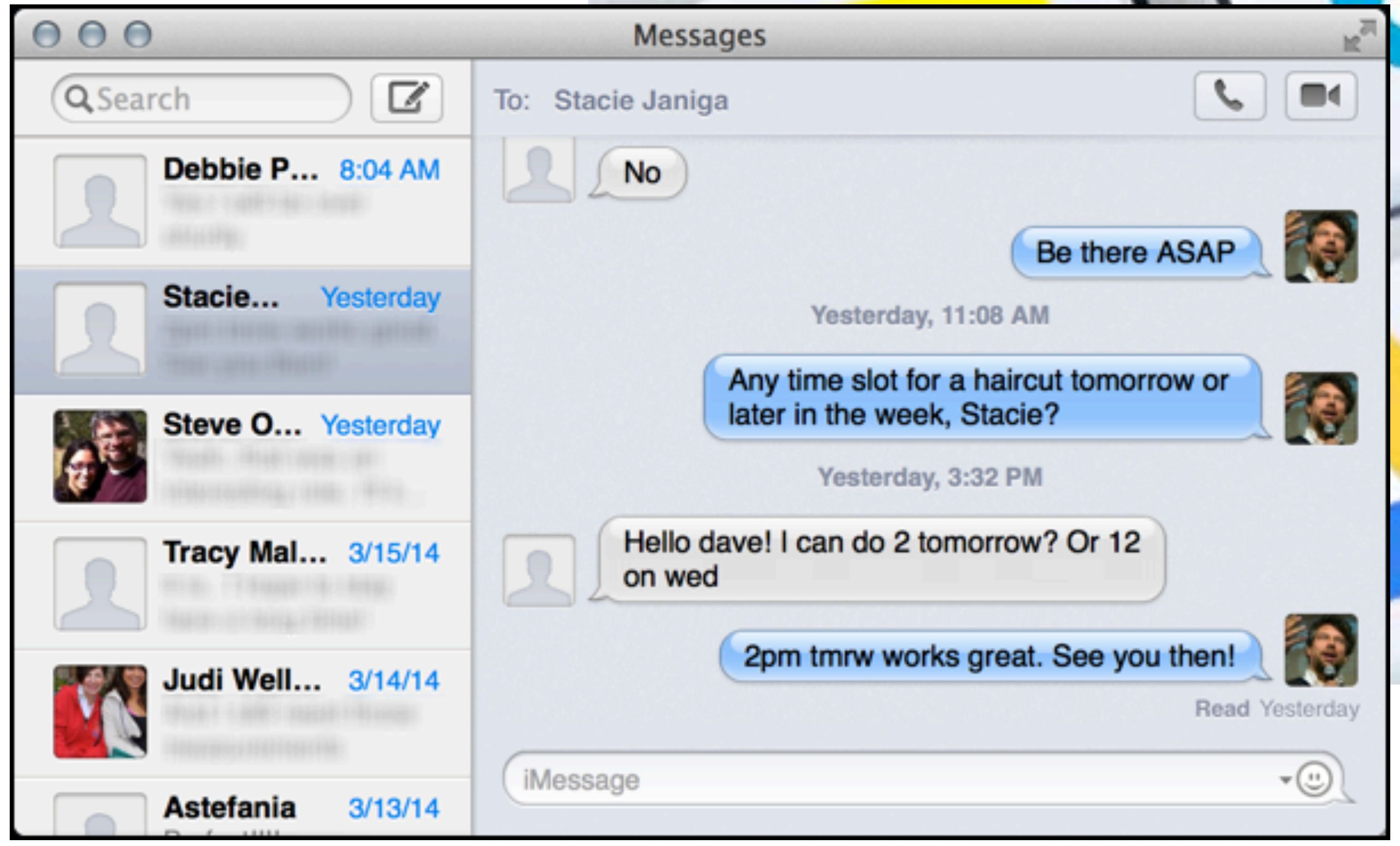
Financial Apps



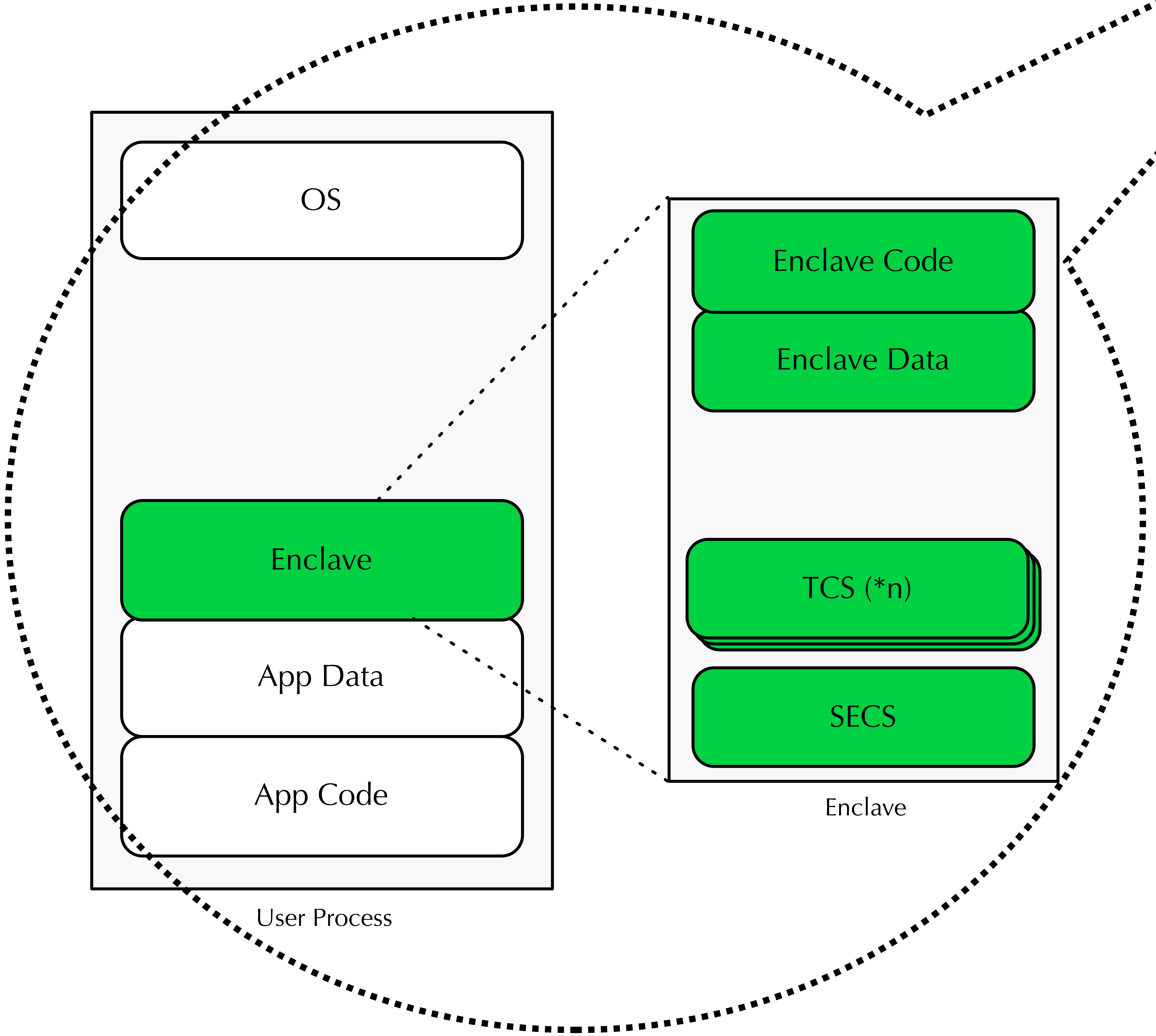
Health & Wellness Apps

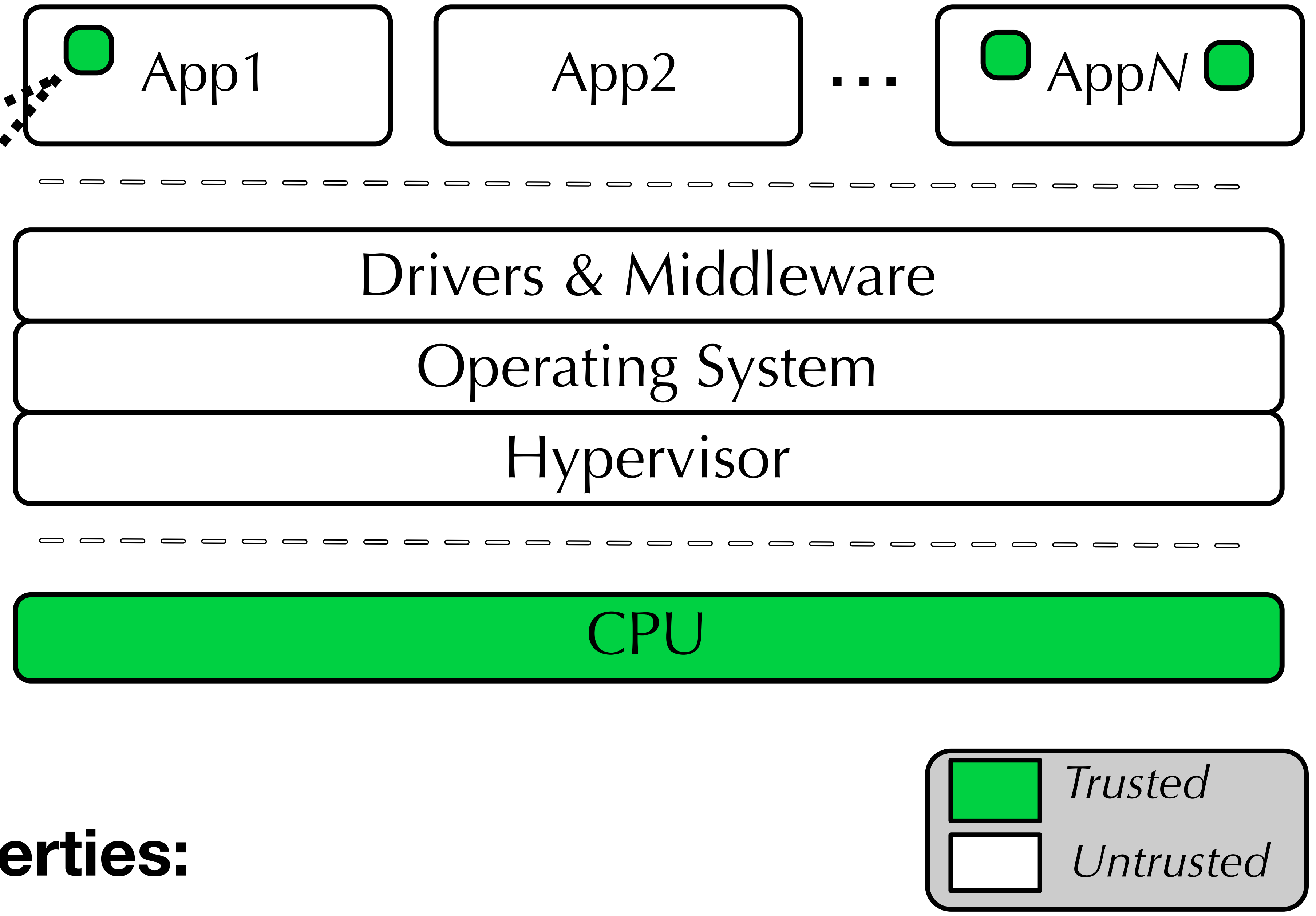


Messaging Apps



Intel's SGX Can Help!





Properties:

- Has its own code and data
- Provides confidentiality & integrity
- Full access to app memory

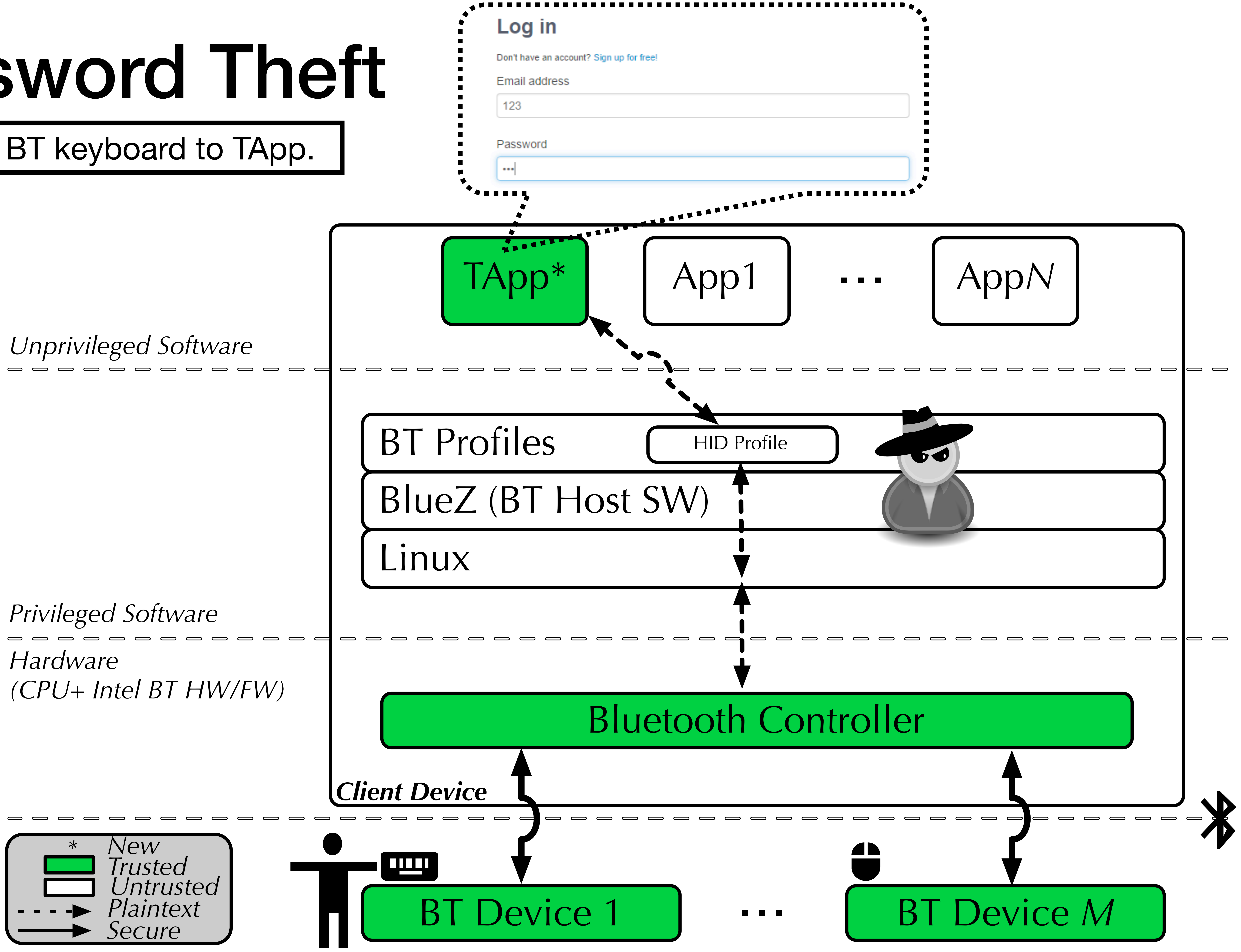
Highlights:

- Small attack surface (app + processor)
- Prevents even privileged SW from stealing or tampering w/ app secrets

I/O Security is ***Also*** Imperative!

Example: Password Theft

Objective: Secure input from BT keyboard to TApp.



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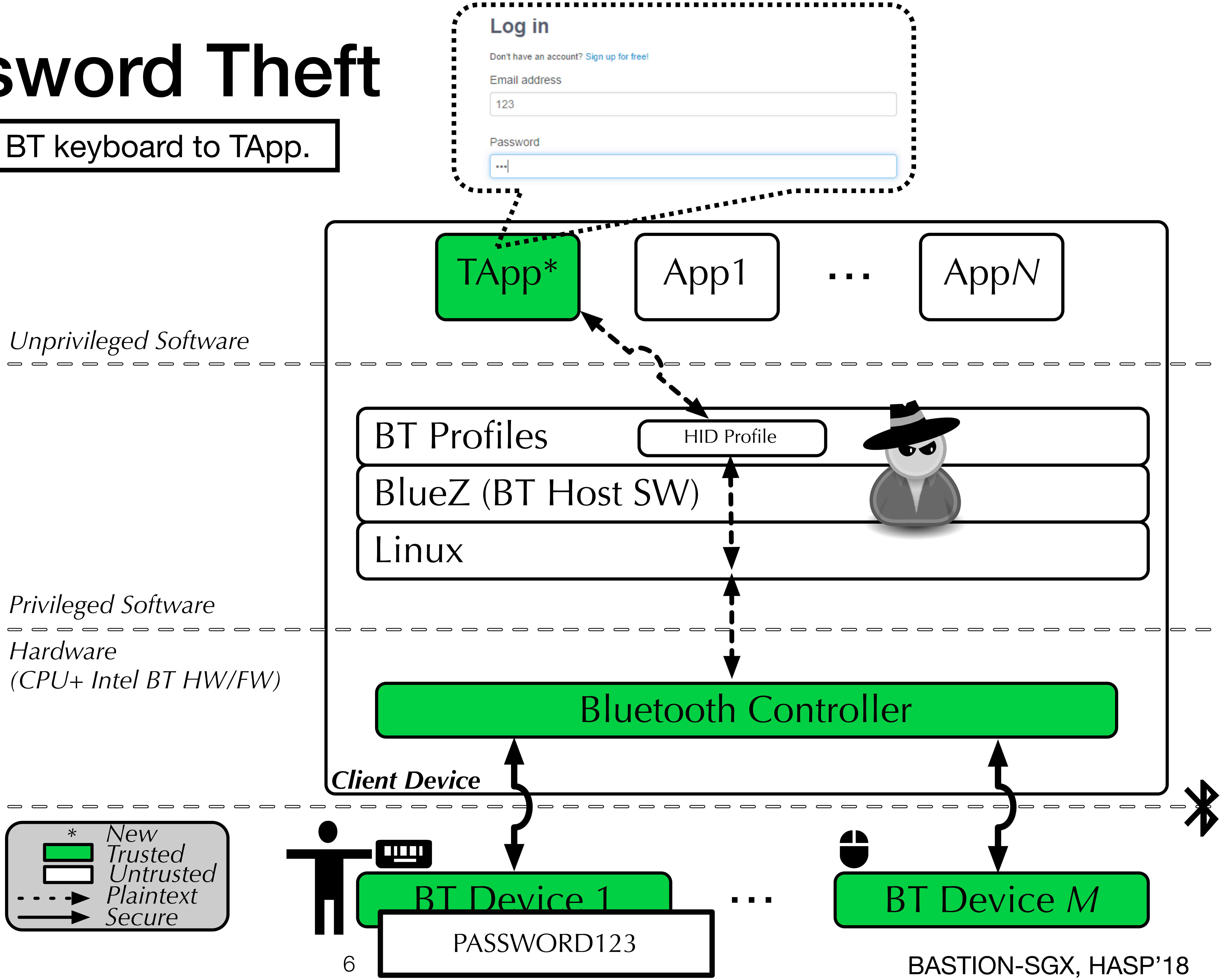

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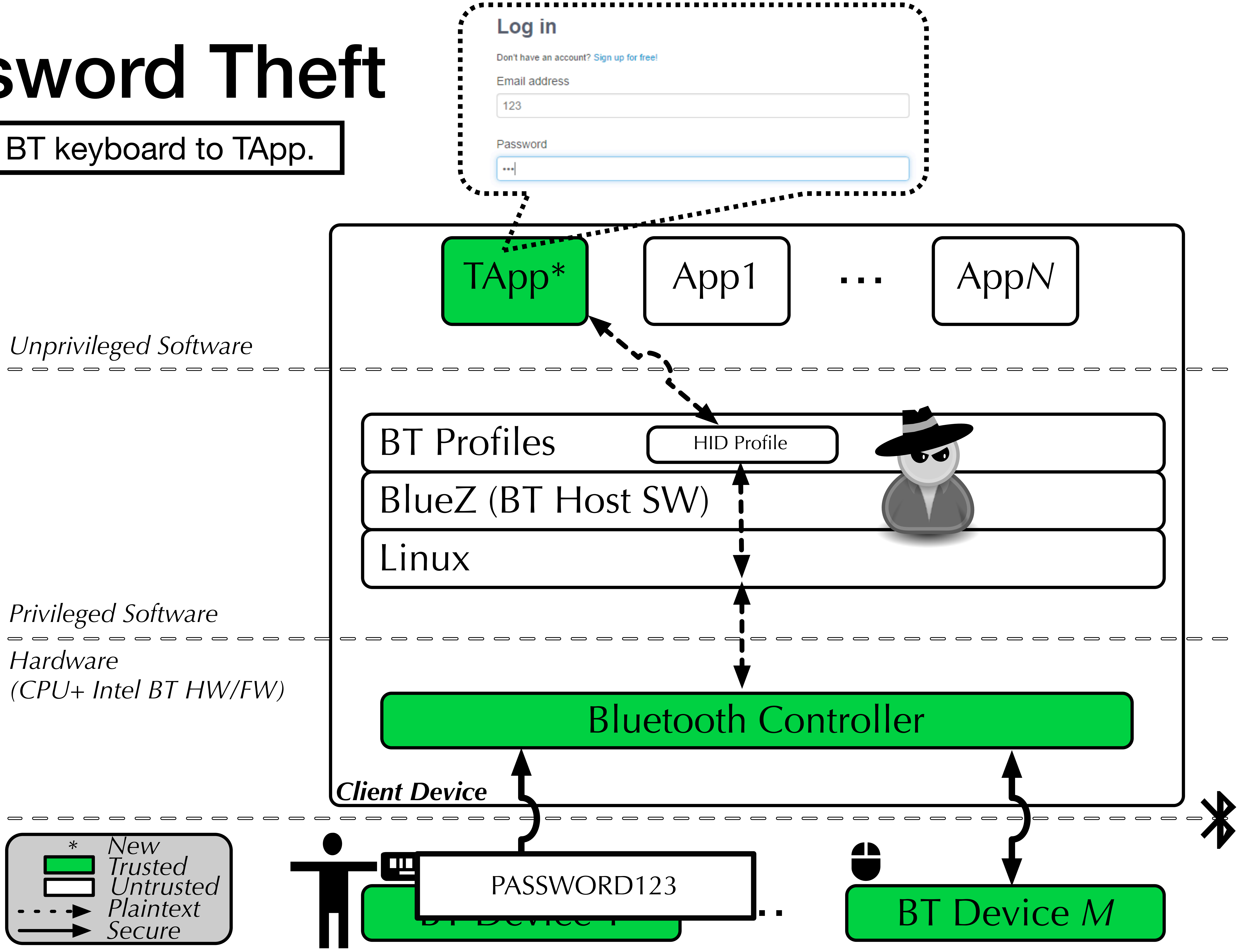

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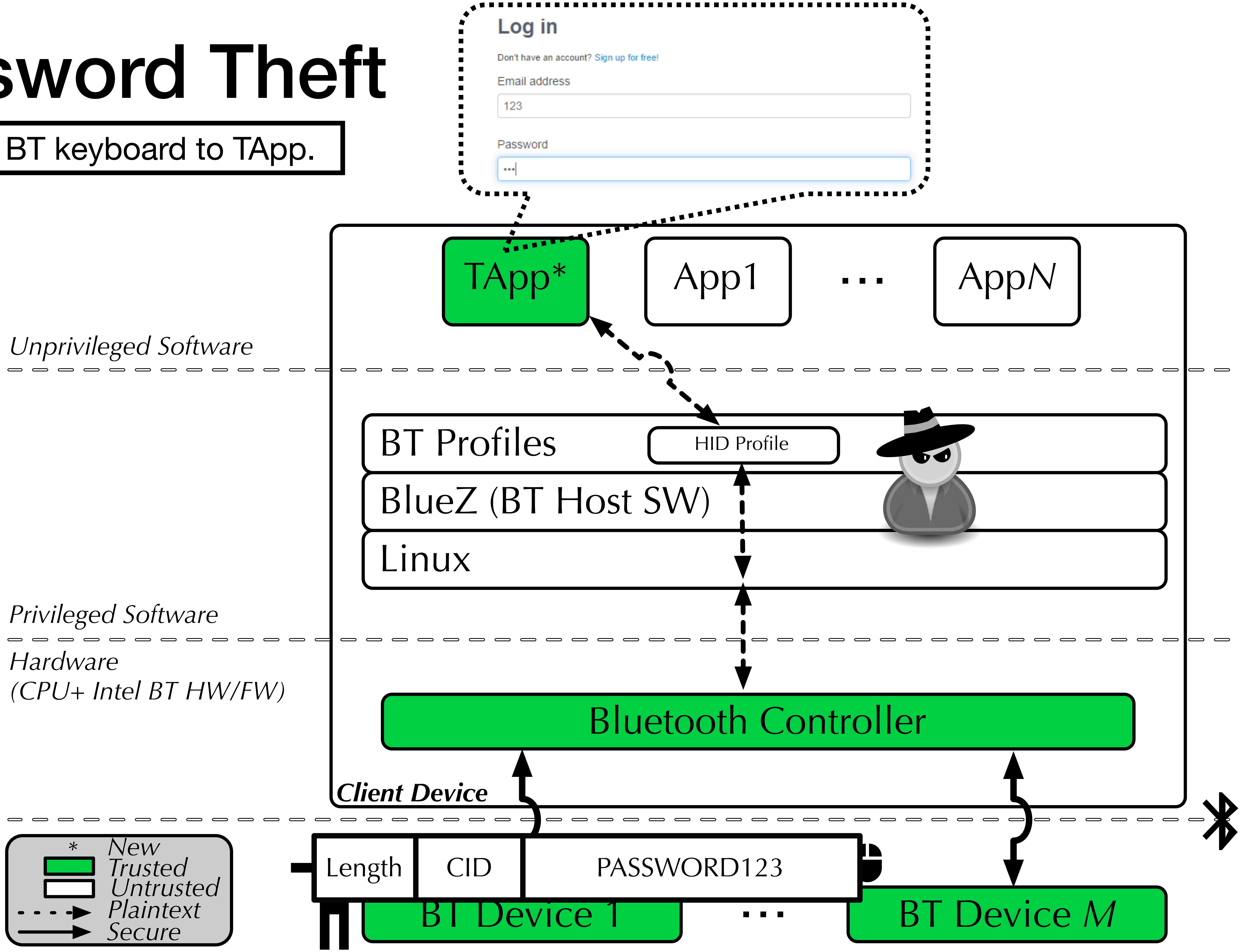

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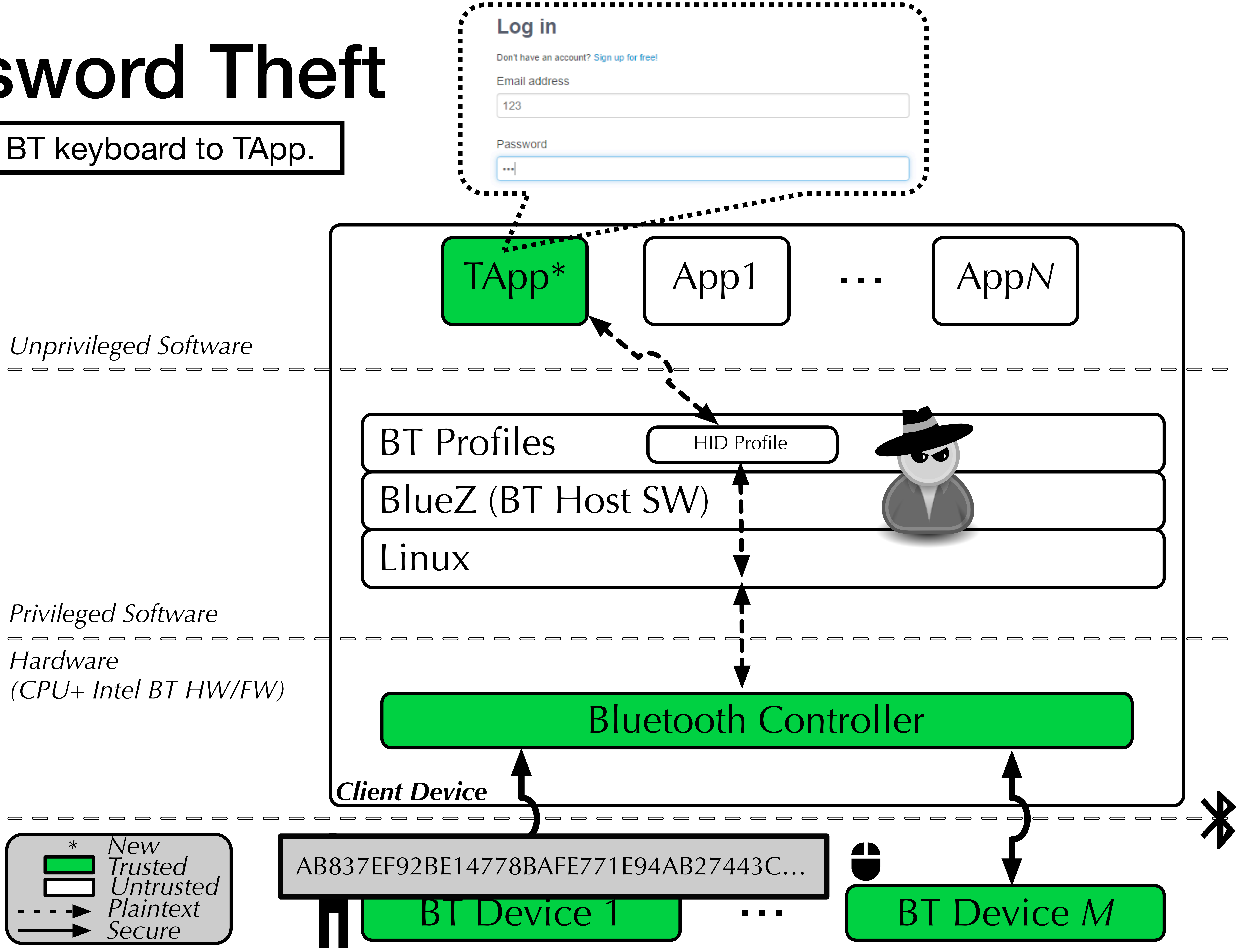

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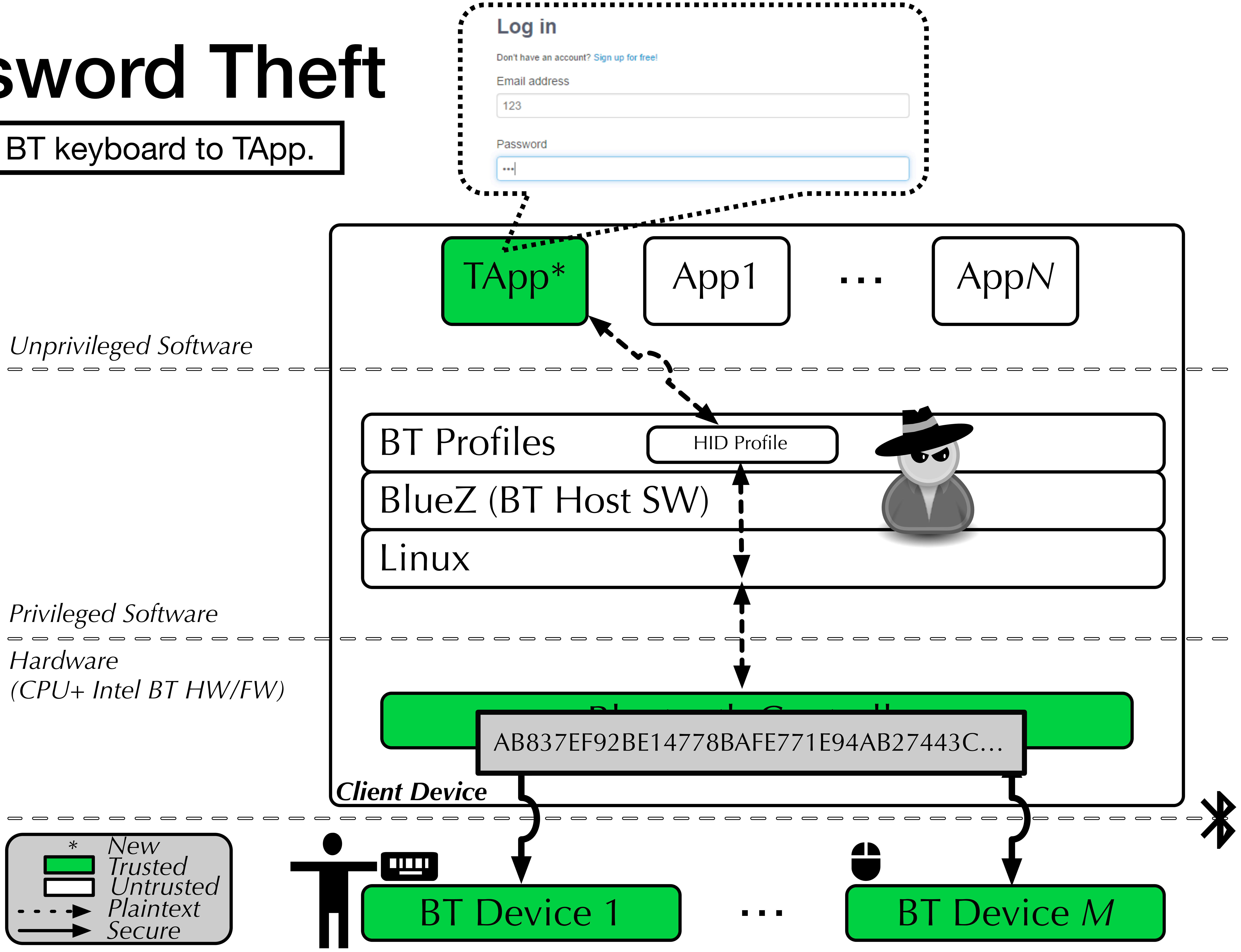

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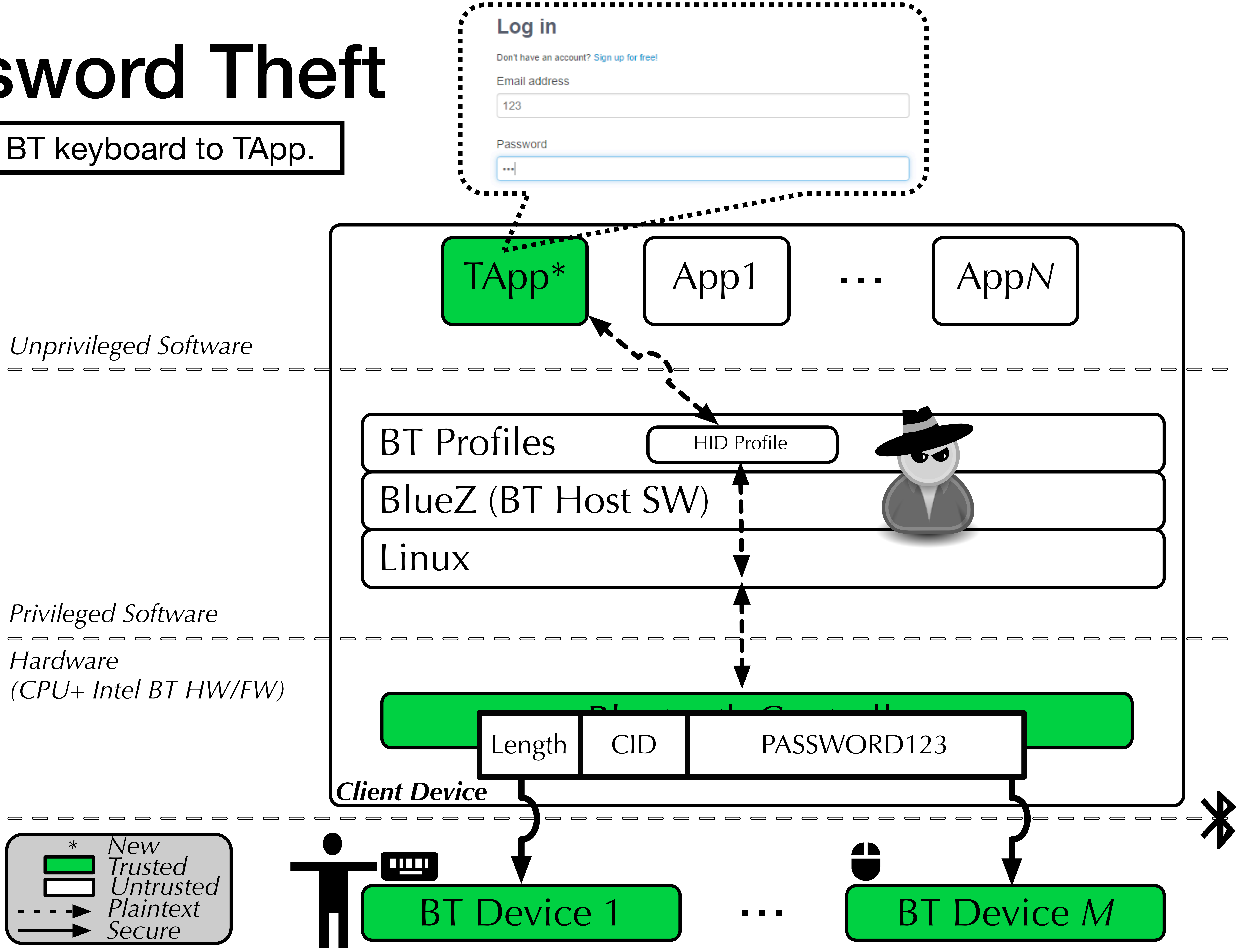

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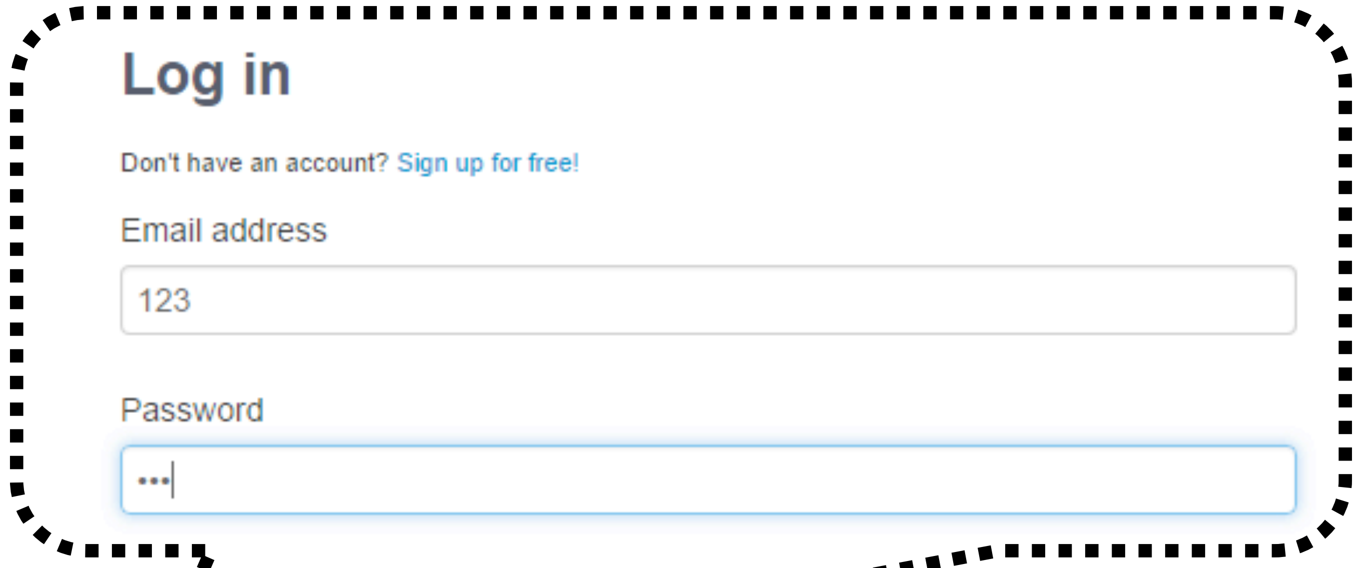

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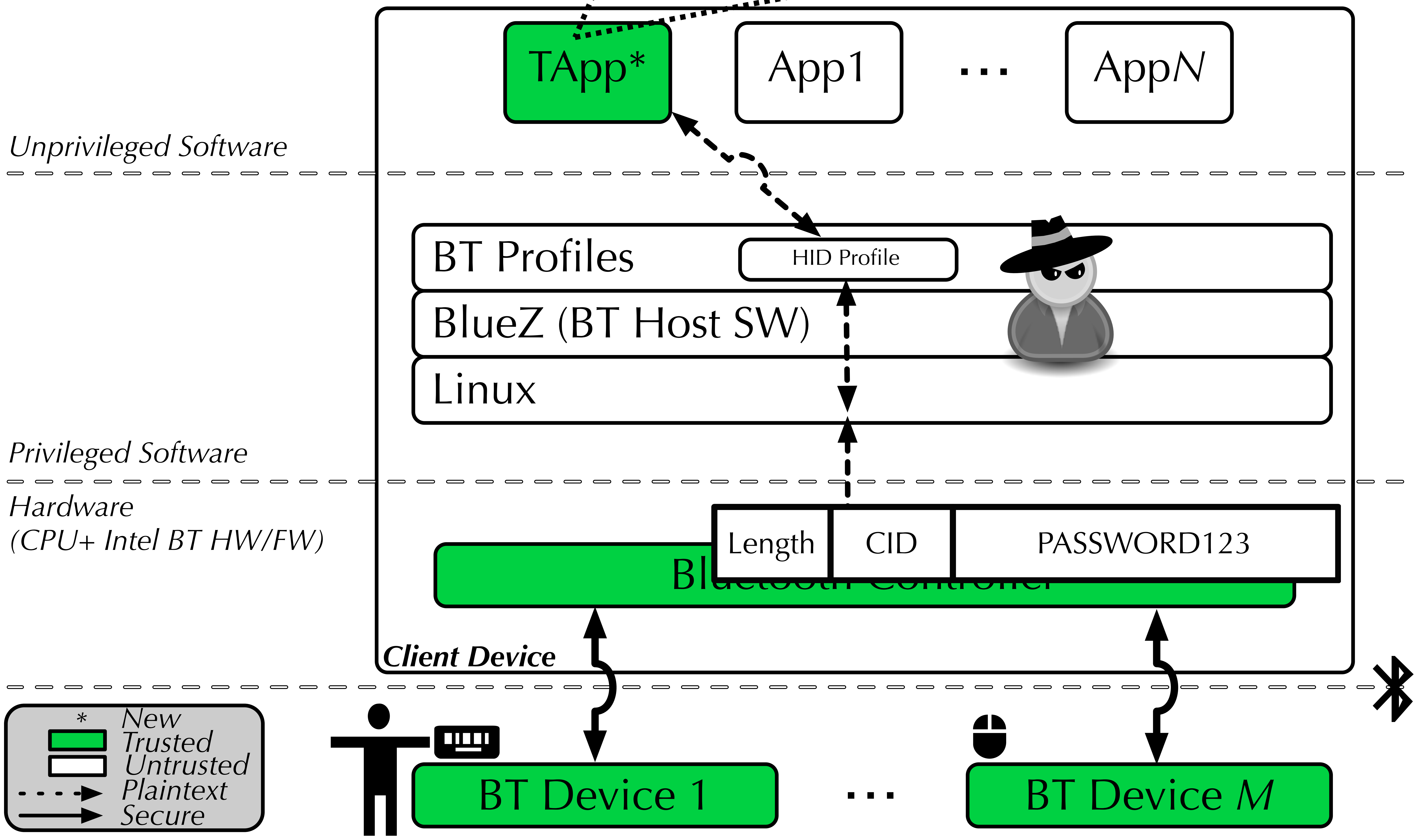

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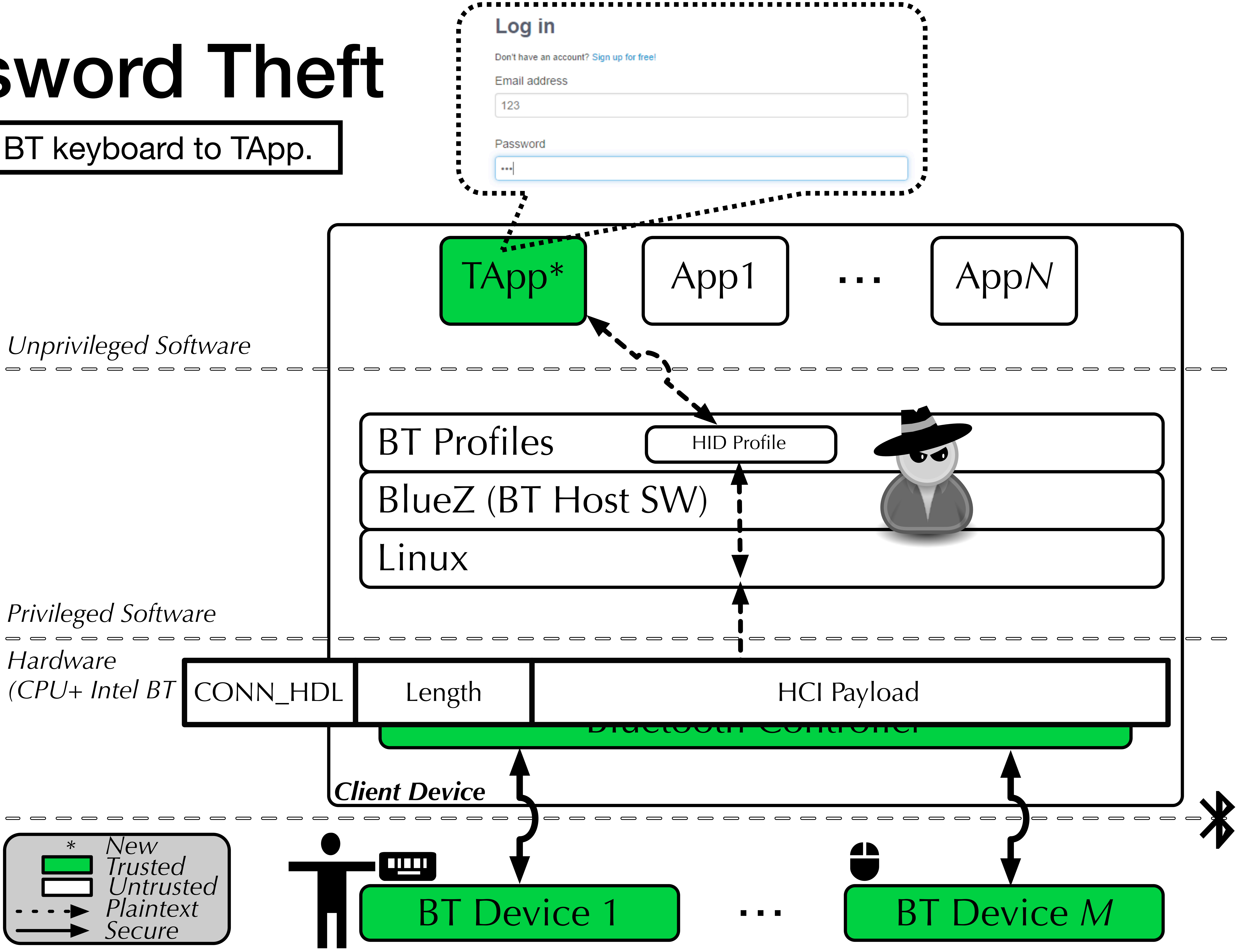

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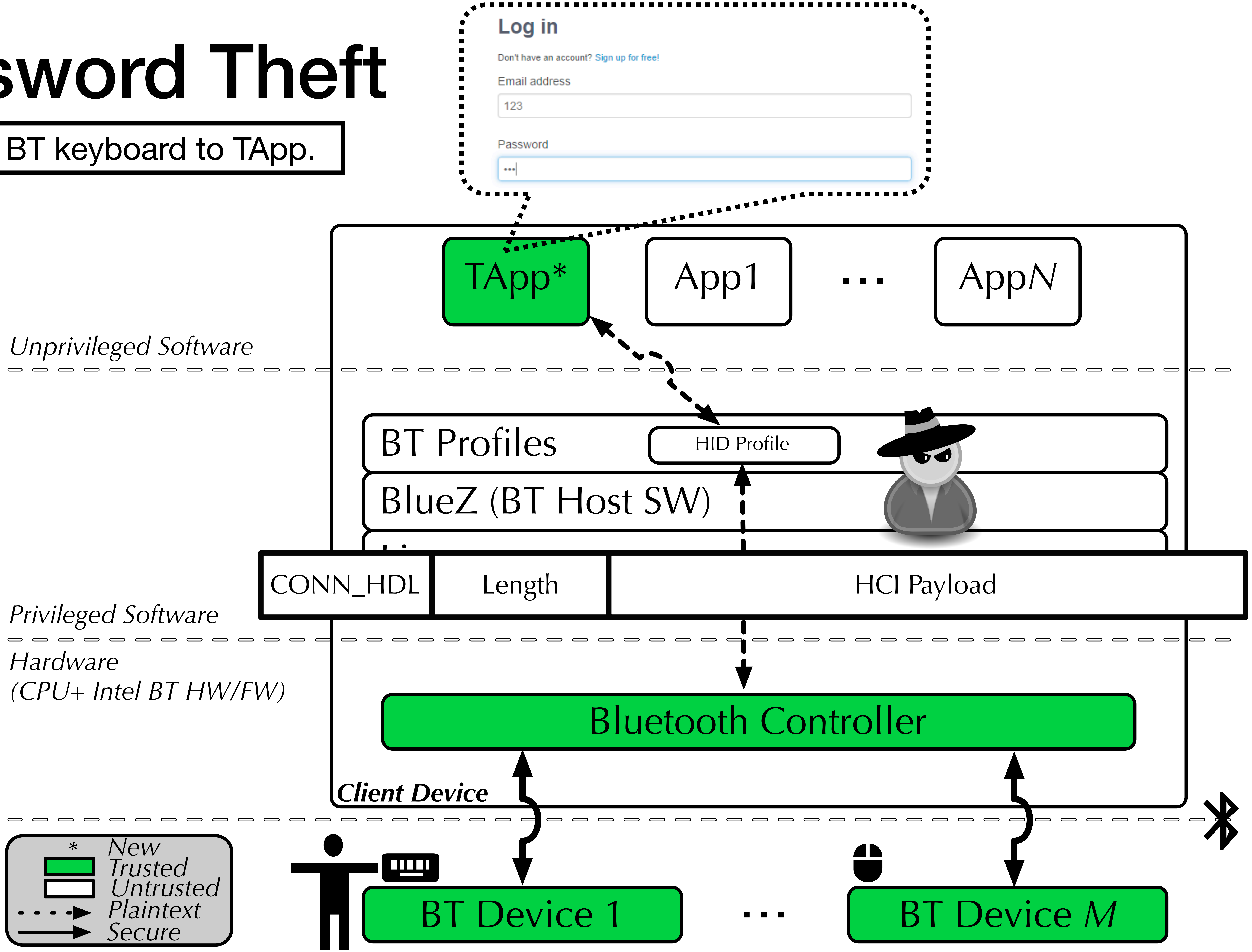

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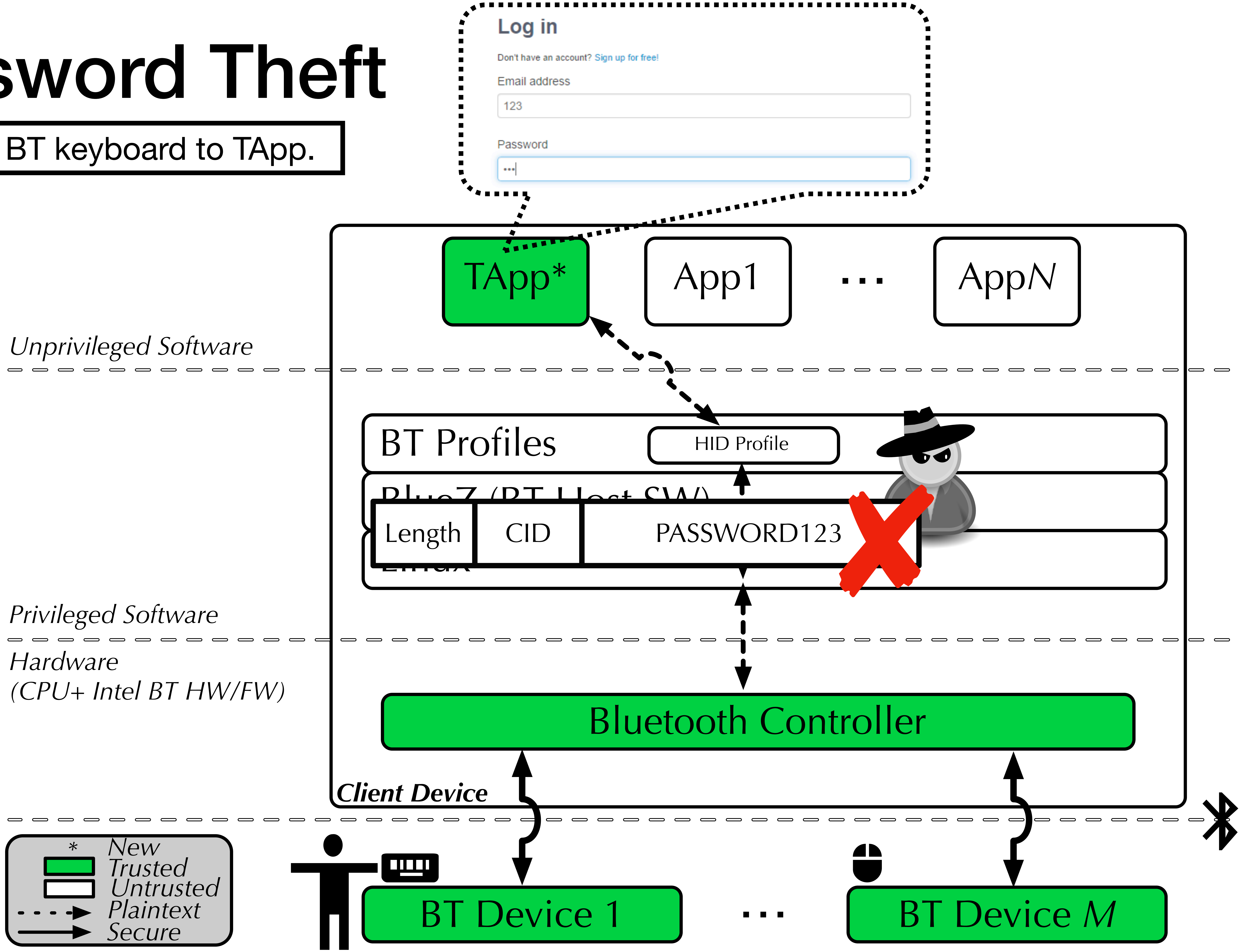
Password is stolen!

Without Trusted I/O, data is vulnerable!



Trusted I/O

Key Insight: Break path into two subpaths (E1-E2, E3-E4).
Re-encrypt data between E1-E2 (enclave-controller).
Use existing OTA security between E3-E4 (client-device).

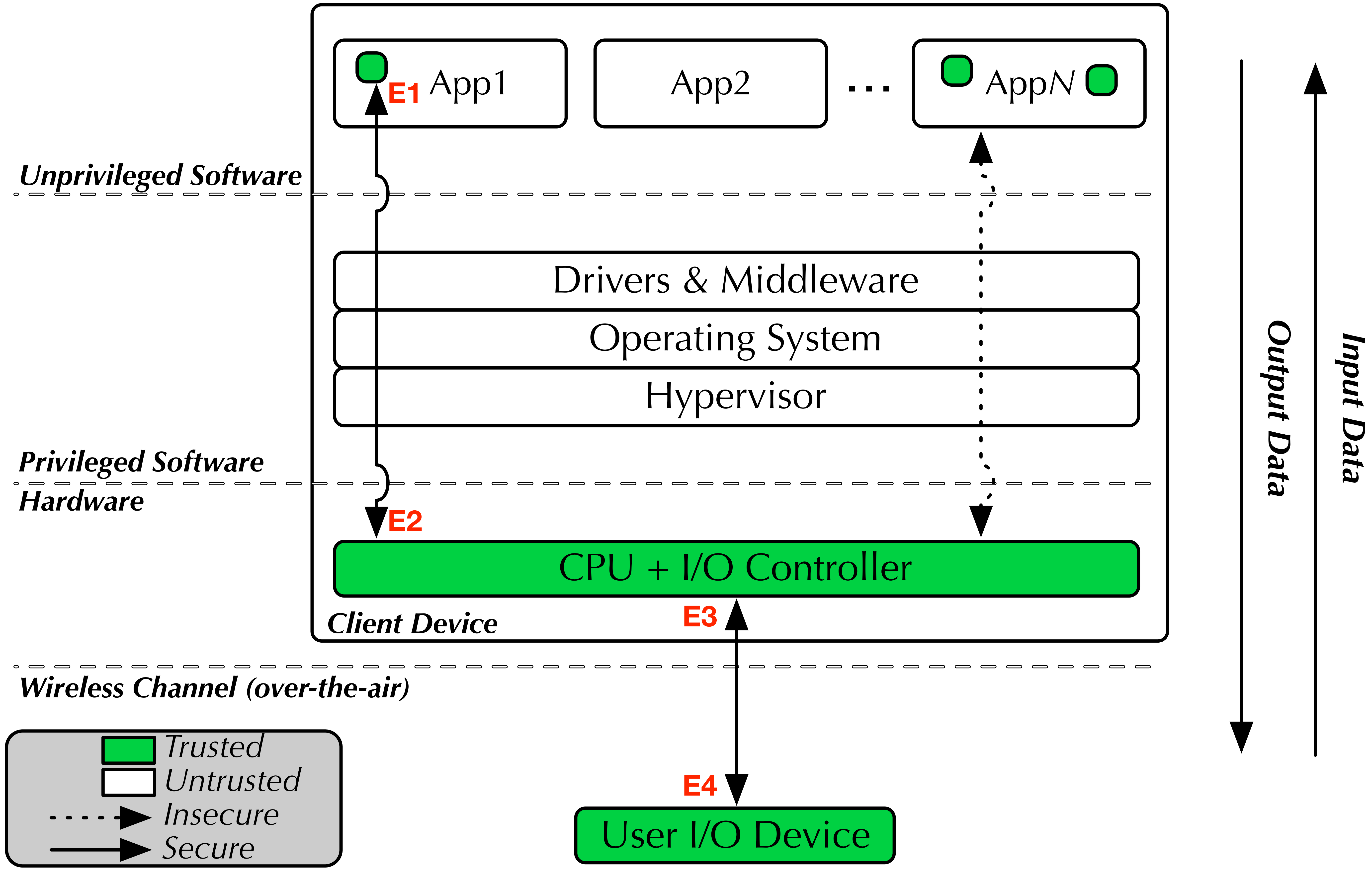
Our Goal:

- E2E security for select I/O data
- No new HW
- No changes to BT stack/devices
- No dependency on system SW

⟶ Minimal TCB!

This paper/talk:

- Focus on feasibility
- Secure *input* data from keyboard



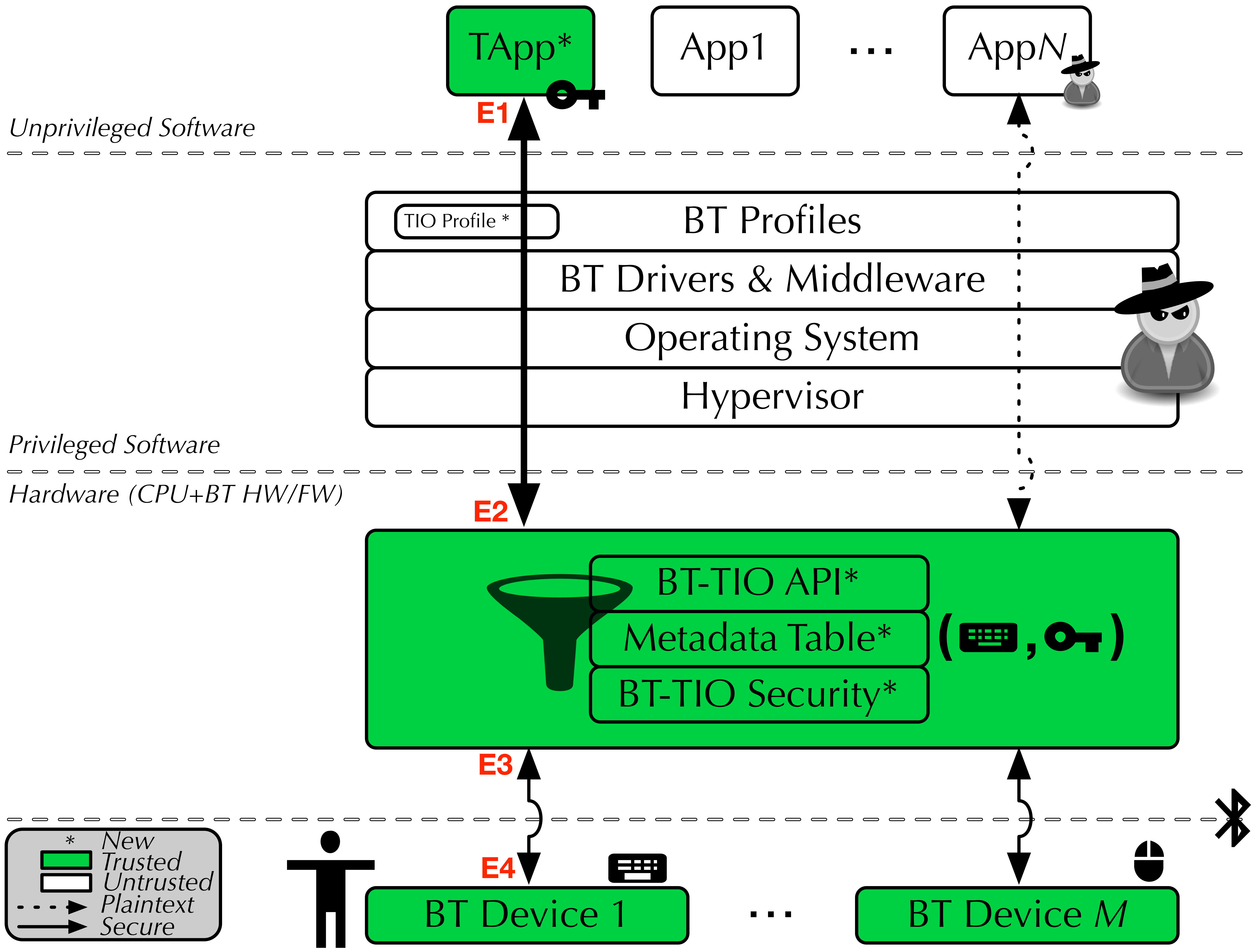
Proposed Architecture: BASTION-SGX

Bluetooth Trusted I/O Monitor & Filter
- Monitor *all* ingress/egress packets
- Update Metadata Table according to BT channel/connection-related events
- Send packets matching security policy to BT-TIO Security Module

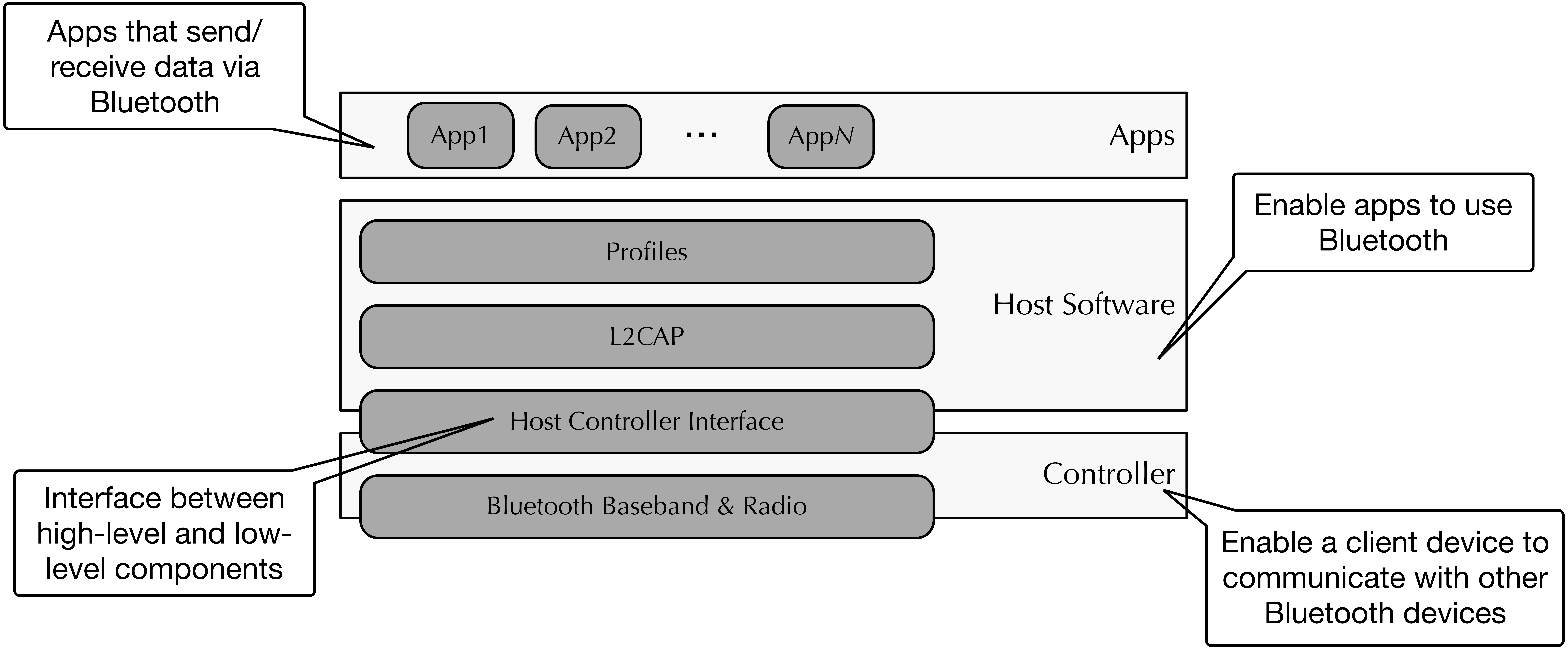
Bluetooth Trusted I/O Metadata Table
- Store connection/channel metadata

Bluetooth Trusted I/O API
- Enable apps to program *security policies* (i.e., tuple of (CHANNEL-ID & KEY))
- Use extensible interface for 3rd party features (Vendor Specific Debug Commands)

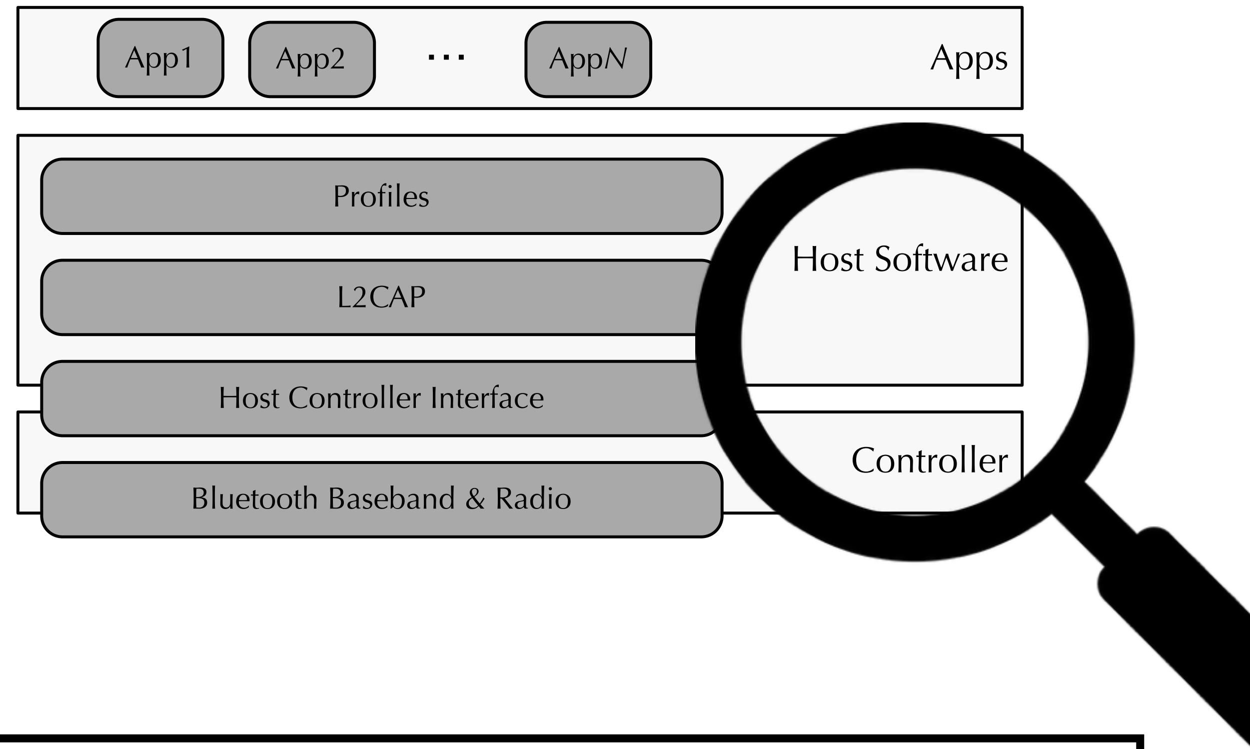
Bluetooth Trusted Security Module
- Cryptographic operations (e.g., encryption, decryption)

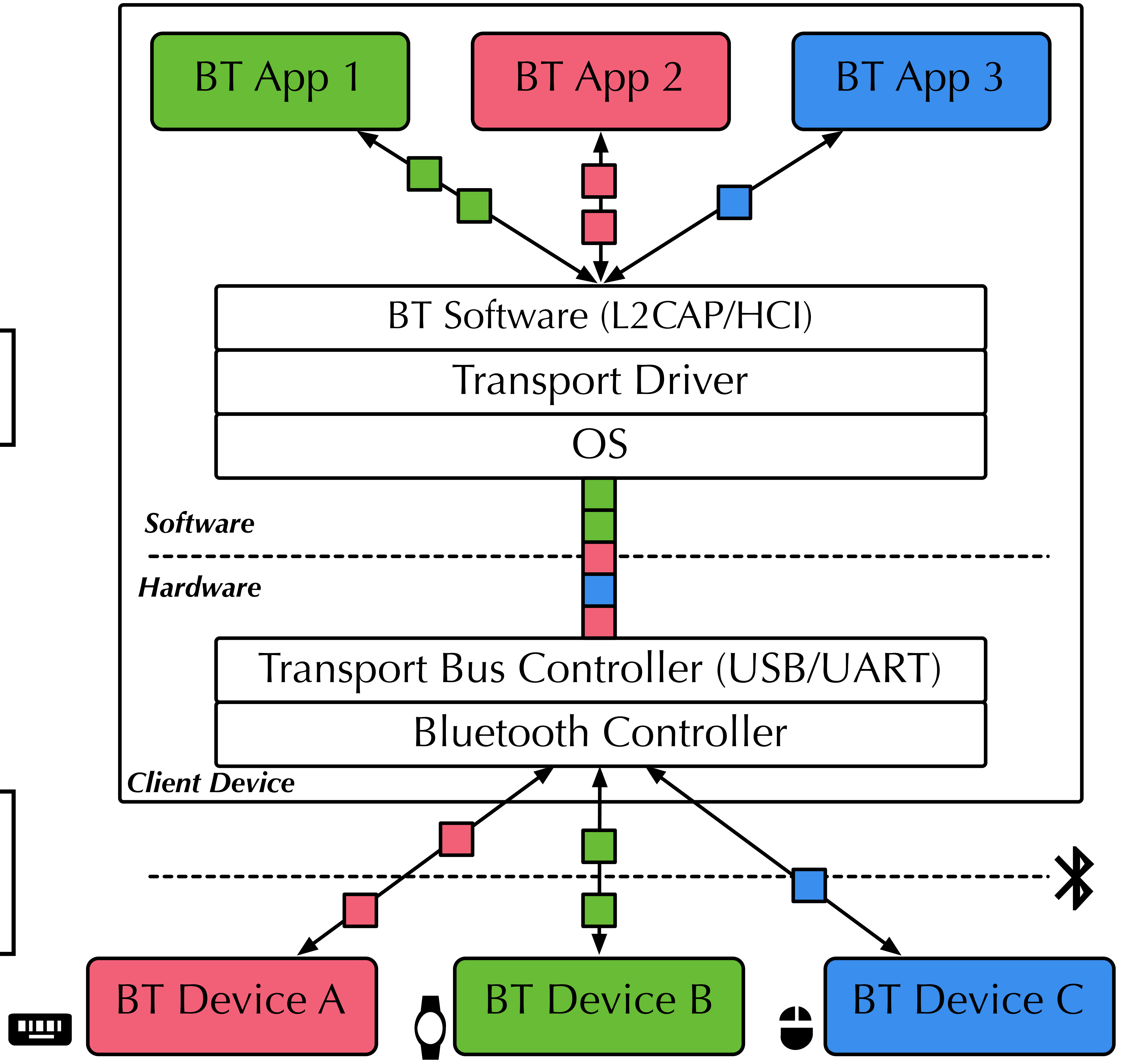


Bluetooth Architecture Overview



Requirements & Challenges





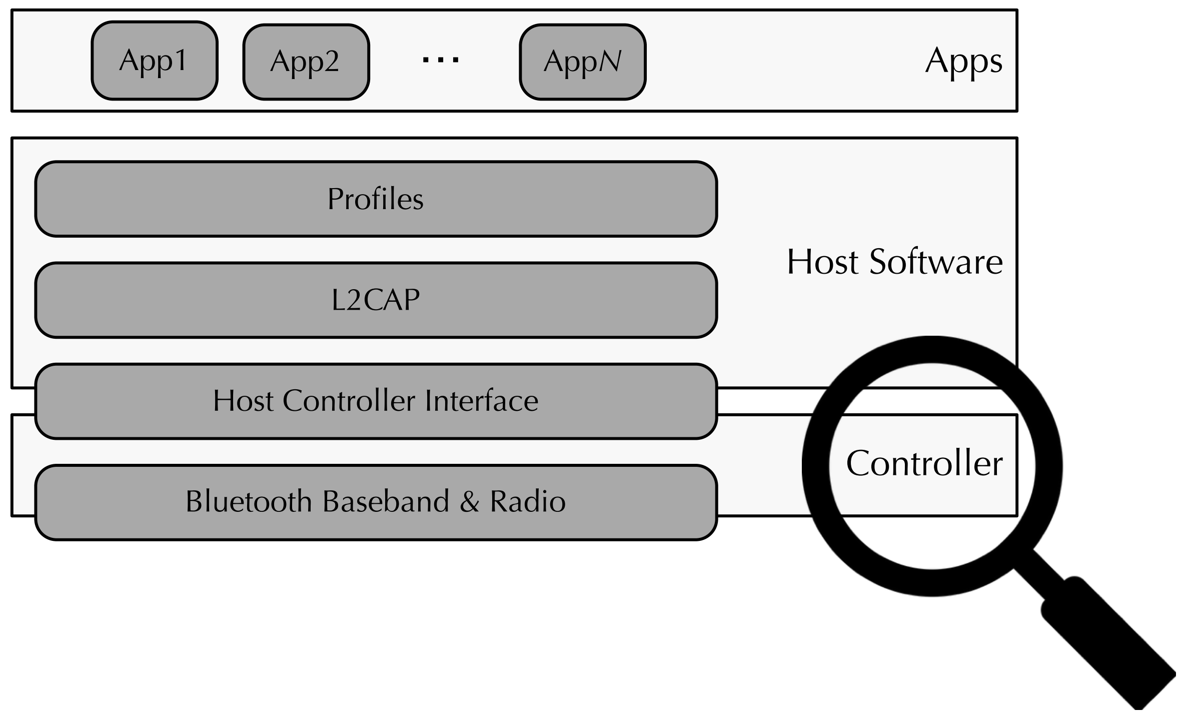
4. Security applied to one channel should not affect other BT channels.

3. Security should only be applied to ***data*** packets, not ***control*** packets.

2. Host SW is responsible for using **HCI** and **L2CAP** packet headers for HCI transport and routing.

1. All packets are multiplexed within the Client's Bluetooth Controller & sent to Host SW in a single stream.

Anatomy of BT Connection

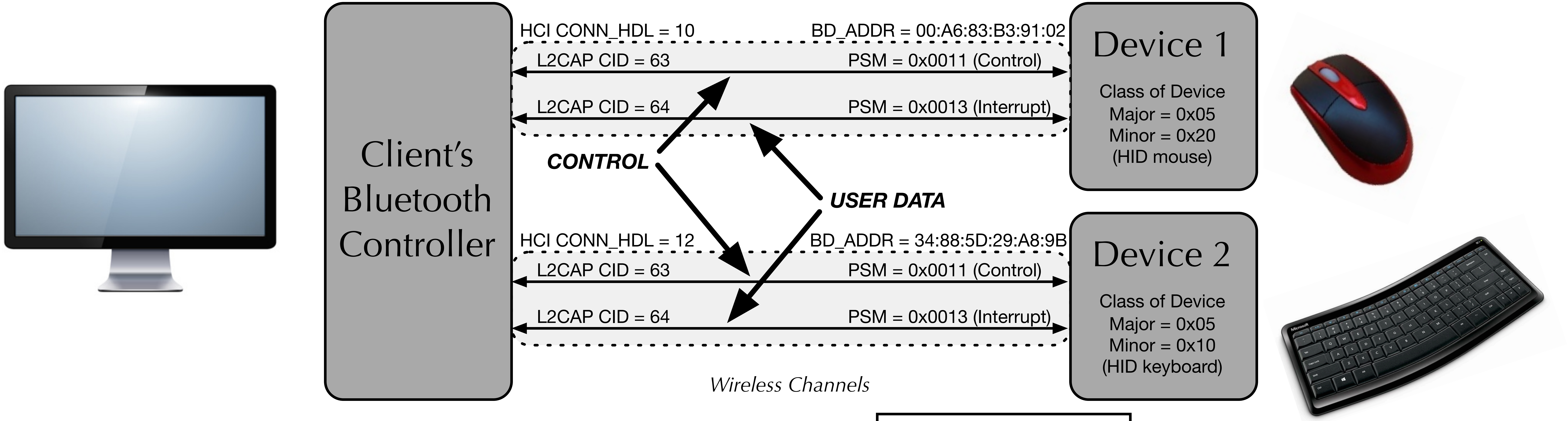


Q: *How can a Bluetooth Controller identify <u>specific channels</u> over which to enforce Trusted I/O security?*

CONN_HDL/BD_ADDR identifies specific device connection

L2CAP CIDs identify individual channels within a connection

CoD defines device type



PSM defines protocol/service type

Case Study: Securing HID Input

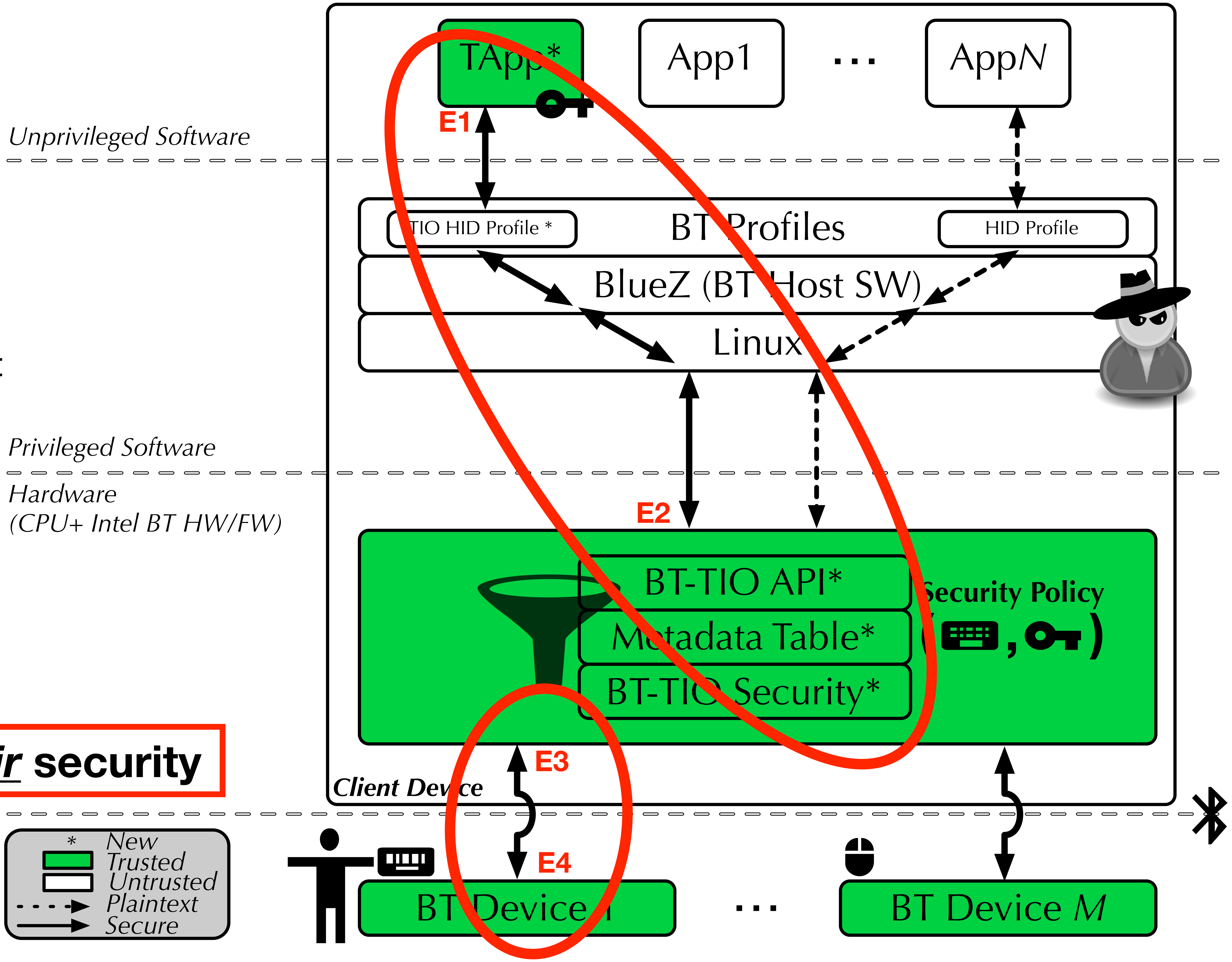
Setup:
- Implement BASTION-SGX architecture (Section 4)
- Implement trusted app (TApp) for password input
- Install privileged keylogger malware — logs *all* HID data

Goals:
- Validate Bluetooth Controller's capabilities (re: fine-grained channel selection)
- Validate that even privileged malware cannot decipher input while security policy is programmed into the Bluetooth Controller

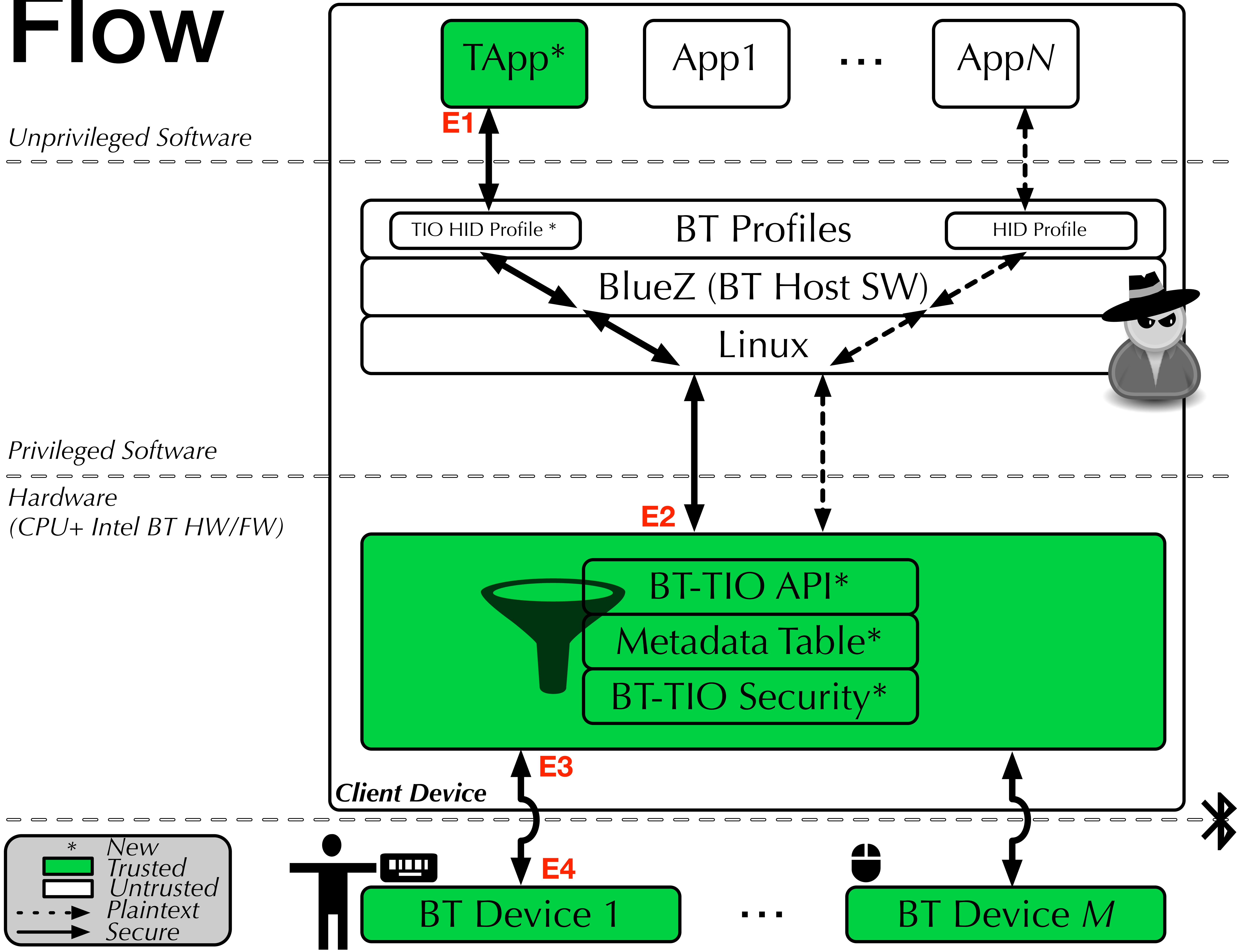
We show that end-to-end (device-to-app) security is possible where....

E1-E2 is secured w/ <u>new</u> <u>*in-host*</u> security

E3-E4 is secured w/ <u>*existing*</u> <u>*over-the-air*</u> security



Secure Input Flow



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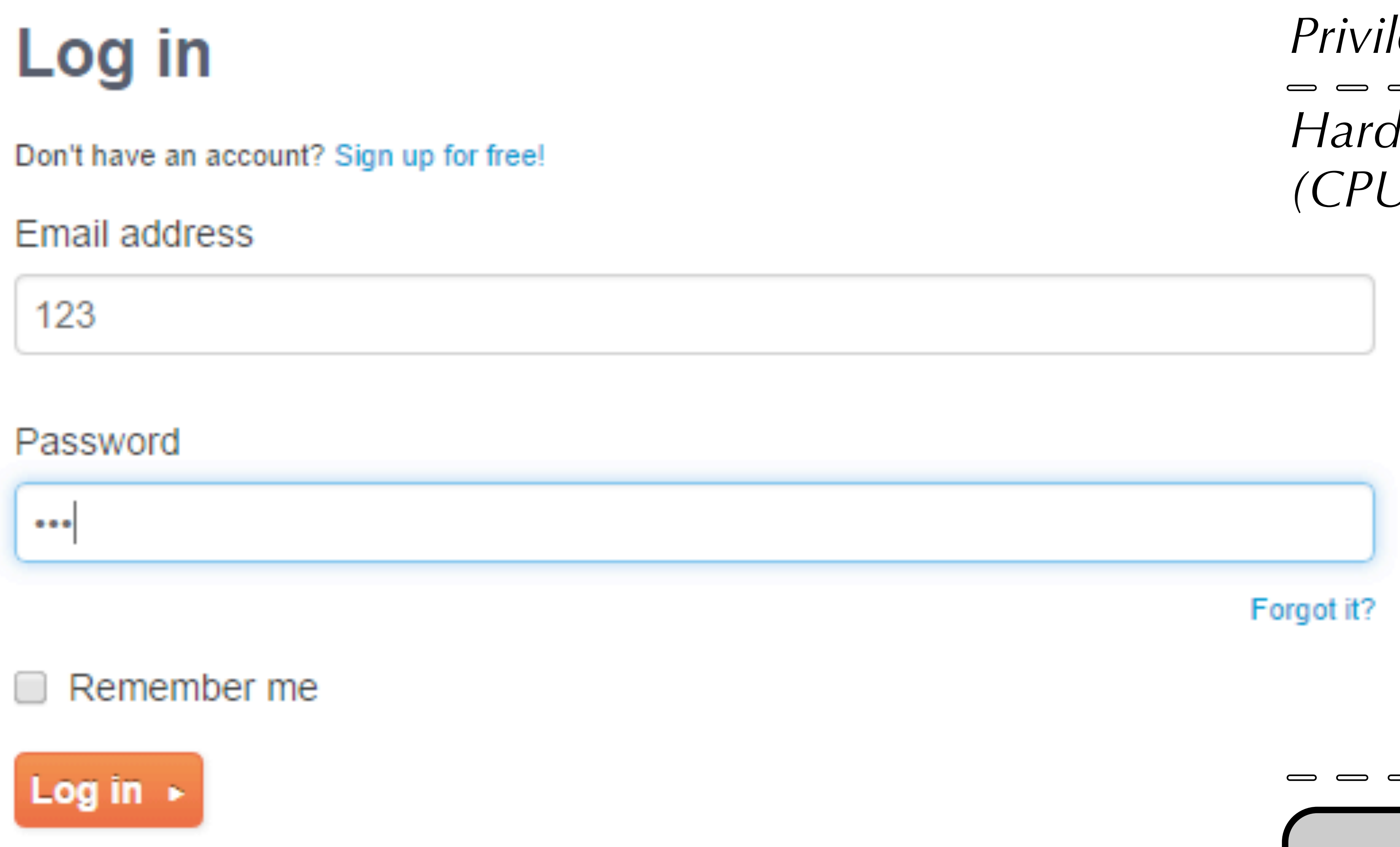

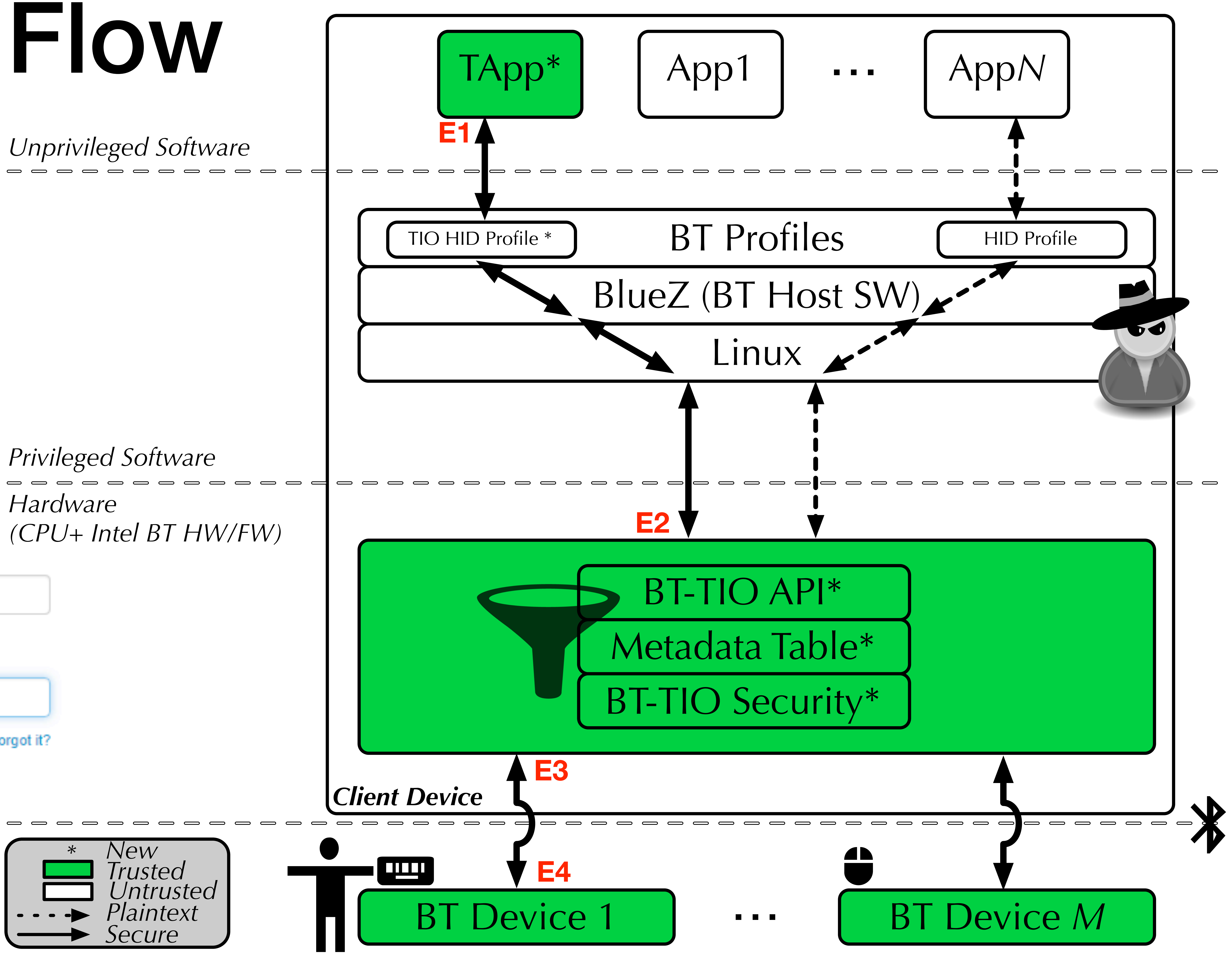

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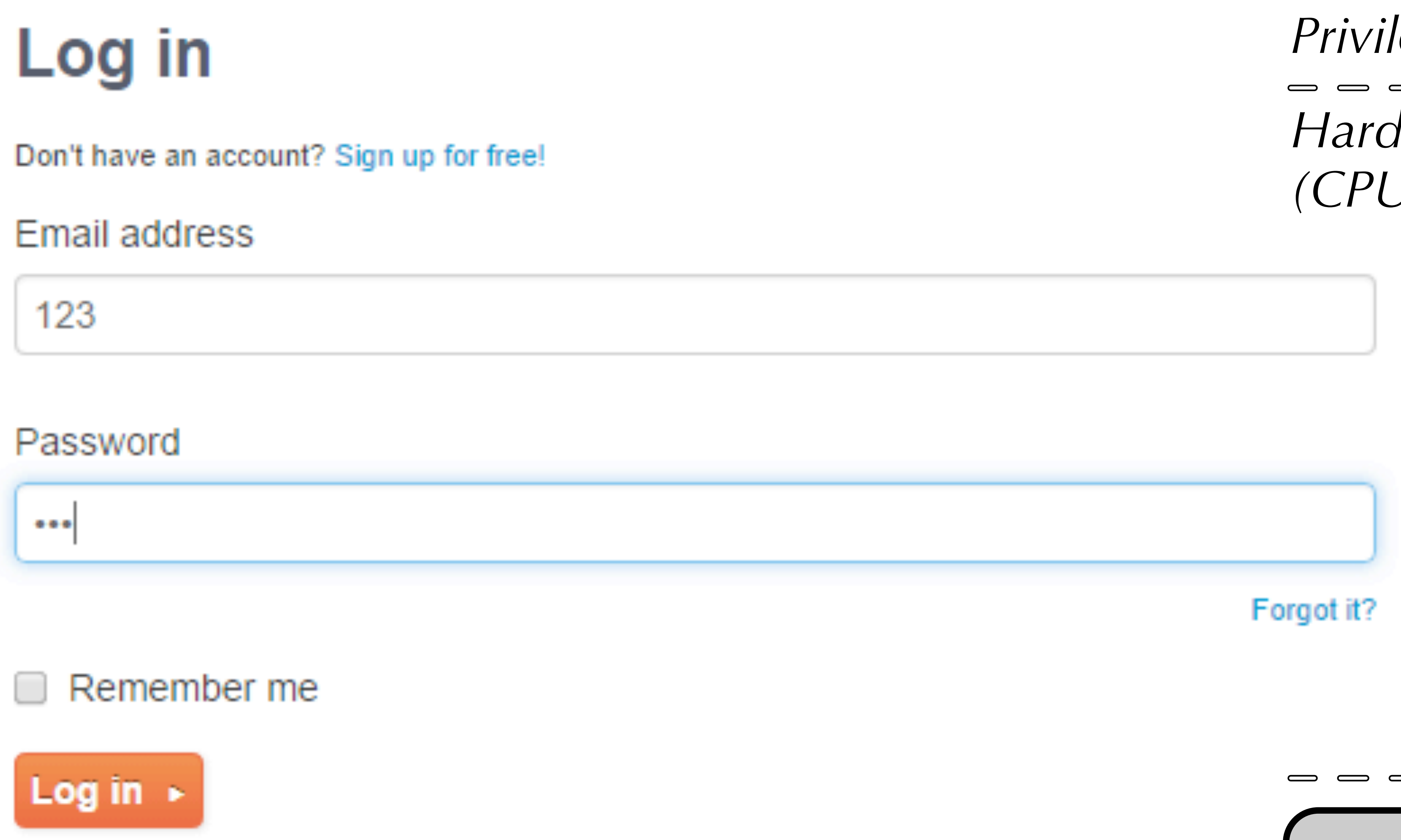

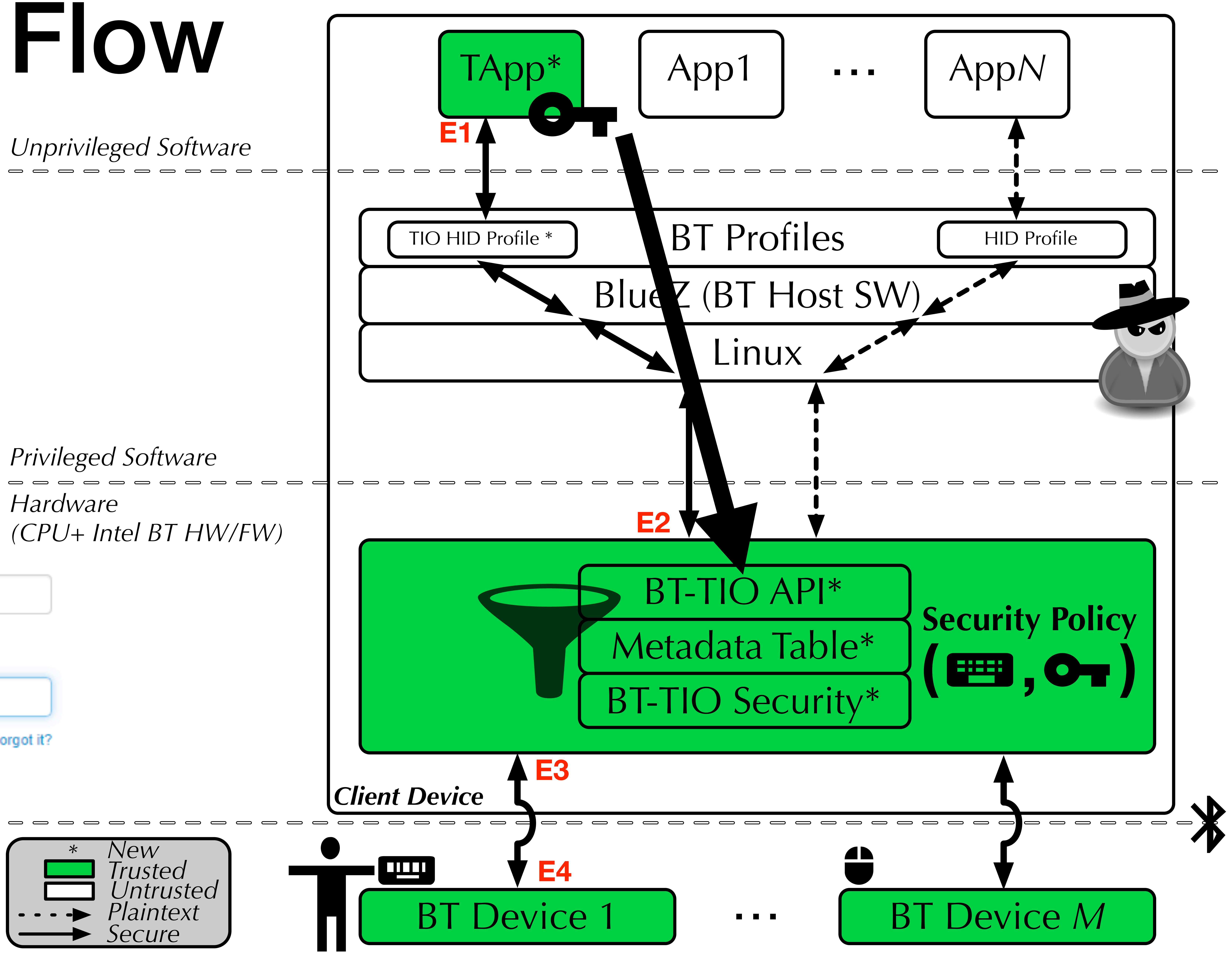

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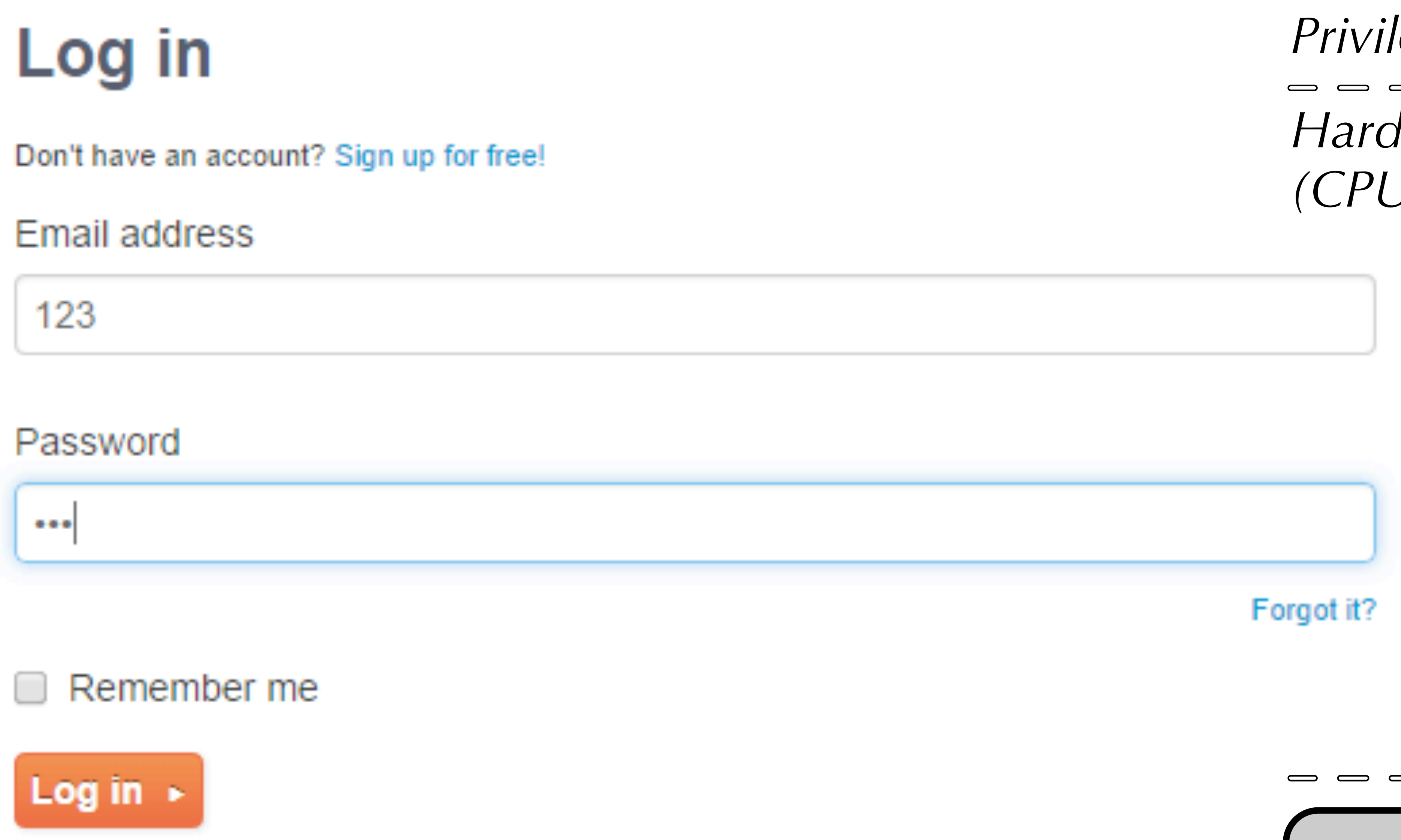

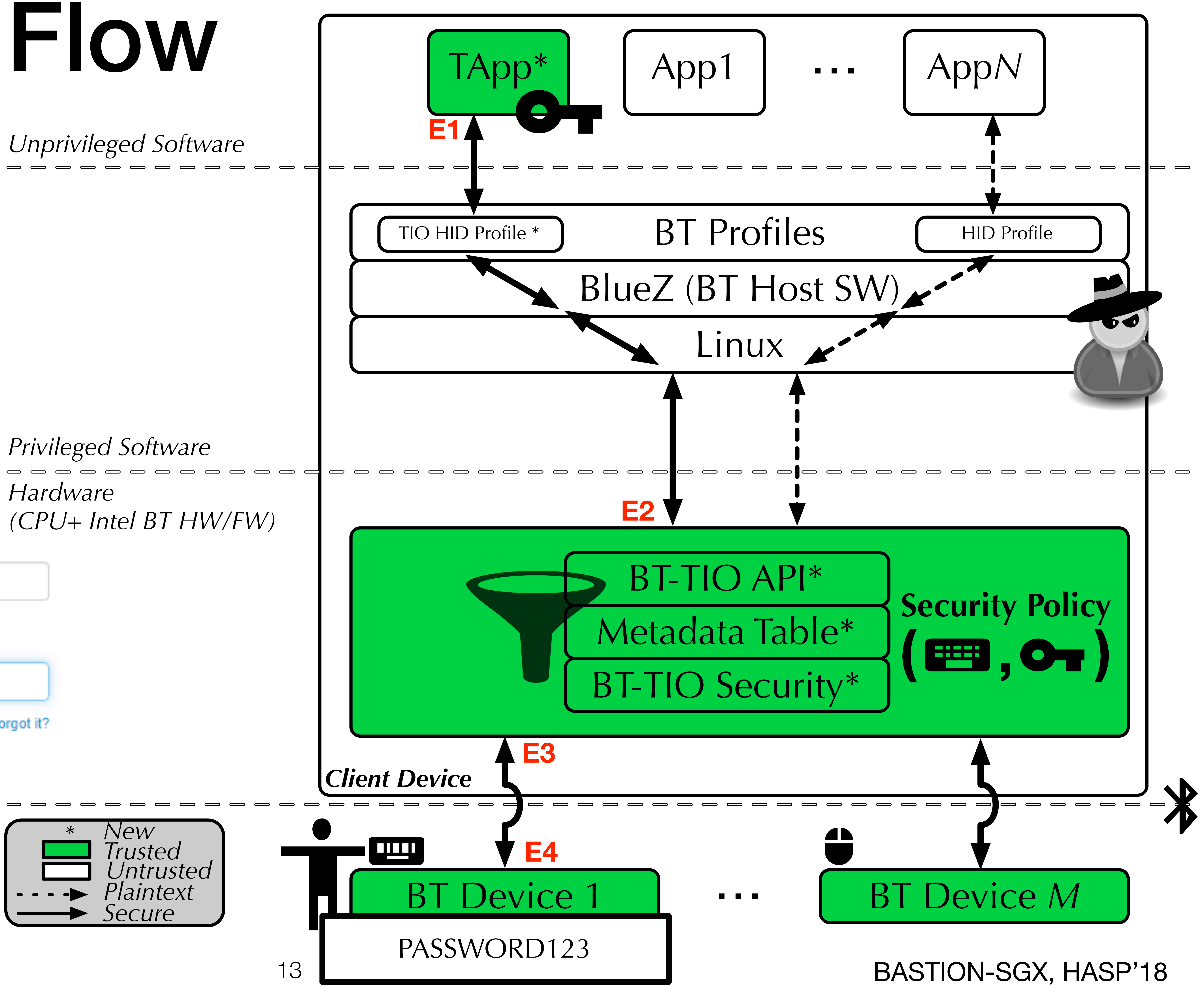

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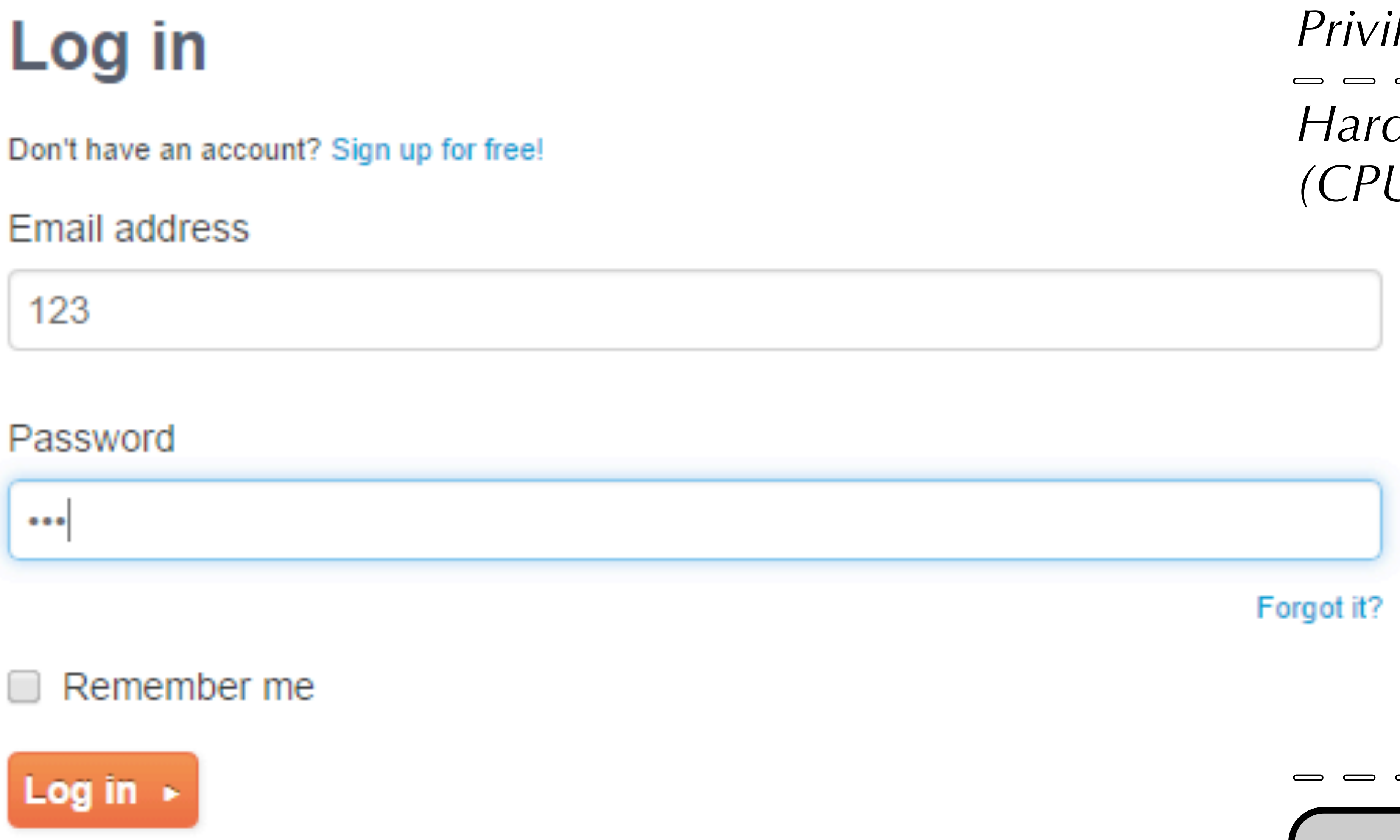

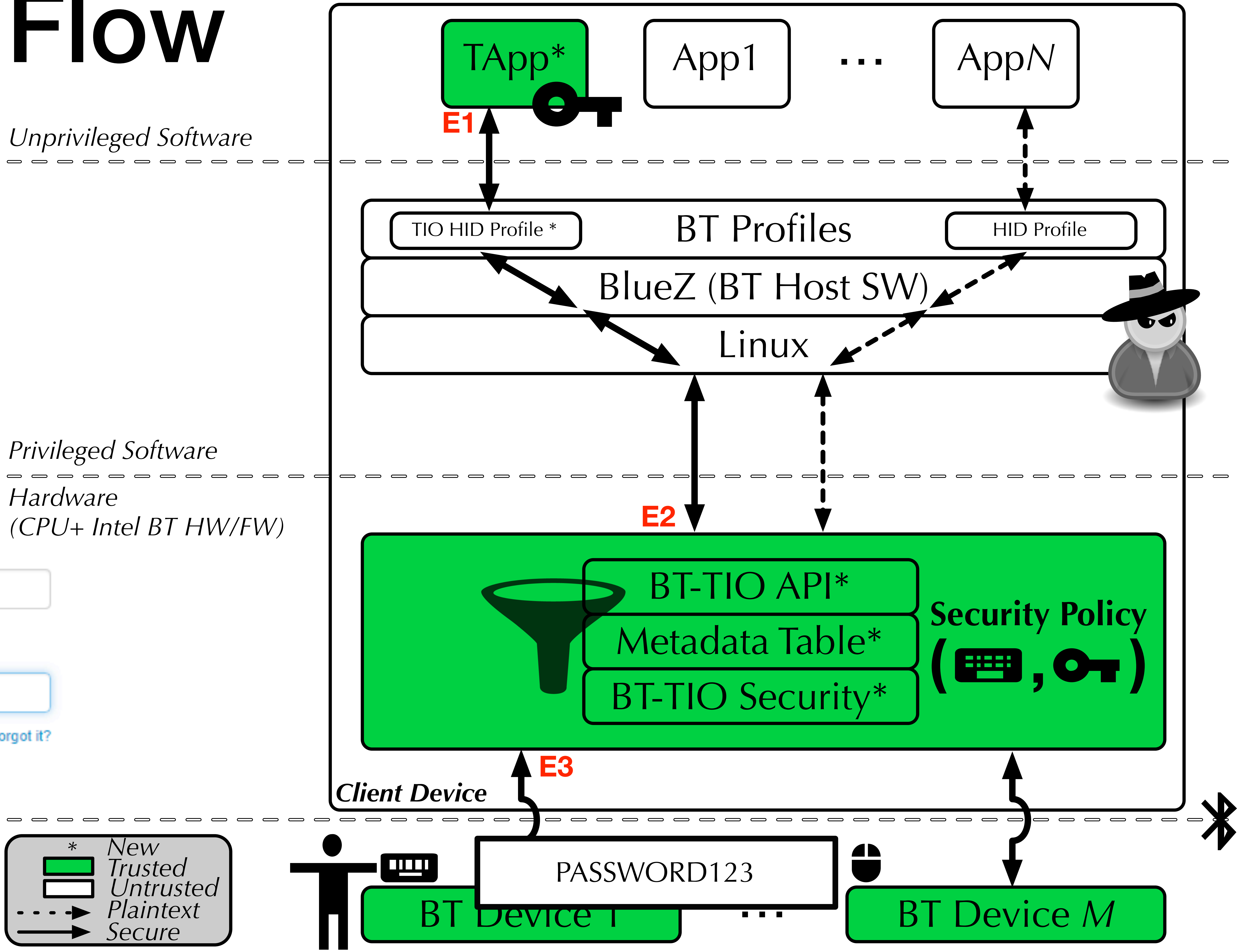

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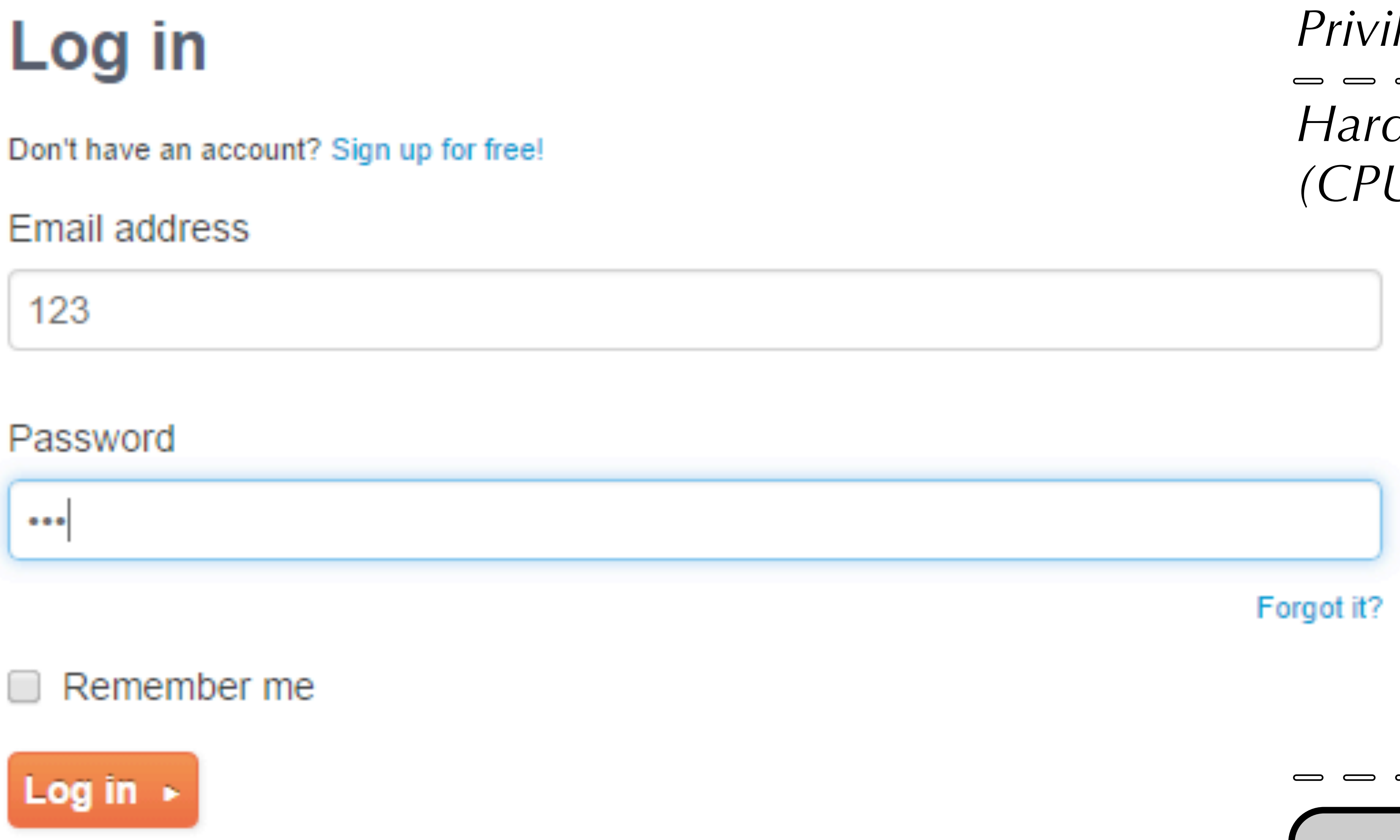

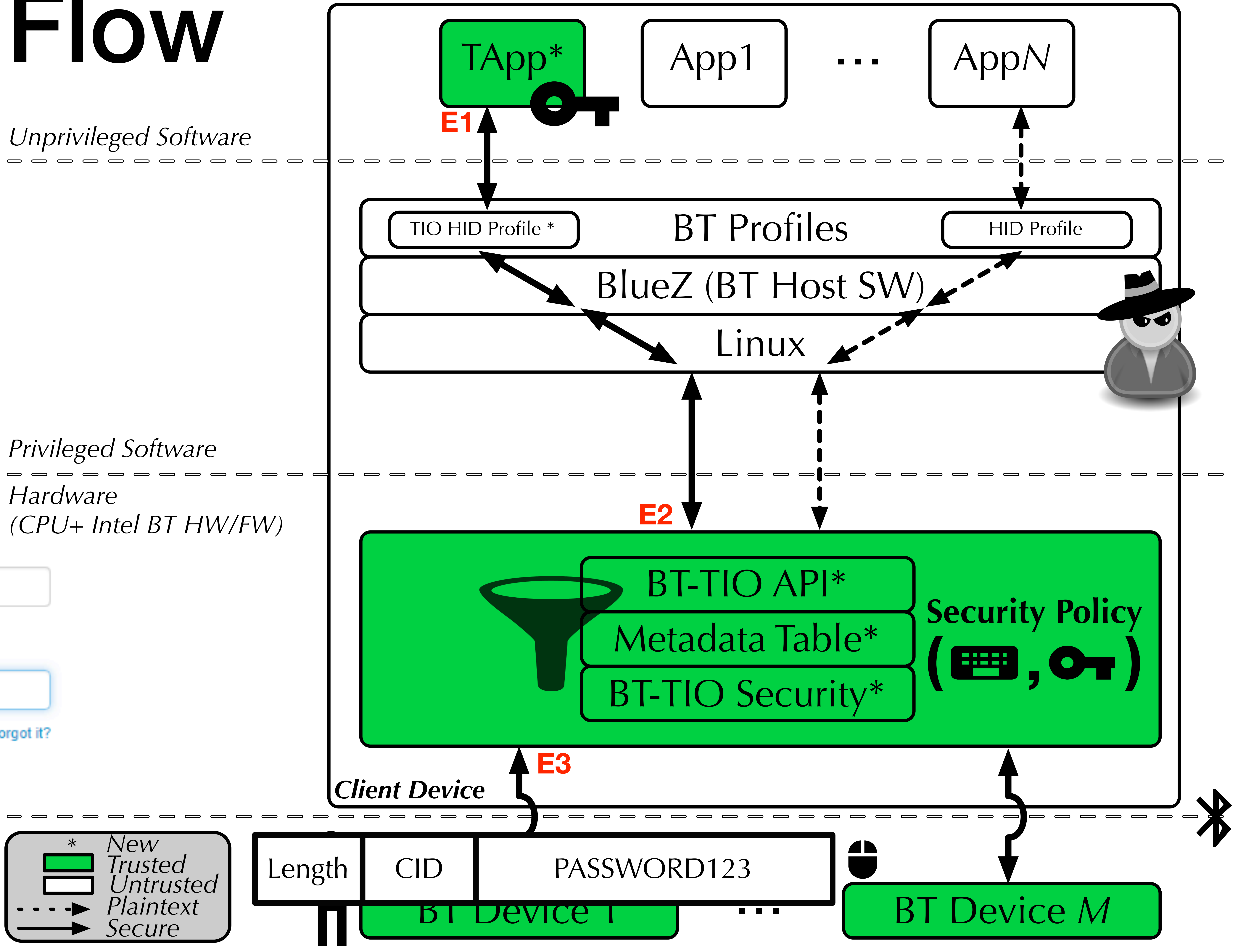

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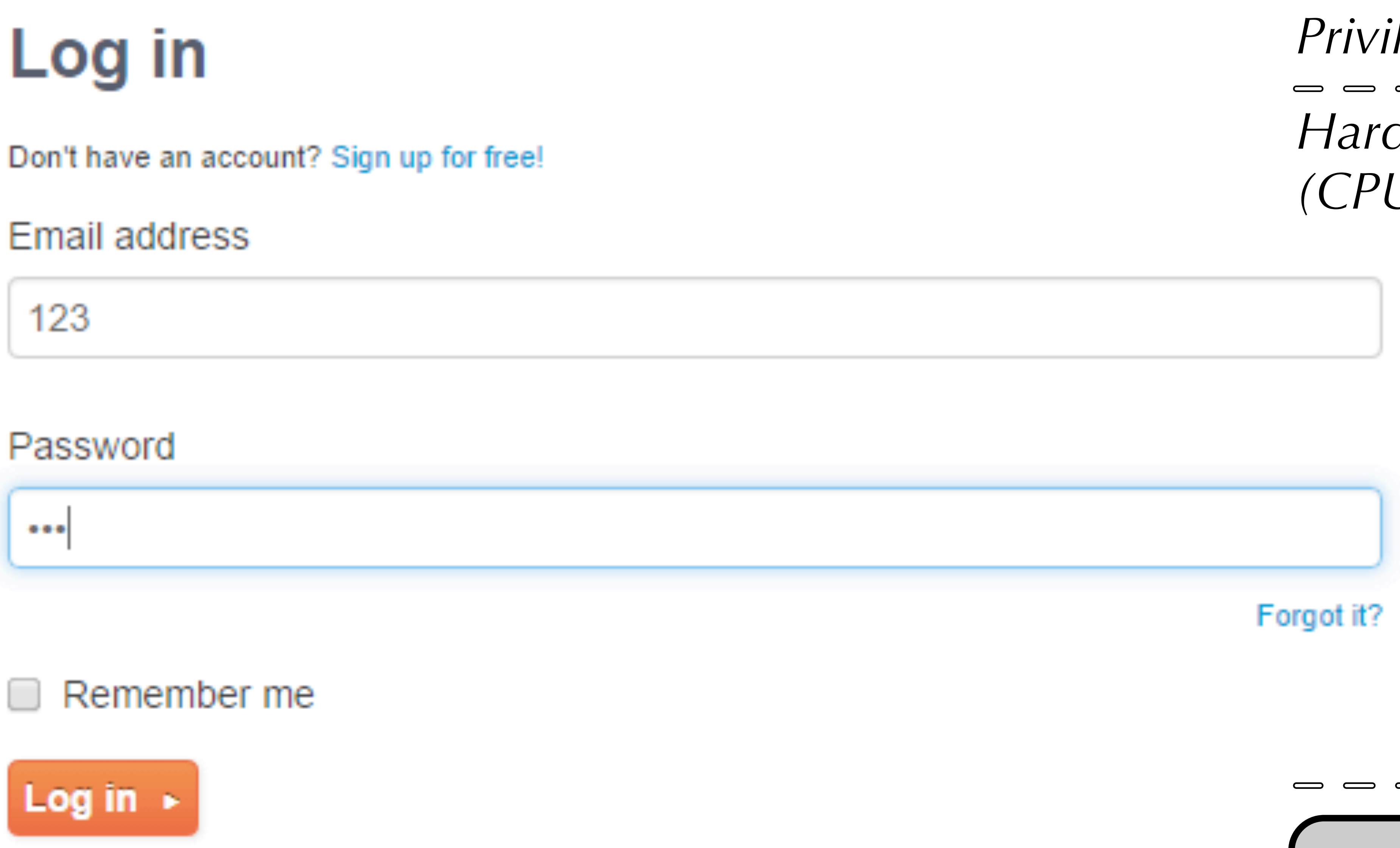

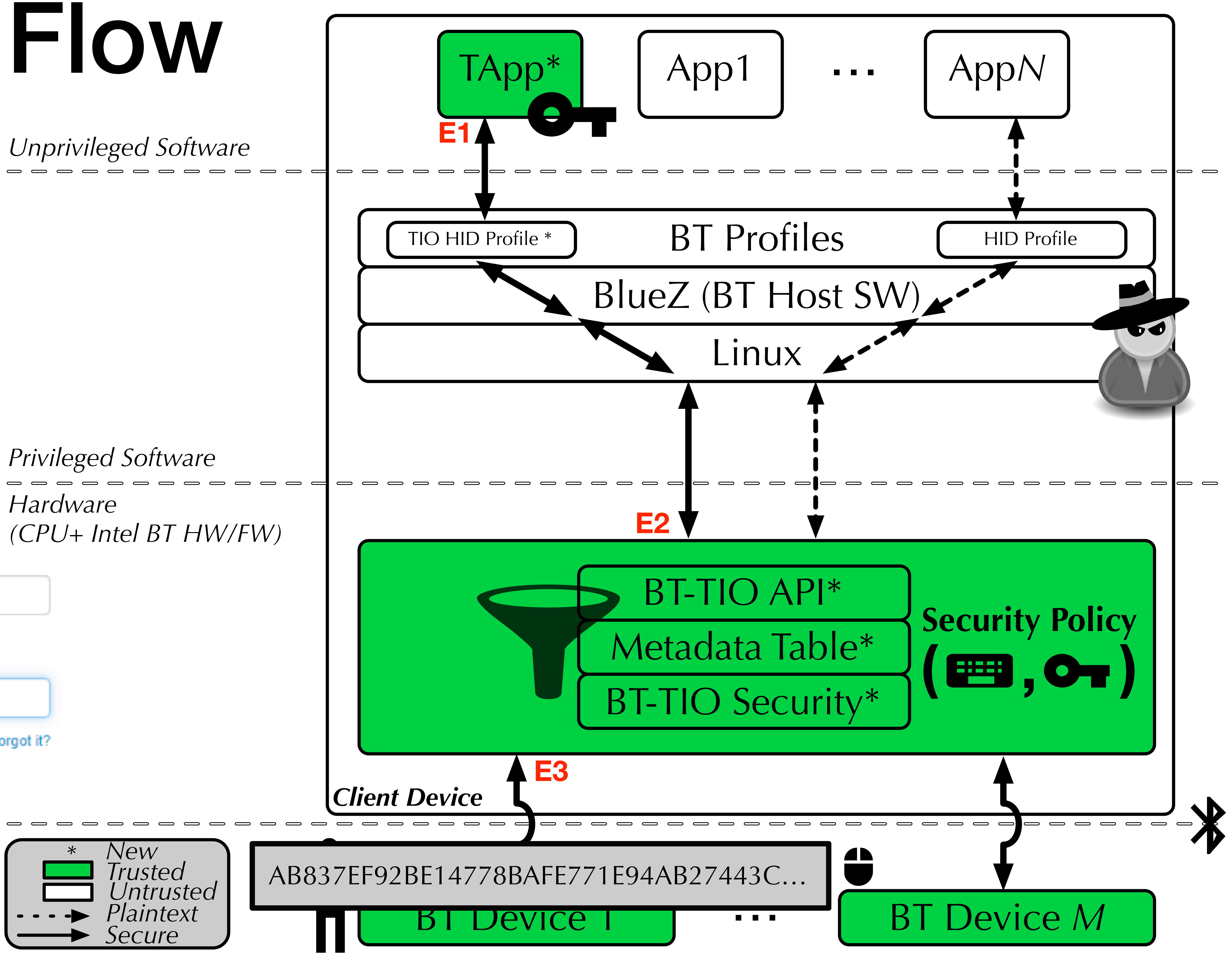

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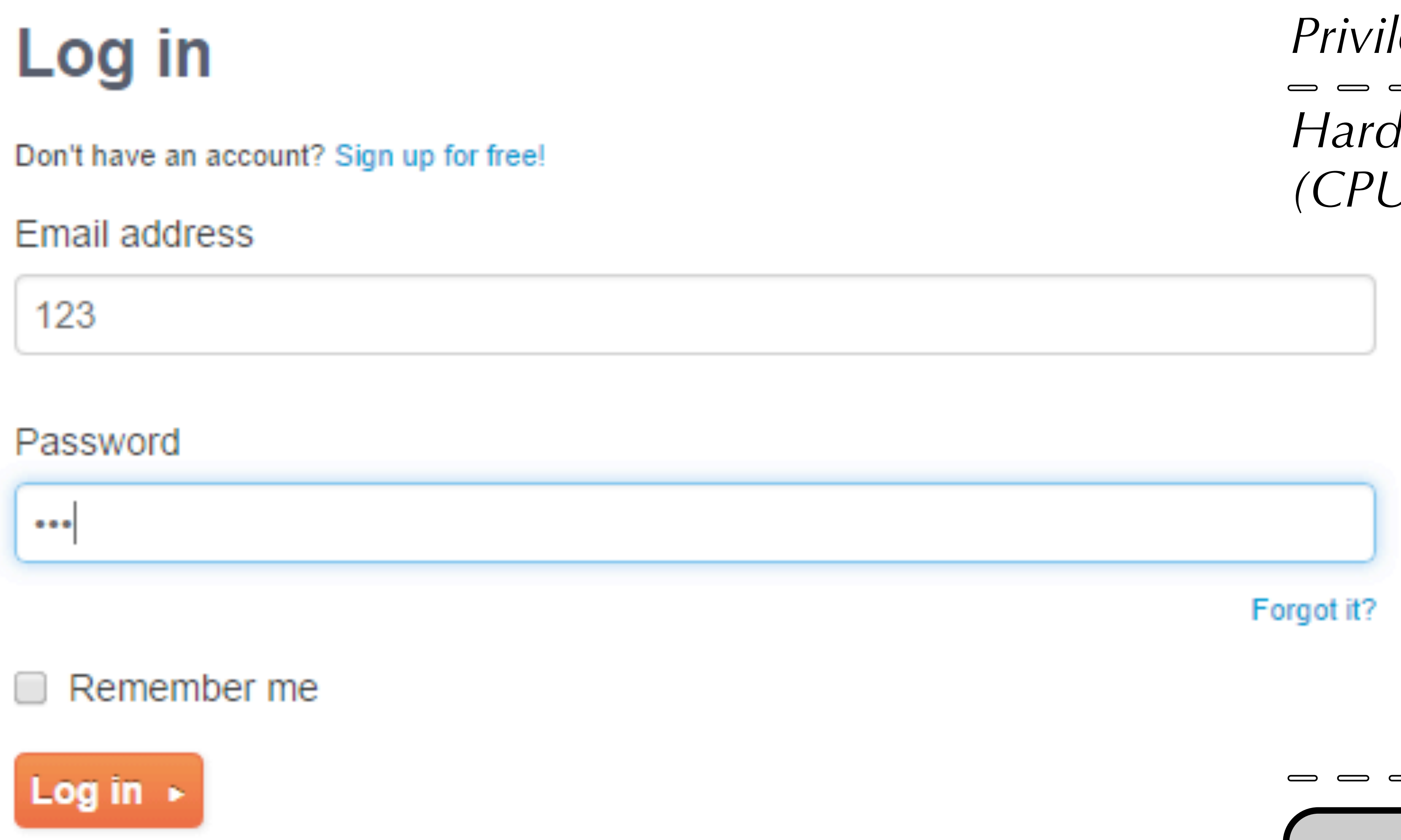

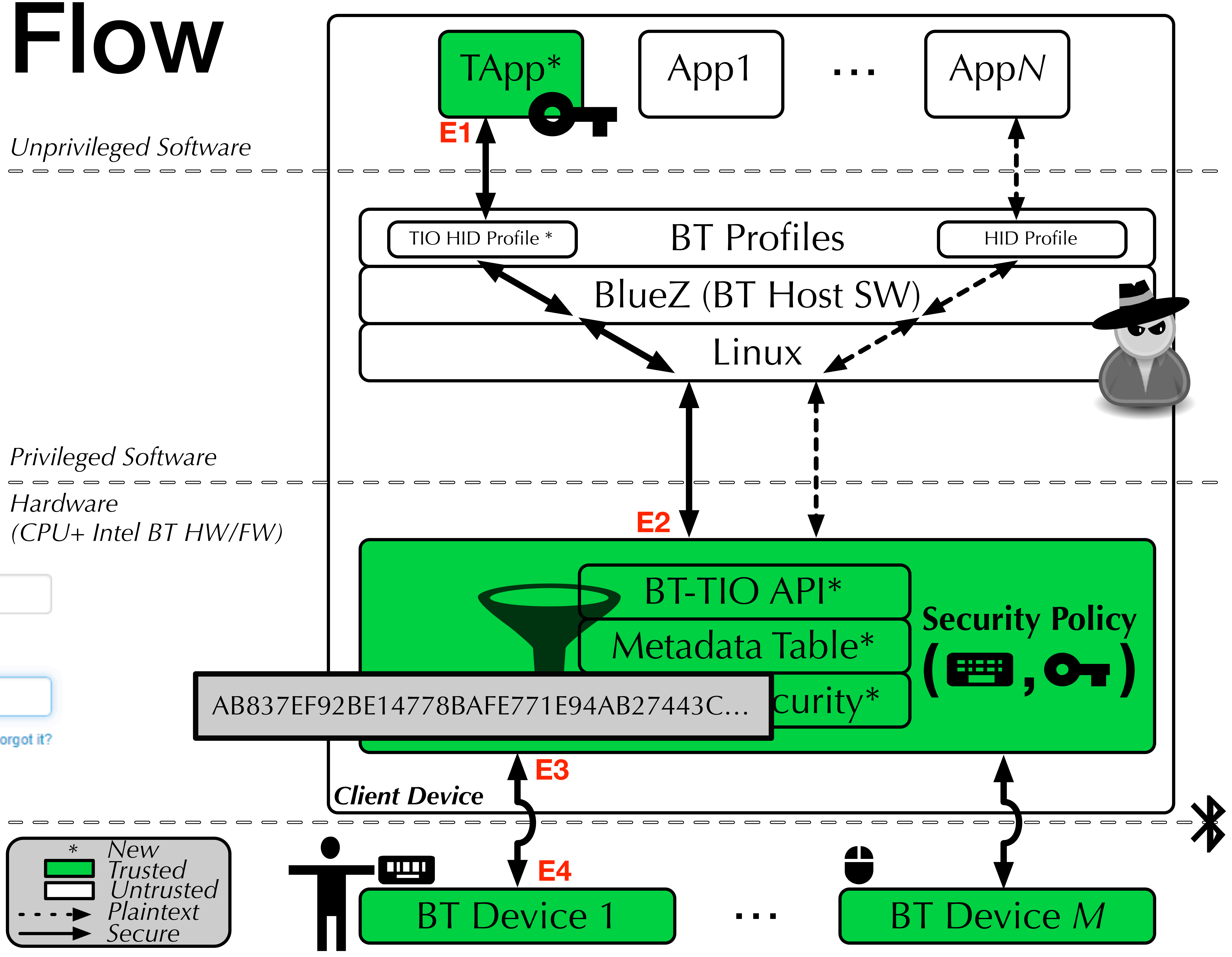

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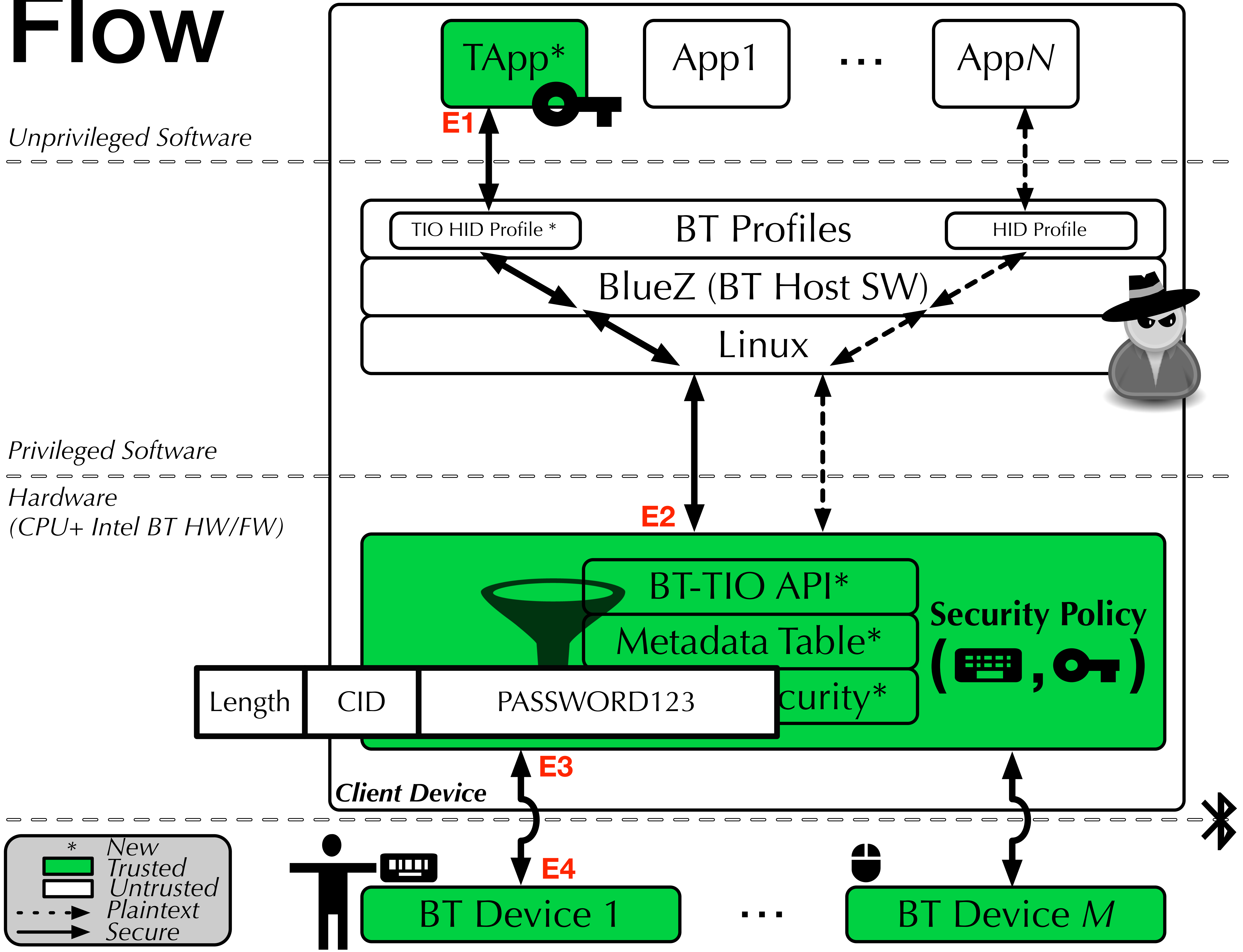

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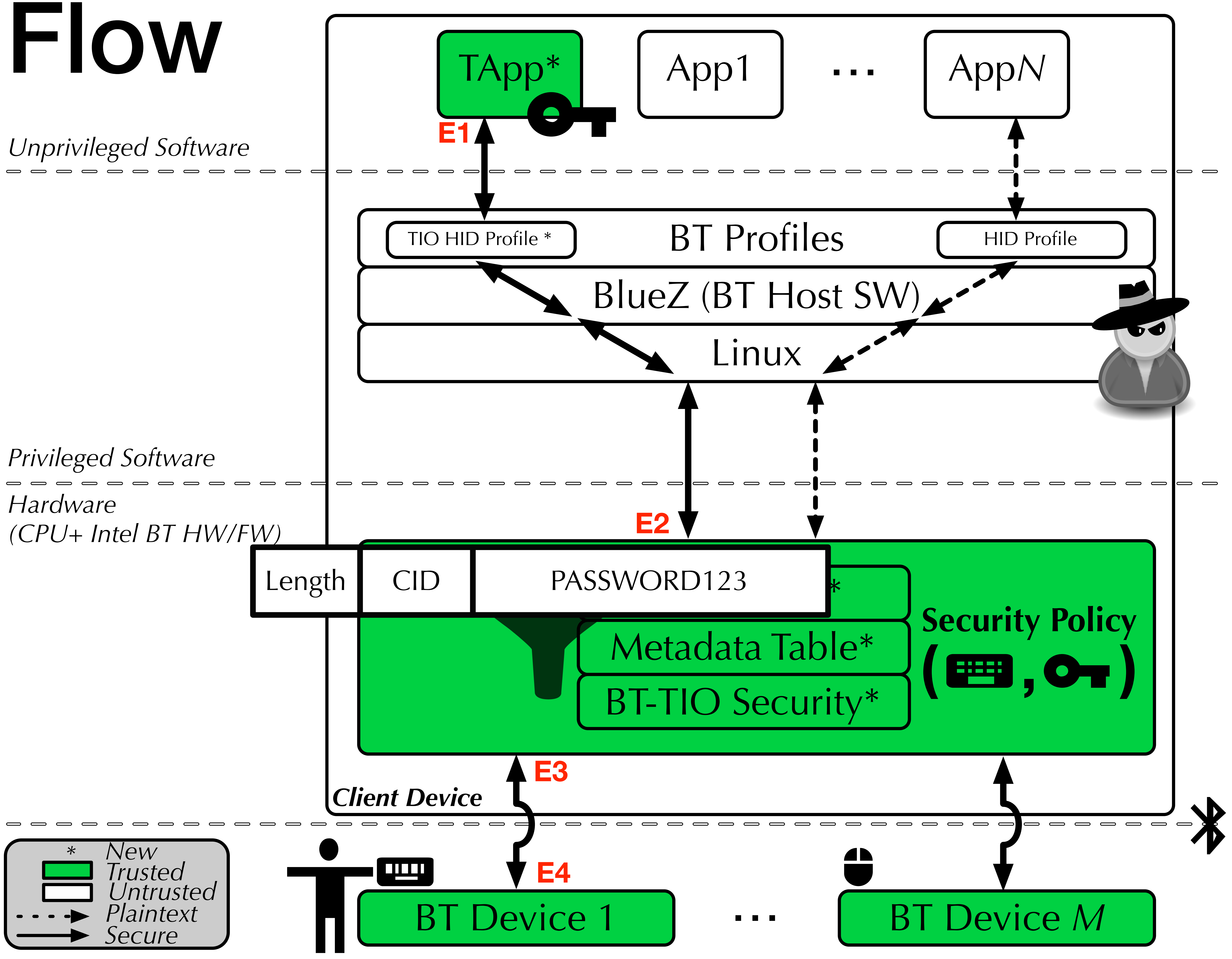

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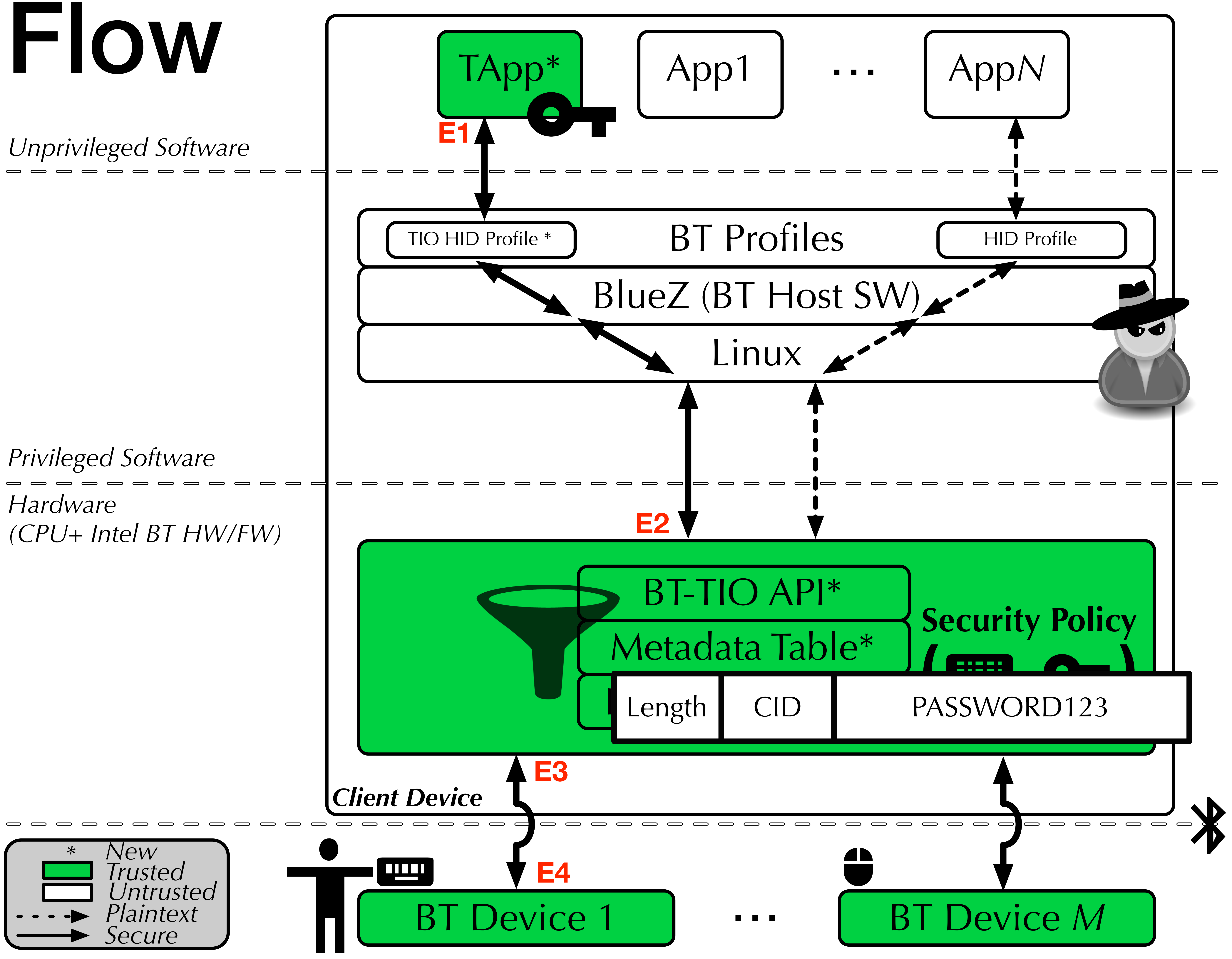

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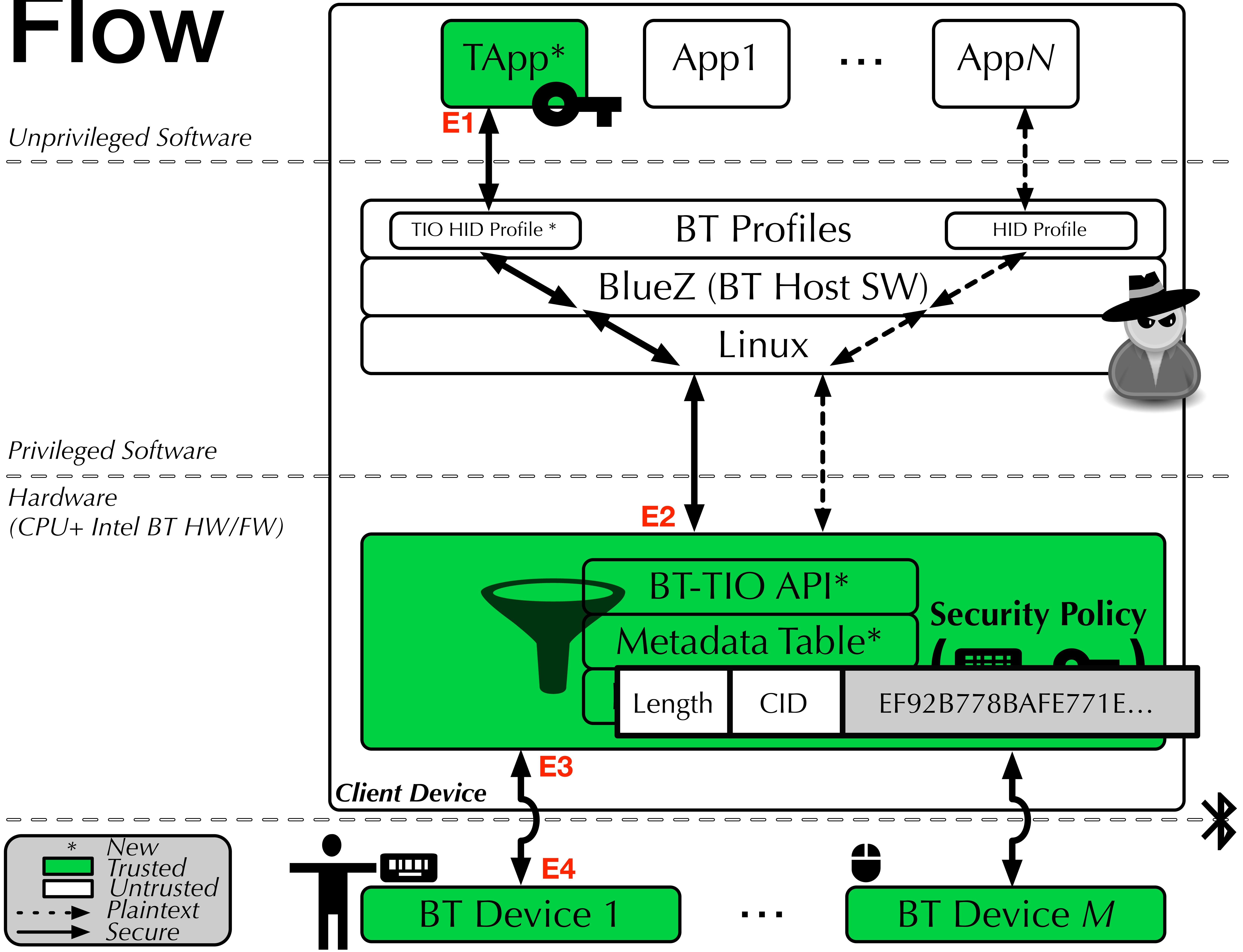

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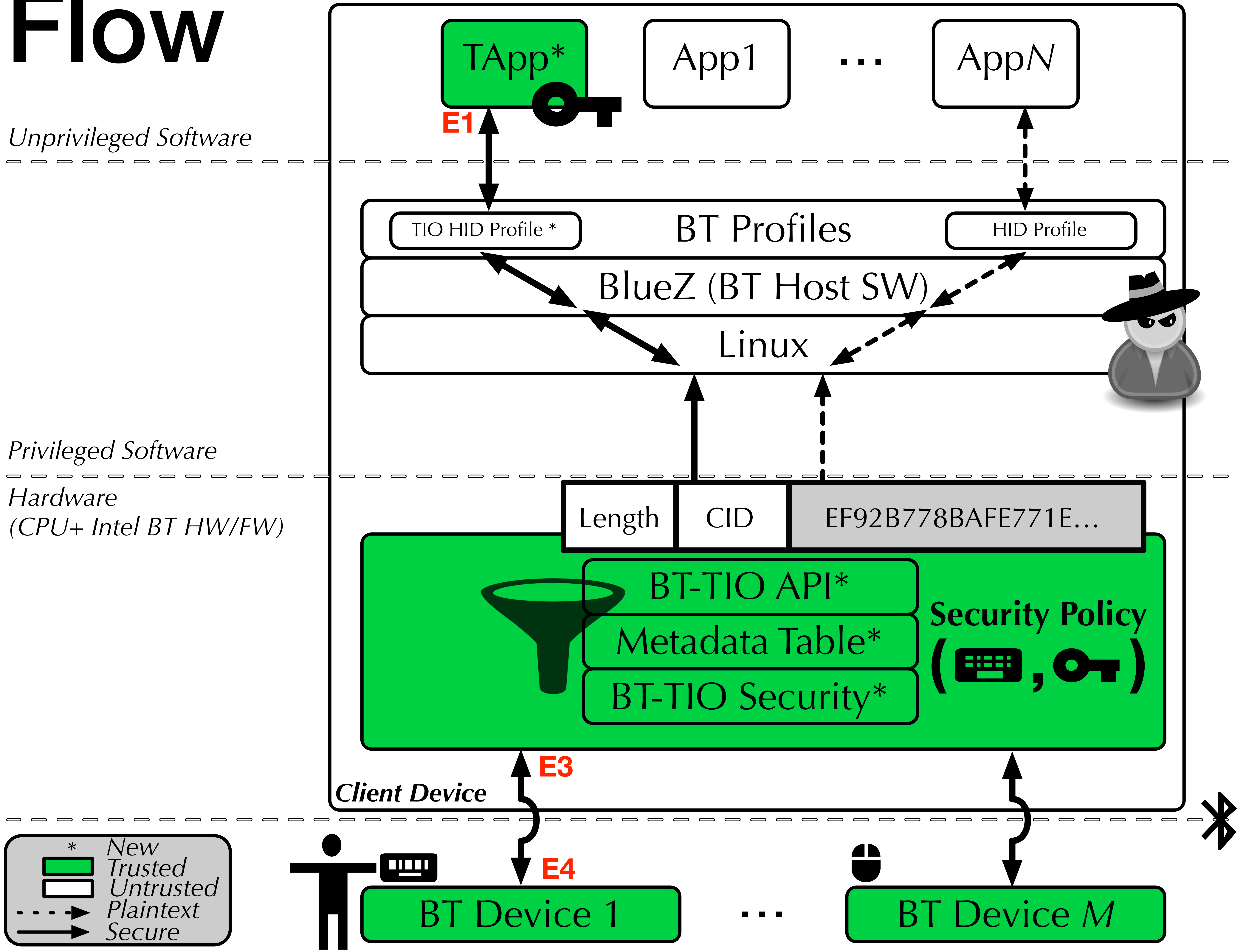

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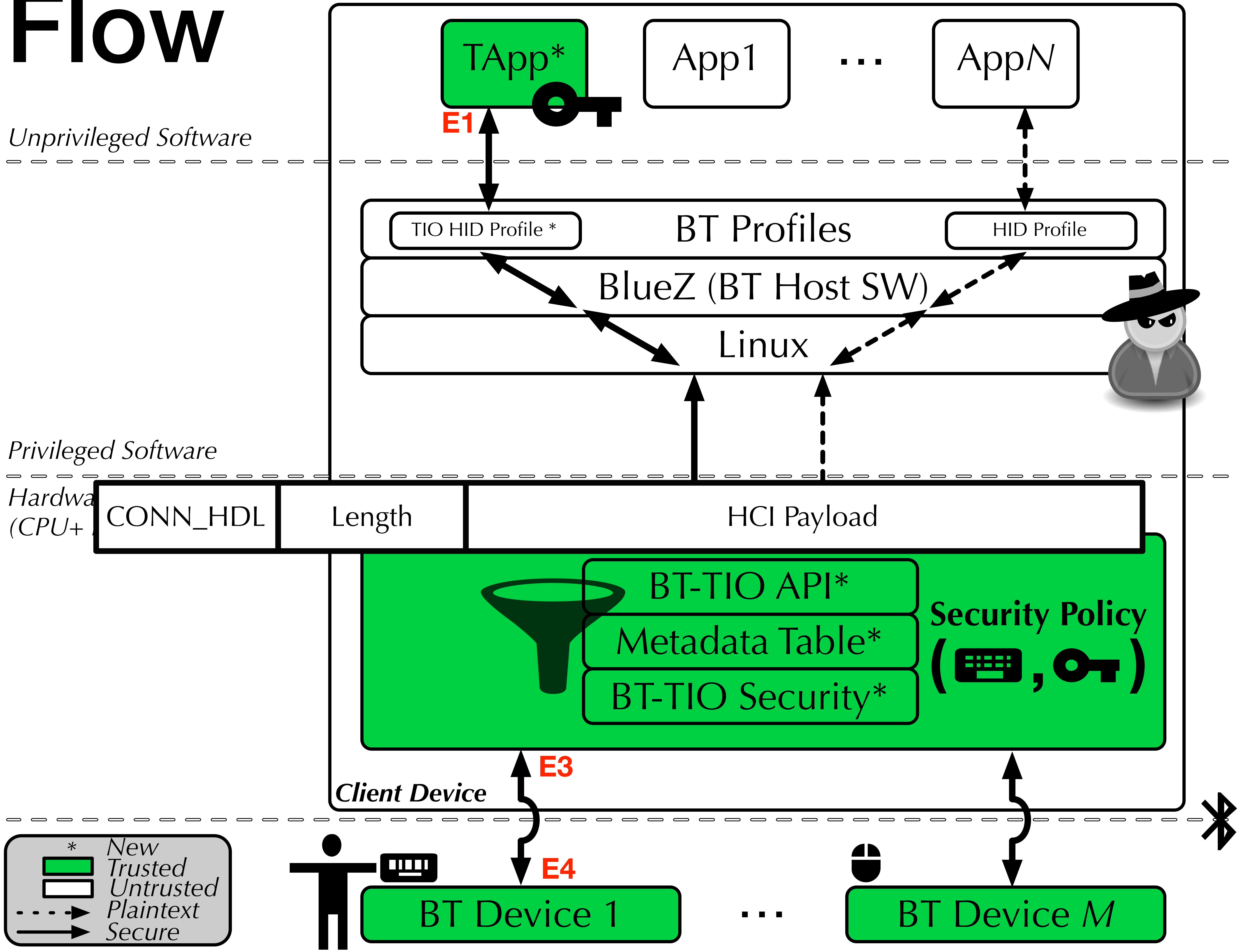

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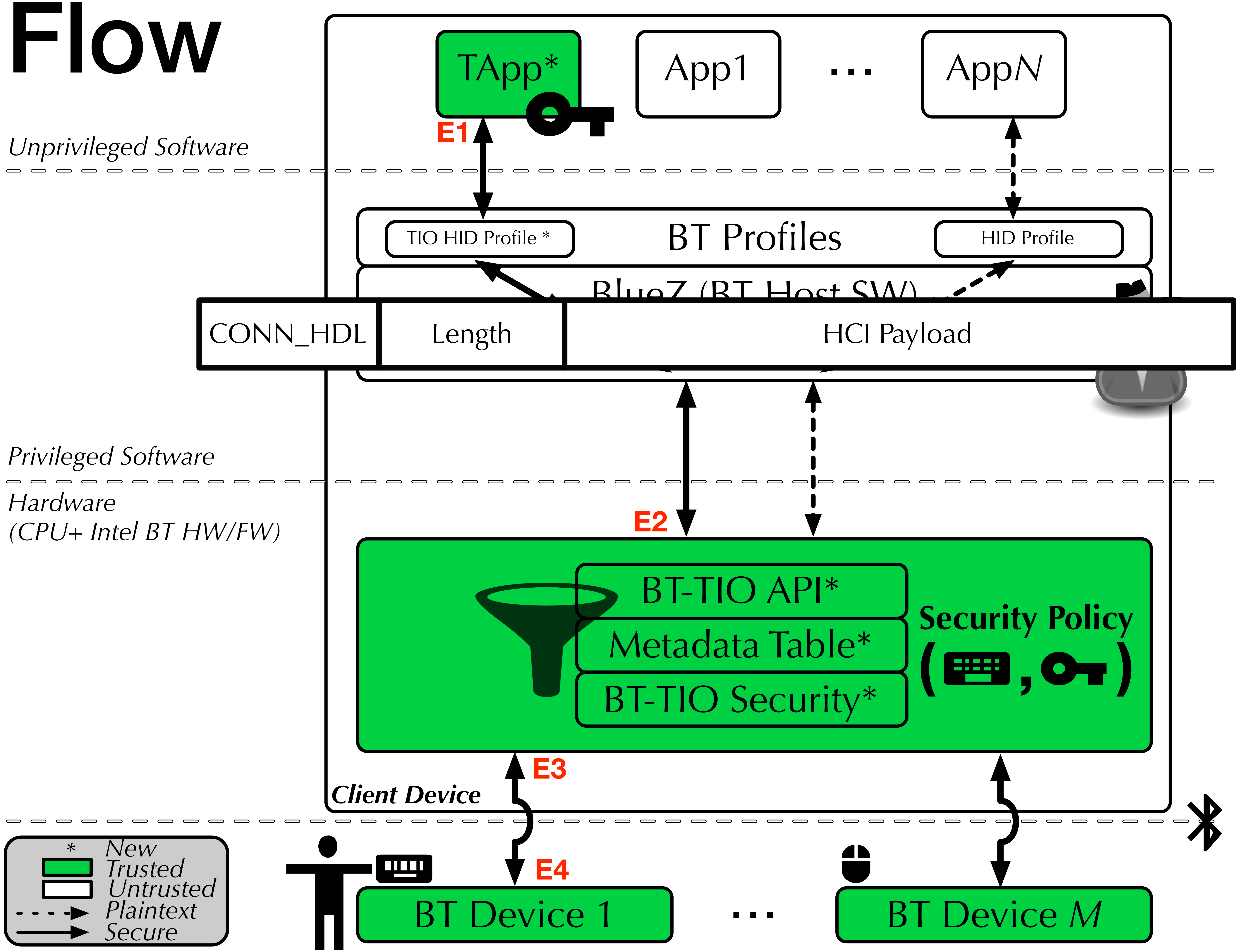

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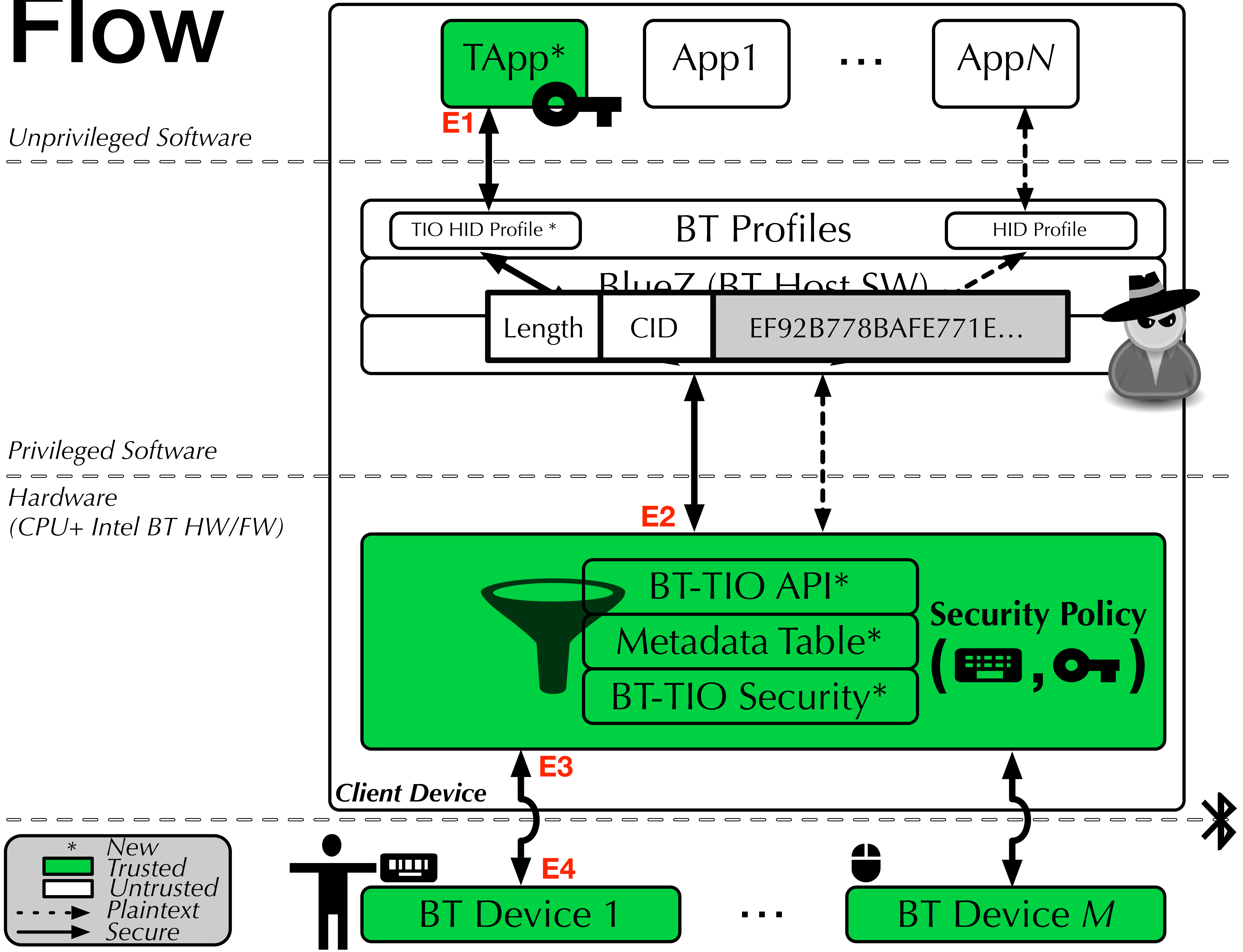

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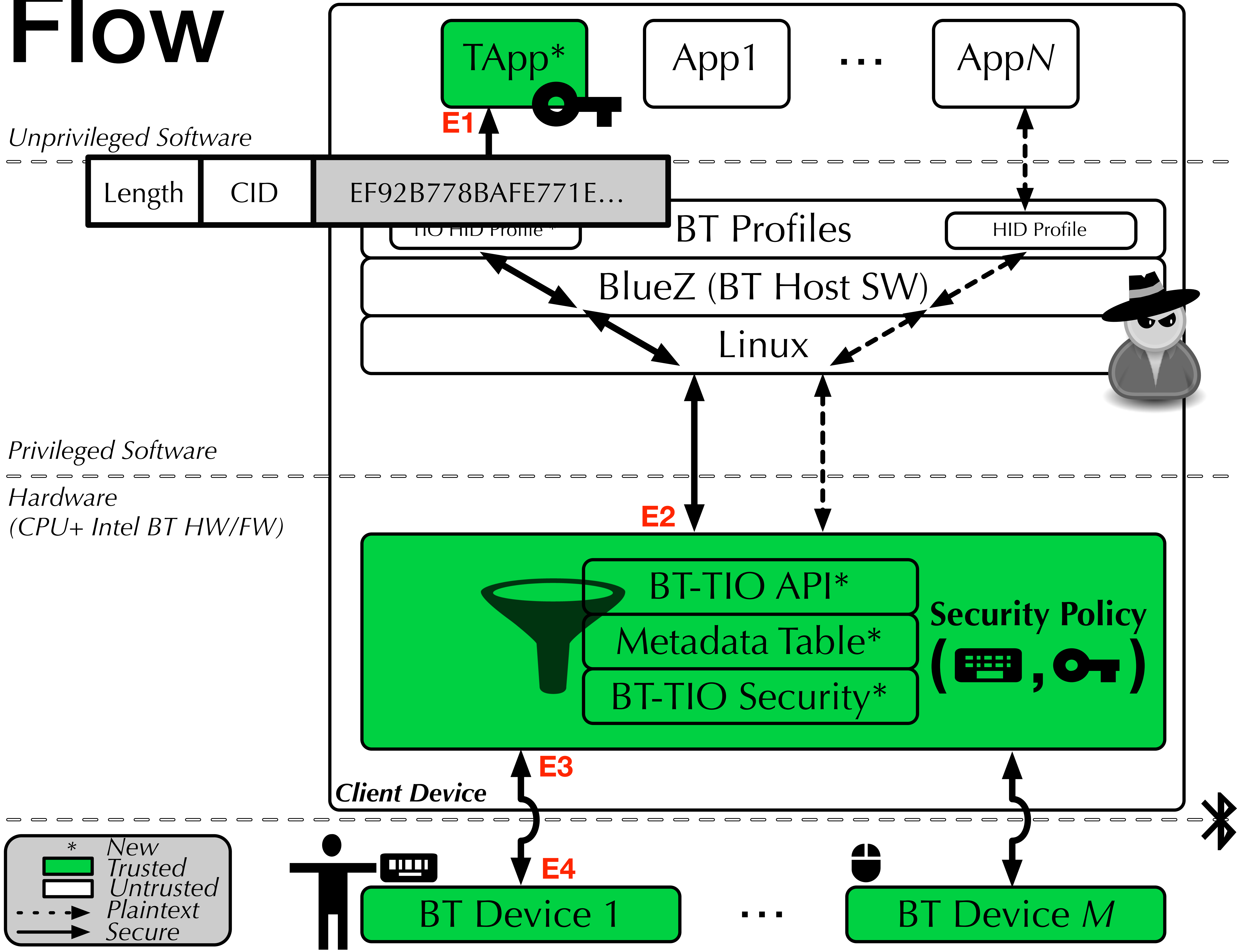

Travis Peters (traviswp@cs.dartmouth.edu)

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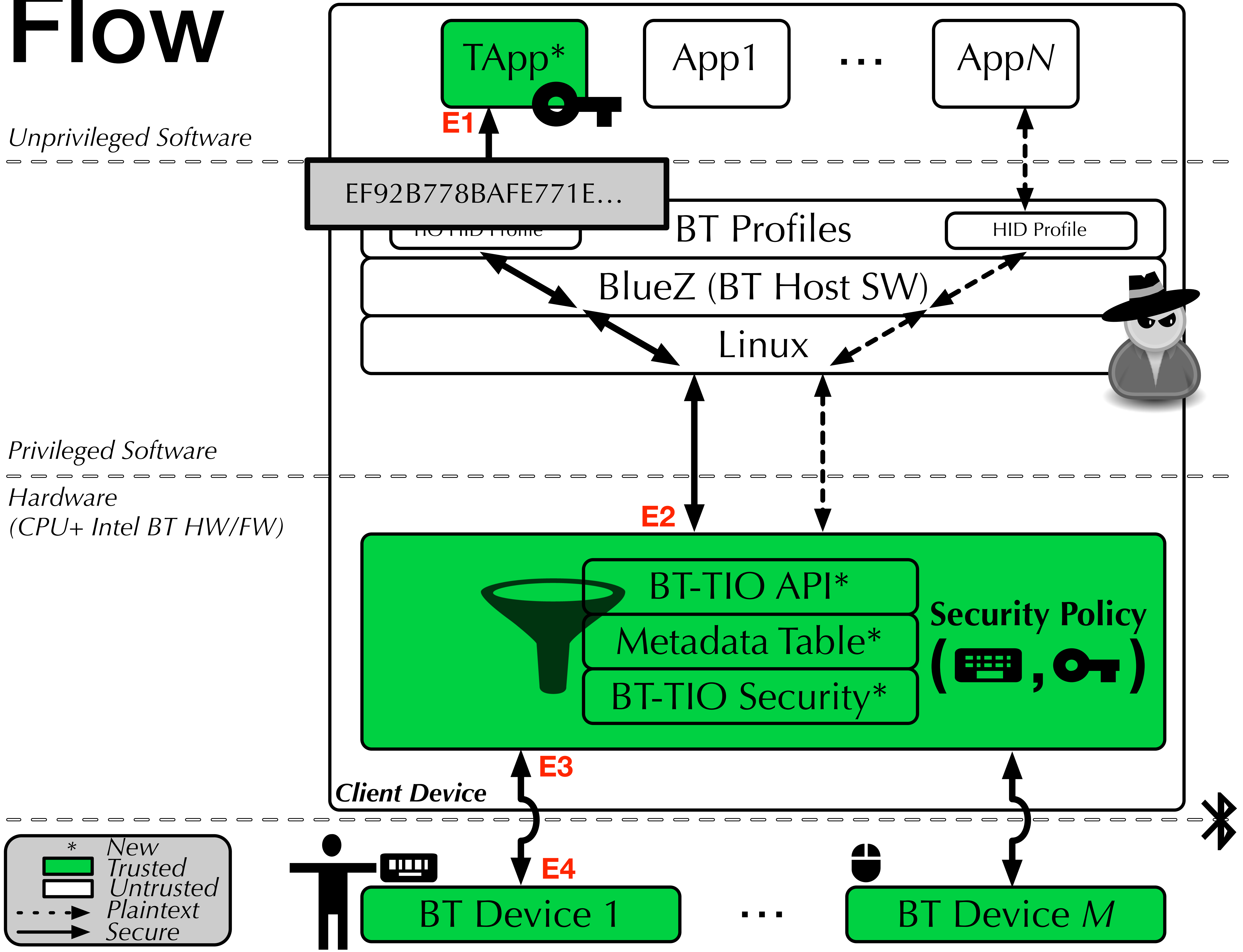
4. HCI transport and L2CAP routing



Secure Input Flow

1. User enters password field context - TA generates a symmetric key ( ) and programs security policy into Controller.

2. User types password

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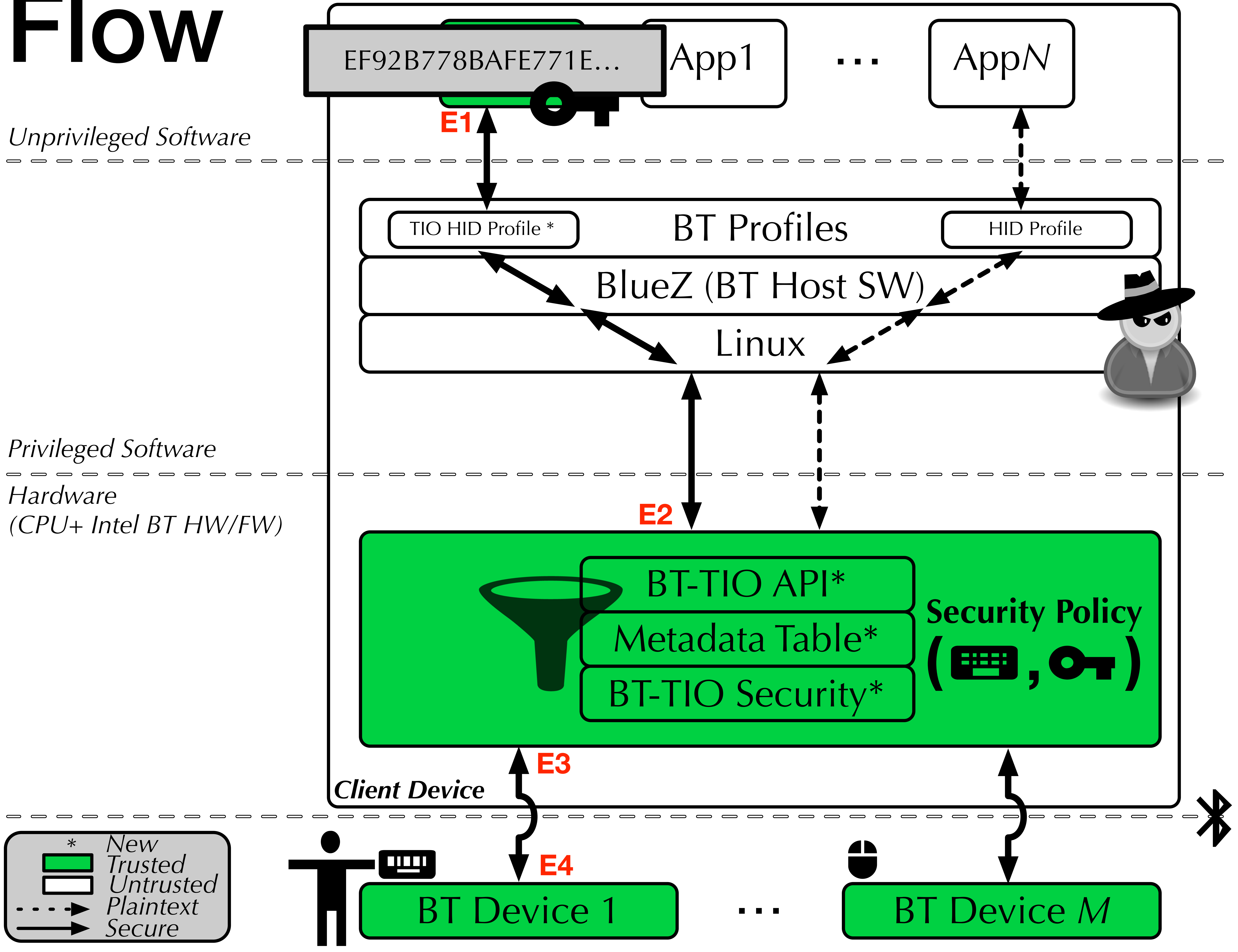

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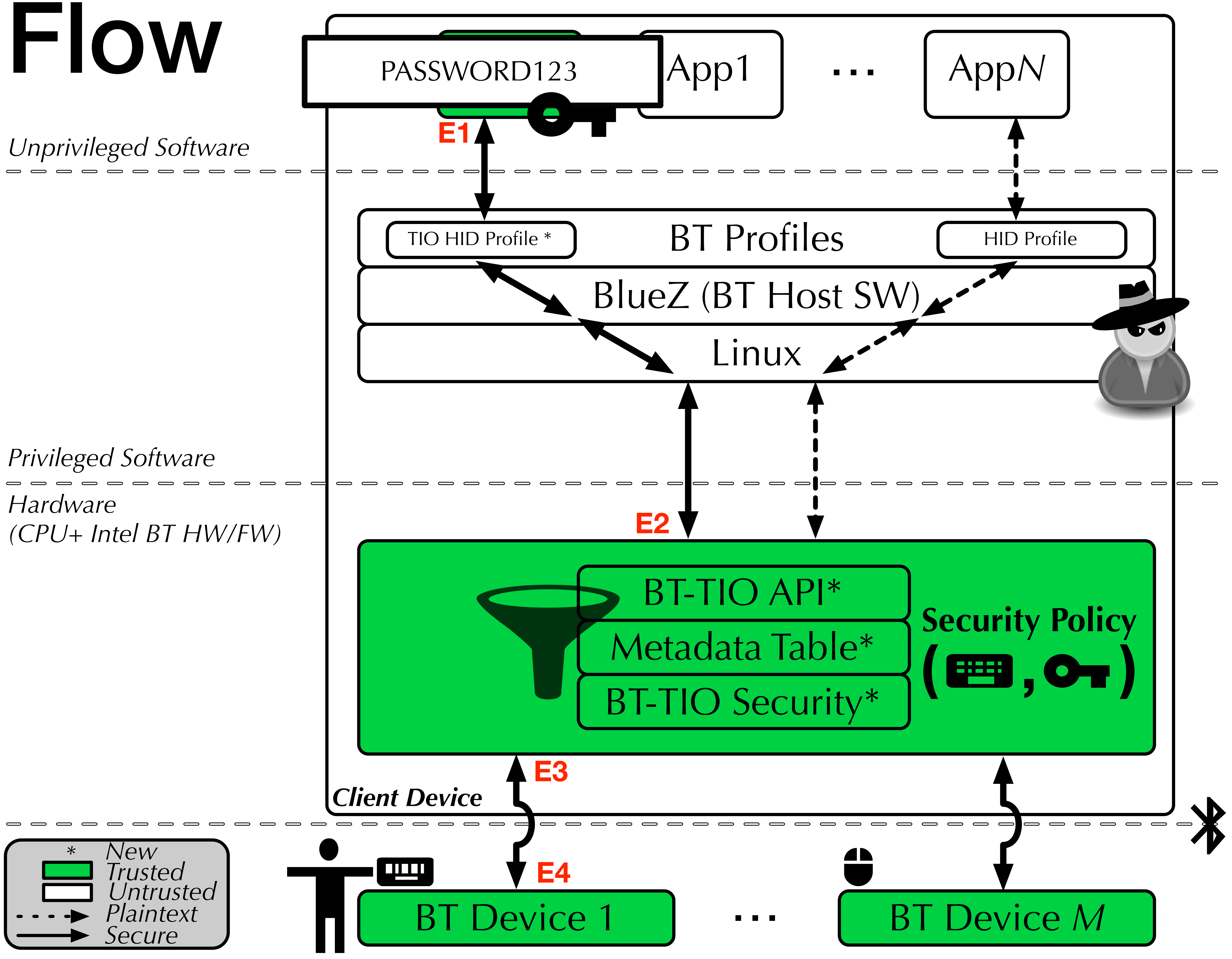

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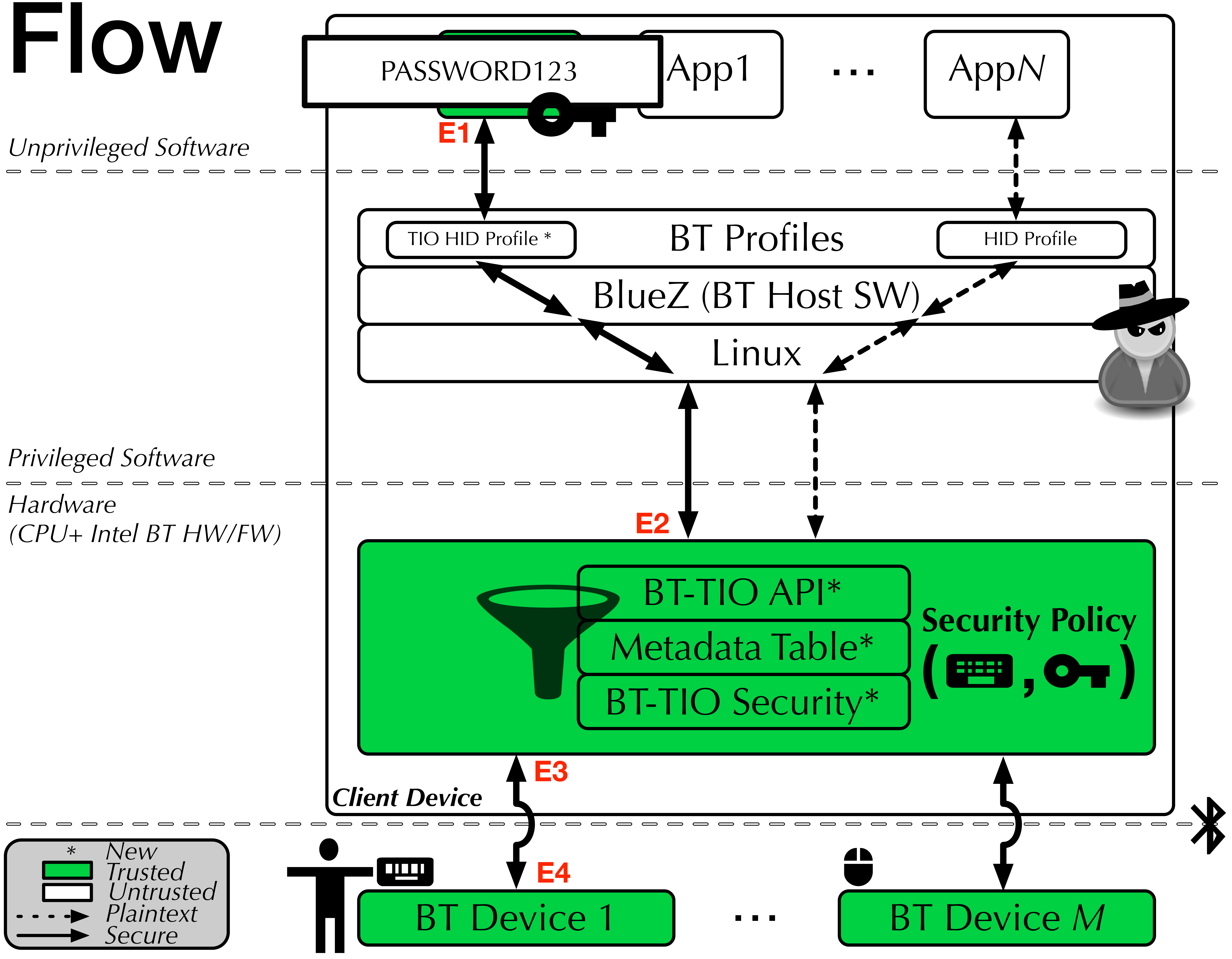
Trustworthy Input!



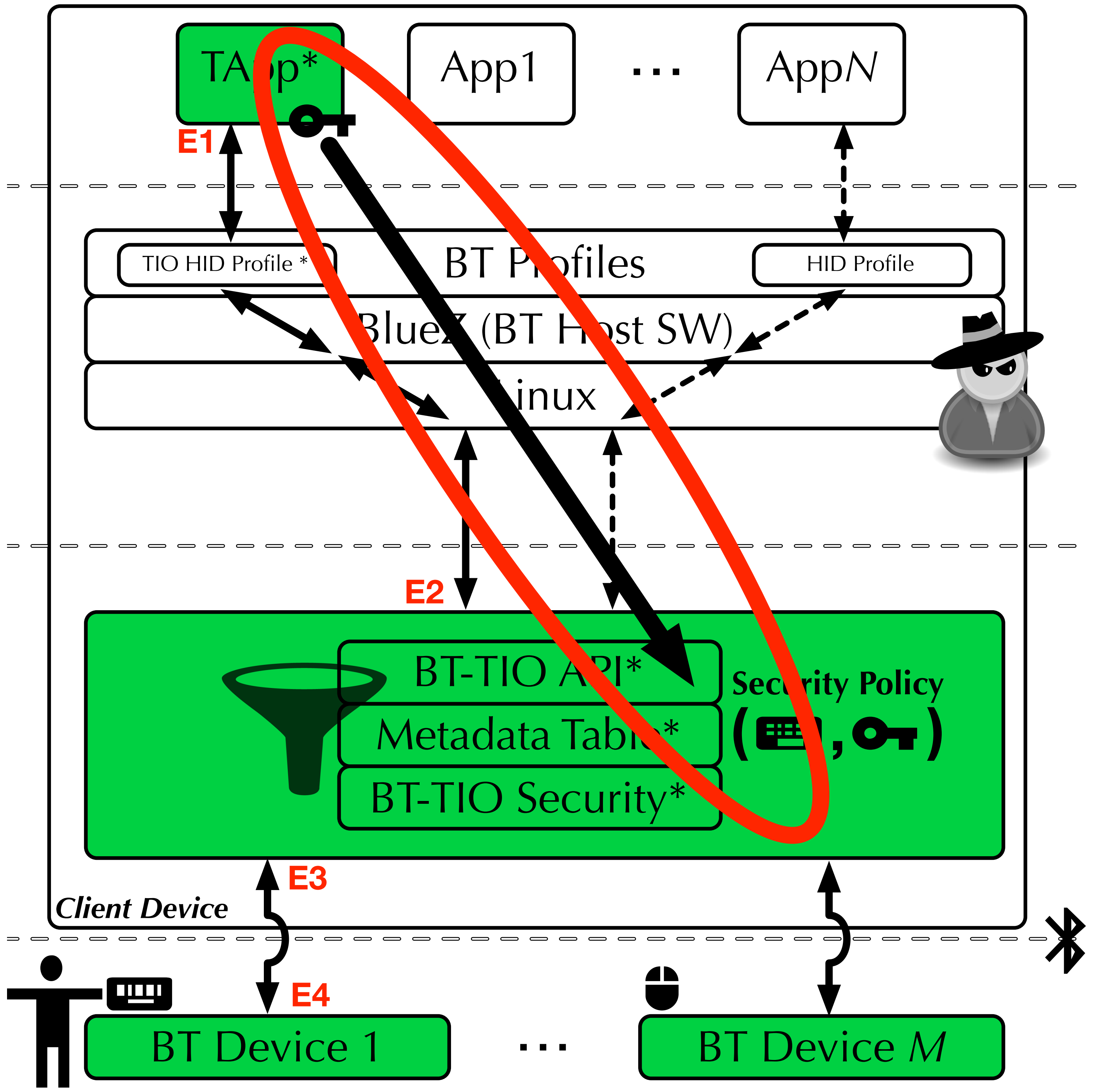
Conclusion

Take-aways

- Achieved E2E (app-to-device) security by extending the Bluetooth Controller firmware.
- Our extensions unobtrusively collect per-connection/per-channel metadata for Bluetooth Trusted I/O.
- Use metadata to secure Bluetooth I/O data between SGX app and Bluetooth Controller ***without…***
  - relying on untrusted host software.
  - requiring changes to SGX, Bluetooth device, or Bluetooth standard.
- PoC demonstrates how privileged keylogger cannot access user input data from connected Bluetooth device (keyboard).

Look in the paper* for details on…

- Dynamic key provisioning (Section 4.1.4) to establish secure channel for security policy key programming — re: PCIe & USB-C approach
- Future considerations
  - Extensions to other I/O paths (e.g., Wi-Fi, NFC)
  - Performance evaluation



**BASTION-SGX: Bluetooth and Architectural Support for Trusted I/O on SGX*

Thanks You!

Questions? Comments?

Please contact me at ***<u>traviswp@cs.dartmouth.edu</u>*** *if you'd like to talk more!*

BASTION-SGX: Bluetooth and Architectural Support for Trusted I/O on SGX

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