Recommendations for TEEP Support of Intel® SGX Technology

Overview of SGX & Selected TEEP Topics

David M. Wheeler

david.m.wheeler@intel.com

Apologies…

- If you are really interested in the details of SGX

  This Won't Satisfy Your Curiosity

- The best public paper can be found at:
  - Intel® SGX Explained https://eprint.iacr.org/2016/086.pdf
  - Stanford Seminar YouTube: https://www.youtube.com/watch?v=mPT_vJrlHlg
  - Other Resources: https://software.intel.com/en-us/sgx/resource-library
    https://software.intel.com/en-us/sgx/academic-research

Please refrain from asking deep questions on SGX Architecture that are not relevant to TEEP ᴍ

We are under a Time Constraint

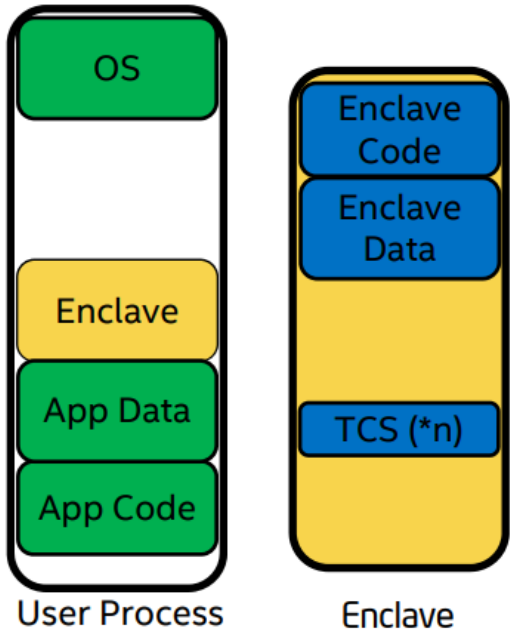
What We Will Cover

- Overview of Intel® Software Guard Extensions (SGX)
- SGX TCB (Trusted Computing Base)
- SGX Attestation

Overview of Intel® SGX

- SGX provides a protected area of memory (EPC Memory) where enclave code and data exist
- Enclave code is packaged with the Client Application, and loaded into EPC Memory by the Application
  - To the REE, both memory areas are within the same process
  - Enclave is prevented from access into Client process memory, AND Client prevented from access to the EPC (see flow chart)
- A special enclave (Launch Control) is used to load an enclave with code and data, and the Launch Control verifies the code during loading (authentication, authorization & integrity)
  - The Enclave must be signed by the Launch Key
- Entering and Exiting the enclave are done through processor instructions
  - EENTER and EEXIT

Trusted execution environment embedded in a process



With its own code and data

Provide Confidentiality

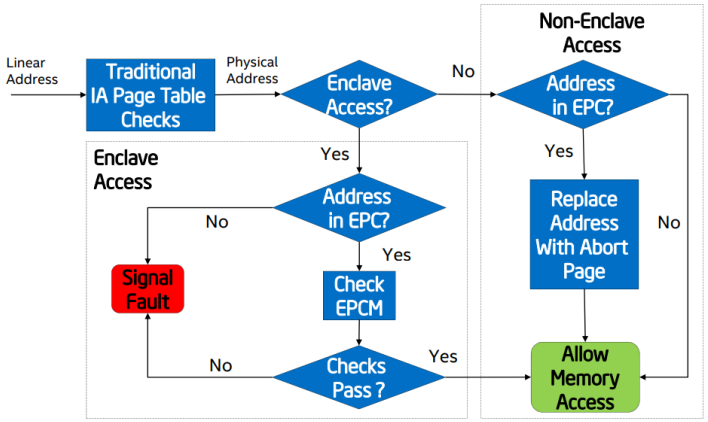
Provide integrity

With controlled entry points

Supporting multiple threads

With full access to app memory

SGX Access Control



EPC = Enclave Page Cache

What is Relevant to TEEP

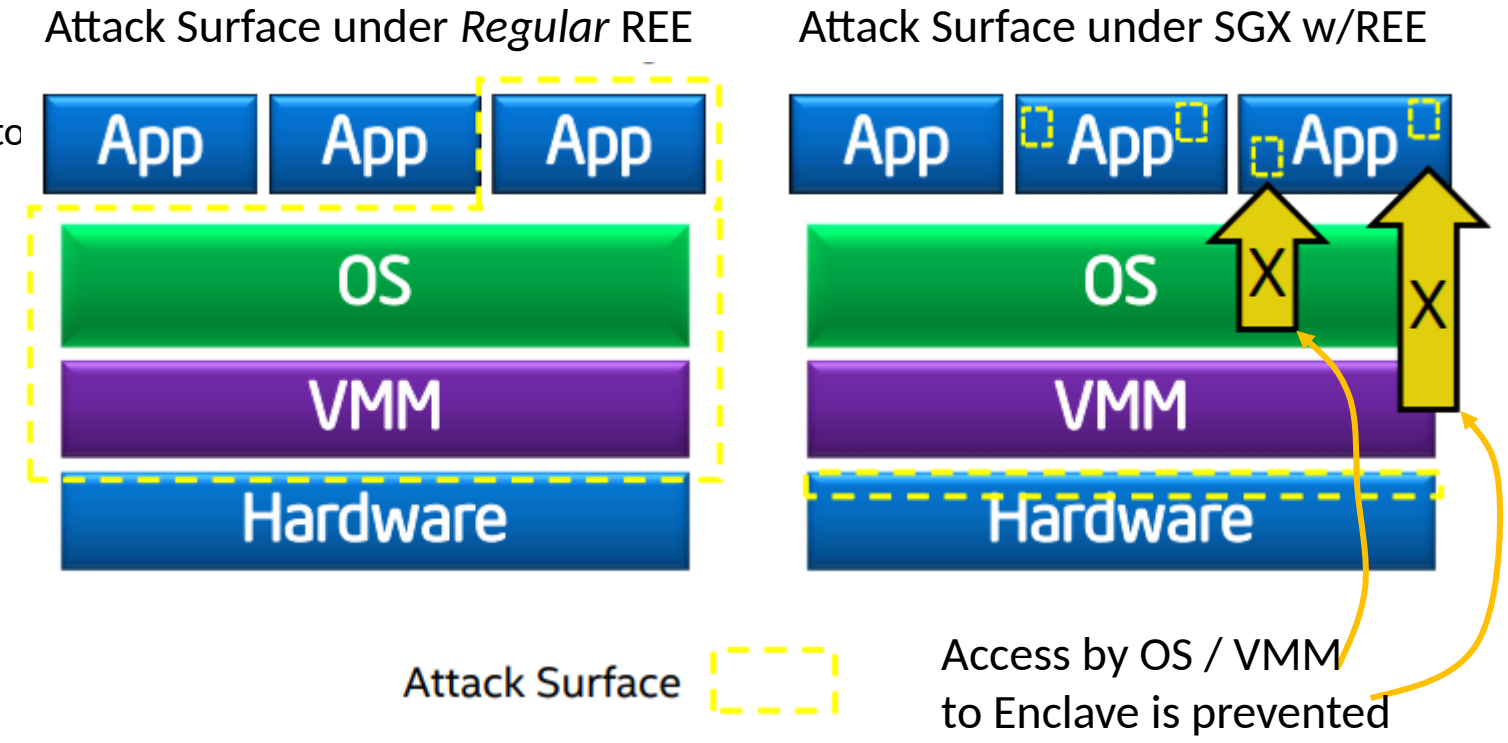
- Trusted Application is **not** Separate from Client Application
  - SGX Applications include both the trusted part (Enclave) and the untrusted part (Client Application)
  - This doesn't prevent a Client Application from presenting all information needed to "authorize" an SGX application to a TEEP Agent
    - Some information is embedded in the enclave
      - Authorized TAM or Service Provider (Mr. Signer), Integrity Proof (Mr.Enclave), Other Rights
    - Other information can be provided by the Client App
      - TAM Identity & authorization signatures, Other stuff?
- There is **no** Security Domain
  - Only one "program" can be loaded a single enclave – multiple separate enclaves can exist simultaneously
  - One can consider an Enclave as a single domain for only one TA
  - Optionally, an implementation of a TEEP Agent can manage TA interactions "as if" they were in the same Security Domain (e.g. secret sharing, secure channels, etc.)
- There is **no** internal Agent watching all Enclaves
  - It isn't possible to report on all the "installed" TAs – installed TA's take no resources from the TEE until loaded
  - It isn't possible to report on all the "running" TAs – as they do not know about each other
    - TEEP Agent could report on all TA's that it loaded as running enclaves
    - Launching an application that contains an enclave does not mean the enclave gets loaded

How would SGX Use TEEP?

- **Install / Uninstall**
  - There is no *real* install/uninstall commands in SGX
    - Any application on the platform file system can carry SGX enclave code (a TA)
    - Same vector as any REE Application install (e.g. HDD, Flash, USB Stick, Network, etc.)
  - One option could be signing the SGX enclave code (TA) so that it can be launched
    - For example:
      1. Service Provider requests TAM to prepare a particular Application for an SGX Platform (e.g. Install)
      2. The TAM holds the Enclave Signing Key for some platforms
      3. TAM authorizes SP, and if OK, then signs the requested Enclave & delivers it to the Platform
    - Simplifies Application Developer deployment
- **Start / Stop**
  - An SGX enclave is launched (Started) by the application (not by the TEE)
  - TEEP Start could be mapped to Client Application launch
    - However, the Client Application can delay the launch of the enclave to a later time

Intel® SGX Trusted Computing Base

- Security Perimeter is the CPU package boundary
  - Data/Code inside CPU is unencrypted
  - Data/Code outside CPU is encrypted/integrity protected
- BIOS is formally outside the TCB
  - BIOS controls how much memory is allocated to EPC, but cannot affect the security of EPC memory
- OS is formally outside the TCB
  - OS controls page tables, but does not control the security or attributes of the pages
  - Interrupts and certain OS features (files, network sockets) are still handled by OS, but considered in Application scope/control
    - State is saved in special EPC memory area for interrupts and context switches



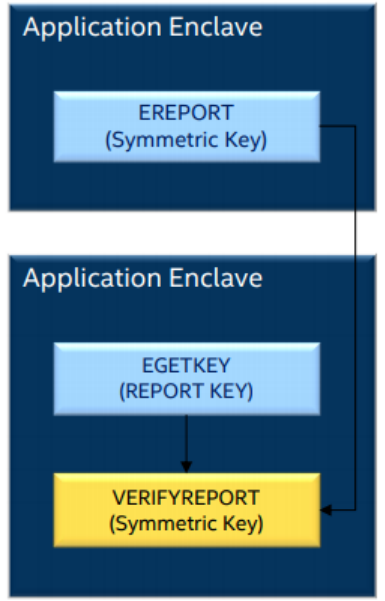
What is Relevant to TEEP

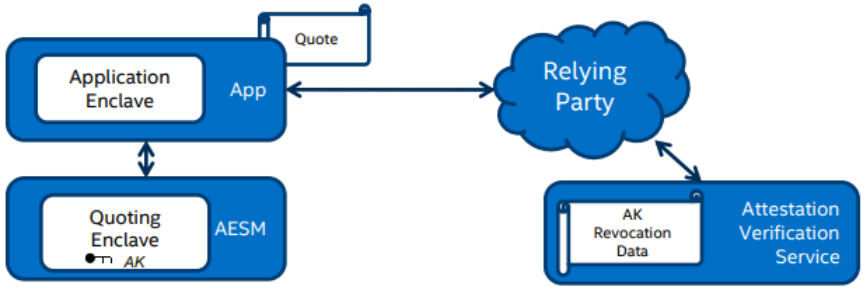
- SGX does not depend on Secure Boot
  - SGX has it's own Roots of Trust for:
    - Measurement (RTM), Integrity (RTI), Verification (RTV),
    - Confidentiality (RTC), Reporting (RTR), Storage* (RTS)
- On an SGX platform, Secure Boot may NOT be turned on
  - Not possible to report from SBM

* The RTS is limited to providing sealing keys – actual storage is based on OS services

Intel® SGX Attestation

- **SGX Includes Two forms of Attestation**
  - Local Attestation – Hash Based
  - Remote Attestation – EPID Signature (Elliptic Curve Group Signature)
- **Local Attestation**
  - AES–CMAC Key Generated from Enclave & Platform
    - Attributes of the Enclave (Signer, Integrity Measurements, Version, etc.)
    - Platform Attributes (Fuses, Microcode Version, CPU Serial #, etc.)
  - Allows inclusion of other message via Hash
  - Can be sent to other enclaves on same platform
- **Remote Attestation**
  - Built from Local Attestation by SGX Signing Enclave
  - Only Signing Enclave has access to EPID key (the RTR)
  - Requires an External Verifier for EPID Signatures





What is Relevant to TEEP

- **Add EPID Digital Signature Algorithm as Optional to Support**
  - Will be supported by default on SGX-Enabled Platforms
  - Must be supported by TAMs to consume attestation from SGX Platforms
    - Or offload to an Intel® SGX Verifier
  - Needed to support SGX Attestation Signatures
  - The only way to verify trust in an SGX Enclave
  - Can use an Attestation to “certify” another RSA or ECDSA key pair
    - This would enable SP to have an Application/TA-specific RSA or ECDSA key pair

- **Local Attestation can be used to provide communication between the TA’s and a TEEP Agent**
  - Can be used to simulate Security Domains and “Universal TEE Knowledge” for reporting state

ISO/IEC 20008-2 Known Patent Rights

- The following are the known (to me on 7/16/2018) IPR claims on EPID
- I make no claim on the part of Intel or other parties that this list is complete or accurate

1. ISO/IEC 20008-2 (EPID Group Signature)
   - NEC corporation – RAND/reciprocal
   - Electronics and Telecommunications Research Institute (ETRI) – RAND/reciprocal

2. ISO/IEC 20009-2 (SIGMA Protocol: P2P Attested Channel)
   - China IWNCOMM Co., LTD. – RAND
   - Electronics and Telecommunications Research Institute (ETRI) – RAND/reciprocal

Other Crypto Recommendations

- **NIST Recommends moving to larger Key Sizes**
  - NIST Recommendations

Algorithm
RSA 3072-bit or larger
Diffie-Hellman (DH) 3072-bit or larger
ECDH with NIST P-384
ECDSA with NIST P-384
SHA-384
AES-256

Date	Minimum of Strength	Symmetric Algorithms	Factoring Modulus	Discrete Logarithm Key	Discrete Logarithm Group	Elliptic Curve	Hash (A)	Hash (B)
(Legacy)	80	2TDEA*	1024	160	1024	160	SHA-1**	
2016 - 2030	112	3TDEA	2048	224	2048	224	SHA-224 SHA-512/224 SHA3-224	
2016 - 2030 & beyond	128	AES-128	3072	256	3072	256	SHA-256 SHA-512/256 SHA3-256	SHA-1
2016 - 2030 & beyond	192	AES-192	7680	384	7680	384	SHA-384 SHA3-384	SHA-224 SHA-512/224
2016 - 2030 & beyond	256	AES-256	15360	512	15360	512	SHA-512 SHA3-512	SHA-256 SHA-512/256 SHA-384 SHA-512 SHA3-512

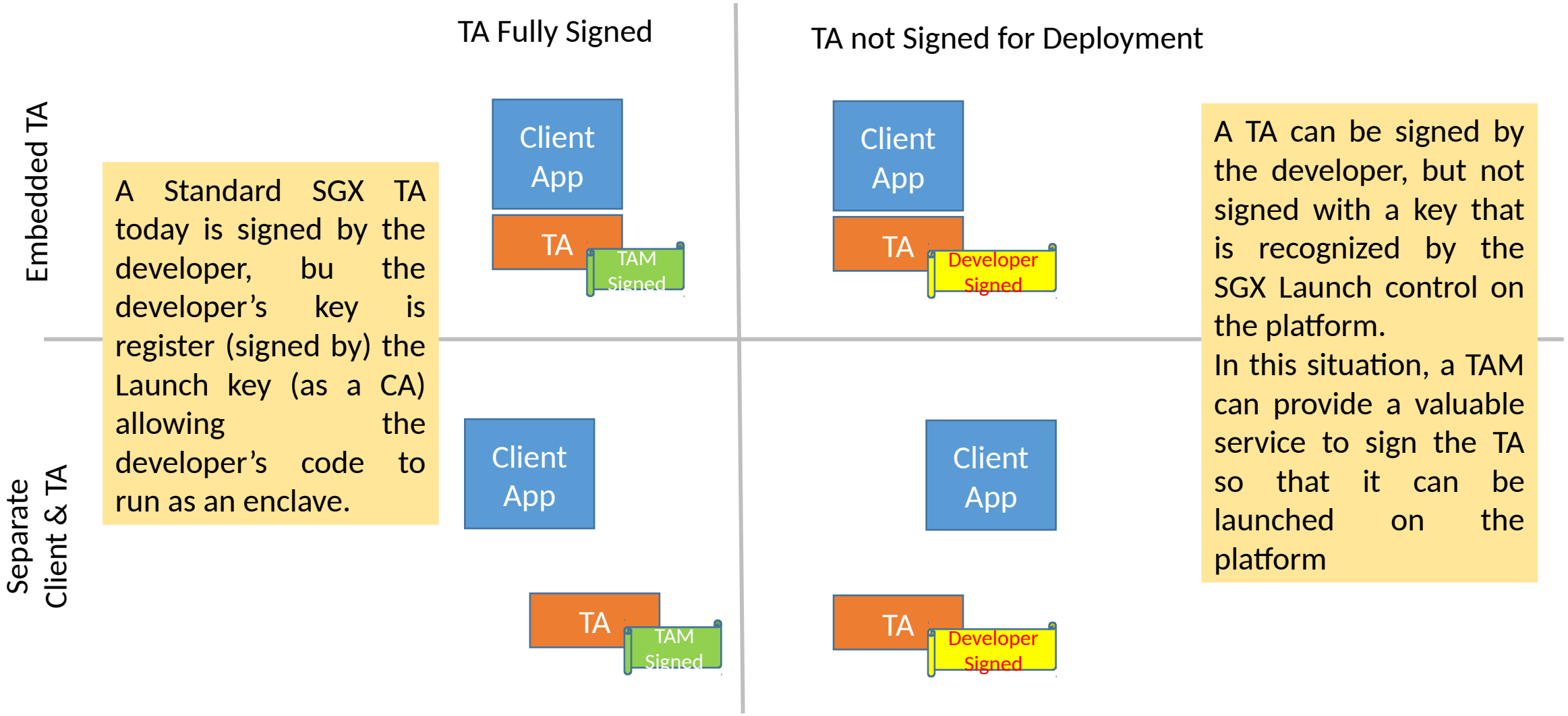
https://www.iad.gov/iad/library/ia-guidance/ia-solutions-for-classified/algorithm-guidance/assets/public/upload/CNSA-Suite-and-Quantum-Computing-FAQ.pdf

- **Minimal to support should be**
  - RSA-3072, RSA-4096, RSA-2048
  - ECDSA using NIST P-384, NIST P-256
  - ECDSA using Ed448-Goldilocks, Ed25519
  - EPID 2.0 Group Signature (Elliptic Curve w/ Bilinear Maps, TCG DAA group signature scheme)
    - Based on ISO Standard – ISO/IEC 20008-2:2013 Information technology -- Security techniques -- Anonymous digital signatures -- Part 2: Mechanisms using a group public key
    - https://software.intel.com/en-us/articles/intel-enhanced-privacy-id-epid-security-technology

What TEEP Services are Relevant to SGX?

- **TEEP on SGX will likely operate much differently than on a TZ platform**
  - The TEEP Agent's counterpart "inside the TEE" will be an enclave just like every other enclave
    - The *TEEP Service Enclave* will perform services as if it were managing the whole TEE
      - But can only manage Enclaves that "cooperate" – have a TEEP Agent Helper library as part of their enclave/App
    - The *TEEP Service Enclave* will provide information on a "best effort" basis – may not know about all enclaves
  - TEEP will only "see" the applications installed/started/stopped through TEEP
- **Get Device State is a "Best Effort" Service**
- **Install/Uninstall a TA is equivalent to same operation on a Client Application**
  - TEEP Agent can report on TAs installed through TEEP, but not on ALL TAs/Applications
  - TEEP Agent cannot prevent TAs / Client Applications from being deleted (Denial of Service)
  - TEEP Agent may not be able to delete / remove a TA (depends on implementation)
- **TEEP Services are Useful in an SGX Environment, but will be limited**

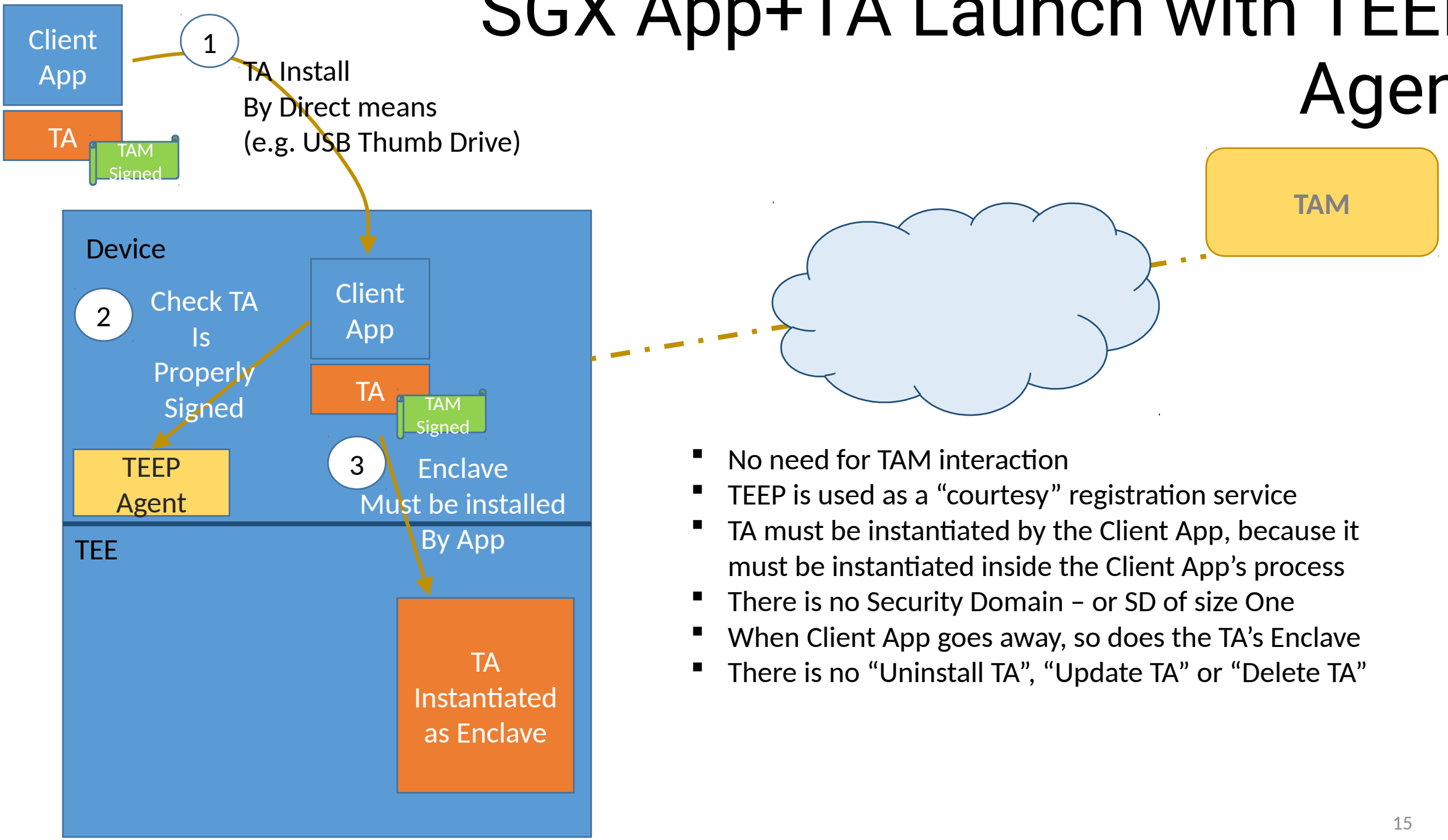
Four Preconditions of App & TA



A Standard SGX TA today is signed by the developer, bu the developer's key is register (signed by) the Launch key (as a CA) allowing the developer's code to run as an enclave.

A TA can be signed by the developer, but not signed with a key that is recognized by the SGX Launch control on the platform.
In this situation, a TAM can provide a valuable service to sign the TA so that it can be launched on the platform

SGX App+TA Launch with TEEP Agent

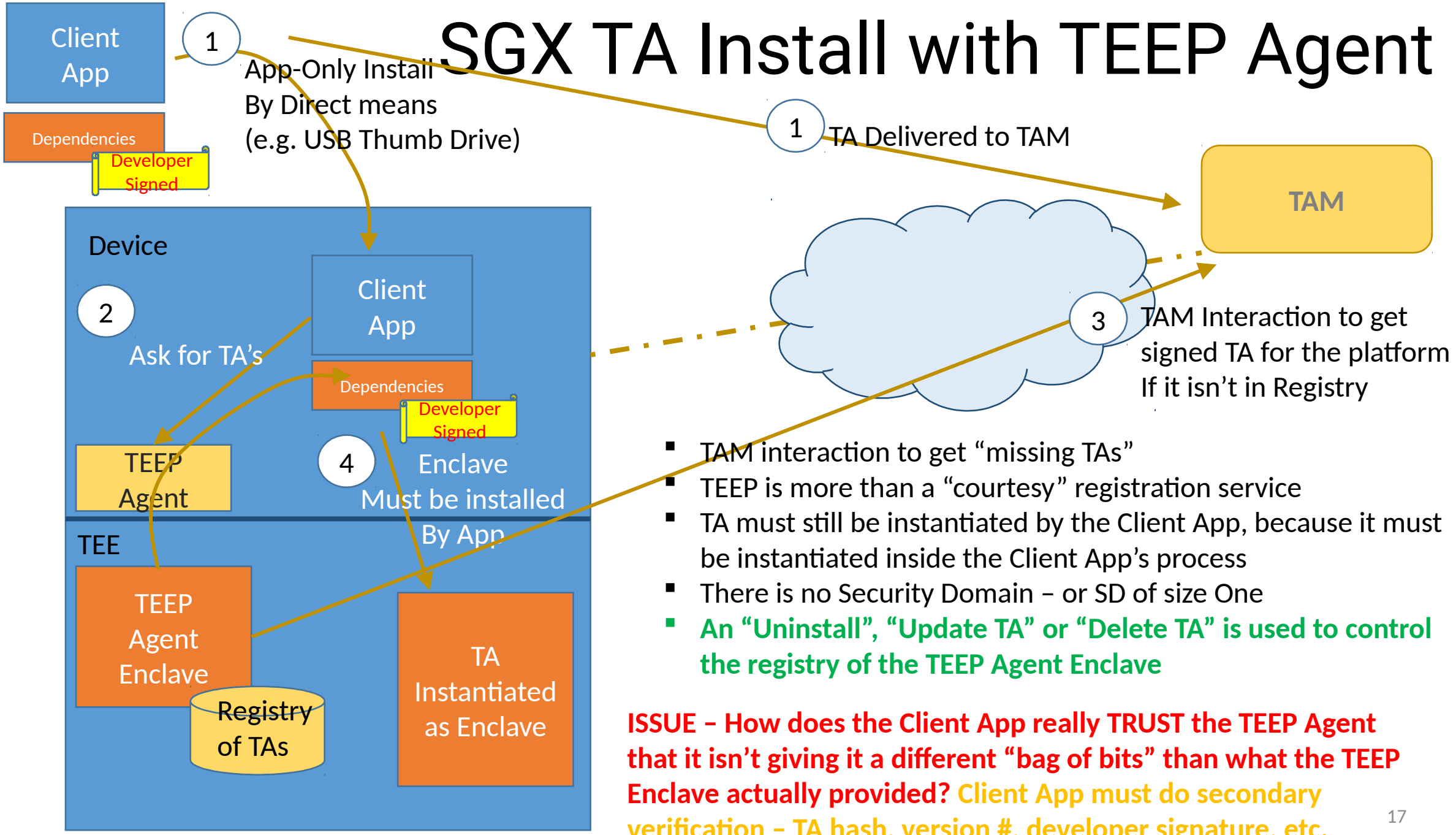


- No need for TAM interaction
- TEEP is used as a “courtesy” registration service
- TA must be instantiated by the Client App, because it must be instantiated inside the Client App’s process
- There is no Security Domain – or SD of size One
- When Client App goes away, so does the TA’s Enclave
- There is no “Uninstall TA”, “Update TA” or “Delete TA”

What if TA's weren't Bound to the Client App

- We could use TEEP for a "TA Registry"
  - Client Apps could "ask for a particular type of TA in the platform's TA registry"
  - But if this done by through an untrusted interface (TEEP Agent on REE side), then how does the App trust this service?
  - Remember, that the Client App must instantiate the TA, so it must be "given a bag of bits"
  - The "bag of bits" must be signed by the TAM, AND is must be verifiable in some other way (hash of the TA, manifest under signature with version #, etc.)

SGX TA Install with TEEP Agent



- TAM interaction to get "missing TAs"
- TEEP is more than a "courtesy" registration service
- TA must still be instantiated by the Client App, because it must be instantiated inside the Client App's process
- There is no Security Domain – or SD of size One
- **An "Uninstall", "Update TA" or "Delete TA" is used to control the registry of the TEEP Agent Enclave**

ISSUE – How does the Client App really TRUST the TEEP Agent that it isn't giving it a different "bag of bits" than what the TEEP Enclave actually provided? Client App must do secondary verification – TA hash, version #, developer signature, etc.

Summary Recommendations for TEEP SGX Support

- TEEP **MUST** support TA delivery within a Client Application
- TEEP **MUST** support EPID Signature Algorithm as Optional
- TEEP **SHOULD** look to support longer key sizes due to Post-Quantum recommendations
- TEEP **SHOULD NOT** require Secure Boot Attestation
  - SBM and TFW are not required of all platforms
  - Attestation Report should be flexible, allowing only required platform-specific elements
- TEEP **SHOULD** further explore the Security Domain Concept and only if valuable and necessary, then develop a crisp definition and model for Security Domains
  - This crisp model should encompass platforms that create SD's of size One
- TEEP **MUST AVOID** definitions of operations that are very platform specific
  - Secure Boot, specific types of reporting, and platform state
  - Some reporting needs to be considered 'Best-Effort' or contain a quality-of-reporting