arm CCA

Arm Confidential Compute Architecture

Placing confidential compute in the hands of every developer

Mark Knight / Gareth Stockwell

Architecture & Technology Group, Arm

October 2021

Arm Confidential Compute Architecture

- Introduced as supplement to Armv9.2-A
- Driven by the expanding need to ensure privacy and security while harnessing data in ever more powerful ways
- Confidential Compute Architecture (Arm CCA) was announced in March 2021 and first specs publicly released in June 2021.
- Arm CCA designed to protect data and code wherever computing happens
- Protects data in-use by preventing privileged access to the resources, whilst retaining the right to manage them

Confidential Compute in Arm

Confidential Computing is the protection of data ***in use,*** by performing computation in a hardware-based secure environment, to shield portions of code and data from access or modification, even from privileged software.

Arm architecture isolation technologies that enable confidential compute

TrustZone®

- Protected from Host OS/Hypervisor
- Platform security use cases for SiP + OEM
- Specific tool chains/Trusted OS
- Limited resource

Virtualization

- Can be used to protect from host primary OS kernel
- Standard OS development
- Limited only by available memory

S-EL2 Virtualization

- Complementary to first two
- Improves modularity and isolation in TrustZone

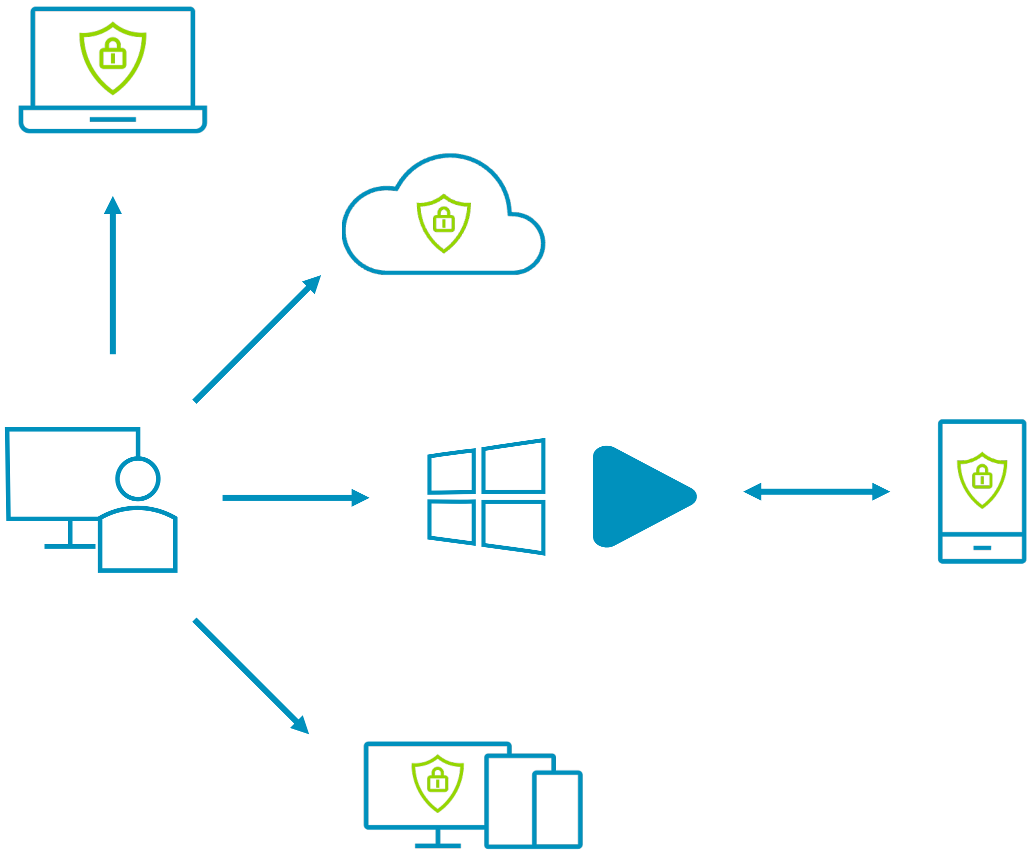
NEW - Arm CCA

- Protects from host OS/Hyp/TrustZone
- Standard OS development
- Limited only by available memory

Confidential compute on Arm happening across the ecosystem

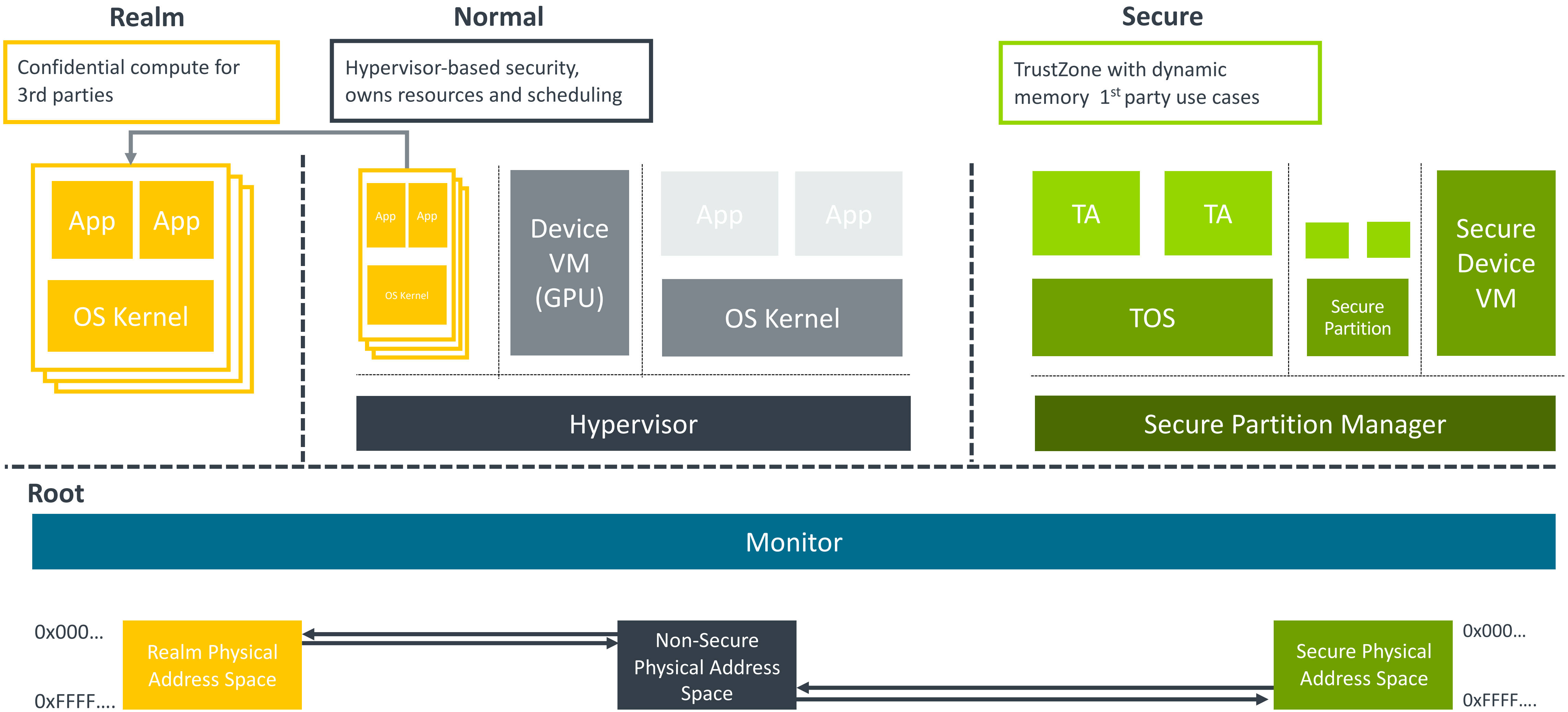
Realms: our vision for confidential compute for every workload

- Offer highly trusted execution environments, "Realms”, in all markets, which can be used by mainstream workloads (apps on operating systems), developed and deployed using standard development environments.
- Remove the need for software workloads to trust their data to a host OS, Hypervisor, or Trusted OS.
- Support attestation so that every owner of a workload can verify trust in the platform or device.
- Democratize secure compute – so every developer can take advantage of it.



Developers can deploy Arm CCA to any device

Overview of Arm CCA



Arm CCA threat model

Confidentiality	Mitigated by
Hypervisor/Kernel/Secure world reads private Realm memory or register state	Arch
Device DMA reads private Realm memory or register state	
Integrity	
Hypervisor/Kernel/Secure world modifies private Realm memory or register state Examples: • Modify saved context • Writing to Realm pages • Memory remapping or aliasing	Arch
Device DMA modifies private Realm memory or register state	Arch
Availability	
Denial of service to a Realm – it is scheduled by OS/Hyp	
Realm mounts a DoS attack on the hypervisor	Arch

Indirect SW attacks	Mitigated by
Known SW error injection – E.g.: Rowhammer, CLKSCREW	Arch, Realm
Known side channels E.g.: Spectre / Meltdown	Arch, Realm
Direct HW attacks	
Physical DRAM probe and replay	HW

Arch — Mitigated by Arm CCA (processor/SMMU/system and FW)

HW — Mitigation requires additional HW

Realm — SW in the Realm has the tools to protect itself

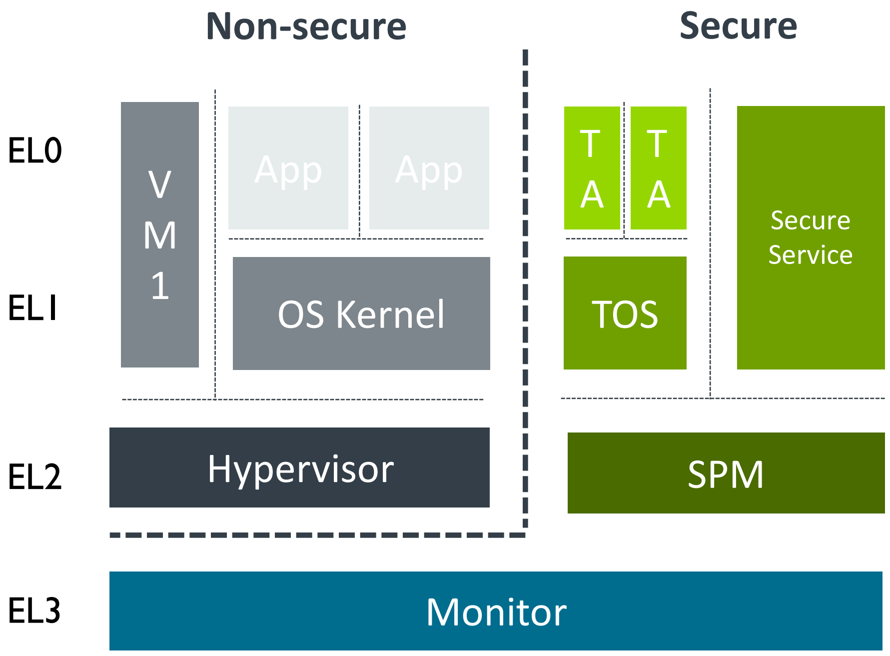
Not mitigated

TrustZone in Armv8.4-A

Two security states: Secure, Non-Secure

Two isolation mechanisms:

1. TrustZone isolation boundaries prevent Non-Secure state from accessing Secure physical addresses
2. Page tables - stage 2 isolation boundaries



Security State/PA space	Non-Secure PA	Secure PA
Non-secure	Allow	Block
Secure	Allow	Allow

Arm CCA hardware features

Two new hardware features in the Realm Management Extension (RME)

New isolation boundaries for 3rd party confidential computing

- Realms: New type of protected execution environment

- Data and/or code are protected from any other execution environments:
  - Hypervisors
  - OS Kernels
  - Other Realms
  - Even TrustZone

Dynamic assignment of memory to physical address spaces / worlds

- Supports Realms **AND** adds dynamic memory support to TrustZone

  - Arm dynamic TrustZone technology
  - Removes boot-time static memory carve-outs

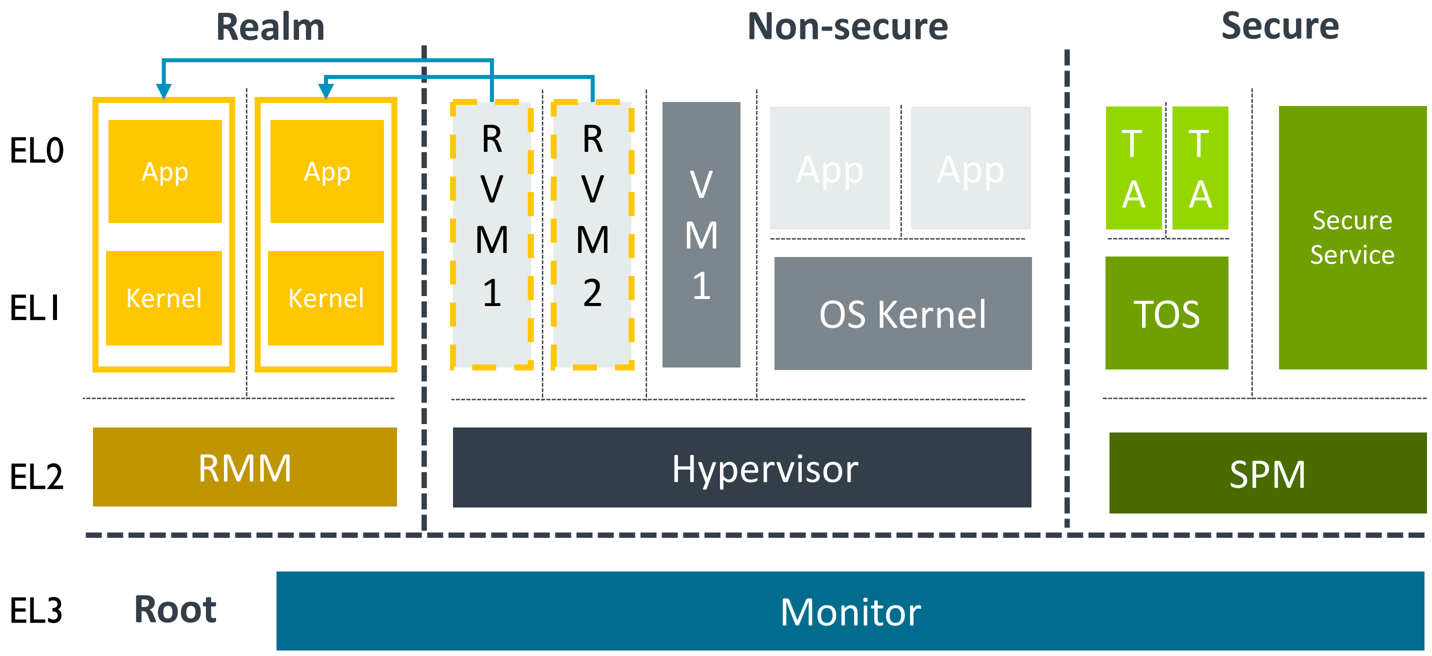
Arm CCA hardware architecture

RME adds another two security states and associated physical address spaces

- Realm: A new mutually distrusting space for confidential compute
- Root: The Monitor gets its own private address space

HW isolation between address spaces is managed through a new Granule Protection Table (GPT), an extension of MMU page tables that is controlled by the Monitor in EL3

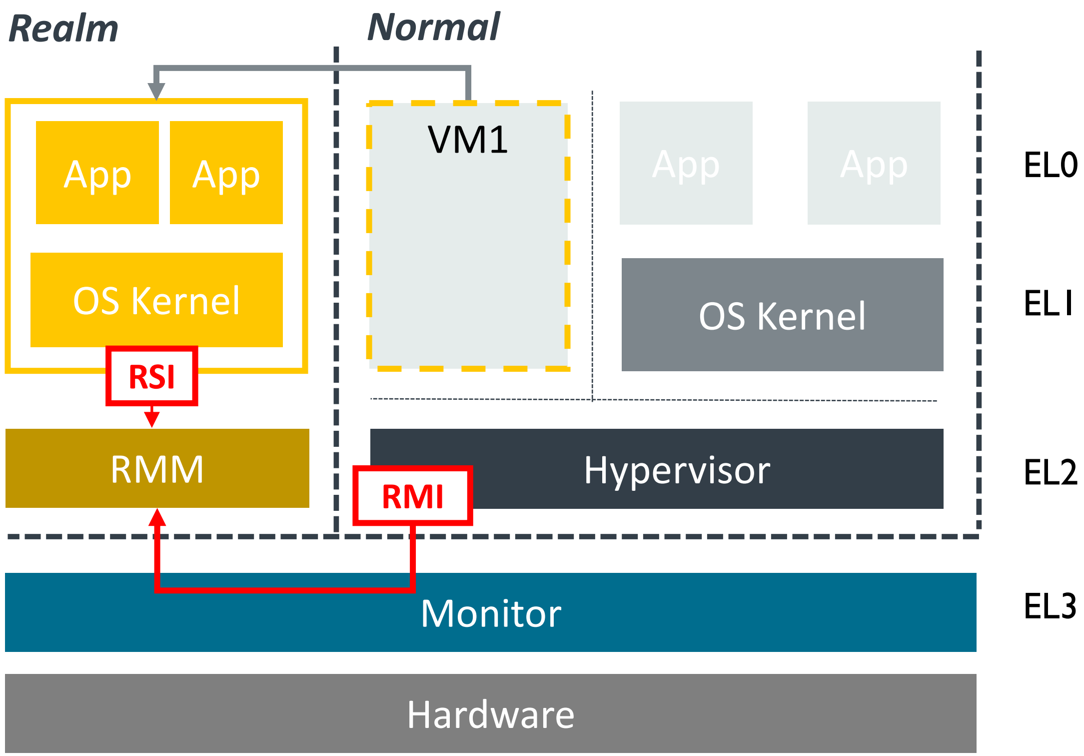
- Invalid accesses raise page faults



Security State/PA space	Non-Secure PA	Secure PA	Realm PA	Root PA
Non-secure	Allow	Block	Block	Block
Secure	Allow	Allow	Block	Block
Realm	Allow	Block	Allow	Block
Root	Allow	Allow	Allow	Allow

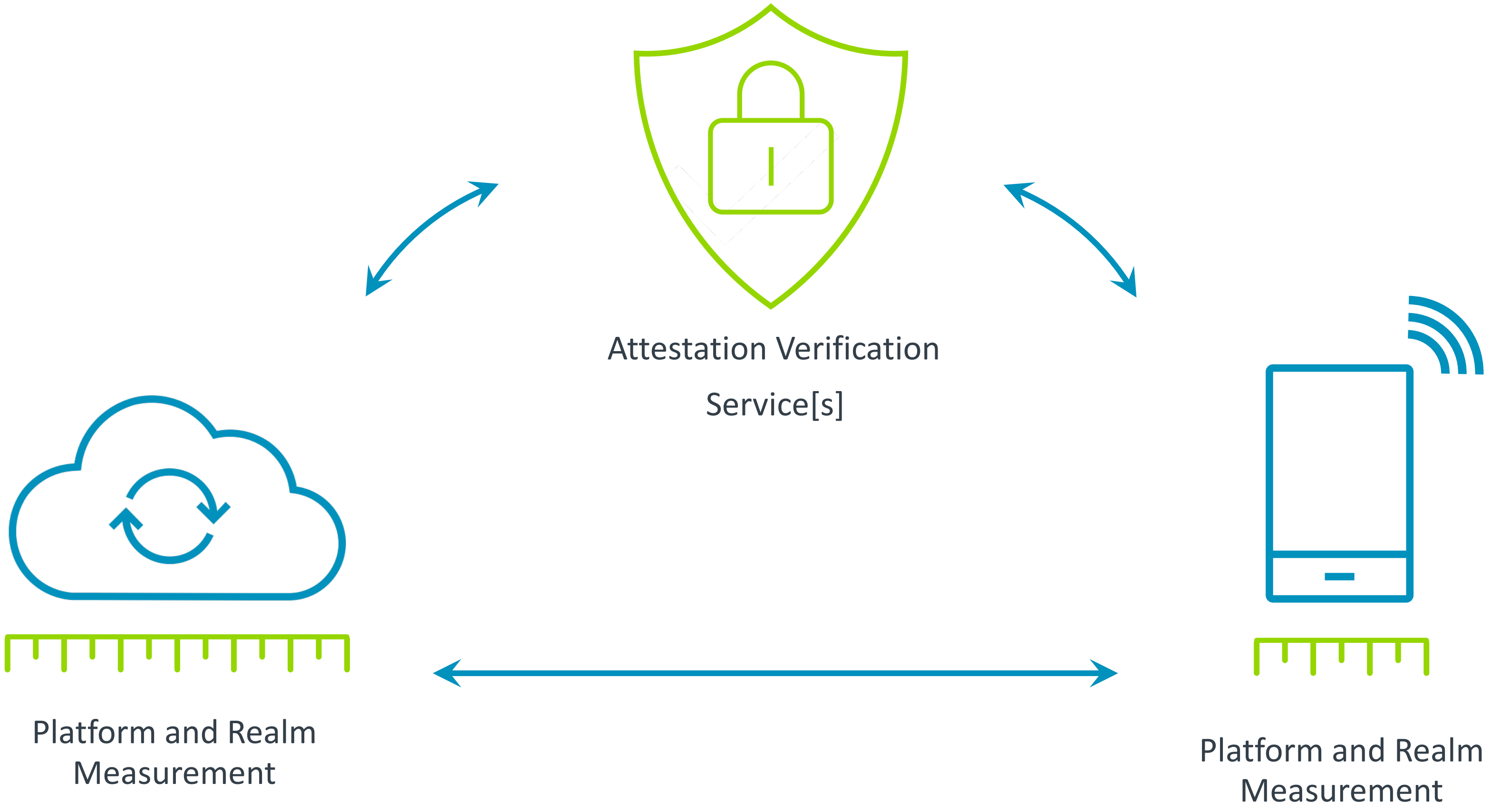
Arm CCA is a combination of hardware and firmware

- Use of firmware (RMM and Monitor) simplifies hardware and increases transparency
- Firmware components manage isolation hardware
- The Monitor controls isolation between worlds by programming the Granule Protection Table
- The Realm Management Monitor (RMM)
  - Manages Realm-to-Realm protection using stage 2 page tables
  - Enables Host to manage Realms (create; destroy; schedule; add / remove memory) via the Realm Management Interface (RMI)
  - Enables Realm to request attestation report via the Realm Services Interface (RSI)
- Arm will provide reference implementations of Monitor and RMM



Arm CCA supports attestation

Assuring data is protected; assuring that data and transactions can be trusted



Hardware-backed isolation for all workloads

Mobile / PC / DTV

- Social Media
- Email
- Browsing
- Content Protection
- OS Services
- Enterprise Apps
- Health / Fitness Apps

IoT

- Machine Learning
- Ambient Compute

Cloud

- Tenant 1
- Tenant n

Edge Compute

- Machine Learning
- Multi-Vendor Environment

Automotive

- OEM Apps
- Personal Data
- Autonomous Driving
- Content Protection

High end Wearables

- Health
- SmartKey
- Fitness
- Medical

Arm CCA – developer resources available now

See https://developer.arm.com/armcca

- Tools
  - Register XML
  - AC6 EAC asm/disasm support for RME complete
  - GNU Binutils available and upstreaming complete

- Reference manual supplements
  - RME Architecture (ARM DDI 0615A.a)
  - SMMU for RME (ARM IHI 0094A.a)
  - MPAM (ARM DDI 0598C.a)

- Platform design documents released June 2021
  - Security Model (DEN0096)
  - RME System Architecture (DEN0129)

- Guides
  - Overview of the Arm CCA (DEN0125)
  - Arm Realm Management Extension (DEN0126)
  - Arm Confidential Compute Software Stack (DEN0127)

- Open Source Implementations
  - TF-A Monitor code branch released June
  - Project Veraison: Software for attestation services

- FVP model with RME support is available
- Blogs on Arm CCA and dynamic TrustZone Technology
- Videos from June Linaro event
  - https://connect.linaro.org/resources/arm-cca/

Arm CCA – what's next

Architecture updates planned for 2022

Software Architecture

- Realm Management Monitor specification under development

Device Assignment

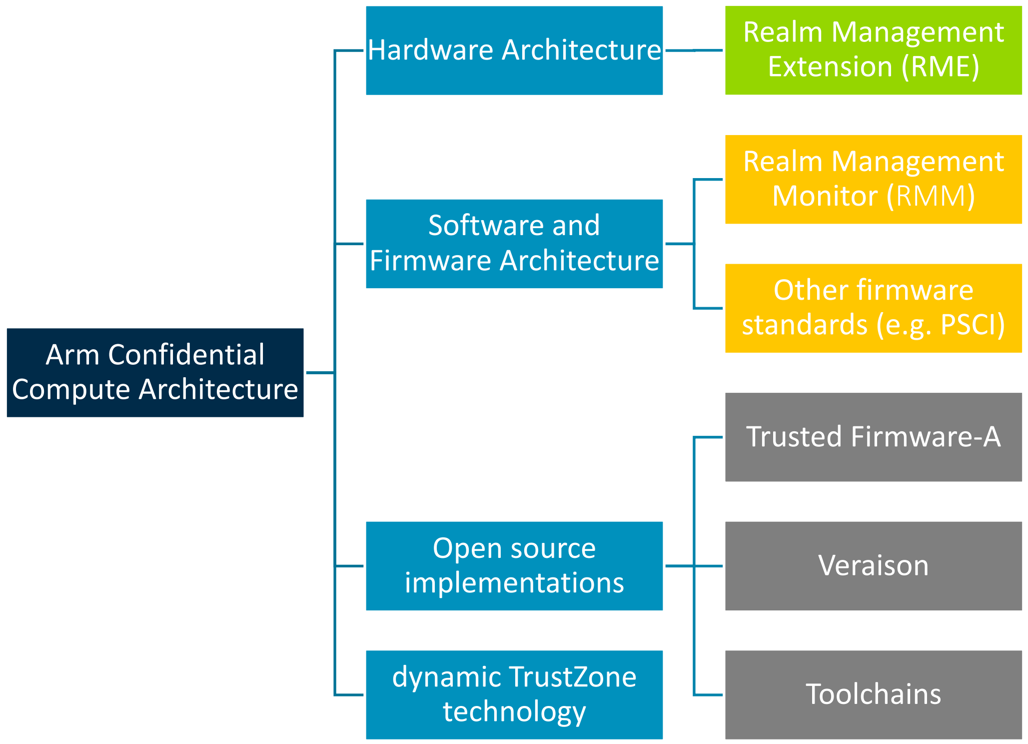
- Device assignment will allow hardware devices to be mapped to Realms
- Focused on the use of accelerators from Realms
- Dependency on an SMMU
- No device may access the memory of a Realm unless the Realm has accepted the device

Memory Encryption Contexts

- Per-Realm encryption key (or tweak)
- Mitigates physical memory replay attacks between Realms
- Defence in depth against attacks on Realm stage-2 translation

Summary

- Security at scale for all classes of device and all workloads – Confidential Compute everywhere
- Simplifying and democratizing the process for every developer
- Continually improving security – Arm CCA builds on earlier innovations in isolation technology
- Hardware specs released publicly June 2021, software specs being developed for publication in 2022
- Start of a journey with the software and toolchain communities



Thank You
Danke
Gracias
谢谢
ありがとう
Asante
Merci
감사합니다
धन्यवाद
Kiitos
شكرًا
ধন্যবাদ
תודה