Spotlight on TCG Technologies in Use

Strong Device Identity in the IoT

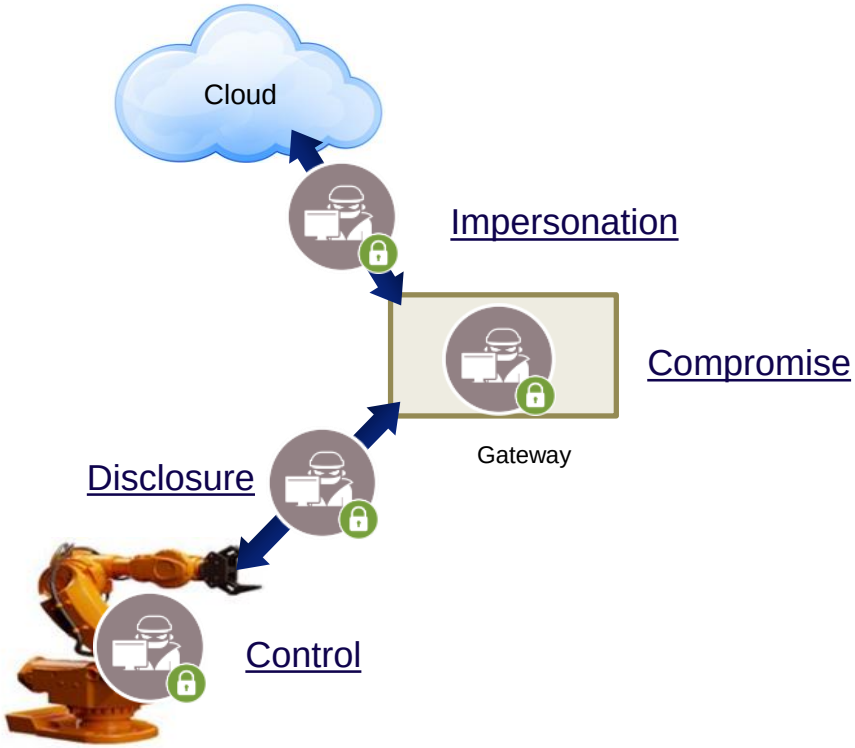
Yasuyuki Inui, GMO GlobalSign

Overview of GlobalSign

GlobalSign uses its managed PKI & IAM experience and technology to build high-volume, high-scale identity management solutions for the billions of devices, people and things comprising the Internet of Everything.

- The world's largest pure-play CA
- More than 350 employees distributed in over 15 countries
- More than 5000 Global partners and over 30000 global customers
- More than 10 million identities issued
- 3 Billion OCSP responses delivered daily

lot of risks



Moving towards Higher Assurance Security

- No Identity authentication for Endpoint
- Gateway authentication for Endpoint using ID/Password
- 2-way authentication using mutual TLS
- Strong authentication using Software TPM for key storage
- Strong authentication using Hardware TPM for key storage

Less Secure

More Secure

PKI /TPM

PKI is a tried and true standard that has been securing machines and devices for decades

PKI

InfoSec “Swiss army knife” - enables a range of information security principles essential to any IIoT product or ecosystem

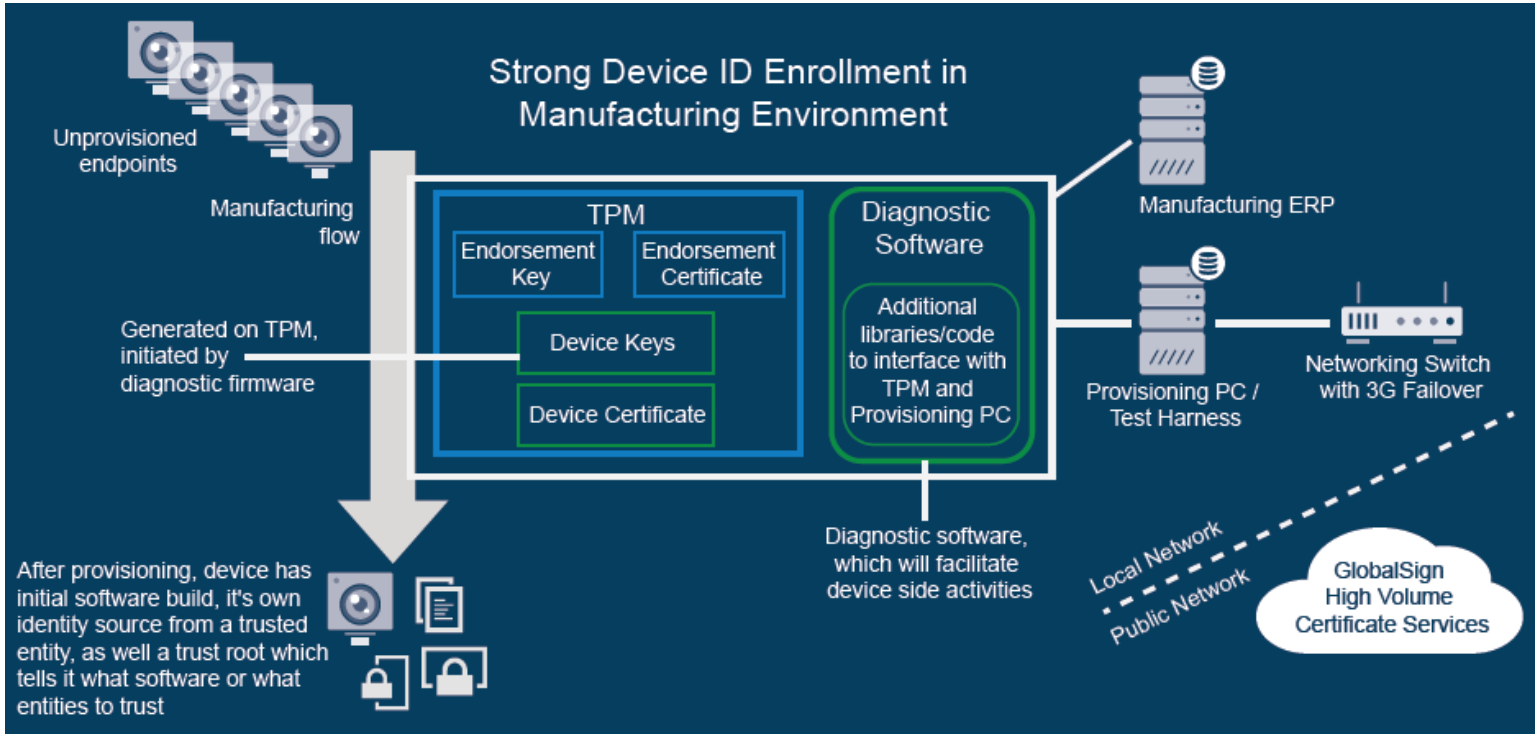
Authentication – Encryption – Data Integrity

TPMs

Ideal for increasing assurance around the integrity and uniqueness of device identity

Security focused crypto-processors, like TPMs, provide strong hardware-based protection of the device's private keys from compromise and unauthorized export

Demo



Windows 10

Device Health Attestation (DHA)

Gabe Stocco (gastoco@microsoft.com)

Program Manager

Microsoft OSG, Enterprise and Security R&D

Windows 10 Device Health Attestation (DHA)

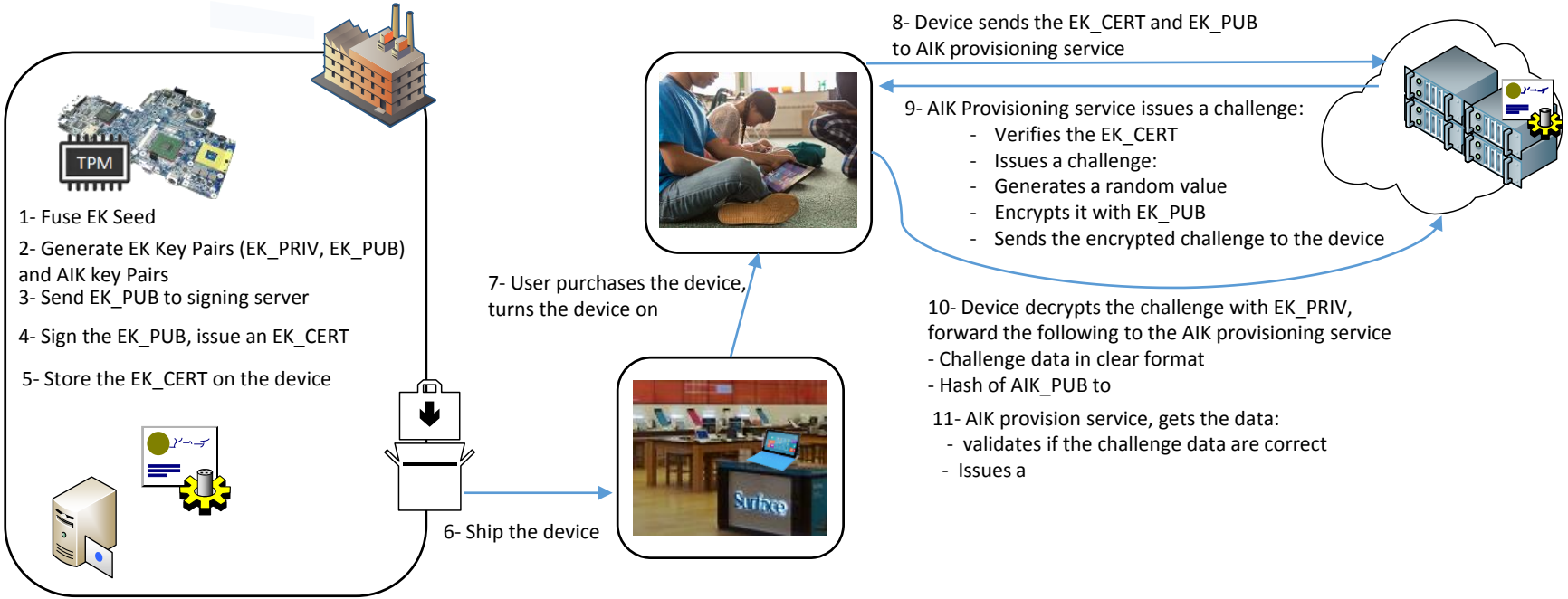
Device Health Attestation (DHA)

- Collects and Provides attested boot state information
- Establishes Attested Link with MDM
- Validates System is in same boot
- Provides a mechanism for remote conditional access based on Device Health

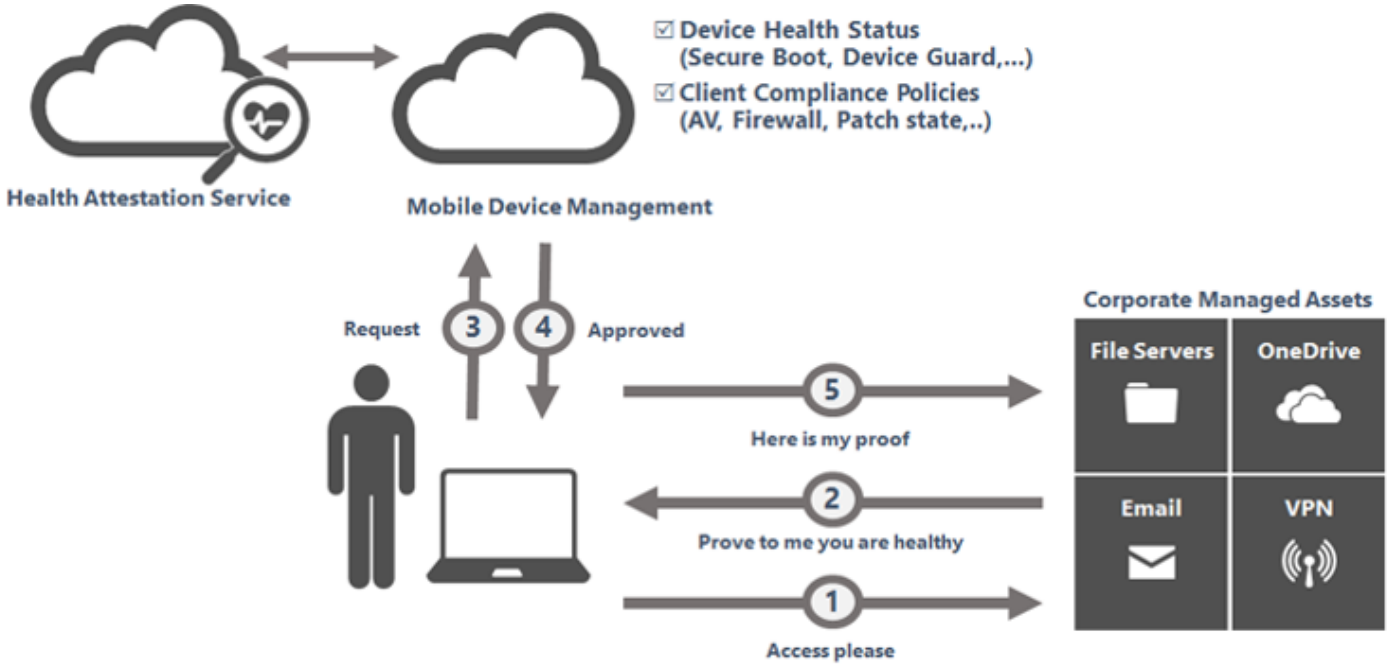
Windows 10 Device Health Attestation (DHA)

- Enroll for AIK Certificate
  - Optional with On-Premises Health Attestation
- Enroll with MDM
- Provide Health Quote to HAS
- Validate Health with MDM
- Request Access to Resources

Obtain AIK Certificate

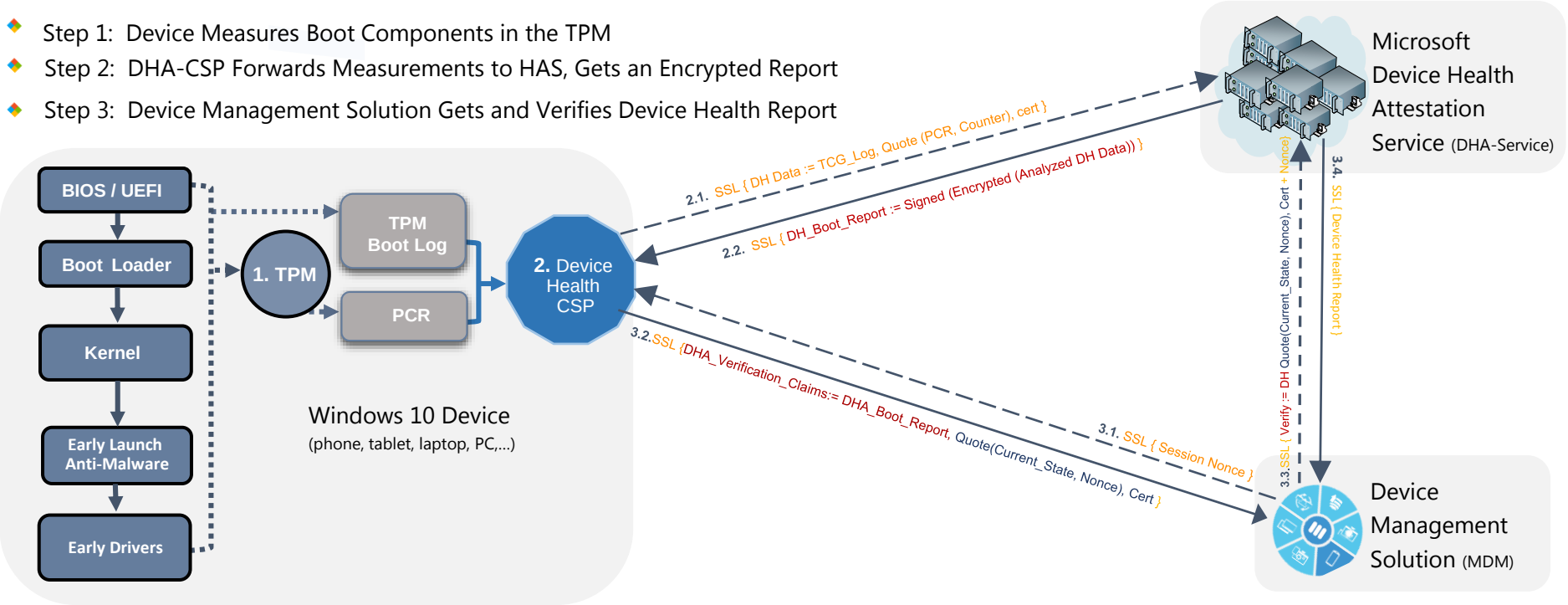


High Level HAS Flow



Detailed HAS Flow

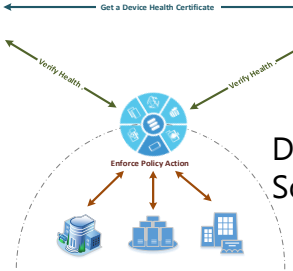
- Step 1: Device Measures Boot Components in the TPM
- Step 2: DHA-CSP Forwards Measurements to HAS, Gets an Encrypted Report
- Step 3: Device Management Solution Gets and Verifies Device Health Report



Windows 10 Mobile Device Management (MDM) options

Windows 10
TPM enabled devices

Device Health Attestation
Service (HAS) options



Device Management
Solution (MDM) options

- **Microsoft Cloud**: ready now
- **On-Prem (2016 Server)**:
- 1st and 3rd party **On-Prem** and **Cloud** MDM solutions

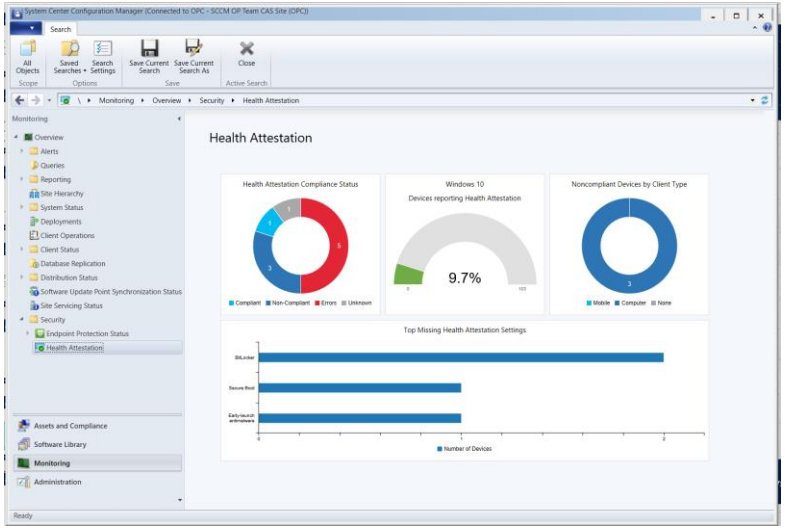
Windows 10 Device Health Attestation (DHA)

Sample data points that is evaluated/reported by HAS

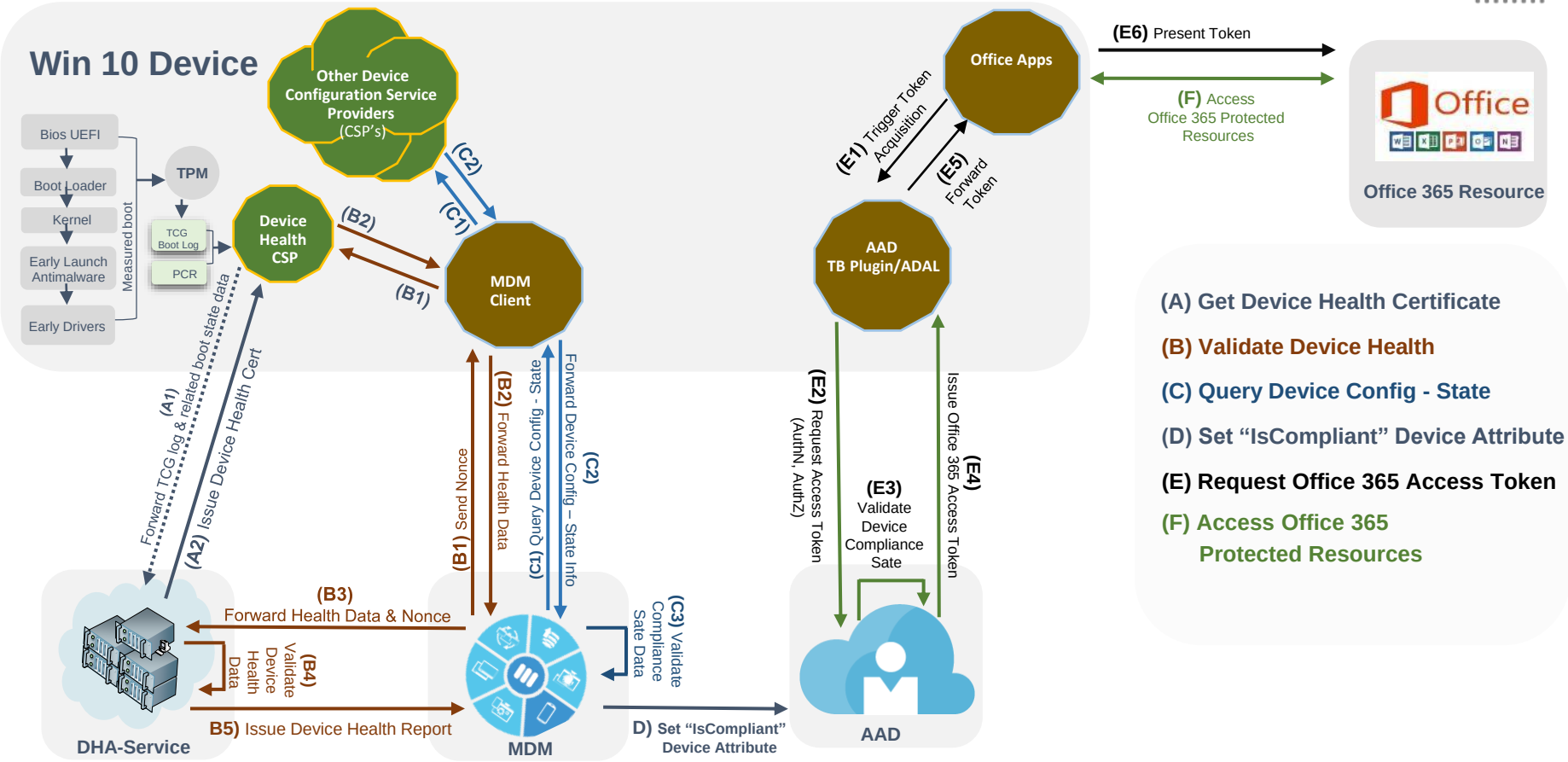
- BitlockerStatus
- SecureBootEnabled
- CodeIntegrityEnabled
- ELAMDriverLoaded
- VSMEnabled
- CIPolicyHash
- SBCPPolicyHash
- DEPPolicy State
- SafeMode
- WinPE
- BootDebuggingEanabled
- OSKernelDebuggingEnabled
- TestSigningEnabled
- AIKCertPresent
- Value of PCR 0
- Reset Count (Hibernation)
- Restart Count (Boot/reboot)
- And more ….

Compliance Monitoring Example

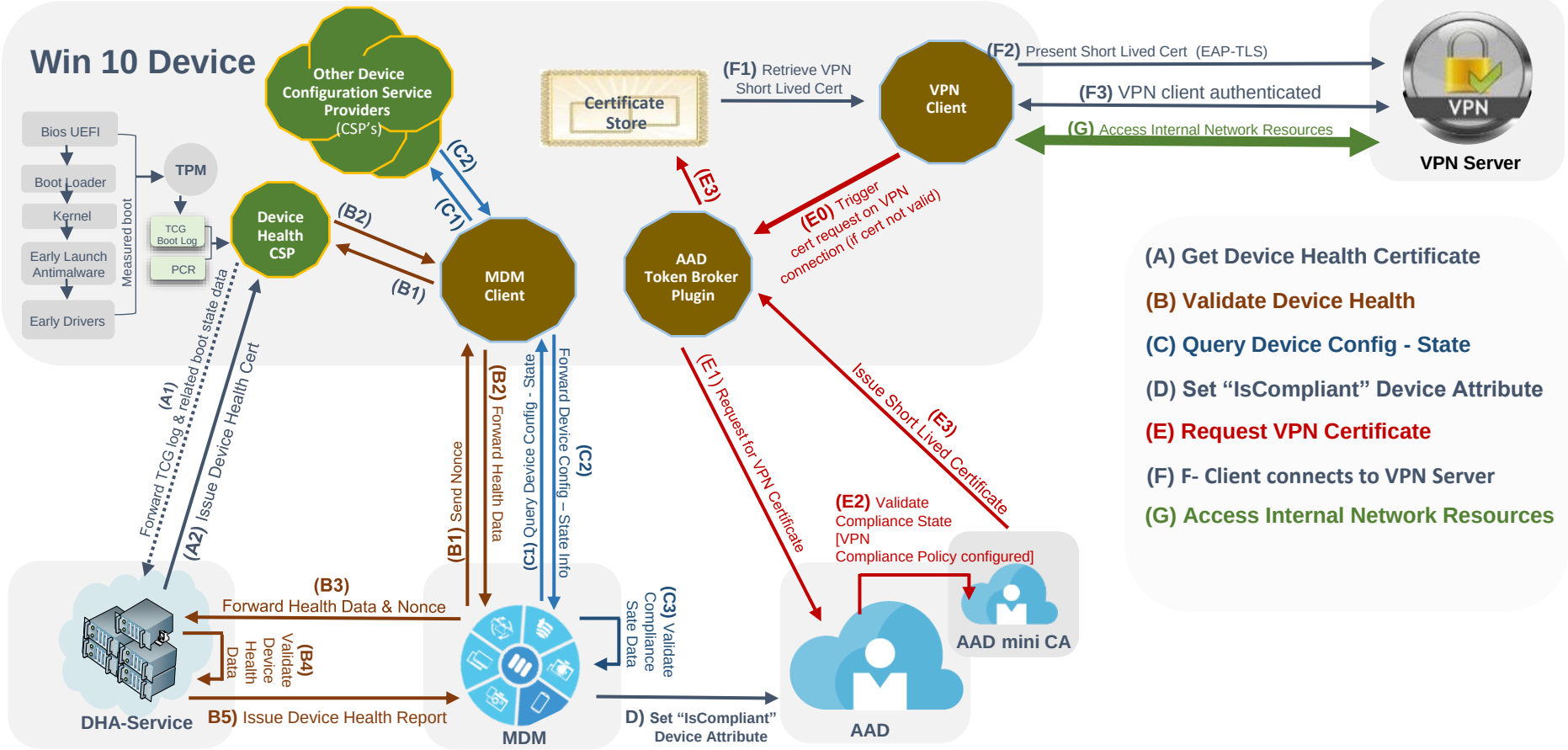
Compliance monitoring example: SCCM



Conditional Access – O365



Conditional Access – VPN



Thank You !

Microsoft

Additional Resources

https://technet.microsoft.com/en-us/itpro/windows/keep-secure/protect-high-value-assets-by-controlling-the-health-of-windows-10-based-devices
https://msdn.microsoft.com/en-us/library/windows/hardware/dn934876(v=vs.85).aspx
https://technet.microsoft.com/en-us/library/mt750346.aspx

Device Identifier Composition Engine Prototype

Stefan Thom

Rob Spiger

TRUSTED COMPUTING GROUP®

Device Identifier Composition Engine (DICE)

- New specification development in the TCG Root of Trust for Measurement sub-workgroup (under the Embedded Systems WG)
- Use: Provide a way to know the first mutable code running on a platform
  - Helpful when patches need to be deployed and their installation verified
  - Can help re-establish trust in a platform after a vulnerability has been discovered

Device Identifier Composition Engine (DICE)

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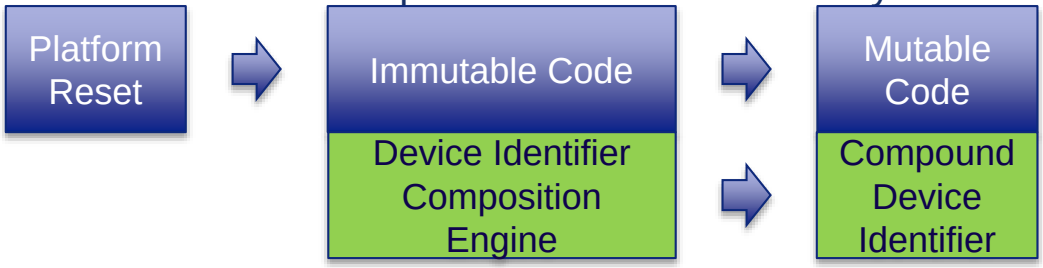
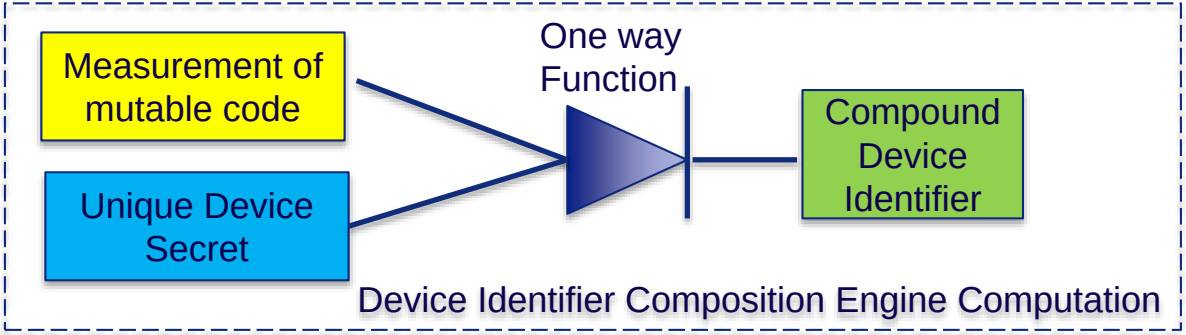


- The Compound Device Identifier is unique to the device and reflects the first mutable code that runs on the platform

Generating the Compound Device Identifier

- DICE computes the Compound Device Identifier:



- Example: Compound Device Identifier =
  Hash(Mutable Code Measurement || Device Secret)
- Immutable code passes the Compound Device Identifier to the first mutable code
- Immutable code has access to the Unique Device Secret, but the mutable code does

The 3 Dice Platform Requirements

- Immutable device initialization code, ideally ROM or one-time programmable
- Unique device identity of at least 128bit, ideally one-time programmable
- Device Identity lockout mechanism that resets only with the entire platform

What the STM32L082KZ offers for DICE

- Ultra low cost and low power Cortex-M0+ @32MHz
- 192kB Flash storage, that can be permanently write locked in parts
- 6kB EEPROM for configuration/data storage
- 20kB RAM
- AES-128 hardware engine with DMA support
- True hardware RNG
- Chrystal-less USB 2.0 hardware support
- Memory Firewall support
- Official price ~$1.89 @10K

How is DICE implemented here?

- The ST Firewall functionality is significant more powerful than we need for DICE and is wasting most of this powerful functionality, that actually should be available for the application itself
- The hardware AES-128 engine is used to calculate CMACs as 128bit *digests*, however a SHA2 hardware engine with 256bit digests would be preferable. The following algorithm substitutions are applied, where the resulting encrypted data is discarded, with the obvious restrictions on operator sizes for the AES algorithm:

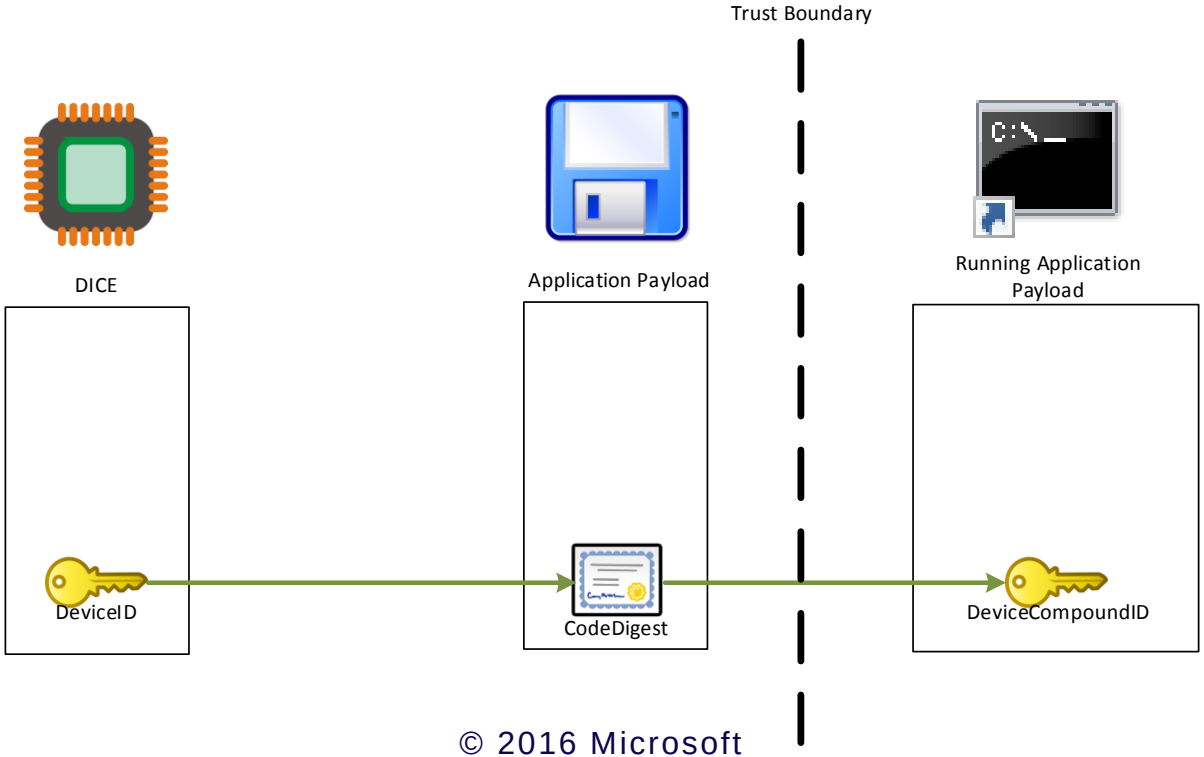
  Digest=KeyedHash(KeyIn, DataToHash) →
  Digest = IV_{OUT} after $AES128\text{-}CBC_{Encrypt}(IV_{IN}=0, Key=KeyIn, Data=DataToHash)$

  Digest=HASH(DataToHash) →
  Digest = IV_{OUT} after $AES128\text{-}CBC_{Encrypt}(IV_{IN}=0, Key=DataToHash, Data=0)$
- The device can be fully locked down by permanently disabling hardware debugging and blowing the read-only fuses for the flash memory hosting the DICE code and Device Identity – making the DICE code immutable

What is this demo going to show

- The simple DICE *functional concept* that the immutable boot code is the sole consumer of a persistently stored identity value. This demo does not necessarily use the most simple implementation to do that
- The device is using the USB Device Firmware Update profile (DFU) to permit a standardized one-time Identity provisioning and a many-time application payload upgrade process
- A glimpse how the device and compound identities of the factory and software release process can be secured with a TPM 2.0 (on a server in the manufacturer's environment) and therefore enforce key distribution policies
- While DICE only knows one Device Identity that is extended with the Code Identity to derive the compound identity, this demo explores some additional identities which are derived in different ways to anticipate customers desired scenarios and provide more flexibility

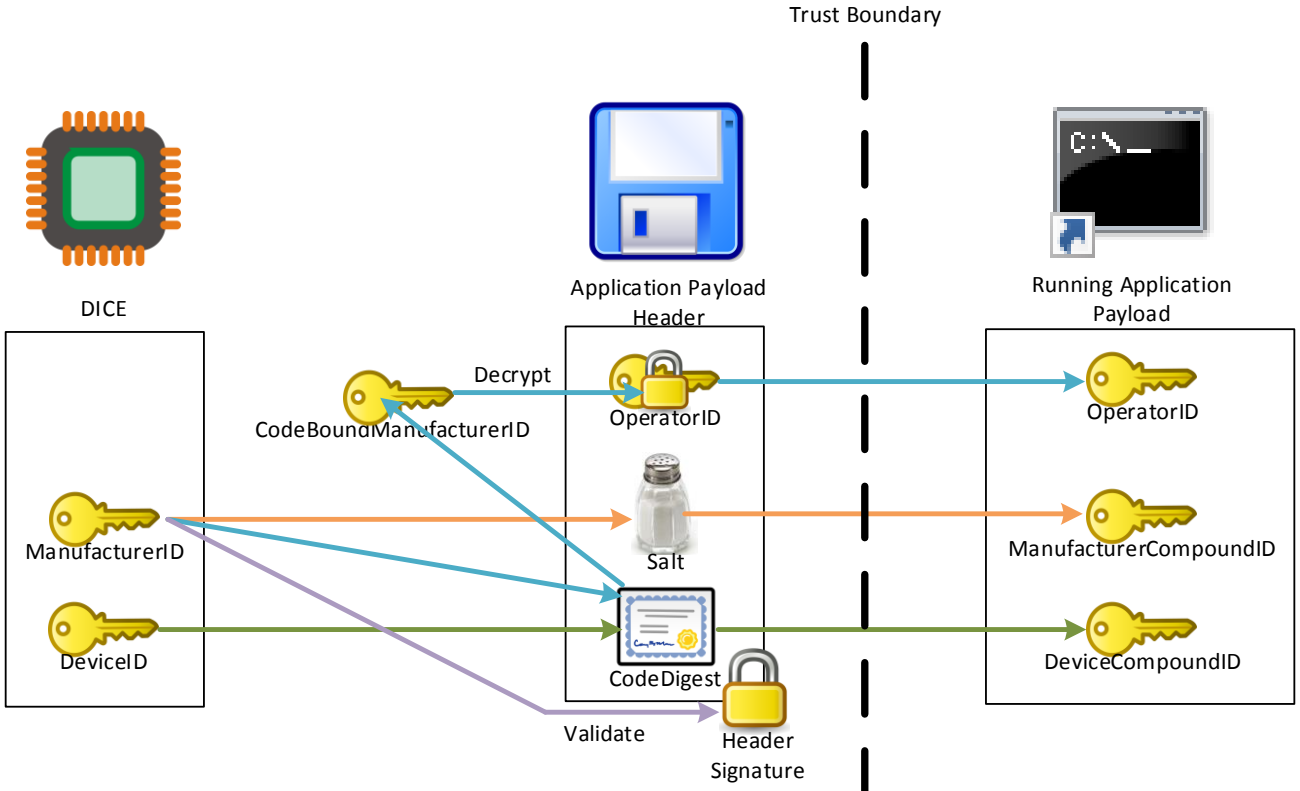
Identity Derivation Overview



The Main Scenario: The Device Identity

1. Every device is provisioned with a unique DeviceRootIdentity
2. This DeviceRootIdentity is derived into the public DeviceRootName for external identification purposes:
   DeviceRootName = HASH(DeviceRootIdentity)
3. With the ApplicationPayload the DeviceCompoundIdentity is derived in the form:
   DeviceCompoundIdentity = KeyedHash(DeviceRootIdentity, ApplicationPayload)
4. And finally the public DeviceCompoundName again for identification purposes as:
   DeviceCompoundName = HASH(DeviceCompoundIdentity)

Expanded Identity Derivation Overview



Expanded Scenario 1: The Manufacturer Identity

1. At DeviceIdentity Provisioning time the manufacturer may also provision a common ManufacturerRootIdentity that is shared between all devices of a class. This root identity is treated in the same way as the unique DeviceRootIdentity and inaccessible when the application is running
2. In that case, the ApplicationPayload header has to be signed with that identity for the device to accept it – implementing a form of authenticated boot
3. The ApplicationPayload header contains a public salt value that is used to derive a specific shared identity between all sibling devices:
   *ManufacturerCompoundIdentity = KeyedHash(*ManufacturerRootIdentity*, HeaderSalt)*

   ManufacturerCompoundName = HASH(ManufacturerCompoundIdentity)
4. It is in the discretion of the Manufacturer to roll that salt value, because it may remain the same for several firmware releases until he has identified a security relevant issue that needs to break the forward migration of this identity

Expanded Scenario 2: The Operator Identity

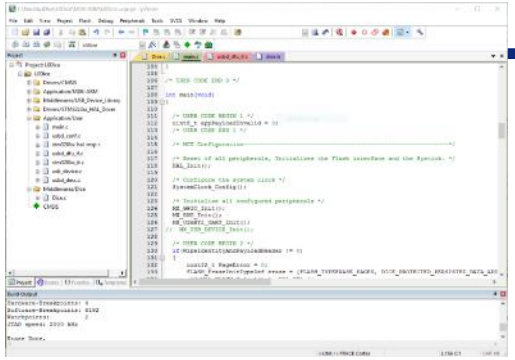
1. A device manufacturer may provide his device to multiple operators that need to run isolated from each other, while they share the same ManufacturerIdentity derived subsequent identities from that family, the operator wants to make sure that devices deployed in his realm are not compromised by identical devices running with different operators
2. For that purpose the operator has his own identity that has to be provided securely to the ApplicationPayload without recompiling the payload itself or needing to specify that identity at the initial provisioning time
3. The manufacturer will derive a manufacturer specific code identity that is the same on all devices with the same ApplicationPayload and then encrypt the operator identity and insert that value into the signed application payload header:
   *ManufacturerCompoundCodeIdentity = KeyedHash(*ManufacturerRootIdentity, *ApplicationPayload)*

   EncryptedOperatorIdentity = AES128CBC$_{Encrypt}$*(IV=0, ManufacturerCompoundCodeIdentity, OperatorIdentity)*
4. Since the encrypted value is covered by the application payload header signature it may not be arbitrarily changed after signing and the manufacturer can calculate a specific encrypted Operator identity for all operators he works with and issuing a customized firmware to them for deployment. This mechanism even permits the manufacturer to prevent an operator to consume a particular firmware version, because if without the explicit code bound encryption that device would not have that identity available.

Now to the actual Demo…

1. The Factory programs the DICE bootloader and provisions the DeviceID and the ManufacturerID
2. The Application Developer creates the application payload and provides to the manufacturer
3. The Manufacturer encrypts the OperatorID and the completes the application payload header and signs it
4. The Operator (or his customers) receive the device and program the firmware package
5. For application payload update process continue at 2.

The Factory programs the DICE bootloader

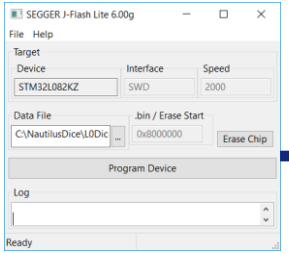


Keil uVision

Compile

L0Dice.hex

Load



Flash Programmer

Write

STM32L082KZ

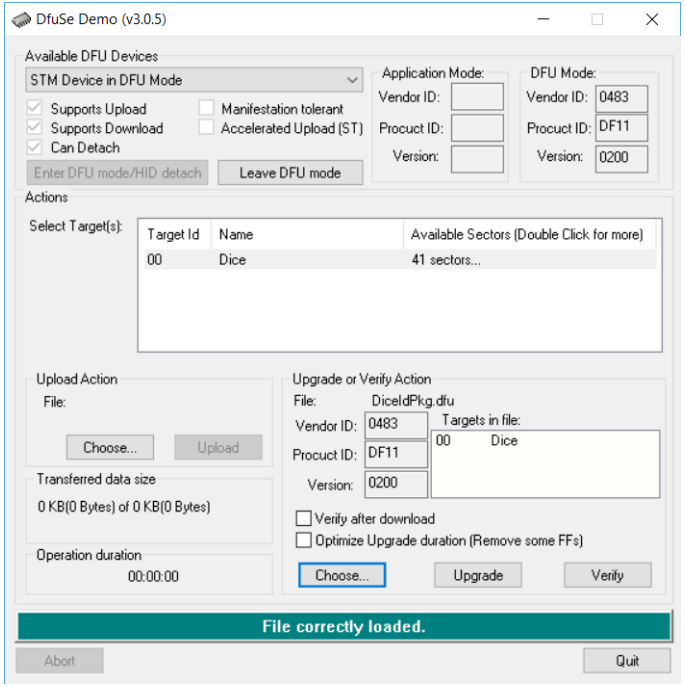
The Factory creates an identity package

Administrator: Command Prompt

```
C:\NautilusDice>Manufacture\DicePrep.exe CDP 0123456789abcdef0123456789abcdef 00112233445566778899aabbccddeeff
Storage Prefix: Manufacture\
---- ProtectedData ----------------------------------------------
Tag:            DICE
Size:           256
Version:        0.1
Date:           2016.8.30-16:56:10
Model:          Nautilus-STM32L082KZ
Serial:         SN12345678
Manufacturer:   StefanTh@Microsoft.com
URL:            http://WindowsOnDevices.com
---- Identities & Names -----------------------------------------
DeviceID:                   PROVISIONED
DeviceRootName[16]:         79abc5c23868ad84d388ce61110a6274
ManufacturerID:             LOCKED
ManufacturerRootName[16]:   fde4fbae4a09e020eff722969f83832b
AppStrongName:              UNLOCKED
-----------------------------------------------------------------

C:\NautilusDice>dir Manufacture
 Volume in drive C has no label.
 Volume Serial Number is 8E71-83D9

 Directory of C:\NautilusDice\Manufacture

08/30/16  09:56    <DIR>          .
08/30/16  09:56    <DIR>          ..
08/30/16  09:56               164 79abc5c23868ad84d388ce61110a6274.TPMKEY
08/30/16  09:56               565 DiceIdPkg.dfu
07/06/16  03:09            35,328 DicePrep.exe
08/30/16  09:56               164 fde4fbae4a09e020eff722969f83832b.TPMKEY
08/30/16  09:55            16,384 NVChip
12/01/15  13:11           518,344 Simulator.exe
06/29/16  03:37           289,280 STDFU.dll
06/29/16  03:37            60,928 STDFUFiles.dll
06/29/16  03:38            64,000 STDFUPRT.dll
06/29/16  03:37            51,712 STTubeDevice30.dll
07/05/16  11:57         2,408,960 TSS.CPP.dll
              11 File(s)      3,445,829 bytes
               2 Dir(s)  47,379,124,224 bytes free

C:\NautilusDice>
```

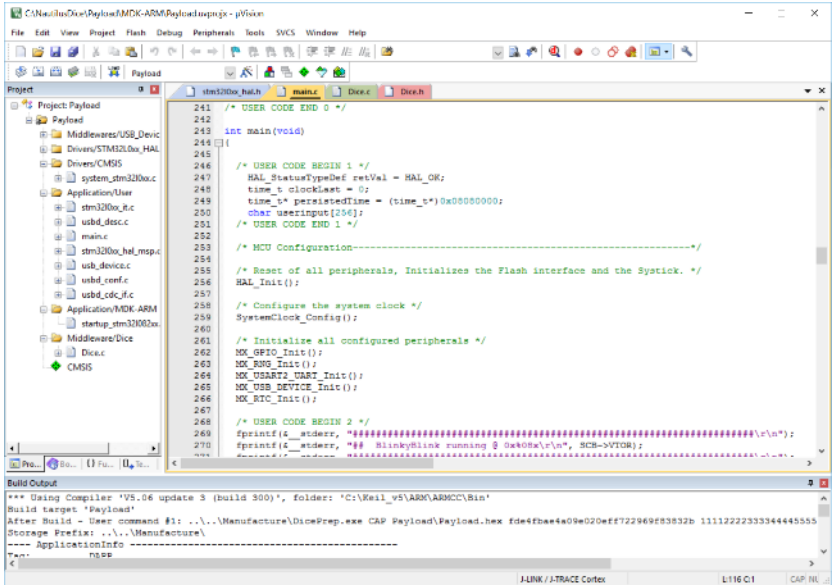
1. DicePrep.exe CDP [DevID] [ManId]
2. Creates a update package DiceIdPkt.dfu
3. Both identities are also imported on the local TPM 2.0 (*.TPMKEY) with a predetermined set of usage and migration policies that prevent these key from leaking

Provision the device identities



1. The device is booted and since it is uninitialized it will enter automatically the USB DFU mode
2. Using the STMicro DfuSe tool to install the update DiceIdPkt.dfu package on the MCU
3. Shutdown the device
4. The device can now be transferred to the manufacturer and the TPM protected keys can be migrated to his authority

The Application provider builds the payload



1. The application payload is relocated behind the DICE code and data
2. The payload.hex file is transferred to the manufacturer

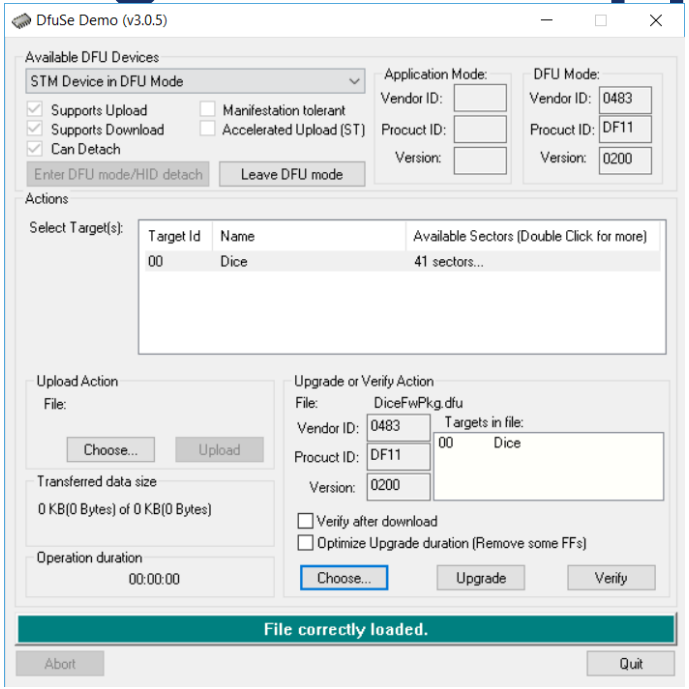
The Manufacturer Integrates the Payload

Administrator: Command Prompt

```
C:\NautilusDice>Manufacture\DicePrep.exe CAP Payload\MDK-ARM\Payload\Payload.hex fde4fbae4a09e020eff722969f83832b 111122
2233334444555566677778888 aaaa5555aaaa5555aaaa5555aaaa5555
Storage Prefix: Manufacture\
---- ApplicationInfo ----------------------------------------
Tag:          DAPP
Size:         32768
Version:      0.1
Date:         2016.8.30-19:16:2
Name:         Payload
Manufacturer: StefanTh@Microsoft.com
-------------------------------------------------------------
AppStrongName[16]:            f78903fddde6100819d52f5ef672a340
ManufacturerRootName[16]:     fde4fbae4a09e020eff722969f83832b
ManufacturerSalt[16]:         1111222233334444555566667777888 8
ManufacturerCompoundName[16]: ef4d1b63bb72ef886322e5fc435bbd08
EncOperatorId[16]:            ce18eb0f80017e6414bc0a17934a7e07
OperatorName[16]:             e9f3934badfeeff09025e3dee4c8fb5d
-------------------------------------------------------------
Authorization[16]:            dfde11d060019b9055064970f1170820
-------------------------------------------------------------

C:\NautilusDice>dir Manufacture
 Volume in drive C has no label.
 Volume Serial Number is 8E71-83D9

 Directory of C:\NautilusDice\Manufacture

08/30/16  10:53    <DIR>          .
08/30/16  10:53    <DIR>          ..
08/30/16  09:56               164 79abc5c23868ad84d388ce61110a6274.TPMKEY
08/30/16  12:16            29,809 DiceFwPkg.dfu
08/30/16  09:56               565 DiceIdPkg.dfu
07/06/16  03:09            35,328 DicePrep.exe
08/30/16  12:16               164 e9f3934badfeeff09025e3dee4c8fb5d.TPMKEY
08/30/16  09:56               164 fde4fbae4a09e020eff722969f83832b.TPMKEY
08/30/16  12:16            16,384 NVChip
12/01/15  13:11           518,344 Simulator.exe
06/29/16  03:37           289,280 STDFU.dll
06/29/16  03:37            60,928 STDFUFiles.dll
06/29/16  03:38            64,000 STDFUPRT.dll
06/29/16  03:37            51,712 STTubeDevice30.dll
07/05/16  11:57         2,408,960 TSS.CPP.dll
               13 File(s)      3,475,802 bytes
                2 Dir(s)  47,143,456,768 bytes free

C:\NautilusDice>
```

1. DicePrep.exe CAP [hex file] [ManID] [Salt] [OprID]
2. Open the specified manufacturerID in the TPM 2.0
3. Encrypt the provided OperatorID and insert in header
4. Calculate code digest and insert in header
5. Copy salt into header
6. Sign header with manufacturerID
7. Prepend the header to the code
8. Generate the DiceFwPkg.dfu package

Program the Application Payload



1. The device is booted and since the application payload is uninitialized it will still enter automatically the UDB DFU mode
2. Using the STMicro DfuSe tool to install the update DiceFwPkt.dfu package
3. Reboot the device
4. The device is now operational

Pre-Calculating the CompoundDeviceID

Administrator: Command Prompt

```
C:\NautilusDice>Manufacture\DicePrep.exe DTI 79abc5c23868ad84d388ce61110a6274 f78903fddde6100819d52f5ef672a340
Storage Prefix: Manufacture\
NewCompoundName[16]: 843c7013cd913b2c56dcaf318e126f5b

C:\NautilusDice>
```

1. DicePrep.exe DTI [rootName] [DerivationID]
2. Use the TPM held DeviceRootIdentity to derive the expected DeviceCompoundIdentity for the application payload on the targeted device
3. Import the new compound device identity into the TPM and store as *.TPMKEY file
4. Calculate the expected DeviceCompoundName

Booting the application payload: Debug

COM6 - PuTTY

```
---- ProtectedData ----------------------------------------------
Tag:            DICE
Size:           256
Version:        0.1
Date:           Tue Aug 30 16:56:10 2016
Model:          Nautilus-STM32L082KZ
Serial:         SN12345678
Manufacturer:   StefanTh@Microsoft.com
URL:            http://WindowsOnDevices.com
ManufacturerID: LOCKED
AppStrongName:  UNLOCKED
-----------------------------------------------------------------
```

When the device boots, the DICE prototype dumps diagnostic information to the serial console:
This first portion shows some generic device information that was provisioned by the manufacturers DiceIdPkg.dfu. It also shows that the device is locked to a manufacturerID, so Secure Boot is enabled.
Alternatively the device may be locked to a particular application payload rather all payloads of a given authority, to lock it even further down.

Booting the application payload: Debug

```
-----------------------------------------------------------------
---- ApplicationInfo ----------------------------------------------
         Tag: DAPP
        Size: 32768
     Version: 0.1
        Date: Tue Aug 30 19:16:02 2016
        Name: Payload
Manufacturer: StefanTh@Microsoft.com
      strongName[16]: f78903fddde6100819d52f5ef672a340
manufacturerSalt[16]: 11112222333344445555666677778888
   encOperatorId[16]: ce18eb0f80017e6414bc0a17934a7e07
   authorization[16]: dfde11d060019b9055064970f1170820
-----------------------------------------------------------------
---- VolatileData -------------------------------------------------
          DeviceRootName[16]: 79abc5c23868ad84d388ce61110a6274
      DeviceCompoundName[16]: 843c7013cd913b2c56dcaf318e126f5b
    ManufacturerRootName[16]: fde4fbae4a09e020eff722969f83832b
ManufacturerCompoundName[16]: ef4d1b63bb72ef886322e5fc435bbd08
           AppStrongName[16]: f78903fddde6100819d52f5ef672a340
            OperatorName[16]: e9f3934badfeeff09025e3dee4c8fb5d
-----------------------------------------------------------------
App payload is *AUTHORIZED*
Persisted device data is *SECURED*
```

Spew

Code Digest

Header Signature

Same as Slide 21

Same as Slide 21

Same as Slide 19

Same as Slide 19

Same as Slide 19

Same as Slide 19

Secure Boot Check

DICE data lockout

1. The ApplicationInfo shows the application payload signed header data that is stored in the application flash area on the device
2. The VolatileData section shows the root and derived identity names. These match with the provisioned names from the previous steps, so DICE is holding the correct identities
3. The header signature is validated to enforce Secure Boot
4. The DICE root identity data is locked out and secured

Booting the application payload: Debug Spew

```
==== Action: Application Launch ====================================
DeInitializing HAL
#####################################################################
##  BlinkyBlink running @ 0x08008200
#####################################################################
XXXX ProtectedData: LOCKED XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
---- ApplicationInfo ----------------------------------------------
         Tag: DAPP
        Size: 32768
     Version: 0.1
        Date: Tue Aug 30 19:16:02 2016
        Name: Payload
Manufacturer: StefanTh@Microsoft.com
      strongName[16]: f78903fddde6100819d52f5ef672a340
manufacturerSalt[16]: 11112222333344445555666677778888
   encOperatorId[16]: ce18eb0f80017e6414bc0a17934a7e07
   authorization[16]: dfde11d060019b9055064970f1170820
-------------------------------------------------------------------
---- VolatileData -------------------------------------------------
           DeviceRootName[16]: 79abc5c23868ad84d388ce61110a6274
       DeviceCompoundName[16]: 843c7013cd913b2c56dcaf318e126f5b
     ManufacturerRootName[16]: fde4fbae4a09e020eff722969f83832b
ManufacturerCompoundName[16]: ef4d1b63bb72ef886322e5fc435bbd08
            AppStrongName[16]: f78903fddde6100819d52f5ef672a340
             OperatorName[16]: e9f3934badfeeff09025e3dee4c8fb5d
-------------------------------------------------------------------
USB_CDC: RTS=0, DTR=0GPIO_LD3: ON
[2016.05.22-12:53:33]GPIO_LD3: OFF
```

Dice Data is locked

Matches pre-calc

1. DICE bootloader is torn down
2. Execution is transferred to application payload located at 0x08008200 in flash
3. Application payload checks that DICE persisted data is unavailable
4. The application can read it's own payload header
5. The application payload can read all the names for attestation purposes, however only the compound identities are still residing in memory and the root identities have been zeroed out and are unavailable
6. The application payload does it's thing

What’s next?

- The demo code currently does not blow the flash rewrite protection fuses and hardware debugging is not disabled the so there are no irreversible changes on the MCU. In order to consider the solution to provide actual security this needs to be added
- The STM32L476RG is a more powerful MCU with additional hardware capabilities that the prototype code is also supposed to be running on
- Merging this demo code with the RazorClam to secure the MCU connection to a discrete TPM 2.0

How to get involved

- Join TCG!
- Participate in new the DICE Architectures workgroup
- Help defined use cases and software specifications for using the compound device identity
- Help compare security benefits to existing TCG technologies like the TPM

References

- RIoT – A Foundation for Trust in the Internet of Things
- STMicro AN4729: STM32L0/L4 FIREWALL overview
- STMicro STSW-STM32080: DfuSe USB device firmware upgrade
- STMicro STM32L082KZ: Ultra-low-power ARM Cortex-M0+ MCU with 192-Kbytes Flash, 32 MHz CPU, USB, AES
- STMicro STM32L476RG: Ultra-low-power with FPU ARM Cortex-M4 MCU 80 MHz with 1 Mbyte Flash, LCD, USB OTG
- RazorClamMCU: Securely binding the MCU and the TPM together

Thank You for Joining Us!

Thank you to our speakers and

Mr. Jungsu Song, MSIP

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