TEEP-DEVICE

The National Institute of Advanced Industrial Science and Technology

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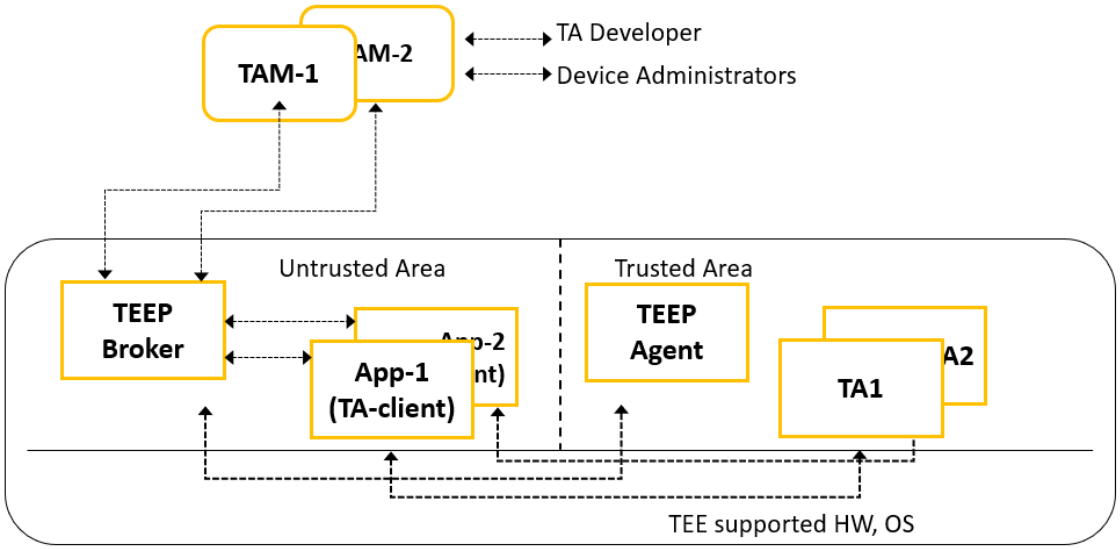
1 Overview of TEEP-Device

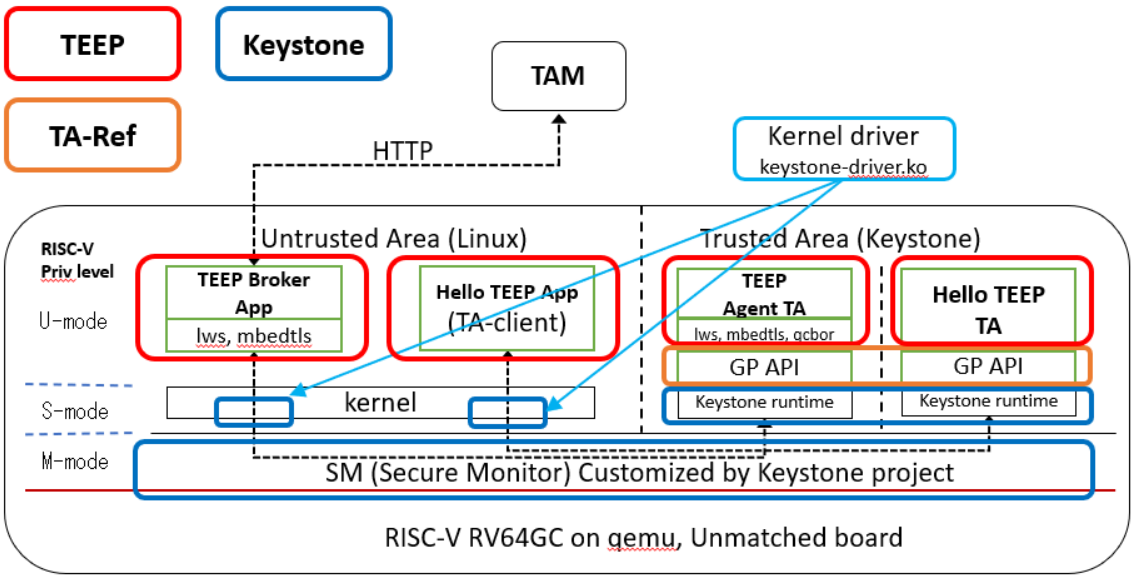


1.1 Features of TEEP-Device

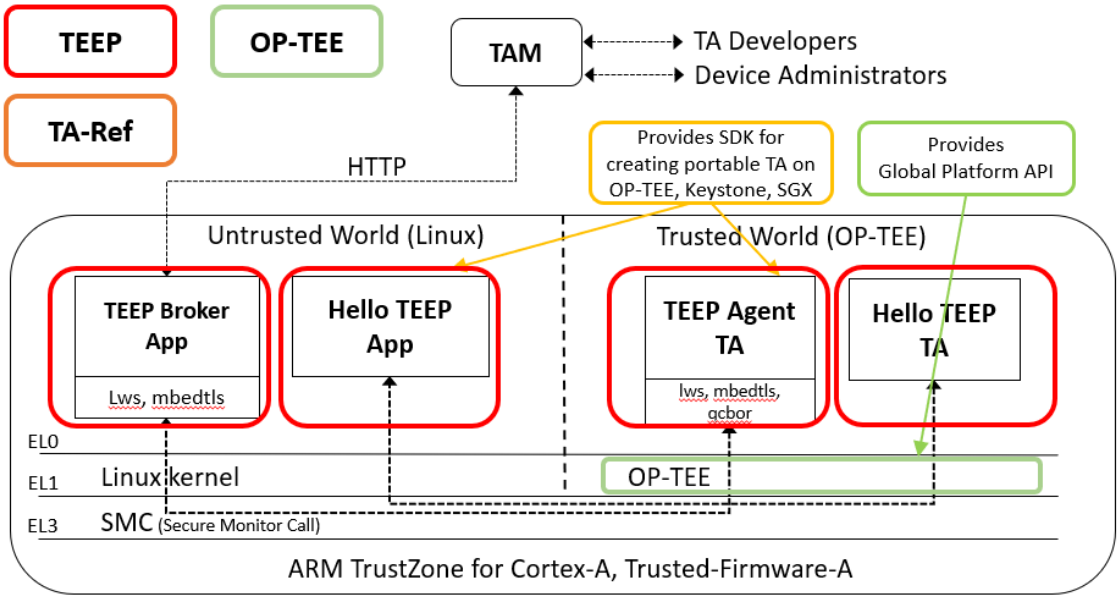
- AIST will prepare

1.2 Components of TEEP-device and TA-Ref

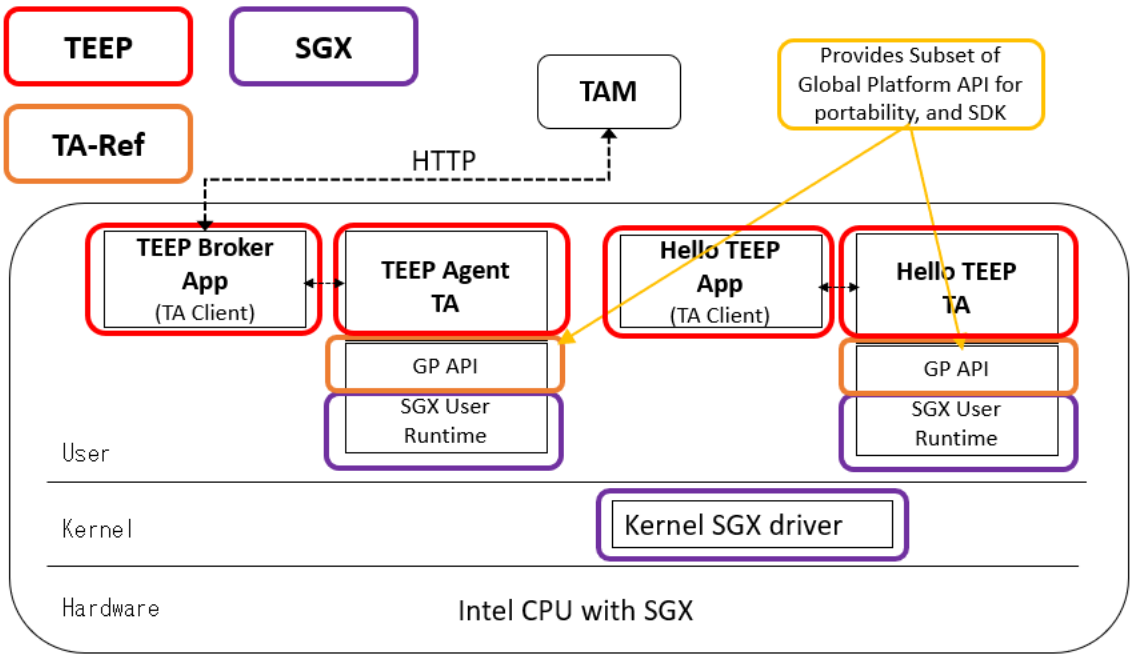
1.2.1 TEEP-device and TA-Ref Components on Keystone



1.2.2 TEEP-device and TA-Ref Components on OP-TEE



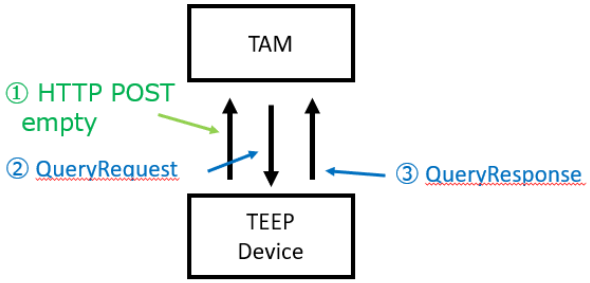
1.2.3 TEEP-device and TA-Ref Components on SGX



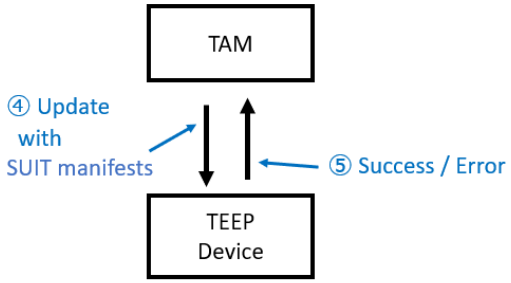
2 TEEP-DEVICE Operations

Four TEEP messages

- QueryRequest Message
- QueryResponse Message
- Update Message <- contains SUIT manifest
- Success Message / Error Message



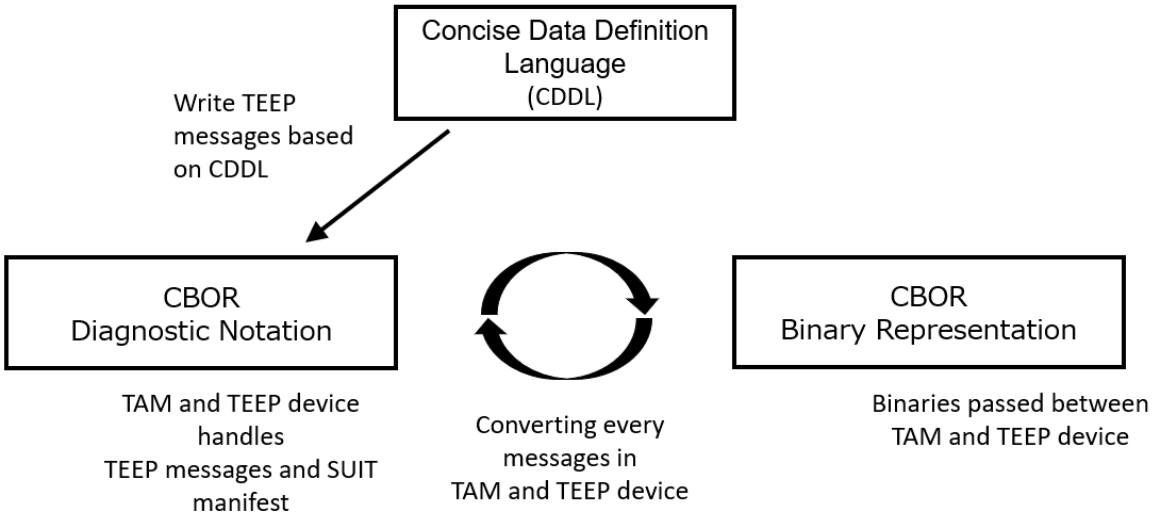
Exchange, Installed Trusted Components
Supported SUIT commands, Cipher suites



TAM sends Trusted Components with / or
associated SUIT manifests

3 CBOR in TEEP-Device

3.1 Three format representations in TEEP and SUIT



3.2 TEEP message format examples

```
D.1.1.  D.1.1.  CBOR Diagnostic Notation
/ query-request = /
[
  1,  / type : TEEP-TYPE-query-request = 1 (uint (0..23)) /
  / options : /
  {
    20 : 0xa0a1a2a3a4a5a6a7a8a9aaabacadaeaf,
           / token = 20 (mapkey) :
             h'a0a1a2a3a4a5a6a7a8a9aaabacadaeaf' (bstr .size
             generated by TAM /
    1 : [ 1 ], / supported-cipher-suites = 1 (mapkey) :
                 TEEP-AES-CCM-16-64-128-HMAC256--256-X25519-E
                 [ 1 ] (array of .within uint .size 4) /
    3 : [ 0 ] / version = 3 (mapkey) :
                 [ 0 ] (array of .within uint .size 4) /
  },
  3   / data-item-requested :
        attestation | trusted-components = 3 (.within uint .s
]
```

```
D.1.2.  D.1.2.  CBOR Binary Representation

  83                    # array(3)
    01                  # unsigned(1) uint (0..23)
    A4                  # map(4)
      14                # unsigned(20) uint (0..23)
      4F                # bytes(16) (8..64)
        A0A1A2A3A4A5A6A7A8A9AAABACADAEAF
      01                # unsigned(1) uint (0..23)
      81                # array(1)
        01              # unsigned(1) within uint .size 4
      03                # unsigned(3) uint (0..23)
      81                # array(1)
        00              # unsigned(0) within uint .size 4
      04                # unsigned(4) uint (0..23)
      43                # bytes(3)
        010203          # "¥x01¥x02¥x03"
    03                  # unsigned(3) .within uint .size 8
```

3.3 SUIT message format examples

```
E.2.  Example 2: SUIT Manifest including the Trusted Component Binary

   ### CBOR Diagnostic Notation of SUIT Manifest

/ SUIT_Envelope_Tagged / 107 ( {
  / suit-authentication-wrapper / 2: << [
    << [
      / suit-digest-algorithm-id: / -16 / cose-alg-sha256 /,
      / suit-digest-bytes: / h'C8363BDF3DCF68F0234A9DD320C2FEA72DE68F46AAE7CE700AFF
    ] >>,
    << / COSE_Sign1_Tagged / 18 ( [
      / protected: / << {
        / algorithm-id / 1: -7 / ES256 /
      } >>,
      / unprotected: / {},
      / payload: / null,
      / signature: / h'E0D2973A7B7185BBDA108458FB68EFAF65CDC
    ] ) >>
  ] >>,
  / suit-integrated-payload / "#tc": h'48656C6C6F2C205365637
  / suit-manifest / 3: << {
    / suit-manifest-version / 1: 1,
    / suit-manifest-sequence-number / 2: 3,
    / suit-common / 3: << {
      / suit-components / 2: [
        [
          h'544545502D446576696365',          / "TEEP-Devic
          h'5365637572654653',                / "SecureFS"
          h'8D82573A926D4754935332DC29997F74', / tc-uuid /
          h'7461'                             / "ta" /
```

```
E.2.1.  CBOR Binary Representation

D8 6B                                    # tag(107) / SUIT_Envelope_Tagged /
   A3                                    # map(3)
      02                                 # unsigned(2) / suit-authentication-wrapper /
      58 73                              # bytes(115)
         82                              # array(2)
            58 24                        # bytes(36)
               82                        # array(2)
                  2F                     # negative(15) / -16 = cose-alg-sha256 /
                  58 20                  # bytes(32)
                     C8363BDF3DCF68F0234A9DD320C2FEA72DE68F46AAE7CE700AFF87085516A335
            58 4A                        # bytes(74)
               D2                        # tag(18) / COSE_Sign1_Tagged /
                  84                     # array(4)
                     43                  # bytes(3)
                        A1               # map(1)
                           01            # unsigned(1) / algorithm-id /
                           26            # negative(6) / -7 = ES256 /
                     A0                  # map(0)
                     F6                  # primitive(22) / null /
                     58 40               # bytes(64)
                        E0D2973A7B7185BBDA108458FB68EFAF65CD031F2283E784129A95D4229F0EB11F8947D3E
```

4 TEEP-Device with docker

4.1 Preparation for Docker

For building teep-device with docker, it is required to install docker on Ubuntu.

For the first time users of docker, please have a look on https://docs.docker.com/engine/

The following installation steps is for Ubuntu 20.04

4.1.1 Installing Docker

```
$ sudo apt update

# Next, install a few prerequisite packages which let apt use packages over HTTPS:
$ sudo apt install apt-transport-https ca-certificates curl software-properties-common

# Then add the GPG key for the official Docker repository to your system:
$ curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo apt-key add -

# Add the Docker repository to APT sources:
$ sudo add-apt-repository "deb [arch=amd64] https://download.docker.com/linux/ubuntu focal stable"

# This will also update our package database with the Docker packages from the newly added repo.
# Make sure you are about to install from the Docker repo instead of the default Ubuntu repo:
$ apt-cache policy docker-ce

#Finally, install Docker
$ sudo apt install docker-ce
```

4.1.2 Executing Docker without sudo

By default, the docker command can only be run the root user or by a user in the docker group, which is automatically created during Docker's installation process. If you attempt to run the docker command without prefixing it with sudo or without being in the docker group, you'll get an output like this:

```
docker: Cannot connect to the Docker daemon. Is the docker daemon running on this host?.
```

To avoid typing sudo whenever we run the docker command, add your username to the docker group.

```
$ sudo groupadd docker
$ sudo gpasswd -a $USER docker
# Logout and then log-in again to apply the changes to the group
```

After you logout and login, you can probably run the docker command without `sudo`

```
$ docker run hello-world
```

4.1.3 Create a docker network tamproto

A docker network named tamproto is required when we run teep device with ta-ref for all targets. The local network is required to connect with tamproto service running locally.

```
$ docker network create tamproto_default
```

4.2 Pre-built Docker Image details

The following are the docker images that has pre-built and tested binaries of teep-device with ta-ref. Since this images are already prepared and built already, you can start using it directly without building the teep-device again. Make sure you have account on docker-hub. If not please create one on `dockerhub.com`

Target	docker image
Keystone	trasioteam/teep-dev:keystone
OP-TEE	trasioteam/teep-dev:optee
Intel SGX	trasioteam/teep-dev:sgx
Tamproto	trasioteam/teep-dev:tamproto
Doxygen	trasioteam/teep-dev:doxygen

4.3 Prepartion for building teep-device on docker

4.3.1 Docker images details for building

If we need to build the teep-device, docker images with all necessary packages for building teep-device for all three targets are already available. The details are mentioned below.

Target	docker image
Keystone	trasioteam/taref-dev:keystone
OP-TEE	trasioteam/taref-dev:optee
Intel SGX	trasioteam/taref-dev:sgx
Doxygen	trasioteam/taref-dev:doxygen

4.4 Building teep-device with Docker

4.4.1 Building teep-device for Keystone with docker

Following commands are to be executed on Ubuntu 20.04.

To run teep-device, first we need to run tamproto inside the same host. Lets clone the tamproto and start it.

tamproto

```
# Clone the tamproto repo and checkout master branch
$ git clone https://192.168.100.100/rinkai/tamproto.git
$ cd tamproto
$ git checkout master
$ docker-compose build
$ docker-compose up &
$ cd ..
```

Trimmed output of starting tamproto

```
tam_api_1  |   TEE_pub: 'teep.jwk' }
tam_api_1  | Load key TAM_priv
tam_api_1  | Load key TAM_pub
tam_api_1  | Load key TEE_priv
tam_api_1  | Load key TEE_pub
tam_api_1  | Key binary loaded
tam_api_1  | 192.168.11.4
tam_api_1  | Express HTTP  server listening on port 8888
tam_api_1  | Express HTTPS server listening on port 8443
```

teep-device

```
# Clone the teep-device repo and checkout suit-dev branch
$ git clone https://192.168.100.100/rinkai/teep-device.git
$ cd teep-device
$ git checkout suit-dev

# Sync and update the submodules
$ git submodule sync --recursive
$ git submodule update --init --recursive
```

Start the docker

```
# Start the docker
$ docker run --network tamproto_default -it --rm -v $(pwd):/home/user/teep-device
       trasioteam/taref-dev:keystone
```

After you start the docker command, you will be logged-in inside the docker container. Following are the commands to be executed inside the docker

```
# [Inside docker image]

# Change to teep-device
$ cd ~/teep-device/

# make the teep-device
$ make

# After the successful build
# Test the teep-device
$ make test
```

Trimmed output printing 'hello TA'

```
buildroot login: root
Password: sifive
PS1='##"## '
```

```
# PS1='##"## '
#### insmod keystone-driver.ko || echo 'err"or'
[    4.980033] keystone_driver: loading out-of-tree module taints kernel.
[    4.987299] keystone_enclave: keystone enclave v1.0.0
#### cd /root/teep-device
#### ls -l
total 1359
-rwxr-xr-x    1 root     root         98088 Feb  8  2022 eyrie-rt
-rwxr-xr-x    1 root     root        437480 Feb  8  2022 hello-app
-rwxr-xr-x    1 root     root        142432 Feb  8  2022 hello-ta
-rwxr-xr-x    1 root     root        247416 Feb  8  2022 teep-agent-ta
-rwxr-xr-x    1 root     root        470568 Feb  8  2022 teep-broker-app
#### ./hello-app hello-ta eyrie-rt
[debug] UTM : 0xffffffff80000000-0xffffffff80100000 (1024 KB) (boot.c:127)
[debug] DRAM: 0x179800000-0x179c00000 (4096 KB) (boot.c:128)
[debug] FREE: 0x1799bb000-0x179c00000 (2324 KB), va 0xffffffff001bb000 (boot.c:133)
[debug] eyrie boot finished. drop to the user land ... (boot.c:172)
hello TA
#### ./hello-app 8d82573a-926d-4754-9353-32dc29997f74.ta eyrie-rt
[Keystone SDK] /home/user/keystone/sdk/src/host/ElfFile.cpp:26 : file does not exist
- 8d82573a-926d-4754-9353-32dc29997f74.ta
[Keystone SDK] /home/user/keystone/sdk/src/host/Enclave.cpp:209 : Invalid enclave ELF
./hello-app: Unable to start enclave
#### ./teep-broker-app --tamurl http://tamproto_tam_api_1:8888/api/tam_cbor
teep-broker.c compiled at Feb  8 2022 05:59:40
uri = http://tamproto_tam_api_1:8888/api/tam_cbor, cose=0, talist=
[debug] UTM : 0xffffffff80000000-0xffffffff80100000 (1024 KB) (boot.c:127)
[debug] DRAM: 0x179800000-0x179c00000 (4096 KB) (boot.c:128)
[debug] FREE: 0x1799c6000-0x179c00000 (2280 KB), va 0xffffffff001c6000 (boot.c:133)
[debug] eyrie boot finished. drop to the user land ... (boot.c:172)
[1970/01/01 00:00:07:7731] NOTICE: POST: http://tamproto_tam_api_1:8888/api/tam_cbor
[1970/01/01 00:00:07:7746] NOTICE: (hexdump: zero length)
[1970/01/01 00:00:07:7782] NOTICE: created client ssl context for default
[1970/01/01 00:00:07:7797] NOTICE: http://tamproto_tam_api_1:8888/api/tam_cbor
[1970/01/01 00:00:08:0379] NOTICE:
[1970/01/01 00:00:08:0387] NOTICE: 0000: 83 01 A5 01 81 01 03 81 00 04 43 01 02 05 14 48
       ..........C....H
[1970/01/01 00:00:08:0396] NOTICE: 0010: 77 77 77 77 77 77 77 77 15 81 00 02
       wwwwwwww....
[1970/01/01 00:00:08:0406] NOTICE:
[1970/01/01 00:00:08:0529] NOTICE: POST: http://tamproto_tam_api_1:8888/api/tam_cbor
[1970/01/01 00:00:08:0544] NOTICE:
[1970/01/01 00:00:08:0550] NOTICE: 0000: 82 02 A4 14 48 77 77 77 77 77 77 77 77 08 80 0E
       ....Hwwwwwwww...
[1970/01/01 00:00:08:0556] NOTICE: 0010: 80 0F 80                                        ...

[1970/01/01 00:00:08:0565] NOTICE:
[1970/01/01 00:00:08:0591] NOTICE: created client ssl context for default
[1970/01/01 00:00:08:0697] NOTICE: http://tamproto_tam_api_1:8888/api/tam_cbor
[1970/01/01 00:00:08:1965] NOTICE:
[1970/01/01 00:00:08:1974] NOTICE: 0000: 82 03 A2 0A 81 59 01 66 D8 6B A2 02 58 73 82 58
       .....Y.f.k..Xs.X
[1970/01/01 00:00:08:1987] NOTICE: 0010: 24 82 2F 58 20 63 70 90 82 1C BB B2 67 95 42 78    $./X
       cp.....g.Bx
[1970/01/01 00:00:08:1998] NOTICE: 0020: 7B 49 F4 5E 14 AF 0C BF AD 9E F4 A4 F0 B3 42 B9
       {I.^..........B.
[1970/01/01 00:00:08:2010] NOTICE: 0030: 23 35 56 05 AF 58 4A D2 84 43 A1 01 26 A0 F6 58
       #5V..XJ..C..&..X
[1970/01/01 00:00:08:2020] NOTICE: 0040: 40 55 43 31 6F D5 98 E6 CA 53 EE 38 3D AD 90 8C
       @UC1o....S.8=...
[1970/01/01 00:00:08:2031] NOTICE: 0050: C6 10 DB 9F D6 F7 4F BA BF C4 CD 28 79 CA 3C C7
       ......O....(y.<.
[1970/01/01 00:00:08:2045] NOTICE: 0060: 6F 72 D7 3D A7 DD 76 45 E6 D7 E9 55 17 D1 82 F5
       or.=..vE...U....
[1970/01/01 00:00:08:2055] NOTICE: 0070: 64 9F 10 0D BD 49 97 0A 7B 62 C9 72 27 A6 CE CA
       d....I..{b.r'...
[1970/01/01 00:00:08:2064] NOTICE: 0080: 68 03 58 EA A5 01 01 02 01 03 58 86 A2 02 81 84
       h.X.......X.....
[1970/01/01 00:00:08:2073] NOTICE: 0090: 4B 54 45 45 50 2D 44 65 76 69 63 65 48 53 65 63
       KTEEP-DeviceHSec
[1970/01/01 00:00:08:2082] NOTICE: 00A0: 75 72 65 46 53 50 8D 82 57 3A 92 6D 47 54 93 53
       ureFSP..W:.mGT.S
[1970/01/01 00:00:08:2091] NOTICE: 00B0: 32 DC 29 99 7F 74 42 74 61 04 58 56 86 14 A4 01
       2.)..tBta.XV....
[1970/01/01 00:00:08:2100] NOTICE: 00C0: 50 FA 6B 4A 53 D5 AD 5F DF BE 9D E6 63 E4 D4 1F
       P.kJS.._....c...
[1970/01/01 00:00:08:2109] NOTICE: 00D0: FE 02 50 14 92 AF 14 25 69 5E 48 BF 42 9B 2D 51
       ..P....%i^H.B.-Q
[1970/01/01 00:00:08:2117] NOTICE: 00E0: F2 AB 45 03 58 24 82 2F 58 20 00 11 22 33 44 55
       ..E.X$./X ..."3DU
[1970/01/01 00:00:08:2128] NOTICE: 00F0: 66 77 88 99 AA BB CC DD EE FF 01 23 45 67 89 AB
       fw.........#Eg..
[1970/01/01 00:00:08:2136] NOTICE: 0100: CD EF FE DC BA 98 76 54 32 10 0E 19 87 D0 01 0F
       ......vT2.......
[1970/01/01 00:00:08:2143] NOTICE: 0110: 02 0F 09 58 54 86 13 A1 15 78 4A 68 74 74 70 3A
```

```
       ...XT....xJhttp:
[1970/01/01 00:00:08:2151] NOTICE: 0120: 2F 2F 74 61 6D 70 72 6F 74 6F 5F 74 61 6D 5F 61
       //tamproto_tam_a
[1970/01/01 00:00:08:2158] NOTICE: 0130: 70 69 5F 31 3A 38 38 38 38 2F 54 41 73 2F 38 64
       pi_1:8888/TAs/8d
[1970/01/01 00:00:08:2170] NOTICE: 0140: 38 32 35 37 33 61 2D 39 32 36 64 2D 34 37 35 34
       82573a-926d-4754
[1970/01/01 00:00:08:2177] NOTICE: 0150: 2D 39 33 35 33 2D 33 32 64 63 32 39 39 39 37 66
       -9353-32dc29997f
[1970/01/01 00:00:08:2184] NOTICE: 0160: 37 34 2E 74 61 15 02 03 0F 0A 43 82 03 0F 14 48
       74.ta.....C....H
[1970/01/01 00:00:08:2191] NOTICE: 0170: AB A1 A2 A3 A4 A5 A6 A7                          ........

[1970/01/01 00:00:08:2197] NOTICE:
command: 20
execute suit-set-parameters
command: 1
execute suit-condition-vendor-identifier
command: 2
execute suit-condition-class-identifier
command: 19
execute suit-set-parameters
command: 21
execute suit-directive-fetch
fetch_and_store component
[1970/01/01 00:00:08:2432] NOTICE: GET: http://tamproto_tam_api_1:8888/TAs/8d82573a-926d-4754-9353-32dc29997f74.ta
[1970/01/01 00:00:08:2444] NOTICE: created client ssl context for default
[1970/01/01 00:00:08:2450] NOTICE: http://tamproto_tam_api_1:8888/TAs/8d82573a-926d-4754-9353-32dc29997f74.ta
component download 142432
store component
  device   = TEEP-Device
  storage  = SecureFS
  filename = 8d82573a-926d-4754-9353-32dc29997f74.ta
finish fetch
command: 3
execute suit-condition-image-match
end of command seq
[1970/01/01 00:00:08:9585] NOTICE: POST: http://tamproto_tam_api_1:8888/api/tam_cbor
[1970/01/01 00:00:08:9589] NOTICE:
[1970/01/01 00:00:08:9592] NOTICE: 0000: 82 05 A1 14 48 77 77 77 77 77 77 77 77
       ....Hwwwwwwww
[1970/01/01 00:00:08:9597] NOTICE:
[1970/01/01 00:00:08:9606] NOTICE: created client ssl context for default
[1970/01/01 00:00:08:9610] NOTICE: http://tamproto_tam_api_1:8888/api/tam_cbor
[1970/01/01 00:00:08:9854] NOTICE: (hexdump: zero length)
#### ls -l
total 1500
-rw-------    1 root     root        142432 Jan  1 00:00 8d82573a-926d-4754-9353-32dc29997f74.ta
-rwxr-xr-x    1 root     root         98088 Feb  8  2022 eyrie-rt
-rwxr-xr-x    1 root     root        437480 Feb  8  2022 hello-app
-rwxr-xr-x    1 root     root        142432 Feb  8  2022 hello-ta
-rwxr-xr-x    1 root     root        247416 Feb  8  2022 teep-agent-ta
-rwxr-xr-x    1 root     root        470568 Feb  8  2022 teep-broker-app
#### ./hello-app 8d82573a-926d-4754-9353-32dc29997f74.ta eyrie-rt
[debug] UTM : 0xffffffff80000000-0xffffffff80100000 (1024 KB) (boot.c:127)
[debug] DRAM: 0x179800000-0x179c00000 (4096 KB) (boot.c:128)
[debug] FREE: 0x1799bb000-0x179c00000 (2324 KB), va 0xffffffff001bb000 (boot.c:133)
[debug] eyrie boot finished. drop to the user land ... (boot.c:172)
hello TA
97f74.ta.secstor.plain-4754-9353-32dc29997f74.ta 8d82573a-926d-4754-9353-32dc2999
cmp: 8d82573a-926d-4754-9353-32dc29997f74.ta.secstor.plain: No such file or directory
####  done
```

4.4.2 Building teep-device for Optee with docker

To run teep-device, first we need to run tamproto inside the same host. Lets clone the tamproto and start it.

tamproto

```
# Clone the tamproto repo and checkout master branch
$ git clone https://192.168.100.100/rinkai/tamproto.git
$ cd tamproto
$ git checkout master
$ docker-compose build
$ docker-compose up &
$ cd ..
```

Trimmed output of starting tamproto

```
tam_api_1  |   TEE_pub: 'teep.jwk' }
tam_api_1  | Load key TAM_priv
tam_api_1  | Load key TAM_pub
tam_api_1  | Load key TEE_priv
tam_api_1  | Load key TEE_pub
tam_api_1  | Key binary loaded
tam_api_1  | 192.168.11.4
tam_api_1  | Express HTTP  server listening on port 8888
tam_api_1  | Express HTTPS server listening on port 8443
```

Copy the IP address of the tamproto which will be passed in the next section.

teep-device

```
# Clone the teep-device repo and checkout suit-dev branch
$ git clone https://192.168.100.100/rinkai/teep-device.git
$ cd teep-device
$ git checkout suit-dev

# Sync and update the submodules
$ git submodule sync --recursive
$ git submodule update --init --recursive
```

Start the docker

```
# Start the docker
$ docker run --network tamproto_default -it --rm -v $(pwd):/home/user/teep-device
       trasioteam/taref-dev:optee
```

After you start the docker command, you will be logged-in inside the docker container. Following are the commands to be executed inside the docker

```
# [Inside docker image]

# Change to teep-device
$ cd ~/teep-device/

# Build the teep device
$ make

# Install the TA on qemu
$ make optee_install_qemu

# After the successful build
# Test the teep-device
$ make test
```

Trimmed output of the test

```
cat /home/user/optee/out/bin/serial1.log
D/TC:0   add_phys_mem:586 TEE_SHMEM_START type NSEC_SHM 0x42000000 size 0x00200000
D/TC:0   add_phys_mem:586 TA_RAM_START type TA_RAM 0x0e300000 size 0x00d00000
D/TC:0   add_phys_mem:586 VCORE_UNPG_RW_PA type TEE_RAM_RW 0x0e160000 size 0x001a0000
D/TC:0   add_phys_mem:586 VCORE_UNPG_RX_PA type TEE_RAM_RX 0x0e100000 size 0x00060000
D/TC:0   add_phys_mem:586 ROUNDDOWN(0x09040000, CORE_MMU_PGDIR_SIZE) type IO_SEC 0x09000000 size
       0x00200000
D/TC:0   verify_special_mem_areas:524 No NSEC DDR memory area defined
D/TC:0   add_va_space:625 type RES_VASPACE size 0x00a00000
D/TC:0   add_va_space:625 type SHM_VASPACE size 0x02000000
D/TC:0   init_mem_map:1129 Mapping core at 0xd3ab6000 offs 0xc59b6000
D/TC:0   dump_mmap_table:737 type IDENTITY_MAP_RX va 0x0e100000..0x0e101fff pa 0x0e100000..0x0e101fff
       size 0x00002000 (smallpg)
D/TC:0   dump_mmap_table:737 type TEE_RAM_RX   va 0xd3ab6000..0xd3b15fff pa 0x0e100000..0x0e15ffff
       size 0x00060000 (smallpg)
D/TC:0   dump_mmap_table:737 type TEE_RAM_RW   va 0xd3b16000..0xd3cb5fff pa 0x0e160000..0x0e2fffff
       size 0x001a0000 (smallpg)
D/TC:0   dump_mmap_table:737 type TA_RAM       va 0xd3d00000..0xd49fffff pa 0x0e300000..0x0effffff
       size 0x00d00000 (smallpg)
D/TC:0   dump_mmap_table:737 type RES_VASPACE  va 0xd4a00000..0xd53fffff pa 0x00000000..0x009fffff
       size 0x00a00000 (pgdir)
D/TC:0   dump_mmap_table:737 type SHM_VASPACE  va 0xd5400000..0xd73fffff pa 0x00000000..0x01ffffff
       size 0x02000000 (pgdir)
D/TC:0   dump_mmap_table:737 type IO_SEC       va 0xd7400000..0xd75fffff pa 0x09000000..0x091fffff
       size 0x00200000 (pgdir)
```

```
D/TC:0   dump_mmap_table:737 type NSEC_SHM     va 0xd7600000..0xd77fffff pa 0x42000000..0x421fffff
       size 0x00200000 (pgdir)
D/TC:0   core_mmu_entry_to_finer_grained:762 xlat tables used 1 / 7
D/TC:0   core_mmu_entry_to_finer_grained:762 xlat tables used 2 / 7
D/TC:0   core_mmu_entry_to_finer_grained:762 xlat tables used 3 / 7
D/TC:0   core_mmu_entry_to_finer_grained:762 xlat tables used 4 / 7
D/TC:0   core_mmu_entry_to_finer_grained:762 xlat tables used 5 / 7
I/TC:
D/TC:0 0 init_canaries:188 #Stack canaries for stack_tmp[0] with top at 0xd3b4aab8
D/TC:0 0 init_canaries:188 watch *0xd3b4aabc
D/TC:0 0 init_canaries:188 #Stack canaries for stack_tmp[1] with top at 0xd3b4b2f8
D/TC:0 0 init_canaries:188 watch *0xd3b4b2fc
D/TC:0 0 init_canaries:188 #Stack canaries for stack_tmp[2] with top at 0xd3b4bb38
D/TC:0 0 init_canaries:188 watch *0xd3b4bb3c
D/TC:0 0 init_canaries:188 #Stack canaries for stack_tmp[3] with top at 0xd3b4c378
D/TC:0 0 init_canaries:188 watch *0xd3b4c37c
D/TC:0 0 init_canaries:189 #Stack canaries for stack_abt[0] with top at 0xd3b43d38
D/TC:0 0 init_canaries:189 watch *0xd3b43d3c
D/TC:0 0 init_canaries:189 #Stack canaries for stack_abt[1] with top at 0xd3b44978
D/TC:0 0 init_canaries:189 watch *0xd3b4497c
D/TC:0 0 init_canaries:189 #Stack canaries for stack_abt[2] with top at 0xd3b455b8
D/TC:0 0 init_canaries:189 watch *0xd3b455bc
D/TC:0 0 init_canaries:189 #Stack canaries for stack_abt[3] with top at 0xd3b461f8
D/TC:0 0 init_canaries:189 watch *0xd3b461fc
D/TC:0 0 init_canaries:191 #Stack canaries for stack_thread[0] with top at 0xd3b48238
D/TC:0 0 init_canaries:191 watch *0xd3b4823c
D/TC:0 0 init_canaries:191 #Stack canaries for stack_thread[1] with top at 0xd3b4a278
D/TC:0 0 init_canaries:191 watch *0xd3b4a27c
D/TC:0 0 select_vector:1118 SMCCC_ARCH_WORKAROUND_1 (0x80008000) available
D/TC:0 0 select_vector:1119 SMC Workaround for CVE-2017-5715 used
I/TC: Non-secure external DT found
D/TC:0 0 carve_out_phys_mem:286 No need to carve out 0xe100000 size 0x200000
D/TC:0 0 carve_out_phys_mem:286 No need to carve out 0xe300000 size 0xd00000
I/TC: Switching console to device: /pl011@9040000
I/TC: OP-TEE version: 3.10.0 (gcc version 8.3.0 (GNU Toolchain for the A-profile Architecture
       8.3-2019.03 (arm-rel-8.36))) #1 Tue 01 Feb 2022 02:37:47 PM UTC aarch64
I/TC: Primary CPU initializing
D/TC:0 0 paged_init_primary:1188 Executing at offset 0xc59b6000 with virtual load address 0xd3ab6000
D/TC:0 0 call_initcalls:21 level 1 register_time_source()
D/TC:0 0 call_initcalls:21 level 1 teecore_init_pub_ram()
D/TC:0 0 call_initcalls:21 level 3 check_ta_store()
D/TC:0 0 check_ta_store:636 TA store: "Secure Storage TA"
D/TC:0 0 check_ta_store:636 TA store: "REE"
D/TC:0 0 call_initcalls:21 level 3 init_user_ta()
D/TC:0 0 call_initcalls:21 level 3 verify_pseudo_tas_conformance()
D/TC:0 0 call_initcalls:21 level 3 mobj_mapped_shm_init()
D/TC:0 0 mobj_mapped_shm_init:434 Shared memory address range: d5400000, d7400000
D/TC:0 0 call_initcalls:21 level 3 tee_cryp_init()
D/TC:0 0 call_initcalls:21 level 4 tee_fs_init_key_manager()
D/TC:0 0 call_initcalls:21 level 6 mobj_init()
D/TC:0 0 call_initcalls:21 level 6 default_mobj_init()
D/TC:0 0 call_finalcalls:40 level 1 release_external_dt()
I/TC: Primary CPU switching to normal world boot
I/TC: Secondary CPU 1 initializing
D/TC:1   select_vector:1118 SMCCC_ARCH_WORKAROUND_1 (0x80008000) available
D/TC:1   select_vector:1119 SMC Workaround for CVE-2017-5715 used
I/TC: Secondary CPU 1 switching to normal world boot
D/TC:1   tee_entry_exchange_capabilities:102 Dynamic shared memory is enabled
D/TC:1 0 core_mmu_entry_to_finer_grained:762 xlat tables used 6 / 7
D/TC:? 0 tee_ta_init_pseudo_ta_session:283 Lookup pseudo TA 7011a688-ddde-4053-a5a9-7b3c4ddf13b8
D/TC:? 0 tee_ta_init_pseudo_ta_session:296 Open device.pta
D/TC:? 0 tee_ta_init_pseudo_ta_session:310 device.pta : 7011a688-ddde-4053-a5a9-7b3c4ddf13b8
D/TC:? 0 tee_ta_close_session:499 csess 0xd3b32a00 id 1
D/TC:? 0 tee_ta_close_session:518 Destroy session
D/TC:? 0 tee_ta_init_pseudo_ta_session:283 Lookup pseudo TA 8d82573a-926d-4754-9353-32dc29997f74
D/TC:? 0 load_ldelf:704 ldelf load address 0x40006000
D/LD:  ldelf:134 Loading TA 8d82573a-926d-4754-9353-32dc29997f74
D/TC:? 0 tee_ta_init_pseudo_ta_session:283 Lookup pseudo TA 3a2f8978-5dc0-11e8-9c2d-fa7ae01bbebc
D/TC:? 0 tee_ta_init_pseudo_ta_session:296 Open system.pta
D/TC:? 0 tee_ta_init_pseudo_ta_session:310 system.pta : 3a2f8978-5dc0-11e8-9c2d-fa7ae01bbebc
D/TC:? 0 system_open_ta_binary:257 Lookup user TA ELF 8d82573a-926d-4754-9353-32dc29997f74 (Secure
       Storage TA)
D/TC:? 0 system_open_ta_binary:260 res=0xffff0008
D/TC:? 0 system_open_ta_binary:257 Lookup user TA ELF 8d82573a-926d-4754-9353-32dc29997f74 (REE)
D/TC:? 0 system_open_ta_binary:260 res=0x0
D/LD:  ldelf:169 ELF (8d82573a-926d-4754-9353-32dc29997f74) at 0x40035000
D/TC:? 0 tee_ta_close_session:499 csess 0xd3b32060 id 1
D/TC:? 0 tee_ta_close_session:518 Destroy session
D/TC:? 0 tee_ta_invoke_command:773 Error: ffff0009 of 4
D/TC:? 0 tee_ta_close_session:499 csess 0xd3b32860 id 1
D/TC:? 0 tee_ta_close_session:518 Destroy session
D/TC:? 0 destroy_context:298 Destroy TA ctx (0xd3b32800)
D/TC:? 0 tee_ta_init_pseudo_ta_session:283 Lookup pseudo TA 68373894-5bb3-403c-9eec-3114a1f5d3fc
D/TC:? 0 load_ldelf:704 ldelf load address 0x40006000
D/LD:  ldelf:134 Loading TA 68373894-5bb3-403c-9eec-3114a1f5d3fc
```

```
D/TC:? 0 tee_ta_init_session_with_context:573 Re-open TA 3a2f8978-5dc0-11e8-9c2d-fa7ae01bbebc
D/TC:? 0 system_open_ta_binary:257 Lookup user TA ELF 68373894-5bb3-403c-9eec-3114a1f5d3fc (Secure
    Storage TA)
D/TC:? 0 system_open_ta_binary:260 res=0xffff0008
D/TC:? 0 system_open_ta_binary:257 Lookup user TA ELF 68373894-5bb3-403c-9eec-3114a1f5d3fc (REE)
D/TC:? 0 system_open_ta_binary:260 res=0x0
D/LD:  ldelf:169 ELF (68373894-5bb3-403c-9eec-3114a1f5d3fc) at 0x4002f000
D/TC:? 0 tee_ta_close_session:499 csess 0xd3b31340 id 1
D/TC:? 0 tee_ta_close_session:518 Destroy session
M/TA: command: 20
M/TA: execute suit-set-parameters
M/TA: command: 1
M/TA: execute suit-condition-vendor-identifier
M/TA: command: 2
M/TA: execute suit-condition-class-identifier
M/TA: command: 19
M/TA: execute suit-set-parameters
M/TA: command: 21
M/TA: execute suit-directive-fetch
M/TA: fetch_and_store component
M/TA: component download 55976
M/TA: store component
M/TA:   device   = TEEP-Device
M/TA:   storage  = SecureFS
M/TA:   filename = 8d82573a-926d-4754-9353-32dc29997f74.ta
D/TC:? 0 tee_ta_init_pseudo_ta_session:283 Lookup pseudo TA 6e256cba-fc4d-4941-ad09-2ca1860342dd
D/TC:? 0 tee_ta_init_pseudo_ta_session:296 Open secstor_ta_mgmt
D/TC:? 0 tee_ta_init_pseudo_ta_session:310 secstor_ta_mgmt : 6e256cba-fc4d-4941-ad09-2ca1860342dd
D/TC:? 0 install_ta:99 Installing 8d82573a-926d-4754-9353-32dc29997f74
D/TC:? 0 tee_ta_close_session:499 csess 0xd3b301c0 id 1
D/TC:? 0 tee_ta_close_session:518 Destroy session
M/TA: finish fetch
M/TA: command: 3
M/TA: execute suit-condition-image-match
M/TA: end of command seq
D/TC:? 0 tee_ta_close_session:499 csess 0xd3b31b40 id 1
D/TC:? 0 tee_ta_close_session:518 Destroy session
D/TC:? 0 destroy_context:298 Destroy TA ctx (0xd3b31ae0)
make[1]: Leaving directory '/home/user/teep-device/platform/op-tee'
```

4.4.3 Building teep-device for SGX with docker

5 Clone and Building teep-device without docker

Clone the teep-device source code and build it for Keystone, OPTEE and SGX. To build please refer to ta-ref.pdf->preparation section

- https://192.168.100.↩ 100/rinkai/ta-ref/-/blob/teep-device-tb-slim/docs/ta-ref.pdf

5.1 Install Doxygen-1.9.2

This PDF was generated using Doxygen version 1.9.2. To install `doxygen-1.9.2` following procedure is necessary.

5.1.1 Install Required Packages

Install following packages on Ubuntu 18.04

```
sudo apt install doxygen-latex graphviz texlive-full texlive-latex-base latex-cjk-all
```

Above packages required to generate PDF using doxygen.

5.1.2 Build and Install

```
git clone https://github.com/doxygen/doxygen.git
cd doxygen
mkdir build
cd build
cmake -G "Unix Makefiles" ..
make
sudo make install
```

5.2 Tamproto Setup

To test teep-device, have to run TAM server on the PC.

Prerequisites

```
sudo apt install rustc npm
sudo pip3 install --upgrade git+https://github.com/ARMmbed/suit-manifest-generator.git@v0.0.2
```

Build and Install

```
git clone https://github.com/ko-isobe/tamproto.git
cd tamproto
git checkout cef99c07b669a49c2748b0c0ff0412ec1628b686 -b 2020-12-18
npm install
```

Make sure your PC is configures with IP address for network connectivity with TEEP device for further testing.

5.3 Keystone

Build `teep-device` with Keystone. Make sure Keystone and its supporting sources have been build already.

5.3.1 Clone and Build

Prepare the environment setup

```
export TEE=keystone
export KEYSTONE_DIR=<path to keystone dir>
export PATH=$PATH:$KEYSTONE_DIR/riscv/bin
export KEYEDGE_DIR=<path tokeyedge dir>
export KEEDGER8R_DIR=<path to keedger8r dir>
```

Clone and Build

```
git clone https://192.168.100.100/rinkai/teep-device.git
cd teep-device
git submodule sync --recursive
git submodule update --init --recursive
make
```

5.3.2 Check teep-device by running hello-app and teep-broker-app

To check teep-device on Unleased, we need to run TAM server and networking with Unleased dev board

5.3.3 Run Tamproto (TAM Server)

First start the TAM server on PC. Make sure IP address configured on PC and Unleased development board.

```
cd tamproto
npm app.js
JWKBaseKeyObject {
  keystore: JWKStore {},
  length: 4096,
  kty: 'RSA',
  kid: 'sWpWma0lDp_RfHKdtkGSVTYQaMIVQaKhESVmzjaW9jc',
  use: '',
  alg: '' }
192.168.0.5
Express HTTP  server listening on port 8888
Express HTTPS server listening on port 8443
```

Once TAM server is up, you see above messages

5.3.4 Copy the hello-app and teep-broker-app binaries to Unleased

5.3.4.1 Manual Copy

- Conneect to Unleased over serial console then assign IP address `ifconfig eth0 192.168.0.6`
- Copy the binaries from build PC over SSH (user:root, password: sifive)

Here `192.168.0.6` is IP Address of Unleased board

```
scp platform/keystone/build/hello-ta/hello-ta root@192.168.0.6:/root/teep-device
scp platform/keystone/build/hello-app/hello-app root@192.168.0.6:/root/teep-device
scp platform/keystone/build/teep-agent-ta/teep-agent-ta root@192.168.0.6:/root/teep-device
scp platform/keystone/build/teep-broker-app/teep-broker-app root@192.168.0.6:/root/teep-device
scp $KEYSTONE_DIR/sdk/rts/eyrie/eyrie-rt root@192.168.0.6:/root/teep-device
scp platform/keystone/build/libteep/ree/mbedtls/library/lib* root@192.168.0.6:/usr/lib/
scp platform/keystone/build/libteep/ree/libwebsockets/lib/lib* root@192.168.0.6:/usr/lib/
```

5.3.4.2 Write to SD card

Please follow below below steps to write the teep-device binaries to SD-card

- Insert SD card to your PC for Unleashed
- Edit `platform/keystone/script/sktinst.sh`
  - Check SD-card device name detected on yor PC and fix `prefix=?`
  - `export prefix=/dev/mmcblk0`
- execute `script/sktinst.sh` as follows
  - `cd platform/keystone; script/sktinst.sh`
- Move the sd to unleashed board and boot it

5.3.5 Check hello-app and teep-broker-app on Unleased

There are two methods to connect to Unleased.

- Serial Port using minicom (/dev/ttyUSB0)
- Over SSH: `ssh root@192.168.0.6`; password is `sifive`

Setup envrionment in Unleased (create /root/env.sh file and add following lines)

```
export PATH=$PATH:/root/teep-device
export TAM_HOST=tamproto_tam_api_1
export TAM_PORT=8888
insmod keystone-driver.ko
```

5.3.5.1 Run hello-app

```
$ source env.sh
[ 2380.618514] keystone_driver: loading out-of-tree module taints kernel.
[ 2380.625305] keystone_enclave: keystone enclave v0.2
$ cd teep-device/
$ ./hello-app hello-ta eyrie-rt
hello TA
$
```

5.3.5.2 Run teep-broker-app

Use the TAM server IP address (i.e 192.168.0.5)

```
./teep-broker-app --tamurl http://192.168.0.5:8888/api/tam_cbor
```

Upon execution, you see following log

```
teep-bro[ 2932.269897] ------------[ cut here ]------------
[ 2932.274191] WARNING: CPU: 4 PID: 164 at /home/arun/projects/ks-0.3/keystone/riscv-linux/mm/page_alloc.c:3926
       __alloc_pages_nodemask+0x150/a
[ 2932.287053] Modules linked in: keystone_driver(O)
[ 2932.291716] CPU: 4 PID: 164 Comm: teep-broker-app Tainted: G        W  O     4.15.0-00060-g65e929792fb9-dirty
       #4
[ 2932.301867] Call Trace:
[ 2932.304314] [<0000000036e46dc0>] walk_stackframe+0x0/0xa2
[ 2932.309686] [<00000000893dfe1c>] show_stack+0x26/0x34
[ 2932.314725] [<00000000c57ed7ce>] dump_stack+0x5e/0x7c
[ 2932.319759] [<00000000a68ce031>] __warn+0xca/0xe0
[ 2932.324445] [<00000000bec1f8a6>] warn_slowpath_null+0x2c/0x3e
[ 2932.330176] [<00000000e8c56bf2>] __alloc_pages_nodemask+0x14c/0x8da
[ 2932.336426] [<00000000ec1f9596>] __get_free_pages+0xc/0x52
[ 2932.341920] [<000000003e8cccc8>] epm_init+0x158/0x1a0 [keystone_driver]
[ 2932.348502] [<0000000032e4188b>] create_enclave+0x56/0xb0 [keystone_driver]
[ 2932.355447] [<000000008a656a96>] keystone_create_enclave+0x16/0x40 [keystone_driver]
[ 2932.363174] [<000000003bbf2147>] keystone_ioctl+0x132/0x164 [keystone_driver]
[ 2932.370288] [<00000000755f7993>] do_vfs_ioctl+0x76/0x4f4
[ 2932.375582] [<00000000b88b9c1d>] SyS_ioctl+0x36/0x60
[ 2932.380533] [<00000000aae667a5>] check_syscall_nr+0x1e/0x22
[ 2932.386132] ---[ end trace 66814e3a8c80ec12 ]---
ker.c compiled at Feb 16 2021 11:17:21
uri = http://192.168.0.5:8888/api/tam_cbor, cose=0, talist=
[1970/01/01 00:48:56:0796] NOTICE: POST: http://192.168.0.5:8888/api/tam_cbor
[1970/01/01 00:48:56:0798] NOTICE: (hexdump: zero length)
[1970/01/01 00:48:56:0801] NOTICE: created client ssl context for default
[1970/01/01 00:48:56:0802] NOTICE: http://192.168.0.3:8888/api/tam_cbor
[1970/01/01 00:48:56:0861] NOTICE:
[1970/01/01 00:48:56:0862] NOTICE: 0000: 83 01 A4 01 81 01 03 81 00 14 1A 77 77 77 77 04
       ...........wwww.
[1970/01/01 00:48:56:0862] NOTICE: 0010: 43 01 02 03 02                                    C....

[1970/01/01 00:48:56:0862] NOTICE:
[1970/01/01 00:48:56:0871] NOTICE: POST: http://192.168.0.5:8888/api/tam_cbor
[1970/01/01 00:48:56:0871] NOTICE:
[1970/01/01 00:48:56:0871] NOTICE: 0000: 82 02 A4 14 1A 77 77 77 77 08 80 0E 80 0F 80
       .....wwww......
[1970/01/01 00:48:56:0872] NOTICE:
[1970/01/01 00:48:56:0873] NOTICE: created client ssl context for default
[1970/01/01 00:48:56:0874] NOTICE: http://192.168.0.5:8888/api/tam_cbor
[1970/01/01 00:48:56:0962] NOTICE:
[1970/01/01 00:48:56:0962] NOTICE: 0000: 82 03 A2 0A 81 59 01 37 A2 02 58 72 81 58 6F D2
       .....Y.7..Xr.Xo.
[1970/01/01 00:48:56:0963] NOTICE: 0010: 84 43 A1 01 26 A0 58 24 82 02 58 20 75 80 7C 54
       .C..&.X$..X u.|T
[1970/01/01 00:48:56:0963] NOTICE: 0020: 62 40 D2 14 E5 7B D5 C4 6A 7C E5 2D ED B0 3D 0E
       b@...{..j|.-..=.
[1970/01/01 00:48:56:0964] NOTICE: 0030: CC 80 75 F3 F7 E0 65 B3 60 CE AD 85 58 40 54 81
       ..u...e.`...X@T.
[1970/01/01 00:48:56:0964] NOTICE: 0040: 49 CD CA D8 17 72 CC EA 61 4A 19 99 05 AB 97 33
```

```
       I....r..aJ.....3
[1970/01/01 00:48:56:0965] NOTICE: 0050: EA 48 D7 1F 13 AE 33 0D 47 FF F5 B8 6C 5C 9B 7A
       .H....3.G...l\.z
[1970/01/01 00:48:56:0965] NOTICE: 0060: BB 12 BC 2D FE 9C 20 6A C8 7F E2 28 58 74 E0 74    ...-.. 
       j...(Xt.t
[1970/01/01 00:48:56:0965] NOTICE: 0070: A3 BD C4 DA B9 20 C4 37 35 8F 67 46 90 76 03 58    ..... 
       .75.gF.v.X
[1970/01/01 00:48:56:0966] NOTICE: 0080: BE A5 01 01 02 01 03 58 60 A2 02 44 81 81 41 00
       .......X`..D..A.
[1970/01/01 00:48:56:0966] NOTICE: 0090: 04 58 56 86 14 A4 01 50 FA 6B 4A 53 D5 AD 5F DF
       .XV....P.kJS.._.
[1970/01/01 00:48:56:0967] NOTICE: 00A0: BE 9D E6 63 E4 D4 1F FE 02 50 14 92 AF 14 25 69
       ...c.....P....%i
[1970/01/01 00:48:56:0967] NOTICE: 00B0: 5E 48 BF 42 9B 2D 51 F2 AB 45 03 58 24 82 02 58
       ^H.B.-Q..E.X$..X
[1970/01/01 00:48:56:0968] NOTICE: 00C0: 20 00 11 22 33 44 55 66 77 88 99 AA BB CC DD EE
       .."3DUfw.......
[1970/01/01 00:48:56:0968] NOTICE: 00D0: FF 01 23 45 67 89 AB CD EF FE DC BA 98 76 54 32
       ..#Eg........vT2
[1970/01/01 00:48:56:0969] NOTICE: 00E0: 10 0E 19 87 D0 01 F6 02 F6 09 58 4E 86 13 A1 15
       ..........XN....
[1970/01/01 00:48:56:0969] NOTICE: 00F0: 78 44 68 74 74 70 3A 2F 2F 31 39 32 2E 31 36 38
       xDhttp://192.168
[1970/01/01 00:48:56:0970] NOTICE: 0100: 2E 31 31 2E 33 3A 38 38 38 38 2F 54 41 73 2F 38
       .0.5:8888/TAs/8
[1970/01/01 00:48:56:0970] NOTICE: 0110: 64 38 32 35 37 33 61 2D 39 32 36 64 2D 34 37 35
       d82573a-926d-475
[1970/01/01 00:48:56:0971] NOTICE: 0120: 34 2D 39 33 35 33 2D 33 32 64 63 32 39 39 39 37
       4-9353-32dc29997
[1970/01/01 00:48:56:0971] NOTICE: 0130: 66 37 34 2E 74 61 15 F6 03 F6 0A 43 82 03 F6 14
       f74.ta.....C....
[1970/01/01 00:48:56:0972] NOTICE: 0140: 1A 77 77 77 78                                    .wwwx

[1970/01/01 00:48:56:0972] NOTICE:
[1970/01/01 00:48:56:0983] NOTICE: GET: http://192.168.0.5:8888/TAs/8d82573a-926d-4754-9353-32dc29997f74.ta
[1970/01/01 00:48:56:0984] NOTICE: created client ssl context for default
[1970/01/01 00:48:56:0985] NOTICE: http://192.168.0.5:8888/TAs/8d82573a-926d-4754-9353-32dc29997f74.ta
teep_message_unwrap_ta_image: msg len 234110
Decrypt
Decrypt OK: length 174887
Verify
Signature OK 0 130552
ta_store_install: ta_image_len = 130552 ta_name=8d82573a-926d-4754-9353-32dc29997f74
[1970/01/01 00:49:01:9453] NOTICE: POST: http://192.168.0.5:8888/api/tam_cbor
[1970/01/01 00:49:01:9454] NOTICE:
[1970/01/01 00:49:01:9454] NOTICE: 0000: 82 05 A1 14 1A 77 77 77 77
       .....wwww
[1970/01/01 00:49:01:9454] NOTICE:
[1970/01/01 00:49:01:9456] NOTICE: created client ssl context for default
[1970/01/01 00:49:01:9457] NOTICE: http://192.168.0.5:8888/api/tam_cbor
[1970/01/01 00:49:01:9505] NOTICE: (hexdump: zero length)
```

5.4 OPTEE

Build `teep-device` with OPTEE. So make sure OPTEE and its supporting sources have been build already.

5.4.1 Clone and Build

Prepare the environment setup

```
export TEE=optee
export OPTEE_DIR=<optee_3.9.0_rpi3 dir>
export PATH=$PATH:$OPTEE_DIR/toolchains/aarch64/bin:$OPTEE_DIR/toolchains/aarch32/bin
```

Clone and Build

```
git clone https://192.168.100.100/rinkai/teep-device.git
cd teep-device
git submodule sync --recursive
git submodule update --init --recursive
make
```

5.4.2 Check teep-device by running hello-app and teep-broker-app on RPI3

To check teep-device on RPI3, we need to run TAM server on PC and networking with RPI3 board

5.4.3 Run Tamproto (TAM Server)

First start the TAM server on PC. Make sure IP address configured on PC and RPI3 board.

```
cd tamproto
npm app.js
JWKBaseKeyObject {
  keystore: JWKStore {},
  length: 4096,
  kty: 'RSA',
  kid: 'sWpWma0lDp_RfHKdtkGSVTYQaMIVQaKhESVmzjaW9jc',
  use: '',
  alg: '' }
192.168.0.5
Express HTTP server listening on port 8888
Express HTTPS server listening on port 8443
```

Once TAM server is up, you see above messages

5.4.4 Copy the hello-app and teep-broker-app binaries to RPI3

5.4.4.1 Copy binaries over SSH to RPI3

- Connect to RPI3 over serial console(/dev/ttryUSB0) then assign IP address `ifconfig eth0 192.168.0.7`
- Copy the binaries from build PC over SSH (user:root) to RPI3

```
TODO - Further update required
```

5.4.4.2 Write to SD card

Please follow below below steps to write the teep-device binaries to SD-card

- Insert SD card to your PC for Unleashed
- Copy the binaries to SD card
- Move the sd to RPI3 board and boot it

```
TODO - Further update required
```

5.4.5 Check hello-app and teep-broker-app on RPI3

There are two methods to connect to RPI3.

- Serial Port using minicom (/dev/ttyUSB0)
- Over SSH: `ssh root@192.168.0.7`

```
TODO - Further update required
```

5.4.5.1 Run hello-app

```
TODO - Further update required
```

5.4.5.2 Run teep-broker-app

Use the TAM server IP address (i.e 192.168.0.3)

```
./teep-broker-app --tamurl http://192.168.0.3:8888/api/tam_cbor
```

Execution logs

```
TODO - Further update required
```

5.5 SGX

Build `teep-device` with SGX. Make sure SGX and its supporting sources have been build already.

5.5.1 Clone and Build on SGX

Prepare the environment setup

```
export TEE=pc
source /opt/intel/sgxsdk/environment
```

Clone and Build

```
git clone https://192.168.100.100/rinkai/teep-device.git
cd teep-device
git submodule sync --recursive
git submodule update --init --recursive
make
```

5.5.2 Check teep-device by running hello-app & teep-broker-app on SGX

To check teep-device on SGX, we need to run TAM server on PC and networking with SGX machine

5.5.3 Run Tamproto (TAM Server)

First start the TAM server on PC. Make sure IP address configured on PC and SGX machine.

```
<p />
cd tamproto
npm app.js
JWKBaseKeyObject {
  keystore: JWKStore {},
```

```
  length: 4096,
  kty: 'RSA',
  kid: 'sWpWma0lDp_RfHKdtkGSVTYQaMIVQaKhESVmzjaW9jc',
  use: '',
  alg: '' }
192.168.0.5
Express HTTP  server listening on port 8888
Express HTTPS server listening on port 8443
<p />
```

Once TAM server is up, you see above messages

5.5.4 Copy hello-app & teep-broker-app binaries to SGX

Copy the binaries to SGX/NUC machine over SSH

```
TODO - Further update required
```

If source is build natively on the SGX/NUC machine, then just copy the binaries to test PATH.

```
TODO - Further update required
```

5.5.5 Check hello-app and teep-broker-app on SGX

```
TODO - Further update required
```

5.5.5.1 Run hello-app

```
TODO - Further update required
```

5.5.5.2 Run teep-broker-app

If your TAM server IP address is 192.168.0.3, then you

```
./teep-broker-app --tamurl http://192.168.0.3:8888/api/tam_cbor
```

Execution logs

```
TODO - Further update required
```