ITU ML5G Build-a-thon

Demonstrate POC done as part of Activity-4 –ORAN Control Loop Instantiation

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GOALS

Goal-1 On reception of Emergency Intent According to the given requirements fetch model from Acumos.

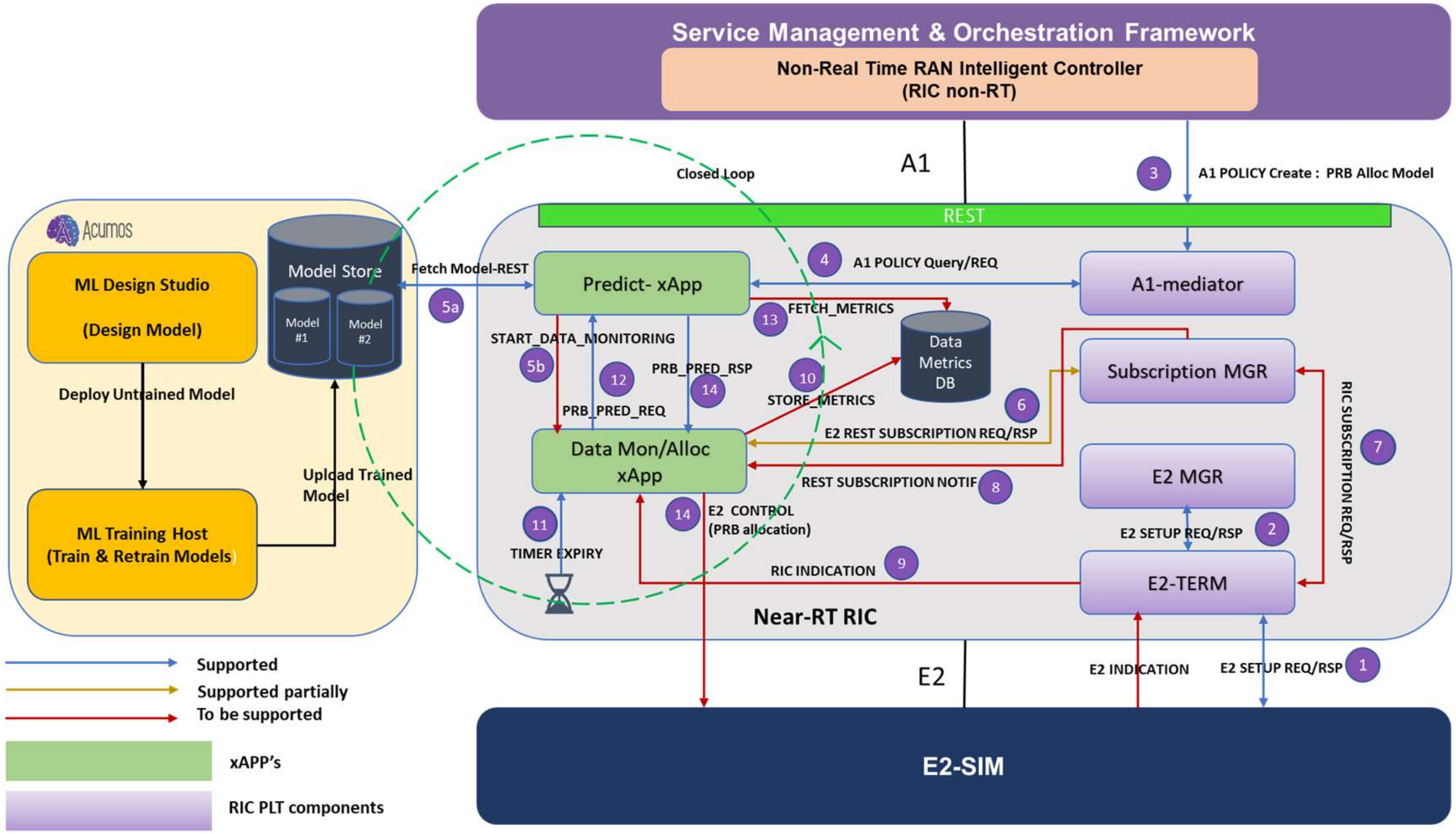
Goal-2 Deploy the model as xApp in ORAN. A pre-trained model might be used for this purpose -

Build-a-thon Activity-4

Achievements

- Brought up ORAN-RIC platform with Dawn release content and attained hands-on knowledge on RIC Platform
- Implemented & Deployed 2 custom xApps in RIC platform that interacts with RIC platform components and amongst each other
- Implemented capability to dynamically fetch model from a remote model store based on A1 policy configured
- Brought up E2 SIM process and registered with RIC E2 components

Workflow- Network Resource Allocation



- RIC is UP and Running, RAN(E2-SIM in this case) is registered/associated with RIC
- RIC receives policy update from A1 for triggering closed loop PRB Allocation
- Fetch model based on the A1 Policy details
- Based on RAN data monitored, predict PRB utilisation [test data was used for POC instead of actual data from E2]
- Compute the PRB to be allocated and send E2 control message. PRB's are always reserved for Emergency Slide and additionally resources can be reallocated based on situational considerations
- Continuously monitor, evaluate and improve decision

Note: E2 Indication is for future reference, currently data is not received via RIC Indication.
In future, based on subscription E2 interface will receive data via RIC Indication.

Credit Note: The pre-trained model, model specific implementation and PRB allocation ALG1 developed by **Team "AUTOMATO"** as part of this build-a-thon is re-used for this POC

xApp POC Implementation Details

Prbpred- xApp is developed as Reactive xApp

i. Upon Initialization does following :-
    i. Registers for PRB_PRED_REQ (PRB Prediction Request) and A1_POLICY_REQ (A1 Policy Request)
    ii. xApp provides details of the policy supported in xApp-descriptor and registers handler function to receive A1_POLICY_REQ
    iii. Queries A1-mediator and gets the Policy details
    iv. As part of step 4,5a in the sequence diagram mentioned in Reference [4]. A specific policy was created which gives info on model and model version info to be used.

ii. Based on the policy details xApp fetches the model from remote model store by constructing the URL based on the information received and stores it locally

iii. Upon reception of PRB_PRED_REQ, based on the model fetched performs prediction of PRB utilisation for each slice and sends response to Alloc xApp

iv. Following are the message types handled by this xApp
    i. Outgoing Message types: - "A1_POLICY_RESP", "PRB_PRED_RSP","A1_POLICY_QUERY"
    ii. Incoming Message Types - "PRB_PRED_REQ", "A1_POLICY_REQ“

alloc xApp – is developed as proactive xApp

i. Is as Proactive xApp

ii. Upon Initialization does following:-
    i. registers with subscription mgr. for E2 information
    ii. And starts timer to trigger PRB_PRED_REQ periodically.

iii. Based on predicted future PRB utilisation computes PRB to be allocated for emergency slice

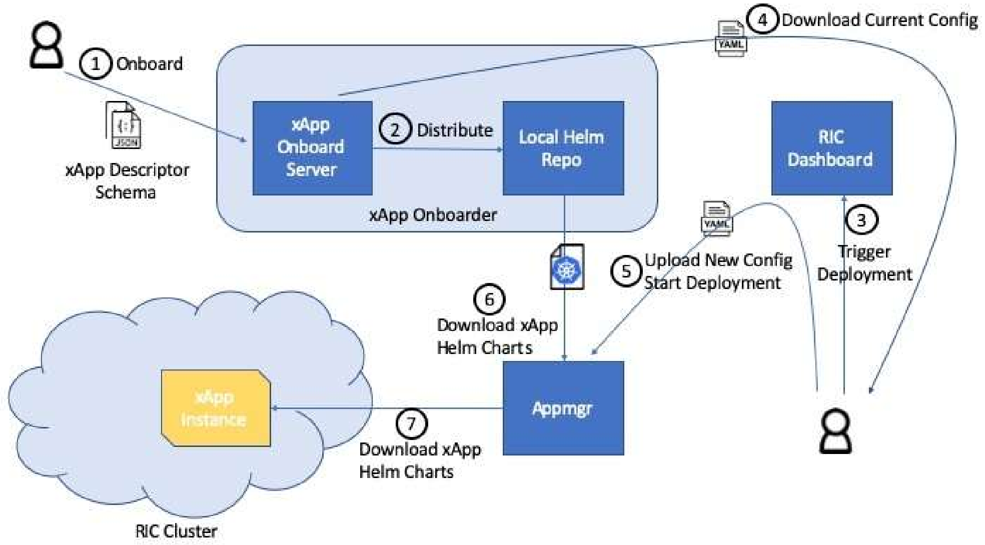
iv. Emergency slice has reserved PRB’s, in addition the remaining unutilised PRB’s are allocated

v. Alloc xApp sends the E2 control message to allocate the available PRB’s from the computation

vi. Following are the message types handled by this xApp
    i. Outgoing Message types: - "PRB_PRED_REQ","RIC_HEALTH_CHECK_RESP“
    ii. Incoming Message Types - "PRB_PRED_RESP", "SUBSCRIPTION_REQ","RIC_HEALTH_CHECK_REQ "

In the Dawn release, creation of A1 policy instance doesn’t trigger A1 Policy create message towards xApp. This was confirmed by ORAN-RIC team https://wiki.o-ran-sc.org/display/IAT/Traffic+Steering+Flows?focusedCommentId=41456537#comment-41456537. **Hence the workflow was modified to send timer-based event from alloc XApp to trigger PRB prediction.**

On-boarding and Deploying xApps



xApp Onboarding Instructions through DMS CLI

```
docker run --rm -u 0 -it -d -p 9090:8080 -e DEBUG=1 -e STORAGE=local -e STORAGE_LOCAL_ROOTDIR=/charts -v $(pwd)/charts:/charts chartmuseum/chartmuseum:latest
export CHART_REPO_URL=http://0.0.0.0:9090
dms_cli onboard --config_file_path=config.json --shcema_file_path=/root/appmgr/xapp_orchestrater/dev/docs/xapp_onboarder/guide/embedded-schema.json
dms_cli install --xapp_chart_name=prbpredxapp --version=0.0.2 --namespace=ricxapp
dms_cli install --xapp_chart_name=alloc --version=0.0.2 --namespace=ricxapp
```

Reference : https://wiki.o-ran-sc.org/display/RICA/On-boarding+and+Deploying+xApps

1.To onboard an xApp, the xApp descriptor and its schema will be submitted to the xApp onboarder. (ADD LINK TO API DOC)

2.xApp onboarder generates helm charts and distributes them to the local helm repo in the RIC platform instance

3.Operator triggers xApp deployment

4.(OPTIONAL)Through RIC dashboard, download an values.yaml file that contains the default xApp configuration parameters

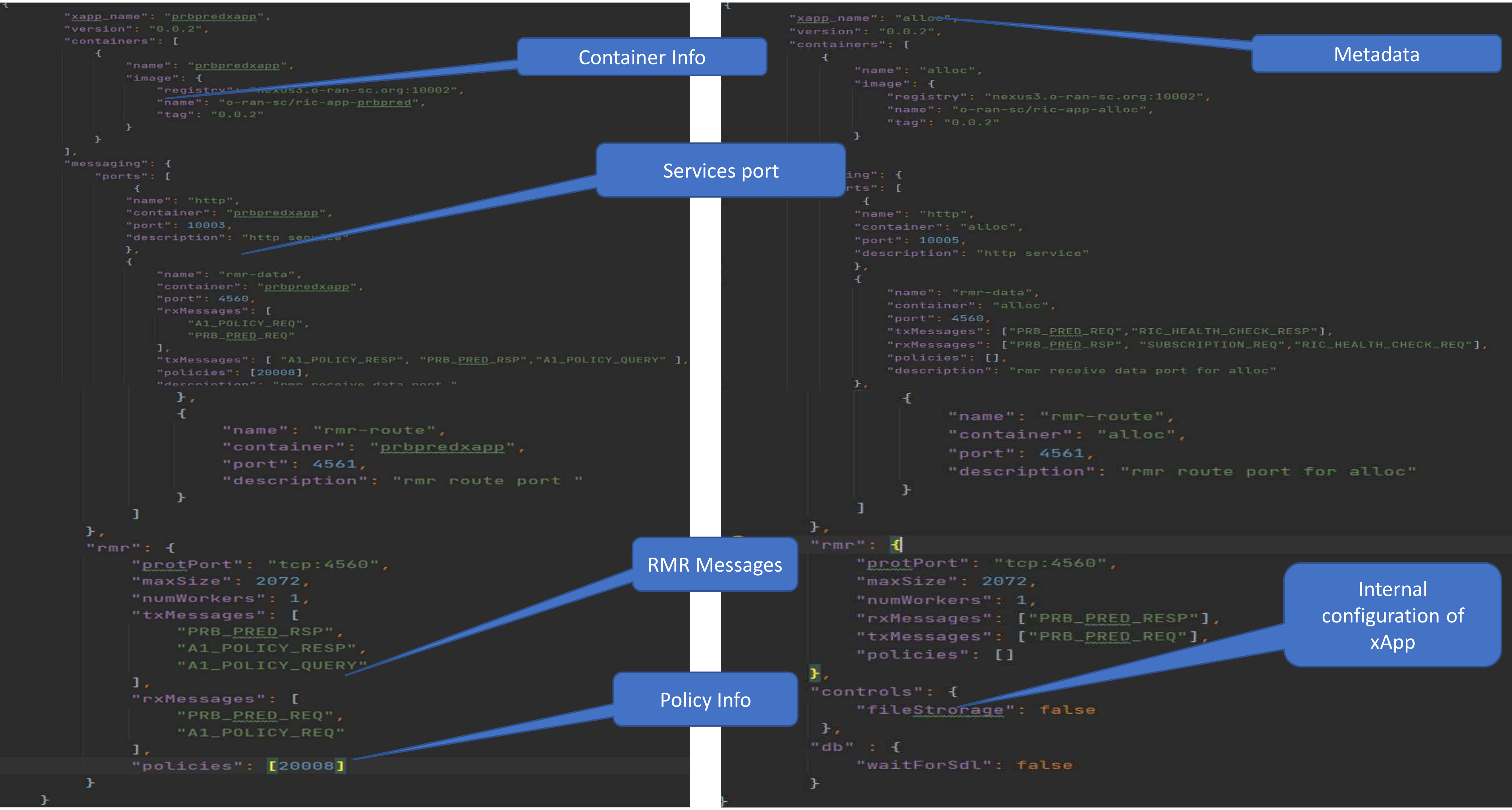
5.(OPTIONAL) Modify the xApp configuration parameters, upload the new configuration to appmgr

6.Appmgr combines the xApp helm charts from local helm repo and the new configuration

7.Appmgr creates an xApp instance

Prbpred-xAppDescriptor

alloc-xAppDescriptor



```
{
        "xapp_name": "prbpredxapp",
        "version": "0.0.2",
        "containers": [
            {
                "name": "prbpredxapp",
                "image": {
                    "registry": "nexus3.o-ran-sc.org:10002",
                    "name": "o-ran-sc/ric-app-prbpred",
                    "tag": "0.0.2"
                }
            }
        ],
        "messaging": {
            "ports": [
                 {
                "name": "http",
                "container": "prbpredxapp",
                "port": 10003,
                "description": "http service"
                },
                {
                    "name": "rmr-data",
                    "container": "prbpredxapp",
                    "port": 4560,
                    "rxMessages": [
                        "A1_POLICY_REQ",
                        "PRB_PRED_REQ"
                    ],
                    "txMessages": [ "A1_POLICY_RESP", "PRB_PRED_RSP","A1_POLICY_QUERY" ],
                    "policies": [20008],
                    "description": "rmr receive data port "
                },
                {
                    "name": "rmr-route",
                    "container": "prbpredxapp",
                    "port": 4561,
                    "description": "rmr route port "
                }
            ]
        },
        "rmr": {
            "protPort": "tcp:4560",
            "maxSize": 2072,
            "numWorkers": 1,
            "txMessages": [
                "PRB_PRED_RSP",
                "A1_POLICY_RESP",
                "A1_POLICY_QUERY"
            ],
            "rxMessages": [
                "PRB_PRED_REQ",
                "A1_POLICY_REQ"
            ],
            "policies": [20008]
        }
}
```

```
{
        "xapp_name": "alloc",
        "version": "0.0.2",
        "containers": [
            {
                "name": "alloc",
                "image": {
                    "registry": "nexus3.o-ran-sc.org:10002",
                    "name": "o-ran-sc/ric-app-alloc",
                    "tag": "0.0.2"
                }

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                rts": [
                 {
                "name": "http",
                "container": "alloc",
                "port": 10005,
                "description": "http service"
                },
                {
                    "name": "rmr-data",
                    "container": "alloc",
                    "port": 4560,
                    "txMessages": ["PRB_PRED_REQ","RIC_HEALTH_CHECK_RESP"],
                    "rxMessages": ["PRB_PRED_RSP", "SUBSCRIPTION_REQ","RIC_HEALTH_CHECK_REQ"],
                    "policies": [],
                    "description": "rmr receive data port for alloc"
                },
                {
                    "name": "rmr-route",
                    "container": "alloc",
                    "port": 4561,
                    "description": "rmr route port for alloc"
                }
            ]
        },
        "rmr": {
            "protPort": "tcp:4560",
            "maxSize": 2072,
            "numWorkers": 1,
            "rxMessages": ["PRB_PRED_RESP"],
            "txMessages": ["PRB_PRED_REQ"],
            "policies": []
        },
        "controls": {
            "fileStrorage": false
        },
        "db" : {
            "waitForSdl": false
        }
}
```

Interactions With RIC Components

As part of this POC, direct/in-direct interactions with below mentioned RIC Platform Components was explored

A1-Mediator

This component listens for policy type and policy instance requests sent via HTTP (the "northbound" interface) and publishes those requests to running xApps via RMR messages (the "southbound" interface).

E2 manager

The E2 manager controls E2 connection establishment and provides REST APIs to manage these connections.

E2 Term

The E2 termination component establishes E2 SCTP connections and routes messages received/sent over E2 to/from RMR.

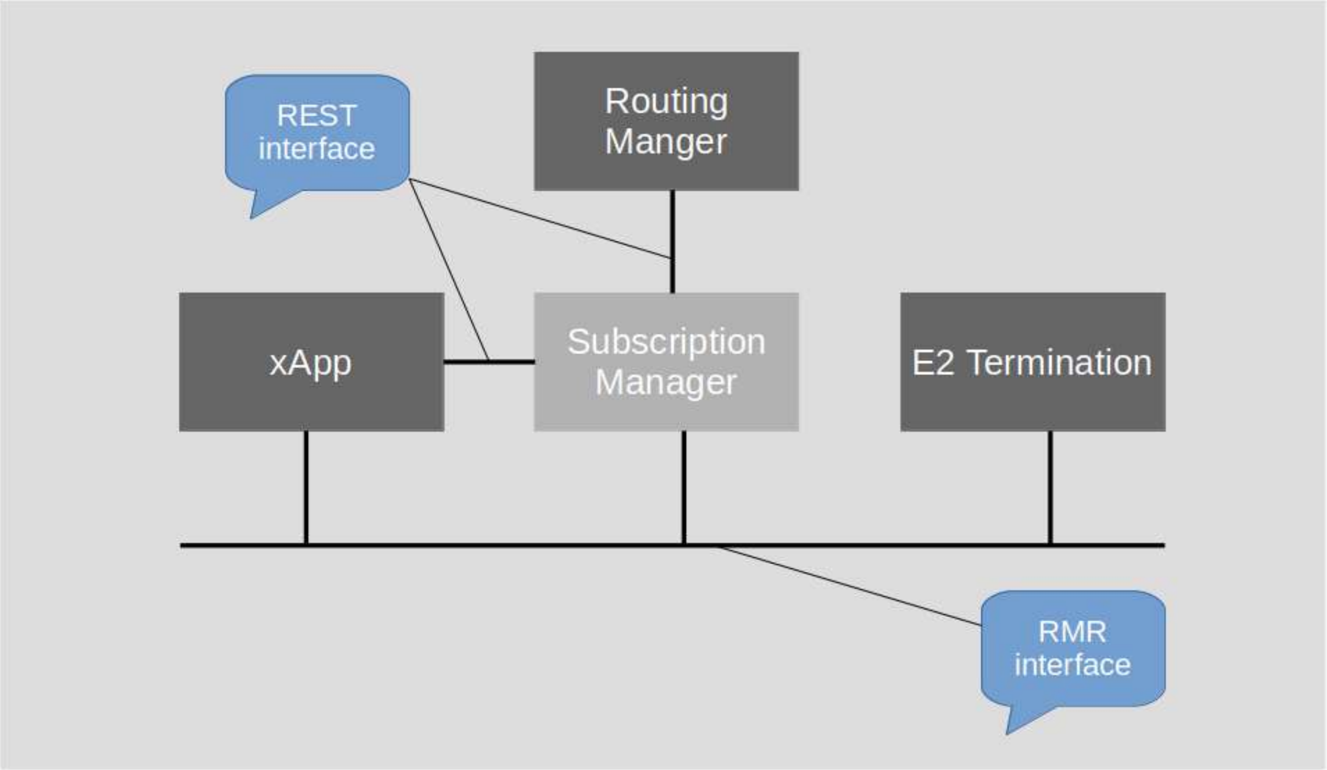
Subscription Manager

Subscription Manager is responsible for managing E2 subscriptions from xApps to the E2 Node (eNodeB or gNodeB). xApp can make subscriptions to E2 Node through Subscription Manager. xApp can subscribe REPORT, INSERT, CONTROL and POLICY type services from E2 Node.

Routing Manager

Routing Manager is responsible for distributing routing policies among the other platform components and xApps.

Messaging Interface



Source: https://github.com/o-ran-sc/ric-plt-submgr/blob/master/docs/images/PlaceInRICSoftwareArchitecture.png

xApp can make subscriptions to E2 Node through Subscription Manager

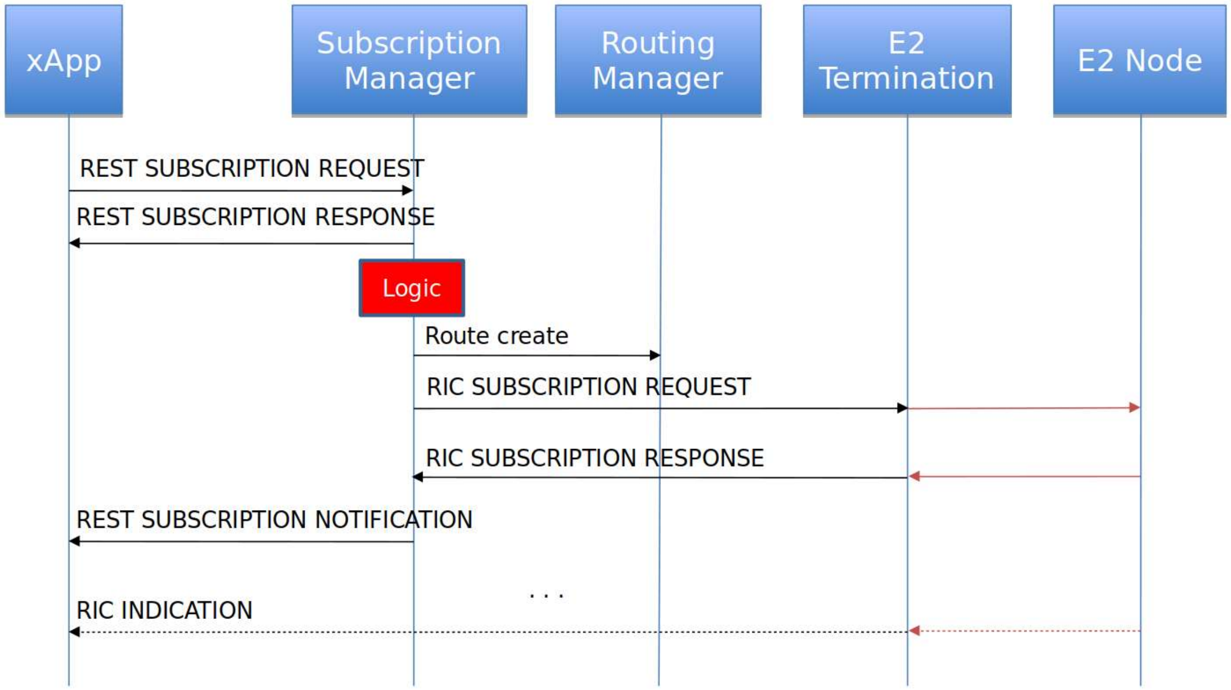
xApp can subscribe REPORT, INSERT, CONTROL and POLICY type services from E2 Node

Subscribed messages from E2 Node are transported to RIC inside RIC Indication message. RIC Indication message is transported to xApp inside RMR message in Payload field of the RMR message.

Subscription Manager allocates unique E2 instance id for every E2 subscription during subscription procedure.

Subscribed messages are routed to xApps based on InstanceId in E2 Indication message.

xApp- E2 Subscription Flow

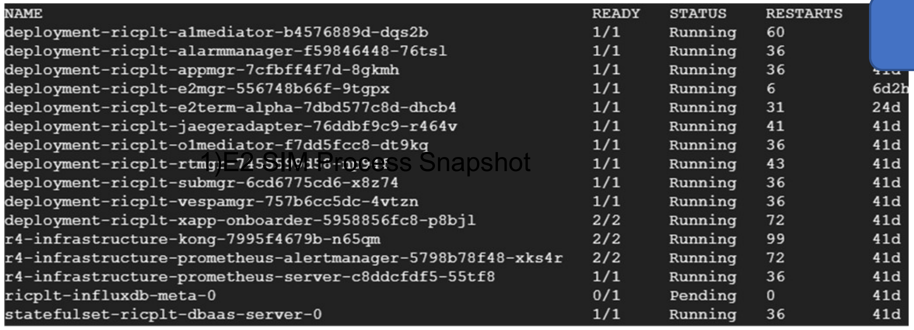


- **Subscription Types**
- **REPORT**:
- **INSERT**:
- **CONTROL**:
- **POLICY**:

Source: https://github.com/o-ran-sc/ric-plt-submgr/blob/master/docs/user-guide.rst

Screen shots from demo Setup

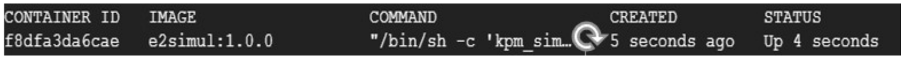
1. RIC Platform Snapshot



```
NAME                                                   READY   STATUS    RESTARTS
deployment-ricplt-a1mediator-b4576889d-dqs2b           1/1     Running   60
deployment-ricplt-alarmmanager-f59846448-76tsl         1/1     Running   36
deployment-ricplt-appmgr-7cfbff4f7d-8gkmh              1/1     Running   36
deployment-ricplt-e2mgr-556748b66f-9tgpx               1/1     Running   6          6d2h
deployment-ricplt-e2term-alpha-7dbd577c8d-dhcb4        1/1     Running   31         24d
deployment-ricplt-jaegeradapter-76ddbf9c9-r464v        1/1     Running   41         41d
deployment-ricplt-o1mediator-f7dd5fcc8-dt9kq           1/1     Running   36         41d
deployment-ricplt-rtmgr-7455?9?5?-????s                1/1     Running   43         41d
deployment-ricplt-submgr-6cd6775cd6-x8z74              1/1     Running   36         41d
deployment-ricplt-vespamgr-757b6cc5dc-4vtzn            1/1     Running   36         41d
deployment-ricplt-xapp-onboarder-5958856fc8-p8bjl      2/2     Running   72         41d
r4-infrastructure-kong-7995f4679b-n65qm                2/2     Running   99         41d
r4-infrastructure-prometheus-alertmanager-5798b78f48-xks4r  2/2  Running  72        41d
r4-infrastructure-prometheus-server-c8ddcfdf5-55tf8    1/1     Running   36         41d
ricplt-influxdb-meta-0                                 0/1     Pending   0          41d
statefulset-ricplt-dbaas-server-0                      1/1     Running   36         41d
```

1)E2 SIM Process Snapshot

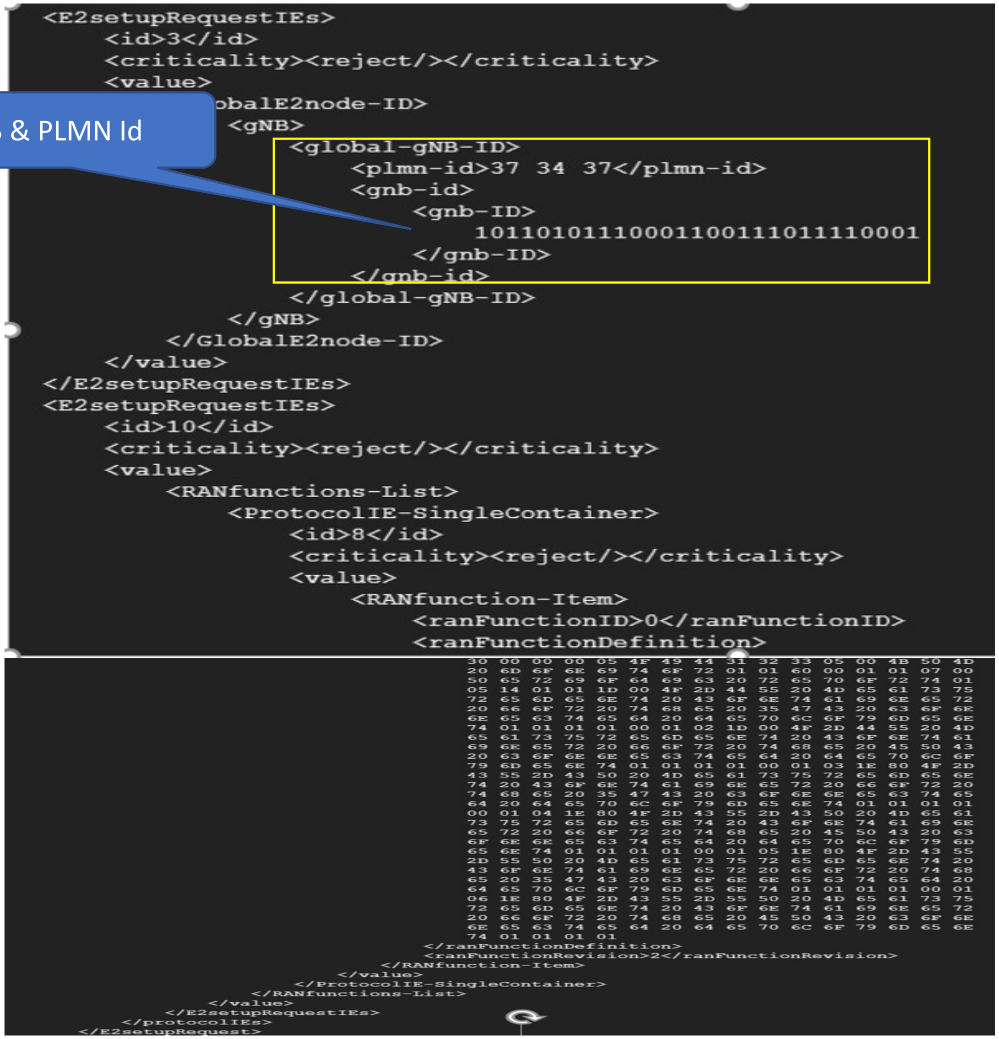
2. E2 SIM Process Snapshot



```
CONTAINER ID   IMAGE           COMMAND                  CREATED           STATUS
f8dfa3da6cae   e2simul:1.0.0   "/bin/sh -c 'kpm_sim…   5 seconds ago     Up 4 seconds
```

3. E2 Setup Procedure :Setup request from E2 SIM

GNiB & PLMN Id



```
<E2setupRequestIEs>
    <id>3</id>
    <criticality><reject/></criticality>
    <value>
            obalE2node-ID>
            <gNB>
                <global-gNB-ID>
                    <plmn-id>37 34 37</plmn-id>
                    <gnb-id>
                        <gnb-ID>
                            10110101110001100111011110001
                        </gnb-ID>
                    </gnb-id>
                </global-gNB-ID>
            </gNB>
        </GlobalE2node-ID>
    </value>
</E2setupRequestIEs>
<E2setupRequestIEs>
    <id>10</id>
    <criticality><reject/></criticality>
    <value>
        <RANfunctions-List>
            <ProtocolIE-SingleContainer>
                <id>8</id>
                <criticality><reject/></criticality>
                <value>
                    <RANfunction-Item>
                        <ranFunctionID>0</ranFunctionID>
                        <ranFunctionDefinition>
                            30 00 00 00 05 4F 49 44 31 32 33 05 00 4B 50 4D
                            20 6D 6F 6E 69 74 6F 72 01 01 60 00 01 01 07 00
                            50 65 72 69 6F 64 69 63 20 72 65 70 6F 72 74 01
                            05 14 01 01 1D 00 4F 2D 44 55 20 4D 65 61 73 75
                            72 65 6D 65 6E 74 20 43 6F 6E 74 61 69 6E 65 72
                            20 66 6F 72 20 74 68 65 20 35 47 43 20 63 6F 6E
                            6E 65 63 74 65 64 20 64 65 70 6C 6F 79 6D 65 6E
                            74 01 01 01 01 00 01 02 1D 00 4F 2D 44 55 20 4D
                            65 61 73 75 72 65 6D 65 6E 74 20 43 6F 6E 74 61
                            69 6E 65 72 20 66 6F 72 20 74 68 65 20 45 50 43
                            20 63 6F 6E 6E 65 63 74 65 64 20 64 65 70 6C 6F
                            79 6D 65 6E 74 01 01 01 01 00 01 03 1E 80 4F 2D
                            43 55 2D 43 50 20 4D 65 61 73 75 72 65 6D 65 6E
                            74 20 43 6F 6E 74 61 69 6E 65 72 20 66 6F 72 20
                            74 68 65 20 35 47 43 20 63 6F 6E 6E 65 63 74 65
                            64 20 64 65 70 6C 6F 79 6D 65 6E 74 01 01 01 01
                            00 01 04 1E 80 4F 2D 43 55 2D 43 50 20 4D 65 61
                            73 75 72 65 6D 65 6E 74 20 43 6F 6E 74 61 69 6E
                            65 72 20 66 6F 72 20 74 68 65 20 45 50 43 20 63
                            6F 6E 6E 65 63 74 65 64 20 64 65 70 6C 6F 79 6D
                            65 6E 74 01 01 01 01 00 01 05 1E 80 4F 2D 43 55
                            2D 55 50 20 4D 65 61 73 75 72 65 6D 65 6E 74 20
                            43 6F 6E 74 61 69 6E 65 72 20 66 6F 72 20 74 68
                            65 20 35 47 43 20 63 6F 6E 6E 65 63 74 65 64 20
                            64 65 70 6C 6F 79 6D 65 6E 74 01 01 01 01 00 01
                            06 1E 80 4F 2D 43 55 2D 55 50 20 4D 65 61 73 75
                            72 65 6D 65 6E 74 20 43 6F 6E 74 61 69 6E 65 72
                            20 66 6F 72 20 74 68 65 20 45 50 43 20 63 6F 6E
                            6E 65 63 74 65 64 20 64 65 70 6C 6F 79 6D 65 6E
                            74 01 01 01 01
                        </ranFunctionDefinition>
                        <ranFunctionRevision>2</ranFunctionRevision>
                    </RANfunction-Item>
                </value>
            </ProtocolIE-SingleContainer>
        </RANfunctions-List>
    </value>
</E2setupRequestIEs>
</protocolIEs>
</E2setupRequest>
```

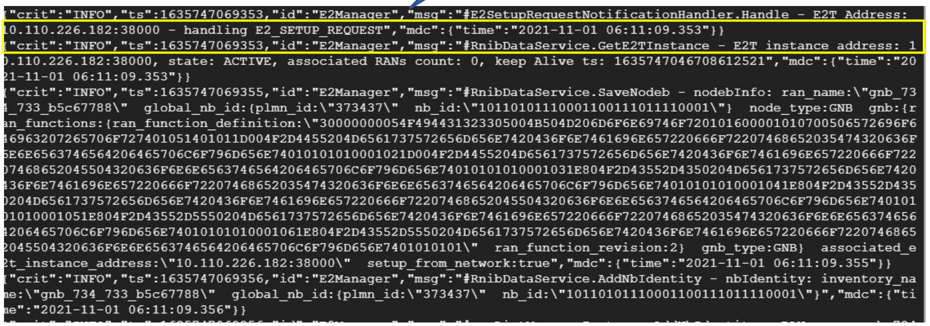
Screenshots of E2 Setup Procedure as seen from E2 Mgr

E2 Mgr Setup Procedure

- GetE2TInstance from
- Saves NodeB data in RNIB Data service
- Creates a POST Request towards Routing Mgr to Associates RAN to E2-TAssociationManager
- On success of response connection status is moved from UNKNOWN_CONNECTION_STATUS-> CONNECTED
- Sends Builds E2Setup Success response Msg

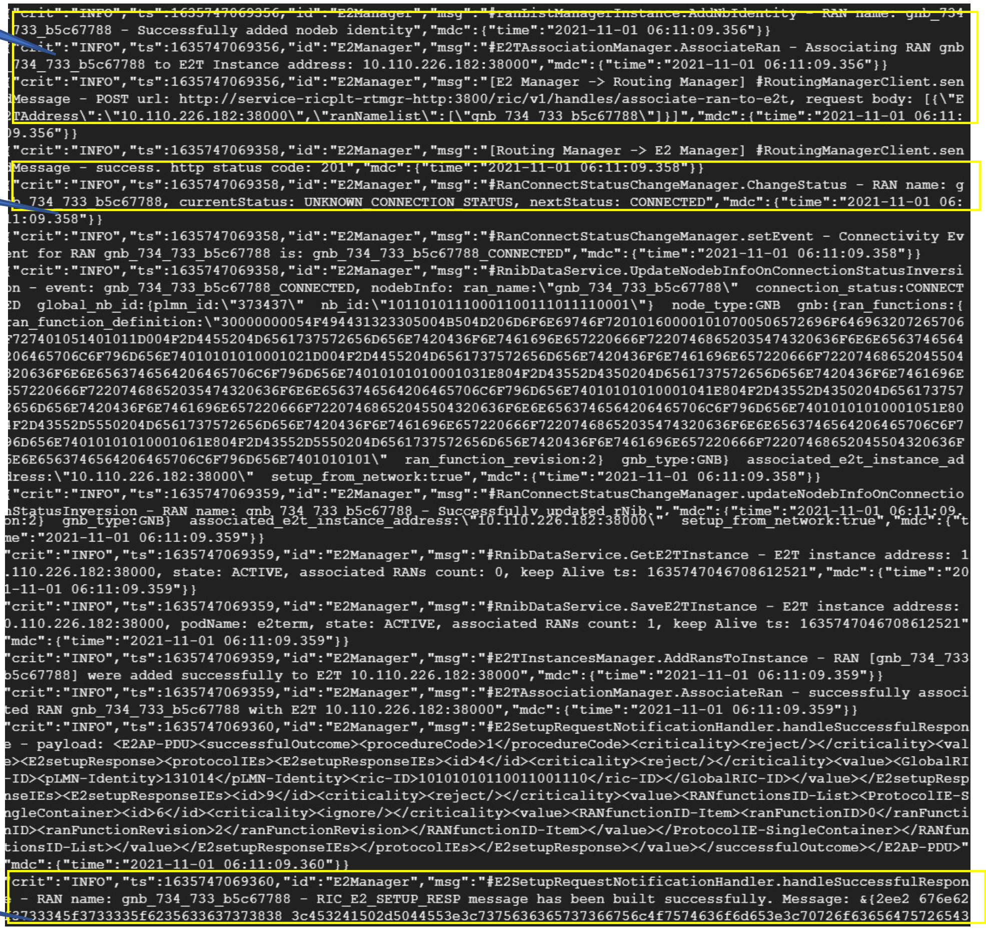
E2 SETUP REQ

4. E2 Mgr receiving E2 Setup Request



```
{"crit":"INFO","ts":1635747069353,"id":"E2Manager","msg":"#E2SetupRequestNotificationHandler.Handle - E2T Address:
10.110.226.182:38000 - handling E2_SETUP_REQUEST","mdc":{"time":"2021-11-01 06:11:09.353"}}
{"crit":"INFO","ts":1635747069353,"id":"E2Manager","msg":"#RnibDataService.GetE2TInstance - E2T instance address: 1
0.110.226.182:38000, state: ACTIVE, associated RANs count: 0, keep Alive ts: 1635747046708612521","mdc":{"time":"20
21-11-01 06:11:09.353"}}
{"crit":"INFO","ts":1635747069355,"id":"E2Manager","msg":"#RnibDataService.SaveNodeb - nodebInfo: ran_name:\"gnb_73
4_733_b5c67788\"  global_nb_id:{plmn_id:\"373437\"  nb_id:\"10110101110001100111011110001\"}  node_type:GNB  gnb:{r
an_functions:{ran_function_definition:\"30000000054F494431323305004B504D206D6F6E69746F7201016000010107005065726 96F6
46963207265706F727401051401011D004F2D4455204D6561737572656D656E7420436F6E7461696E657220666F72207468652035474320636F
6E6E656374656420646570 6C6F796D656E74010101010001021D004F2D4455204D6561737572656D656E7420436F6E7461696E657220666F722
074686520455043 20636F6E6E656374656420646570 6C6F796D656E74010101010001031E804F2D43552D4350204D6561737572656D656E7420
436F6E7461696E657220666F72207468652035474320636F6E6E656374656420646570 6C6F796D656E74010101010001041E804F2D43552D435
0204D6561737572656D656E7420436F6E7461696E657220666F722074686520455043 20636F6E6E656374656420646570 6C6F796D656E740101
01010001051E804F2D43552D5550204D6561737572656D656E7420436F6E7461696E657220666F72207468652035474320636F6E6E656374656
4206465706C6F796D656E74010101010001061E804F2D43552D5550204D6561737572656D656E7420436F6E7461696E657220666F7220746865
20455043 20636F6E6E656374656420646570 6C6F796D656E7401010101\"  ran_function_revision:2}  gnb_type:GNB}  associated_e
2t_instance_address:\"10.110.226.182:38000\"  setup_from_network:true","mdc":{"time":"2021-11-01 06:11:09.355"}}
{"crit":"INFO","ts":1635747069356,"id":"E2Manager","msg":"#RnibDataService.AddNbIdentity - nbIdentity: inventory_na
me:\"gnb_734_733_b5c67788\"  global_nb_id:{plmn_id:\"373437\"  nb_id:\"10110101110001100111011110001\"}","mdc":{"ti
me":"2021-11-01 06:11:09.356"}}
```

5. E2 Mgr changing the state as connected and sending response E2 setup response



```
{"crit":"INFO","ts":1635747069356,"id":"E2Manager","msg":"#ranListManagerInstance.AddNbIdentity - RAN name: gnb_734
733_b5c67788 - Successfully added nodeb identity","mdc":{"time":"2021-11-01 06:11:09.356"}}
{"crit":"INFO","ts":1635747069356,"id":"E2Manager","msg":"#E2TAssociationManager.AssociateRan - Associating RAN gnb
734_733_b5c67788 to E2T Instance address: 10.110.226.182:38000","mdc":{"time":"2021-11-01 06:11:09.356"}}
{"crit":"INFO","ts":1635747069356,"id":"E2Manager","msg":"[E2 Manager -> Routing Manager] #RoutingManagerClient.sen
dMessage - POST url: http://service-ricplt-rtmgr-http:3800/ric/v1/handles/associate-ran-to-e2t, request body: [{\"E
2TAddress\":\"10.110.226.182:38000\",\"ranNamelist\":[\"gnb_734_733_b5c67788\"]}]","mdc":{"time":"2021-11-01 06:11:
09.356"}}
{"crit":"INFO","ts":1635747069358,"id":"E2Manager","msg":"[Routing Manager -> E2 Manager] #RoutingManagerClient.sen
dMessage - success. http status code: 201","mdc":{"time":"2021-11-01 06:11:09.358"}}
{"crit":"INFO","ts":1635747069358,"id":"E2Manager","msg":"#RanConnectStatusChangeManager.ChangeStatus - RAN name: g
nb_734_733_b5c67788, currentStatus: UNKNOWN_CONNECTION_STATUS, nextStatus: CONNECTED","mdc":{"time":"2021-11-01 06:
11:09.358"}}
{"crit":"INFO","ts":1635747069358,"id":"E2Manager","msg":"#RanConnectStatusChangeManager.setEvent - Connectivity Ev
ent for RAN gnb_734_733_b5c67788 is: gnb_734_733_b5c67788_CONNECTED","mdc":{"time":"2021-11-01 06:11:09.358"}}
{"crit":"INFO","ts":1635747069358,"id":"E2Manager","msg":"#RnibDataService.UpdateNodebInfoOnConnectionStatusInversi
on - event: gnb_734_733_b5c67788_CONNECTED, nodebInfo: ran_name:\"gnb_734_733_b5c67788\"  connection_status:CONNECT
ED  global_nb_id:{plmn_id:\"373437\"  nb_id:\"10110101110001100111011110001\"}  node_type:GNB  gnb:{ran_functions:{
ran_function_definition:\"30000000054F494431323305004B504D206D6F6E69746F720101600001010700506572696F646963207265706
F727401051401011D004F2D4455204D6561737572656D656E7420436F6E7461696E657220666F72207468652035474320636F6E6E6563746564
206465706C6F796D656E74010101010001021D004F2D4455204D6561737572656D656E7420436F6E7461696E657220666F72207468652045504
320636F6E6E656374656420646570 6C6F796D656E74010101010001031E804F2D43552D4350204D6561737572656D656E7420436F6E7461696E
657220666F72207468652035474320636F6E6E656374656420646570 6C6F796D656E74010101010001041E804F2D43552D4350204D656173757
2656D656E7420436F6E7461696E657220666F722074686520455043 20636F6E6E656374656420646570 6C6F796D656E74010101010001051E80
4F2D43552D5550204D6561737572656D656E7420436F6E7461696E657220666F72207468652035474320636F6E6E6563746564206465706C6F7
96D656E74010101010001061E804F2D43552D5550204D6561737572656D656E7420436F6E7461696E657220666F72207468652045504320636F
6E6E656374656420646570 6C6F796D656E7401010101\"  ran_function_revision:2}  gnb_type:GNB}  associated_e2t_instance_ad
dress:\"10.110.226.182:38000\"  setup_from_network:true","mdc":{"time":"2021-11-01 06:11:09.358"}}
{"crit":"INFO","ts":1635747069359,"id":"E2Manager","msg":"#RanConnectStatusChangeManager.updateNodebInfoOnConnectio
nStatusInversion - RAN name: gnb_734_733_b5c67788 - Successfully updated rNib.","mdc":{"time":"2021-11-01 06:11:09.
on:2}  gnb_type:GNB}  associated_e2t_instance_address:\"10.110.226.182:38000\"  setup_from_network:true","mdc":{"t
me":"2021-11-01 06:11:09.359"}}
"crit":"INFO","ts":1635747069359,"id":"E2Manager","msg":"#RnibDataService.GetE2TInstance - E2T instance address: 1
.110.226.182:38000, state: ACTIVE, associated RANs count: 0, keep Alive ts: 1635747046708612521","mdc":{"time":"20
1-11-01 06:11:09.359"}}
"crit":"INFO","ts":1635747069359,"id":"E2Manager","msg":"#RnibDataService.SaveE2TInstance - E2T instance address:
0.110.226.182:38000, podName: e2term, state: ACTIVE, associated RANs count: 1, keep Alive ts: 1635747046708612521"
"mdc":{"time":"2021-11-01 06:11:09.359"}}
"crit":"INFO","ts":1635747069359,"id":"E2Manager","msg":"#E2TInstancesManager.AddRansToInstance - RAN [gnb_734_733
b5c67788] were added successfully to E2T 10.110.226.182:38000","mdc":{"time":"2021-11-01 06:11:09.359"}}
"crit":"INFO","ts":1635747069359,"id":"E2Manager","msg":"#E2TAssociationManager.AssociateRan - successfully associ
ted RAN gnb_734_733_b5c67788 with E2T 10.110.226.182:38000","mdc":{"time":"2021-11-01 06:11:09.359"}}
"crit":"INFO","ts":1635747069360,"id":"E2Manager","msg":"#E2SetupRequestNotificationHandler.handleSuccessfulRespon
e - payload: <E2AP-PDU><successfulOutcome><procedureCode>1</procedureCode><criticality><reject/></criticality><val
e><E2setupResponse><protocolIEs><E2setupResponseIEs><id>4</id><criticality><reject/></criticality><value><GlobalRI
-ID><pLMN-Identity>131014</pLMN-Identity><ric-ID>10101010110011001110</ric-ID></GlobalRIC-ID></value></E2setupResp
nseIEs><E2setupResponseIEs><id>9</id><criticality><reject/></criticality><value><RANfunctionsID-List><ProtocolIE-S
ngleContainer><id>6</id><criticality><ignore/></criticality><value><RANfunctionID-Item><ranFunctionID>0</ranFuncti
nID><ranFunctionRevision>2</ranFunctionRevision></RANfunctionID-Item></value></ProtocolIE-SingleContainer></RANfun
tionsID-List></value></E2setupResponseIEs></protocolIEs></E2setupResponse></value></successfulOutcome></E2AP-PDU>"
"mdc":{"time":"2021-11-01 06:11:09.360"}}
"crit":"INFO","ts":1635747069360,"id":"E2Manager","msg":"#E2SetupRequestNotificationHandler.handleSuccessfulRespon
e - RAN name: gnb_734_733_b5c67788 - RIC_E2_SETUP_RESP message has been built successfully. Message: &{2ee2 676e62
3733345f3733335f6235633637373838 3c453241502d5044553e3c73756363657373667756c4f7574636f6d653e3c70726f63656475726543
```

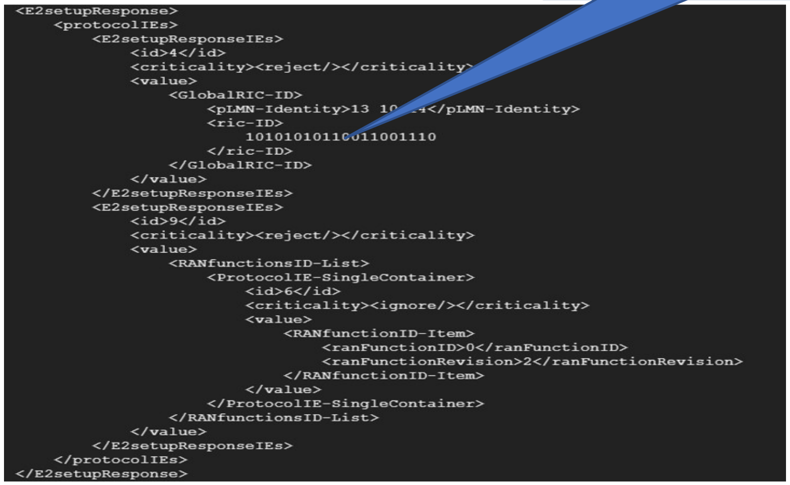
Associate RAN ->E2T Instance

State change to CONNECTED

RIC E2 SETUP RESP

E2 RAN registration can confirmed with response from below CURL command

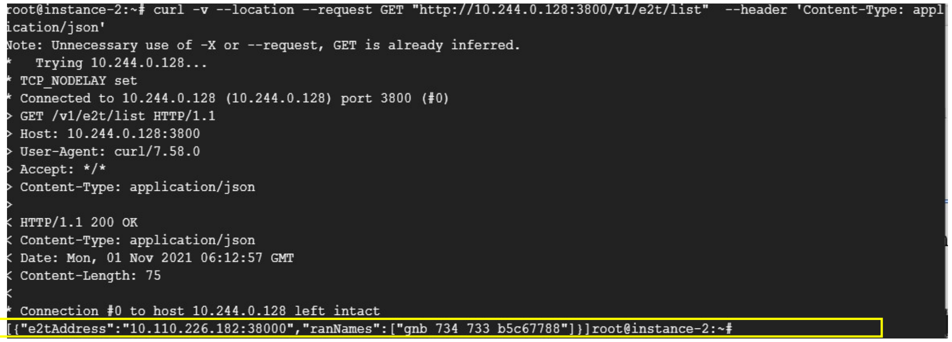
6. E2 Setup Response at E2 SIM end



```
<E2setupResponse>
    <protocolIEs>
        <E2setupResponseIEs>
            <id>4</id>
            <criticality><reject/></criticality>
            <value>
                <GlobalRIC-ID>
                    <pLMN-Identity>13 10[illegible]4</pLMN-Identity>
                    <ric-ID>
                        10101010110011001110
                    </ric-ID>
                </GlobalRIC-ID>
            </value>
        </E2setupResponseIEs>
        <E2setupResponseIEs>
            <id>9</id>
            <criticality><reject/></criticality>
            <value>
                <RANfunctionsID-List>
                    <ProtocolIE-SingleContainer>
                        <id>6</id>
                        <criticality><ignore/></criticality>
                        <value>
                            <RANfunctionID-Item>
                                <ranFunctionID>0</ranFunctionID>
                                <ranFunctionRevision>2</ranFunctionRevision>
                            </RANfunctionID-Item>
                        </value>
                    </ProtocolIE-SingleContainer>
                </RANfunctionsID-List>
            </value>
        </E2setupResponseIEs>
    </protocolIEs>
</E2setupResponse>
```

7.curl –v --location --request GET "http://<E2Mgr ip>/v1/e2t/list" --header 'Content-Type: application/json

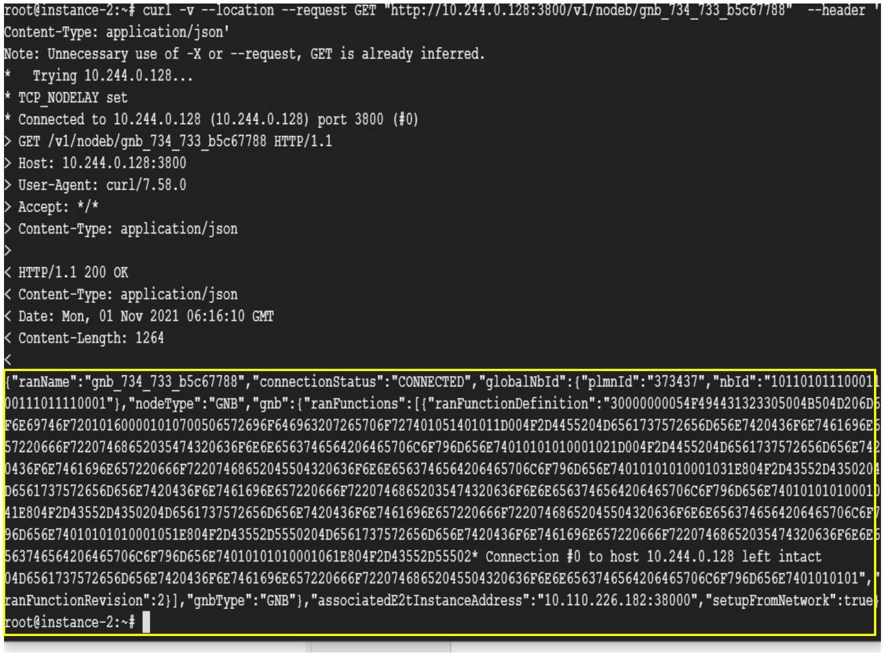
Result displays the e2Term instance and RAN name associated



```
root@instance-2:~# curl -v --location --request GET "http://10.244.0.128:3800/v1/e2t/list"  --header 'Content-Type: appl
ication/json'
Note: Unnecessary use of -X or --request, GET is already inferred.
*   Trying 10.244.0.128...
* TCP_NODELAY set
* Connected to 10.244.0.128 (10.244.0.128) port 3800 (#0)
> GET /v1/e2t/list HTTP/1.1
> Host: 10.244.0.128:3800
> User-Agent: curl/7.58.0
> Accept: */*
> Content-Type: application/json
>
< HTTP/1.1 200 OK
< Content-Type: application/json
< Date: Mon, 01 Nov 2021 06:12:57 GMT
< Content-Length: 75
<
* Connection #0 to host 10.244.0.128 left intact
[{"e2tAddress":"10.110.226.182:38000","ranNames":["gnb 734 733 b5c67788"]}]root@instance-2:~#
```

8. Fetch the gNB details associated on trigger of GET request from E2mgr

curl -v --location --request GET "http://<E2Mgr ip>/v1/nodeb/gnb_734_733_b5c67788" --header 'Content-Type: application/json’



```
root@instance-2:~# curl -v --location --request GET "http://10.244.0.128:3800/v1/nodeb/gnb_734_733_b5c67788"  --header '
Content-Type: application/json'
Note: Unnecessary use of -X or --request, GET is already inferred.
*   Trying 10.244.0.128...
* TCP_NODELAY set
* Connected to 10.244.0.128 (10.244.0.128) port 3800 (#0)
> GET /v1/nodeb/gnb_734_733_b5c67788 HTTP/1.1
> Host: 10.244.0.128:3800
> User-Agent: curl/7.58.0
> Accept: */*
> Content-Type: application/json
>
< HTTP/1.1 200 OK
< Content-Type: application/json
< Date: Mon, 01 Nov 2021 06:16:10 GMT
< Content-Length: 1264
<
{"ranName":"gnb_734_733_b5c67788","connectionStatus":"CONNECTED","globalNbId":{"plmnId":"373437","nbId":"101101011100011
00111011110001"},"nodeType":"GNB","gnb":{"ranFunctions":[{"ranFunctionDefinition":"30000000054F494431323305004B504D206D6
F6E69746F7201016000010107005065726 96F646963207265706F727401051401011D004F2D4455204D6561737572656D656E7420436F6E7461696E6
57220666F72207468652035474320636F6E6E656374656420646570 6C6F796D656E74010101010001021D004F2D4455204D6561737572656D656E742
0436F6E7461696E657220666F72207468652045504320636F6E6E656374656420646570 6C6F796D656E740101010101000 1031E804F2D43552D4350204
D6561737572656D656E7420436F6E7461696E657220666F72207468652035474320636F6E6E656374656420646570 6C6F796D656E7401010101010001 0
41E804F2D43552D4350204D6561737572656D656E7420436F6E7461696E657220666F72207468652045504320636F6E6E656374656420646570 6C6F7
96D656E74010101010001051E804F2D43552D5550204D6561737572656D656E7420436F6E7461696E657220666F72207468652035474320636F6E6E6
563746564206465706C6F796D656E74010101010001061E804F2D43552D55502* Connection #0 to host 10.244.0.128 left intact
04D6561737572656D656E7420436F6E7461696E657220666F72207468652045504320636F6E6E656374656420646570 6C6F796D656E7401010101","
ranFunctionRevision":2}],"gnbType":"GNB"},"associatedE2tInstanceAddress":"10.110.226.182:38000","setupFromNetwork":true}
root@instance-2:~#
```

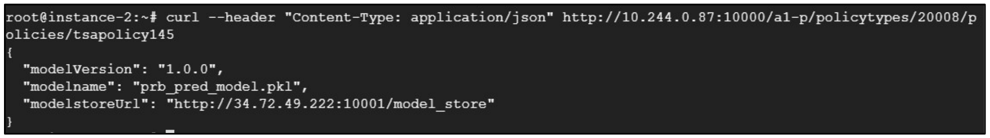
A1 Policy and Policy Instances

- **9** A1- Policy and Policy Instances are created by executing following curl commands ..Indicating an emergency and defines the model to be used here.
- A1-Policy
    - curl -X PUT --header "Content-Type: application/json" -d @create1.json http://<a1med_ip>: <a1med_port>:/a1-p/policytypes/20008

A1 Policy Instance creation

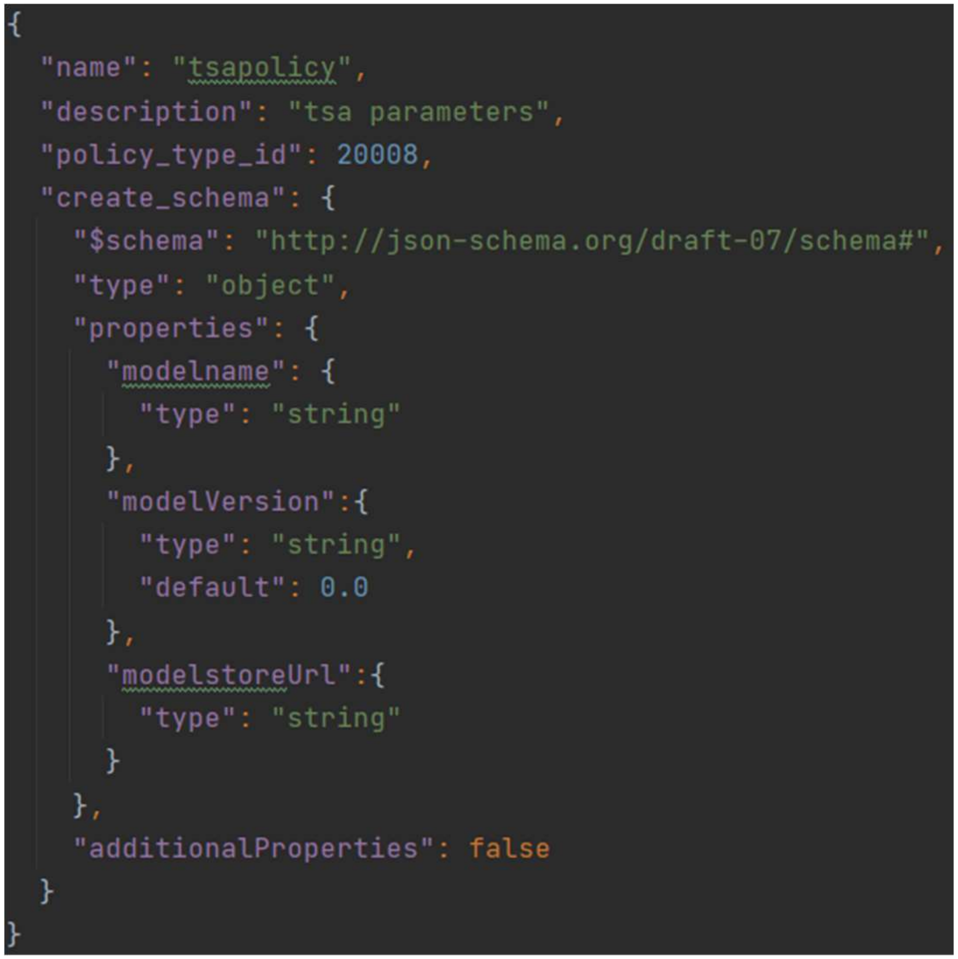
- curl -X PUT --header "Content-Type: application/json" --data '{"modelVersion" : "1.0.0", "modelname":" prb_pred_model.pkl", "modelstoreUrl": "http:// <modelstore IP >/model_store"}' http://<a1med_ip>: <a1med_port>/a1-p/policytypes/20008/policies/tsapolicy145

Below snapshot shows the policy instance is created with the values supplied in the curl command



```
root@instance-2:~# curl --header "Content-Type: application/json" http://10.244.0.87:10000/a1-p/policytypes/20008/p
olicies/tsapolicy145
{
  "modelVersion": "1.0.0",
  "modelname": "prb_pred_model.pkl",
  "modelstoreUrl": "http://34.72.49.222:10001/model_store"
}
```

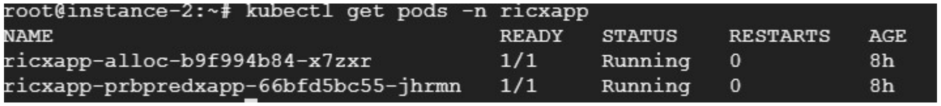
Policy Schema Used



```
{
  "name": "tsapolicy",
  "description": "tsa parameters",
  "policy_type_id": 20008,
  "create_schema": {
    "$schema": "http://json-schema.org/draft-07/schema#",
    "type": "object",
    "properties": {
      "modelname": {
        "type": "string"
      },
      "modelVersion":{
        "type": "string",
        "default": 0.0
      },
      "modelstoreUrl":{
        "type": "string"
      }
    },
    "additionalProperties": false
  }
}
```

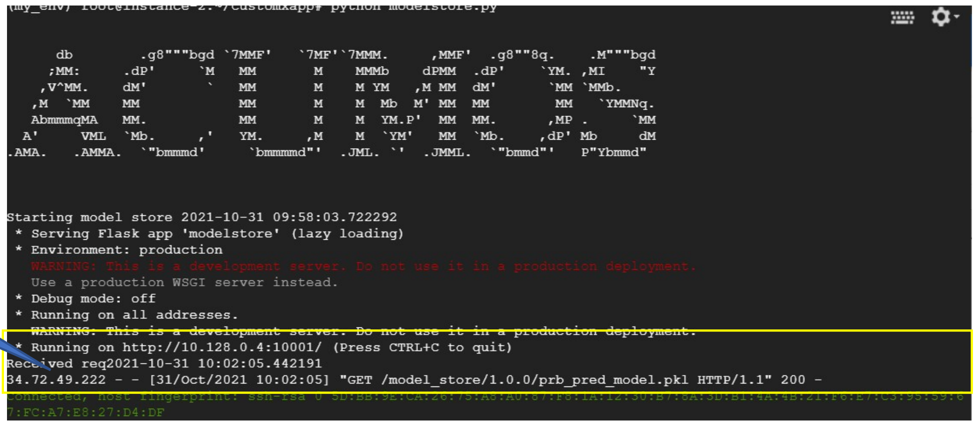
xApp Screenshots & Model store

10. Alloc xApp is deployed



```
root@instance-2:~# kubectl get pods -n ricxapp
NAME                                   READY   STATUS    RESTARTS   AGE
ricxapp-alloc-b9f994b84-x7zxr          1/1     Running   0          8h
ricxapp-prbpredxapp-66bfd5bc55-jhrmn   1/1     Running   0          8h
```

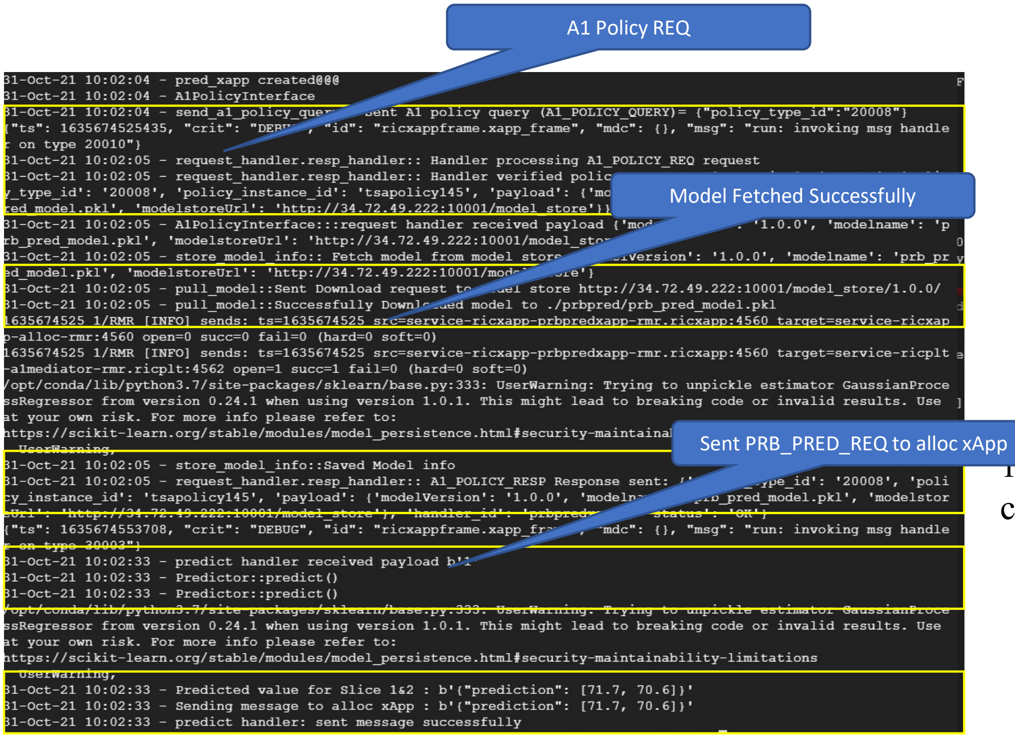
11. Emulated Acumos Model Store listening on 10001 port, receives REST REQ for fetching model. Acumos functionality was emulated considering HW requirements in bringing up Acumos.



```
(my_env) root@instance-2:~/customxapp# python modelstore.py


      db         .g8"""bgd `7MMF'    `7MF'`7MMM.      ,MMF'  .g8""8q.     .M"""bgd
     ;MM:      .dP'     `M   MM        M    MMMb     dPMM  .dP'    `YM. ,MI    "Y
    ,V^MM.     dM'       `   MM        M    M YM    ,M MM  dM'       `MM `MMb.
   ,M  `MM     MM            MM        M    M  Mb  M' MM  MM         MM   `YMMNq.
   AbmmmqMA    MM.           MM        M    M  YM.P'  MM  MM.       ,MP .     `MM
  A'     VML   `Mb.     ,'   YM.      ,M    M  `YM'   MM  `Mb.     ,dP' Mb     dM
.AMA.   .AMMA.   `"bmmmd'     `bmmmmd"'  .JML. `'  .JMML.  `"bmmd"'   P"Ybmmd"



Starting model store 2021-10-31 09:58:03.722292
 * Serving Flask app 'modelstore' (lazy loading)
 * Environment: production
   WARNING: This is a development server. Do not use it in a production deployment.
   Use a production WSGI server instead.
 * Debug mode: off
 * Running on all addresses.
   WARNING: This is a development server. Do not use it in a production deployment.
 * Running on http://10.128.0.4:10001/ (Press CTRL+C to quit)
Received req2021-10-31 10:02:05.442191
34.72.49.222 - - [31/Oct/2021 10:02:05] "GET /model_store/1.0.0/prb_pred_model.pkl HTTP/1.1" 200 -
Connected, host fingerprint: ssh-rsa 0 5D:BB:9E:CA:26:75:A8:A0:87:F8:1A:12:30:B7:8A:3D:B1:4A:4B:21:F6:E7:C3:95:59:6
7:FC:A7:E8:27:D4:DF
```

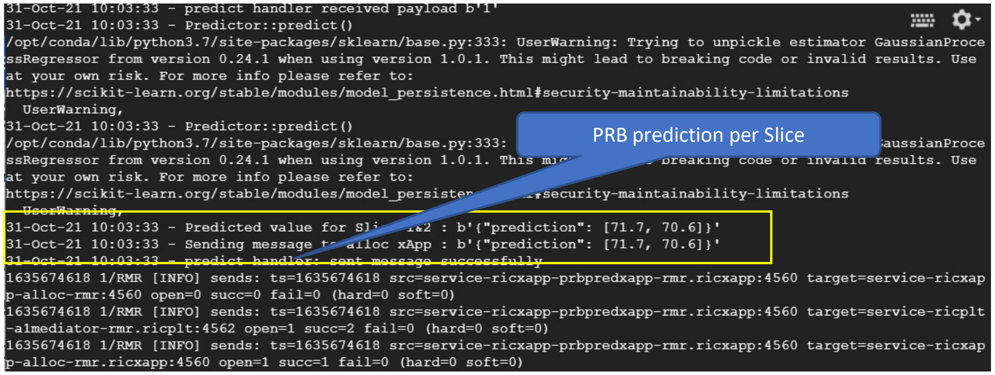
Model Fetch Request

12. Below Snapshot shows REST Req being sent to model store with the details received from A1 policy request. Model store URL being constructed based on the A1 policy request. Model is successfully downloaded to prbpred container.



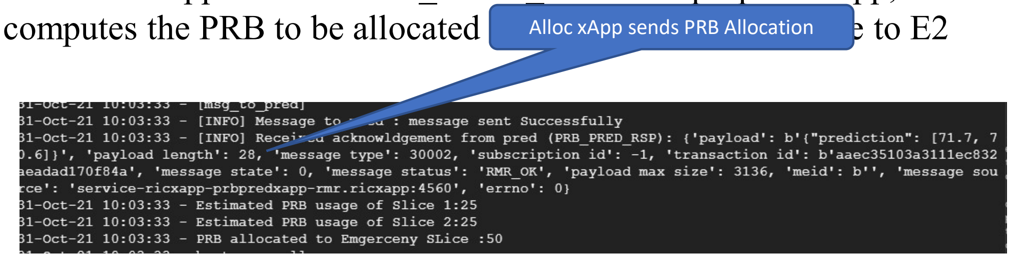
```
31-Oct-21 10:02:04 - pred_xapp created@@@
31-Oct-21 10:02:04 - A1PolicyInterface
31-Oct-21 10:02:04 - send_a1_policy_quer      ent A1 policy query (A1_POLICY_QUERY)= {"policy_type_id":"20008"}
{"ts": 1635674525435, "crit": "DEB   , "id": "ricxappframe.xapp_frame", "mdc": {}, "msg": "run: invoking msg handle
r on type 20010"}
31-Oct-21 10:02:05 - request_handler.resp_handler:: Handler processing A1_POLICY_REQ request
31-Oct-21 10:02:05 - request_handler.resp_handler:: Handler verified polic
y_type_id': '20008', 'policy_instance_id': 'tsapolicy145', 'payload': {'mo
red_model.pkl', 'modelstoreUrl': 'http://34.72.49.222:10001/model_store'}}
31-Oct-21 10:02:05 - A1PolicyInterface:::request handler received payload {'mod          : '1.0.0', 'modelname': 'p
rb_pred_model.pkl', 'modelstoreUrl': 'http://34.72.49.222:10001/model_sto
31-Oct-21 10:02:05 - store_model_info:: Fetch model from model store      lVersion': '1.0.0', 'modelname': 'prb_pr
ed_model.pkl', 'modelstoreUrl': 'http://34.72.49.222:10001/mod      ore'}
31-Oct-21 10:02:05 - pull_model::Sent Download request to   del store http://34.72.49.222:10001/model_store/1.0.0/
31-Oct-21 10:02:05 - pull_model::Successfully Downl   ded model to ./prbpred/prb_pred_model.pkl
1635674525 1/RMR [INFO] sends: ts=1635674525 src=service-ricxapp-prbpredxapp-rmr.ricxapp:4560 target=service-ricxap
p-alloc-rmr:4560 open=0 succ=0 fail=0 (hard=0 soft=0)
1635674525 1/RMR [INFO] sends: ts=1635674525 src=service-ricxapp-prbpredxapp-rmr.ricxapp:4560 target=service-ricplt
-a1mediator-rmr.ricplt:4562 open=1 succ=1 fail=0 (hard=0 soft=0)
/opt/conda/lib/python3.7/site-packages/sklearn/base.py:333: UserWarning: Trying to unpickle estimator GaussianProce
ssRegressor from version 0.24.1 when using version 1.0.1. This might lead to breaking code or invalid results. Use
at your own risk. For more info please refer to:
https://scikit-learn.org/stable/modules/model_persistence.html#security-maintainal
  UserWarning,
31-Oct-21 10:02:05 - store_model_info::Saved Model info
31-Oct-21 10:02:05 - request_handler.resp_handler:: A1_POLICY_RESP Response sent: {'       ype_id': '20008', 'poli
cy_instance_id': 'tsapolicy145', 'payload': {'modelVersion': '1.0.0', 'modelna      b_pred_model.pkl', 'modelstor
eUrl': 'http://34.72.49.222:10001/model_store'}, 'handler_id': 'prbpred       status': 'OK'}
{"ts": 1635674553708, "crit": "DEBUG", "id": "ricxappframe.xapp_fra    , "mdc": {}, "msg": "run: invoking msg handle
r on type 30003"}
31-Oct-21 10:02:33 - predict handler received payload b'1'
31-Oct-21 10:02:33 - Predictor::predict()
31-Oct-21 10:02:33 - Predictor::predict()
/opt/conda/lib/python3.7/site-packages/sklearn/base.py:333: UserWarning: Trying to unpickle estimator GaussianProce
ssRegressor from version 0.24.1 when using version 1.0.1. This might lead to breaking code or invalid results. Use
at your own risk. For more info please refer to:
https://scikit-learn.org/stable/modules/model_persistence.html#security-maintainability-limitations
  UserWarning,
31-Oct-21 10:02:33 - Predicted value for Slice 1&2 : b'{"prediction": [71.7, 70.6]}'
31-Oct-21 10:02:33 - Sending message to alloc xApp : b'{"prediction": [71.7, 70.6]}'
31-Oct-21 10:02:33 - predict handler: sent message successfully
```

13. On Timer expiry Alloc xApp sent PRB_PRED_REQ to prbpred xApp and prbpred xApp receives PRB_PRED_REQ, performs prediction of the PRB's and sends message to Alloc XAPP



```
31-Oct-21 10:03:33 - predict handler received payload b'1'
31-Oct-21 10:03:33 - Predictor::predict()
/opt/conda/lib/python3.7/site-packages/sklearn/base.py:333: UserWarning: Trying to unpickle estimator GaussianProce
ssRegressor from version 0.24.1 when using version 1.0.1. This might lead to breaking code or invalid results. Use
at your own risk. For more info please refer to:
https://scikit-learn.org/stable/modules/model_persistence.html#security-maintainability-limitations
  UserWarning,
31-Oct-21 10:03:33 - Predictor::predict()
/opt/conda/lib/python3.7/site-packages/sklearn/base.py:333:                                             aussianProce
ssRegressor from version 0.24.1 when using version 1.0.1. This mi       breaking code or invalid results. Use
at your own risk. For more info please refer to:
https://scikit-learn.org/stable/modules/model_persisten      l#security-maintainability-limitations
  UserWarning,
31-Oct-21 10:03:33 - Predicted value for Sli   1&2 : b'{"prediction": [71.7, 70.6]}'
31-Oct-21 10:03:33 - Sending message t  alloc xApp : b'{"prediction": [71.7, 70.6]}'
31-Oct-21 10:03:33 - predict handler: sent message successfully
1635674618 1/RMR [INFO] sends: ts=1635674618 src=service-ricxapp-prbpredxapp-rmr.ricxapp:4560 target=service-ricxap
p-alloc-rmr:4560 open=0 succ=0 fail=0 (hard=0 soft=0)
1635674618 1/RMR [INFO] sends: ts=1635674618 src=service-ricxapp-prbpredxapp-rmr.ricxapp:4560 target=service-ricplt
-a1mediator-rmr.ricplt:4562 open=1 succ=2 fail=0 (hard=0 soft=0)
1635674618 1/RMR [INFO] sends: ts=1635674618 src=service-ricxapp-prbpredxapp-rmr.ricxapp:4560 target=service-ricxap
p-alloc-rmr.ricxapp:4560 open=1 succ=1 fail=0 (hard=0 soft=0)
```

14. Alloc xApp receives PRB_PRED_RSP from prbpred xApp, computes the PRB to be allocated e to E2



```
31-Oct-21 10:03:33 - [msg_to_pred]
31-Oct-21 10:03:33 - [INFO] Message to   ed : message sent Successfully
31-Oct-21 10:03:33 - [INFO] Recei   d acknowldgement from pred (PRB_PRED_RSP): {'payload': b'{"prediction": [71.7, 7
0.6]}', 'payload length': 28, 'message type': 30002, 'subscription id': -1, 'transaction id': b'aaec35103a3111ec832
aeadad170f84a', 'message state': 0, 'message status': 'RMR_OK', 'payload max size': 3136, 'meid': b'', 'message sou
rce': 'service-ricxapp-prbpredxapp-rmr.ricxapp:4560', 'errno': 0}
31-Oct-21 10:03:33 - Estimated PRB usage of Slice 1:25
31-Oct-21 10:03:33 - Estimated PRB usage of Slice 2:25
31-Oct-21 10:03:33 - PRB allocated to Emgerceny SLice :50
```

Proposed Future Work

- Build a multivariant timeseries model with monitored data and arrive at proper inference.
- It is recommended that gNode/E2 interface has reserved resources for Emergency situations. Additionally, based on the situation resource reallocation from lower QOS based services should be explored.
- Develop a user friendly webapp to onboard xApp's & trigger policy towards near-RT RIC and support visualisations
- Extend the solution to self learning Closed Loops with following capabilities :-
  - Continuously perform Collection, Analytics, Decision and Actuation
  - Detect model performance and trigger a switch-over to another better performing model
- Analyse and trigger different set of data/measurements for data analysis
- Points for future study from FGAN-O-013 :=
  1) How ML pipelines can be synchronized/managed across the edge and emergency responder devices ?
  2) The split of inference tasks/model functionalities between edge and emergency responder devices

Open Issues

a. ricplt-influxdb-meta-0 pod is in pending state in RIC platform. Tried all the suggestion as mentioned in RIC wiki but couldn't succeed

b. Not receiving Subscription response from Subscription Manager

c. Behaviour on A1 mediator sending A1 POLICY REQ when policy instance is CREATED/UPDATED to xApps is suppressed in Dawn release

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