ITU ML5G Build-a-thon

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

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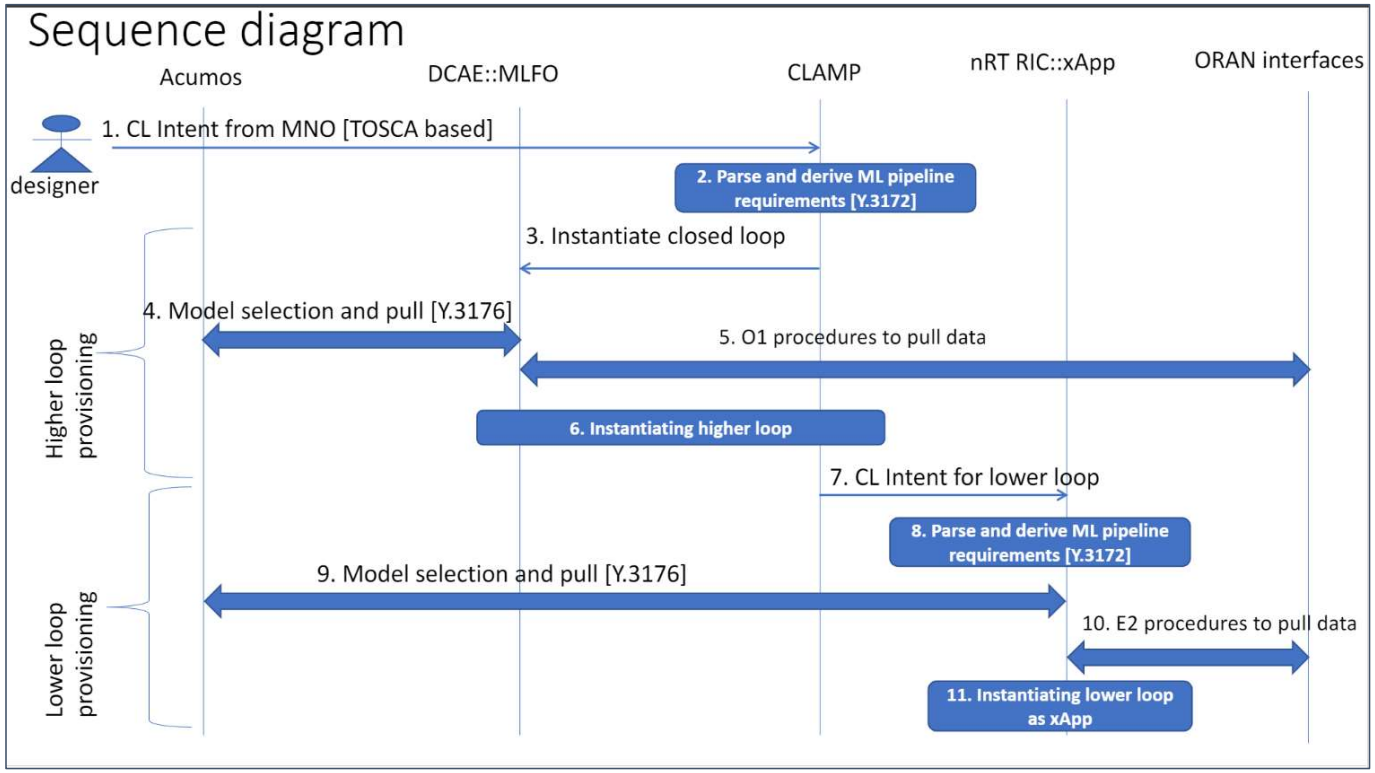
Build-a-thon Activity-4 ORAN CONTROL LOOP INSTANTIATION

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 -

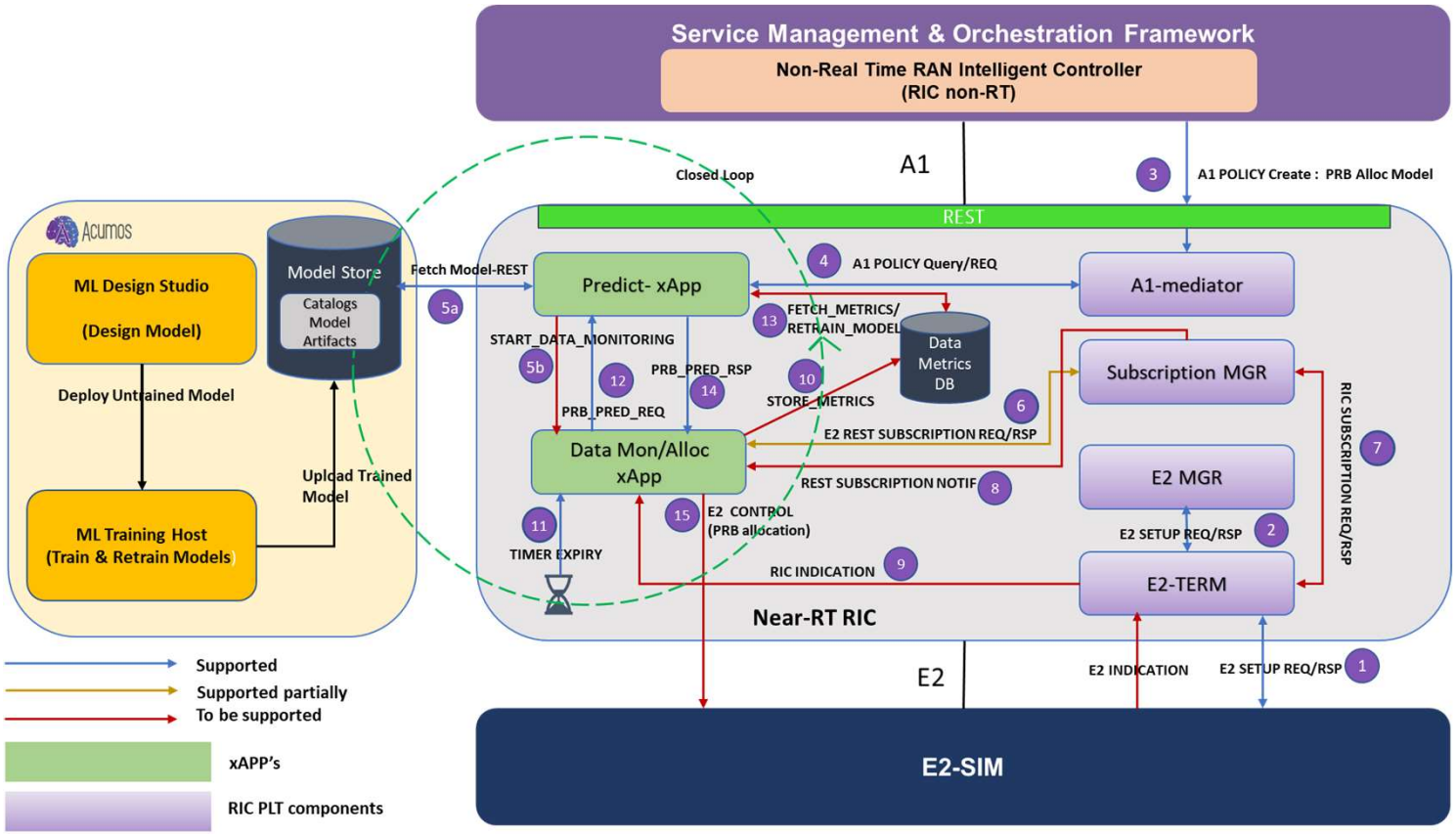
Note:- Activity 4 corresponds to Steps 8 &9



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

WorkFlow

Points 1&2 show E2 SIM is up and association with RIC is setup

Point 3 nRT RIC receives A1 policy update to trigger closed loop monitoring

Point 4 A1-mediator sends A1 Policy REQ to prbpred xApp

Point 5a, Point 5b show the model is fetched from model store as per policy guidelines and prbPred instructs DataMon/Alloc xApp to start monitoring the data

Point 6,7,8 shows the messaging done for subscribing to E2 for data

Point 9 shows Data reception from E2 node. The received metrics are stored in metrics DB as in Point 10

Upon timer expiry as in Point 11, request for Prediction is sent to prbpred xApp as in Point 12.

prbPred uses ML model to predict the future utilisation. Based on new data model retraining may be done. Predicted values may be send to Datamon/Alloc xApp as in Points 13,14.

DataMon/Alloc xApp computes the PRB to be allocated and sends E2 control message towards E2 as in Point 15

xApp POC Implementation Details

Prbpred- xApp is developed as Reactive xApp

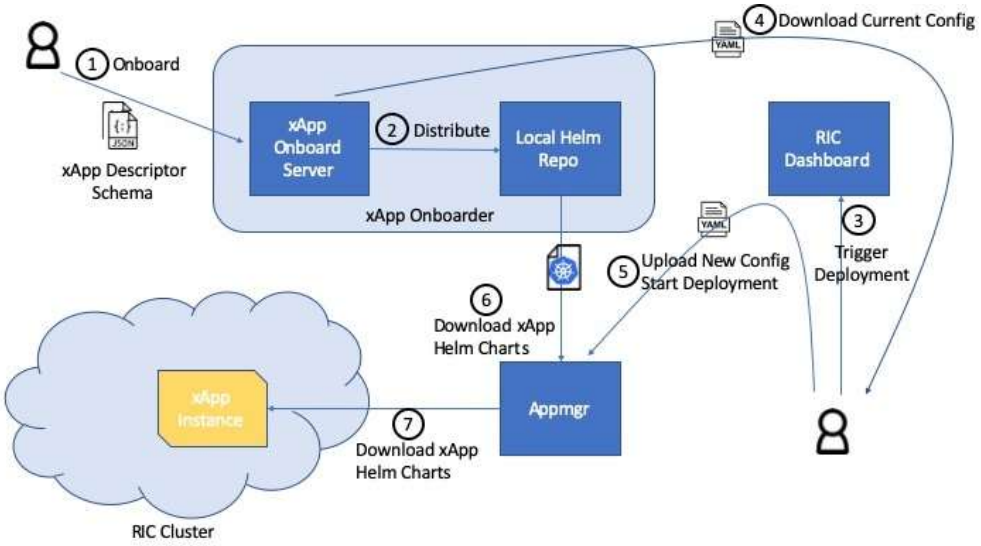
i. Upon Initialization does following :-
    i. Registers for PRB_PRED_REQ (PRB Prediction Request) and A1_POLICY_REQ (A1 Policy Request)
    ii. xApp provides details of the policy supported in xApp-descriptor and registers handler function to receive A1_POLICY_REQ
    iii. Queries A1-mediator and gets 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

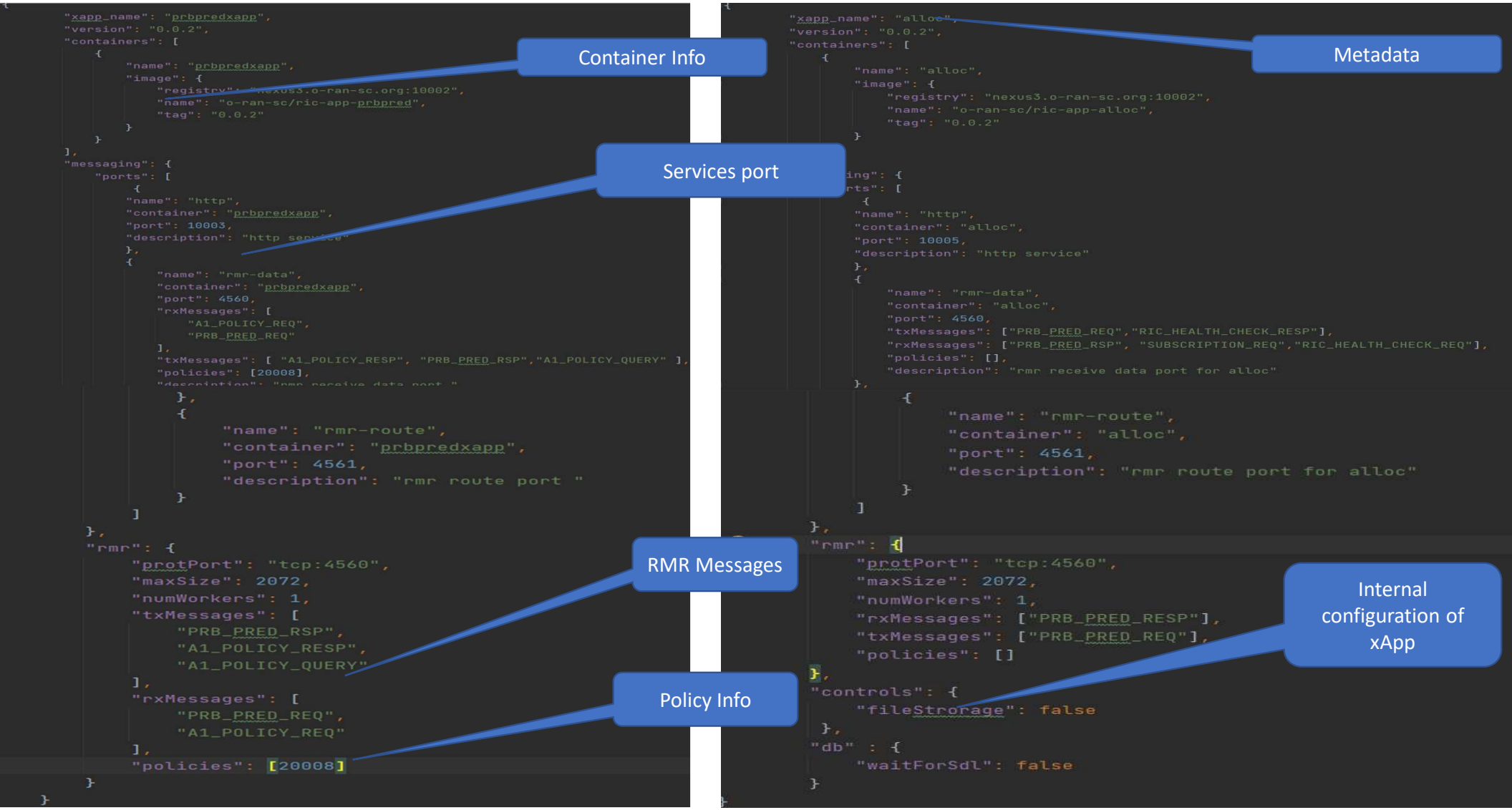
docker run --rm -u 0 -it -d -p 9090:8080 -e DEBUG=1 -e STORAGE=local -e STORAGE_LOCAL_ROOTDIR=/charts -v $(pwd)/charts:/charts chartmuseum/chartmuseum:latest
export CHART_REPO_URL=http://0.0.0.0:9090
dms_cli onboard --config_file_path=config.json --shcema_file_path=/root/appmgr/xapp_orchestrater/dev/docs/xapp_onboarder/guide/embedded-schema.json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



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.

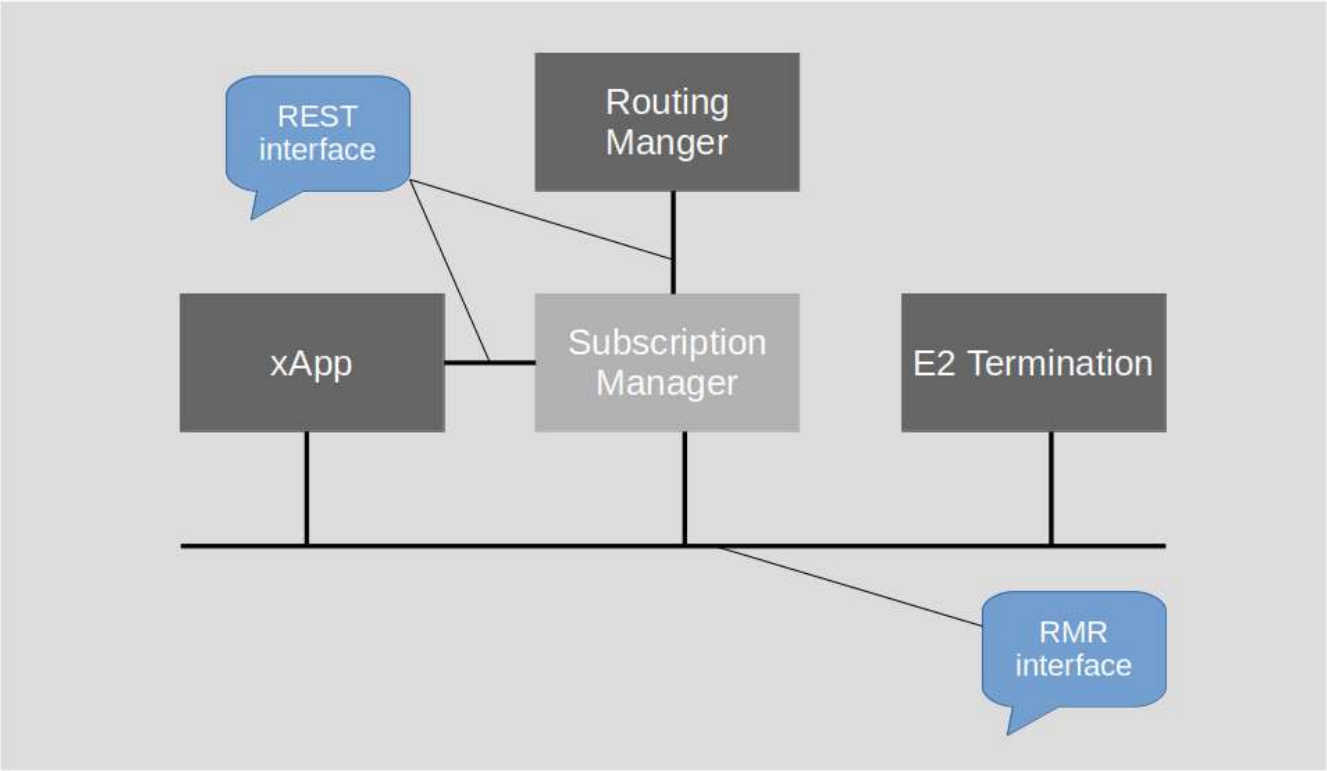
Subscription Manager

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



xApp can make subscriptions to E2 Node through Subscription Manager

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

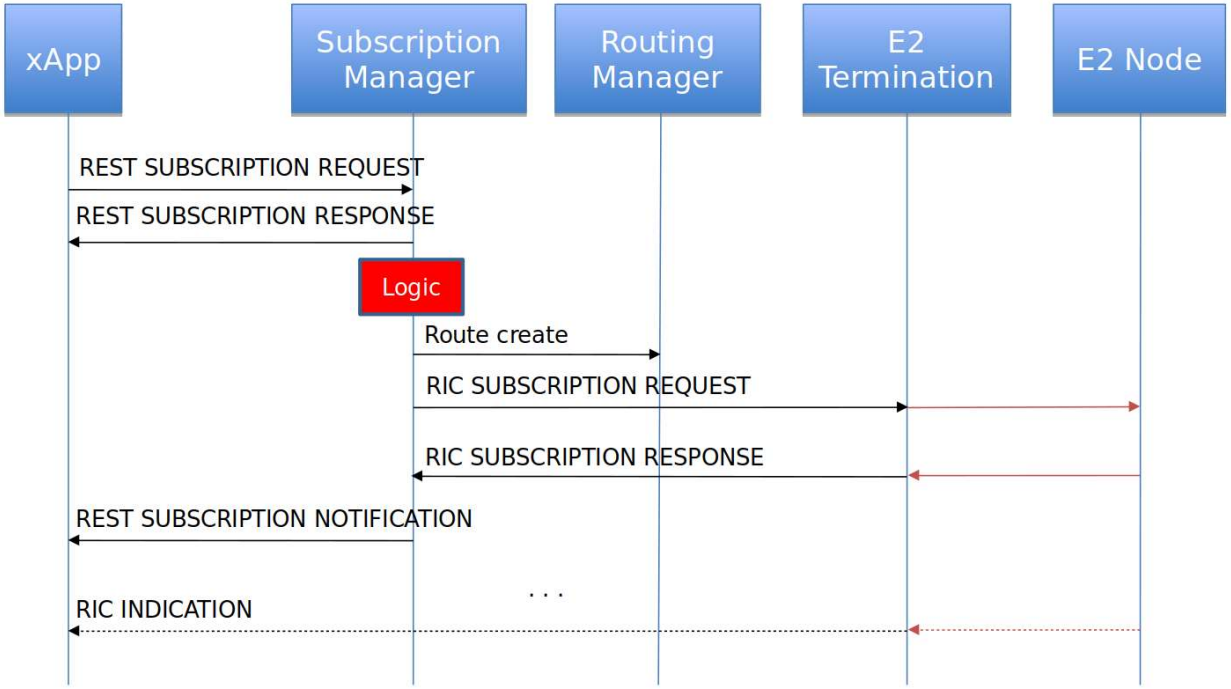
Subscribed messages from E2 Node are transported to RIC inside RIC Indication message. RIC Indication message is transported to xApp inside RMR message in Payload field of the RMR message.

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.

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

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	41d
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[illegible]	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

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>
        <GlobalE2node-ID>
            <gNB>
                <global-gNB-ID>
                    <plmn-id>37 34 37</plmn-id>
                    <gnb-id>
                        <gnb-ID>
                            1011010111000110011101111000 1
                        </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

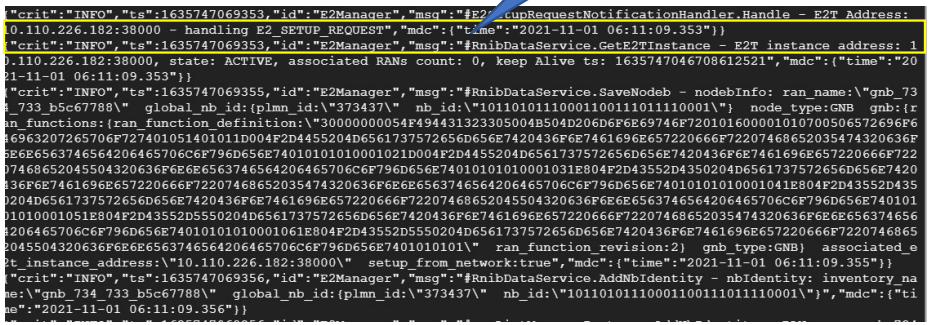
Associate RAN ->E2T Instance

State change to CONNECTED

E2 SETUP REQ

RIC E2 SETUP RESP

4. E2 Mgr receiving E2 Setup Request



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

E2 Setup details can be confirmed with response from below CURL command

6. E2 Setup Response at E2 SIM end

E2 SETUP RESPONSE- ricid

```
<E2setupResponse>
    <protocolIEs>
        <E2setupResponseIEs>
            <id>4</id>
            <criticality><reject/></criticality>
            <value>
                <GlobalRIC-ID>
                    <pLMN-Identity>13 10</pLMN-Identity>
                    <ric-ID>
                        1010101011001110
                    </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":"10110101110001
00111011110001"},"nodeType":"GNB","gnb":{"ranFunctions":[{"ranFunctionDefinition":"30000000054F494431323305004B504D206D
F6E69746F72010160000101070050657269 6F6469 6207265706F72740105140101 1D004F2D4455204D6561737572656D656E7420436F6E7461696E
57220666F722074686520354743206 36F6E6E6563746564206465706C6F796D656E7401010101000102 1D004F2D4455204D6561737572656D656E742
0436F6E7461696E657220666F722074686520455043206 36F6E6E6563746564206465706C6F796D656E7401010101000103 1E804F2D43552D435020
D6561737572656D656E7420436F6E7461696E657220666F722074686520354743206 36F6E6E6563746564206465706C6F796D656E7401010101000 1D
41E804F2D43552D4350204D6561737572656D656E7420436F6E7461696E657220666F722074686520455043206 36F6E6E6563746564206465706C6F7
96D656E7401010101000105 1E804F2D43552D5550204D6561737572656D656E7420436F6E7461696E657220666F722074686520354743206 36F6E6E6
5637465642064657 06C6F796D656E7401010101000106 1E804F2D43552D55502* Connection #0 to host 10.244.0.128 left intact
04D6561737572656D656E7420436F6E7461696E657220666F722074686520455043206 36F6E6E6563746564206465706C6F796D656E7401010101","
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/policies/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
  }
}
```

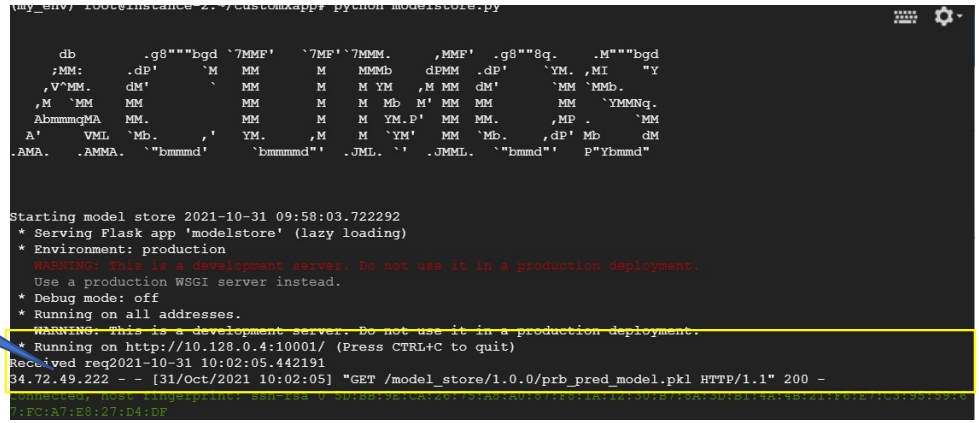
xApp Screenshots & Model store

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
```

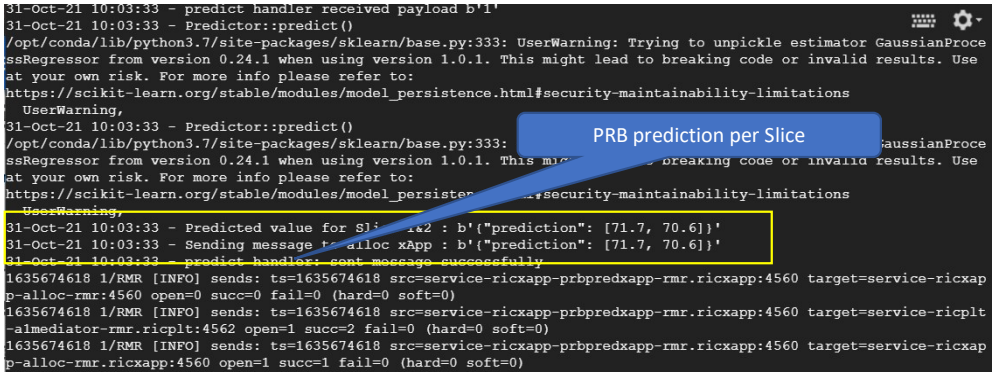
11. Emulated Acumos Model Store listening on 10001 port, receives REST REQ for fetching model. Acumos functionality was emulated considering HW requirements in bringing up Acumos.

Model Fetch Request

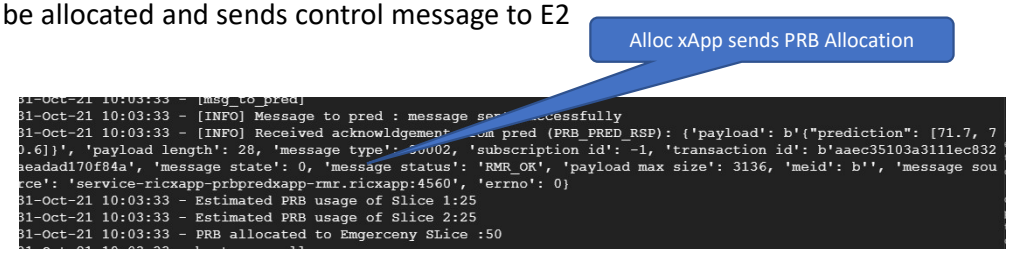


12. Below Snapshot shows REST Req being sent to model store with the details received from A1 policy request. Model store URL being constructed based on the A1 policy request. Model is successfully downloaded to prbpred container.

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



14. Alloc xApp receives PRB_PRED_RSP from prbpred xApp, computes the PRB to be allocated and sends control message to E2



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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