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Traffic Steering xApp

TECHNICAL SPECIFICATION

Overview

In 5G networks, users can be served with the use of multiple Radio Access Technologies (RATs), e.g., 5G-NR, LTE, LAA and 802.11x standards. Moreover, within each RAT, users can be associated with a specific cell, and then allocated to one or more of the available frequency bands and component carriers. In addition, a user may be simultaneously connected to the two base stations, with the use of Dual Connectivity (DC). On the other hand, 5G networks are to be capable of serving highly diversified traffic. There are many use cases related to fulfilling specific Quality-of-Service (QoS) requirements, e.g., buffered video streaming requires large bandwidth, and allows relatively relaxed latency, while voice connection demands small bandwidth, but low and predictive latency is of high importance, not mentioning URLLC services. On top of that, users, characterized by similar QoS requirements, can be served within the dedicated Network Slices.

As mentioned, 5G networks are characterized by various options for serving users (RATs, frequency bands, cells), and diversified mobile traffic of heterogeneous QoS demands. The challenge for the Mobile Network Operators (MNOs) is to effectively decide how to serve a particular user (or a group of users) to meet their per-Slice, or per-QoS type demands. Especially, it is of high importance to avoid load unbalancing between cells, e.g., in situations where a particular cell is highly loaded, while a neighboring cell serves only a few users. Fortunately, the contemporary mobile networks are deployed in such a manner that the user usually is in the range of several cells, that possibly offer several frequency bands and component carriers. This opens up an opportunity to introduce Traffic Steering (TS), aimed at associating users with certain cells, frequency bands, and component carriers, e.g., to balance the network load. The typical approach to TS is that all users are treated in the same way, which means that handover or cell reselection decisions are taken based on average KPI values. As a result, TS rules are limited to setting e.g., general handover thresholds, and cell priorities. However, a much more efficient approach to the TS is to formulate context-based rules, e.g., user-centric, related to QoS Flows, or Slice-specific. Such TS rules allow flexible, and intelligent cell reselection rules possibly based on accurate Machine Learning (ML) inference. This document describes a solution dedicated to this problem developed by the Rimedo Labs in the form of an xApp operating within the O-RAN architecture, at the Near-Real-Time RAN Intelligent Controller (Near-RT RIC).

Traffic Steering xApp

For the purpose of intelligent and flexible user-to-cell association, Rimedo Labs proposes a Traffic Steering xApp (TS-xApp). It can be used by the MNO to realize different TS targets, e.g., one target can be to balance the cell load within the network, a different possibility is to perform service-based association, yet another is to utilize energy saving mechanisms to improve energy efficiency. The xApp intelligently controls the cell preferences, and mobile handovers, related to individual users, users within the same QoS Flows, or users being associated with a given network slice, in order to improve utilization of radio resources within the network and meet users' QoS demands.

In the example shown in Figure 1, mobile users are requesting two types of services: Voice (light blue users), and Mobile Broadband (dark blue users). The users are being served by one of the two cell types: Macro Cell

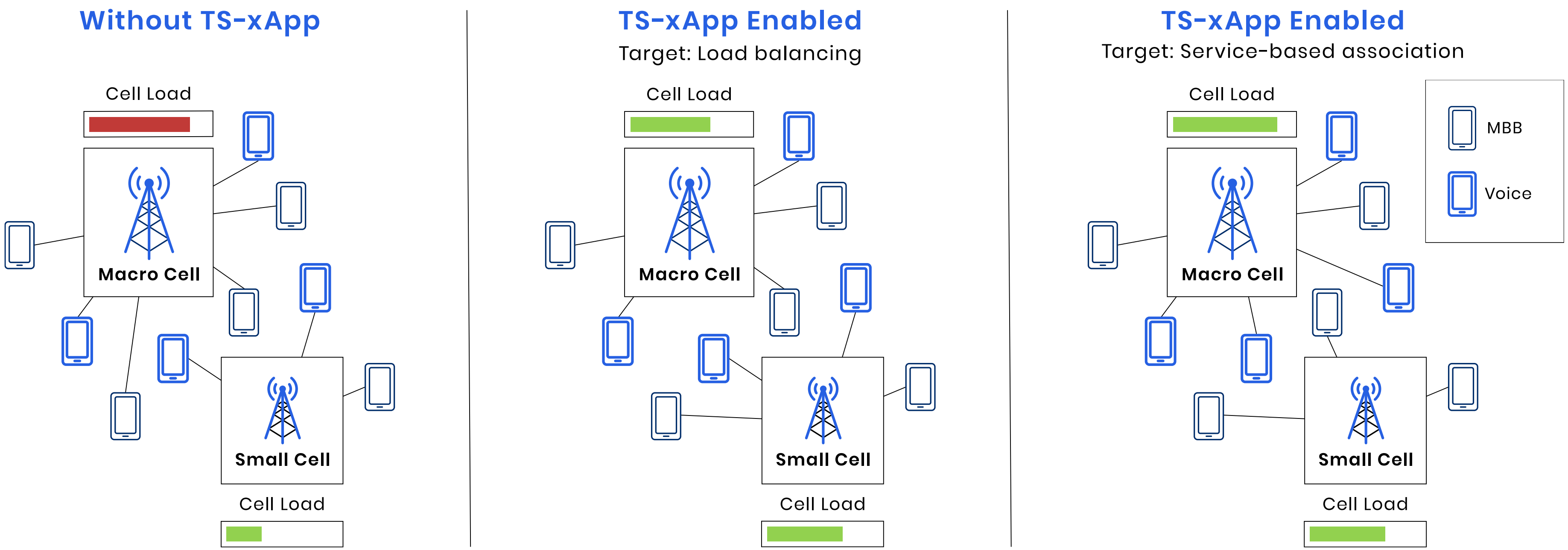

Figure 1. Example of TS-xApp operation

providing general coverage, and Small Cell to increase network capacity. Initially, users are assigned to cells on the basis of a static threshold, based on the Reference Signal Received Power (RSRP). This result in a highly loaded Marco Cell, and low load at Small Cell. This is a place for TS-xApp to enable intelligent handover in order to improve network performance. The TS-xApp can act in order to meet different MNO- defined targets. The first target is to update cell preferences so as to balance the load between cells in the network, i.e., to split users equally between the cells. Another target is service-oriented, i.e., cell preferences for the MBB users are set by the MNO to prefer Small Cell, while Voice users' cell preferences are set by the MNO to prefer Macro Cell. Such a policy is motivated by the fact that for the voice users the main objective is to avoid frequent handovers and utilize relatively small bandwidth. These requirements for the Voice users can be ensured by associating them with the Macro Cell of large coverage. On the other hand, MBB users require high throughputs, which can be achieved by offloading them into the Small Cell of high capacity. Such a policy also improves the load balance, i.e., by offloading MBB

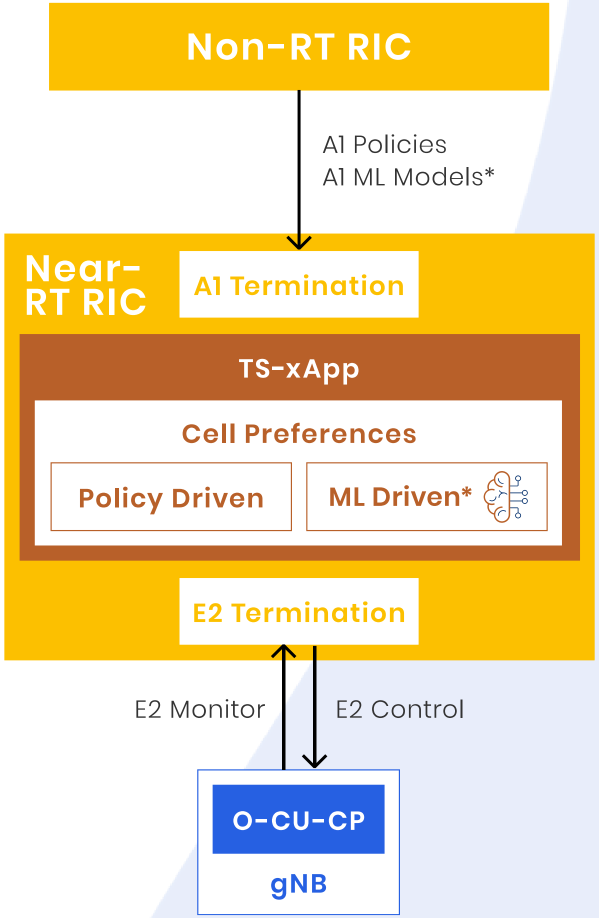

Figure 2. The deployment of TS-xApp within the O-RAN architecture.
*ML modules are currently under development

users to the Small Cells, Macro Cell has enough radio resources to provide the required QoS for the Voice users.[1]

The interfaces related to the QRA-xApp within O-RAN architecture is depicted in Figure 2 and are described in the next sections.

Parameters Monitored Through E2 Interface – Inputs to TS xApp

The TS-xApp is deployed at the Near-RT RIC to perform network optimization within the control loop of between 10 ms, and 1 s. To achieve this goal, the TS-xApp must determine the current network state via the E2 interface. In compliance with the O-RAN Alliance specification [1] the following parameters are monitored by the TS-xApp:

Mandatory Parameters – necessary to update cell preferences and assure basic load balancing and slice-oriented handover

- **Distribution of Synchronization Signal Reference Signal Received Power (SS-RSRP)** – provides TS-xApp with the information about the distribution of SS-RSRP received by the gNB from the UE. The distribution of SS-RSRP can be measured both for UE's serving, and neighboring cells [2].
- **User Equipment Identity (UE ID)** – provides the TS-xApp with information about the user identifier to be used, for the purpose of monitoring parameters, and control actions on the E2 interface
- **Cell Global Identity (CGI)** – the combination of Public Land Mobile Network Identity (PLMN ID) and E-UTRAN Cell Identity (ECI) or New Radio Cell Identity (NCI) [3].
- **Single** – Network Slice Selection Assistance Information (S-NSSAI) – identifies a network slice within a PLMN. It is a combination of the slice/service type (SST) and a slice differentiator (SD) [4].
- **5G QoS Identifier (5QI)** – a parameter associated with a particular 5G QoS characteristic. These characteristics define requirements for a QoS Flow, e.g., packet error rate, and priority [4]

[1] Currently TS-xApp supports user-centric and QoS Flow-oriented service based association. Load balancing features are under the development

- **Mean number of RRC Connections** – provides the TS-xApp with information about the mean number of active UEs. It is defined as a mean number of users in RRC connected mode for each NR cell during granularity period. It can be split per PLMN ID [2].
- **Max number of RRC Connections** – provides the TS-xApp with information about the max number of active UEs. It is defined as the maximum number of users in RRC connected mode for each NR cell during granularity period. It can be split per PLMN ID [2]..

Optional Parameters – useful to deploy advanced load balancing features, improve mobility robustness, and ML inference

- **Distribution of DL/UL UE throughput in gNB** - provides the xApp with information about the distribution of user throughput in either DL or UL. These measurements can be obtained within the scope of a gNB, network slice, or QoS Flow [2].
- **Radio Resource Utilization** - is a group of parameters being obtained by the TS-xApp to monitor the utilization of Physical Resource Blocks (PRBs) at a certain gNB. These are [2]:
    - **DL/UL total available PRB** – provides TS-xApp with information about the total number of PRBs available for DL/UL transmission at certain gNB
    - **Mean DL/UL PRB used for data traffic** – provides TS-xApp with information about the average number of PRBs being used in DL/UL for data traffic over a given period. These statistics can be obtained within the scope of gNB, network slice, or QoS flow.
    - **Peak DL/UL PRB used for data traffic** - provides TS-xApp with information about the peak number of PRBs being used in DL/UL for data traffic over a given time. This information can be provided within the scope of gNB, network slice, or QoS Flow.
- **Mobility Management** – is a group of parameters being obtained by the TS-xApp to monitor the mobile handover statistics. These are [2]:
    - **Inter-gNB handovers** – provides the TS-xApp with information about the statistics of the inter-gNB handovers, including the number of requested handovers, and the number of successful handovers.
    - **Intra-gNB handovers** - provides the TS-xApp with information about the statistics of the

intra-gNB handovers, including the number of requested handovers, and the number of successful handovers.

- **Intra/Inter-frequency Handover related measurements** - provides the TS-xApp with information about the statistics of the handovers, between frequency bands within the same (intra), or between the neighboring (inter) cells.

Parameters Controlled Through E2 Interface – Outputs from TS xApp

To improve the performance of a mobile network, the TS-xApp balances the load between cells. This load balancing can be understood as switching users between cells, e.g., to achieve equal cell loads, and separate users of different QoS demands (service-based association). The TS-xApp performs cell association via the E2 interface, with the use of the dedicated **handover control mechanisms** defined in the O-RAN Alliance specification [5]. In compliance with this specification the TS-xApp controls the following parameters:

Mandatory parameters – parameters that are necessary to be set in order to switch users between cells

- **User Equipment Identity (UE ID)** – used to specify which UE will be subject to handover procedure
- **Primary Cell ID** – CGI of the primary cell, that serves the UE selected for handover
- **Target Primary Cell ID** – CGI of the cell that is target primary cell for the UE in the handover procedure
- **List of PDU sessions for handover** – list of the Protocol Data Unit (PDU) sessions identifiers, that are subject to the handover procedure
- **List of DRBs for handover** – list of the Data Radio Bearers (DRBs) identifiers, that are subject to the handover procedure

Optional parameters – parameters that increase the flexibility of TS:

- **List of Secondary cells to be setup** – identifiers of the secondary cells that would be setup for the UE that is subject to handover procedure

Policy-Driven Traffic Steering – Inputs to TS xApp from A1

The aim of the TS-xApp is to dynamically (under a near-RT control loop) switch users between cells to achieve TS targets, e.g., service-based association. The user association is done through the E2 interface with the use of O-RAN-defined handover control mechanisms. By default, the TS-xApp switches users between cells, based on policies sent by the Non-RT RIC through the A1 interface. These policies contain rules that indicate TS-xApp the cell preferences. These cell preferences can be user-centric, or slice-oriented. Additionally, to enable service-based association QoS Flow can be specified together with either UE ID or S-NSSAI. The TS-xApp using the cell preferences provided from Non-RT RIC through the A1 interface, and SS-RSRP values obtained from the E2 interface makes proper handover decisions. According to the O-RAN Alliance specification, the policy type for traffic steering purpose is named "Traffic Steering Preferences", and consists of the Traffic Steering Preference Resources (TspResources), which are defined as follows [6].

Parameter	Data Type	Obligatory	Description
cellIdList	CellIdList	Yes	list of CellIDs
preference	PreferenceType	Yes	the preference of cell usage [SHALL/PREFER/AVOID/FORBID]
primary	Primary	Optional	indicates applicability to the selection of primary cell

"Traffic Steering Preferences" policies are sent from the Non-RT RIC to the TS-xApp through the A1 interface in the form of JSON files. A representative example of such a policy is depicted in Figure 3.


```
{
  "scope": {
    "ueId": "0000000000000855"
  },
  "tspResources": [
    {
      "cellIdList": [
        {"plmnId": {"mcc": "248","mnc": "35"},
          "cId": {"ncI": 39}},
        {"plmnId": {"mcc": "248","mnc": "35"},
         "cId": {"ncI": 40}}
      ],
      "preference": "PREFER"
    },
    {
      "cellIdList": [
        {"plmnId": {"mcc": "248","mnc": "35"},
          "cId": {"ncI": 81}},
        {"plmnId": {"mcc": "248","mnc": "35"},
          "cId": {"ncI": 82}},
        {"plmnId": {"mcc": "248","mnc": "35"},
         "cId": {"ncI": 83}}
      ],
      "preference": "FORBID"
    }
  ]
}
```


Figure 3. Example of JSON file containing TS Preferences policy that defines user-centric cell preferences UE [6]

Machine Learning Driven Traffic Steering[2]

TS-xApp can operate can use an ML model to dynamically select Traffic Steering Preferences policy, on the basis of observed network conditions. It can be done either instead, or as a supplement to the policy obtained by the TS-xApp from A1 interface. In the first option, the ML model decides on the policy enforcement, while in the second option, ML is used to establish cell preferences within the group of cells predefined by the MNO-defined policy. The ML model is continuously improved/trained in Non-RT RIC through interaction with the RAN (environment), i.e., following the concept of Reinforcement Learning. First, the pre-trained ML model is provided to the TS-xApp from the Non-RT RIC through the A1 interface. It is used to determine the proper per-user, per-slice, or per-QoS policies to be enforced by the TS xApp in order to update users' cell preferences (action) based on input information from the E2 interface, e.g., UE throughputs, number of active UEs (state). At the same time, Non-RT RIC monitors the performance of actions in terms of cell load, or by comparing QoS metrics obtained through the O1 interface against SLAs and individual QoS Flows requirements, i.e., obtains reward. Finally, on the basis of action, state, and reward sequences non-RT RIC can improve the ML model. The resultant Reinforcement Learning Cycle is depicted in Figure 4.

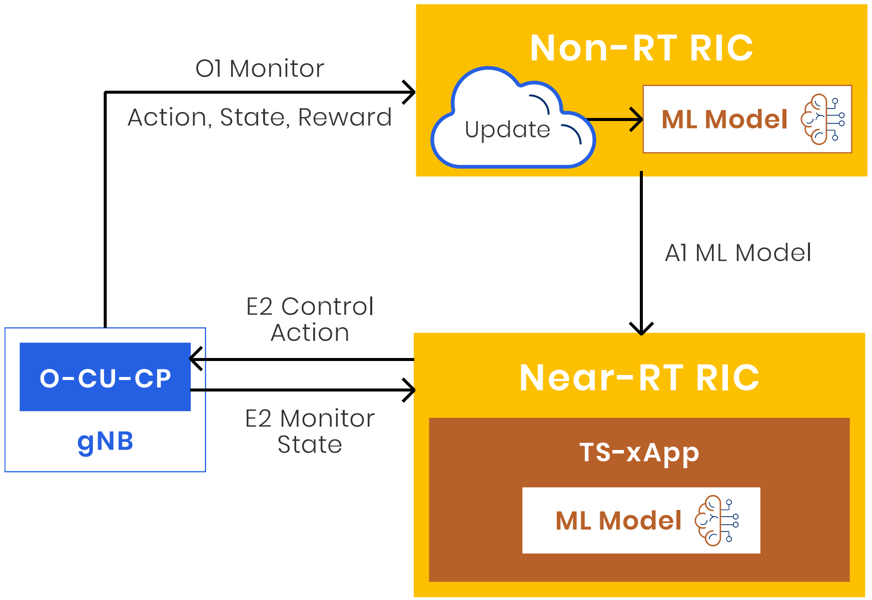

Figure 4. The Machine Learning-Driven resource allocation in TS-xApp

[2]The Machine Learning modules are currently under the development

Features and Applications

- TS-xApp addresses a use case of Traffic Steering as identified by the O-RAN Alliance [7]. The main objective of the use case is to allow operators to flexible switching individual users between cells.
- TS-xApp can be used by MNOs to improve the performance of the network, in terms of either load balancing, or service-based association.
- The radio resource allocation can be driven either by the policies defined by the MNOs or independently by the internal intelligence of TS-xApp, i.e., Machine Learning
- TS-xApp is suitable for optimization of the heterogeneous networks, e.g., cell preferences of Mobile Broadband users (like video streaming) can be set to "prefer" small cells, while cell preferences of voice users can be configured to prioritize Macro-Cells.
- The policy-driven version of TS-xApp is integrated with the SD-RAN environment. A simplified TS xApp version is open-source and available at: https://github.com/onosproject/rimedo-ts
- The performance of TS-xApp can be improved when working in the cooperation with other Rimedo xApps, and rApps e.g., QoS-based Resource Allocator xApp (QRA-xApp), Frequency Band Selector rApp*

More resources

- Rimedo's blog post covering the topic of Traffic Steering use-case within the context of O-RAN architecture:
  - O-RAN Use Cases: Traffic Steering
- Rimedo's blog post, and scientific paper, covering the topic of TS xApp concept and implementation, including utilization of the ML inference for the policy selection:
  - xApp Implementation: O-RAN Traffic Steering Use Case
  - Toward Modular and Flexible Open RAN Implementations in 6G Networks: Traffic Steering Use Case and O-RAN xApps
- Rimedo's blog post, on the open-source implementation of the TS xApp:
  - Policy-based Traffic Steering xApp implementation within O-RAN

Bibliography

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[2] 3GPP TS 28.552 V17.6.0, "Technical Specification Group Services and System Aspects, Management and orchestration, 5G performance measurements", 3rd Generation Partnership Project, March 2022

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[4] 3GPP TS 23.003 V17.5.0, "Technical Specification Group Core Network and Terminals, Numbering, addressing and identification", 3rd Generation Partnership Project, March 2022

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[7] O-RAN.WG2.A1TD-v02.00, " O-RAN A1 interface: Type Definitions", O-RAN Alliance, October 2021

[8] O-RAN.WG2.Use-Case-Requirements-v05.00, "O-RAN Non-RT RIC & A1 Interface: Use Cases and Requirements", O-RAN Alliance, March 2022

Notes:

- For cooperation models, reach out to us at: info@rimedolabs.com
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RIMEDO LABS

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RIMEDO Labs specializes in providing high quality consulting, implementation and R&D services in the field of Open RAN, 5G and 6G. We are a spin-off from the Poznan University of Technology, Poland from the Institute of Radiocommunications.

Our services in the Open RAN area include:

- xApp and rApp development for the RAN Intelligent Controller;
- Pre-recorded an Live technical courses delivery;
- Live webinars;
- Dedicated simulations and algorithm design;
- Whitepapers and technical articles delivery

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