ProSLICE
Programmable Multi-RAT Network Slicing with OAI in the Open RAN Era

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Disaggregating the Radio Access Network

### Background

The Open RAN Treatment

#### Traditional Monolithic RAN
- **Black-box approach** with **closed** internal interfaces
- **Limited flexibility** due to one-size-fits-all design
- **Limited** third-party application ecosystem for network assurance and control

#### Disaggregated Open RAN
- **Disaggregated approach** with **open** internal interfaces
- **Rich** third-party support for network assurance and control through Near-RT and Non-RT RICs
- **Enabler of softwarization** and **programmability** within RAN

### O-RAN Use Cases
- Infrastructure sharing, network slicing, enterprise wireless, UAV networks, etc.

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# Background

## A Closer Look at the O-RAN Architecture

### O-RAN Architectural Principles

- New architectural paradigm for the RAN with a focus on:
  - **Disaggregation**
  - **Programmability**

<table>
<thead>
<tr>
<th>Disaggregation</th>
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<tbody>
<tr>
<td>O-RAN disaggregates the DU into:</td>
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<tr>
<td>- <strong>O-RAN DU</strong>: RLC, MAC, and high PHY</td>
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<tr>
<td>- <strong>O-RAN RU</strong>: Low PHY and RF</td>
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<tr>
<td>3GPP split <strong>7-2x-based</strong> fronthaul between O-DU and O-RU</td>
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</tbody>
</table>

### Programmability

- O-RAN injects programmable control through:
  - **Non-RT RIC**: Policy formulation, ML training, long-term statistics through rApps
  - **Near-RT RIC**: Policy interpretation and execution, ML inference, short-term statistics through xApps
  - **New interfaces**: E2, A1, O1, and O2
RAN Slicing Within O-RAN

Setting the Context

RAN Slicing: Flagship Use Case

- Key use case for the O-RAN architecture
- Several slicing focused initiatives from the O-RAN Alliance:
  - RAN Slice SLA Assurance
  - NSSI Resource Allocation Optimization
  - RAN Sharing

Research Objectives

- Multi-RAT O-RAN platform with support for both monolithic as well as fully disaggregated network functions
- Programmable multi-RAT RAN slicing across 4G LTE and 5G SA
- Simplifying Near-RT RIC-related operations in support of RAN slicing
RAN Slicing Within O-RAN
Leveraging OpenAirInterface

OpenAirInterface—Setting the Standard for Open-source RAN Solutions

- **Excellent starting point** for building an O-RAN-compliant platform:
  - 4G LTE, 5G NSA, and 5G SA supported
  - Disaggregation support with CU-DU split
- **Rapid rolling releases** with weekly updates
- **Fantastic community** with active developer participation
- **Comprehensive feature set** with both FDD and TDD support
- **UE stack** to assist with non-standards-compliant research
- **RFSIM/emulation mode** for rapid development and testing

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Introducing ProSLICE

An O-RAN Compliant Multi-RAT RAN Platform for Network Slicing
ProSLICE: Programmable Multi-RAT Network Slicing for O-RAN

The RAN Slicing Framework

- **3GPP RAN slicing** for 5G SA + non-3GPP RAN slicing for LTE
- **RAN slice characterization**: RAT type, state, CU-UP associations, resource configuration, scheduling algorithm, associated users
- **Novel RAN slice state machine** for efficient resource utilization
- **Set of RAT-agnostic APIs** for slice configuration and statistics collection

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**Multi-RAT RAN Slicing Framework**

- Idle
  - Num. UEs = 0
  - RAN Slice Initialization
  - State Transition Request
  - UE Registration
  - Dedicated
    - Num. UEs > 0
    - Default Active State
  - Shared
    - Num. UEs > 0
    - Default Active State
  - Prioritized
    - Num. UEs > 0
    - State Transition Request
- Prioritized
  - Num. UEs > 0
  - UE Deregistration
  - Shared
    - Num. UEs > 0
    - Default Active State
  - Dedicated
    - Num. UEs > 0
    - Default Active State
- Dedicated
  - Num. UEs > 0
  - State Transition Request
  - UE Deregistration
  - Default Active State
  - RAN Slice Initialization

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**Slice State Machine**

**Slice 2:**
- Shared → Dedicated
- Dedicated → Prioritized

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**Multi-RAT RAN Slicing**

**Slice State Machine Impact**

- **Downlink Throughput [Mbps]**
- **Time [s]**
- **5G SA**
- **4G LTE**

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ProSLICE: Programmable Multi-RAT Network Slicing
The mRSH RAN Function and Service Model

<table>
<thead>
<tr>
<th>mRSH RAN Function for Multi-RAT Slicing</th>
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<tbody>
<tr>
<td>• New RAN function for network slicing—multi-Radio Slicing Helper (mRSH), along with E2 Service Model specification, E2SM-mRSH</td>
</tr>
<tr>
<td>• Leverages our multi-RAT RAN Slicing Framework</td>
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<tr>
<td>• mRSH RAN Function API for RAN slicing configuration and statistics collection by xApps</td>
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</tbody>
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<tr>
<th>Event Triggers for Reporting</th>
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<tr>
<td>• Periodic reporting with specific resource target, i.e., one or more slices or UEs</td>
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<td>• On-demand reporting with specific resource target</td>
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<td>• UE-NSSI context change reporting</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Slice Statistics Report</th>
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</thead>
<tbody>
<tr>
<td>• RAT Type</td>
</tr>
<tr>
<td>• Slice State</td>
</tr>
<tr>
<td>• CU-UP Association List</td>
</tr>
<tr>
<td>• Slice Scheduler</td>
</tr>
<tr>
<td>• Slice Resource Configuration</td>
</tr>
<tr>
<td>• Associated UE List with Throughput, Latency, and Buffer Occupancy</td>
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</table>

<table>
<thead>
<tr>
<th>UE Statistics Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>• UE RAT</td>
</tr>
<tr>
<td>• UE Priority</td>
</tr>
<tr>
<td>• Last Known Slice Context Change Event</td>
</tr>
<tr>
<td>• Per-slice State</td>
</tr>
<tr>
<td>• Per-slice UE Throughput</td>
</tr>
<tr>
<td>• Per-slice UE Latency</td>
</tr>
<tr>
<td>• Transport Block Size</td>
</tr>
<tr>
<td>• RLC Buffer Occupancy</td>
</tr>
<tr>
<td>• Channel Quality Indicator</td>
</tr>
<tr>
<td>• Modulation and Coding Scheme</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slice and UE Configuration</th>
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<tbody>
<tr>
<td>• Slice Parameters: State, Scheduler, Radio Resource, CU-UP Association</td>
</tr>
<tr>
<td>• UE Parameters: UE RAN Priority</td>
</tr>
<tr>
<td>• 4G LTE: Add/remove/modify slices and slice-user associations</td>
</tr>
<tr>
<td>• 5G SA: Modify slice and UE configuration</td>
</tr>
</tbody>
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ProSLICE: Programmable Multi-RAT Network Slicing
Near-RT RIC with RAN Slice Configuration and Statistics xApps

- Based on the reference Near-RT RIC implementation from the O-RAN Software Community (OSC)
- Two new xApps for RAN Slicing:
  - **mRSH Configuration**: Provides a simple REST API to add, modify, and delete RAN slices. Supports translation of high-level sliceProfiles to low-level configuration parameters
  - **mRSH Statistics**: Obtains slice and user-related performance data. Works in tandem with mRSH Configuration to maintain SLAs for both slices as well as users
  - GUI with “**one-click**” slice configuration and user-slice management and a “**single-pane-of-glass**” statistics visualization dashboard
ProSLICE: Programmable Multi-RAT Network Slicing

Near-RT RIC Graphical Frontend

- Live Network Map
- Live Network Status
- Network Slice Creation Dashboard
- Network Slice Status Dashboard
- Network Slice Statistics Dashboard
ProSLICE: Programmable Multi-RAT Network Slicing
5G SA Slicing Demo Overview and Setup

Key Features

- Run-time programmability and control of slicing operations
- Resource isolation for guaranteed performance
- Slice state control for operational flexibility

Demo Objectives

- Fine-grained performance control
- Operational flexibility through RAN slice state machine
ProSLICE: Programmable Multi-RAT Network Slicing

5G SA Slicing Demo Video