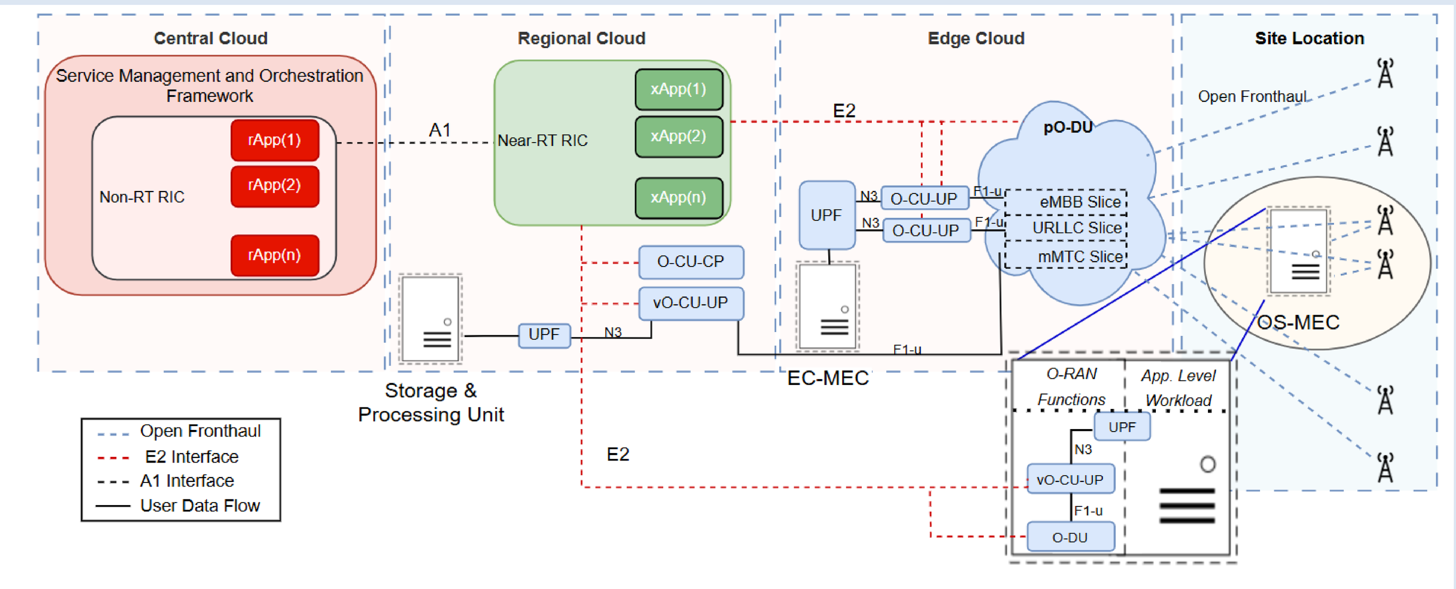
An Optimal Framework for Integrating O-RAN and MEC via Pooled DU/CU Deployment

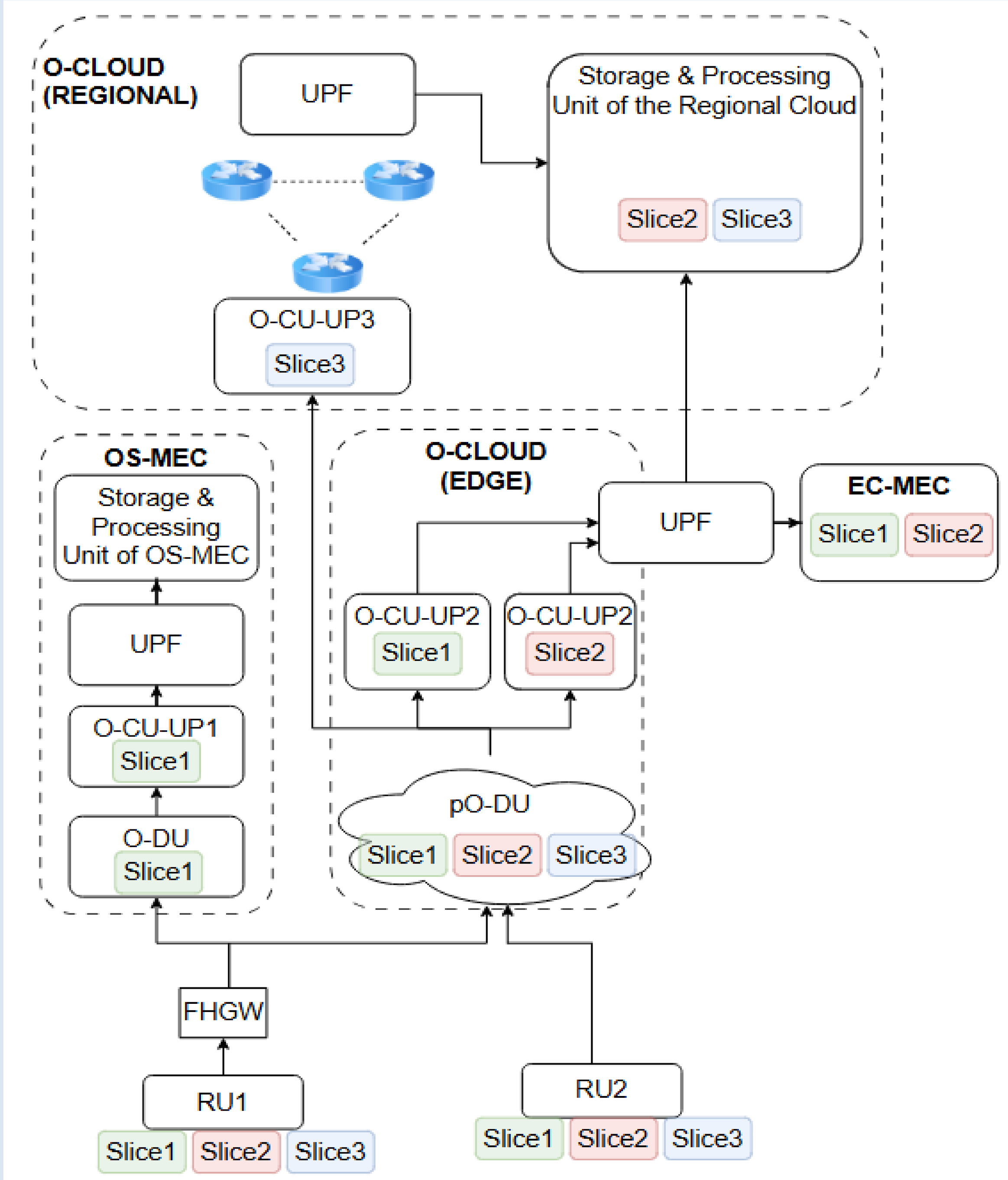
Motivation

- **Pooled Centralisation of O-DU (pO-DU)**
  i. Not all RUs require full capacity simultaneously over a large coverage area, pO-DU enables more efficient resource allocation by resource sharing.
  ii. Adding radio carriers and equipment additions is coarse-grained: A whole unit must be installed rather than fractional increments; this minimum upgrade step can lead to poor utilisation.
  iii. pO-DU addresses challenges such as high maintenance costs and frequent hardware upgrades by centralising baseband processing and reducing the need for site-specific equipment and upgrades.
- **MEC Resource Allocation**
  i. MEC resources provide processing capabilities for latency-sensitive, application-level workloads, and support O-RAN RU/DU functionalities.
  ii. Typically, Edge Cloud resources are located within 20 km of RUs. However, placing MEC within this radius can consume significant transport-network capacity, and a P2P connection may be necessary to meet stringent latency requirements.
- **Research Challenges**
  i. What is the optimal workload distribution between MEC and O-Cloud to minimise delay and cost?
  ii. How can pooling of O-DU resources at the edge be optimised to reduce CAPEX and OPEX while satisfying performance requirements?
  iii. How should intelligence be distributed between the RIC and MEC to orchestrate O-RAN functions and application-layer workloads efficiently?



System model illustration. RUs in the neighbourhood of OS-MEC in the cell site can offload their data to O-DU in the OS-MEC or pO-DU. The interface between RU and DU is Open-Fronthaul. OS-MEC resources are shared by O-RAN functionalities and application-level workloads.

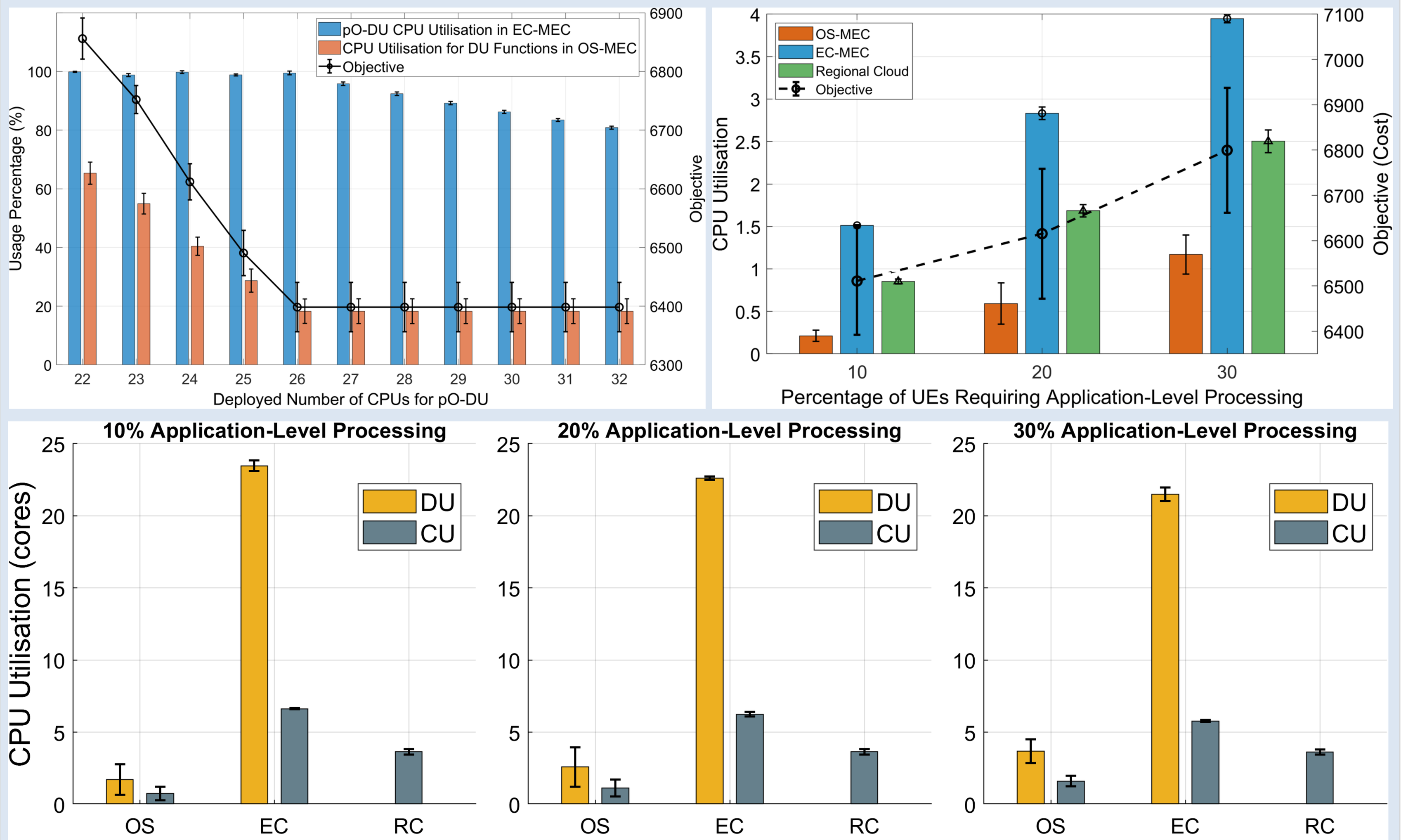
Methodology



Contributions

i. We formulate a novel MILP problem that jointly minimises the cost of deploying DU/CU functions and application-level workloads, as well as the associated transmission and processing delays.
ii. We introduce a pO-DU strategy that pools DU resources in the edge cloud, reducing overall resource usage while still meeting strict latency and capacity demands.
iii. Our framework orchestrates O-RAN functions via the RIC and allocates computationally intensive, delay-sensitive applications to MEC resources, ensuring real-time control loops at the edge, balancing the workload between the RIC and MEC nodes.

Results



Objective Function

$$\min_{\mathbf{x},\rho} (\omega + D)$$

$$\mathbf{x} = \{x_{c,d,r,n}, x_{d,r,n}, x_{c,r,n}\}$$

$$\omega = \sum_{d \in D} \omega_d + \sum_{c \in C} \omega_c^{RAN} + \sum_{c \in C} \omega_c^{App} - \sum_{r \in R} \sum_{n \in N} \rho_{\{r,r',n\}} \quad D = \sum_{c \in C} \sum_{d \in D} \sum_{r \in R} \sum_{n \in N} x_{c,d,r,n}\left(T_{d,r}^{trans} + T_{c,d}^{trans} + T_d^{proc} + T_c^{proc}\right)$$

Key Achievements

a. Our pO-DU strategy achieves an ≈ 19 % reduction in allocated DU cores at 85 % network density, almost one-fifth lower CAPEX/OPEX, while still meeting strict delay targets.
b. Since on-site MEC incurs a higher unit cost, on-site MEC CPU utilisation is limited, which highlights the benefit of offloading to more economical edge cloud MEC resources.
c. RU/slice sessions with the strictest latency demands were almost exclusively offloaded to on-site/ edge cloud MEC resources, RU/slice sessions with more relaxed requirements routed entirely to the Regional Cloud.

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