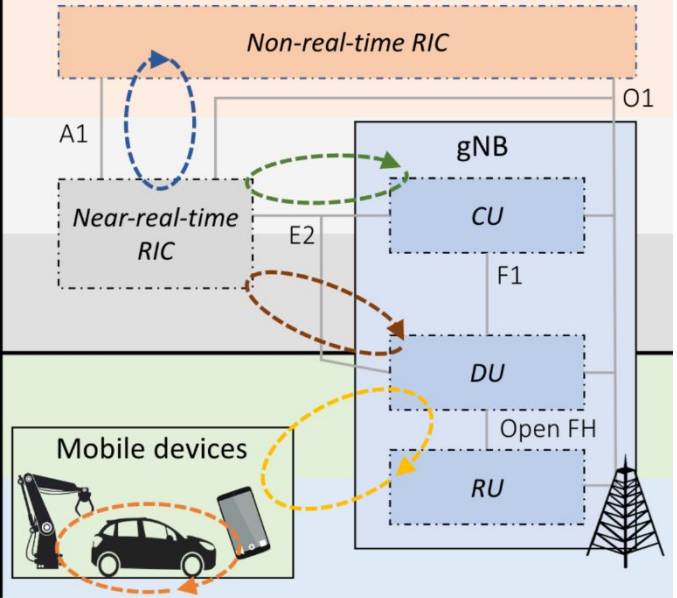
Closed-loop Control in ORAN

Control and learning objective	Scale	Input data	Timescale	Architecture
Policies, models, slicing	> 1000 devices	Infrastructure-level KPMs	Non-real-time > 1 s	
User Session Management e.g., load balancing, handover	> 100 devices	CU-level KPMs e.g., number of sessions, PDCP traffic	Near-real-time 10-1000 ms	
Medium Access Management e.g., scheduling policy, RAN slicing	> 100 devices	MAC-level KPMs e.g., PRB utilization, buffering	Near-real-time 10-1000 ms	
Radio Management e.g., resource scheduling, beamforming	~10 devices	MAC/PHY-level KPMs e.g., PRB utilization, channel estimation	Real-time < 10 ms	
Device DL/UL Management e.g., modulation, interference, blockage detection	1 device	I/Q samples	Real-time < 1 ms	



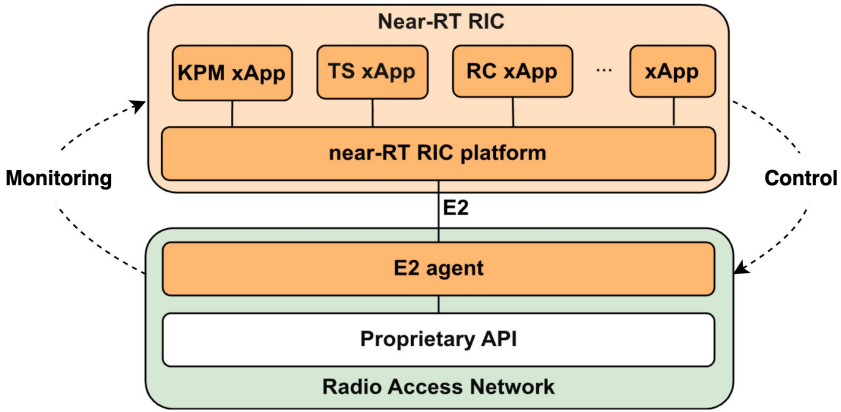
[Polese et al]

Near-real-time Radio Intelligence Controller (Near-RT RIC)

- **Near-RT RIC:** A logical function that enables near-real-time control and optimization of RAN elements and resources via fine-grained (e.g. UE basis, Cell basis) data collection and actions over E2 interface

- The logic of monitor and control is implemented in **xApps**

- **E2 interface** regularizes communication b/w RAN and RIC, offering interoperability among vendors

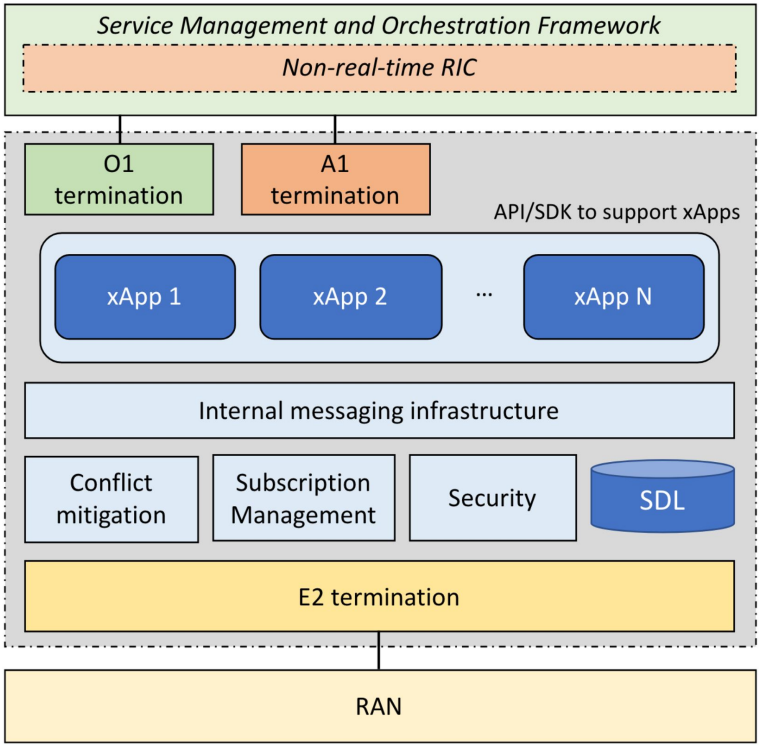


[Ngo et al]

[ORAN Alliance Working Group 3: Near-RT RIC and E2 Interface, E2 General Aspects and Principles (E2GAP)]

Near-RT RIC Architecture

- **Internal messaging infrastructure**
  - connects xApps, platform services, and interface terminations to each other
- **Conflict mitigation**
  - addresses possible conflicts emerging among different xApps
- **Subscription manager**
  - allows xApps to connect to RAN functions

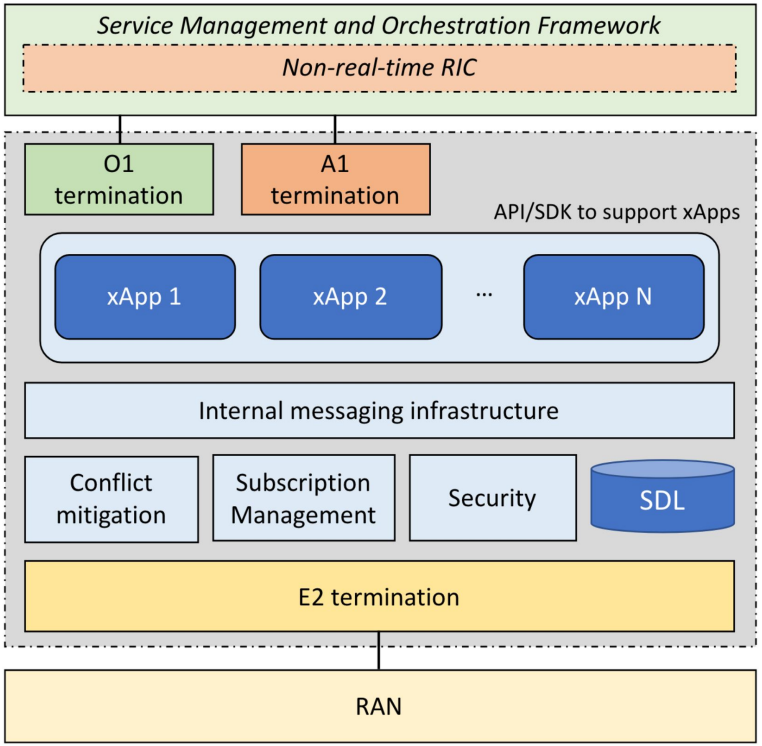


[Santos et al]

Near-RT RIC Architecture (Cont'd)

- **Security**
  - prevent malicious xApps from leaking sensitive RAN data or from affecting the RAN performance

- **Database and Shared Data Layer API**
  - stores information on the E2 nodes, and the UE-NIB contains entries for the UEs and their identity

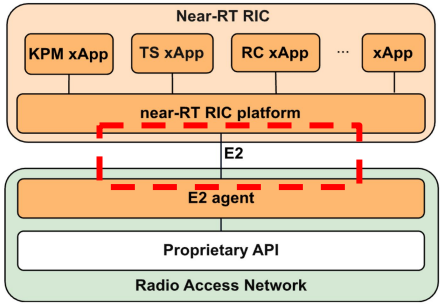


[Santos et al]

E2 Interface

E2 Interface

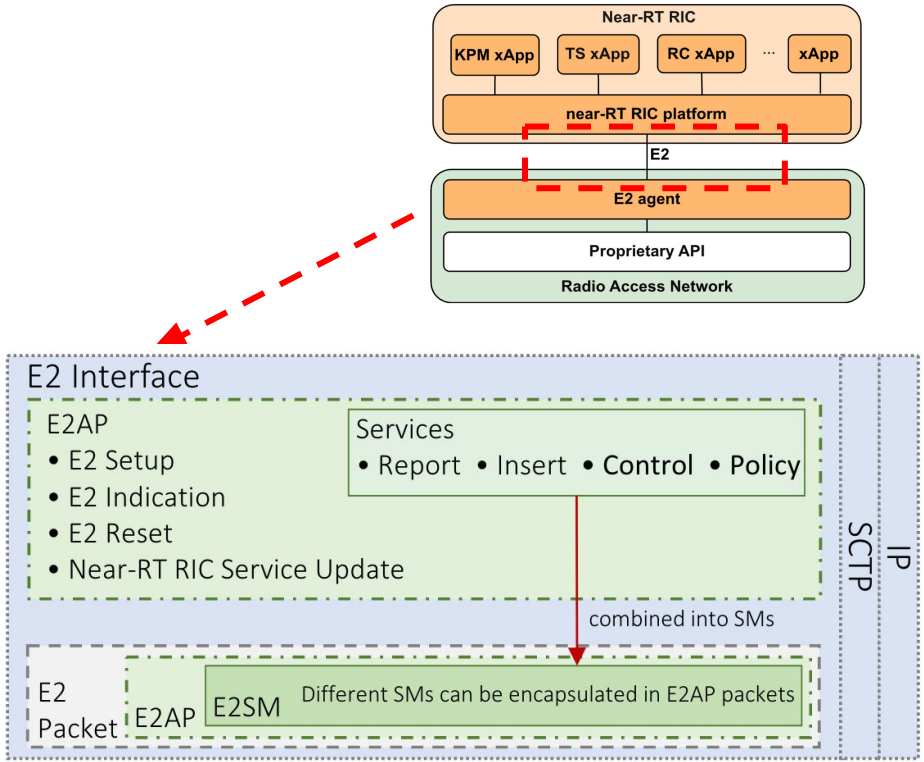
- **Governs communication between Near-RT RIC and the underlying RAN nodes**
  - Connectivity between Near-RT RIC and E2 Node (gNBs, eNBs, or O-RU/O-DU) supplied by different vendors
  - Exposure of E2 Node data (e.g. configuration information, network measurements, etc.) towards the Near-RT RIC
  - Enables the Near-RT RIC to control selected functions on the E2 Node



[Ngo et al]

E2 Interface: Main Components

- **E2 Application Protocol**
  - A procedural protocol that is the building block of communication over E2
- **E2 Service Model**
  - A combination of different E2AP procedures
  - Formalizes the interaction with the RAN Functions



[Santos et al, Polese et al]

E2AP Procedures

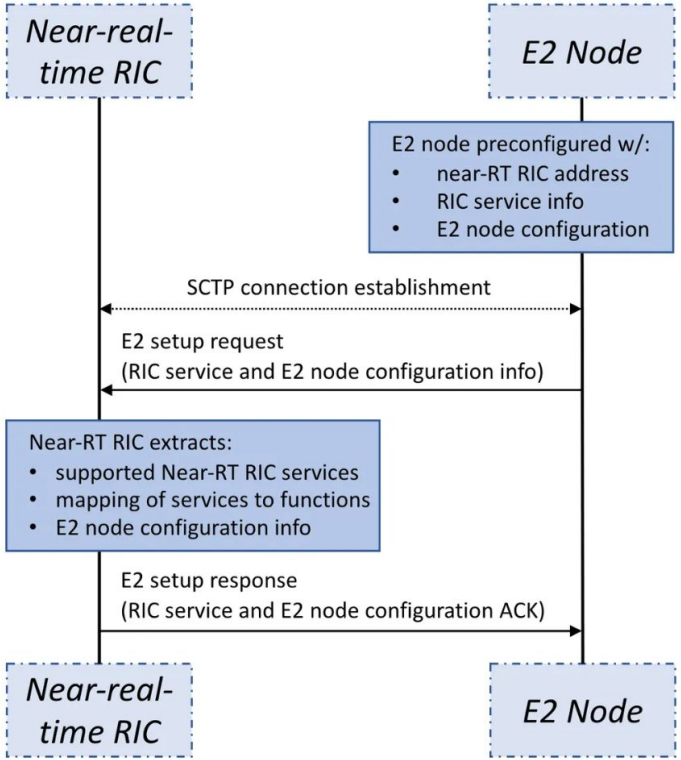
- Procedures are well-defined sequences of messages exchanged between entities over the E2 interface to achieve specific tasks or functions

- **Type 1: RIC Functional Procedures**
  Procedures used to pass application specific messages between Near-RT RIC applications and a target RAN Function
  - RIC Subscription: establish RIC Subscriptions on E2 Node
  - RIC Indication: report metrics to RIC
  - ….

- **Type 2: Global Procedures**
  Procedures that are not directly related to a specific application
  - E2 Setup: connecting RAN to the RIC (covered in Lab 1)
  - Error Indication: initiated by either the E2 Node or the Near-RT RIC to report detected errors in one incoming message
  - ….

* ORAN Alliance Working Group 3: Near-RT RIC and E2 Interface, E2 Application Protocol (E2AP)

E2AP Global Procedure Example: E2 Setup



[Polese et al]

E2 Interface Hands-on

- **Objective**
  - Introduction to Flexric and its connection to OAI
  - Introduction to E2 interface and the exchanged packets

- **They'll be provided with**
  - Deployed RAN and core with simulated UEs (covered in TEP workshop 1)
  - Deployed Flexric

- **Lab1**
  - Connect RAN to RIC: running two commands and observing the logs
  - Investigate the exchanged E2 packets (in the form of .pcap files that already captured)
    - Getting familiar with E2 packets structure
    - Getting familiar with E2 Setup procedure and the functionalities that RAN advertises

Resources and References

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2. Ngo, M. V., Yoo, H. M., Pua, Y. H., Le, T. L., Liang, X. L., Chen, B., ... & Quek, T. Q. (2024). RAN Intelligent Controller (RIC): From open-source implementation to real-world validation. ICT Express.
3. Santos, J. F., Huff, A., Campos, D., Cardoso, K. V., Both, C. B., & DaSilva, L. A. (2024). Managing O-RAN Networks: xApp Development from Zero to Hero. arXiv preprint arXiv:2407.09619.
4. Chen, C.-C., Chang, C.-Y., & Nikaein, N. (2023). FlexSlice: Flexible and real-time programmable RAN slicing framework. In GLOBECOM 2023-2023 IEEE Global Communications Conference (pp. 3807-3812). IEEE.