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Intelligent radio access networks: architectures, key techniques, and experimental platforms

Key words: Intelligent network architecture; Artificial intelligence; Experimental platforms

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Introduction

A comprehensive survey of recent advances in intelligent radio access networks (RANs) from industry on intelligent networks (standard organizations, equipment vendors, and operators) to the academic community:

- Intelligent RAN architectures proposed by the academic community

(intent-driven RAN and network with enhanced data analytic)

- Key techniques related to intelligent RANs
- Experimental platforms facilitating the implementation of intelligent RANs
- Future challenges

(standard open data sets, enabling AI with a computing power network, realization of edge intelligence, and software-defined intelligent satellite-terrestrial integrated network)

Industrial progress

- Project “Study on Further Enhancement for Data Collection” further extends AI functions to RANs.
- Zero-touch network and service management architecture introduce the AI-driven domain intelligence.

Huawei

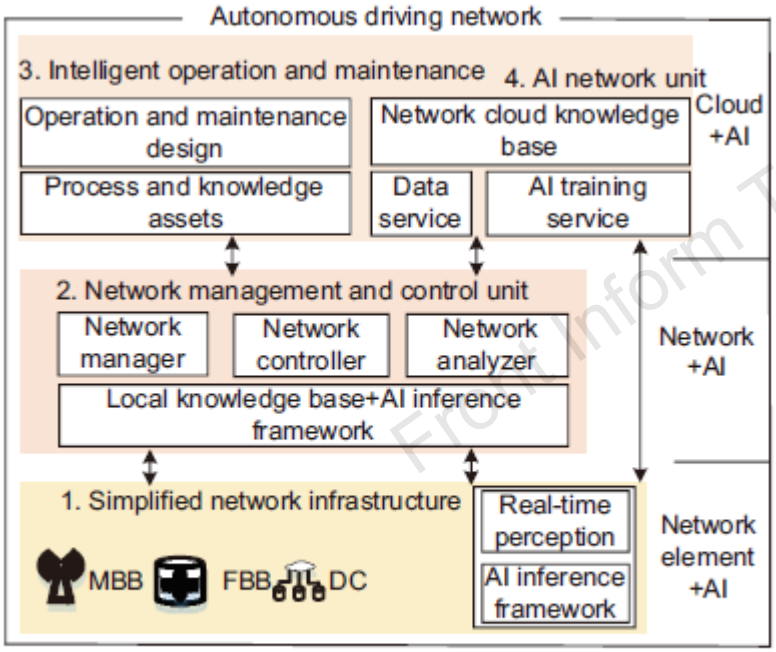

Fig. 1 Solution to the autonomous driving network (Huawei, 2020)

Autonomous driving network

O-RAN alliance

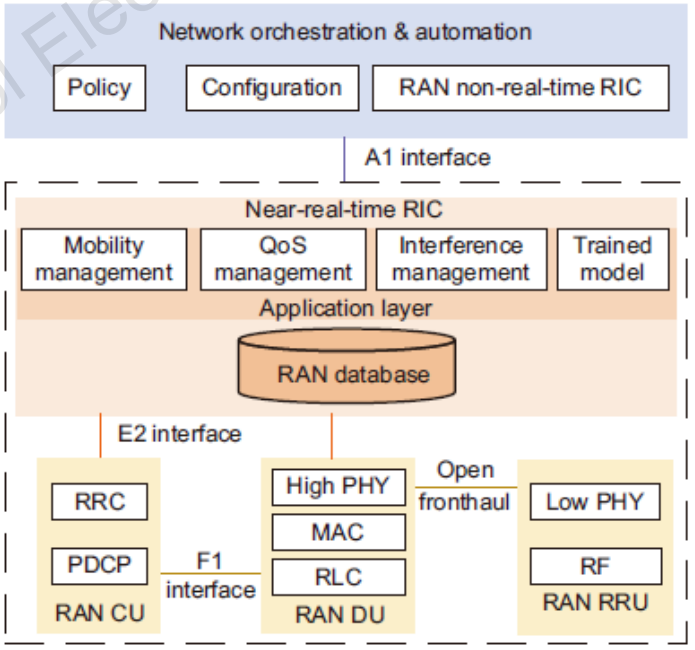

Fig. 2 O-RAN architecture (RAN Alliance, 2018)

RAN: radio access network; RIC: RAN intelligent controller; QoS: quality of service

O-RAN architecture

Academic progress

Intelligent and concise RAN

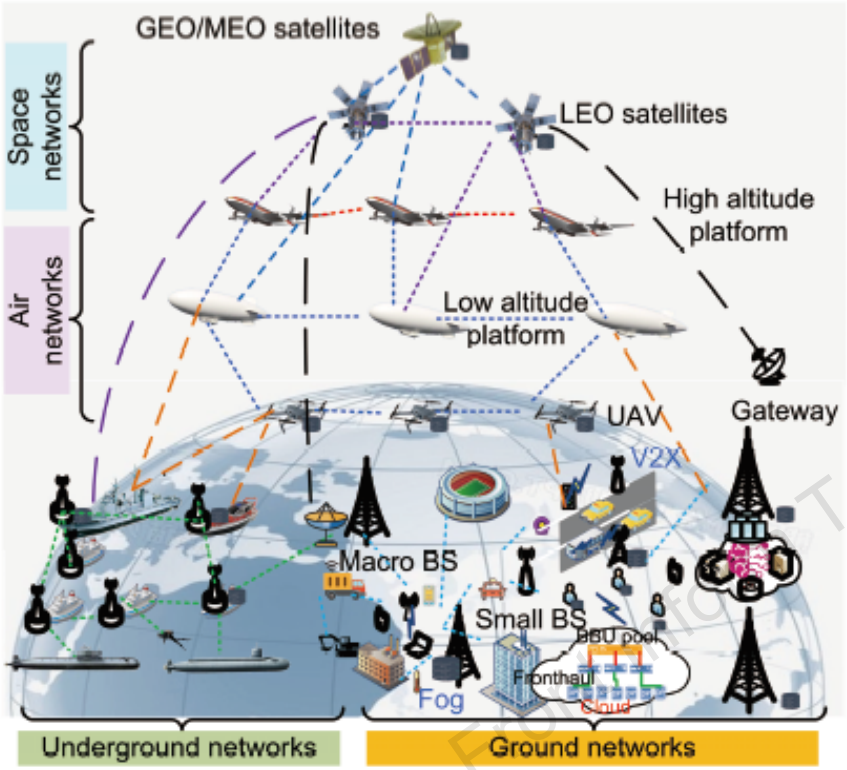

Fig. 3 Intelligent and concise RAN architecture (Peng et al., 2020)

BS: base station; RAN: radio access network; UAV: unmanned aerial vehicle

Air-space-ground-underground integrated networking and collaboration of communication, computing, caching, and control resource

Intent-driven radio access network

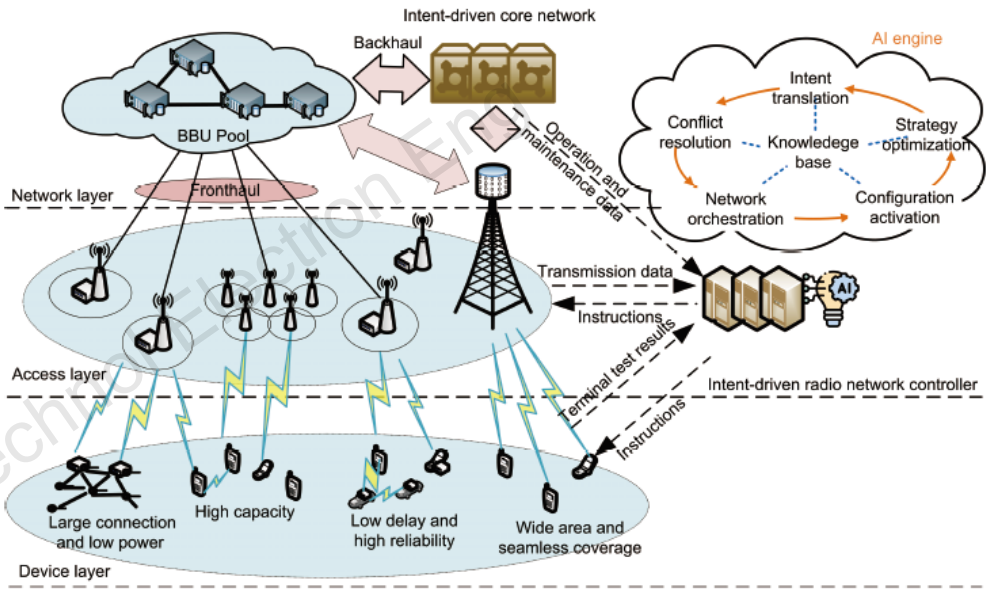

Fig. 4 Intent-driven radio access network architecture (Zhou et al., 2020)

Five modules:

- intent translation
- conflict resolution
- network orchestration
- configuration activation
- strategy optimization

Academic progress

- Intelligent endogenous trusted network

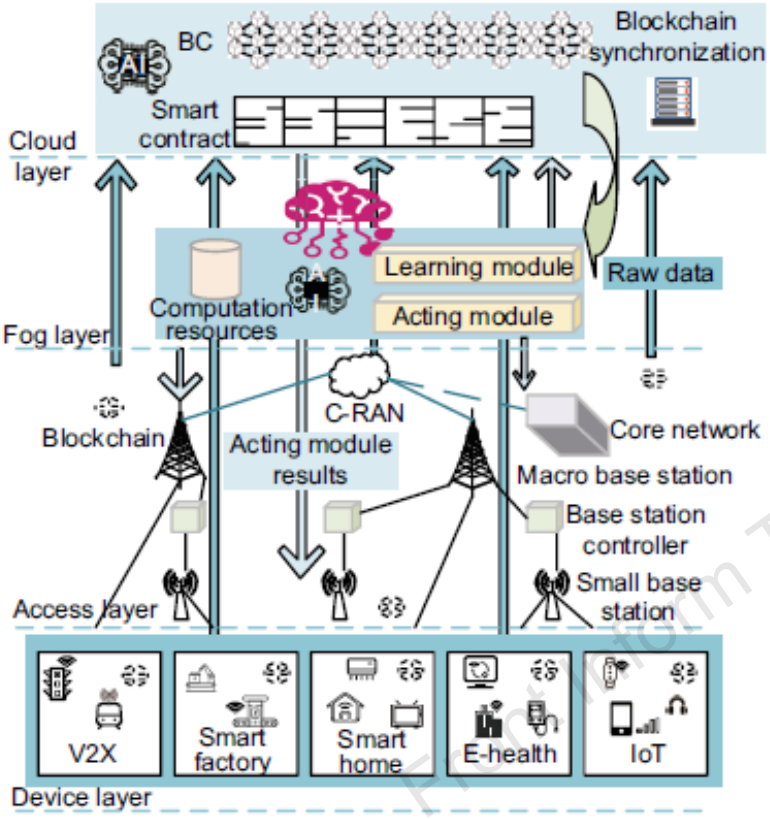

Fig. 5 Intelligent endogenous trusted network architecture (El Azzaoui et al., 2020)

- An intelligent and secure architecture "Block5GIntell" for data analysis
- Device layer, access layer, fog layer, and cloud layer

- AI agent based software-defined network

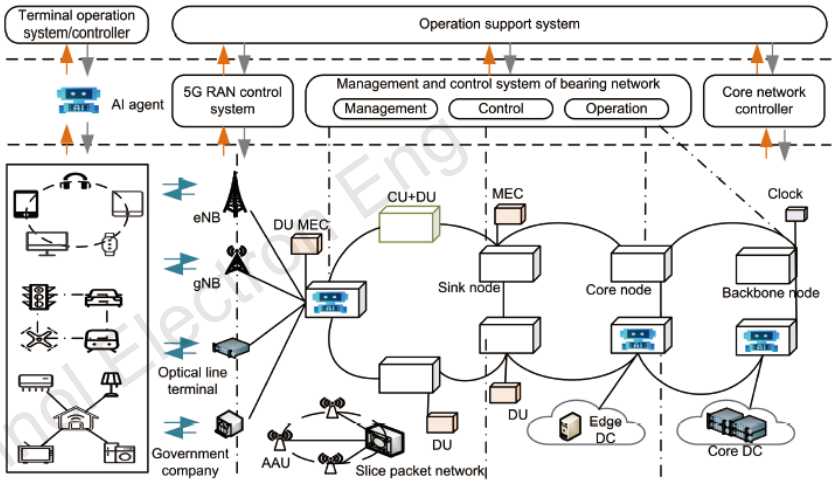

Fig. 7 System architecture of the artificial intelligence agent based software-defined network (Cao et al., 2020)

Deployment of AI agents: device layer, base station layer, and SDN controller layer

Functions: network service prediction, resource scheduling

Key techniques

- AI-driven network slicing
  - Handling the allocation of communication and computing resources and the scheduling and deployment of network functions, to realize the differentiated customization of network functions and ensure the service capabilities of slices
- Intent perception and translation
  - Transforming wireless network intent into network configuration strategies, to realize the accurate identification and transformation of the dynamic intent
- Intelligent operation and maintenance
  - AI-enabled fault diagnosis and recovery techniques to quickly and efficiently solve anomalies, such as weak coverage, signal interruption, and strong interference
- AI-based cloud-edge collaborative networking
  - A joint cache and resource management method based on game theory and RL and a joint mode selection and resource management method based on DRL
- Intelligent multi-dimensional resource allocation
  - Considering the time scale characteristics of resources in different dimensions and the differences in resource granularity

Experimental platforms

- Experiment of network slicing management by running Mosaic 5G FlexRAN software on an OpenAirInterface (OAI) platform
- Integrating and demonstrating data-driven closed-loop control based on the O-RAN architecture

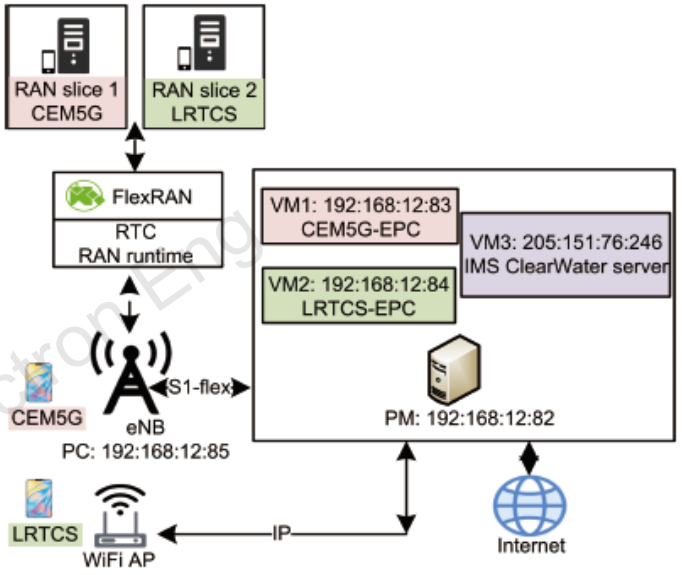

Fig. 9 System structure of the experimental scenario (Issa et al., 2019)

RAN: radio access network; RTC: realtime controller

Experimental scenario (FlexRAN)

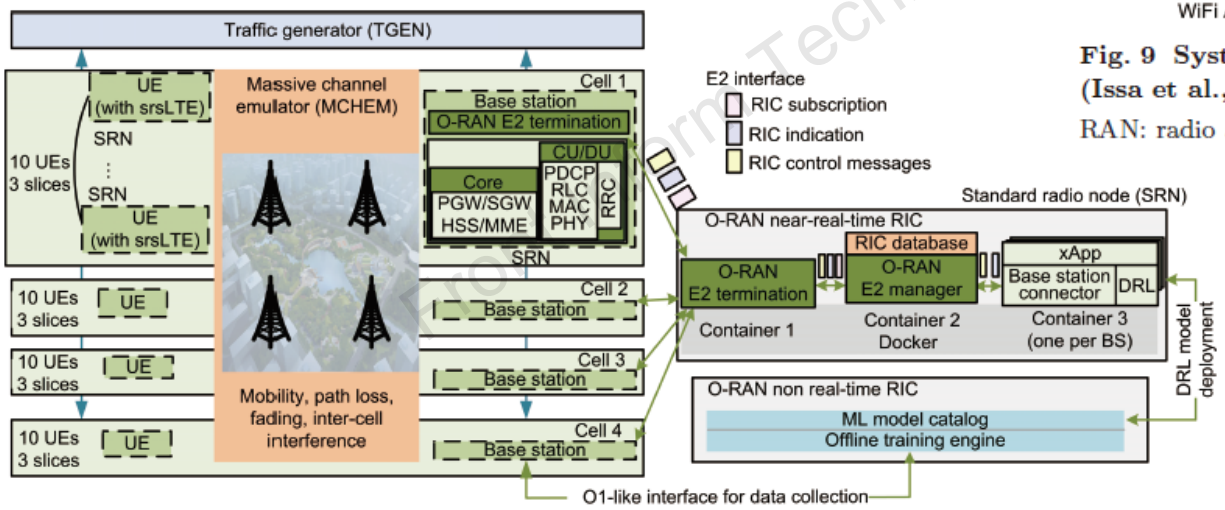

Fig. 10 O-RAN integration in Colosseum (Bonati et al., 2020)

DRL: deep reinforcement learning; ML: machine learning; RAN: radio access network; RIC: RAN intelligent controller

O-RAN integration in Colosseum

Future directions

- Standard open data set
  - Facilitate the research community to study and fairly evaluate the performance of key techniques for RAN intelligence
  - Investigate the schemes of generating high-quality training samples in the case where real network data cannot be easily obtained
- Enabling AI with a computing power network
  - Satisfy the huge demand for computing power to better support AI model training within RANs
- Realization of edge intelligence
  - Edge intelligence moves AI services from the remote data center to the network edge, which raises the intelligence level of network edge and reduces AI service latency
- Software-defined intelligent satellite-terrestrial integrated network
  - With software-defined networking and AI, software-defined intelligent satellite-terrestrial networks can provide much flexibility in networking and resource management

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