FlexRAN: A Flexible and Programmable Platform for Software-Defined Radio Access Networks

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Evolution of Mobile Networks

Driving factors behind 5G evolution

- Dramatic increases in data traffic
- Emerging communication paradigms like Machine Type Communications
- Support for a diverse set of performance and service requirements through isolated logical networks

Dimensions of innovation towards 5G

- Scaling capacity (ultra-densification, new radio access technologies, new spectrum bands)
- New more flexible network architectures
- Support of network virtualization and slicing

Key technology for evolving mobile networks: Software-Defined Networking (SDN) [1]

Paradigm shifting ideas underlying SDN

- Control and data plane separation through a well-defined API
- Consolidation of the control plane
- Flexibility introduced to the network through its programmability

SD-RAN in 5G Networking

Benefits of a Software-Defined Radio Access Network (SD-RAN) design

- Simplified base station coordination that enables strategies and technologies aimed to improve spectrum efficiency and scale system capacity
- Softwarized RAN control that allows easier evolution through programmability and enables a wide range of use cases and novel services considered in the context of 5G, like *virtualization of the RAN* and *Mobile Edge Computing*.

Existing SD-RAN work

- Largely conceptual (e.g. [2][3])
- No implemented solutions that researchers can use to evaluate their SD-RAN designs and to assess the benefits of new SD-RAN enabled services.

Our contribution: FlexRAN

FlexRAN is the **first open-source SD-RAN platform** to fill this void**.** It's **salient features** are:

Control and data plane separation in the RAN

- Allow operators to open RAN to authorized third-parties
- Deploy innovative applications and service endpoints for mobile subscribers, enterprises and vertical segments

Centralized & real-time control

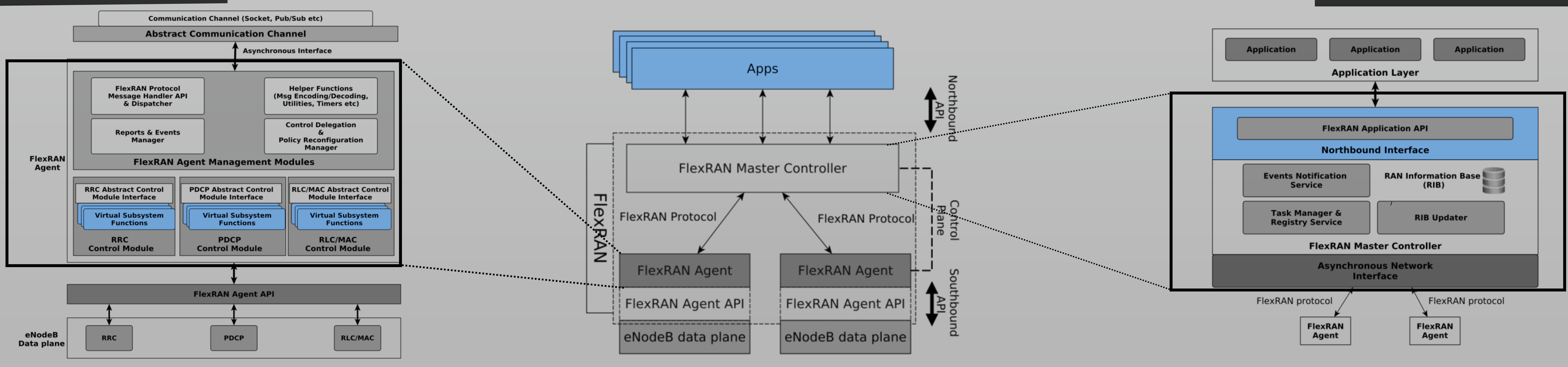
- Simplified base station coordination and sophisticated control
- Support for real-time control applications with stringent time constraints (e.g. MAC scheduler)

Virtualized control functions

- Control functions with clean structure and well-defined interfaces
- Can be replaced in a flexible manner without affecting the rest of the system

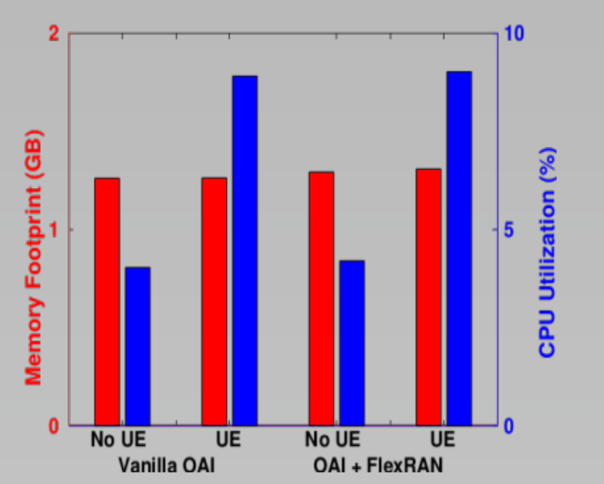
Control delegation & Policy reconfiguration

- Delegate control functions from centralized controller to agent at runtime
- Reconfigure the function parameters on-the-fly

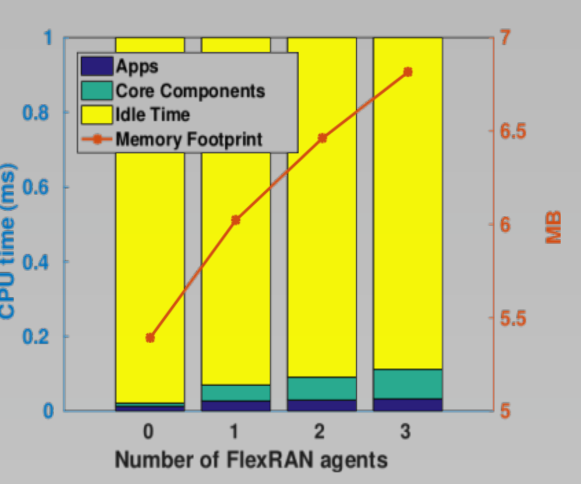


FlexRAN Architecture

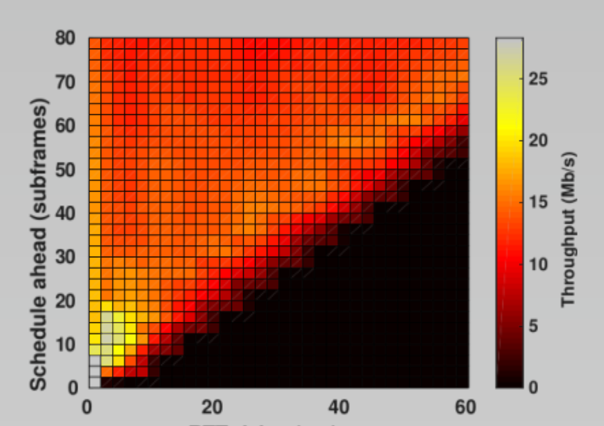
FlexRAN Performance



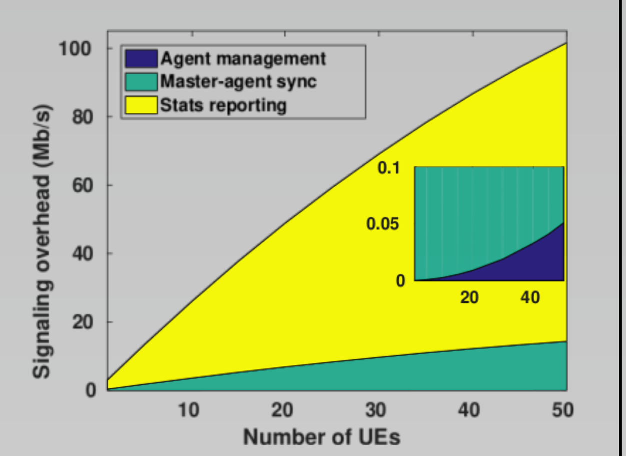
Minimal memory and CPU overhead increase at eNodeB by introduction of agent



Lightweight and scalable operation of master controller

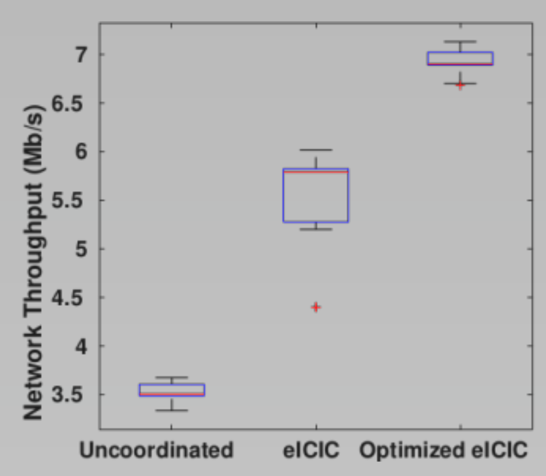


Adaptable centralized scheduling in the presence of master-agent communication latency

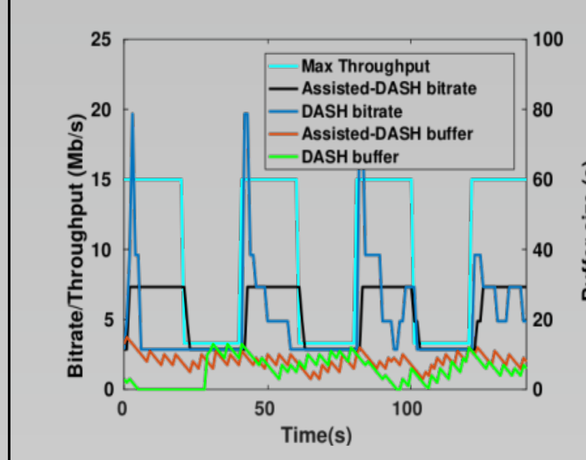


Sublinear signaling overhead increase for the agent-master communication

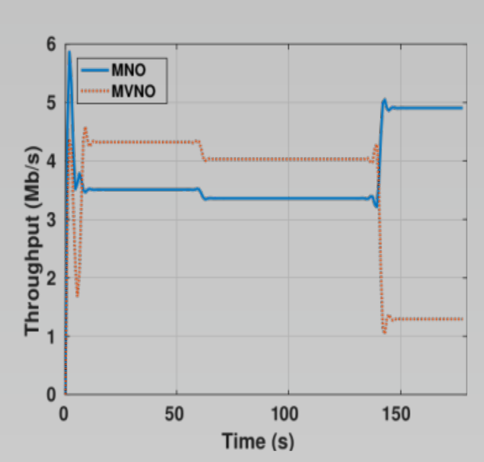
FlexRAN Use Cases



Improved interference management through coordinated scheduling of cells



Improved video bitrate adaptation over conventional streaming services



Dynamic on-demand allocation of radio resources in MVNOs

FlexRAN Implementation

FlexRAN controller

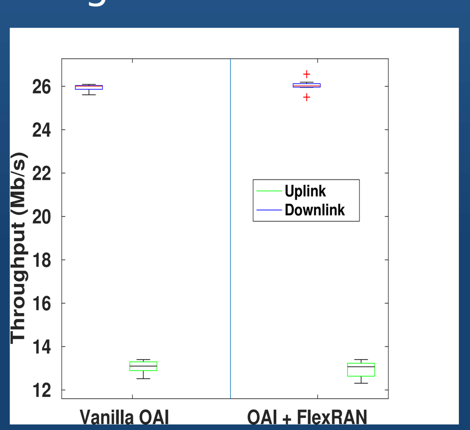
Linux-based C++ implementation from scratch
Real and non-real time modes of operation

FlexRAN agent

Implemented in C on top of OpenAirInterface (OAI)

- Code refactoring for separation of control and data plane
- Implementation of FlexRAN agent API

Google Protocol Buffers protocol implementation



Full UE transparency and equal service quality to vanilla OAI

FlexRAN Use Cases

Improved interference management through coordinated scheduling in HetNet settings

- Real-time centralized MAC scheduler deployed over FlexRAN master controller

Adaptive bitrate video streaming at the network edge in the context of Mobile Edge Computing

- Mobile Edge Computing application deployed over FlexRAN master controller
- Real-time monitoring of MAC network information for improved bitrate adjustment

Active RAN Sharing and on-demand resource allocation among Mobile Virtual Network Operators (MVNOs)

- Dynamic introduction of new MVNOs
- On-demand modification of scheduling policy and resource allocation per MVNO

Acknowledgement

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References

[1] L. E. Li et al. Toward software-defined cellular networks. In *European Workshop on Software Defined Networking (EWSDN)*, pp. 7-12. IEEE, 2012.
[2] A. Gudipati et al. SoftRAN: Software defined radio access network. In *Proceedings of the second ACM SIGCOMM workshop on Hot topics in software defined networking*, pp. 25-30. ACM, 2013.
[3] V. Yazici et al. A new control plane for 5G network architecture with a case study of unified handoff, mobility and routing management. *Communications Magazine*, IEEE, 52(11):76-85, 2014.