C-RAN Supporting Multi-RATs for 5G Mobile Networks

Ms. Priya S
II Sem, M.Tech, Computer Science & Engineering
City Engineering College
Bengaluru, India

Mrs. Ambika P R
Asst.Professor, Dept. of CSE
City Engineering College
Bengaluru, India

***Abstract*— A cloud radio access network (Cloud-RAN) is a new cellular technology which brings baseband processing units for a set of base stations into a central server retaining only the radio front-ends at the cell sites. The main idea behind C-RAN is to pool the Baseband Units(BBUs) from multiple base stations into centralized BBU Pool. C-RAN provides energy efficient network operation and possible cost savings on baseband resources. It improves network capacity by performing load balancing and cooperative processing of signals originating from several base stations. C-RAN is a key enabler for future mobile networks which helps to meet the explosive capacity demand of mobile traffic, and reduce the capital and operating expenditure burden of the operators. As a significant scenario of a 5G system, the ultra dense network deployment based on C-RAN is discussed with focuses on flexible backhauling, automated network organization, and advanced mobility management. Another main feature of a 5G system is the long-term coexistence of multiple radio access technologies (multi-RATs). Therefore, some directions and preliminary thoughts are presented for future C-RAN which supports Multi-RATs, with joint resource allocation, mobility management, traffic steering and service mapping.**

Keywords-5G, C-RAN, Mobile Networks, Network Virtualization, UDN, multi-RATs.

I. INTRODUCTION

In recent years, the number of smart terminals (smart phones and tablet PCs) has proliferated and mobile Internet applications are used widely, leading to the explosion of mobile traffic. The current vision towards 5G is often driven by traffic forecasts which suggest increase in data volumes, more number of intelligent terminals and growing capacity and service-aware demand. With the popularity of the Internet of Things, the communications over mobile Internet raise more demands to network performance, such as low-delay and high-automation. These requirements will go beyond the natural evolution of IMT-Advanced technologies, which shows the need for a new mobile generation, e.g. 5G technologies.

There are two main motivations for 5G mobile networks. Firstly, the future mobile network will deal with new services e.g., massive sensor communication and vehicular to anything communication [5], which requires shorter setup time and delay, and also reduced signaling overhead and energy consumption [6]. In addition, it will also have many more use cases, including managing multi-cell and multi-user together, network deployments with Multi-RAT coexisting or multi-layer networks, known as Heterogeneous Networks(HetNets). Various services and complicated deployment scenarios require the future 5G systems to have the following abilities 1) to support 10-100 times transition rate than today; 2) to ensure a low delay (millisecond); 3) to support 10-100 times more devices than today; 4) to provide 1000 times traffic density; v) to support up to 500km/h fast mobility for User Equipment [7]. At the same, it is desirable to have 99.9999% coverage, whereas energy consumption and cost for the infrastructure should not increase.

Secondly, operators wish to see a reduce in networks operational costs and improve spectral efficiency within an area, to maintain optimal performance in future cellular systems by more flexible resource usage and more advanced self-organization functions.

II. C-RAN OVERVIEW

In this section deployment architectures and potential solutions of C-RAN systems are described.

The general architecture of C-RAN is shown in Fig. 1, that consists of three main components, namely (i) BBU pool with centralized processors, (ii) RRHs with antennas located at the remote sites, (iii) fronthaul network which connnects the RRHs to the BBU pool and requires high bandwidth and low-latency .

The RRHs transmit the RF signals to UEs in the downlink or forward the baseband signals from UEs to the BBU pool for further processing in the uplink. The RRH includes RF amplification, up/down conversion, filtering, A/D and D/A conversion and interface adaptation. By conducting signal processing functions in the BBU pool, RRHs can be relatively simple, that can be distributed in the large network in a cost-efficient manner.

The BBU pool is composed of BBUs that operate as virtual base stations which processes baseband signals and optimize the network resource allocation. By Considering different demands on network performance and system implement complexity, the BBU assignment for each RRH could be implemented in a centralized or distributed manner depending on different resource management in BBU pool.

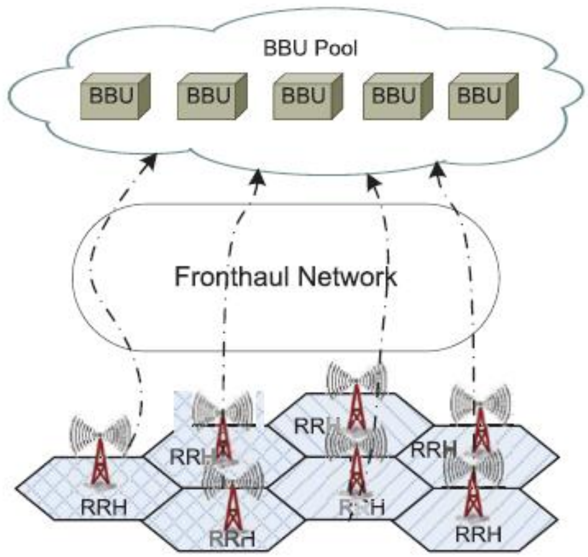


FIGURE 1. C-RAN architecture.

In a distributed manner, one RRH directly connects to its exclusive BBU. This manner is simple to be realized. But it is not beneficial in exploiting the advantages of joint signal processing and central controlling in C-RAN. In the centralized manner, all RRHs may connect to a switcher/central device, which flexibly schedules processing of resource in BBU pool for one RRH or a set of RRHs. This manner has many advantages in term of flexibly resource sharing and efficient energy efficiency by joint scheduling. Beside, centralized processing allows the implementation of efficient interference avoidance and cancelation algorithms across multiple cells. It allows to selectively turn RRHs on/off in line with the traffic fluctuations in various scenarios.

The fronthaul links can be realized by various different technologies, like fiber or wireless way, that falls into two categories: ideal without bandwidth constrain and non-ideal.

Allocation of RRH-BBU Functions. As the ideal fronthaul link is not available everywhere, some function split options between RRH and BBU are presented, which will have a big impact on the details of C-RAN architectures [14]. Although there are various possibilities, three cases are listed as shown in Fig. 2 Option 1: the L1 (Layer 1, PHY), L2 (Layer 2, MAC) and L3 (Layer 3, network) functions all implemented in BBU. This option is the premier C-RAN configuration, that is clear and simple. The disadvantage is high burden on fronthaul, due to a large amount of data from RRH. Option 2 is moving the L1 function to RRH, which greatly reduce the RRH-BBU data load as L1 takes major computation parts of RAN.

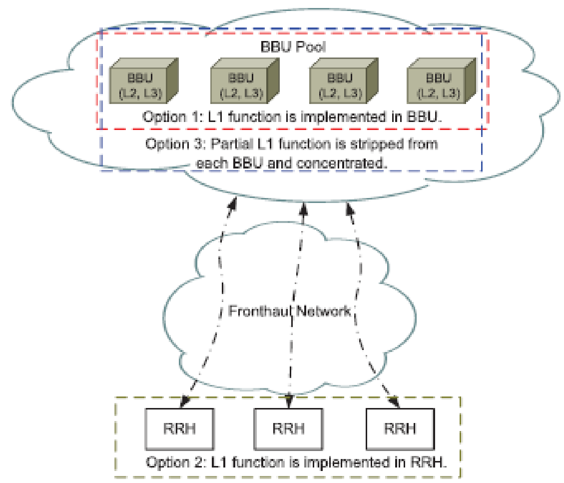


FIGURE 2. Three possible options of RRH-BBU function split.

III. RELATED WORK

i) DEVELOPED MODES

Some operators in China already start the C-RAN network deployment. And many service providers and equipment manufacturers also have developed the prototype system, e.g., Light Radio from Alcatel Lucent [20], Antenna-integrated Radio (AIR) from Ericsson, FluidNet from NEC and CloudIQ Framework proposed by several corporations. The first two architectures place emphasis on designing scalable and power-efficient RRH which supports multiple access technologies and multiple bands. FluidNet focuses on design a flexible framework by combining one-to-one and one-to-many mapping between BBUs and RRU to help heterogeneous users and traffic profiles. CloudIQ works on virtualization of the base station and scheduling of computing resources in the BBU pool for satisfying their real-time constraints.

ii) FRONTHAUL ISSUES

As one of the evolution path for future cellular network architecture, C-RAN has attracted many academic research interests. Through the ability of centralized processing/controlling/decision in C-RAN, the joint processing becomes relatively easy, including CoMP defined in 3GPP Release 10, joint scheduling, joint interference alignment/cancellation and other more advanced future technologies, such as multi-RAT support, common Operation and Maintenance, reliability and network sharing, which are difficult to be implemented in current cellular networks. Some joint processing techniques provided for such cloud-based networks require RRH to deliver received signals to BBU pool, in the form of in-phase and quadrature-phase components (I/Q-stream), that demand a higher data rate on the fronthaul link than decoded user data. Until recently, the required data rate could only be provided by fiber and not by wireless links, which could be reached more easily and at lower cost in C-

RAN architecture. There are two kinds of efforts having been done to solve the problem: one is to reducing the throughput requirement on transportation links by means of joint coding under a data rate constraint or resampling, rescaling and removing some unnecessary parts of the signal the other is developing enhanced fronthaul technology which supports wideband and high data rate, such as millimeter radio links [17]. Millimeter-Wave (mmWave) technology has been addressed again due to the advances in circuit technologies, using which wide bandwidth (up to several GHz) can be provided, that enables multi-Gbps data rate. To compensate for the path loss, beamforming and spatial multiplexing from multi-
element antenna arrays are proposed is used for mmWave radio communication. The measurements in New York City at 28 and 73 GHz demonstrate that, even in an urban canyon environment, significant non-line-of-sight (NLOS) outdoor, street-level coverage is possible up to approximately 200m from a potential low-power microcell or picocell base station with electrically steerable antennas, closing the gap between wireless and fiber backhaul . This makes mmWave links a viable option for fronthaul links on the ``last mile" from RRHs to the BBU pool. They can also be used to cross obstacles like rivers or large roads, where fiber cannot be deployed because of safety or economic reasons.

IV. C-RAN IMPLEMENTATION IN 5G MOBILE NETWORKS

UDN and coexistence of Multi-RATs are significant scenarios of 5G mobile networks. In this section the challenges and potentials for C-RAN implementation in a foresaid scenarios are discussed.

1. *CHALLENGES OF C-RAN IN UDN DEPLOYMENT*

Small cell deployment is one of the most promising technological trends to cope with the rising need for very high data rates foreseen in future mobile networks which involve various types of small cells such as picocell, relay, Machine- to-Machine, and also Device-to-Device. According to the research of IMT-2020, Table I lists some typical UDN scenarios and key performance indicators required by 5G system, which shows high data rate buand also great users' experience and strict end-to-end delay expected by UDN.

TABLE 1. Typical UDN scenarios and indicators.

Indicators	Traffic Densi-ty(bps/Km2, DL/UL)	End-to-end delay(ms)	User Experi-ence(Mbps, DL/UL)	Mobility(Km/h)
Suburban Commu-nities	1T/130G	15-40	1024/512	0-3 for pedes-trian 50 for cars
Commercial Districts	1102G/150G	5-10	1024/512	0-3
Subways	10T/-	15-40	1024/512	110

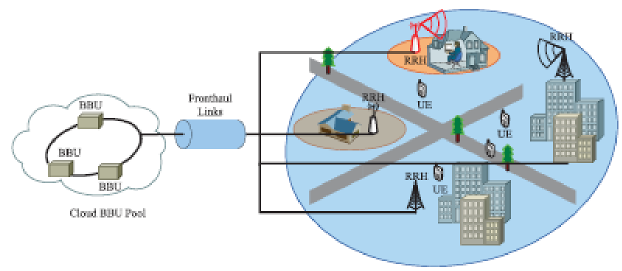


FIGURE 3. C-RAN architecture under UDN deployment.

As shown in Fig. 3 illustrates, because of the densification of small cells, the distance between UE and access point is greatly reduced, i.e. tens of meters, therefore one UE falls into several small cell coverages, and all of those small cell BSs can receive the UL signal from the UE or serve the UE in downlink. Based on this property of UDN, some joint/collaboration mechanisms are able to provide better experience of users. In traditional cellular networks, the cooperation among cells requires a large amount of signaling exchange, and always do not perform as well as expected under practical constraints because of backhaul delay, backhaul capacity and user mobility. With the help of C-RAN, the information exchange and central decision are able to be performed in BBU pool, that brings performance gain from cooperative processing. Besides, the non-ideal characteristics of fronthaul link require a joint design with BBU processing.

2. *INTEGRATED MULTI-RATs IN C-RAN*

As described above, UDN is a step further towards low cost, self-confuiguring and self-optimizing networks. In addition, 5G system will have to deal with many more base stations, deployed dynamically in a heterogeneous manner and consisted of multi-RATs, like GSM, UMTS, LTE, Wireless Fidelity (Wi-Fi), etc., which has to be flexibly integrated. Current wireless communications systems are deployed using multiple RATs both in licensed and unlicensed bands, and the operations of different RATs are independently defined by their specific standards. However, independent RAT operation will lead to suboptimal usage of the wireless resources. Multi-RAT joint radio operation is necessary to improve the system resource usage. For example, as GSM usage is reducing, a joint radio operation would allow the GSM spectrum to be reused by LTE in high-capacity- demanding deployments with less impact on the GSM system. WLAN/LTE joint operation could also effectively of_oad traffc to unlicensed bands and reduce the traffic provided by LTE. We can expect to see higher gains by joint operation of multiple RATs in 5G system based on C-RAN architecture.

With the evolution of future mobile networks, decoupling of control plane and data plane is with long-term trends. Therefore, some user-related functions on traditional core network must be transferred to RAN. These changes of network structure demand C-RAN to make a corresponding adjustment. On the other hand, by integrating user plane functions, C-RAN can collect more information to perform better customization, traffic steering and mobility management. Fig. 4 presents such a concept, where collab- orative functions are used for supporting Multi-RATs, such as joint resource allocation, mobility management, traffic steering and service mapping. In this section, we take the next step and concentrate on describing some open-ended problems and basic ideas of solutions to implement C-RAN in Multi-RAT coexistence networks, depending on assumptions that there is a uniform interface for different RATs in C-RAN.

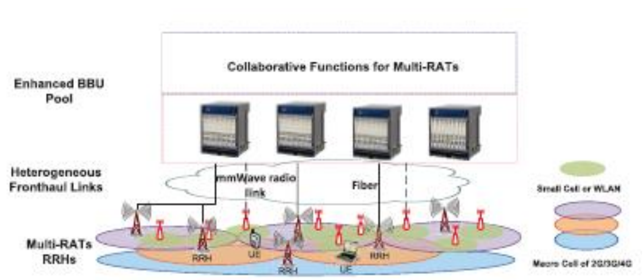


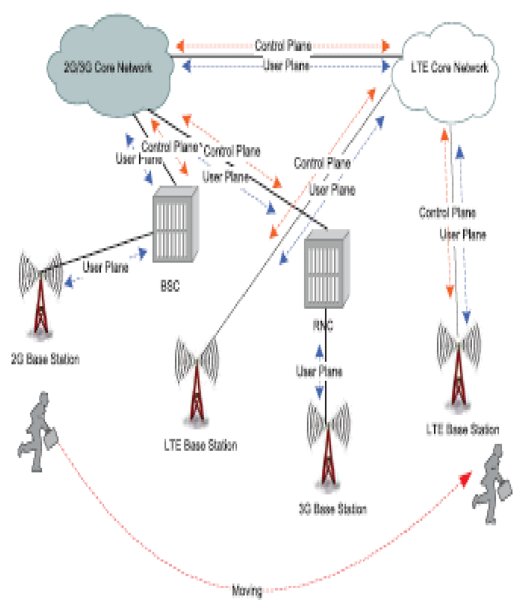
FIGURE 4. Conceptual C-RAN architecture supporting multi-RATs.

a) JOINT RESOURCE ALLOCATION

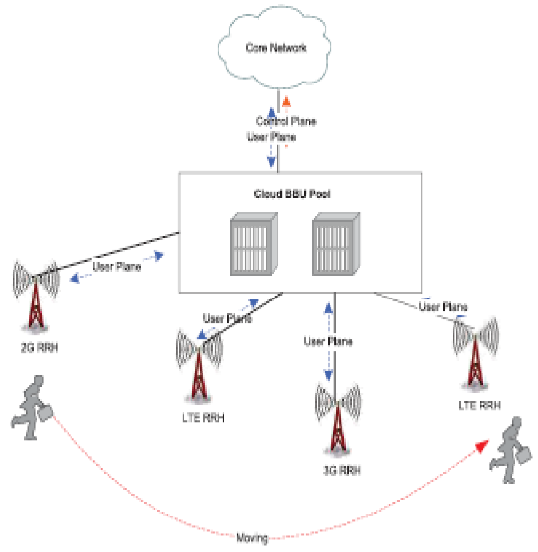
As mentioned above, multi-RATs, working with different system configurations and resources, have evolved and will coexist for a long time to meet the heterogeneous demands for the network and mobile UEs with different capabilities. Along with that, background noise across the network upgrades, with Quality of Service (QoS) not to be guaranteed. Also, service continuance will be damaged as there is not enough collaboration among multipleRATs. Enhanced mechanisms for interference avoiding and multi-RAT coordination are expected to benefit whole system performance. Many possible ways of collaboration are given below. The fixed spectrum allocation in current wireless network has seriously restricted the efficiency of the spectrum, and affected the development of wireless networks because of the spectrum sparse and imbalanced load distribution among different RATs. For example, refarming GSM spectrum to LTE suggests that dynamic spectrum sharing between GSM and LTE improves the spectral efficiency while maintaining legacy device connectivity of GSM. RRH on/off flexible configuration is simple to implement across multiple RATs in the whole network. This configuration does not only base on traffic profile varying over time and space, but also the interference to other cells in order to optimize overall system performance. From a hardware usage standpoint, scheduling baseband computing resources on demand for completing communication process for multiple RATs via NFV technique can improve operational efficiency and reduce energy consumption.

b) MOBILITY MANAGEMENT

Currently, LTE supports inter-RAT handover for GSM, UMTS, and now specified to support interworking with WLAN. As shown in Figure 5 a), the architecture of interworking between LTE and different RATs requires the connection of their core networks. This Multi-RAT architecture might be workable but the latency of an inter-RAT handover may be high. To improve the user experience, a simplified network structure for lower latency using C-RAN architecture is presented.



a)



b)

FIGURE 5. Mobility management scenario. a) Current Network. b) C-RAN Network supporting Multi-RATs.

c) TRAFFIC STEERING AND SERVICE MAPPING

Additionally, the notion of intelligence is being exploited so as to guarantee the reliable user experience and improve performance of Multi-RAT integrated deployments by taking advantage of global information about users, services and network status. The inputs to this intelligence process comprise information on the traffic, mobility levels, and interference levels (which corresponds to the complex context of operation), regarding transceivers and physical elements on the cloud. Intelligence will then lead to decisions related to: 1) the cell configuration and resource allocation, and the traffic distribution to the cells; 2) the assignment of functional components to the computing resources; and 3) the best connections between RRH and BBU pool and the best interconnections between the multi-RAT operations.

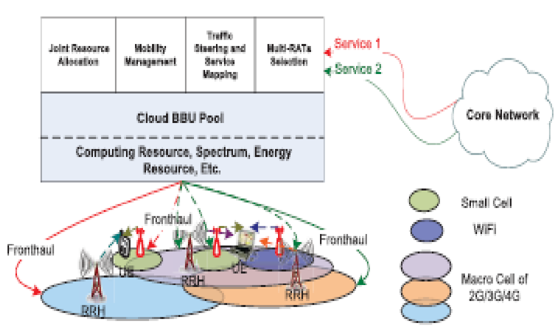


FIGURE 6. An illustration of service management.

The Intelligence on traffic steering and service mapping avoids over-provisioning of resources and maximize the user experience by using decisions related to the combination/allocation of traffic to different RATs. As shown in Fig. 6, the decision-making entity will be located centrally in BBU pool of C-RAN, where all the information of the air interface as well as the fronthaul and computing resources are available and intelligent algorithms are implemented.

V. CHALLENGES AND POTENTIAL SOLUTIONS FOR C-RAN

C-RAN is designed to not only address deployment issues but also improve spectral efficiency (e.g. via collaborative radio or joint processing techniques) as well as energy efficiency (e.g., via resource cloudification). Some features such as centralization are relatively easy to realize while other features such as resource cloudification require long-term development. This section analyzes the major challenges for C-RAN implementation and realization and proposes potential solutions.

1.FIBER RESOURCE CHALLENGE BY CENTRALIZATION

For simplicity, front-haul is defined in the paper as the link between BBUs and RRUs. Centralization is the critical first step required in order to realize all the other features of C-RAN. Centralization aggregates different BBUs (typically several dozens or several hundred carriers) into one central office with shared facilities. The key challenge for centralization is that it requires a large number of fiber resources if using a dark fiber solution, i.e. direct fiber connection. The issue can be illustrated by the following example. In a TD-LTE system with 20MHz band- width and RRUs equipped with 8, the CPRI data rate between one BBU and one RRU for one TD-LTE carrier transmission is as high as 9.8Gbps. When considering both UL and DL, 4 fiber connections would be required with 6Gbps optical modules. Since usually one site consists of three sectors with each supporting at least one carrier, the number of fiber connections for one site is as high as 12, which is difficult to achieve for most operators due to limited fiber resources. In order to overcome the fiber disadvantage in a centralization implementation, various solutions have been proposed. Some are mature enough while others are still in the early stage of development.

Compression techniques are the first steps taken to reduce fiber consumption. There are various kinds of compression techniques such as non-linear quantization and IQ data compression with a lossless 2:1 compression ratio. Another solution is Single Fiber Bi-direction (SFBD) which allows simultaneous transmission of UL and DL on the same fiber. SFBD could further reduce the usage of fiber by another 50%. As a result, when combining SFBD with compression, fiber resources can be reduced 4-fold with lossless performance. Another method to reduce ber consumption is to introduce new transport nodes for front-haul transmission. This includes wavelength-division multiplexing (WDM) and microwave transmission. WDM can carry dozens of carriers on a single fiber but may introduce additional delay and noise jitter, requiring careful design and implementation. In addition, microwave transmission may come to play a role as the last 100 meter front-haul solution for the scenarios where it is too expensive or even impossible to deploy fiber.

2. APPLICATION OF CLOUD COMPUTING AND VIRTUALIZATION

C-RAN's core feature is resource cloudification in which processing resources can be dynamically allocated to form a soft BBU entity. Given current vendors' proprietary and closed platforms, it is advantageous to develop a new BBU platform based on virtualization technology found in modern data centers. One suitable method of network virtualization is to use network function virtualization (NFV) which ``consolidate{s} many network equipment types onto industry standard high volume servers, switches and storage, which could be located in Data centers, network nodes and in the end user premises". A new reference system architecture that uses concepts from data center virtualization technologies is proposed in order to realize base station virtualization. As shown in Fig. 7, the baseband resource pools are deployed on multiple standard IT servers. On each physical server there is an additional dedicated hardware accelerator for the computation-intensive physical layer function processes. The additional hardware accelerator design is required to meet the strict real-time requirements for wireless signal processing. The L2/L3 functionalities are implemented via Virtual Machine (VM) in a virtualization environment. Additional user applications such as Web Cache can be also deployed on the open virtualized platform.

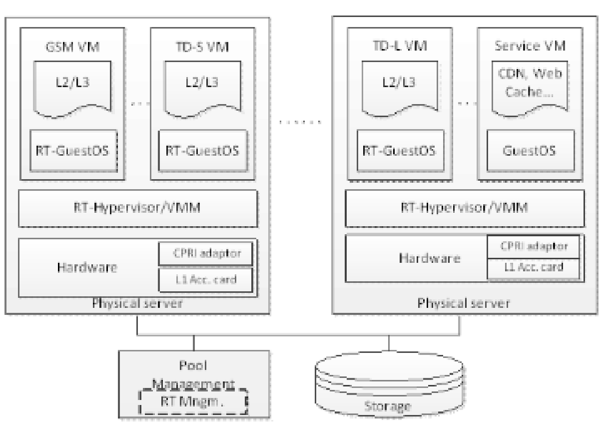


FIGURE 7. RAN Virtualization

Despite the conceptual simplicity of virtualization, the actual implementation is more difficult. Wireless communication is distinct from IT data centers in that wireless communication has extremely strict requirements for real-time processing. For example, for Time-Division Duplexing Long Term Evolution (TDD-LTE) systems it is required that an ACK/NACK must be produced and sent back to the UE/Enb within 3ms after a frame is received. Traditional data center virtualization technology cannot meet this requirement. Therefore, applying virtualization to the base station requires careful design and special optimization on key function blocks.

VI. CONCLUSION

In this paper, we present an overview of C-RAN architecture and several important issues especially in UDN and Multi-RAT coordination. With the introduction of NFV and SDN, C-RAN can define a unified interface for various RATs, and integrate their processing resources (even spectrum resource) into the whole BBU pool. Placing data plane in RAN facilitates C-RAN to perform advanced traffic steering and mobility management based on user perception and mobility prediction in Multi-RAT coexisted networks. Even though the benefits of C-RAN are clear and reasonable, the implement in practical networks still need in-depth research, considering practical constrains of the heterogeneous fronthaul links. Finally, we argue that network virtualization, through the cooperation of software defined networking and network function virtualization, is required both from a technology and cost points of view in order to enable implementations of the RAN architecture options for 5G networks.

REFERENCES

[1] *Cisco Visual Networking Index: Global Mobile Data Traf_c Forecast Update, 2013-2018*, Cisco, San Jose, CA, USA, Feb. 2013.
[2] *Future Technology Trends of Terrestrial IMT Systems*, document ITU working 5D/TEMP/250, Aug. 2013.
[3] *Scenarios, Requirements and KPIs for 5G Mobile and Wireless System*, document ICT-317669 METIS project, May 2013.
[4] J. F. Monserrat *et al.*, ``Rethinking the mobile and wireless network architecture: The METIS research into 5G," in *Proc. Eur. Conf. Netw. Commun. (EuCNC)*, Jun. 2014, pp. 1_5.
[5] J. Zhang, L. Shan, H. Hu, and Y. Yang, ``Mobile cellular networks and wireless sensor networks: Toward convergence," *IEEE Commun. Mag.*,vol. 50, no. 3, pp. 164_169, Mar. 2012.
[6] R. Baldemair *et al.*, `` Evolving wireless communications: Addressing the challenges and expectations of the future," *IEEE Veh. Technol. Mag.*, vol. 8, no. 1, pp. 24_30, Mar. 2013.
[7] *2020: Beyond 4G, Radio Evolution for the Gigabit Experience*, Nokia Siemens Networks, Zoetermeer, The Netherlands, Aug. 2011.
[8] China Mobile Research Institute. (Apr. 2010). *The 1st C-RAN International Workshop*. [Online]. Available: http://labs.chinamobile. com/focus/C-RAN [9] FP7. (Dec. 2013). *Future Networks Cluster 5G Radio Network Architecture*. [Online]. Available: http://cordis.europa.eu/fp7
[10] (Oct. 2012). *Network Functions Virtualization: An Introduction, Bene_ts, Enablers, Challenges and Call for Action*. [Online]. Available: http:// portal.etsi.org/nfv/nfv-white-paper.pdf
[11] Open Networking Foundation. (Aug. 2013). *Software-De_ned Networking: The New Norm for Networks*. [Online]. Available:https://www.opennetworking.org/images/stories/downloads/sdn-resources/white-papers/wp-sdn-newnorm.pdf
[12] P. Rost *et al.*, ``Cloud technologies for _exible 5G radio access networks,"*IEEE Commun. Mag.*, vol. 52, no. 5, pp. 68_76, May 2014.
[13] A. Basta, W. Kellerer, M. Hoffmann, K. Hoffmann, and E.-D. Schmidt,``A virtual SDN-enabled LTE EPC architecture: A case study for S-/P-gateways functions," in *Proc. IEEE SDN Future Netw. Services (SDN4FNS)*, Nov. 2013, pp. 1_7.
[14] NGMN Alliance. (Jan. 2013). *Suggestions On Potencial Solutions to C-RAN*. [Online]. Available: http://ngmn.org/uploads/media/NGMN-CRAN-Suggestions-on-Potential-Solutions-to-CRAN.pdf

[15] EU FP7. (Oct. 2012). Interworking and JOINt Design of An Open Access and Backhaul Network Architecture for Small Cells Based on Cloud Networks. [Online]. Available:http://cordis.europa.eu/fp7/ict/future networks/documents/call8-projects/ijoin.pdf

[16] P. Chanclou et al., ``Optical _ber solution for mobile fronthaul to achieve cloud radio access network," in Proc. Future Netw. Mobile Summit, Jul. 2013, pp. 1_11.

[17] J. Bartelt, G. Fettweis, D. Wubben, M. Boldi, and B. Melis, ``Heterogeneous backhaul for cloud-based mobile networks," in Proc. IEEE 78th Veh. Technol. Conf., Sep. 2013, pp. 1_5.

[18] D. Sabella et al., ``RAN as a service: Challenges of designing a _exible RAN architecture in a cloud-based heterogeneous mobile network," in Proc. Future Netw. Mobile Summit, Jul. 2013, pp. 1_8.

[19] C. J. Bernardos, A. De Domenico, J. Ortin, P. Rost, and D. Wubben, Challenges of designing jointly the backhaul and radio access network in a cloud-based mobile network," in Proc. Future Netw. Mobile Summit, Jul. 2013, pp. 1_10.

[20] Alcatel Lucent. (Feb. 2012). LightRadio Network: A New Wireless Experience. [Online]. Available: http://www2.alcatel-lucent.com/techzine/lightradio-network-a-new-wireless-experience/

[21] Aleksandra Checko, Henrik L. Christiansen, Ying Yan, Lara Scolari, Georgios Kardaras, Michael S. Berger, and Lars Dittmann *Cloud RAN for Mobile Networks—A Technology Overview* VOL. 17, NO. 1, 2015.

[22] *Recent Progress on C-RAN Centralization and Cloudification* published August 22, 2014, date of current version September 19, 2014.

[23] *RAN Architecture Options and Performance for 5G Network Evolution* Huaning Niu, Clara (Qian) Li, Apostolos Papathanassiou, Geng Wu Standards and Advanced Technology, Mobile and Communications Group, Intel Corporation Santa Clara, CA, USA