
Ms. Harshada Bhatu Chaudhari and Mr. Pramhesh Patil
Computer Science and Engineering Department,
Shri Sant Gadge Baba College of Engineering and Technology,
Bhusawal, North Maharashtra University, Jalgaon, Maharashtra, India

Abstract- Compared with fourth generation (4G) cellular systems, fifth generation wireless communication systems (5G) are proposed to provide spectral and energy efficiency growth. To achieve these goals, a heterogeneous cloud radio access network (H-CRAN) is taken as progressive wireless access network paradigm and cost-efficient potential solution by incorporating the cloud computing into HetNets. Heterogeneous Cloud Radio Access Networks (H-CRANs) are proposed to mitigate the severe inter-tier interferences & enhance limited cooperative gains resulting from the constrained and non-ideal transmissions between close base stations in heterogeneous networks (HetNets). Then, system architecture and promising key technique Cooperative Radio Resource Management are discussed. A great emphasis is given towards promising key technique Cooperative Radio Resource Management (CRRM) based on cloud computing in H-CRANs to improve both spectral and energy efficiencies.

Keywords- H-CRAN, HetNets, Remote radio heads (RRHs), CRRM.

I. INTRODUCTION

With the rapid advancement of mobile internet and internet of things (IoTs), the demands for high speed data applications, like high-quality wireless video streaming, social networking and machine to machine communication (M2M), have been growing exponentially presently. It is proposed that the total daily mobile traffic in the representative Western European countries will raise 67 times from 186 terabyte (TB) to 12540 TB through 2010 to 2020, and the overall worldwide mobile traffic of 351 Exabyte (EB) in 2025 represents a 174% growth compared with 2020 [1]. Currently, the cellular networks including 1st generation (1G), 2nd generation (2G), 3rd generation (3G) and 4th generation (4G) are far from satisfying the major traffic increments and the high energy efficiency (EE) because a lot of power of a base station (BS) is used to reduce path loss, which in turn causes interferences to other users. The fifth generation (5G) system deployed initially in 2020 is expected to deliver about 1000 times higher wireless area capacity and save up to 90% of energy consumption per service associated with the current 4G system. More than 1000 Gbit/s/km2 area spectral competency in dense urban environments, 10 times more battery life time of connected devices, and 5 times reduced end-to-end (E2E) latency are anticipated in 5G systems[2]. To achieve these goals of 5G systems, advanced radio access technologies & all internet protocol (IP) architectures should be evolved smoothly from 4G systems [3].

A. 5G CRAN

Some advanced technologies, like cloud radio access network (C-RAN) and ultra small cells based heterogeneous network (HetNet), have been offered as potential 5G solutions. C-RAN has attracted intense research interests from both academia and industry [4]. In C-RANs, a large number of low-cost remote radio heads (RRHs) are randomly deployed and connect to the base band unit (BBU) pool via front-haul links.

B. 5G HetNet

To increase the capacity of cellular networks in dense areas with high traffic demands, the low power node (LPN) serving for pure “data-only” service with high capacity is identified as one of the key components in HetNets [5]. One important advantage of HetNets is to decouple the control plane and user plane. LPNs only have the control plane, whereas the control channel overhead and cell-specific reference signals of LPNs can be fully shifted to macro base stations (MBSS). Inadequately, an under-laid structure that MBSS and LPNs reuse the same spectral resources could lead to severe inter-tier interferences. Hence, it is acute to suppress interferences through advanced signal processing techniques to fully release the potential gains of HetNets, such as adopting the advanced coordinated multi-point (CoMP) transmission and reception technique to extinguish both intra-tier and inter-tier interferences. It was reported that the average spectral efficiency (SE) performance achieved from the uplink CoMP in downtown Dresden field trials was only about 20 percents with non-ideal backhaul in [6].

C. 5G H-CRAN

To fulfill new advances anticipated in 5G systems, and overcome the challenges in both C-RANs and HetNets, heterogeneous cloud radio access networks (H-CRANs) is presented as 5G RANs [7], which are fully backward compatible with different kinds of C-RANs and HetNets. The incentive of H-CRANs is to embed the cloud computing technology into HetNets to realize the large-scale cooperative signal processing so as SE and EE performances are substantially improved beyond existing HetNets and C-RANs. In H-CRAN based 5G system, the control plane and user plane are decoupled. MBSSs are mostly used to deliver control signalling of the whole H-CRAN and provide the seamless coverage, whereas RRHs are used to offer the high speed data transmission in the hot spots with huge data services.

II. SYSTEM ARCHITECTURE AND PERFORMANCE ANALYSIS OF H-CRANs

Though HetNets are good options to provide seamless coverage and high capacity in 4G systems, there are still two significant challenges to block their commercial development:

- The SE performance should be improved because the intra- and intercell CoMPs need a huge amount of signaling in backhaul links to mitigate interference among LPNs and MBSSs, which often makes the capacity of backhaul links over constrained.
- Ultra dense LPNs can improve capacity at the cost of consuming too much energy, which results in low EE performance.

Cloud radio access networks (C-RANs) are by now recognized as curtailing the capital and operating expenditures, as well as providing a high transmission bit rate with fantastic EE performance [4]. The remote radio heads (RRHs) operate as soft relay by compressing and forwarding the received signals from UEs to incorporated baseband unit (BBU) pool through the wired/wireless front-haul links. To distinguish the benefits of C-RANs, the joint decompression and decoding schemes are executed in the BBU pool. Accurately, HPNs should still be critical in C-RANs to guarantee backward
compatibility with the existing cellular systems and support seamless coverage since RRHs are mostly deployed to provide high capacity in special zones. With the help of HPNs, the multiple heterogeneous radio networks can be combined, and all system control signalings are delivered therein. Consequently, we include HPNs into C-RANs, and thus H-CRANs are proposed to take full advantage of both HetNets and C-RANs, in which cloud computing capabilities are distorted to solve the aforementioned challenges in HetNets.

A. System Architecture of H-CRAN

Similar to the traditional C-RAN, as shown in Fig. 1, a huge number of RRHs with low energy consumption in the proposed H-CRANs cooperate with each other in the centralized BBU pool to achieve high cooperative gains. Only the front radio frequency (RF) & simple symbol processing functionalities are implemented in RRHs, while the other important baseband physical processing and procedures of upper layers are executed jointly in the BBU pool. Subsequently, only partial functionalities in the PHY layer are merged in RRHs, and the model with these partial functionalities is denoted as PHY RF in Fig. 2. However, different from C-RANs, the BBU pool in H-CRANs is interfaced with HPNs to mitigate the cross-tier interference between RRHs and HPNs through centralized cloud computing-based cooperative processing techniques. Moreover, the data and control interfaces between the BBU pool and HPNs are supplemented and denoted as S1 and X2, respectively, whose definitions are inherent from the standardization definitions of the Third Generation Partnership Project (3GPP). Since voice service can be provided efficiently via the packet switch mode in 4G systems, the proposed HCRAN can support both voice and data services simultaneously, and administration of voice service is preferred to be done by HPNs, while high data packet traffic is mainly attended by RRHs. Compared to the traditional C-RAN architecture, the predicted H-CRAN alleviates the front-haul necessities with the participation of HPNs. The control signaling and data symbols are not coupled in H-CRANs. All control signaling and system broadcasting data are delivered by HPNs to UEs, which abbreviates the capacity and time delay limitations in the front-haul links between RRHs and the BBU pool, and makes RRHs active or sleep efficiently to decrease energy consumption. Furthermore, some or instant messaging service with a small amount of data can be supported efficiently by HPNs. The adaptive signaling between connection-oriented and connectionless is supported in H-CRANs, which can accomplish significant overhead savings in radio connection/release by moving from a pure connection oriented tool. For RRHs, different transmission technologies in the PHY layer can be used to improve transmission bit rates, such as millimeter wave and even optical light. For HPNs, multiple-input multiple-output (MIMO) is one potential approach to extend coverage and enrich capacity. Since all signals are centrally processed in the BBU pool for UEs associated with RRHS, the cloud-computing-based cooperative processing techniques generated from virtual MIMO can attain high diversity and multiplexing gains. Similar to C-RANs, inter-RRH interference can be suppressed by the advanced large scale cooperative processing approaches based on cloud computing in the BBU pool. The cross-tier interference among HPNs and RRHs can be alleviated through cloud-computing-based cooperative RRM (CC-CRRM) via interface X2 between the BBU pool and HPNs. To improve EE performance of H-CRANs, the activated RRHs are adaptive to traffic volume. When the traffic load is less, some potential RRHs fall into sleep mode under administration of the BBU pool. However, when the traffic load becomes excessive in a small special zone, both the HPN with massive MIMO and compact RRHs work together to meet the huge capacity demands, and even the corresponding desired RRHs can derive radio resources from neighboring RRHs.

B. Spectral and Energy Efficiency Performance

By minimizing the communication distance between the serving RRH and desired UEs, and reaching cooperative processing gains from cloud computing in the BBU pool, the SE performance gains are significant in H-CRANs. Compared to the traditional wireless cellular networks, the multiple RRHs connected to one BBU pool in H-CRANs could offer much better performance, where higher degrees of freedom in interference control and resource allocation are achieved. Thanks to the cloud computing technology, exponential EE performance gains can be achieved at the cost of linearly increasing SE only when the circuit power is not large in CRANs [10]. Therefore, for improving both SE and EE performance it is necessary to decrease the circuit power consumption of front-haul links. The efficient centralized cooling system in the BBU pool and the low transmit power in RRHs significantly reduce the total energy consumption. RRHs can be completely switched off to save much energy when there is no traffic, which presents energy saving opportunities of approximately 60 percent in contrast to non-sleep mode [11]. HPNs are responsible for providing the basic service coverage and delivering the control signaling, while RRHs are used to support packet traffic with high bit rates. Partial services and overheads are managed by HPNs, which alleviates constraints on front-haul and decreases circuit energy consumption in RRHs, thus improving both SE and EE performance. As shown in Fig. 2a, EE performance in terms of the number of cell edge UEs are compared among 1-tier HPN, 2-tier-underlaid HetNet, 2-tier overlaid HetNet, 1-tier C-RAN, and 2-tier H-CRAN, where the same helping coverage, frequency spectrum, transmit power of both RRH and HPN, and number of served UEs are assumed [12]. The EE performance decreases with the increasing number of cell edge UEs in the 1-tier HPN scenario because extra resource blocks and power are assigned to the cell edge UEs for guaranteeing their basic transmission rates. Due to lesser transmit power is required and a higher transmission bit rate is achieved, the EE performance is better in 2-tier Het- Nets than in 1-tier HPN. Also, the EE performance in the 2-tier H-CRAN scenario is more desirable than that in the 1-tier C-RAN because RRHs in C-RANs suffer from the limited coverage an HPN could serve. Meanwhile, the EE performance of the 1-tier C-RAN is
desirable than that of both 1-tier HPN and 2-tier HetNet due to

gains from the characteristic of cloud computing. In H-
CRANs, there are frequently ultra dense RRHs in hotspots,

which results in a desired UE being associated with numerous
RRHs and HPNs. Therefore, the user-centric RRH/HPN
clustering mechanism is critical, in which the cluster is
dynamically enhanced for each active UE, and different
clusters for different UEs may overlap. It is not always optimal
that a UE associates with the RRH via the maximum received
signal ratio or the minimum signal-to-interference plus
noise ratio (SINR) because the transmit power among HPNs
and RRHs are significantly different. Meanwhile, larger
cluster size can provide better SE performance for the desired
UE at the cost of leading to more front-haul consumption.

Accordingly, the RRH/HPN association strategy should
optimize the cluster size for each UE, in which the front-haul
overhead and cooperative gains should be balanced.

Furthermore, the association, whether with RRHs or an HPN,
have great impact on SE performance of HCRANs. If UEs only
associate with RRHs, the proposed H-CRAN is simplified to
the C-RAN. The only one nearest and N-nearest RRH
association strategies for H-CRANs are tackled in [13]. As
shown in Fig. 2h, the comparison is done between ergodic
capacity performance under different numbers of associated
RRHs and varying transmit power of RRHs. The capacity
raises monotonically with increasing transmit power because
interference can be avoided due to the consolidated cloud-
computing-based cooperative processing. The capacity gain of
the 2-nearest RRH association over the single nearest RRH
union is significant. However, the capacity gaps among 4, 8,
and infinite RRH association strategies are not large, which
specifies that no more than 4 RRHs are associated for each UE
to balance performance earns and implementation cost.

Besides enhancing SE and EE performance, there is a strong
incentive to improve mobility performance in H-CRANs; for
example, there are less handover failure, lower ping-pong rate,
and lower drop ratio for high-mobility UEs than for C-RANs.

Although the handover between adjacent RRHs is
administrated in the same BBU pool, which means that most
handover signaling are avoided, the RRH re-association and
radio resource reconfiguration are still challenging to mobility
performance. Therefore, in high density C-RANs, high-
mobility UEs are likely to be victims who encounter radio link
failures (RLF) before ending the handover process.

Fortunately, in H-CRANs, high-mobility UEs are performed
by HPNs with reliable connections, and low-mobility UEs
preferably access the RRHs. Consequently, in contrast to C-
RANs, there are remarkable mobility performance gains in H-

CRANs.

III. CLOUD-COMPUTING-BASED COOPERATIVE RADIO
RESOURCE MANAGEMENT

To fully release the potential benefits of HCRAN, the
intelligent CC-CRRM is urgent, and there are various
technical challenges involved. Firstly, CC-CRRM needs to
support real-time and bursty mobile data traffic, such as
mobile gaming, vehicle-to-vehicle transmission, and high-
definition video streaming applications. Hence, CC-CRRM
should have time delay awareness. Most traditional RRMs are
based on heuristics, and there is a lack of theoretical
understanding on how to design delay-aware CC-CRRM.

Then Secondly, CC-CRRM has to be scalable with respect to
H-CRAN size, so traditional RRM is infeasible due to its huge
computational complexity as well as the signaling latency and
complexity involved. These challenges become even beat for
H-CRANs because there are more thin RRHs connected to the
BBU pool through the constrained front-haul. Unlike normal
cross-layer RRM, which is designed to optimize the resource
of a single base station, CC-CRRM involves shared radio
resources among all RRHs/HPNs; thus, the scalability in terms
of computation and signaling is a key obstacle [8]. CC-CRRM
should have delay-aware and cross-layer characteristics to
tackle the above issues and make HCRANs a practical
advancement. Accurately, the CC-CRRM for HCRAN can be
regarded as a cloud-computing based stochastic optimization
problem, which adapts the radio resources (e.g., power, data
rate, CC-CoMP/LS-CMA, user scheduling, and RRH/HPN
association) corresponding to the actual time CSI and queue
state information (QSI). In practice, the signaling and control
are usually mandatory at the frame rank in the PHY or lower
MAC layers, while they are usually done over longer
timescales in the upper MAC and network covering. Based on
the structural property of the stochastic control problem and
the separation of timescales, the speculative control problem
for H-CRANs can be decomposed into a number of lower
dimension sub-problems and further solved by stochastic
online learning techniques, as depicted in Fig.2. Delay-aware
CC-CRRM for H-CRANs is robust to both the global QSI and
CSI, which not only acquires the opportunity to transmit
indicated by the QSI, but also captures the necessity of data
flows indicated by the CSI. With the separation of timescales,
CC-CRRM requires minimized signaling overhead and
estimated complexity. The stochastic online learning instead
of heuristic methods guarantees that the CC-CRRM solution is
flexible to uncertainty in CSI estimation, traffic bursty arrival
statistics as well as other key boundaries. However, since the
delay-aware CC-CRRM is based on the global QSI and CSI,
the underlying curse of dimensionality related with the system

Fig. 2. EE and SE performance evaluations of H-CRANs: a) EE performance
comparisons with various networks; b) SE performance comparisons with
different association numbers.
States and coupled queue dynamics will complicate the derivation of scalable CC-CRRM in H-CRANs. Favorably, the utilization of stochastic differential equation in a Markov decision process (MDP) lights a new way to make the derivation of low complexity and scalable policy for the H-CRAN and has attracted further study [9].

Fig 3. Decomposition of mixed timescale stochastic optimization for CC-CRRM

IV. ADVANTAGES OF C-RAN

Advantages of Cloud-Ran (C-Ran) In Mobile Network Expansion-

- Energy efficiency and power cost reduction- With the centralized processing of the C-RAN architecture, the number of base station sites can be lowered by a factor of 10. Thus, air conditioning and other onsite power-consuming equipment can be minimized. This directly converts into CapEx and OpEx reduction. Small cells with lower transmission power can be set up while network coverage and capacity is improved.

- Capacity and spectral efficiency improvement- In C-RAN, virtual base terminals (macro, micro & small) are aggregated in a large physical BBU pool where they can easily share signalling, data & Channel State Information (CSI) for active users in the system. With C-RAN, it is much easier to implement algorithms to relieve inter-cell interference and improve spectral efficiency. For example, Cooperative Multipoint Processing Automation (CoMP in LTE-Advanced), can easily be implemented within the C-RAN infrastructure.

- Adaptability to non-uniform traffic- C-RAN architecture can efficiently handle non-uniform data traffic due to the load-balancing capacity in the distributed BBU pool.

- Smart Internet traffic offload - Aggregation of the baseband functionality in C-RAN now supplies a central port for traffic offload and content management to handle growing Internet traffic from smartphones and other portable devices. The benefits are reduced backhaul traffic; reduced core network traffic; and lowered latency, all governing to a better quality of user experience.

- Network extensibility -C-RAN architecture guides multistandard operations effects and multicell collaborative signal processing, making it easier to upgrade and expand network capacity from the accumulated point. The integration of SDN architecture with C-RAN enables new software applications and brilliance in the network. The C-RAN architecture naturally facilitates flexible network topology designs.

CONCLUSION

Thus, in this paper we have provided a summary of H-CRAN based 5G technology having features of both HetNet and CRAN to act as the access network. Then system architecture of H-CRANs having components BBU pool and RRHs. Key technique called Cooperative Radio Resource Management is provided for achieving high throughput and low energy consumption in heterogeneous cloud radio access networks (H-CRANs). Recent advancements in the computing convergence of heterogeneous wireless networks, the heterogeneous cloud radio approach network (H-CRAN) is scheduled as a promising new paradigm to achieve high SE and EE performances through the combination of cloud computing and HetNet. Then advantages of CRAN are discussed.

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