Reducing The Number Of Base Stations And Replacing Them With C-Ran & LTE Advanced: True 4g & Beyond In Clouds

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Abstract- *We need to exploit interference among users eligible for cooperation C-RAN this increases the flexibility of network optimization and also increases the scalability of computational resources. We propose C-RAN based architecture and a working scheme of an uplink joint processing in critical situations. Where strong interference can effects cell edge users for reliable transmission over radio access network, we need to consider characteristics of real network modern technological solution. C-RAN & LTE Advanced: The Road to "True 4G" analyzes the C-RAN opportunity and the challenges the industry must overcome for the technology to emerge as a mainstream next-generation radio access platform.*

Keywords: C-RAN, LTE, TRUE 4G, Uplink, Downlink, Radio Access Network, Reliable Transmission.

I. INTRODUCTION

In my new Heavy Reading report, C-RAN & LTE Advanced: The Road to "True 4G" & Beyond, I discuss the emergence of an important new radio access network (RAN) architecture that promises superior performance in coordinated systems such as LTE Advanced.

Standing for both centralized RAN and cloud RAN, the C-RAN concept is based around the idea of a centralized baseband processing pool serving n number of distributed radio access nodes.

Centralized baseband processing is primarily useful because it enables faster coordination of radio resources across distributed access nodes than a classic macro cell architecture. In systems such as Long Term Evolution (LTE) and LTE Advanced (LTE-A), where coordinated processing is important to performance improvements, the capability to manage resources centrally rather than via an external X2 interface between base stations could generate important capacity and end-user performance gains.

Indeed, in the context of hyper-densification of the RAN it is arguable that centralized, collaborative processing to reduce and manage inter-cell interference will become a hard requirement. Looking further ahead toward 5G and to the concept of integrated management of cloud and radio resources, the C-RAN model could become more attractive still.

Asian operators are -- unquestionably -- driving the pace of C-RAN development. China Mobile in particular is forcing an aggressive pace that combines substantial in-house development with collaborative R&D with specialist and large, integrated vendors. South Korean operators KT and SK Telecom are more reliant on vendor collaboration, but have been able to make rapid progress on base station hoteling (centralized RAN) and can transition this to shared baseband "cloud" model over time. And in Japan NTT Docomo is actively pursuing development of its Super Cell platform on which it will deploy LTE-A.

Over the past year or so, Western operators have started to take a much greater interest in C-RAN because of how the technology dovetails with the push toward LTE-A. Operator R&D departments have been familiar with the concept for a long time, but more recently the focus has shifted to thinking about potential implementation and deployment models. Thus operators such as Deutsche Telekom, Orange, AT&T, and Verizon are evaluating how C-RAN might apply to their networks.

Vendor perspectives on cloud RAN are mixed: All see the potential, but there is not yet a consensus about when and how this technology should be implemented commercially. We think the top six or seven vendors harbor similar perspectives, albeit articulated and marketed a little differently. Huawei, ZTE, and Alcatel-Lucent are more progressive in terms of trials and public communication. Ericsson and NSN are more conservative in their external communication, but are very much engaged in coordinated system development. And Samsung is arguably some way along the line towards a virtualized control-plane with its "smart scheduler" node, which runs on standard IT servers.

There are, of course, substantial challenges to overcome if C-RAN is to be widely deployed commercially (virtualized baseband and better "fronthaul" solutions, for example), but an emerging set of use-cases that scale down to smaller, more approachable deployments look encouraging.

C-RAN is typically thought of as a large-scale urban macro solution, but the concept of pooled baseband serving n number of radio access nodes can apply to a variety of scenarios, such as small cell underlays (using micro RRUs), so-called Super Cells, and outdoor/indoor hotzone systems. These models, identified and defined partly through the NGNM Alliance, could prove an attractive way to introduce and develop C-RAN technology.

II. COOPERATIVE UPLINK PROCESSING

The idea of interference management through BS cooperation spans over several aspects of a cellular network regarding the amount of available channel state information (CSI) and shared data (compressed signal or decoded data), the FH network architecture (distributed or centralized processing), the communication infrastructures between BSs (e.g., fibre, microwave) and cooperation technique used (e.g., coordinated scheduling, joint detection). In this section, we investigate the state-of-the-art of uplink cooperative techniques already used in today’s cellular networks or reported in standards and research papers.

A. The Network MIMO concept

In theory, we can assimilate multi-cell Multiple-Input Multiple-Output (MIMO) network without limitation in fronthaul connections to conventional multi-user MIMO (MUMIMO), so that in the uplink, with full cooperation, the capacity of each cell should be the same as that in an interference free scenario [5]. Due to several practical and theortical constraints, this capacity results cannot be applied to real cellular networks as already pointed out in[2]. Still, we can have several methods to exploit the inter-cell interference with fully or partially centralized signal detection [6]. Multi-cell joint detection can be realized like that in single-cell MIMO case using either Maximum Likelihood (ML) or Minimum Mean Square Error (MMSE) detection. However, the high complexity of ML does not allow implementation in real-time systems. On the other hand, joint MMSE is suboptimal but requires more reasonable computational cost. Detection of each signal can be done by applying sucessive interference cancellation(SIC). The drawback of SIC is the possible error propagation if first signals cannot be accurately detected. A main difficulty of joint detection is to forward received signal to the collective processing unit (see sub-section II-C). Signal compression before sending on the fronthaul links can address this practical constraint, but can affect accuracy of detection.

Compression followed by SIC detection was studied in [7]. In [8] authors propose to forward to the BBU-pool a quantized version of demodulated symbols which is then used in joint processing. Amount of data sent over fronthaul links can also be reduced if a BS forwards already decoded signal that can be used to perform SIC for the other. Another form of decode and-forward scheme is that a part of the message is individually decoded at the BS while the other part is forwarded for joint decoding in the BBU-pool [9]. Decentralized cooperation similar to decode-and-forward was investigated in [10], where decoded data is shared among neighbouring BSs instead of a central unit. In future cellular networks C-RAN architecture can be adopted due to which there is advantage from low latency communication between collocated BBUs and more optimal scheme of multicell cooperation.

III. LITERATURE SERVEY

KEY TECHNOLOGIES FOR COOPERATIVE TRANSMISSIONS

C-RAN

Advantages of centralization: As mentioned before, a centralized architecture can facilitate cooperation between inter-cells.Between BBUs of different cells C-RAN is particularly appropriate for low-latency communications since these are located in the same processing unit. Centralization of BBUs also facilitates the handover procedure which otherwise would require cooperation and communication between distributed BSs through for example the 3GPP X2 interface [12].

The need for such architecture is not only for improving network performance, but also for reducing deployment and operational costs. To satisfy future data rate and coverage requirements, antenna density should be increased while operators’ per-subscriber income decreases. In order to deploy denser networks at lower cost, processing capacity should be centralized so that system scalability, energy efficiency and flexibility to upgrade and manage computational resources can be guaranteed, which will result in lower Operational Expenditure (OPEX)

The overall dimension of computational resources can be reduced Since several BBUs are located in the same server, results of pooling. BBU-pools are also susceptible to be shared between several operators using the concept of RAN as a Service [14], which allows to have several instances of various standalone modules that can be attributed to different operators. The emerging technology of SDN provides centralization of BBUs requires resource management and data flow control. This can be provided by the , to be discussed in subsection III-

CPRI used in Fronthaul transport: In existing C-RAN deployments, RRHs are connected to BBU-pool through dedicated point-to-point fiber link on which synchronous CPRI packets containing baseband I/Q symbols are sent. As pointed out in [15], this type of infrastructure cannot meet future network requirements such as dynamic mapping and network resource allocation between RRHs and BBU-pool. Ethernet based Fronthaul technology connected through a CPRI-toEthernet gateway is a good candidate for transport CPRI packets [13]. Since todays FH cannot guarantee to transport baseband I/Q symbols for large scale MIMO transmissions, the common target of centralizing all the baseband processing cannot be ensured. However, to benefit from C-RAN and CoMP features, we have to design a dynamic architecture allowing the centralization of PHY functions.

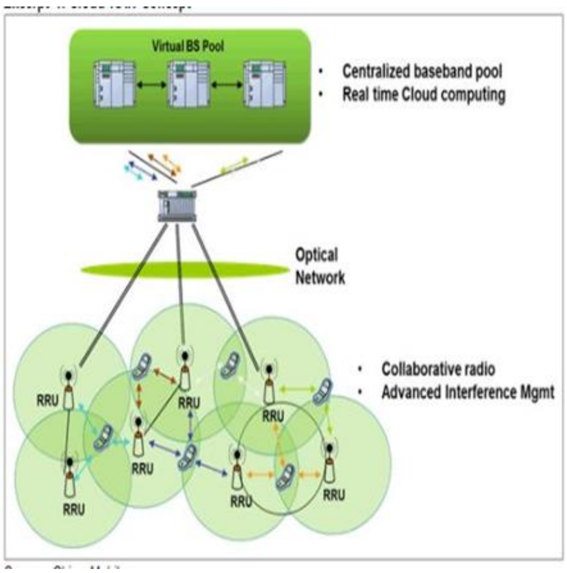
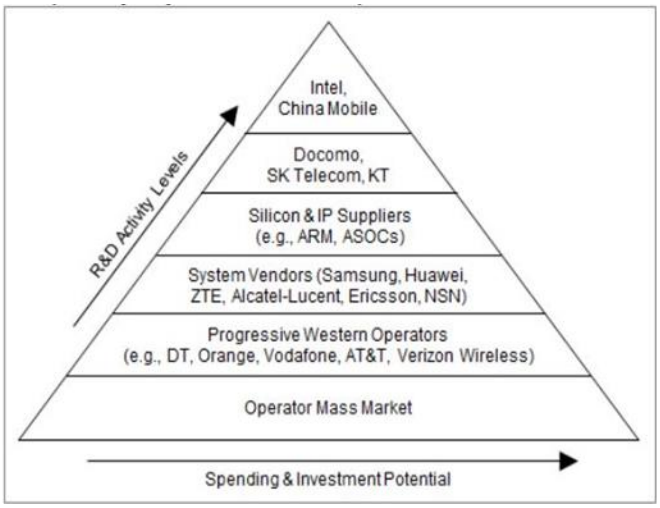


Fig 2.1 C-RAN Cloud Technology

C-RAN is being driven by Asian operators, and by China Mobile in particular. The operator is acutely aware of the ambitious nature of its C-RAN project and of the benefits of building a support ecosystem around the concept. The excerpt below shows a hierarchy (of sorts) of the companies driving C-RAN development, with those having the most influence and committing the most R&D resources at the top.

C-RAN LEVELS

IV. PRAPOSED SYSTEM



Bandwidth Allocation and Traffic Handling

Scheduling

The scheduler resides in the eNodeB to dynamically allocate uplink and downlink resources over the uplink and downlink shard channel U-SCH and D-SCH, respectively. Uplink scheduling is performed per SC-FDMA while downlink is performed for OFDMA. The eNodeB calculates the time-frequency resources given the traffic volume and the QoS requirements of each radio bearer. However, the resources are allocated per UE and not per radio bearer. The uplink and downlink schedulers are invoked to allocate resources every TTI. The minimum TTI duration is of one subframe length; that is, 1 ms. However, the LTE specification allows adaptive downlink TTI duration where multiple subframes can be concatenated to produce a longer TTI duration. This concatenation reduces the overhead for higher layers. The TTI length can be set dynamically by the eNodeB through defining the modulation and coding scheme used and the size of the resource blocks. Otherwise, it can be set semi-statically through higher layer signaling. Adaptive TTI length can be used to improve the Hybrid Automatic Repeat Request (HARQ) performance or the support of lower data rates and quality of service. In the following two sections we summarize the operation of the downlink scheduler and uplink scheduler.

Downlink Scheduling

The unicast downlink transmission is carried over the shared downlink channel (D-SCH) and the operation takes place at the MAC layer of eNodeB. At each TTI, the eNodeB has to dynamically decide which UE is supposed to transmit, and when and using which frequency resources. The decision depends on different factors including the cell's nominal capacity, QoS parameters (BER, minimum and maximum data rate and delay), backlogged traffic waiting for retransmission, link channel quality relayed to the eNodeB as a CQI, buffers sizes, and the UE's capabilities. More than one UE can be scheduled during one TTI. However, the number of UEs scheduled that can be scheduled during one TTI is limited by the signaling overhead. Allocations are signaled to UEs on the PDCCH, and a UE with enabled downlink reception monitors the PDCCH every TTI. In addition to the dynamic allocation, LTE standard provides the flexibility to what is called persistent scheduling where the time-frequency resources can be implicitly reused in the consecutive TTIs according to a specific periodicity. Persistent scheduling reduces the overhead scheduling for applications such as VoIP.

Scheduler design is not specified in the standard and is left for vendor implementation. An efficient scheduler, however, should take into account the channel quality of the link from the eNodeB to the UE and the buffer length of the radio bearers. It should also cater to fairness among the UEs based on their service level agreement (SLA), that is, subscription type and priority level. A UE monitors a shared reference signal broadcast to all UEs in the cell by eNodeB to estimate the instantaneous downlink channel quality and signal it in a CQI report. CQI can be about either a single or multiple resource blocks, and can be either periodic or aperiodic. The periodic CQI report is transmitted together with uplink data on the PUSCH or on the PUCCH, while the aperiodic CQI is scheduled by the eNodeB via the PDCCH and transmitted together with uplink data on PUSCH.

Uplink Scheduling

The uplink scheduler resides in eNodeB and the UE. Similar to the downlink scheduler, the uplink scheduler at eNodeB is invoked every TTI to decide which UEs will transmit over the uplink shared channel U-SCH, when and using which resources. In addition to assigning the time-frequency resources to the UE, the eNodeB scheduler decides on the modulation and coding scheme that each UE shall use as a consequence of the estimation of the uplink channel quality at the eNodeB. Fairness, opportunistic (i.e., channel-quality-dependent scheduling), interference coordination and buffer length are performance measures for uplink and downlink scheduling. Considering the buffer size of an uplink radio bearer in scheduling decision to the eNodeB station entails higher overhead and complexity. The UE information about its own radio bearers' buffer sizes is always newer than any signaled information from the UE to the eNodeB. This is one of the reasons for allocating the time-frequency resources per the UE, where in this case the UE will manage the sharing of its uplink resources among its own radio bearers. The Radio Resource Control (RRC) part of the UE MAC layer allocates uplink resources among the radio bearers within the UE. The RRC arbitrates among the radio bearers based on their assigned priorities and an assigned radio bearer parameter called the prioritized bit rate (PBR). RRC first serves the radio bearers in deceasing priority order up to their PBR. Secondly, if there are any residual resources, they are allocated in decreasing priority. In the case that all PBRs are set to zeros the uplink resources are allocated in strict priority order.

To exploit uplink channel quality, the eNodeB requires estimating the uplink channel quality. To achieve this, reference signals, called the channel-sounding reference signals are sent from each UE to the eNodeB. The channel-sounding reference signals are not limited for the frequency resources allocated to the UE, and may span the entire system bandwidth of the cell. Moreover, the channel sounding reference signals may also be transmitted by UE which does not have any uplink allocated frequency resources.

V. QOS IN LTE-ADVANCED

Most of the functionalities and specifications related to QoS and radio resource management deployed by LTE are supported by LTE-Advanced to guarantee backward compatibility, which is an essential requirement for the LTE-Advanced standardization. Specifically, QoS performance measures, classification, signaling bandwidth requests and grants are almost similar to LTE. Bandwidth allocation and traffic handling includes some enhancements required to support the new features included in LTE-Advanced to meet or exceed the IMT-Advanced requirements. In this section, we will discuss the major enhancements related to QoS and bandwidth reservation procedures.

Carrier Aggregation

LTE-Advanced provides support for a new feature called Carrier Aggregation, which entails aggregating two or more component carriers that are either contiguous or non-contiguous. The main objective of Carrier Aggregation is to provide larger bandwidth to meet the IMT-Advanced requirements of a spectrum up to 100 MHz. Carrier Aggregation has an impact on both scheduling and HARQ. For HARQ, it is required in Carrier Aggregation, whether contiguous or non-contiguous, to have one independent HARQ entity per scheduled component carrier. Note that the maximum number of HARQ entities allowed by LTE-Advanced is eight entities for the FDD duplexing. For scheduling, and similar to Release 8, each UE may be simultaneously scheduled over multiple component carriers. However, at most one random access procedure is scheduled per UE in any timeframe. For TDD, it is required that the number of component carriers uplink should be equal to that of the downlink. As in LTE, a single component carrier is still mapped into one transport block.

Relaying in LTE-Advanced

Relaying is currently being studied as an enhancement of LTE towards LTEAdvanced, that is, at the moment it is not part of the standard. The main objective of introducing relaying in LTE-Advanced is to provide extended LTE coverage at low cost. Standardization for relaying is at its early stages and is expected to be finalized by the end of year 2011. LTE-Advanced relay defines two types of relays, Type-I and Type-II. Type I corresponds to the non-transparent relay in 802.16j, yet differs by being strictly limited to two hops. Type-II corresponds to the transparent relay. In Type-I, the relay node controls its own cell and serves only the purpose of extending the coverage to UEs beyond the eNodeBs effective coverage. A Type I relay node is hence required to transmit the common reference signal and control information to UEs. In Type-II, the UE is within the eNodeB coverage, and is capable of receiving the eNodeB’s common reference signal and control information directly. The main objective of Type-II relay node is to increase the overall system capacity by achieving multipath diversity and transmission gains at the UE.

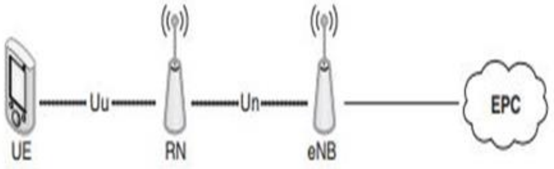


Fig 4.2 LTE Advanced Relay Architecture

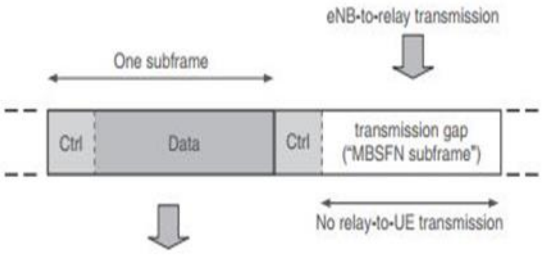


Fig 4.3 Downlink partitioning

Performance evaluation

There are two steps to validate the proposed joint processing scheme. First, we check whether symbols can be accurately detected for the jointly scheduled users. Secondly, we evaluate the throughput improvement in the case where many users are in each cell and jointly detected users are selected between them.

In our first simulation study, we implement a single carrier model where one user in each cell transmits simultaneously towards the receivers (RRHs) who share the received signals for joint detection using multi-cell MMSE. We use LTE urban macro-cell channel model [24], where 16-QAM modulated symbols are sent. We compare error rate after QAM demodulation without any repeat mechanism. Since our joint detection scheme does not affect user-PHY processing, it is appropriate to evaluate error rate at this point. Fig. 3 shows the error rates in the following cases for comparison: (i) interference-free transmission, (ii) 2-user cooperation, (iii) 3-user cooperation, and (iv) non-cooperative detection.

We see that in the JD cases we need slightly higher transmit power to reach the same error rate as in singleuser transmission, but we transmit on one PRB only instead of using one for each user. This confirms that if frequency resources become scarce, using JD in the BBU-pool enables accurate high-rate transmission on the uplink. We notice also that higher cluster-size requires higher power since meansquare error at detection can increase with the dimension of received signal. It appears also clearly that without cooperation

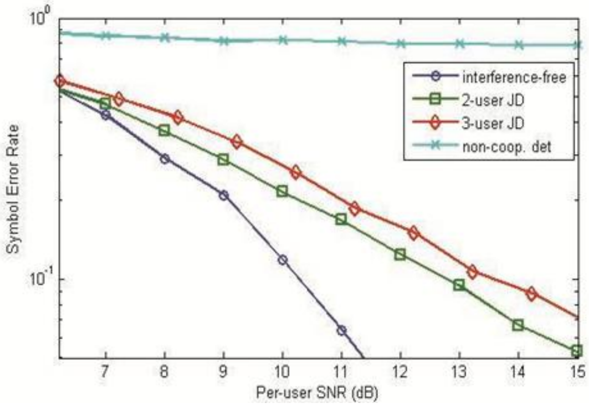


Fig. 4: Required SNR for achieving 10−1 symbol error rate during the joint detection and improvement of energy efficiency w.r.t. the 1 user/PRB case.At the receiver side, the SINR is too low to perform accurate detection.

$$= \frac{\sum_i \sum_j |h_{ij} x_j|}{\sigma_n^2} \qquad \mathbf{2}$$

As the complexity of the joint MMSE detection scales as O(n2) where n is the number of jointly detected users, we studied the possibility of reducing this complexity by realizing the JD over a subset of the cooperation cluster only. This would allow jointly detected users to benefit from CSI of all co-channel users, but we should deal with interference coming from non-JD users. In addition, it turns out that for users transmitting with the same power and having path losses of the same order

$$\sum_{i\neq j}\sum[h_{ij}x_i]$$

does not scale with the transmission power, so JD cannot achieve target error rate unless all co-channel users are jointly detected. Note that to handle potential implementation complexity, one can also consider to distribute the joint MMSE function among BBUs, in a parallelized system implementation.

To evaluate how much the system average throughput and cell-edge throughput are improved by user selective joint detection, in our current work we are implementing system simulations with realistic traffics. By adding a joint scheduling optimization algorithm and joint detection function for selected subcarriers in full-stack LTE base stations, we can simulate a full-load network scenario where we expect system performance improvement.

VI. CONCLUSION AND FUTURE WORK

In this paper, we explore C-RAN architecture as an enabler for CoMP, including its limitations and the perspectives for next-generation cellular networks. We investigate the network elements required for C-RAN such as SDN-controller and evolved fronthaul transport. They can greatly facilitate the implementation of uplink cooperation between users, taking into account the practical limitations. The proposed joint detection method satisfies real network constraints and can improve cell throughput and cell-edge QoS.

Centralized baseband processing is primarily useful because it enables faster coordination of radio resources across distributed access nodes than a classic macro cell architecture. In systems such as Long Term Evolution (LTE) and LTE Advanced (LTE-A), where coordinated processing is important to performance improvements, the capability to manage resources centrally rather than via an external X2 interface between base stations could generate important capacity and end-user performance gains. We can also evaluate the impact of adding this joint detection and its actual computation time. The evolution of C-RAN from today's physical BBU centralization towards future.

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