Departure talk

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Planning and Dimensioning in H-CRAN
References


Motivations

- (ADSL)-like user experience will be provided in the fifth generation (5G) wireless systems
  - average area capacity of 25 Gb/s/km²
  - 100 times higher than current fourth generation (4G) systems
  - a 1000× improvement in energy efficiency (EE) is anticipated by 2020

- Cell densification, is a necessary step to reach such improvements
  - HetNet (Small, pico and femto cells): use of low-power node (LPN).
Motivations (problems...)

- Too dense LPNs incur severe interference, which restricts performance gains and commercial development of HetNets.
- CoMP transmission and reception is the most promising techniques in 4G but it has disadvantages in real networks.
- Performance gain depends heavily on the backhaul constraints and even degrades with increasing density of LPNs.
- Traditional C-RAN deployments impose extremely high demands on backhauls...
- ...and at the current development stage of most operators, it will require high investments to be deployed.
H-CRAN

- Combine LPNs with a high-power node (HPN, e.g., macro or micro base station) to form a HetNet.
- Integrate with a C-RAN architecture by connecting the HPN to the BBU pool.
- Distribute operations by the C-RAN and the HPN:
  - HPN supports voice and low-rate data
  - C-RAN supports high-rate data
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 the centralized baseband unit (BBU) pool through the wired/wireless fronthaul links. To distinguish the advantages 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 mainly deployed to provide high capacity in special zones. With the help of HPNs, the multiple heterogeneous radio networks can be converged, and all system control signalings are delivered wherein. Consequently, we incorporate 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 exploited to solve the aforementioned challenges in HetNets.

**SYSTEM ARCHITECTURE OF H-CRAN**

Similar to the traditional C-RAN, as shown in Fig. 2, 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) and simple symbol processing functionalities are implemented in RRHs, while the other important baseband physical processing and procedures of the upper layers are executed jointly in the BBU pool. Subsequently, only partial functionalities in the PHY layer are incorporated 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. Furthermore, the data and control interfaces between the BBU pool and HPNs are added and denoted as S1 and X2, respectively, whose definitions are inherited from the standardization definitions of the Third Generation Partnership Project (3GPP). Since voice service can be provided efficiently through the packet switch mode in 4G systems, the proposed H-CRAN 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 served by RRHs. Compared to the traditional C-RAN architecture, the proposed H-CRAN alleviates the front-haul requirements with the participation of HPNs. The control signaling and data symbols are decoupled in H-CRANs. All control signaling and system broadcasting data are delivered by HPNs to UEs, which simplifies the capacity and time delay constraints in the fronthaul links between RRHs and the BBU pool, and makes RRHs active or sleep efficiently to decrease energy consumption. Furthermore, some burst traffic or instant messaging service with a small amount of data can be supported efficiently by HPNs. The adaptive signaling/control mechanisms...
Conventional H-CRAN
Proposed approach

- Local processing units
- Trade-off between energy consumption and fronthaul/backhaul load
Proposed approach (detailed view)

Interconnection architecture and technologies

MEC/BBU Processing/

Switch/Splitter

Line cards

CO
Research opportunities: static scenario

### Planning

- **Given:** Wireless network load
- **Determine:**
  - Placement of processing functions
  - Level of splitting
  - Control operation (BBU processing, CoMP, etc)

### Dimensioning

- **Given:** network load and topology
- **Determine:**
  - The number of wavelengths to local processing functions
  - The number of wavelengths to fronthauling

1/21/16
Research opportunities: dynamic scenario

Planning

- Load Balancing strategies for Dynamic Access topologies
  - Enable/Disable local processing units according to wireless traffic fluctuations
  - Consider EE to switch on/off RRH or HPC.
  - Re-optimize parameters for the new topology

Dimensioning

- Re-size the amount of resources (wavelengths) available to each function
  - Processing
  - Fronthauling
QoS-aware service degradation in EON
In the occurrence of resource shortage, services should be degraded by either:

- Change the modulation format
  - Decrease transmission rate
  - Increase delay
- Preempt existing connections to accommodate new ones

Weights assigned to lightpaths might be tightened to a QoS model, which in its turn determines the precedence relation among lightpaths.
QoS model vs. state of the network

- For practical purposes not only the QoS model should be considered but also the state of the network.

- However, considering the state of the network to make decisions would lead to violation of the QoS model.

Proposed solution: to provide a dynamic weighting function to prioritize requests depending on the QoS model and on the state of the network.
In a proportional service differentiation model it is expected that:

\[
\frac{q_i}{s_i} = \frac{q_j}{s_j} \quad (i, j = 1, \ldots, N)
\]

where \( q_i \) is the evaluated QoS metric and \( s_i \) the differentiation factor for class \( i \) and \( N \) the total number of classes.

Let \( \tau \) be a short interval, the measured QoS metrics obtained during \( \tau \) is given by:

\[
\frac{q_i(t, t + \tau)}{s_i} = \frac{q_j(t, t + \tau)}{s_j} \pm \Delta_{ij}
\]
Dynamic weighting function

From equation 1 we have

\[
\frac{a_1 q_1}{a_1 s_1} = \ldots = \frac{a_n q_n}{a_n s_n} = \frac{a_1 q_1 + a_2 q_2 + \ldots + a_n q_n}{a_1 s_1 + a_2 s_2 + \ldots + a_n s_n}
\]

Or in another words:

\[
q_i^* = s_i \frac{\sum_{k=1}^{N} a_k q_k}{\sum_{k=1}^{N} a_k s_k} = s_i \frac{\sum_{k=1}^{N} a_k q_k}{\sum_{k=1}^{N} a_k s_k} = s_i \frac{q_T}{s_{wt}}
\]

where \(q_T\) and \(s_{wt}\) represent the total blocking probability and the sum of weighted differentiation parameters and are given by:

\[
q_T = \frac{\sum_{k=1}^{N} a_k q_k}{a_T}, \quad s_{wt} = \sum_{k=1}^{N} \frac{a_k s_k}{a_T}
\]
Dynamic weighting function

The following equation can be used to measure the deviation of $q_i$ regarding $q^*_i$

$$\Delta_i = \frac{q_i}{q_i^*}$$

The following dynamic weighting function can be applied to prioritize requests according to the previous deviation

$$w_i = \alpha(\Delta_i \frac{p_i}{N_i}) + \beta s(t)$$

Where $P_i$ represents the static priority of each class, $N_i$ is the number of class “I” requests and $s(t)$ is a compound function representing the state of the network (fragmentation, lightpath completion time, signaling cost..etc)
Problem: Scheduling VPONs to support CoMP

Design and implementation of simulator

Analysis of $2^K$ factorial experimental design

ICC paper: Load Balancing and Latency Reduction in Multi-User CoMP over TWDM-VPONs

Extension to journal: New metrics, load-aware scheduling algorithm
## Collaborations

<table>
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<tr>
<th>Task</th>
<th>Fellow</th>
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<tbody>
<tr>
<td>1 Bayesian Network and Dynamic Bayesian Network models for</td>
<td>Carlos</td>
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<td>capturing cascading failures</td>
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<td>2 Analytical Model based on Generalized Processor Sharing to</td>
<td>Zhizhen</td>
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<td>estimate maximum achievable delay in degraded service networks</td>
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<td>3 Scheduling algorithm for VPON formation to support SU-CoMP</td>
<td>Zhizhen</td>
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<td>4 BBU placement in Optical Data centers to support multi-tenant</td>
<td>Carlos</td>
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<td>systems</td>
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<td>5 A fuzzy optimization model to the traveling repairman,</td>
<td>Chen Ma</td>
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<td>6 Optimality proofs for scheduling algorithms in NG-EPON</td>
<td>Lin</td>
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<td>7 CoMP-set Selection and VPON scheduling for MU-COMP</td>
<td>Xinbo</td>
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<td>8 Resource allocation strategies in application-aware networks</td>
<td>Divya</td>
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Learnings

- “Be a leader”
- “Be problem-oriented rather than solution oriented”
- “Everything can be researchable but we're only interested in problems that can be fundable”
- “We're not interested in problems that were studied by others”

Bis

- “High-quality results and presentation is the minimum expected”

Massimo
Goals

- Improve English
- Make friends
- Collect cultural experiences
Personal Goals

- Improve English
- Make friends
- Collect cultural experiences
Thank you