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Real-life C-RAN deployment considerations

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***Abstract*— Cloud-Radio Access Network (C-RAN) is seen as a promising mobile network architecture for both current and future Radio Access Technologies (RATs). However, commercial C-RAN deployments are not yet commonly seen and thus experience from operational networks is limited. This means that standard procedures and best practices for roll out are yet to be established. This work provides a case study, where a small but densely populated part of the network owned by the Danish mobile network operator, TDC, is evaluated for C-RAN deployment. A roadmap is provided which uses traffic data as input and the output is a sequence of when the specific cells should have C-RAN deployed. Any operator to create their own roadmap towards C-RAN deployment can use the methods derived for the roadmap in this work.**

Keywords*— C-RAN; deployment; inter-cell cooperation; network operator; shared processing

I. INTRODUCTION

The users' demand for mobile traffic is steeply increasing. By 2022, the worldwide amount of smartphone subscriptions are forecasted to reach 6.8 Billion [1]. All these users demand to be online everywhere, all the time. To comply with these demands, cell sizes are decreasing while the number of base-stations is increasing. This evolution can lead to higher interference among the cells. In a traditional base-station, the capacity offered to the users is static, and this does not comply very well with the users' daily movements as users move between different areas during the day. For example, they are at work during daytime and at home in the evening. Due to the users daily movements certain cells will need more capacity at certain times while other cells need it at other times. In order to comply with the increasing interference and improve the resource utilization, network operators are searching for new ways to expand their networks to be ready for future demands. A solution that is widely discussed is Cloud-Radio Access Network (C-RAN) [2].

C-RAN is a mobile network architecture, which can be used in both future 5G networks and existing 2G, 3G and 4G networks. In C-RAN, the baseband and radio functions are split into a BaseBand Unit (BBU) and a Remote Radio Head (RRH) connected by a so-called fronthaul network [2]. By separating the BBU and RRH it is possible to gather the processing powers from several base stations in a centralized place, a BBU pool [2]. Establishing a BBU pool leads to a better inter-cell cooperation, subsequently, better interference management and the possibility of shared processing [2].

This paper introduces a case study scenario where a part of the network owned by the Danish mobile network operator TDC is investigated in terms of C-RAN implementation. The work in [3] uses an integer linear programming model to solve a BBU placement problem and investigates the model using three case study scenarios. [4] presents a model computing the number and placements of processing units, and considers the city of Lisbon as a scenario. Previous studies [5] have also looked into simulation of C-RAN deployments by maximizing the shared resources, but a roadmap deployment strategy for C-RAN in a case study area, is a new angle for deployment considerations. This paper investigates the challenges that faces a network operator when implementing C-RAN, and deducts a method to evaluate which cells it will benefit most from by implementing C-RAN. The remainder of this paper is structured as follows: In section II the considerations toward a C-RAN roadmap are outlined, section III presents the case study, leading to a roadmap in section IV, section V presents a discussion on the methods used, and section VI concludes the paper.

II. CONSIDERATIONS FOR A ROADMAP TOWARD C-RAN

Network operators are showing increased interest in the advantages obtained by implementing the C-RAN architecture. The first thing to consider when a network operator wants to deploy C-RAN should be whether it is feasible to deploy C-RAN in the particular area. Therefore, it is crucial to find a method for determining how well cells in the area will benefit from implementing C-RAN.

In order to provide the network operator with a useful roadmap, a starting point is to define some general properties for that cell, which will benefit the most from implementing C-RAN (LTE-based). The cell will:

- Have low inter-site distance to neighbor cells.
- Suffer from high interference.
- Have different peak time compared to neighbor cells.
- Have a high peak to average ratio.
- Have a low average traffic.

According to these properties, a network operator will achieve most advantages when two neighbor cells are located in the same BBU pool, because then the interference between the cells will be reduced and the user mobility will be enhanced due to shared processing.

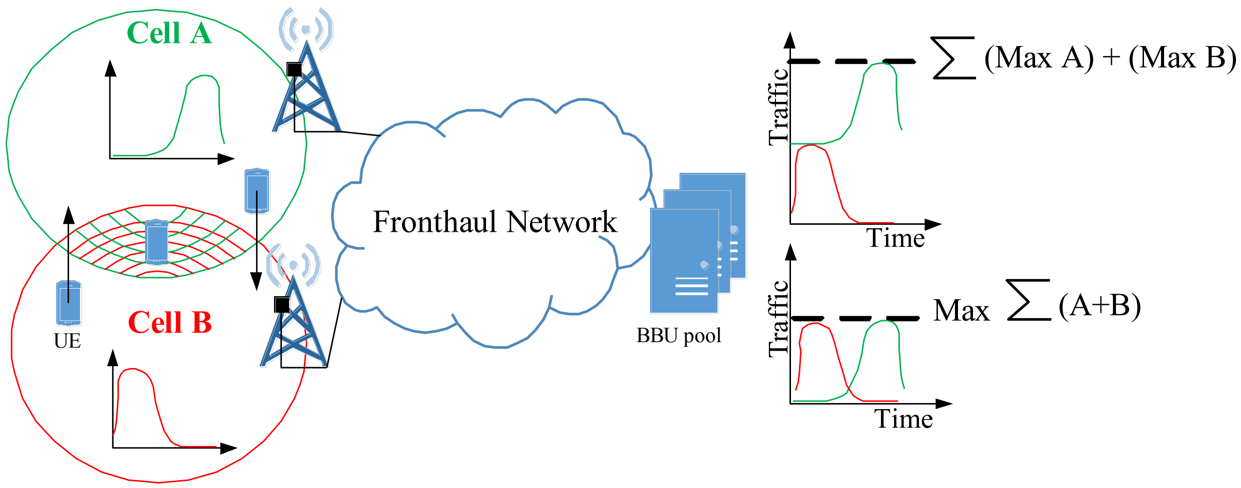

Fig. 1: C-RAN with interference between cells and shared processing in the BBU pool

Shared processing introduces a statistical multiplexing gain in the BBU pool, describing how many resources can be saved when combining cell A and B. This is illustrated in fig. 1. The multiplexing gain is calculated as:

$$\text{MUX gain}=\frac{\sum(\max \text{A})+(\max \text{B})}{\text{Max}\ \sum(\text{A+B})} \quad (1)$$

The general properties listed, lead to deduction of what we call the cell ranking method, which ranks the combination of two cells, A and B, after how well the network operator will benefit from implementing C-RAN in this combination of cells:

$$\text{Cell ranking}=\frac{\left(\frac{avg_{AT}}{avg_{PA}}\right)\cdot \text{PA}+avg_{AT}\cdot \text{PT}}{\left(\frac{avg_{AT}}{2\cdot avg_{I}}\right)\cdot \text{I}+\text{AT}+\left(\frac{avg_{AT}}{avg_{ISD}}\right)\cdot \text{ISD}} \quad (2)$$

The input parameters are worked out for all combinations of two cells in the area. Afterwards an algorithm using the cell ranking method calculates the ranking for each combination of two cells. A description of the input parameters to the cell ranking method follows below:

- PA: Peak to average ratio of the traffic in cell A + cell B, avgPA is the average peak to average traffic in the entire area.
- AT [GB/h]: Average traffic in cell A + cell B, avgAT is the average traffic in the entire area.
- PT: Peak time constant, which is 1 if cell A and B have peak times within the same hour, otherwise 2.
- I [dBm]: Interference in cell A. avgI is the average interference in the entire area.
- ISD [m]: Distance between sites in cell A and B. avgISD is the average distance between all neighbor cells.

In the cell ranking method, the input parameter AT and the average values are used to establish an equal weighting of all inputs. I and PT are assessed as being the inputs affecting the exploitation of shared processing and interference mitigation the most, hence these inputs are weighted higher.

When the first two cells are pooled together, chosen based on the cell ranking method, then a BBU pool has been established. When the BBU pool is established, it must be determined which of the remaining cells will be beneficial to include in this specific BBU pool. A particular cell within the area, cell C, is ranked after how well it will benefit from being implemented in this BBU pool. We call this the pool ranking method:

$$\text{Pool ranking}=\frac{\left(\frac{avg_{AT}}{avg_{PA}}\right)\cdot(\text{PA}_{\text{cell C}}+\text{PA}_{\text{pool}})+avg_{AT}\cdot \text{PT}}{\left(\frac{avg_{AT}}{2\cdot avg_{I}}\right)\cdot \text{I}_{\text{cell C}}+(\text{AT}_{\text{cell C}}+\text{AT}_{\text{pool}})} \quad (3)$$

The pool ranking method's input values are obtained by calculating the average value of the cells already incorporated in the BBU pool. These values will be referred to as:

- PApool: Average value of peak to average ratio in the pool.
- ATpool: Average traffic in the pool.
- PT: 1 if another cell in the pool have the same peak time as cell C, otherwise 2.

A. *Roadmap process*

When a network operator wants to expand his network by upgrading to C-RAN, the first thing it needs to do is to find the two cells that will benefit the most from implementing C-RAN. These are found using the cell ranking method. Then, a BBU pool is created from these two cells and the pool ranking method can be used to find the remaining cells to incorporate in the BBU pool. Every time a new cell is added to the BBU pool, the statistical multiplexing gain is calculated. The statistical multiplexing gain is increasing until it starts to decrease. When the statistical multiplexing gain is peaking, the optimal number of cells within this particular BBU pool is found. Then the network operator should implement C-RAN in these chosen cells. The process is iterative, if the operator wishes to deploy another BBU pool it can repeat the process.

III. CASE STUDY SCENARIO

The area used for reference covers a very densely populated area in Denmark. The coverage is provided by 56 cells and in this case study, only LTE is considered as RAT. The area covers approximately 12 km2, and can in theory easily be covered by one BBU pool. The base-stations are connected to the transmission sites using Gb Ethernet over fiber. In the area, most of the peak times appear in the interval between 19:00 and 00:00. The area does not suffer from interference and in most of the sites the average traffic is relatively low, and the peak to average traffic varies a lot from site to site. Illustrations and further information about these are provided in [6].

IV. ROADMAP FOR CASE STUDY SCENARIO

The roadmap created for TDC follows the roadmap creation process. Therefore, first the cell ranking method is used on all 56 cells in the area, and the combination of cells that will benefit the most from implementing C-RAN is found. Then the pool ranking method is used to find the remaining cells in the pool. The statistical multiplexing gain is peaking at 2.03 when 16 cells are incorporated in the BBU pool. The first thing for TDC to do is to implement RRHs in all the chosen cells and centralize the BBUs. When looking at the cells chosen by the method compared to the current situation, then the method chooses cells with high interference, different peak times and low average traffic. The peak to average traffic is low in cell A and relatively high in cell B. This complies with the fact that the method is weighting interference and different peak times higher than the remaining input parameters. Then, as TDC wants C-RAN implemented all over the area, the process continues. In the second iteration 26 cells are implemented in the BBU pool and the multiplexing gain peaks at 1.97. Now 14 cells are left outside C-RAN and pooling them together, they achieve a multiplexing gain of 1.47. The three iterations of C-RAN implementation are illustrated in fig. 2.

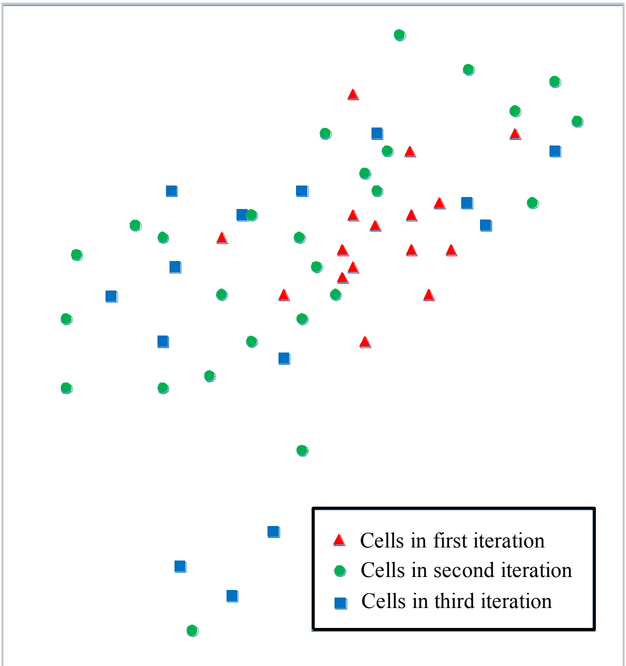

Fig. 2: All three iterations of C-RAN deployment

V. DISCUSSION

The primary benefit TDC will obtain by introducing C-RAN right now is shared processing. By introducing shared processing the network operator obtains a reduction in power consumption and lower cost as less BBUs are needed. It is expected though that the amount of interference will increase in future networks, and then the introduction of C-RAN and enhanced inter-cell cooperation will positively affect the users' experiences. This work allows any operator to evaluate their current network using the network deployment steps provided, and consider whether they will gain any benefits from introducing C-RAN using the cell ranking method derived. The roadmap process is not limited to a certain size of area.

VI. CONCLUSION

This work introduced a roadmap process for a network operator to follow towards C-RAN deployment. The roadmap process were used in a real-life case study investigating an area within TDC's network. This area has 56 sites deployed already and is an area with a high population density. The cell and pool ranking methods used within the roadmap process defined, ensure that the cells which will benefit the most from incorporating C-RAN will have C-RAN deployed in the first iteration. The multiplexing gain is used to determine the number of cells in each pool for an optimal resource sharing. The result was three BBU pools with 16, 26 and 14 cells incorporated, respectively. The cell ranking method and pool ranking method prioritizes different peak times and interference higher. All suggestions and recommendations provided in this work are universal, and can be used by any network operator.

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