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DC-RAN dynamic coverage methods to improve its performance

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Abstract

In cellular networks there are usually times when the density of the network changes at different times of the day.

Congested areas attract a high demand for communications and data, generating peak demand at specific times of the day and vice versa also happens in the same area but at another time of the day.

In order to meet the needs of this changing demand, the network must keep pace with changes in the density of the areas served.

This can only be done if the network has a dynamic ability to handle the change in traffic density and demand intensity, which requires turning on/off a certain number of Remote Radio Heads (RRHs) that represent the Radio Frequency (RF) front end of the mobile network. For the purpose of providing a reliable and A communication service that is acceptable to users in terms of quality standards, and financially useful to network operators by rationing energy consumption and meeting the required needs in 5G cellular network systems.

Dynamic Cloud Radio Access Network (DC-RAN) in 5G networks can do this by relying on that enables them to respond to demand variables by shifting several types of coverage cells to a single serviced area and stopping them when needed.

Keywords: turining off/on; dense networks; varibal density network; multi coverage area

الخلاصة: في الشبكات الخلوية عادة ما تكون هناك فترات تتغير فيها كثافة الشبكة في أوقات مختلفة من اليوم، حيث تجذب المناطق المزدحمة طلبا كبيرا على الاتصالات والبيانات، مما يولد ذروة الطلب في أوقات محددة من اليوم، والعكس صحيح يحدث أيضا في نفس المنطقة ولكن في اوقات آخر من اليوم، ومن أجل تلبية احتياجات هذا الطلب المتغير، يجب أن تواكب الشبكة التغيرات في كثافة المناطق المخدومة. لا يمكن القيام بذلك إلا إذا كانت الشبكة تتمتع بقدرة ديناميكية على التعامل مع التغيير في كثافة حركة المرور وكثافة الطلب ، الأمر الذي يتطلب تشغيل / إيقاف تشغيل عدد معين من رؤوس الراديو البعيدة (RRHs) التي تمثل الواجهة الأمامية للتردد اللاسلكي (RF) لشبكة الهاتف المحمول وما يقابلها من معدات الشبكة. لغرض توفير خدمة اتصال موثوقة ومقبولة للمستخدمين ومفيدة ماليا لمشغلي الشبكات حيث يتم تقنين استهلاك الطاقة وتلبية الاحتياجات المطلوبة ، يمكن لشبكة الوصول الراديوي السحابية الديناميكية (DC-RAN) من شبكات ال 5G الاستجابة لمتغيرات الطلب عن طريق تحويل عدة أنواع من خلايا التغطية إلى منطقة واحدة مخدومة و تشغيلها اوإيقافها عند الحاجة.

1. INTRODUCTIN

Licensed spectrum has always been the most expensive and scarce supplier from the point of view of cellular network engineers and operators. With the significant and rapid growth in the demand for high capacity in cellular networks, the importance of the frequency spectrum is increasing because it is the best way to communicate on mobile and meet the needs of users with ever-increasing high capacity, in the sense of increasing cell coverage throughput, i.e., bits/s/km^2 [1]. So, the idea of increasing the BandWidth (BW) of the assigned spectral band is very likely in order to provide the required amount of data. However, his method adds new costs, complexities and challenges to the deployment of cellular networks. Therefore, it is known that the effective distribution of rare spectrum between the cells of the network to achieve spectral efficiency is a very difficult task. The basic idea of spectrum distribution in the first generations of cellular networks was the Fixed Spectral Allocation (FSA) of each frequency network cell that is reused repeatedly within separate geographic regions (cells) called clusters to ensure that all cells have a specific spectral allocation [2]. Make sure that there is no interference in frequency between the different cells.

In this approach, a plan is developed to estimate the initial capacity of each cell based on field studies and therefore for the entire network. BW is allocated to Base Stations (BSs) for a network depending on the maximum demand for each station. This BW assignment remains constant and cannot be used in another denser cell that needs more spectrum of frequencies, and this allocation is done using one Remote Radio Head (RRH) per cell as shown in "Figure (1)". Therefore, it is unable to meet the variable capacity requirements in the network for different BSs operating in the same network. This position may change in Dynamic Cloud Radio Access Network (DC-RAN), and the obstacle of allocating fixed frequency that leads to non-reuse in denser cells may also change, using other methods to cover the need of dense network areas using very small coverage cells, peer-to-peer connection and other methods [1].

This way is added to the Cloud Radio Access Network (C-RAN) to provide the possibility of sharing infrastructure with other operators to make cost reduction double [3]. This has significantly improved cellular network efficiency, improved use of spectral resources, provided high-capacity coverage that automatically (dynamically) responds to demand variables, reduced power consumption, reduced deployment of new BSs, reduced upgrade of BSs in older networks, and used virtualization software to implement these networks. However, the improved addition of C-RAN networks that makes this network more dynamic by using more than one controllable RRH (on/off) in the same geographical coverage location and on the same tower. Thus, creating more than one cell with different coverage areas. To provide a frequency spectrum capable of meeting the change in user density and the amount of data required. This method made the network work with Dynamic Spectrum Allocation (DSA) instead of FSA. DSA technology has been of great importance since its invention because it adds the passive spectrum of the network and increases the spectral efficiency of the network [4]. The other, more interesting method is to use a single physical RRH and increase the signals it reaches to suit the needs of the network and actually deploy its multiplicity via virtualization, i.e., RF front-end virtualization, which is an economically viable method rather than deploying multiple RRHs [5]. This method began to be used recently and you need to upgrade network equipment and links or replace them with modern equipment, links and software that achieves the required goals.

The rest of this paper is organized as follows: in section II the related works, which represent a mention of some similar works, section III is dynamic activation of BS/s and access spectrum, section IV variable network load is a key factor, which describes variable load in multi-density and load networks as a key factor for developing networks and making them dynamic. Section V switch –on/off strategies in DC-RANs presents the most important current strategies related to the DC-RAN on/off process and finally section VI conclusions of this work.

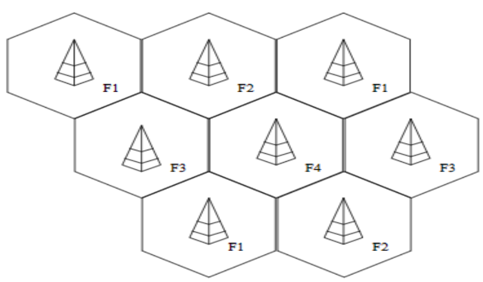

Figure 1 FSA in early cellular networks

2. **Related Work**

In this section, we describe and discuss some relevant parts of the work on virtualization. Of all the relevant works compared, there are only a few agnostic technologies, and they can provide virtual radios for any Radio Access Technology (RAT) as in [6]. At work [7] and [8] there is an endeavor to implement the design on the BS tuning strategy for on/off by identifying the total cost of the Mobile Network Operator (MNO) and all third parties as a goal for improvement as well as in the work [9] new methods of provisioning and allocation of virtual base stations (VBSs) in the baseband unit (BBU) have been proposed, and their advantages and disadvantages are thoroughly discussed. Research in this area needs further study and can only progress if the necessary applications of different virtualization are provided to compare them and better understand their functions, features and requirements to be able to choose what is appropriate and in [10] this study offered the pros and the downsides of current technologies and their future challenges to enhance coverage in 5G networks. It also illustrates the exact trajectory of coverage enhancement solutions and their future requirements.

3. Dynamic Activation of BSs And Access Spectrum

To combine the properties of a C-RAN network with the dynamic customization property, these two characteristics (dynamic and cloud) must be combined.

To configure the DC-RAN network, in order to accommodate the diversity of different use cases and to reduce network costs, by saving spectral resources and optimizing them and reducing energy consumption. Where the network can dispense with some Access Points (APs) in certain periods of the operating time determined in advance based on the statistical data of different network locations. That is, reducing the number of effective stations in a specific period of time with the possibility of restarting them when needed.

This procedure can be considered the first type of dynamic control. The dynamic network can also provide a number of access points in one coverage cell to serve multiple types of requests for variable density mobile users, where the capacity of one access point will differ from the other and as needed. Which means that the number of users and the amount of data required for each access point will vary dynamically with the time of day, meaning that the spectrum density and network throughput will change based on monitoring the statistical data received on the density of subscribers and the amount of their requests in the coverage cell, which is the second type of dynamic control. For the network [11]. By Using two algorithms to achieve network dynamics.

In this study, we will choose to consider each multi-coverage cell belonging to a single MNO, as a stand-alone unit with its own requirements. Spectral aggregation is managed by an intelligent controller considering C-RAN a Software-Defined Network (SDN) as well as a set of algorithms for implementing the dynamic network characteristic [12].

It is clear from the following equation based on the capacity of an Additive White Gaussian Noise (AWGN) equation

$$C = m\left(\frac{W}{n}\right)\log_2\left(1 + \frac{S}{I+N}\right) \quad (1)$$

Where *W* is the BS allocated bandwidth, *n* denotes the BS load factor (i.e., the number of users sharing the given BS, *m* is the spatial multiplexing factor (i.e., it denotes the number of spatial data streams connecting the BS and devices) *S* gives the signal power and *I* and *N* represent the interference and power noise, respectively.

It is clear, in order to increase the capacity, it is necessary to reduce the *n*, which can be achieved by cells redivision to meet the actual need i.e., add additional BW [4], and another important issue is to enhance the signal strength and reduce the path loss where the subscribers are closer to the BS [13], which reflects positively on the performance of the network in providing suitable signal to all subscribers in their various locations and their latency.

Additional BW reallocation to meet the need of cells in the multi-coverage area dynamically requires running an algorithm (BW reallocation algorithm) that calculates and sorts the need of each cell in this area, giving the denser cell a greater chance of obtaining additional allocation of BW according to the density of each cell, otherwise the reallocated BW is not the cause of interference in this area.

In addition to another algorithm (latency adjustment algorithm) that ensures that the specified latency of the network is not exceeded by adjusting the maximum coverage area in the multi-coverage area and in a way that suits the front link used in the network. The blending process can be achieved in two main ways, as mentioned earlier, to meet demand:

1) Deploying multi RRHs on a single BS to cover the geographic area to configure multi deferent coverage cells (umbrella cell approach).

2) Using single broadband RRH (ranging from 10 to 250 MHz) on a single BS to cover the geographic area and using RF front-end virtualization to provide different multi coverage cells, as shown in the" Figure (2)".

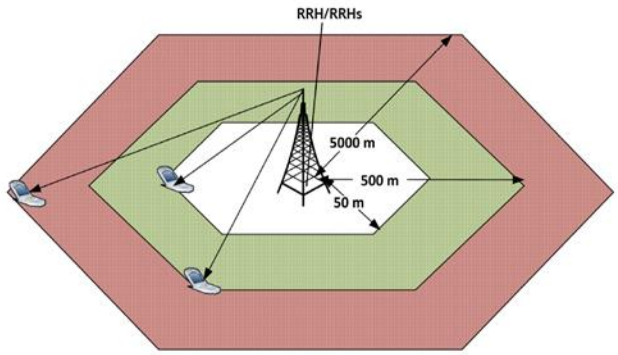

Figure 2 Multi coverage cells by RRH/RRHs

In general, the two ways should ensure Quality of Service (QoS) to users by applying the network design criteria related to the length of the FrontHual (FH) of the network and its type as a transmission medium, which is determined depending on the coverage area of the serviced cell, the nature of climatic conditions and other obstacles, and on the latency specified for the network.

The achievement of high demand rates depends directly on the optimal use of the available spectrum bands in the network in general, and since the spectrum available in the network is fragmented and its use is not continuous, that is, the available spectrum is divided into isolated parts and is not used all the time. It is necessary to use a flexible and agile transport scheme for the purpose of effectively sending it [14].

In this study, the use of Orthogonal Frequency Division Multiplexing (OFDM) is important and useful because of its characteristics that enable the effective exploitation of available spectrum and improving the area throughput.

- Abstraction: The work of this feature is to hide the basic characteristics of the equipment erected on it, as well as provide simplified interfaces for accessing and sharing hardware resources, allows hypervisor clients to use hardware resources without changing the radio stack of the upper layer, i.e., the Mida Access Control (MAC) layer, and provides simultaneous real-time access to the many virtual Radio Frequency (RF) interfaces created .In this architecture, multiple vPHYs can coexist on the same radio frontend simultaneously, forming different RF access points/transmitting multiple different primary spectrum signals by splitting the available bandwidth based on subcarrier-based divergent OFDM signals and other characteristics available in this modulation mode.

- Programmability: The use of hypervisor software provides the advantage of programmability or reconfiguration. The work of this feature is summarized in providing radio frequencies with the set of functions provided by the actual single front end of radio frequencies, but in a multiple way by configuring central frequencies, appropriate bandwidths, transmitter and reception gains, in addition to providing multiple radio stacks on a single physical front end.

- Isolation: The use of hypervisor software must ensure that the wireless stacks it creates do not interfere with any other wireless stack, allowing fault tolerance, security and privacy for the multiple radio stacks that have been created to achieve proper coexistence with other stacks located on the same front radio interface [13].

Deploying additional infrastructure leads to more capital as well as operational expenditures (CAPEX & OPEX). This aspect is not desirable for network operators, while the second solution, which involves sharing network infrastructure using virtual configuration software that introduces Virtual Mobile Network Operators (VMNO), is a suitable solution for operators and reduces costs of both types and can even bring new additional resources in the case of leasing the broadband infrastructure RRH and FH as well as BroadBand units (BBUs) of the network to other network operators [15,16,17]. The use of the virtual environment can provide the availability of Radio Access Network as a Service (RANaaS) as well as providers of this virtual infrastructure can provide isolated and independent virtual PHYs as a Service (vPHYaaS) for MVNOs.

As we know, the three main DC-RAN network components BBU, FH and RRHs have sequential effects on each other that should not be exceeded when designing the network, and this requires strict restrictions on these components to complete the network performance optimally. For example, physical separation imposes some kind of delay (based on the type of functional separation of the BBU from full centralization, partial centralization, or hybrid centralization) i.e., processing and switching delay ($D_{P/S}$) that will occur for data in a DC-RAN network which also depends on the processing speed of the equipment used imposes strict latency and jitter requirements on FH [18], which is often the most expensive component of the network[19 ,20] and the latter imposes restrictions in two important aspects: the type of fronthaul link used, which in turn determines the power consumption and bandwidth and thus the spectral efficiency, in addition to determining the length of the fronthaul link i.e., the propagation delay (D_P) required, in other words, the network latency End to End (*E2E*) latency is

$$E2E = D_P + D_{P/S} \qquad (2)$$

These two effects determine the maximum area that can be covered in dense multi-coverage areas and the number of users can be served that are carried out using the multiple coverage methods mentioned above.

Stringent requirements in DC-RAN network design also apply to FH broadband transport protocols for transmission of baseband signals, which must meet latency and jitter requirements. With this resonance, the telecommunications industry has identified three leading front-end transport traffic transmission protocols, namely Open Base Station Infrastructure Initiative (OBSAI) [21], Common Public Radio Interface (CPRI) [22] and Open Radio Equipment Interface (ORI). However, CPRI is considered the most capable of meeting the requirements and is adopted by many companies and mobile network operators [23].

4) **Variable Network Load Is a Key Factor**

The distribution of traffic load in different geographic areas is usually uneven in real networks, therefore. This fluctuation in spatial traffic load creates an opportunity to reuse unused spectrum and save energy significantly, by turning off untapped BSs or shutting off other units in the network called the sleep mechanism [24]. since network load density determines the shutdown/operation of network modules, real-time spatial load perception approaches are used to determine the shutdown of a number of targets (network modules) when the traffic load is less than a certain limit for a given period. For example, it was observed by integrating load balancing between different types of BSs into the design of shutdown strategies for BSs, in dynamic networks, Energy Efficiency (EE) gains of up to 68% can be achieved for low traffic load and up to 33% for medium traffic load [24]. a guided algorithm was developed to determine the number and locations of BSs to be turned on or off, based on the intensity of Unit Equipment (UE) that each BS in the network studied could serve. This requires knowing the density and location of users at each base station, which makes this strategy useless in real-world networks as it deals with unstable elements in terms of number and location quickly and continuously [25].

In so the ideal load strategy is derived as follows:

When the load is low, one BS (or a very limited number of BS) can handle traffic efficiently and all other BSs can be turned off, but as the load increases, one or more BSs will be triggered depending on the estimated load and traffic information [26]. Next, the behavior of this case strategy is studied based on the statistical information of complete traffic. The simplest strategy for turning off BSs was proposed based on traffic statistics over time only, i.e., as the load changes over time, BS is turned off based on a fixed timer [27]. This timer is determined manually by statistical information for one operating cycle and periodically, allowing to know the peak and idle times in the specific network sector, for example, when the traffic load is very low during certain time periods at night. Or you can rely on more adaptive sleep strategies based on dynamic monitoring of time-changing traffic that relies on the network's cumulative and reliable power consumption. [28, 29].

In order to achieve the necessary adaptation of network resources to the actual need for real-time traffic, two algorithms are adopted the first indicative and the second progressive for the purpose of dynamically deactivating unnecessary BSs in Heterogeneous Networks (HetNets). Both algorithms can track the change in traffic density over time [29]. assuming that the statistical daily traffic profile for the entire HetNet is closer to being similar in each running cycle i.e., repeated periodically it is considered repetitive cyclic behavior the “Figure (3)”. shows the traffic curve [29].

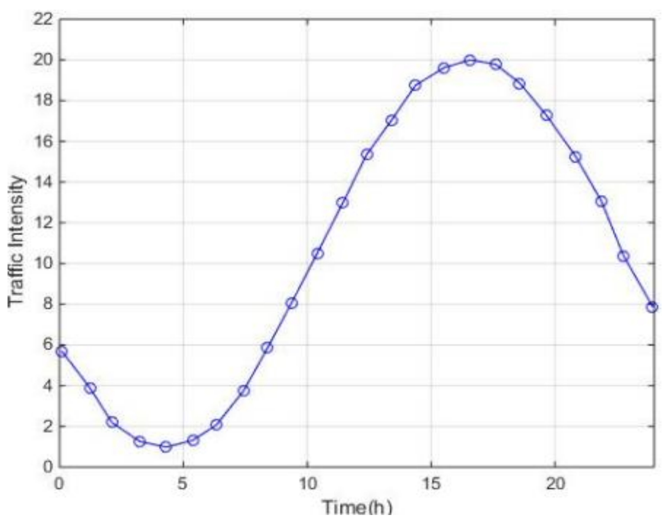

Figure 3 Periodic traffic load changing over one operation cycle [29].

This produces coexistence between different mobile operators and stimulates this coexistence in the same geographical area. Research work, where a traffic-based turning off strategy for mobile networks was proposed with the help of cooperation between mobile operators, and by ensuring the quality of service for reconnected UE reconnected unified telecommunication networks by integrating roaming-based infrastructure sharing between competing mobile operators, where a central entity is assumed in the network [30]. This centralized entity is used to collect the information required across the entire network to implement the BS turning off strategy with a focus on decentralized implementation [31].

5) SWITCH ON/OFF STRATEGIES IN DC-RAN NETWORKS

In C-RANs in 5G systems, the functions of RRHs of traditional BSs are separated at different levels and concentrated in multiple BBU units and placed in a single place called the BBU pool and BBU resources are allocated via virtualization techniques, while RRHs are left at cell sites.

With this type of system architecture, the C-RAN networks allow baseband signal processing for many RRHs deployed in coverage areas of the BBU pool, where resources such as compute and storage are configured as multiple virtual BBUs.

Its compute capacity and storage depend on the amount allocated to it through virtualization and on the maximum amount of baseband processing required per RRH. Multiple RRHs can also be supported by a single default BBU and a number of RRHs can need multiple virtual BBUs.

The process of turning off RRHs and virtual BBU modules can be done separately, and their idle resources can be converted to active units by combining flexible resource allocation and turning off /on virtual BBUs. Then the C-RAN networks are called DC-RANs and this is done using several strategies as follows:

1) BBUs switching off strategy:

The individual BBU in the BBUs pool is designed as a container with a specific capacity, and the RRHs resources are the contents of the container to be filled which are the procedures for processing baseband signals with all their technical details related to good coverage that comes from the corresponding RRHs as packaged items.

After filling these elements into some BBU units and absorbing them appropriately in these units, the number of unused BBU units should be reduced (extinguished) and the units used (filled with RRHs) should be left to complete the required processors. Depending on the number of active units, energy consumption will be rationed in all assembly facilities [32].

Further emphasis is placed on the case of supporting a number of units for RRHs by a single BBU in the BBU pool, designing a strategy based on balancing the load in traffic [33].

To assign minimum active BBU units to RRHs so that power saving is maximized. In this strategy, if resources for a single BBU are used to the upper limit, partial traffic for that BBU is dumped to another lightly loaded or sleeper BBU, in turn, the untapped BBU will be shut down after its traffic is completely unloaded to another suitable BBU.

Similar to, through proper scheduling, unloading and timely consolidation of the traffic load required to be processed by active BBUs, one heuristic strategy is implemented in to dynamically reduce the number of active BBUs and vice versa i.e., running the required units when needed [33]. In addition, a testing platform was created for the diversity of concepts and the evaluation of practical performance in [34].

2) Fronthaul link switching off strategy

In DC-RAN networks, due to their centralized processing architecture in the BBU pool, the FH connection links that connect BBUs to RRHs that provide high-capacity communications, consume a significant amount of total network power. At idle, the power consumption via the FH connectors becomes large and cannot be ignored. Thus, to reduce the power consumption of the entire network of the DC-RAN, it is also important to turn off some RRHs as well as their corresponding fronthaul links connections and according to the requirements of data traffic and turn them on when necessary [35,36,37].

6) CONCLUSIONS

In this paper, we discussed several actions on the BS on/off for 5G systems, the objectives and constraints of optimization were presented for the design of the BS off strategy, some BSs stop/on strategies and the impact of these actions on improving network performance in terms of passive resource sharing and making them more effective and the resulting reduction in power consumption, and the corresponding returns for network operators and users in improving their experience when using more flexible dynamic networks, which improved overall performance. for the network. However, current research results still need to be strengthened and challenges that remain to be investigated in the future.

The multiple virtual operation of a single RRH entity using the hypervisor virtualization is capable of transforming the RF frontend into a configurable interface of a number of RF virtual frontends, which, working in tandem with DC-RAN virtualization, integrate network work to make the most of network components as well as reduce overall operational and overall costs. The effect of the types of front connections in determining the coverage areas that can be generated when the demand increases in both directions (network density and the amount of data required by users) was discussed due to the limits imposed by latency in the network that determine the length and type of front link and the area of coverage and thus affect the entire network architecture. In addition to mentioning some of the strategies used to stop/turn BSs on DC-RAN networks described above.

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