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Energy Efficient Data Downloading Scheme for C-RAN

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Abstract

Cloud Radio Access Network (C-RAN) is considered as the noble technology for the current challenges of the operators like as the demands of higher capacity and lower cost for system deployment which comes from the exponential growth of the subscriber density. And it is also seem as the green radio access network for the next generation mobile network upcoming beyond 2020. This research focus on the reducing of power consumption in C-RAN network during while users are downloading the data files from the servers. We proposed the energy efficient data downloading scheme for C-RAN. Firstly, the data downloading path from subscriber to server is separated into two parts as the optical part and wireless part. Then, calculate the energy requirement to transmit a bit over each part. And the initial threshold value is assigned and compared with the number of the requests from the users. If the number of requests is less than the threshold, the request will go to the server and send back the requested content to the subscriber. If the comparison is greater than threshold, the requested content already saved in base station's memory by the proposed scheme and send to the subscriber. We simulated our proposal by using MATLAB. According to the simulation results, the proposed scheme delivers the better energy efficient performance comparing to the traditional one.

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CHAPTER 1

INTRODUCTION

1.1 Impact of ICT upon the Modern Society

Nowadays, mobile telecommunications acts as a main role in voice and data network communication sector. The effect of mobile telecommunication upon the modern society is so huge that it is unmeasurable. Firstly, wireless mobile network are used to communicate each other by voice and short messages. However, now its main purpose has changed to data transferring service. Moreover to communicate each other via voice and message, a lot of peoples are using the smart phones and port-able internet connected devices for several purposes including learning, advertising, entertaining and even shopping. The total worldwide mobile subscription is 7,300 million in 2015 and it will be increased to 9,000 million in 2021 [5]. By allowing the peoples all over the world to receive and share a lot of information while decreasing the time and distance difficulties, it develops and promotes the people's life style of those who connect and access with it. As the developing of the smart phones and internet devices, the technology is more and more efficient and participates in people's daily life by supporting in varieties of ways in communication, education, business, economic, politics, health care and a lot of other sectors which are the important parts of our modern civilization. With the bigger user's demand and further user's requirement, the wireless mobile communication technologies have changed from the first analog cellular mobile generation (1G) to the last launched fourth generation LTE network (4G).

1.2 Evolution of the Mobile Network Generation

The wireless mobile technology is developed by year and year and generations of mobile technologies are as shown in Figure 1.

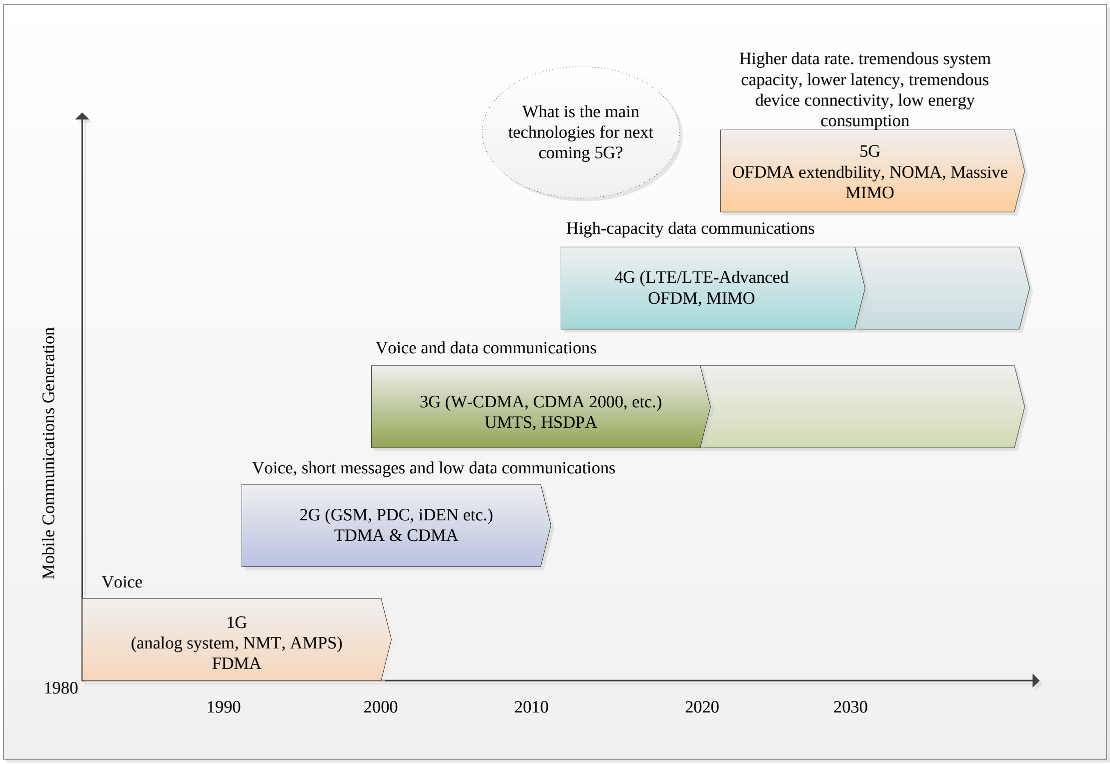

Figure 1: Evolution of the wireless mobile generations (modifies and refers from 5G Radio Access Technology [26])

In 1979, Nippon Telephone and Telegraph (NTT) deployed the first cellular mobile phone system in Japan [1]. And then, mobile technologies varied and developed so that to fulfill user's requirements and following are the evolutions of the mobile network generation.

- 1G : Analog Cellular Phones, Nordic Mobile Telephone (NMT). Advanced Mobile Phone System (AMPS)
- 2G : TDMA & CDMA , Global System for Mobile Communication (GSM), Integrated Digital Enhanced Network (iDEN)
- 2.5G : General Packet Radio Service (GPRS), Wideband Integrated Dispatch Enhanced Network (WiDEN)
- 2.75G : Enhanced Data Rates for GSM Evolution (EDGE)
  Enhanced GPRS (EGPRS)
- 3G : CDMA 2000, W-CDMA, UMTS, HSDPA
- 4G : LTE, LTE Advanced, WiMAX

Now, the researchers from all over the world are focusing on next generation network (5G) that will provide the ubiquitous network to all internet connected devices and applications.

1.3 The Next Generation Network (5G)

As increasing the using of internet connected devices, the demand of the high bandwidth connectivity also increase. (5G) will be seemed the key technology for the tremendous growth of high traffic and wide bandwidth demand. The tremendous numbers of connected devices will be met the real times requirement by 5G and will get the high-efficient bandwidth connectivity for advanced applications. (5G) will support the reliable connectivity for the verities of modern applications inclusive of wearables, high speed media broadcasting, critical infrastructure, smart homes, smart stores, smart offices, connected cars, industry process and traffic safety or controlling, and so, it will speed up the growth of the Internet of Things (IoT) [3].

The common requirements factors and expectations for next generation mobile (5G) are summarized and described in figure 2.

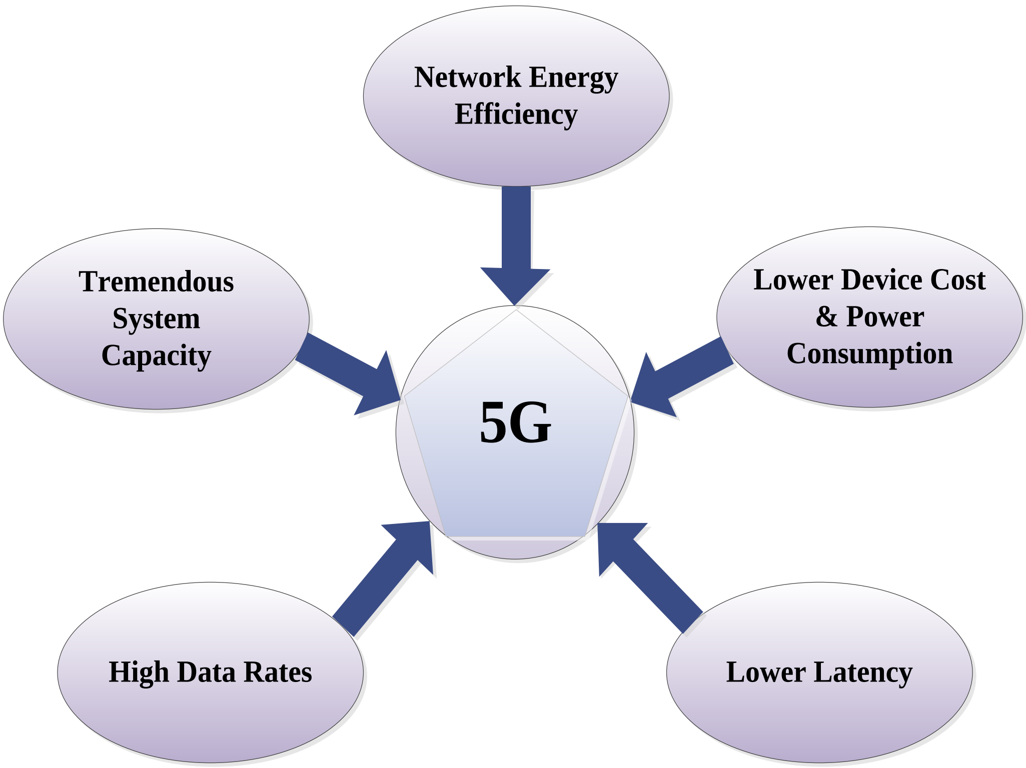

Figure 2: Common Expectations for the (5G) network (modifies and refers from DOCOMO 5G White Paper [27])

- Tremendous system capacity

  According to the reports of mobile operators over the world, the traffic demand of wireless mobile network will be sharply increased in coming years. The next generation mobile network should be feasible to manage the massive requests from exponential growth of tablets, mobile smart phones and internet connected devices compare to current network.

- High Data Rates

  The data rate supported by next generation mobile network should be exceeding 10Gbps both in indoor and condensed outside environments, and minimum 10Mbps should be in usually everywhere inclusive of rarely populated rural areas in both developed and developing countries [3].

- Lower Latency

  Modern applications are need to support with lower latency network compare with current one. So 5G should provide the lower latency than 1ms for supporting the latency demand applications [3].

- Lower Device Cost and Power Consumption

  Inexpensive mobile devices with low power consumptions should be taken as main factor in thinking about next generation mobile network because billions of devices will connect and access the network in future.

- Network Energy Efficiency

  Huge amount of total power consumption of operators are used to feed up the Base Station (BS) and Nodes in Radio Access Network (RAN).

Energy Efficiency (EE) is should be taken as the important fact for the next generation network not only for designing and upgrading the better BSs and nodes but also for the reducing of operational costs of the operators.

Those factors make distinct that low power consumptions devices and energy efficient network are playing acts the main role in designing the future coming mobile network. As estimation, in current cellular system, nearly 80% of total power consumption of the whole network is used for operators and 57% of that total amount is used to feed up the Base Stations where 24 hours standby antennas, radio remote units and baseband hardware components are working according to the user's requests [4]. The hardware components rooms also need the other electrical facilities like air-cons and lighting. And according to the traditional radio access network technologies, base stations (BS) are equipped with the fixed number of sector antennas which can deliver the small coverage are and can control Tx/Rx signals only in their own cells. It is very hard to improve the system capacity that limited by interferences.

Those natures make many barriers for operators. As an example, the operators had deployed more the Base Stations to support the better coverage and higher system capacity. More BSs need more initial investments for site hunting and renting, civil works, site installation, management costs and site supports such as power and air-conditioning equipment. And it will drive to increase the operational expenditure (OPEX) and capital expenditure (CAPEX) for operators.

As the consequences, operators also had to use the more power consumptions for the more Base Stations.

On the other hand, over the past century, by rising $1.5\,°\mathrm{F}$ of the earth average temperature, our planet becomes more and more warming [6]. And it is estimated to rise another 0.5 to $8.6°\mathrm{F}$ in coming next hundred years [6]. Although being the little numbers change in earth average temperature, it is so harmful and dangerous to world by making causes to change climates.

Therefore, in the last decades, the governments and organizations from all over the world are caring about the emission of Carbon Dioxide (CO_2) that is the fundamental reason of Global Warming. The main reason of (CO_2) emission is the power consuming in every sectors and industries. So the energy efficiency of wireless network is becoming the main factor in information and communication sector too. Prior studies, the 4% of the total annual energy production is approximately used to support for the energy consumption of the information and communication sector and that amount is hoped to expand more and more in coming years [7].

Now 2-4% of the total carbon emission from worldwide comes from the ICT sector and it will be doubled in 2020 if there is no action to fix this terrible growth of power consumption [8]. Early experiments already shown that the radio access network (RAN) is responsible for large amount of CO_2 emission and approximately around the two-third of overall CO_2 emission of these radio access network (RAN) comes from the power consumptions to feed up the Base

Stations in the network [15]. Therefore, the next generation mobile network need the energy efficient radio access network which projected to the lower OPEX and lessened impact on the environments.

The new wireless radio access scheme should be addressed for solving the following claims of next generation mobile network according to [9]:

- Providing the multiple air interface standards with easy software upgrading
- Supplying the reliable service with cost reduction and robust maintenance cost
- Optimizing to higher system capacity, better mobility and bigger cell coverages in the broadband cellular systems.

C-RAN, refers to the various names as cloud, clean, centralized radio access network, is an advanced radio access scheme that characterizes the centralized baseband processing, radio remote collaboration and energy efficient network. In C-RAN, different to traditional system, the baseband components are centralized in BBU pools in data center and distributed radio remote heads are linked to the BBU pools. The receiving radio signals from regionally deployed antennas by the receivers of radio heads (RRH) are delivered to the data center cloud platform by fiber optic cable link.

By decoupling the radio components from the baseband processing, the centralized pooling and processing technique get the benefits of lower (OPEX) and (CAPEX) cost with the fewer numbers of cell sites and flexible software upgrading. The remote radio heads also cause the lower energy consumption than the base station by reducing the power bill for site supports such as lighting and air conditioning. Centralized processing also improves the system performance by coordinated multi-cell signal processing.

1.4 The Thesis outline

In Chapter 2, the overviews of C-RAN will be introduced with its infrastructure and advantages. The related works for energy efficient mobile radio network will be presented too. Then the proposed model for energy efficient data downloading scheme for C-RAN will be described in Chapter 3. Next, in Chapter 4, simulation result will be shown followed by evaluations. And in Chapter 4, the last one, present the conclusion with future works.

Chapter 2

Background and Theoretical Framework

In this section, the background, fundamental concepts and overview of C-RAN which is the basic foundation for the proposed scheme and related works for energy efficient radio access network will be presented.

2.1 Cloud Radio Access Network

Cloud Radio Access Network (C-RAN) seems as the unique mobile radio access networks mechanism that can solve the current challenges and can support the exponential growth of the users' requirements of the telecom operators' potential facing and should be addressed as the green radio access network for the next generation mobile network (5G) that will be launched beyond 2020. Nowadays, amount of internet data using via mobile devices are increasing regularly by driving the exponential growth of the smart phones and tablet users. While the operators are trying to expand the system capacity to satisfy the above problems, on the other hands, the spectral efficiency (SS) of the Advanced (LTE) network closes to Shannon Limit and CO_2 emission come out from the energy consumption of network equipment and electrical facilities are continuously increase [12]. Telecom operators tried to get the higher network capacity with some appropriate techniques like as follows

- adding the numerous cells among the existing ones and building up the multiplex system architecture of Heterogeneous and Small cell Networks (HetSNets)[10]
- applying some outstanding mechanisms like as the multiusers Multiple Input Multiple Output (MIMO) and Massive MIMO systems which serves continuously numerous numbers of antennas[11]

But, there are still some problems like noise and interferences, and higher (OPEX) and (CAPEX) costs.

2.1.1Evolution of the Radio Base Stations

C-RAN is composed of the centralized base band units (BBUs) in pooling and decoupled radio units connected with the optical cable which is referred as the "fronthaul" that is different from the "backhaul" which is link from BBU to core network. By centralizing the baseband processing, it has the ability to fit with the non-uniform traffic and radio resource utilization. The radio base stations (RBSs) can be divided as the baseband units and radio units. The baseband units perform the baseband processing while the radio remote heads performs transmitting and receiving signal functions to and from the subscribers. The evolution and developments of the radio base stations are described in Figure (3), (4) and (5).

- **Macro Base Station**

  It was the popular architecture for first and second generation wireless cellular mobile networks. Not only baseband and remote radio processing units but also the batteries and other supporting equipment are integrated in a cabinet which has the same size to large refrigerator, and the antennas are equipped at the few meter height while connecting with the coaxial cable which deliver the high losses [12] as shown in figure (3). Some higher (2G) system like (2.75) GSM system used the fiber optic cable instead of the coaxial cables. S1 interface is used as the interface to couple the radio base stations to core network while X2 interface is used to distinguish among the base stations.

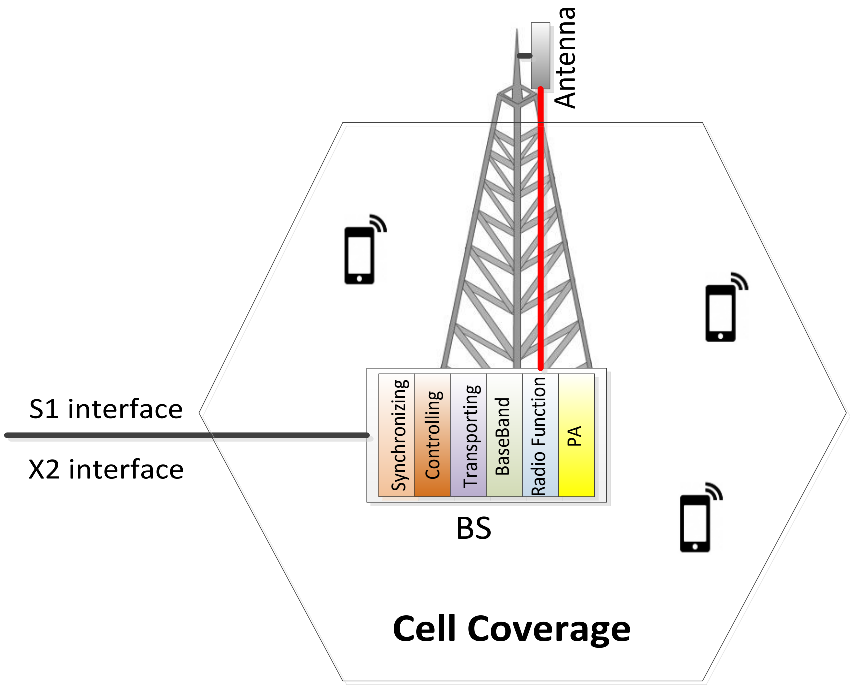

Figure 3: Traditional macro base station (refers and modifies from Cloud RAN for Mobile Network- A Technology Overview [12])

- Base station with RRH

As shown in figure (4b), the signal processing baseband unit and radio units are isolated in this architecture. The Remote Radio Unit (RRU) support the power amplifying and filtering functions, analog to digital converter function, digital to analog function, digital processing function and optical interface functions [14]. The fiber optic cable are used to connect the BBU and RRUs, and the distance can allowed up to 40km although there are some processing difficulties and propagation delays. It was introduced at the beginning of 3G system.

In this mechanism, comparing with the traditional architecture in which BBU have to equipped near to the antennas, base band units are can be located in easy access places and it make the cost saving in site renting fees and maintenance charges. By fixing the Radio remote units are on the poles as well as at the top of towers, this infrastructure gets the benefits from the adequate and economical natural cooling system and it also make to save the power bill for air conditioners in BBU rooms. Many radio remote units can be assigned to a BBU.

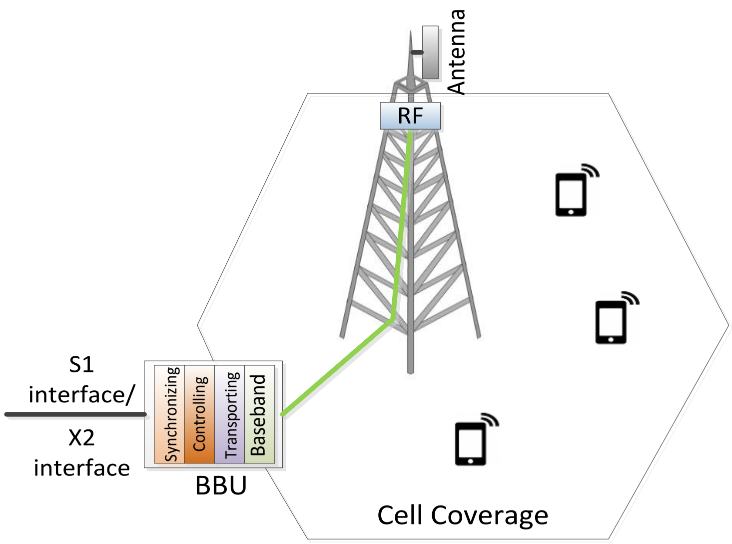

Figure 4: Base Station with distributed Radio Remote Heads station (refers and modifies from Cloud RAN for Mobile Network [12])

- C-RAN Base Station

  In cloud radio access network mechanism, base band units are pooled into one thing which is called the BBU Hotel/Pool so that to adjust and balance the different loading of the base stations. A base band unit pooling serves as a virtualized bunch of BBUs which possess the multi processors with general purposes to implement the baseband processing. The centralized baseband processing is shared among the deployed cell sites. The new form of X2 interface, sometimes called as X2+ interface, performs the internal communication of cluster.

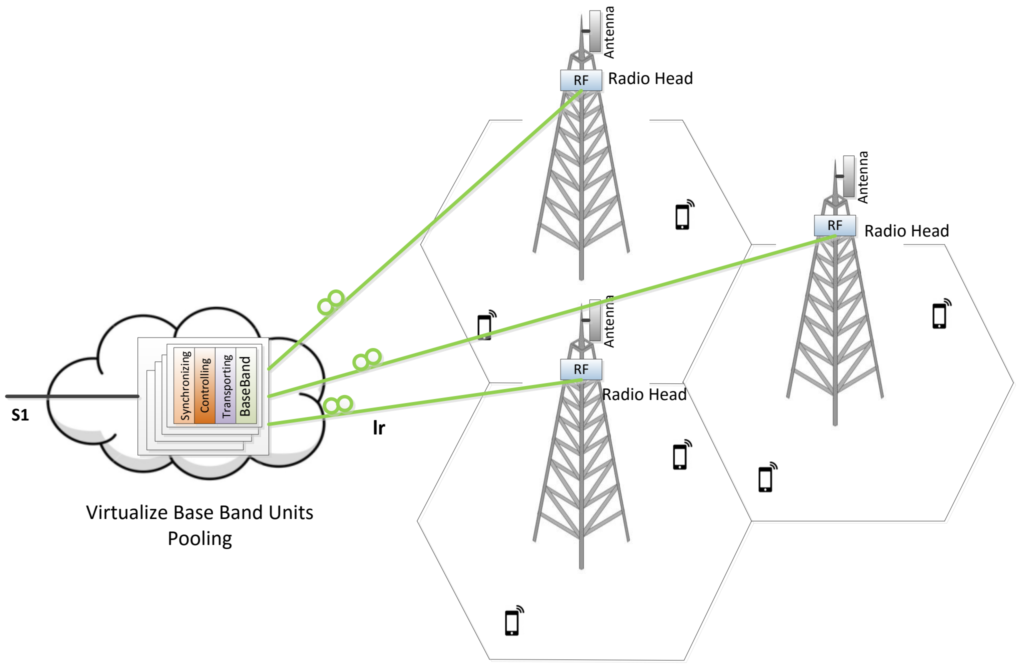

Figure 5: C-RAN with RRHs (refers and modifies from Cloud RAN for Mobile Network- A Technology Overview [12])

2.2 C-RAN Function Splitting Methods

Depending on the different methods of splitting the functions, generally two types of C-RAN are classified: the first one is named ‘full centralization’ and the second one is known as ‘partial centralization’ [15].

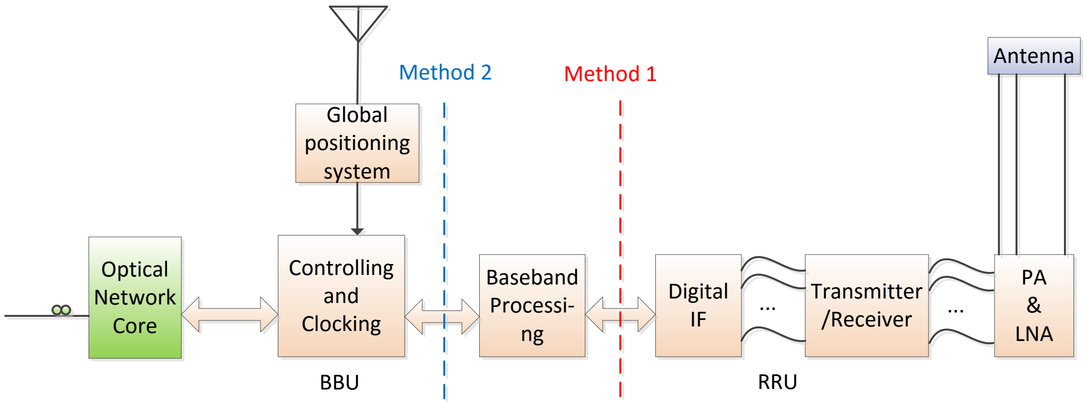

Figure 6: Different BS functions splitting methods for C-RAN (refers and modify from C-RAN, The Road towards Green RAN [15])

2.2.1 Fully Centralization

Author from [15] says that in the fully centralized splitting method architecture, baseband layer 1, layer 2 and layer 3 functions are located in base band units and it has the advantages of easy to upgrade and capability to expand the system capacity; has efficient ability to handle the various operation standards, ultimate resource sharing and providing of more efficient multi-cell cooperative signal processing. However, there are some disadvantages like the high bandwidth requirements. Figure7 describes the fully centralized C-RAN.

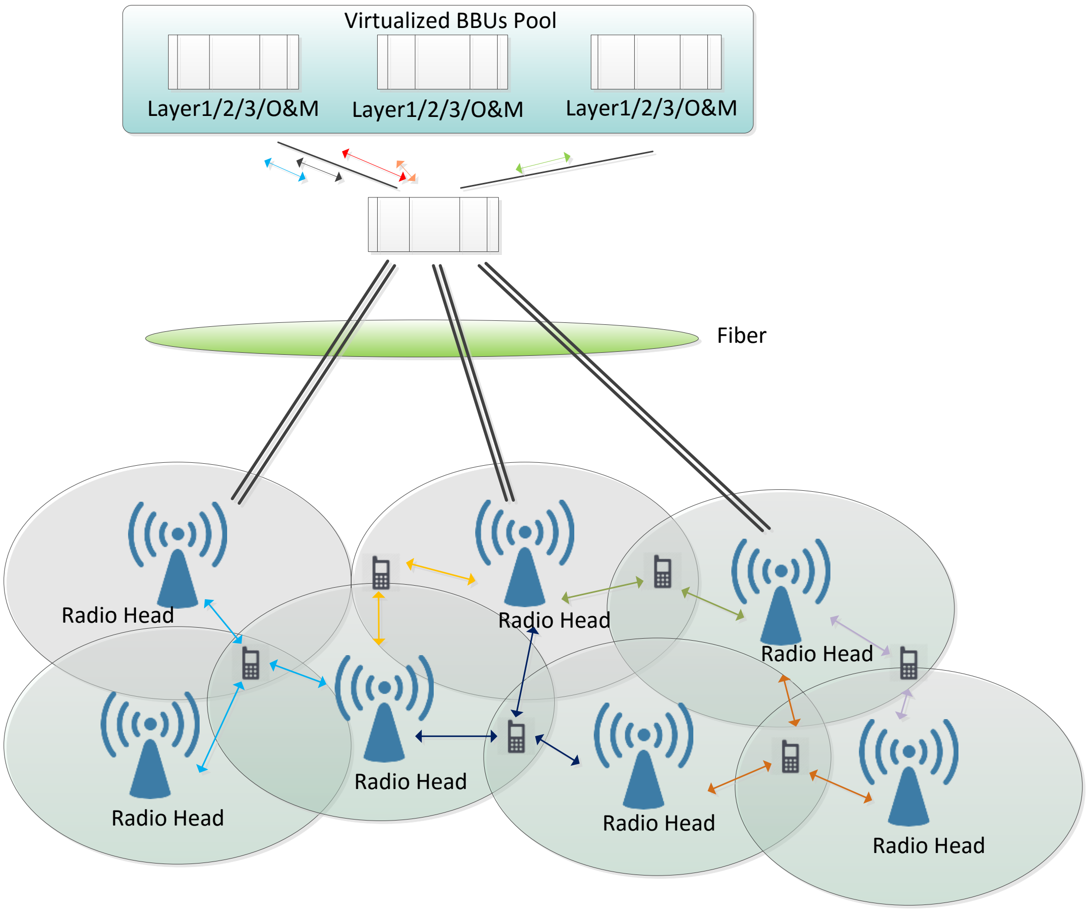

Figure 7: Fully Centralized C-RAN Method (refers and modify from C-RAN, The Road towards Green RAN [15])

2.2.2 Partial Centralization

Author from [15] said that in partial centralization, RRHs are integrated by adding the baseband function to the radio functions. Some functions from BBU higher layer as like the cooperative function, Layer 2 and Layer 3 base station transceiver system functions are still left in centralized BBU pools. In this architecture, there is no baseband processing function in the base band unit (BBU), but continue calling as BBU for avoiding the confusing. Partially centralized BBU functions are located in a single cluster while connecting with the remained BBU remote function and RRU with the optical link. Partial centralization need the lessen data bandwidth between the BBU pooling and remotes parts than the bandwidth requirement in the fully centralization architecture. However, the housing need for the remote radio devices become the main disadvantages of this mechanism. And there will be some impact, by delaying in data exchange, upon the system performance.

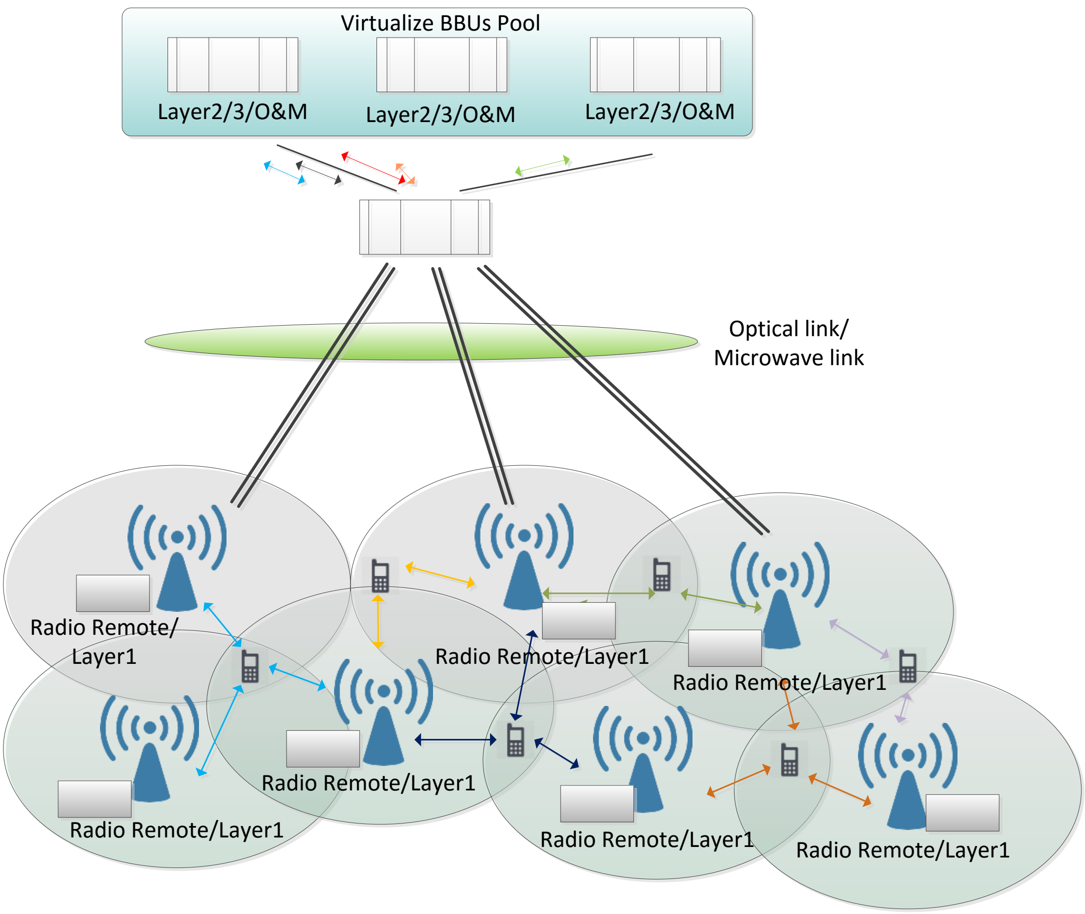

Figure 8: Partially Centralized C-RAN Method (refers and modify from C-RAN, The Road towards Green RAN [15])

Both of the C-RAN system architecture described above is easy to deploy and upgrade to the existing network of the operators. For increasing the network coverage, it requires only to equip the new RRUs depending on the splitting type and couple to the centralized BBUs in data centre. And it is just upgrading the centralized BBU pools to improve the system processing capacity for the exponential growth of network load. Those are the very good points for the mobile operators in the perspective views of further upgrading and system management ability.

2.3 Advantages of C-RAN

C-RAN architecture makes the benefits for the both macro and small cell sites. The following are the benefits and advantages of C-RAN.

- Energy saving

  According to the prior research, 80% of CAPEX are used to spend on RAN and 41% of OPEX per cell site are spent on power bill for power amplifiers, RRHs and BBUs' power and air conditioning [12]. In C-RAN, comparing with the traditional architecture, BBU housings are reduced and that can save the energy consumption for power supply to equipment, lighting and cooling systems. Again, for the traffic imbalances of the different times and locations such as day time in office area and early night time in residences, RRHs can changed and assigned to other lower traffic loading BBUs and some BBUs can switched off . Moreover, by the installing the RRUs at the top of towers as well as hanging on pole or on building walls, it can reduce the power consumption for the air cooling system of radio modules.

- Cost saving

  In C-RAN, base band units and other peripheral devices for site supporting are placed in one point and it makes the operators to easy access and manages. Operators can get the benefits from the saving the tremendous amount of operation and maintenance (O&M) costs comparing with the lot of RBS sites in conventional radio network. For the radio remote deployment, the number of the RRHs is same to the conventional system but RRHs in C-RAN has the more simplicity by reducing the size and power consume and easy to install and manage while requiring the smaller site support. And it makes the benefits to operators by reducing the site hunting and renting fee also.

- Upgrading Capacity

  In Cloud RAN, virtualized BBUs in pool can share the channel information, singling data and traffic news of the active subscribers in the network by virtualizing. So it is easy to implement the new technologies like cooperative multi-point processing (COMP), can easily operate and upgrade under the C-RAN architecture.

- Adaptable with Non-uniform Traffic

  Having the load-balancing ability among the deployed BBU pools, C-RAN mechanism can handle and available to the traffic distributed non-uniformly.

2.4 International Activities of C-RAN

Various activities of C-RAN are performed by many organizations all over the world. The concept is addressed as the noble solving method for the current difficulties of RAN and seemed as the one of the promising technology for future next generation wireless network. The famous and biggest operators of South Korea, SK telecom and Korea telecom, adopted the Cloud RAN method in upgrading to the LTE infrastructure in Seoul. And Japan telecom giant DoCoMo also used the centralized RAN method for the Advanced LTE deployment. The followings are the timeline of C-RAN activities according to [15] [16].

- C-RAN project named P-CRAN was founded by Next Generation Network (NGMM) in 2009
- China Mobile started the promoting of idea of C-RAN in 2010
- Intel, IBM, ZTE and Huawei signed MOU on C-RAN cooperation with CMRI
- Green Touch accepted the key technologies of C-RAN in 2012
- Network Function Virtualization(NFV) Industry Specification Group(ISG) is founded by European Telecommunication Standards Institute (ETSI) in 2012

Moreover, various kinds of C-RAN related projects like iJOIN and Mobile Cloud Networking (MCN) are performed under the EU Commission’s programs.

Chapter 3

Energy Efficient Data Downloading Scheme for C-RAN

3.1 Introduction of the proposed scheme

As the user's claiming of the higher transmission speed and gradual exploding of the numbers of the internet connected devices, Energy Efficiency (EE) issue plays as the main role in the next generation wireless radio access network (5G). In the previous, most of the scholars focused to reduce the power consumption of the user equipment for the better (EE) performance. But, nowadays, researchers from all over the world are also focusing on power consumption of the cellular network and the optimization of Base Station energy consumption. In this section, we proposed the energy efficient data downloading scheme based on the Cloud Radio Access Network (C-RAN) with the lower power consumption.

In the traditional C-RAN, every User Equipment (UEs) request directly to the server for the downloading the data files. However, applying our proposed scheme, if the (UEs) download the data files already saved in the BS's memory up to their popularity instead of directly requesting and downloading from the server, we can get the better network EE performance.

3.2 System Model

3.2.1 Network Architecture

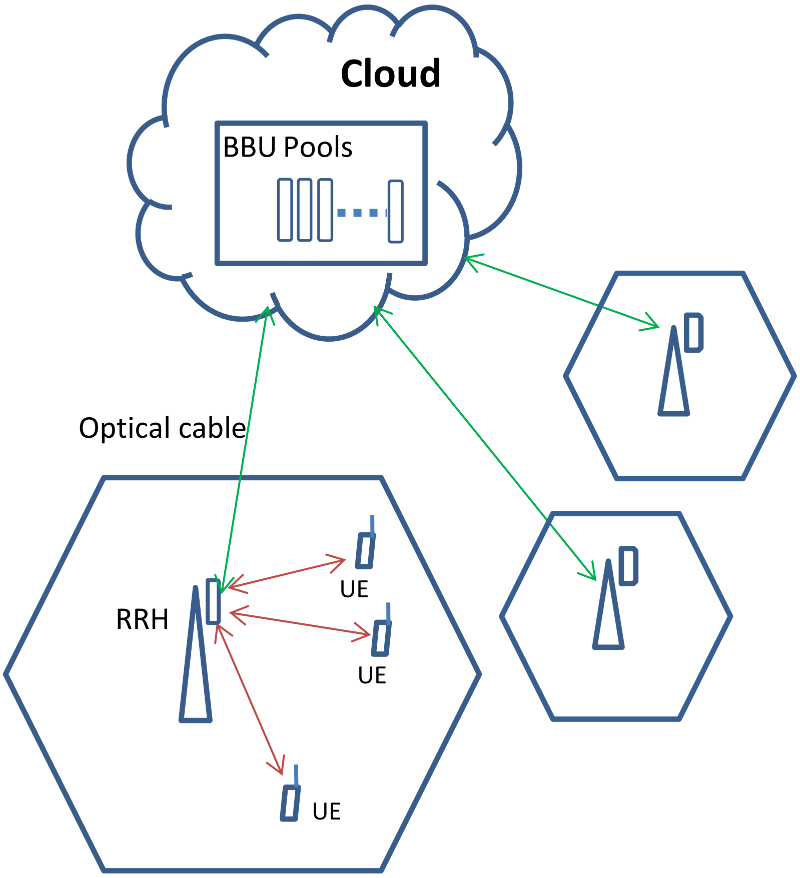

Figure 9: Architecture of C-RAN

Figure 9 show the architecture of C-RAN and it consists of the centralized Baseband Unit (BBU) pools and Radio Remote Heads (RRHs) deployed locally. Receiving data by means of antennas will be send to the BBU pools in data centre via the optical backhaul links. The purpose of this scheme is to introduce new idea for downloading the data in C-RAN with lower energy consumption. In the conventional system, data files are downloaded from the server directly across the back haul optical link. When a subscriber request to download a specific data file, the request of the content will be send to server directly via BS and then the requested content will be send back to the users directly. Therefore, for the very popular contents like live broadcasting soccer match and famous Television shows, millions of peoples will be watching and enjoying at the same time for the same program. In this case, a lot of subscribers will request the same content to the server and will download the same data stream from server. It makes the energy consumption of overall network to be so high.

In our proposed scheme, firstly the requested contents from the subscribers will be sent to the server directly and will send back to the UEs directly. However, those contents will be checked and some popular contents will be saved in the BS's memory up to their popularities. And then, when a subscriber request the popular content which is already saved in BS's memory, the request does not need to go to till the server and the content saved in base station will be shared to the requested UEs. So we can reduce the power consumption across the backbone optical transport cable for later requests. In C-RAN, radio units are locally deployed and those are linked to the several kilometres away centralized BBU pools with long distance optical backbone cables. Therefore the father from the BBU pools, the lower the overall network power consumption and the better the energy efficiency performance we got. But, in this case, although there will be some power consumption for the BS's memory, we neglect that in this research and left for future works.

3.2.2 Energy Consumption Calculation

For energy consumption calculation over the network, we separate the network into two parts while calculating the energy per bit needed in transmitting over the network. One part is wireless part from subscriber to BS and another left part is the backhaul optical transport cable part from BS to Server.

3.2.3 Optical Burst Switched (OBS) Network

In our study, we need to calculate the energy consumption to transmit a bit over the optical network because backbone link of the current day communications. For the energy calculation on optical cable, we adopt the Optical Burst Switched (OBS) network model. The advantages of OBS network are [17]

- Delivering the higher bandwidth and granulated packet size of the optical packet switched network
- Better energy efficiency

In calculating the energy consumption of overall the optical network, two different kinds of power consumption associated with the network can be classified as [18]

- Energy consumption used to transmit a bit over the optical cable
- Power consumption used in switching an optical signal by each Wavelength Routed Node (WRN) router

The WRN router is composed of the inline EDFAs, de-multiplexer and multiplexers and WRN switch [18]. These nodes also possess the ability like the adding/dropping channels by handling the transmitter array and receiver array. The network architecture of a WRN node is as shown in Figure 10.

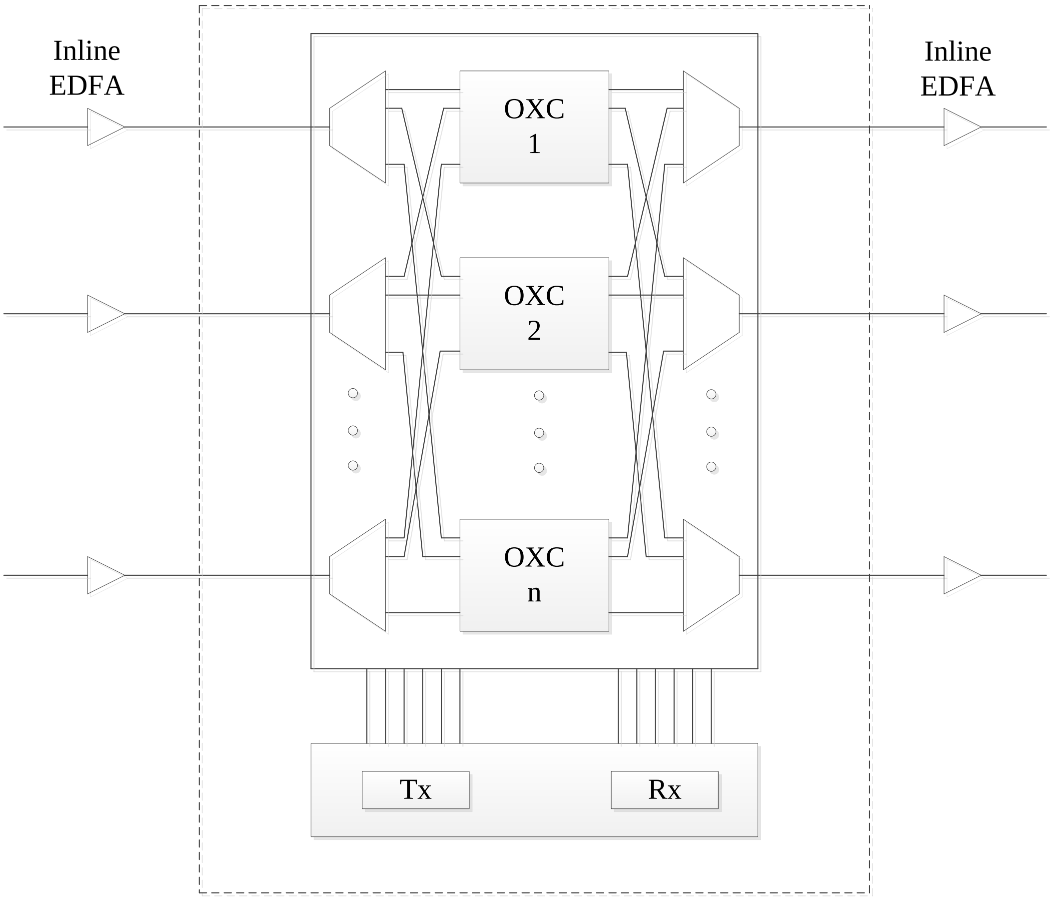

Figure 10: Architecture of the Wavelength Routed Node (WRN) (refers and modify from Energy Efficient OBS network (18))

3.2.4 Calculation of Energy per Bit

The Energy per bit is specified as the multiply of the time taken with the power dissipated used in transmission an optical bit over the fiber optic network. The inverse of the average bit rate (Br) is equal to the average transmission time per bit over a channel. Thus the energy need to transmit a bit can be expressed as [18],

$$E_{bit} = P_d T_{bit} \tag{1}$$

where T_{bit} is defined as the time needed to transmit a bit over the optical cable (T_{bit} =1/Br) and P_d is defined as the power dissipated. Hence (1) denote the energy needed to transmit an optical bit over a physical distance L km. The power consumption in optical network is given [2],

$$P_d = P_{signal} + P_{WRN} + P_{EDFA} \tag{2}$$

where P_{signal} is the signaling power, P_{WRN} is the power consumed by WRN and P_{EDFA} is the power consumed by inline EDFA amplifiers.

By replacing the (2) into (1), it given that the energy needs to transmit a bit in WRN is $P_{WRN}T_{bit}$ and the energy per bit in EDFA is $P_{EDFA}T_{bit}$. The approximate values of $E_{bit}^{(WRN)}$ for a WRN switch is 10nJ [19]. Correspondingly, the approximate values of $E_{bit}^{(EDFA)}$ for an inline amplifier is 0.1nJ respectively [19]. So we can understand that an optical bit is transmitted over H hops which consist of k numbers of amplifiers in each, if so, the energy consumption because of the WRN and EDFA is [18],

$$(H+1)E_{bit}^{(WRN)} + k\ H\ E_{bit}^{(EDFA)} \quad (H > 1) \tag{3}$$

3.2.5 Calculation of P_{signal}

For P_{signal} calculation, Shannon theorem given by

$$C = B_0\ log_2\ (1 + \frac{S}{N}) \tag{4}$$

where channel capacity is defined as C, optical bandwidth is as B_0, signal power is S, noise is N and S/N is the signal-to-noise ratio. In this case, we assume no noise and N=1.

3.2.6 Calculation of Number of Amplifiers

Let L_n be the real distance between the two adjacent nodes named node (n) and node (n+1), and m is defined as the physical distance between two inline amplifies in the fiber optical network.

Then, for the numbers of inline optical amplifiers used between two adjacent nodes (n,n+1) is given by [18],

$$k_n = \left[\frac{L_n}{m}\right] - 1 \tag{5}$$

For the distance on optical fiber cable which hasn't been compensated with the inline optical amplifiers is defined as m_n and it is given by [18],

$$m_n = L_n - a_n \times m \tag{7}$$

So we can define the energy consumption to transmit a bit for a given source-destination pair (s,d) is shown as

$$E_{bit<s,d>} = P_{signal} T_{bit} + \sum_{\forall i \in R} k E_{bit}^{(EDFA)} + (H+1) E_{bit}^{(WRN)} \quad (8)$$

where R is defined as the shortest route for given (s,d).

Here, calculation of energy per bit need in transmission of an optical bit over the optical network is based on the network architecture as shown in Figure 10.

3.2.7 Calculation for Energy per Bit in Wireless Part

For the energy per bit of the wireless part from the subscriber to BS, we also calculate the power consumed by using the Shannon theorem again.

$$C = B \log_2 \left(1 + \frac{P_{signal}}{N}\right) \quad (9)$$

where channel capacity is defined as C, channel bandwidth is as B, signal power is P_{signal}, noise is N and S/N is the signal-to-noise ratio. Here we assume no noise.

Here, in this case, we understand that

$$P_d = P_{signal} \quad (10)$$

So, the energy per bit for wireless part from subscriber to BS is given by,

$$E_{bit} = P_{signal} T_{bit} \quad (11)$$

where E_{bit} is the energy need to transmit a bit over the wireless network, P_{signal} is the power consumed to transmit and T_{bit} is the time taken.

3.3 Proposed Scheme

In this section, we describe our proposed energy efficient scheme comparing with the conventional scheme in flow charts. Figure (11) shows the traditional data downloading scheme for C-RAN. In the traditional scheme, when a user tries to download the data file, firstly the request from subscriber sends to server via the base station. Then the server will send back the request content to the subscriber which made the request through the base station. This procedure will happen again and again whenever the subscribers request the contents even if a lot of subscribers request the same popular contents.

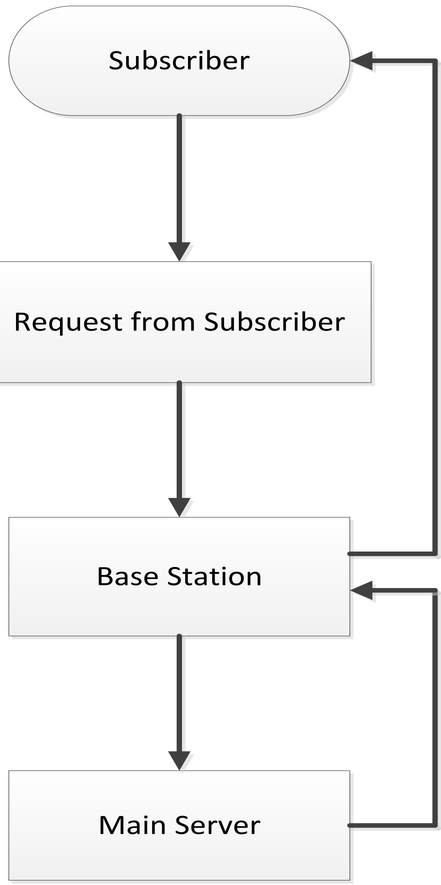

Figure 11: Traditional Downloading Scheme of C-RAN

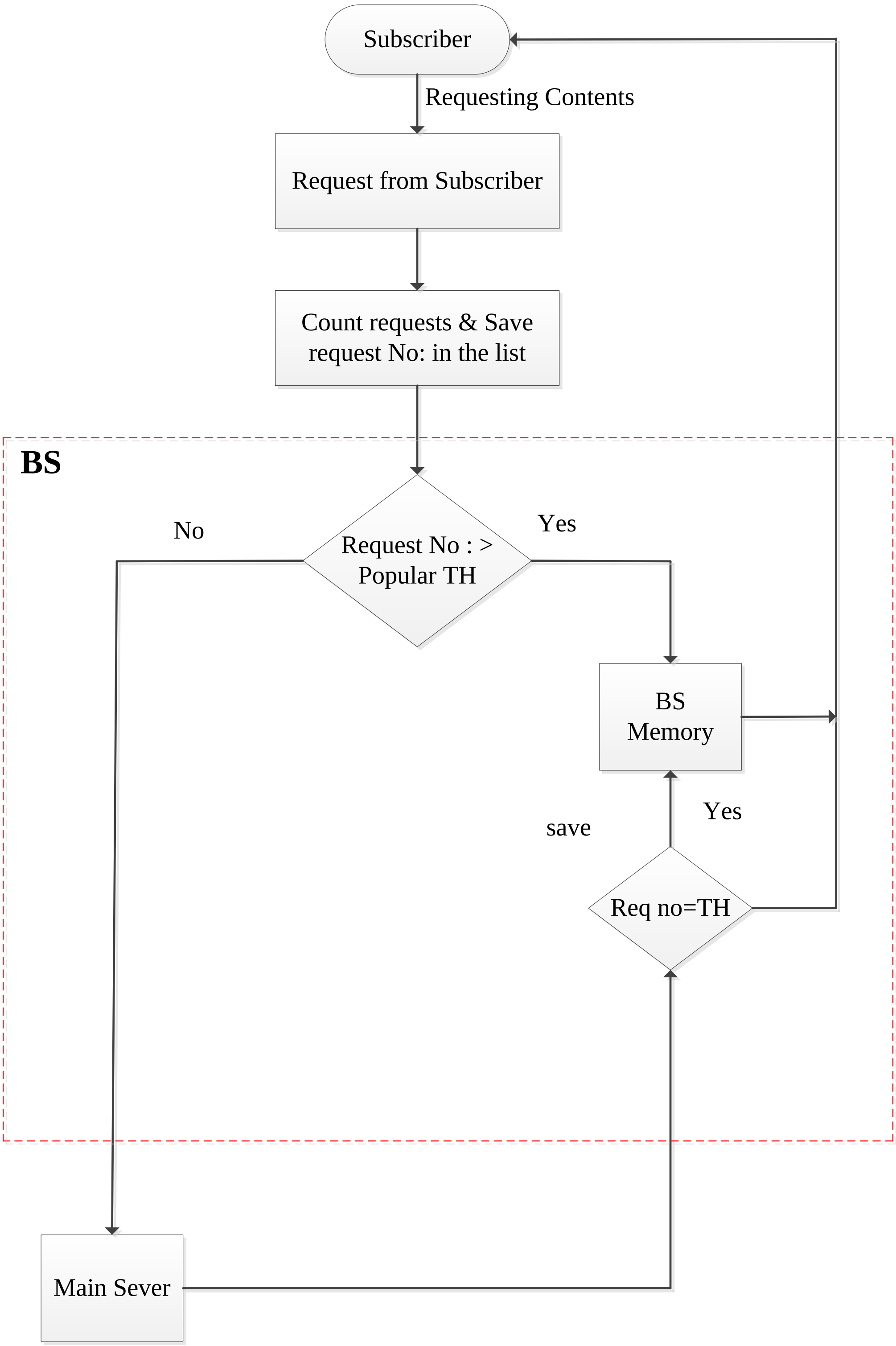

Figure 12: Proposed energy efficient downloading scheme

Figure 12 shows the proposed energy efficient data downloading scheme for C-RAN. In our proposed scheme, when a user request the data file from server, firstly the request from subscriber will send to the base station's memory. In the memory, the number of request will be counted and saved in the list. Here, we need to assign the initial threshold value and then the number of the request will be compared with that threshold value. Depending on the comparison with the threshold value, there will be two cases.

- **Case (i)**

  If the request number is smaller than the threshold value, the request will be send to the main server. The main server will send back the content which is requested to the base station. Here again, in this step, the requested number of the content will be checked and compared again with the threshold value that it is equal to the threshold value or not. If it is equal to the threshold value, the content send from the server will be saved in the BS's memory firstly and then send to the subscriber. If the number of the request content is not equal to the threshold value, the content is send to subscriber directly without saving in the memory.

- **Case (ii)**

  If the request number is larger than the threshold, the requested content already saved and exist in the base station's memory will be send to the subscriber which is requested.

By applying our proposed scheme, we can reduce the power consumption of the optical backhaul part from base station to server for the later requests for the popular contents which is larger than the threshold values.

Chapter 4

Evaluation and Results

In this section, evaluation of our proposal is described with the computer based simulation procedure. We evaluate the energy efficient performance of the proposed data downloading scheme of C-RAN while showing the comparing result with the traditional downloading scheme.

4.1 Simulation Parameters

Table 1: Simulation Parameters

Simulation Parameters	Value
Transmission Bit Rate (Br)	10 Gbps
Optical Channel capacity (C)	100 Gbps
Optical Bandwidth	70 GHz
Physical distance	2800km,1100km
Physical Distance between the Amplifiers (m)	70 km
Inline Amplifier Numbers(k)	43
Number of Hops (H)	4,3
Number of Fiber/Links	2
Sub-channel Bandwidths (B)	20 MHz
Number of UEs	40,60
Number of Content Types	5
Threshold Values	2,3,4

Simulation conditions are shown in Table 1.

4.2 Simulation Topology

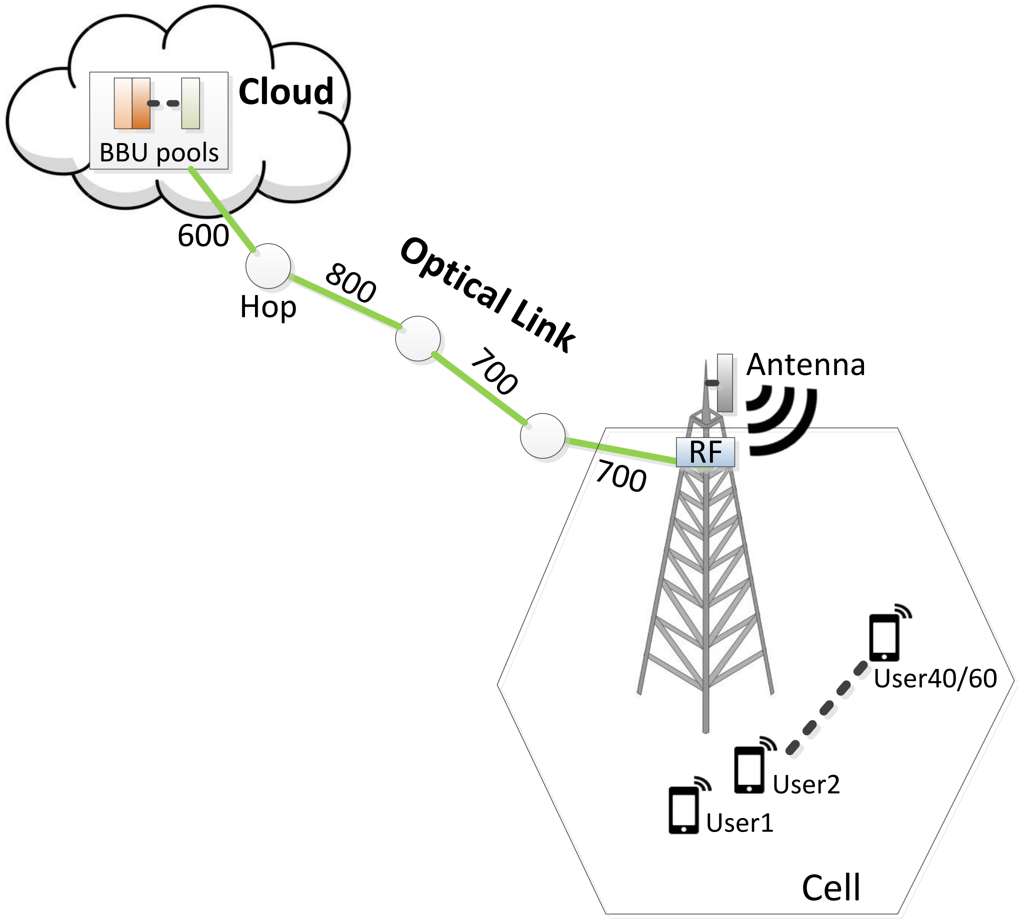

Figure 13: Simulation Topology

The topology of simulation is made up of the main server, optical link which consists of amplifiers and WRN nodes, and base stations. Here, some parts of the NSF network are used as the optical part from the server to base station for studying. Bi directional links carry the data with the maximum 10 Gbps rate. The numbers described on link refer to the distance of optical fibers between the hops.

4.3 Simulation Results

Figure 14 show the result obtained when the physical distance is 2800 km and user's request number is 40. We put the three different threshold values as 3, 4, and 5 and the experiment delivers the best performance at threshold value 3. By applying the proposed scheme, the total energy consumption of the network can be reduced about 57% with the proposed scheme of threshold value 3.

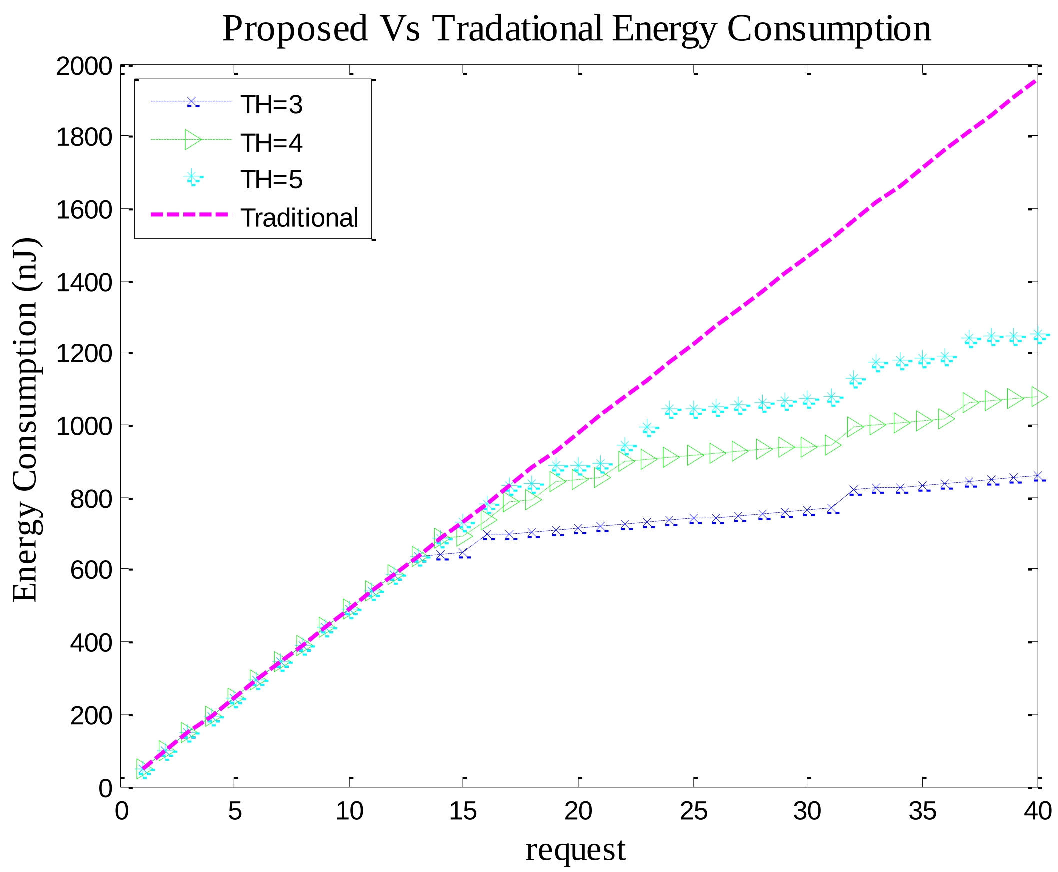

Figure 14: Energy Consumption Comparison (physical distance 2800 km and user request number 40)

In figure 15, we reduce the physical distance to 1100 km and let the user's request remain the same number 40. In this experiment, we get the best performance at the threshold level 3 and can reduce the 50 % of overall network power consumption from using proposed scheme comparing with the conventional scheme. Though it is the better performance than the traditional scheme, delivers lower energy efficiency than the previous simulation performance at the physical distance 2800 km.

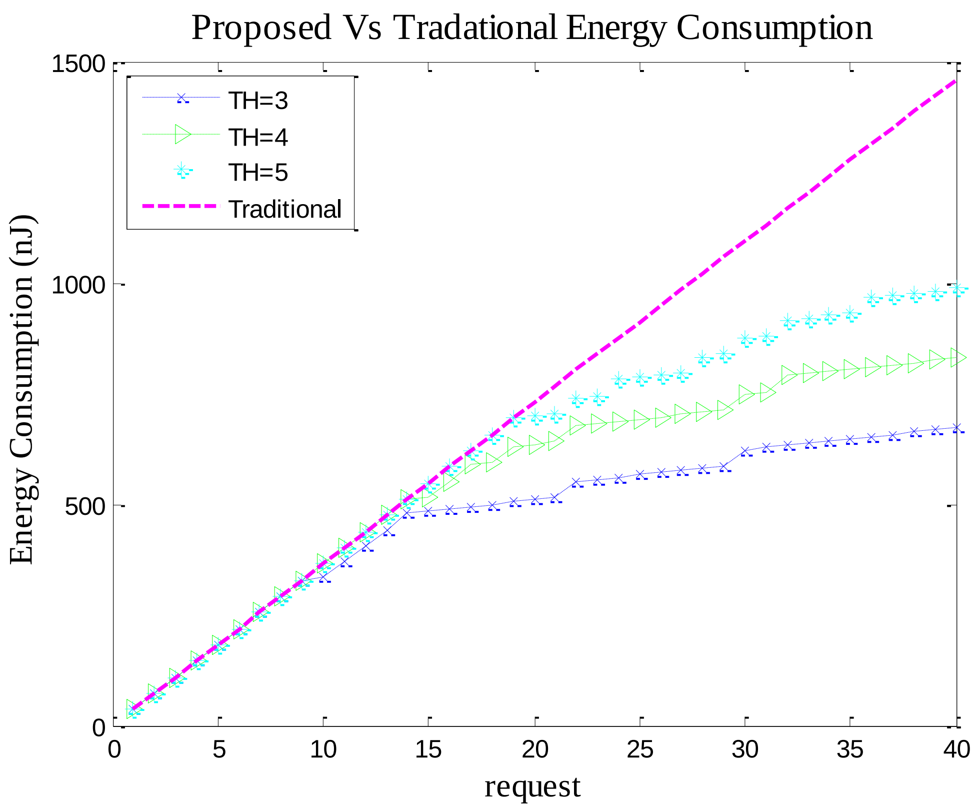

Figure 15: Energy Consumption Comparison (physical distance 1100 km and user request number 40)

In figure 16, we increase the numbers of user's request to the 60 and let the physical distance of optical cable still remain as 1100 km. The best energy efficiency performance is at the threshold level 3 and it can reduce the 62% of the network power consumption than the traditional scheme. And it is also better than the performance that can reduce 50% of power consumption when we let the user's request number as 40.

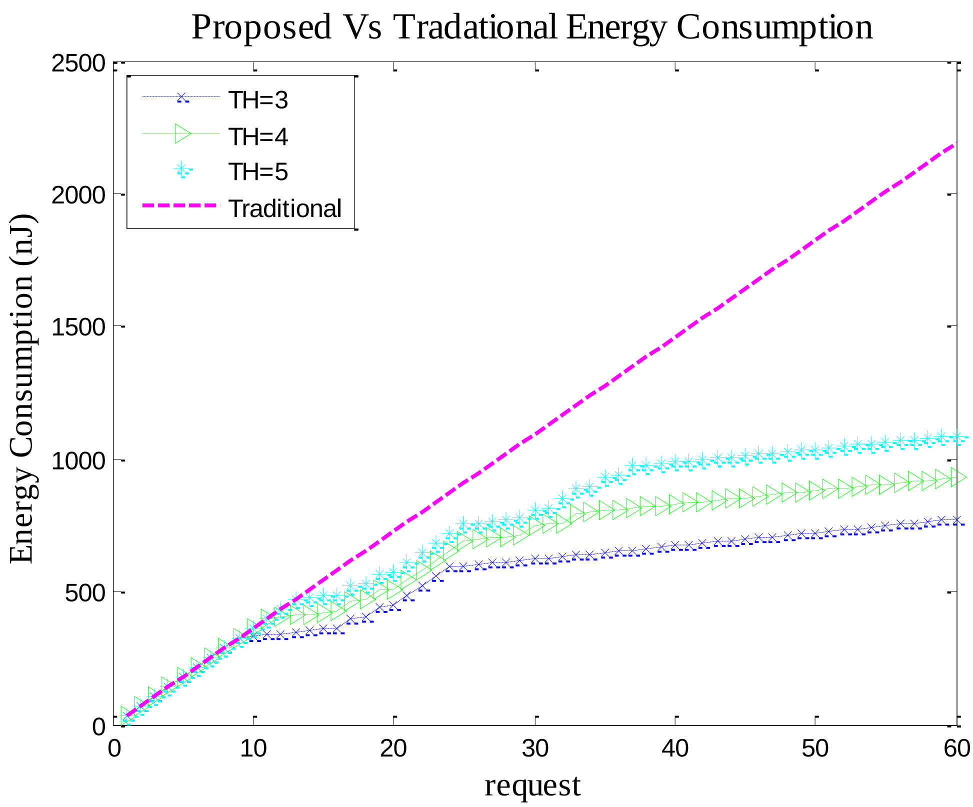

Figure 16: Energy Consumption Comparison (physical distance 1100 km and user request number 60)

According to the above simulation results described, our proposed data downloading scheme for C-RAN gives the best energy efficient performance at the smallest threshold level. Moreover, the scheme delivers the better performance results for the further distance from base station to server and more users' request numbers.

CHAPTER 5

Conclusion

In this paper, we proposed the energy efficient data downloading scheme for the cloud radio access network (C-RAN). By separating the network into two parts as from subscriber to base station and base station to main server, calculate the power consumption per bit to transmit over each part. WRN optical network is adopted for the calculation for the energy consumption in optical link from base station to main server. Then our proposed schemed is verified and evaluated with the computer based comprehensive simulation. Based on this work, in our simulation, we compare the modified downloading scheme with the traditional one and obtained the significant energy saving result.

However, in our work, we neglect the energy consumption for supporting the power to base station memory and left for the future works. And I will also focus on the latency of the proposed scheme as the following study.

REFERENCE

[1] Tutor Voice, “Generations of Wireless Communication Technology,” October 11, 2015.

[2] Karthik Kumar, “Mobile Technology,” March 15, 2014.

[3] Ericsson, “White Paper: 5G Radio Access – Capabilities and Technologies,” April 2016.

[4] Di Zhang, Keping Yu, Zhenyu Zhou and Takuro Sato, “Energy Efficiency Scheme with Cellular Partition Zooming for Massive MIMO Systems,” 2015 IEEE Twelfth International Symposium on Autonomous Decentralized System, pp.266-271, March 2015.

[5] Ericsson, “Ericsson Mobility Report,” June 2016.

[6] United States Environmental Protection Agency, from “https://www3.epa.gov/climatechange/basics/,”

[7] Margot Deruyck, Emmeric Tanghe, Wout Joseph, Luc Martens, “Modelling and Optimization of Power Consumption in Wireless Access Networks,” Computer Communication, Vol. 2, Issue 17, pp. 2036-2046, November 2011.

[8] Willem Vereecken, Ward Van Heddeghem, Margot Deruyck, Bart Puype, Bart Lannoo, Wout Joseph, Didier Colle, Luc Martens, and Piet Demeester, “Power Consumption in Telecommunication Networks: Overview and Reduction Strategies,” IEEE Communication Magazine, Vol. 49, Issue. 6, pp. 62-69, June 2011.

[9] Jun Wu, Zhifeng Zhang, Yu Hong, Yonggang Wen, “Cloud Radio Access Network (C-RAN) A Primer,” in IEEE Network, Vol. 29, Issue 1, pp. 35-41, January 2015.

[10] I. Hwang, B. Song, and S. Soliman, “A Holistic View on Hyper-Dense Heterogeneous and Small Cell Networks,” Communications Magazine, IEEE, vol. 51, no. 6, pp. –, 2013.

[11] D. Gesbert, M. Kountouris, R. Heath, C.-B. Chae, and T. Salzer, “Shifting the MIMO Paradigm,” Signal Processing Magazine, IEEE, vol. 24, no. 5, pp. 36–46, 2007.

[12] Aleksandra Checko, Henrik L. Christiansen, Ying Yan, “Cloud RAN for Mobile Networks - a Technology Overview,” in IEEE Communications Surveys & Tutorials, Vol. 2, Issue. 1, September 2014.

[13] Renato L.G. Cavalcante, Slawomir Stan´czak, Martin Schubert, Andreas Eisenblätter, and Ulrich Türke, “Toward Energy-Efficient 5G Wireless Communications Technologies,” IEEE Signal Processing Magazine, November 2014.

[14] G. Kardaras and C. Lanzani, “Advanced Multimode Radio for Wireless and Mobile Broadband and Communication,” in European Wireless Technology Conference, 2009. EuWIT 2009, pp. 132–135.

[15] China Mobile, “C-RAN, the Road towards Green RAN,” White Paper, Version 3.0, December 2013.

[16] Wikipedia, from “https://en.wikipedia.org/wiki/C-RAN,”.

[17] Suresh Pandian. V, Arjun Kumar. C. R, Karapagarajesh. G, “To Analyze the Performance of Optical Burst Switched Networks for Energy Savings,” in International Journal of Science and Modern Engineering (IJISME), Vol. 1, Issue. 3, February 2013.

[18] Balagangadhar G. Bathula, Jaafar M. H. Elmirghani, “Energy efficient Optical Burst Switched (OBS) network,” 2009 IEEE Globecom Workshops, pp. 1-6, November 2009.

[19] R. S. Tucker, “A green internet (plenary paper),” in Proc. IEEE/LEOS, 21th Annual Meeting, Newport Beach, USA, November 2008.

[20] Shinobu NAMBA, Takayuki WARABINO, Shoji KANEKO, “BBU-RRH Switching Schemes for Centralized RAN,” in 7th International ICST conference, pp. 11, 2012.

[21] M. Marsan, L. Chiaraviglio, D. Ciullo, and M. Meo, “Optimal Energy Savings in Cellular Access Networks,” IEEE ICC, pp.1–5, Jun. 2009.

[22] C. Han, S.A. T. Harrold, I. Krikidis, S. Videv, P. Grant, H. Haas, J.S. Thompson, I. Ku, C. Wang, T. Anhle, M. Nakhai, J. Zhang, and L. Hanzo, “Green radio: Radio Techniques to Enable Energy-efficient Wireless Networks,” IEEEComm.Mag., Vol.49, no.8, pp.46–54, June 2011.

[23] L. Liu, F. Yang, R. Wang, Z. Shi, A. Stidwell, and D. Gu, “Analysis of Handover Performance Improvement in Cloud-RAN Architecture,” in Communications

and Networking in China (CHINACOM), 2012 7th International ICST Conference on, pp. 850–855, 2012.

[24] Z. Ghebretensae, K. Laraqui, S. Dahlfort, J. Chen, Y. Li, J. Hansryd, F. Ponzini, L. Giorgi, S. Stracca, and A. Pratt, “Transmission solutions and architectures for heterogeneous networks built as C-RANs,” in Communications and Networking in China (CHINACOM), 2012 7th International ICST Conference on, pp. 748–752, 2012.

[25] S.-H. Park, O. Simeone, O. Sahin, and S. Shamai (Shitz), “Robust and Efficient Distributed Compression for Cloud Radio Access Networks,” Vehicular Technology, IEEE Transactions on, vol. 62, no. 2, pp. 692 –703, February 2013.

[26] Anass Benjebbour, Keisuke Saito, Yuya Saito, Yoshihisa Kishiyama, “5G Radio Access Technology,” in NTT Technical Journal, Vol. 17, No.4.

[27] Docomo, “Docomo 5G White Paper 5G Radio Access: Requirements, Concept and Technologies,” July 2014.

List of Publications

[1] Zin Ko Ko Win, Di ZHANG, and Takuro SATO , “Energy Efficient Data Downloading Scheme for C-RAN,” IEICE General Conference, Fukuoka, March 2016.