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Dynamically Energy-Efficient Resource Allocation in 5G CRAN Using Intelligence Algorithm

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Abstract

5G network is the next generation for cellular networks to overcome the challenges and limitations of the 4G network. Cloud Radio Access Network(C-RAN) is providing solutions for cost-efficient and power-efficient solutions for the 5G network. The aim of this paper proposed an energy-efficient C-RAN to minimize the cost of the network by dynamically allocating BBU resources to RRHs as per facing traffic, and also minimize the energy consumption of centralized BBU resources that affect dynamically allocate of RRHs. Particle Swarm Optimization (PSO) algorithm is a Swarm Intelligence algorithm for optimization of mapping between BBU-RRH for resource allocation in C-RAN. The main objective of the paper is as per resource usage in C-RAN the BBU is put in the active or in-active mode to minimize energy consumption in C-RAN of 5G technology. As per our proposed C-RANapplication, the proposed PSO algorithm 90% minimizes energy consumption and maximizes energy efficiency compared with existing work.

Keywords: 5G network, C-RAN, BBU, RRH, Front haul, Swarm Intelligence algorithm, PSO algorithm

1. INTRODUCTION

Day by day introducing of technology, huge applications and also to process video and other real-time entertainment video contents are effects high data traffic. The traditional cellular architecture not suitable for effectively manage these heavy traffic because of these reasons. First reason, every base-station connect with fixed size antennas that cover small area. Second reason, base stations are not utilization properly because of network traffic dynamically processing. Third reason, traditional base stations are not support for coordinated multipoint communication for improving spectral efficiency

5G network is a next generation for cellular networks to overcome the challenges and limitations of 4G network. C-RAN is providing solutions for cost-efficient and power efficient solutions of 5G network. C-RAN is architecture for centralizing of base stations with minimum cost, high efficient energy and providing centralizing network. C-RAN architecture contain of Base Band Unit(BBU) pool, Remote Radio Unit(RRU) network, Fronthaul. BBU pool placed centralized cloud area or it will be placed data center. BBU high storage capabilities and taking response for resource processing as well as dynamically allocating resources to RRU. RRU is a wireless network that connects wireless devices like access points. Fronthaul is connectivity between BBU and RRU for providing high bandwidth links for accessing communication. The centralized Cloud RAN architecture is beneficial for reducing network consumption and increased network flexibility [1- 4].

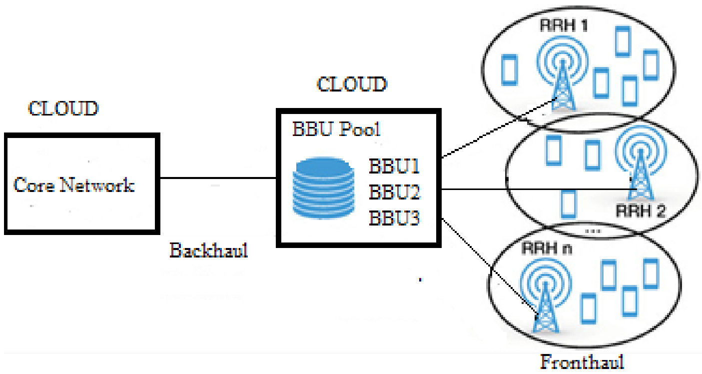

Figure 1. 5G C-RAN Architecture shows BBU-RRH connectivity show network topology

The research paper organizing as follows. Section -1 represents the Introduction, Section -2 represents the Existing work, Section -3 represents the Proposed Energy Consumption Model for C-RAN, Section 3.1 represents the Proposed C-Ran Architecture For Simulation, Section-4 represents Particle Swarm Optimization Algorithm for proposed Resource Allocation in C-RAN, Section-5 represents the Results and Discussion and follows Conclusion & Future work , References.

2. RELATED WORKS

The authors[5] proposed a method C-RAN as per arising dynamically communicate of BBU and RRH. The main aim of this paper is to balance load on 5G C-RAN. To improve the quality of services and to optimize balancing network traffic authors apply a Genetic algorithm.

The authors[6] proposed a resource allocation of 5G-CRAN by balancing of network load and reach quality of services. The mapping of UE with RRH and mapping of RRH with BBU to reach efficient resource allocation and improvement energy efficiency. The authors apply hybrid optimization method by ABC-ACO to reach their goals of not wasting of resources and improve throughput and reach quality of services.

The Authors [7] proposed dynamic resource allocation in 5G C-RAN for logical mappings of BBU-RRH and RRH-UE depending on traffic load as well as network conditions. The optimization qualities were reached and applied by the modified ABC algorithm of swarm intelligence.

The authors [8] proposed six sense seamless handover protocol (6S-HO) to sense bandwidth, energy level, cost, cost of network using artificial swarm intelligence algorithm. The authors used OMNET++ simulator for simulation. The proposed work show efficiency to connect to the network with low latency and improves the quality of service. The proposed algorithm shows better results than the existing method.

The authors [9] proposed a method for the management of RFBs to deliver HD video to the user in 5G network. They propose P5G algorithm for providing solutions of association of users to notes, allocation of RRH RFBs, allocation of BBU and MEC RFBs. By using P5G on MC, SC, EMP notes. The PG5 perform better results improve throughput and reach 100 mbps.

The authors [10] proposed BBU with RRH associate to reduce power consumption by communicate overhead. The results shows that improved power consumption by 20% and reduces overhead 30% with traditional approach method.

3. ORIGINALITY

The novelty of this proposed paper enhance of energy efficient model of C-RAN is minimize energy consumption of BBU supports RRH at duration of time period. The proposed PSO algorithm performs mapping between BBU to RRH. The proposed PSO algorithm perform switch BBU on/off operations as per the load of network conditions for better resource allocation/utilization and minimize energy consumption load in network and maximize overall performance of network.

4. SYSTEM DESIGN

4.1 PARTICLE SWARM OPTIMIZATION (PSO)

Particle Swarm Optimization – Particle Swarm Optimization(PSO) is Swarm Intelligence algorithm. SI algorithms are one of the flavor of Nature inspired computing algorithm. SI algorithms features are self-adaptation, collective behavior, co-ordination. PSO is famous for collective behavior of particles to fulfill its task. PSO introduced by Kennedy and Eberhart get inspired by social behavior of bird flocking or fish schooling[12]. The system is initialized with a population of random solutions and searches for optima by updating generations. In particular, the PSO variation can avoid unnecessary computations, having fast convergence rate[13]. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. The detailed information will be given in following sections.

In PSO algorithm, a group of particles(i.e. birds) are for searching for food randomly in a particular area. These particles are searching one of food(solution) in that area. The particles identify how far the food in every iteration. The bird which is nearest food has to be follow.

The PSO is the best algorithm for solve optimization problems in a real-world. Every particle having the fitness value that is evaluate by fitness function is to be optimized, the velocity which has to be direct the flying of these particles. These particles flying over the problem space. PSO is being initialized with a group of random particles known as solutions. For each iteration, each particle updated by two best values i.e. pbest and gbest. pbest is known as personnel best and gbest is known as global best. The finding the these two best values, the particles updated their velocity as well as positions as equation (1).

In PSO every particle related to a population S is defined as X_i = [xi_1, xi_2, …xi_D] consider for dimension D, by adjusting of velocity v_{id} in every dimension d for a new iteration i.e. t+1.

$$v_{id} = v_{id} + c_1.rand_1\left(p_{id} - x_{iD}\right) + c_2.rand_2\left(pgbest_{1d} - x_{iD}\right) \quad (1)$$

In equation (1), p_{id} denotes the best local position for every dimension. $pgbest_{1d}$ denotes the best global position gained by the all population(particles) in a particular dimension d. c1 and c2 are considered constants for cognitive and social learning rates. The newer particle position for the next generation in dimension d, getting by add for the adjusted velocity for its current position.

$$x_{iD} = x_{iD} + v_{id} \quad (2)$$

In equation (2) ω is consider as random inertia weight for velocity update for control previous gain velocity to current velocities.

$$v_{id} \leftarrow \omega.v_{id} + c_1.rand_1\left(p_{id} - x_{iD}\right) + c_2.rand_2\left(pgbest_{1d} - x_{iD}\right) \quad (3)$$

In equation (3) the balancing of local exploitation and global exploration is affected. Local (exploitation) searching for optimum results in current area in a provided space. While global(exploration) search for optimum results in a global search space. A higher value inertia weight, ω provides a maximum global search for gain optimality. A smaller inertia weight ω provides a minimum local search for gain optimality.

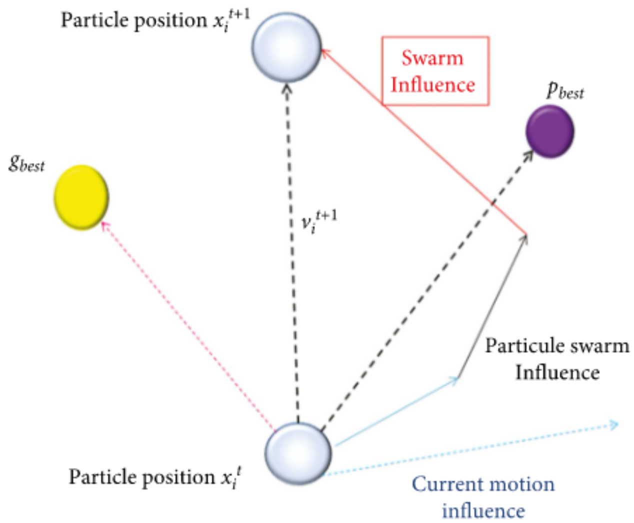

Figure 1. Particle movement in a swarm

Algorithm 1: Proposed Resource Allocation Algorithm using PSO for balancing of overload on BBU

```
Init population of size p randomly
Init particles velocities to 0
Init individual best to current population
Init global best to minparticle{F(particle)}
While generations remain AND value not reached do
     for each particle p do
       v←α .v+c1.rand1.(individual_best-particle)
           +c2.rand2.(global_best-particle)
           search list R for RRH with minimum traffic users
        for(i=0;i!endoflist R)
                RRHt ←  RRHi
                search list for BBU that can accommodate RRHt
                  for(i=0;i<endofL<i++)
                  {
                   If(lowerlimit<CACBBU1<upplimit)then
                   List B   ←  Add(BBUi)
                      else if(CAD_BBUi <lowerlimit>then
                      List N  ←  Add(BBUi)
                   }
            if(list B) then
                     List B ←  sort
                      Select the first BBU from the list B and
                      assign RRHt to it
                       List R  ←     remove(RRHt)
                        Update CAC values in listL
            else select any BBU from list N and assign RRHt to it
             Repeat 5 & 6
             if(BBU still overloaded)then
               Repeat step 1,2,3,4,5,6 and7
             else end
                 if F(particle) <F(global_best)then
                    Global_best ←particle
                 End
        End for
End while
```

4.3 ENERGY CONSUMPTION MODEL

The earth model of energy consumption is very efficient for analyzing energy efficiency. The equation given as

$$Power_{in} = \begin{cases} N_{TRA}\ P_{\min\_load} + \Delta_{power\_Cons}.P_{power\_out}; & 0 < P_{power\_out} \le P_{\max\_load} \\ N_{TRA}\ P_{sleep\_mode}; & P_{power\_out} = 0 \end{cases} \quad (4)$$

In equation (4), $power_{in}$ and $power_{out}$ represent the total power supply regarding the base station to calculate measuring antenna power output input. N_{TRA} represents the number of antennas at base stations. P_{sleep_mode} mode represents power consumption. Δ_{power_cons} represent the variation of load power consumption.

The previous earth model is a fixed model. Dynamic mapping of BBU-RRH is not possible for earth model architecture. The newly proposed C-RAN infrastructure dynamic allocation of BBU pool to RRHs. BBU-RRH dynamic mapping will minimize energy consumption rate by putting sleeping mode when BBU not functioning.

4.4 PROPOSED ENERGY CONSUMPTION MODEL

The proposed Energy consumption model useful for BBU and RRH separately measured power consumption by application following equation.

$$PC_{BBU(time)} = PC_{BB} + \sum_{i}^{n} PC_{RRH\_i} \quad (5)$$

where

$PC_{BBU(time)}$ =Power consumption rate of BBU.

PC_{BB} = Power consumption of particular BBU

$\sum_{i}^{n} PC_{RRH\_i}$ = Total power consume by RRHs is supported by each BBU at an instance of time.

Considering of Earth model results for RRH section, the proposed equation is described as equation (6).

$$\sum_{i}^{n} PC_{RRH\_i} = \frac{P_{power\_out}}{\eta_{PA}} + P_{radio\_freq}.N_{TRA} \quad (6)$$

where

η_{PA} = represents efficiency of power amplifier

freq = radio frequency circuit's power consumption

N_{TRA} = represents the no. of transceiver antennas

The power out will be calculated at every transmission sub-frame as per the packet schedule number of physical resource blocks. The linear relationship for transmission power assumes as per the number of schedule of physical resource blocks as shown in equation (7).

$$P_{power\_out} = slope_m.(N_{PRB}) + n \tag{7}$$

where,

P_{power_out} = total power supply regarding base station to calculate measuring antenna power output
$slope_m$ = curve as per power allocation options.
N_{PRB} = Number of PRBs scheduling per sub-frame as well as allocation of related no. of PRB.

The total power consumption of BBU pool is shown by equation (8)

$$PC_{BBU\_pool} = \sum pool_{BBU} + PC_{CSI} \tag{8}$$

where,

PC_{BBU_pool} = total power consumption of BBU pool
$\sum Pool_{BBU}$ = total of all active BBUs in a pool
PC_{CSI} = power consumed by common site infrastructure.

The CSI has site monitoring solutions, environmental control systems, lights, etc. The power of CSI is represented as the equation (9).

$$PC_{CSI} = PC_{cool} + PC_{backhaul} + PC_{light} + PC_{monitor} \tag{9}$$

The total BBUs are placed centrally located to manage and provide cooling centrally and to minimize half of the cost when compared to traditional methods.
The power consumption of BBU pool is represented in equation (10)

$$PC_{CSI} = \begin{cases} \sum_{j}^{n}\left(P_{BBj} + \sum_{i}^{n} P_{RRH\_i}\right); & 0 < PC_{out} \le PC_{\max} \\ P_{sleep}; & P_{out} = 0 \end{cases} \tag{10}$$

Table 1 shows the components of the power model and related values used in the purpose of simulation. The parameters have been referred and taken from the paper [14].

Table 1. Power value parameters

Component_model	Symbol	Average_power_ consumption
BBU	PC_{BB}	200W
RF circuit_power	P_{RF}	100W
Cooling(CSI)	$P_{cooling}$	4000W (for2 units)
Backhaul(CSI)	$P_{backhaul}$	200W
Lighting (CSI)	P_{light}	50W
Monitor(CSI)	$P_{monitor}$	50W
PA efficiency factor	ηPA	30%

4.5 PROPOSED C-RAN ARCHITECTURE FOR SIMULATION

Figure 2 shows the architecture of C-RAN which consists of BBU centralized data centers BBU1, BBU2, and BBU3 located centralized in a cloud. Locally deployed RRH are RRH1, RRH2, RRH3, RRH4, RRH5, RRH6. CPRI is a common public radio interface is acting as connectivity between BBU and RRHs. For providing the handling of data as per limitations one - many i.e. one BBU is having the capability to support either one or many RRHs. C-RAN can minimize network cost and power consumption by minimizing no. of hardware equipment needed for cell sites. Compared with the existing method architecture, the proposed C-RAN architecture can minimize network overhead, minimize network cost, minimize energy consumption and maximize energy efficiency.

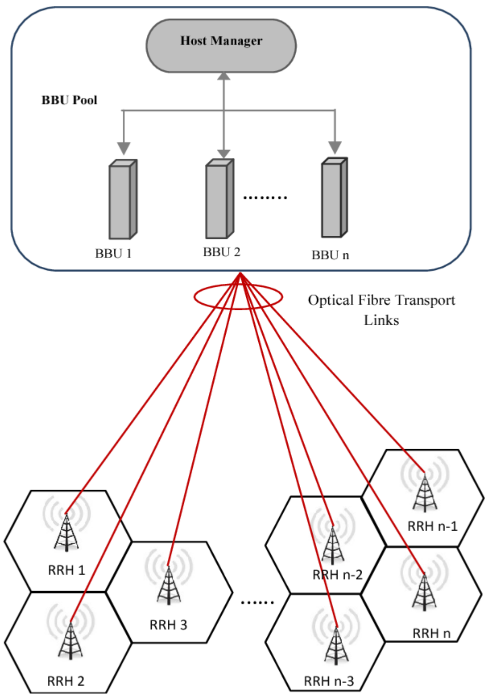

Figure 2. C-RAN Architecture

The proposed work C-RAN architecture extended for utilization of Host manager server placing in a BBU pool [11]. In BBU pool, every BBU frequently provides information about the active / inactive status of BBU to Host manager. The host manager acts as a manager to monitor load conditions of every BBU for utilization of resources that exceeds limits or falls limits. The proposed algorithm optimizes the BBU-RRH mapping for load balancing.

5. EXPERIMENT AND ANALYSIS

In C-RAN architecture key performance indicator(KPI) acts as monitoring for the availability of resources of BBU[14]. The proposed algorithm applies composite available capacity(CAC) for getting information from BBU for available physical resource blocks (PRB) for utilization of load balancing for up-link / down-link individually. The lower value represents composite available capacity(CAC) and the higher value represents the availability of physical resource blocks(PRB).

The working procedure of proposed algorithm monitoring for balancing the load of BBU for certain RRHs[15]. If any BBU extends the limits of usage of resources, then it is essential to minimize the load of that BBU for that automatically proposed algorithm offloading the BBU traffic to other BBU which BBU is in sleeping status. The process of assigning traffic load to overloaded BBU to sleeping mode BBU is that under-utilized BBU is being switched on/off after being offloading its traffic load to another BBU i.e. sleeping mode BBU. In this way, the proposed algorithm assigns overloaded BBU traffic load to lightly traffic loaded BBU for balancing load among the BBUs in a BBU pool to minimize energyconsumption and maximize the energy efficiency as well as maximize throughput better utilization of BBUs of 5G C-RAN.

In the proposed work, BBU1 connectivity with 3 RRHs i.e. RRH1, RRH2, RRH3. BBU2 is connected to RRH4 and RRH5. Every RRH is randomly assigned the traffic. As per increase/decrease users' mapping between BBU-RRH varying time-to-time. In our proposed work, a maximum of 20 users can support by RRH. The proposed algorithm proper balancing of the workload of BBUs in a BBU pool. An algorithm assigns overloaded BBU’s traffic load to lightly traffic-loaded BBU for balancing load among the BBUs in aBBU pool to minimize energy consumption and maximize the energy efficiency as well as maximizethroughput better utilization of BBUs of 5G C-RAN.

Table 2. Simulation parameter settings

Parameters	Value
System Bandwidth	20 MHz
Scheduler Type	RrFfMacScheduler
Number_ of_BBUs	3
Number_ of_RRHs	6
SRS periodicity	6
Time for Simulation	5 seconds
UE Mobility Model	Random Direction Mobility Model
Inter Packet interval	100 milliseconds
Downlink transmission Power	46 dBm
Periodicity of SRS	20
Traffic duration	24 Hours
Participle Size	200
P_{best}	Personnel best value
G_{best}	Global best value

Figure 3 shows X-axis as Time (seconds), and Y-axis as Traffic(%). The graph represents the power consumption of BBU. While network traffic is decreasing, it will minimize power consumption. As per network traffic, the power consumption is also minimized. For managing the power consumption and to improve the energy efficiency, as shown in Figure 3, whenever per network traffic, the utilization of BB1 is switched off for 2-3 seconds. This means that it gains power and energy efficiency by upto 90% compared with the existing method. It could be observed while the BBU1 is switched off for 2-3 seconds, at the same time BBU2 and BBU3 can manage the entire load of the network. If no load, the BBU1, and BBU2 automatically switched off for a time of 3.25 seconds. Using this way, the system could minimize the total power consumption in a network and maximize the power efficiency by 90%. Again network traffic rises then BBU1 and BBU2 are in an active position to manage current traffic for various timings. In our proposed C-RAN, 90% of the power is reduced, and the power efficiency and utilization will maximizing by 100% compared with existing work [16,17,18,19,20,21].

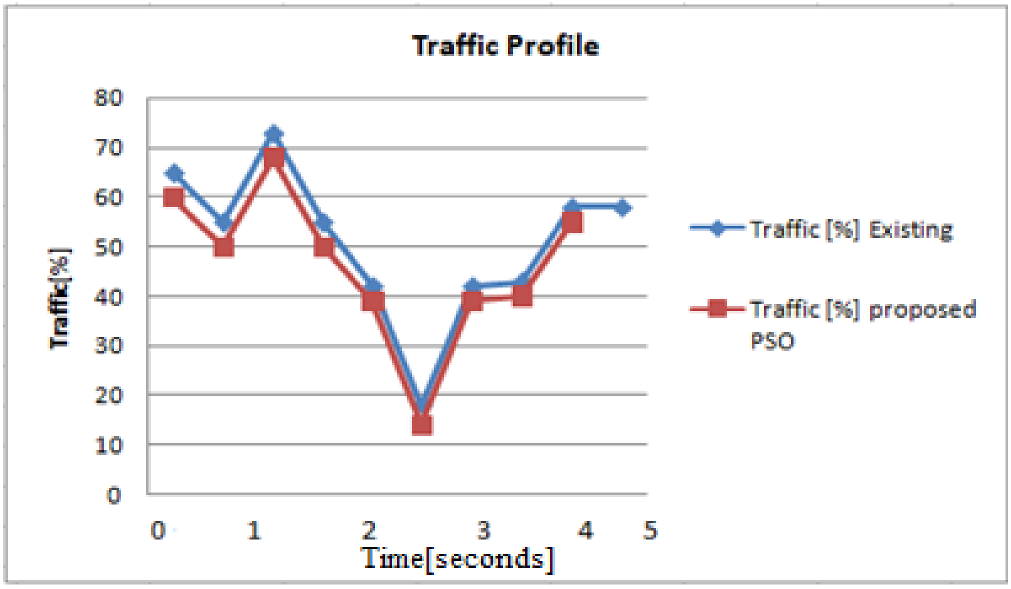

Figure 3. Traffic Profile

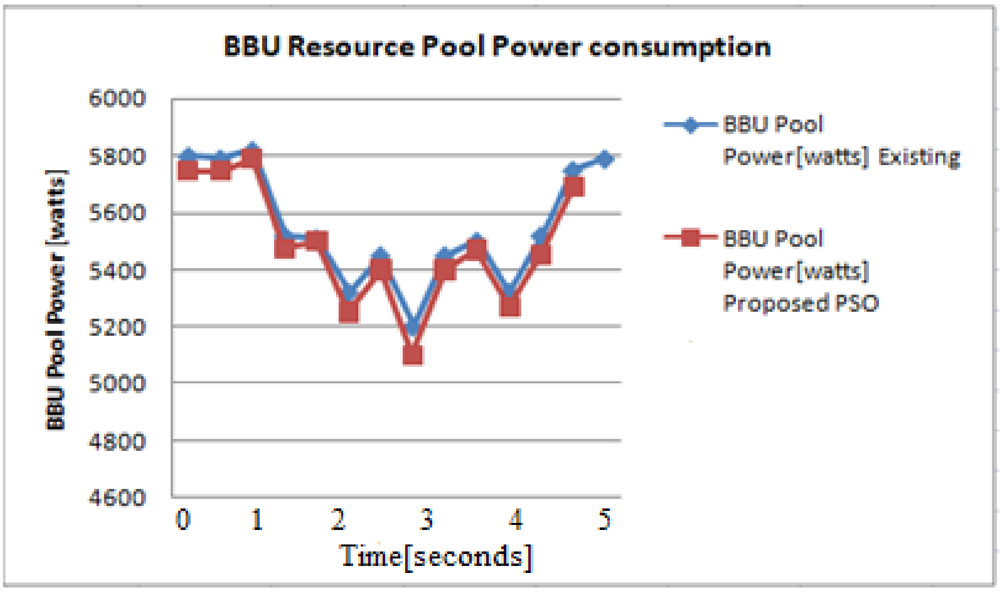

Figure 4. Power consumption of BBU Resource Pool w.r.t vary traffic profile

Figure 4 shows the utilization of BBU varies as per a load of traffic conditions. The decreasing of traffic load in a network will automatically minimize the power consumption in BBU. Minimizing power consumption will automatically maximize the energy efficiency of BBU. While comparing with the existing work, the proposed work by using PSO algorithm power consumption produces the less value. This means that less power consumption will increase energy efficiency as shown in Figure 5.

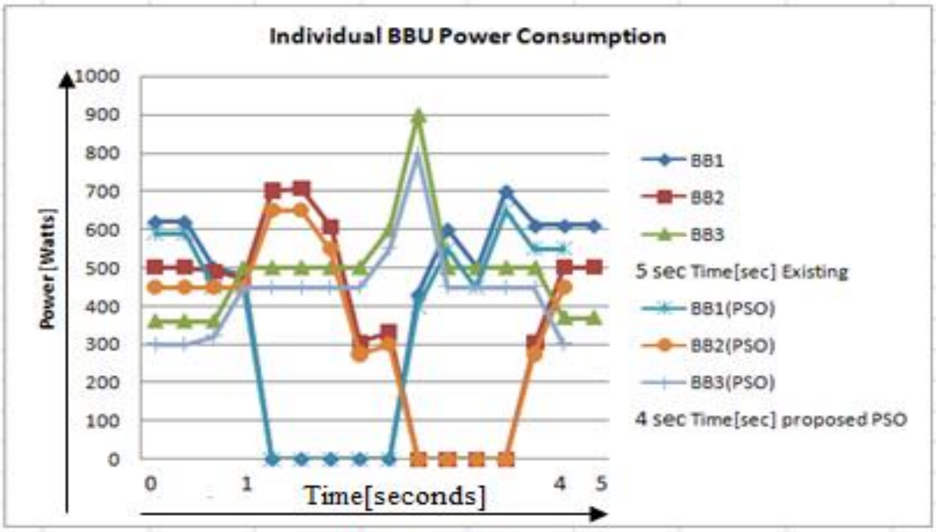

Figure 5. Power consumption Individual BBU w.r.t. vary traffic profile

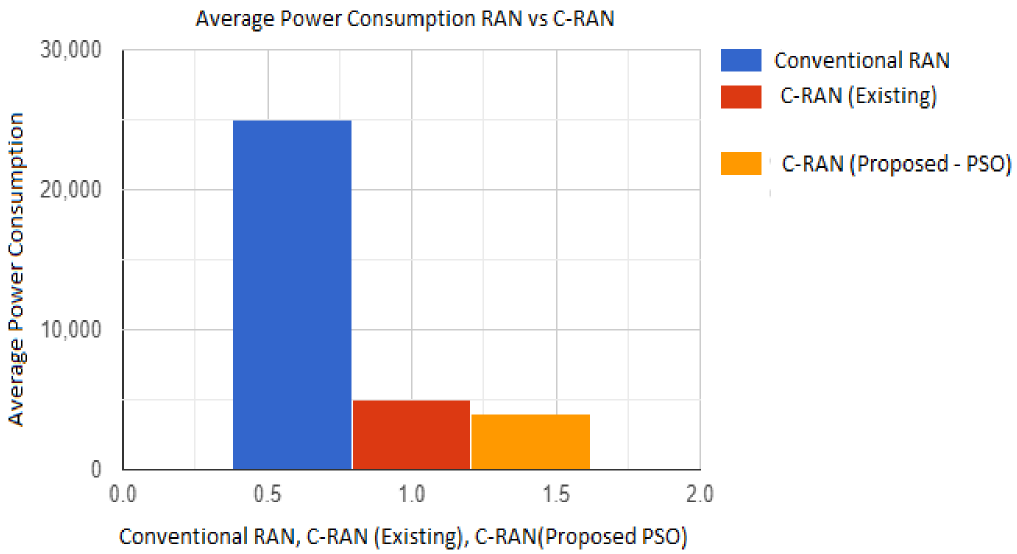

Figure 6. Comparison of average power consumption between Conventional RAN and C-RAN

As shown in Figure 5, the network load in BBU1, BBU2, and BBU3 in a BBU pool are varying according to the increase of time. This existing method takes time for 5 seconds. Meanwhile, the proposed work applying the PSO algorithm takes 4 seconds. The proposed paper takes less time to minimize power consumption and maximize energy efficiency.

Figure 6 shows the conventional RAN vs C-RAN's average power consumption. There are conventional RAN, C-RAN (Existing), and C-RAN (Proposed PSO). In the conventional architecture, 1 RRH supporting to 1 BBU. Whereas in the proposed C-RAN architecture 3 BBU supporting by 6 RRHs. The dynamically managing network traffic in a balancing way is supported by the PSO algorithm. It is observed that the same network traffic can be reached more 90% power reduction and automatic power-saving compared to conventional RAN. By applying the proposed PSO algorithm, utilize of BBU with RRH will minimize 90% energy consumption, and automatically power-saving and maximize(100%) energy efficiency.

6. CONCLUSION

The proposed research work has maximized the energy efficiency of the C-RAN architectural model by dynamically assigning RRHs. The proposed Particle Swarm Optimization (PSO) algorithm is a popular Swarm Intelligence algorithm that maps between BBU-to-RRH to assign overloaded BBU's traffic load to lightly traffic-loaded BBU for balancing load among the BBUs in a BBU pool for efficient use of all BBU in BBU pool of C-RAN. In this paper PSO algorithm optimization minimize energy consumption and minimize network load of particular overloaded BBUs as well as maximize the energy efficiency for better utilization of BBUs of 5G C-RAN. The results showed 90% of minimizing of power consumption and 100% maximize the efficiency of BBUs by balancing of workload among all BBUs.

REFERENCES

[1] C. M. R. Institute, **C-RAN: the road towards green RAN**, White Paper, version 3

[2] I.Chih-Lin, J. Huang, R. Duan, C. Cui, J. X. Jiang, L. Li, **Recent progress on C-RAN centralization and cloudification**, IEEE Access 2 (2014) 1030–1039.

[3] Ari, Ado Adamou Abba, et al. **Resource allocation scheme for 5G C-RAN: a Swarm Intelligence based approach**." *Computer Networks* 165 (2019): 106957.

[4] Yuemeng, Tang. **Dynamical Resource Allocation Using Modified Artificial Bee Colony Algorithm in 5G C-RAN**. Diss. Waseda University, 2020.

[5] Khan, M., R. S. Alhumaima, and H. S. Al-Raweshidy. **Quality of service aware dynamic BBU-RRH mapping in cloud radio access network**. *2015 International Conference on Emerging Technologies (ICET)*. IEEE, 2015.

[6] Ari, Ado Adamou Abba, et al. **Resource allocation scheme for 5G C-RAN: a Swarm Intelligence based approach**. *Computer Networks* 165 (2019): 106957.

[7] Yuemeng, Tang. **Dynamical Resource Allocation Using Modified Artificial Bee Colony Algorithm in 5G C-RAN**. Diss. Waseda University, 2020.

[8] Balamurugan, K. S., and B. Chidhambararajan. **Six sense seamless handover protocol for 5G subscribers using artificial swarm intelligence**. *Advances in Natural and Applied Sciences* 10.8 (2016): 127-138.

[9] Shojafar, Mohammad, et al. **P5G: A bio-inspired algorithm for the superfluid management of 5G Networks**. *GLOBECOM 2017-2017 IEEE Global Communications Conference*. IEEE, 2017.

[10] Sahu, Bharat JR, et al. **Energy-efficient BBU allocation for green C-RAN**." *IEEE Communications Letters* 21.7 (2017): 1637-1640.

[11] Aldaeabool, Sally R., and Maysam F. Abbod. **Reducing power consumption by dynamic BBUs-RRHs allocation in C-RAN**. *2017 25th Telecommunication Forum (TELFOR)*. IEEE, 2017.

[12] J. Kennedy and R. Eberhart, **Particle swarm optimization**, vol. 4, nov. 1995, pp. 1942–1948.

[13] J. Kennedy and R. Eberhart, **A discrete binary version of the particle swarm algorithm**, vol. 5, oct. 1997, pp. 4104–4108 vol.5.

[14] Khan, M., Raad S. Alhumaima, and Hamed S. Al-Raweshidy. **Reducing energy consumption by dynamic resource allocation in C-RAN**. *2015 European Conference on Networks and Communications (EuCNC)*. IEEE, 2015.

[15] Ari, Ado Adamou Abba, et al. **Resource allocation scheme for 5G C-RAN: a Swarm Intelligence based approach**. *Computer Networks* 165 (2019): 106957.

[16] Khan, M., Raad S. Alhumaima, and Hamed S. Al-Raweshidy. **Reducing energy consumption by dynamic resource allocation in C-RAN**. *2015 European Conference on Networks and Communications (EuCNC)*. IEEE, 2015.

[17] Wang, Kezhi, Kun Yang, and Chathura Sarathchandra Magurawalage. "**Joint energy minimization and resource allocation in C-RAN with mobile cloud**." *IEEE Transactions on Cloud Computing* 6.3 (2016): 760-770.

[18] Aqeeli, Emad, Abdallah Moubayed, and Abdallah Shami. "**Power-aware optimized RRH to BBU allocation in C-RAN**." *IEEE Transactions on Wireless Communications* 17.2 (2017): 1311-1322.

[19] Xia, Wenchao, et al. "**Power minimization-based joint task scheduling and resource allocation in downlink C-RAN**." *IEEE Transactions on Wireless Communications* 17.11 (2018): 7268-7280.

[20] Ari, Ado Adamou Abba, et al. "**Resource allocation scheme for 5G C-RAN: A Swarm Intelligence based approach**." *Computer Networks* 165 (2019): 106957.

[21] Marzouk, Fatma, et al. "**Power minimizing BBU-RRH group based mapping in C-RAN with constrained devices**." *ICC 2020-2020 IEEE International Conference on Communications (ICC)*. IEEE, 2020.