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Energy Efficient Throughput Aware Traffic Load Balancing in Green Cellular Networks

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ABSTRACT With the augmentation of affordable multimedia wireless gadgets, the ubiquitous availability of the internet access, and the rapid pace of mobile traffic motivate research towards fifth generation (5G) communications to realize energy-efficient cloud radio access networks (C-RAN) with guaranteed quality of experience. Exploiting green energy harvesting for powering the C-RAN substantially alleviates the energy procurement from the utility grid, carbon footprint, and operational expenses. In this paper, we propose a new dynamic point selection coordinated multipoint (DPS CoMP) based load balancing paradigm emphasizing achievable throughput and energy efficiency (EE) by reducing utility grid consumption from a network level perspective. This paper investigates the radio efficiency, EE, and average on-grid energy saving addressing the key challenges of tempo-spatial dynamics of traffic intensity and renewable energy (RE) generation under a wide range of network setup. Endeavoring load balancing technique strives a balance in network utilities such as green energy utilization and user association based on BS coordination technique in a cluster. Provision of cell sleep approach is contemplated for further energy saving by turning off lightly loaded base stations (BSs) during low traffic arrivals. The proposed CoMP based load balancing algorithm proficiently manages resource block allocation to the new users and elevated the energy efficiency over the conventional location and traffic centric mechanisms. Extensive system-level simulations manifest that the suggested framework enables an adjustable trade-off between radio efficiency and EE, and saves 22% on-grid power consumption and increases EE index by 32%. Afterward, an exhaustive comparison of the proposed method with the existing schemes is pledged for further validation highlighting sustainable 5G wireless systems.

INDEX TERMS Energy efficiency, coordinated multipoint, hybrid power supply, centralized RAN, load balancing, cell zooming, green communications, 5G.

I. INTRODUCTION

Over the last few years, the emergence call for diversified wireless applications is growing astronomically due to the rapid boom of wireless subscribers, a wide range of multimedia and data applications. The climbing nature of high-speed data demands steering to step forward of newer technologies to meet increased throughput with greater capacity. The next-generation 5G networks promise to deliver an attractive deal with energy challenges, enhanced quality of services, and a wide range of potential solutions [1]. According to [2], the internet subscribers will be uplifted to 59.7% globally by 2022 from 44.3% in 2018 and cellular data traffic will be three times from 2018 to 2021, about 49 exabytes increasing data demand. In addition, 8 billion mobile users are expected to increase by 2030 and over 10% global 5G mobile devices

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will be connected by 2023, which put the immense pressure on the existing networks and conventional utility grid as well [3]. This volatile escalation of global traffic urges telecom operators to deploy a massive number of cellular base stations to handle future demand by fulfilling extra spectrum requirements.

Moreover, the demand for fast pace and seamless wireless services pushes mobile operators to expand their infrastructure including access networks and core networks and extending the radio remote head enabled antenna power level in C-RAN [4], [5]. In general, the cellular networks are heavily dependent on the traditional non-renewable powered grid across worldwide. A drastic hike of increased energy consumption and carbon footprints exposes harmful toxic radiations to the atmosphere together with financial implications. Reference [6]–[9] reveals that the telecom networks contribute nearly 51% carbon emissions in the information and communications technology (ICT) circle whereas ICT sector constitutes around 3-4.5% of global toxic ejections worldwide. A study reveals that the ICT sector is one of the major sources of global carbon content due to the burning of fossil fuels. The upsurge increment of carbon footprints raises the global temperature by 6 degree Celsius whereas approximately 2 ^{o}C growth due to burning fossil fuels [6]. The price of grid electricity increased dramatically because of the power generating station depends on fossil fuels which is another key disadvantage apart from atmospheric pollution. However, the electrical energy expenditure by the ICT industry will be raised from 611 TWh to 1852 TWh by 2030 [2]. Therefore, the tremendous rate of energy consumption to tackle the unprecedented growth of mobile traffic in wireless communications is a paramount concern in the near future if no proper steps are taken to address the existing trend. However, the wireless communication system has undergone a rapid periodic transformation from 1G to 5G networks. The upgradation of different generations of cellular networks has some advantages and limitations. For example, 5G technology enables 100 times more transmission rate and 2.5 times greater spectral efficiency compared to fourth generation LTE technology. In contrast, the power required to operate 5G BSs are high and the corresponding CO_2 emission is about 1.5 times larger than 4G technology [2], [10]. However, the modern cellular networks can become self-sustainable particularly in off-grid remote areas thanks to the green energy sources.

Another downside, BSs in the C-RAN infrastructure accounted as the most energy hungry equipment that constitutes about 60-80% of total cellular network consumption whereas telecom networks consume around 0.6% of the global energy [11]–[14]. The increasing energy requirement has led to research on the subject of green cellular networking aiming to assure sustainable energy-efficient wireless communications. With the emergence of cognizance regarding global warming, environmental concern, and economic perspectives, envisioning cellular BSs with renewable energy is a promising option to diminish the traditional grid energy consumption in the cellular industry. In other words, powering the next-generation cellular networks with green energy considerably reduces the energy procurement from the utility grid, toxic carbon emissions, and operational expenses. It is widely recognized that renewable energy sources are omnipresent and bountiful in the atmosphere, which is also cheap and toxic free. Note that green energy harvesting is dependent on nature and geographical location. The high capital expenses of the RE system are counterbalanced by the lower cost of grid purchase. The abundant availability of green energy resources have considerably reduces operation expenditure and curtail the need for fossil fuel based power consumption [15]–[17]. According to [2], India has over 350,000 cellular base stations that consume around 3 billion liters of diesel yearly. The power supply shifting from fossil fuel to alternative renewable energy sources reduces about 6 Mtons of carbon emissions and thereby, saves a significant amount of operating expenses for mobile operators. In addition, paradigm shifting to green communications can contribute millions of carbon tax credits that could substantially balance the overall expenses by the telecom industry. The available research works [18]–[21] focusing on improving spectral efficiency and quality of data service, while ignoring the energy efficiency (EE) issue.

It is very important to find the effective methods to enhance EE while guaranteeing the expected quality of experience. Since the internal equipment such as baseband (BB) unit, digital signal processing (DSP) unit, high power amplifier (HPA), cooling mechanism and feeder cables are accounted as fixed components in cloud RAN. On the other hand, several dynamic mechanisms can enhance entire system performance, for example, optimizing radio transmission process, cooperation deploying relay nodes, turning off base stations (BS) components, deployment of small cells e.g., heterogeneous networks (HetNet), cognitive radio networking, massive MIMO, incorporating renewable energy (RE) sources, power optimization, adopting load balancing and cell adjustment mechanisms [22]–[29]. In recent time, efficient energy management techniques have become one of the key pillars while designing a large-scale cellular network. However, conventional cellular system design a few decades ago primarily focused on higher throughput performance, extending cell coverage, and user capacity regardless of energy efficiency [30], [31]. Needless to say, 5G based C-RAN deals with various evolutionary technologies, for example, mm-wave, massive MIMO, BS on/off, RE management, load handling scheduler, and CoMP ICI control scheme to attains optimal EE performance. Over the last decade, the paradigm is shifted towards the emergence of energy-efficient communication systems as a key performance indicator owing to the massive proliferation of energy hungry applications.

To handle the above concerns, industry and academia are paying closer attention to centralized RAN powered by green power sources prominently. However, the next-generation cellular networks can become eco-friendly, cost-effective, and energy efficient systems thanks to green energy resources. Intending to address the energy efficiency issues, numerous efforts are carried out to develop the best solution with the intention of improved sustainability and the least amount of net present cost [32]–[37]. The prime objective of the proposed green cellular paradigm is to maximizing RE usage resulting in the minimum grid energy purchase.

The prominent challenges of utilizing standalone utilization of solar energy for the C-RAN is largely intermittent and dynamic nature over time and space domain, leading to a significant mismatch between RE harvested power and BS load demand. Therefore, a single green power technology is not an extent efficient choice to assure zero outage for designing a large-scale 5G cellular network. To address the unreliable behavior and dynamic variability of RE production, the joint utilization of green energy and conventional grid energy is an excellent alternative in order to achieve a viable power supply solution. In light of this, this paper studied the integration of RE supply with grid energy incorporating adaptive load balancing policy in the context of green radio communications. A number of recent relevant research works provisioning BS to be supplied by hybrid sources aiming to improve EE in green wireless communications have been widely discussed in [28], [38]–[42].

In recent years, the technique of BS coordination in a cluster is referred to as a coordinated multipoint (CoMP) transmission, which has been adopted in cellular networks utilizing the same frequency and time resources [43]–[45]. CoMP technique has the potential to mitigate inter-cell interference and spectrum shortage problems together with an increased level of throughput performance. In CoMP transmission, BSs coordinate in such a way that BSs serve to a single UE using the same network resources or coordinating their transmission among themselves to cancel out inter-cell interference [46]–[48]. According to 3GPP, the CoMP transmission technique is broadly classified into three types; dynamic point selection (DPS), joint transmission (JT), and coordinated beamforming [44]. This paper considers DPS CoMP transmission method in hybrid powered C-RAN architecture. Under the DPS CoMP technique, a UE ranks the multiple BSs in a descending approach depending on the received signal strength. After that, a BS offering the highest signal power is selected to serve the particular user regardless of the link distance.

A suitable UE-BS connection policy balances the downlink traffic demand among collocated BSs that can downsize the on-grid energy consumption by enabling the capabilities of green-powered cellular BSs. This paper studies the throughput aware traffic load balancing scheme for the considered cellular layout to satisfy telecom providers' requirements through balancing traffic arrivals under different conditions. However, the cell zooming technique considerably reduces net energy consumption through balancing experienced traffic among collocated BSs, where each BS adaptively adjusts the cell coverage based on the traffic load [49]. It is anticipated that the BSs should dynamically adjust i.e. shutdown/wake-up according to the temporal variation of traffic load or other factors such as UE-BS distance, availability of resource blocks in the context of 5G cellular communications. On the other hand, the cell zooming mechanism in BSs enables to dynamically adjusts its own coverage based on the traffic demand and increase the retrenchment of power expenditure under given criteria [50]. It is worthy to mention that a poor channel state occupies a higher number of radio resource blocks to support a given transmission rate [51]. In light of this, the concept of applying the DPS CoMP technique with load balancing enabled cellular systems offers the best signal quality with the least number of resource block allocation. Note that the DPS CoMP enabled cell zooming method is comparatively more efficient than the other two techniques since this scheme occupies fewer number of RBs. The centralized control server in baseband (BB) pool coordinate BS load in order to make zooming decision. The central load balancing server broadcast zooming information based on the signal to interference plus noise ratio (SINR) performance of arrival traffic intensity whether it goes into sleep mode or expand coverage. Provisioning of sleep mode mechanism governed by the cell zooming method significantly reduces overall energy consumption over the conventional user-centric balancing technique.

The organization of the paper is as follows. A thorough discussion of related works is discussed in Section II followed by the key contributions of the paper in Section III. Section IV represents the proposed system model highlighting the mathematical and theoretical modeling of the system components. Section IV primarily discuss the formulation of performance metrics and heuristic load balancing algorithms. The performance analysis including simulation setup and comprehensive insights of results analysis are carried out in Section V. Section VI concludes the paper summarizing the key findings.

II. RELATED WORKS

For the aforementioned reasons, the maximum utilization of green energy is essential importance for global development in the ICT sector targeting of least grid consumption in a cost-efficient way. Therefore, the improvement of EE at different levels integrating load balancing and coordinated multipoint technique has received intensive attention in green radio communications. There have been several efforts devoted dealing with load balancing optimization and RE utilization contemplating dynamic BS operations [52]–[59]. Authors proposed a combinatorial framework including dynamic BS sleep/awake operation, adaptive resource block allocation, enabling an efficient trade-off mechanism between system performance with traffic handling and energy consumption [52], [59]. In general, traffic may entirely offloaded from considered BSs to the surrounded cells in order to save energy through entering BSs into sleep mode. On the other hand, load balancing adopting cell coverage expansion (CCE) is pointed out in [60], where all the BSs are assumed to be ON state. For instance, a CCE load balancing algorithm is adopted for maximizing energy saving through controlling UE association assuming proportional fairness [53]. A game theoretic approach for spectrum allocation and green energy saving is developed in [61]. Albeit the considerable amount of energy saving attained by the above solutions, but they overlook tempo-spatial variation of renewable energy availability and traffic arrival distribution. To address the research gap, Chamola *et al.* [55] proposed a grid energy saving reduction method guided by the temporal allocation of renewable energy and power control load balancing scheme. On the other hand, a Lyapunov optimization based low-complexity online policy is suggested in [57] to curtail average network cost incorporating an energy delay trade-off load balancing algorithm. Despite these solutions exploits the temporal variability of green energy harvesting, they do not consider the burst nature of traffic arrivals in the space domain.

Several researches are conducted pointing to BS topology management taken into consideration of traffic load redistribution during off-peak periods. Fan and Ansari proposed [62] energy and throughput aware traffic load balancing for HetNets to save on-grid power in addition to analyzing effective data rate based on the UE-BS channel condition and workload. A previous work by Han and Ansari [63] studied the optimal utilization of renewable energy to minimize on-grid consumption adjusting cell size. Authors in [64] examined the combined user connection policy and resource allocation in the heterogeneous network objective function to increase link fairness. Reference [65] suggested green energy availability based user association policy for optimizing green energy utilization allowing optimal bandwidth allocation. A distributed user connection scheme for HetNets is proposed in [66] for optimizing the trade-off between traffic latency and grid consumption. The study of trade-off between renewable energy utilization and QoS provisioning in the form of traffic latency for hybrid powered heterogeneous cellular networks is carried out in [67]. Authors studied catch enabled load balancing solutions for small cell networks adopting interference management techniques for the future generation mobile communication systems [68]. Furthermore, authors in [69] analyzed joint performance of spectral efficiency and EE for mm-wave based small cell networks. In [70], advanced resource allocation technique is adopted in a single cell HetNet for maximizing EE without considering multi-cellular networks.

The idea of cell zooming method as a traffic load balancing is suggested in [71] to minimize entire energy consumption in the context of green cellular networks. Wang and Chein [72] proposed a traffic-aware small cell management framework for 5G networks with objective function to save a significant amount of green energy over the considered geographic region. Authors studied distributed and centralized user association mechanisms targeting to achieve highest energy efficiency through load balancing while guaranteeing desired spectral efficiency [73]. Xu *et al.* [74] reported traffic-aware transmit power and cell coverage adaption based signal transmission quality parameters, but for the single cell base station case. Taking the added benefits of green energy harvesting technology, authors reported [75] energy cooperation policy among collocated BSs in accordance with traffic load implementing cell zooming method. Authors investigated the combined resource block allocation and BS sleep/awake optimization method [18], and optimal packet scheduling [76] for hybrid powered networks taking into account of user blocking constraints. However, the impact of burst traffic patterns on energy efficiency performance is more significant than uniform traffic distributions enabling enter the BSs into sleep mode for a prolonged period. The study of EE and traffic load latency accounting burst traffic is conducted in [77]. All the reported works focused on the system performance integrating BS on/off mechanisms or conventional user-centric cell zooming mechanisms adjusting transmission power. None of these studies consider coordinated multipoint transmission enabled load balancing scheme accounting tempo-spatial traffic demand fluctuations.

The cell breathing focused cell zooming method, off-peak traffic offloading and BS switch off mechanisms for improving EE of heterogeneous networks is presented in [78]. Following on [78], authors extend this work integrating the multi dimension user BS association approach under hybrid power supplies [19]. Reference [20] proposed a joint resource allocation management load balancing inspired by traffic density for HetNets. On the other hand, authors in [79] insight coordinated small cell on/off policies providing traffic offloading from centralized macrocell BS. A combined energy aware UE-BS connection method and BS on/off operation state mechanism is analyzed to deal with network power consumption [80]. Reference [81] focused on the inherent benefits of energy aware metrics in terms of resource usage over the conventional traffic based cell zooming scheme. An effective traffic load estimation mechanism for C-RAN contemplating green energy aware UE-BS association is studied in [82]. Authors adopt an optimal policy for enhancing EE based on resource allocation and scheduling according to the stochastic behavior of RE production availability and channel conditions [83]. However, the dynamic switching of the BSs turning on from the sleep mode condition is not feasible in practice since coverage holes can be generated. These works do not consider dynamic nature of traffic diversity and transmission coordination technique. The prime target is to reduce the dependency on utility grid supply empowering the cellular networks with green energy supply, integrating coordinated multipoint technique for enhancing SE to capture desire quality of services (QoS), and finally, implementing cell zooming method for further improvement of EE.

III. CONTRIBUTIONS

The upsurge in energy demand and greenhouse gas (GHG) deductions in telecommunication industries have motivated this research on the EE performance of green wireless communications. As observed, extensive research works are carried out in this area on different objectives, methodology, and network models. To our best knowledge, this paper first examined the dynamic point selection coordinated multipoint enabled traffic load balancing scheme in green mobile communications perspective. A new energy efficient throughput-aware user-BS connection policy is proposed accounting for adaptive cell zooming leaded load balancing policy. The proposed algorithm makes a trade-off between radio efficiency and energy efficiency through assigning UEs to the best signal offered BS. Take a step forward, we examined the EE, grid energy savings, radio efficiency, and spectral efficiency defining performance metrics. The key contributions can be summarized as follows.

- A generalized solar PV/grid tied hybrid power supplies model for centralized radio access networks is developed addressing energy efficiency issue. A set of on-site solar PV array modules acts as a primary power source including sufficient capacity of battery bank as a storage device, whereas conventional grid remains standby supply during green energy shortage. This study primarily focuses on the two different goals; maximize EE and SE ensuring the least grid power consumption.
- A heuristic throughput aware energy efficient load balancing user-BS association framework is developed contemplating dynamic point selection CoMP, which has not been investigated in previous literature yet. A comprehensive simulation is performed to verify the effectiveness of the proposed scheme with other existing techniques for benchmarking varying different system parameters.
- Several performance metrics are defined such as energy saving index, radio efficiency, and energy reduction gain in order to assess the best extent efficient option of the considered system. However, the system performance is evaluated taking into account some limiting factors such as inter-cell interference, fading induced path loss model under a non-LOS environment. In addition, traffic dependent BS power consumption model over the tempo-spatial domain and temporal variation of green energy harvesting is also considered.

IV. SYSTEM MODEL

A. NETWORK MODEL

We consider a large-scale two-tier networks comprising of N number of BSs ($\mathbb{B}$) and a central baseband unit (BBU) pool where $\mathbb{B} = \{\mathcal{B}_1, \mathcal{B}_2, \ldots.., \mathcal{B}_N\}$. A geographical coverage area $\mathcal{A} = \{\mathcal{A}_1 \cup \mathcal{A}_2 \cup \ldots \cup \mathcal{A}_N\} \subset \mathbb{R}^2$ is defined, where the total number of user equipment (UE) ($\mathcal{U}$) are uniformly distributed. Note that $\mathcal{A}_i$ is the coverage area of BS $\mathcal{B}_i$, $\forall i \epsilon \{1, \ldots, N\}$ i.e. $i \epsilon N$ corresponds to the index of the i^{th} BS. All the BSs are assumed to be arranged in remote radio head (RRH) between transmission antenna and baseband unit (BBU) with 2/2/2 tri-sector based hexagonal grid fashion. In other words, signal transmission pertained between BBU and RRH via optical cable and RRH for establishing UE connection via wirelessly. Note that all the base stations are equipped with joint power supplies such as solar PV panels with adequate battery bank devices, which are also capable of complementing their energy storage with utility grid supply. However, provisioning of entering sleep mode is considered for further on-grid saving i.e. the BSs are able to switch between on state to off status mode depending on the traffic density. A smart energy management (EM) device is installed for efficient energy handling, which is connected to locally available PV array, storage device, and power grid at the same time. The EM unit can refrain the battery bank from overcharging/discharging and control the key selection of primary energy sources.

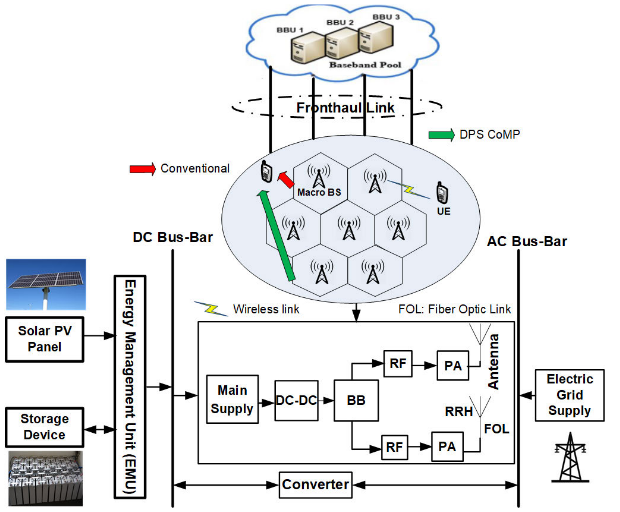

FIGURE 1. A schematic layout of the proposed system.

Each time slot has a length of τ sec over total T duration time slots where $\tau \epsilon T$. The respective cell updates cell size in every τ sec adjusting their transmit power according to the strongest received signal and redistribute the traffic arrivals. OFDMA technique nullifies the intra-cell interference whereas coordinated multipoint technique remarkably reduces the inter-cell interference (ICI). On the other hand, the BBU pool manages complex signal RF processing in both uplink and downlink directions. However, the centralized control server under the BBU pool handles signal power adjustment, traffic intensity, and overall load balancing decision in each time slot.

B. SOLAR PHOTOVOLTAIC (PV) GENERATION

The daily solar energy production shows temporal dynamics throughout geographical location, which is greatly depends on sunlight intensity capture, PV module materials, production technology, atmospheric implications, and tracking mode technique. Due to the intermittent behavior of solar energy production, the harvested energy may not guarantee the sufficient powersupply to BSs over a long duration. Fig. 2 shows the PV power generation for 1 kW panel capacity estimated by System Advisory Model (SAM) [37].

The locally available solar energy harvested at $\mathcal{B}_i$, $i \in \{1, \ldots, N\}$ during time slot m is modeled as a random variable defined by $r_i\ (t) \in [0, r_i^{max}]$, where r_i^{max} is peak solar

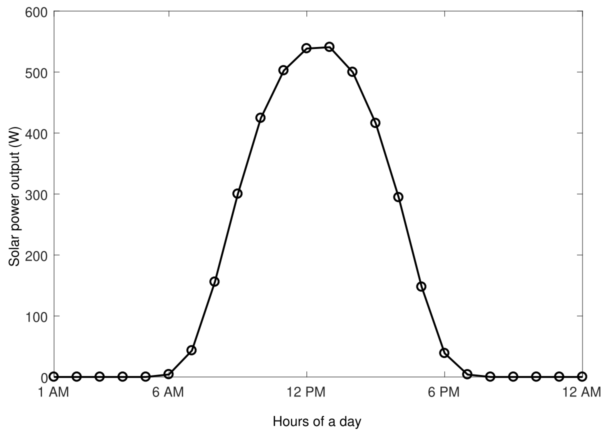

FIGURE 2. Average hourly 1 kW solar power generation in a day.

energy generation by $\mathcal{B}_i$. However, RE generation at a particular time can be defined as $\int_{(m-1)\tau}^{m\tau} b_i(t)dt = r_i(t)$, where $b_i(t)$ represents the instantaneous value obtained from the solar power profile depicted in Fig. 2 and τ is the time slot duration, typically one hour. Average solar energy obtained can be characterized by the following model [37]

$$\bar{r}_i(t) = \frac{r_i^{max} exp^{-(n-\beta_i)^2}}{\kappa_i^2}\tau \tag{1}$$

where β_i represents the position in time of the peak generation chosen to be noon, i.e. 12 hours, $\forall i \in \{1, \ldots, N\}$, κ_i implies the shape width at half maximum of the peak, chosen to be 3 hours, $\forall i \in \{1, \ldots, N\}$. The total amount of solar PV energy produced annually can be computed as [37]

$$E_{PV} = C_{PV} \times \gamma_d \times \zeta \times \delta_r, \quad kWh/year \tag{2}$$

Here, C_{PV} is the rated solar PV array capacity in kW, γ_d is the daily solar radiation in $kWh/m^2/day$, ζ is the derating parameter account the effect of cable loss, dust, temperature fluctuations and δ_r denotes the double-axis sun tracking factor. For sake of simplicity, we assume the individual BSs are equipped with adequate rechargeable battery bank capacity in the form of energy storage devices (ESS) to ensure reliability. ESS store surplus electricity during peak PV production and plays as a backup device during load-shedding, night time, or PV malfunctions.

C. BS POWER MODEL

In the conventional mobile networks, BSs are designed in operating maximum transmission power to cater to the peak-hour request demand, which pushes non-essential energy consumption during low traffic hour periods. In a cellular network, the traffic variations in a BS incurred tens of minutes in the time scale [49]. Traffic arrival process are independent and traffic density per arrival follows exponential distribution according to the inhomogeneous Poisson process. The average traffic density ρ_j in a BS can be calculated by aggregating load densities of arrival demands. ρ_{ij} indicates the time duration occupies when BS_i is busy.

$$\rho_j = \sum_{j \epsilon U} \rho_{ij} \tag{3}$$

The BS power consumption directly depends on traffic demand experience at a particular time t. The approximated daily traffic arrival presented in Fig. 3 can be derived using the Poisson distribution model as follows,

$$\lambda(t) = \frac{p(t,\alpha)}{max[p(t,\alpha)]} \tag{4}$$

$$p(t,\alpha) = \frac{\alpha^t}{t!}e^{-\alpha} \tag{5}$$

where $\lambda(t)$ is the normalized traffic distribution, $p(t,\alpha)$ is the Poisson distribution function of traffic demand, and α is the average value of peak number of traffic arrived.

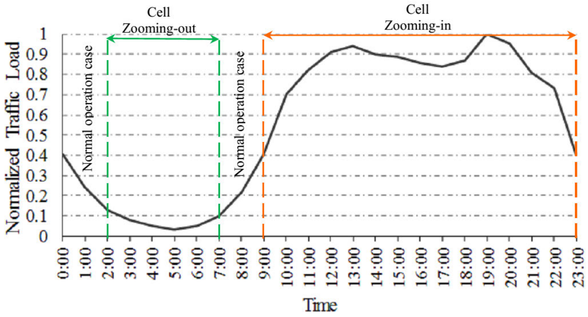

FIGURE 3. Hourly normalized traffic load profile in a day.

The total estimated power consumption by a macrocell BS is function of traffic intensity (χ) and number of transceivers ($N_{TRX} = N_{sec} \times N_{ant}$) given by [9]

$$P_{in} = \begin{cases} N_{TRX}[P_1 + \triangle_p P_{Tx}(\chi - 1)], & \text{if } 0 < \chi \leq 1 \\ N_{TRX}P_{slp}, & \text{if } \chi = 0 \end{cases} \tag{6}$$

$P_1 = P_0 + \triangle_p P_{Tx}$ is the maximum power consumption of a BS sector and P_0 is the power consumption at idle state. $\triangle_p$ denotes the load dependency parameter that is accounted by the power gradient. However, the traffic scaling parameter $\chi = 1$ refers fully loaded BS and $\chi = 0$ indicates idle condition i.e. no traffic load. The approximate parameters of BS power consumption is summarized in Table 1 and Table 2 respectively.

TABLE 1. BS approximate power consumption model parameters [9].

BS Type	N_{TRX}	$P_{Tx}[W]$	$P_0[W]$	$\triangle_P$	$P_{slp}[W]$
Macro	6	20	84	2.8	56

However, P_1 can be computed as

$$P_1 = \frac{N_{TRX}\frac{\mathcal{BW}}{10MHz}(P'_{BB} + P'_{RF}) + \frac{P_{Tx}}{\eta_{PA}(1-\sigma_{feed})}}{(1-\sigma_{DC})(1-\sigma_{MS})(1-\sigma_{cool})} \tag{7}$$

P'_{BB} and P'_{RF} is the baseband and RF power consumption respectively. $\mathcal{BW}$ represents the system bandwidth, η_{PA} defined the power amplifier efficiency. σ_{DC}, σ_{feed}, and σ_{cool}

TABLE 2. Macro BS with RRH power model parameters [9].

Components	Parameters	Value
Feeder loss	σ_{feed} [dB]	0
Power amplifier efficiency	η_{PA} (%)	31.1
Baseband unit	P'_{BB} [W]	29.6
Radiofrequency unit	P'_{RF} [W]	12.9
DC-DC	σ_{DC} (%)	7.5
Cooling	σ_{cool} (%)	0
Mains Supply	σ_{MS} (%)	9
Max PA out	P_{PA}	64.4
Sectors	N_{sec}	3
Antenna	N_{ant}	2

represents the loss incurred by DC power conversion, feeder cable and active cooling respectively. No cooling arrangement is required for RRH enabled macro BS.

The BS energy expenditure can be categorized into two parts: static and dynamic consumption.

$$E_{in}(t) = \sum_{i=1}^{N}(P_i^{act} y_i(t)\tau + P_i^{slp}(1 - y_i(t))\tau + \sum_{i=1}^{N}\sum_{j=1}^{U}\Delta_i P_{Tx}^{i,j}(t) x_{i,j}(t)\tau \tag{8}$$

By rearranging terms, (8) can be reinterpreted as

$$E_{in}(t) = E^{dym}(t) + E^{sta} \tag{9}$$

where $E^{dym}(t)$ and E^{sta} refers to the dynamic and static energy consumption of input energy supply E_{in} respectively.

$$E^{dym}(t) = \sum_{i=1}^{N}(P_i^{act} - P_i^{slp})y_i(t)\tau + \sum_{i=1}^{N}\sum_{j=1}^{U}\Delta_i P_{Tx}^{i,j}(t) x_{i,j}(t)\tau \tag{10}$$

$$E^{sta} = \sum_{i=1}^{N} P_i^{slp}\tau \tag{11}$$

where P_i^{act} and P_i^{slp} designated for the power consumption of BS $\mathcal{B}_i$ operating in active and sleep mode respectively. The binary variable $x_{i,j}$ models the association between BSs and UEs, expressed in the following:

$$x_{i,j} = \begin{cases} 1, & \text{if } UE_j \text{ is served by } BS_i \quad \forall i\epsilon \text{N}, \forall kj\epsilon \text{U} \\ 0, & \text{otherwise} \end{cases} \tag{12}$$

On the other hand, the BS activity condition is modeled by the binary variable y_i(t), such that

$$y_i = \begin{cases} 1, & \text{if } BS_i \text{ is active} \quad \forall i\epsilon \text{N} \\ 0, & \text{if } BS_i \text{ is in sleep mode} \end{cases} \tag{13}$$

Provisioning of BS sleep mode technique governed by cell zooming enabled load balancing scheme substantially minimizes additional energy dissipation over the conventional user-centric method.

D. WIRELESS LINK MODEL

We assume a log-normally distributed shadow fading channel model where path-loss in dB can be expressed as [84]

$$\psi(l) = \psi(l_0) + 10\mu log(\frac{l}{l_0}) \tag{14}$$

where l is the separation between transmitter and receiver. $\gamma(l_0)$ is the free-space reference path loss in dB at a distance l_0, and μ denote the path-loss exponent.

The received signal power for a particular j^{th} user at a distance $l = l^{i,j}$ from $\mathcal{B}_i$ is given by

$$P_{Rx}^{i,j} = P_{Tx}^{i,j} - \psi(l) - X_\omega, \quad dBm \tag{15}$$

where $P_{Tx}^{i,j}$ is the transmitted power in dBm from the $\mathcal{B}_i$ and X_σ refers to the shadow fading parameter modeled as a zero-mean Gaussian random variable with a standard deviation ω dB. The transmission power $P_{Tx}^{i,j}$ from $\mathcal{B}_i$ to UE j satisfies $\sum_{k\epsilon U} P_{Tx}^{i,k} \leq P_i^{max}$, where P_i^{max} is RF output power of BS $\mathcal{B}_i$ at its maximum traffic load.

However, inter-cell interference (ICI), $\mathcal{I}_{j,ICI}$ can be expressed as:

$$\mathcal{I}_{j,ICI} = P_{ICI}^{i,j} = \sum_{m\neq 1}(P_{Tx}^{m,j}) \tag{16}$$

Note that intra-cell interference is zero due to orthogonality (i.e. OFDMA technique) condition.

Then signal to noise plus interference ratio (SINR), $\Omega_{i,j}$ at j^{th} UE from BS $\mathcal{B}_i$ can be given by

$$\Omega_{i,j} = \frac{P_{Rx}^{i,j}}{\mathcal{I}_{j,ICI} + \mathcal{P}_N} \tag{17}$$

$\mathcal{P}_N$ is the additive white Gaussian noise power given by $\mathcal{P}_N = -174 + 10log_{10}(BW)$ in dBm with $\mathcal{BW}$ is the bandwidth in Hz. However, 18 surrounding BSs are considered to fully realize the ICI effect for a two-tier C-RAN cellular network. In addition, DPS CoMP based mechanisms outperform over the non-CoMP based conventional load balancing method.

E. PERFORMANCE METRICS

This section defines the formulation of different system level metrics to assess the effectiveness of the proposed system performance in comparison with existing schemes.

Energy consumption gain (ECG)

ECG evaluates the consumption of energy relative to the baseline reference system. The lesser value of ECG indicates better EE performance for the given network setup. However, the value of ECG is 1.0 for all methods without the cell zooming technique that can be considered as a reference baseline system. ECG metrics quantify the energy needed to transmit requested data over a specified duration. ECG can be defined as the ratio of the energy consumption ratio (ECR) metrics of proposed system (ECR_{prop}) to the reference scheme (E_{ref}) under the specified network settings.

$$ECG = \frac{ECR_{prop}}{ECR_{ref}} \times 100\% \tag{18}$$

Load factor (L_F)

Load factor can be defined as the ratio of the number of active resource blocks occupied (RB_{Act}) to the total number of available resource block (RB_{Tot}) in a given system bandwidth. Without loss of generality, we presume one RB is occupied by a single active user and the occupancy of RB allocation linearly scaled with incoming traffic profile. As the number of demand request increases led to occupied more number of resource blocks in order to satisfy the QoS. For example, a cellular system operating at 10 MHz bandwidth has 50 RBs that can be allocated simultaneously at a particular time. However, L_F can be expressed as:

$$L_F = \frac{RB_{Act}}{RB_{Tot}} \tag{19}$$

A RB is the least unit of physical resource allocation assigned to every user. Resource block allocation decide the number of simultaneous users connected to the 5G base stations. In general, one physical RB occupied 10 kHz bandwidth, having 12 subcarriers (each 15 kHz) and 14 symbols over 1 msec duration. Typically, 10% RBs are kept reserved in C-RAN system in order to avoid overlapping issue.

Energy efficiency (η_{EE})

Various components in RAN architecture consume a different portions of energy. EE metric is the best way to assess the system performance to represents the entire cellular networks including different levels like facility, system, component, and network. As expected, EE improves when the grid consumption is lower. In other words, greater solar energy generation lessens the grid consumption and thereby leads to an increase the EE. η_{EE} can be defined as the ratio of total achievable throughput per unit grid power consumption.

Given that transmission rate is a function of a number of resource block allocations, whereas the RBs allocation varies directly with the traffic profile. Throughput directly depends on SINR and spectral efficiency is a function of throughput.

$$T_{tot} = \sum_{j=1}^{U}\sum_{i=1}^{N} \mathcal{BW} log_2(1+\Omega_{i,j}), \text{ bps} \tag{20}$$

$$\eta_{EE} = \frac{T_{tot}}{P_{grid}}, \text{ bits/joule} \tag{21}$$

where $P_{grid} = \sum_{i=1}^{N} P_{in}(i,t)$-$\sum_{i=1}^{N} P_{PV}(i,t)$ is the net grid energy consumption in BS $\mathcal{B}_i$ at time t, $P_{in}(t)$ is the is the total power supply in BS $\mathcal{B}_i$ at time t and $P_{PV}(t)$ is the harvested RE at time t. The lower grid energy dissipation resulting higher energy efficiency. In other words, the maximum utilization of solar energy leading to maximizing EE and curtail grid purchase as well.

On the other hand, EE index (EEI) is an equipment level metrics that quantify the enhancement of EE performance of the proposed framework considered to the reference system. According to the representation in the performance metrics section, EEI is a direct function of throughput. The up-trending manner of EEI responses indicates better system performance through the minimum energy consumption. EEI can be defined as follows

$$\eta_{EEI} = \frac{T_{tot}}{P_{in}}, \text{ bits/joule} \tag{22}$$

Another metrics named energy saving index (ESI) measure the energy saving gain introducing the load balancing concept under different cell zoom out range.

$$ESI = \frac{E_\theta - E_\nu}{E_\theta} \times 100\% \tag{23}$$

where E_θ refers the power consumption for conventional cellular networks and E_ν denotes the power requirement for the proposed cellular architecture respectively.

The spectral efficiency (η_{SE}) in bps/Hz can determined as follows.

$$\eta_{SE} = \begin{cases} 0, & \text{if } \Omega_{i,j} < \Omega_{min} \\ \xi log_2(1+\Omega_{i,j}), & \text{if } \Omega_{min} < \Omega_{i,j} < \Omega_{max} \\ \eta_{SEmax}, & \text{if } \Omega_{i,j} \geq \Omega_{max} \end{cases} \tag{24}$$

where $0 \leq \xi \leq 1$ denote the attenuation factor. The number of available RBs needed to satisfy user j can be defined as

$$N_{RB} = \frac{R_{i,j}}{B_{RB} \times \eta_{SE}} \tag{25}$$

where $R_{i,j}$ is the bit rate for j^{th} UE in bit/sec and B_{RB} is the bandwidth of each resource block in Hz. On the other hand, the number of total RBs N_{RBtot} can be computed as follows

$$RB_{Tot} = \frac{\mathcal{BW}}{B_{RB}} \tag{26}$$

On the other hand, radio efficiency (η_{RE}) is a network level metric that quantify the overall energy expenditure and the attainable data transmission capacity over the given cell radius. In particular, η_{RE} in $(bit \cdot m)/sec/Hz/Watt$ measures the achievable spectral efficiency over the coverage distance for the given level of power consumption.

F. ALGORITHM

The load carrying capability of a particular BS is a crucial impact for throughput aware user association. To guarantee the UE quality of experience, we presume the workload of each BS should not exceed the highest threshold capacity allowed by cellular operators. We propose a heuristic load balancing algorithm to solve UE-BS association problem in each time slot. The dynamic nature of traffic load distribution at BSs is modeled as a linear discrete time system, where the traffic density is updated according to user arrival and departure. Leveraging a centralized control server, an user association policy is developed such a way that lightly loaded BS offload traffic to the maximum SINR providing neighboring BSs.

According to the DPS CoMP theory, a BS offers maximum SINR provide the best received signal power to users. Needless to mention that a base station closest to a particular UE may not offer the strongest signal level owing to the intensive path loss expedited by shadow fading. In comparison with the joint transmission CoMP mechanism, DPS CoMP method is more effective since JT transmission involves two BSs simultaneously to serve a single UE and occupies double RBs as well. Thus, the overall energy consumption of the entire cellular networks tends to increase and shrinks the opportunity of load balancing concurrently. Under the DPS CoMP transmission, a UE sort the BSs in descending manner of SINR and connected to the top most BS in a two-tier cluster. However, the lightly loaded BSs may either enter into sleep mode through shifting their own traffic load or serve more number of incoming users depending on the network scenario. The load balancing procedure incorporating DPS CoMP technique is referred to as SINR aware scheme.

On the other hand, BSs are sorted in an ascending order according to with the traffic arrival intensity under traffic aware scheme. For example, set the threshold load χ_{th}. If traffic arrival of BS_i at particular time, $\chi_i < \chi_{th}$, redistribute UE access through releasing corresponding load and then enter into sleep mode. Check the load carrying capability of the surrounded BSs, then update χ_i and transmission power, $P_{Tx}^{i,j}$. In contrary, the users are typically connected to its nearest BS regardless signal quality, which is referred as a distance aware method. Under this conventional scheme, BSs are sorted in ascending fashion according to the UE-BS distance. When the UE-BS distance, d is less than threshold limit, d_{th}, reallocate UEs to collocated base stations through reducing P_{Tx}. Compute the user blocking during the load balancing based on available RBs in the co-located BSs. Then, check the UE handling capacity and update the transmission power and load set accordingly. The Pseudo code of proposed DPS CoMP based load balancing algorithm is presented in Table 3. Similarly, the algorithms for other methods can be demonstrated.

Here, $S_{i,j}$=S_1, S_2, … S_{Zi}=set of operating BSs whose traffic is shifting, $C_{i,j}$=$C_{i,1}$, $C_{i,2}$ … $C_{i,Mi}$=candidate BS. $C_{i,j}^a$= set of acceptor candidate BS, and $Z_{i,j}$=traffic distribution it owns set of active BSs. $C_{i,j}^s$= β_i goes to turn off when it shifts traffic to all BSs in $S_{i,j}$, $\chi_{i,j}$=χ_1, χ_2 … χ_j each BS in active mode, $F_{i,j}$ =β_i set of best combination BSs (F_{ij}) in C_{ij}^a or C_{ij}^s.

V. PERFORMANCE ANALYSIS

A. SIMULATION SETUP

Performance of the dynamic point selection CoMP based load balancing enabled green cellular networks is analyzed MATLAB based Monte-Carlo simulations. A two-tier cellular layout is sufficient to realize the practical network deployment scenario where eighteen surrounding BSs contribute inter-cell interference. We presume that all the available resource blocks can be reused among the neighboring BSs. We assume that no UE share the same locations over the considered geographical region and the data service rate is constant over the duration since it depends on the channel conditions and modulation scheme. Furthermore, we consider one available resource block is assigned to each connected active user. This implies a user with assigned RB has guaranteed throughput over the time interval. If the number of incoming users exceeds the available RBs in a BS incurred outage i.e., a new active user cannot be served. The system parameters considered for the simulation are summarized in Table 4.

TABLE 3. SINR based traffic steering load balancing algorithm.

```
Initialize: $\mathcal{RB}$, $\chi_{i,j}$, $j\forall\mathcal{U}$, $i\forall N$
for $k = 1 : T$
  for $i = 1 : N$
    Locations and received power of $\mathcal{U}$ =$\chi_{i,j}\mathcal{RB}$ of $\mathcal{B}_i$ are updated
    Compute $\Omega_{j\forall i}$
      for $j = 1 : \mathcal{U}$
        Sort $\Omega_{j\forall N}$ in descending order
        Read the neighboring traffic load for connection
        Associate $\chi_j$ to the $BS_i$ providing maximum SINR
          if $\beta_i$ active, $S_{i,j} = 1$, $\chi_{i,j} < \chi_{th}$, $Z_{i,j} = 0$, and $C_{i,j}^a \neq \phi$
            Find $F_{i,j} \in C_{i,j}^a$
            Stop searching neighboring acceptor BSs
            else $\beta_i$ active, $S_{i,j} \neq \phi$, $\chi_{i,j} < \chi_{th}$, $Z_{i,j} \neq 0$ and $C_{i,j} = \phi$
            Find $F_{i,j} \in C_{i,j}^s$ such that $\chi_{i,j} \subseteq F_{i,j}$
            $\mathcal{U}$ = $\chi_{i,j}\mathcal{RB}$ associated with $\mathcal{B}_i$ are updated
          end if
          Assign available RBs to all active UEs
          Update $\chi_{i,j}$
      end for
    end for
end for
```

B. RESULTS AND DISCUSSION

Fig. 4 presents the energy consumption gain (ECG) metric variation for different load balancing algorithms. According to the statement of ECG, a lower value signifies better system performance with respect to the corresponding reference scheme. As observed, ECG follows similar trend to reach their least values with the increment of cell zoom out level. So, ECG exhibits prominent performance for the higher value of cell zooming. Note that all the user association methods show similar performance without zooming conditions. On the other hand, SINR based UE-BS connection algorithm attains superior performance, whereas the traditional distance aware cell zooming scheme shows degraded performance and the traffic enabled method lies in between them. Therefore, the SINR aware mechanism outperforms compared to other schemes and the best performance is attained for the higher zoom out level where the maximum level of load balancing

TABLE 4. Simulation parameters [85].

Parameters	Values
Resource block (RB) bandwidth	180 kHz
System bandwidth	5, 10, 15, 20 MHz
Number of RBs	25, 50, 75, 100
Number of subcarriers	300, 600, 900, 1200
Carrier frequency	2.1 GHz
Duplex Mode	FDD
Cell radius	1000 m
BS Transmission Power	43 dBm
Noise power density	-174 dBm/Hz
Reference distance	100m
Path loss exponent	3.574
Shadow fading	8 dB
Downlink access technique	OFDMA
Traffic model	Randomly distributed

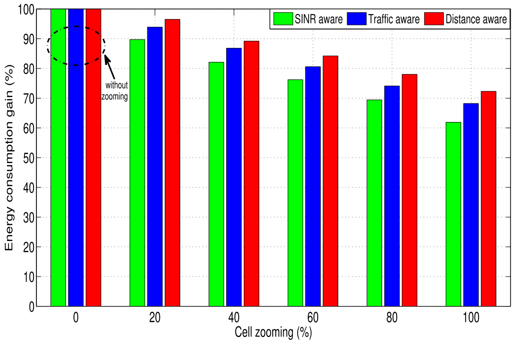

FIGURE 4. Energy consumption gain (ECG) vs. cell zooming level.

is incurred. BS provides the best signal quality for user association under SINR based scheme as mentioned earlier.

Percentage of average energy saving performance for the three different UE-BS association schemes are illustrated with load factor, amount of load shifting to the collocated BSs, and BS sleeping hours in Fig. 5, Fig. 6 and Fig. 7 respectively. It is commonly stated that the amount of energy saving will decay when a cluster experiences peak traffic arrivals since the load shifting plausibility decreases among neighboring BSs. According to the interpretation of load factor, the less number of unoccupied resource blocks remains under peak traffic request. However, all the three energy saving curves are moving downward direction with the higher values of L_F as clearly observed from Fig. 5. Note that energy saving is very insignificant for the higher value of L_F as it lessens the load balancing option. The SINR based scheme achieves around 10% more energy efficient than distance aware when L_F is half. On the other hand, a quantitative comparison of the percentage of energy saving is clearly demonstrated in Fig. 6 with respect to the amount of load transfer. The overall energy consumption of the considered system decreasing when the percentage of traffic shifting is higher. This is because the lightly loaded BS may enter into sleep mode for curtailing energy expenditure. As expected, the energy saving starts to increase considerably for the greater value of traffic shifting as seen in Fig. 5 under 10 MHz system bandwidth. Owing to better received signal quality, SINR based load balancing mechanism inherently reduces considerable amount of on-grid energy consumption and thereby achieves greater energy saving. It is clearly observed that SINR based schemes attain 10% additional energy saving when the percentage of shifted load moves to 20 from 10. It can be safely inferred that the energy saving is linearly scaled with the amount of load transfer to the neighboring BSs. For better clarification, Fig. 7 presents the average energy reduction depending on the amount of BS sleeping hours per day. It is obvious that a larger sleeping hours lead to greater energy saving performance as explained beforehand. All the curves follow an identical pattern to move upward direction where the gap of energy

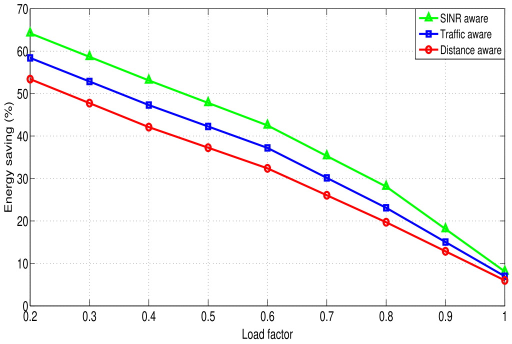

FIGURE 5. Performance of energy saving with load factor for $\mathcal{BW}$=10 MHz.

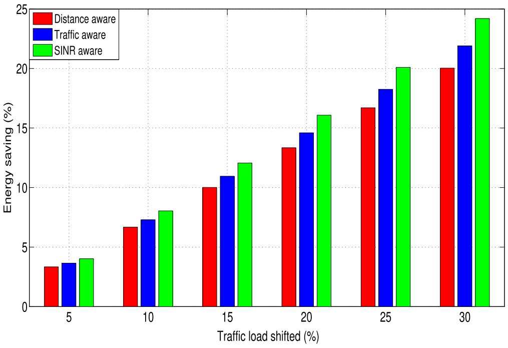

FIGURE 6. Performance of energy saving by transferring traffic demand to the collocated BS.

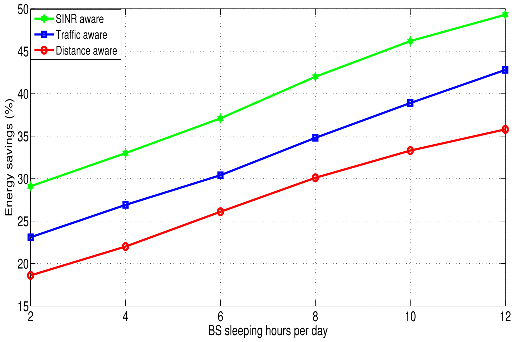

FIGURE 7. Average energy saving vs. BS sleeping hours in a day.

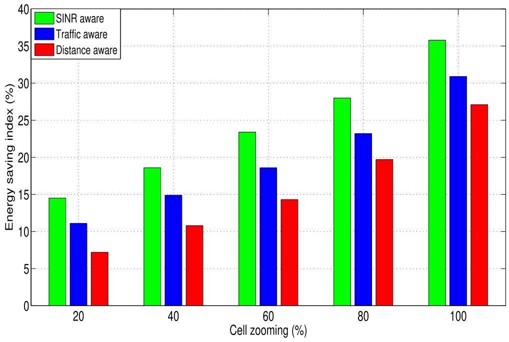

FIGURE 8. Energy saving index with cell zoom out level for $\mathcal{BW}$=10 MHz.

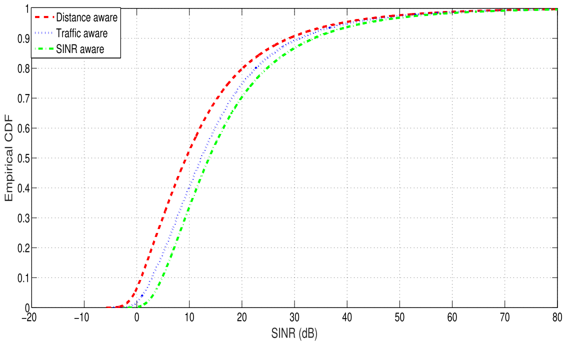

FIGURE 10. Empirical cumulative distribution function variation with respect to SINR.

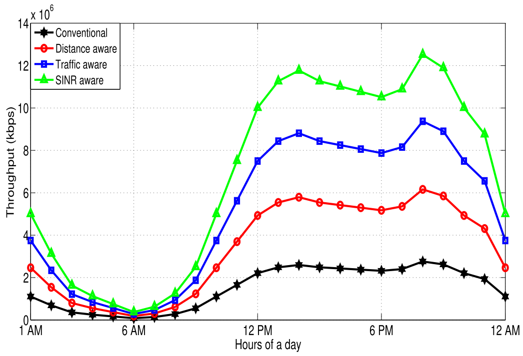

FIGURE 11. Throughput performance over a day for different load balancing scheme for $\mathcal{BW}$=10 MHz.

saving is noticeable for the higher number of hours of BS under sleeping condition through shifting load as seen from the figure. Once again, SINR aware load shifting mechanism exhibits superior performance for the particular network configurations.

A quantitative comparison of energy saving index (ESI) for different UE association schemes is presented in Fig. 8. ESI entails the percentage of average on-grid energy saving integrating the load-balancing policy over the conventional method. Note that the conventional scheme implies the hybrid powered cellular system without contemplating traffic handover algorithms. It is anticipated that all the mechanisms follow up trending movement with the increment of cell zoom out level, where SINR based algorithm exhibits remarkable performance compared to others. The proposed system is about 22% more energy efficient for 100% cell zooming level since the considered BS will entirely turn into sleep mode through distributing its own traffic. On the other hand, SINR based scheme secured 9% and 5% additional ESI performance in comparison with distance aware and traffic aware methods respectively.

Fig. 9 depicts the ESI representation under various system bandwidth. With the increase of load factor i.e. decrement of available resource blocks, ESI falls down to zero level where no adequate RBs remain. Note that this simulation is derived for SINR based UE-BS load shifting method. Needless to say, energy-saving index performance incorporating zooming and CoMP techniques reduces with the increment of incoming traffic arrivals as clearly evident from the graph. Moreover, the system with high operating bandwidth offers superior ESI performance about 14% improvement. It is commonly accepted that a large bandwidth enables a greater number of RBs and thereby, provides higher throughput as well as energy saving efficiency.

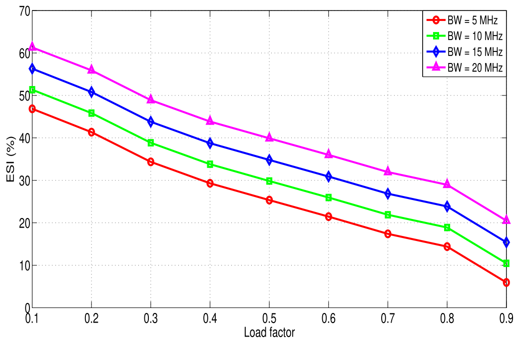

FIGURE 9. Energy saving index comparison with load factor varying bandwidth.

Fig. 10 represents the empirical cumulative distribution illustrating the distribution of the user received SINR throughout the two-tier network coverage. We assume the system is operating in 10 MHz bandwidth and fully occupied the RBs (i.e. χ =1). A considerable difference in SINR distribution among three different mechanisms is observed from the figure. As seen, DPS CoMP (SINR aware) method maintains its optimistic nature over the entire SINR range. On the other hand, distance aware enabled system provides the pessimistic performance as it spreads out over a wide range of SINR distribution. Meanwhile, a DPS CoMP enabled algorithm experiences the least amount of path loss and inter-cell interference and thereby, a UE receives the best SINR quality over the other schemes. However, the traffic aware load balancing scheme lies in between the two other methods as traffic handover takes place among neighboring cells based on their threshold traffic carrying capability regardless of the signal strength and UE-BS distance. Notably, the closest BS to the user is not guaranteed to offer the best signal quality owing to the stochastic nature of shadow fading. Therefore, a user enjoys the strongest signal level under SINR aware scheme regardless of the link distance.

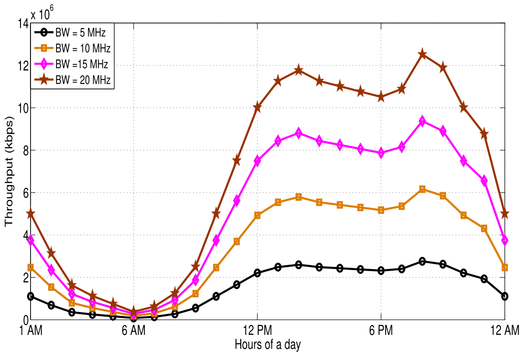

FIGURE 12. Comparison of throughput varying $\mathcal{BW}$ for SINR-aware load balancing scheme.

A comprehensive throughput comparison of the proposed system with other existing methods is clearly demonstrated in Fig. 11, Fig. 12, and Fig. 13 respectively. From the figure, it is evident that throughput curves follow the traffic distribution pattern presented in Fig. 3. This is because the total number of associated RBs in a cluster proportionally varies with traffic load distribution. In other words, throughput performance directly depends on the resource block allocation at a particular time in a day. As observed, the throughput curves reach the highest point during peak traffic load arrivals and vice-versa in the morning. However, the data transmission rate is a direct function of SINR according to the definition of throughput presented in the performance metrics section. SINR based load shifting scheme offers the best throughput and spectral efficiency performance out of all other methods due to integration of DPS CoMP mechanism as evident from figure 11. Fig. 12 represents the throughput comparison for CoMP enabled SINR aware system under different bandwidth. It is obvious that higher bandwidth drives greater throughput performance due to a large number of RBs allocation. Moreover, the gap is more considerable under peak traffic demand during evening. Therefore, the CoMP enabled system with high bandwidth exhibits better throughput and SE performance compared to other mechanisms. On the other hand, the aggregate throughput performance with cell zoom out level is depicted in Fig. 13. All the curves apparently follow a similar pattern to reach their peak values with the extended coverage of the designated cell. It can be readily identified that the load balancing driven CoMP enabled C-RAN cellular architecture is the suitable choice of all other mechanisms in terms of spectral efficiency performance.

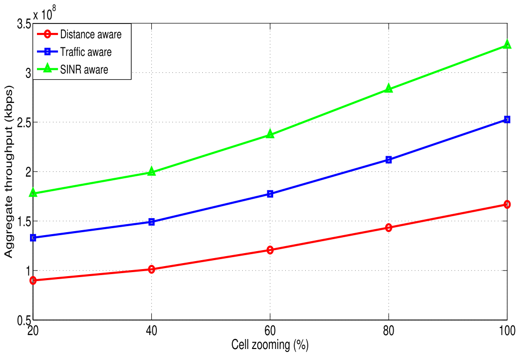

FIGURE 13. Illustration of total throughput performance of SINR based load-balancing scheme for $\mathcal{BW}$=10 MHz with cell zoom out level.

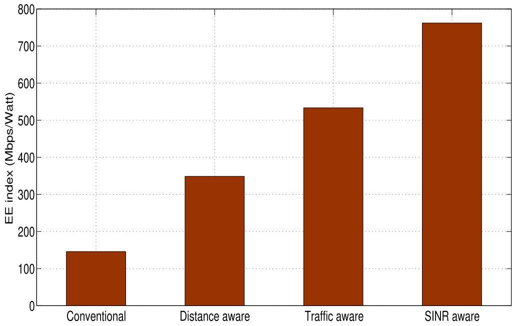

FIGURE 14. Quantitative comparison of energy efficiency index for different user association algorithms.

A detail comparison of energy efficiency metrics contemplating three distinctive load-balancing algorithms is presented in the following Figs. 14, 15, 16, 17, and 18 respectively. In accordance with the representation in section IV-E, EEI and EE are directly proportional to the aggregate throughput of the network and inversely vary to the power consumption. From the EEI point of view, CoMP enabled SINR aware hybrid cellular system is an appropriate choice as it provides about 81% more energy efficient compared to the conventional scheme. However, Fig. 14 is simulated for 10 MHz bandwidth considering the spatial distribution of traffic arrivals among the BSs.

Likewise the throughput graph presented in Fig. 13, EE curves follow a similar trend to reach their respective maximum values with the increment of cell zooming level as observed in Fig. 15. From the graph, a clear distinction among three EE curves is found incorporating CoMP technique with cell zooming scheme under load balancing system. For instance, the proposed system uplifts EE metric performance around 7.5% under 60% cell zoom out level in comparison with distance based system and outperforms additional 25.8% energy efficient when cell zooming level reaches to 100%. Further analysis of Fig. 15, EE metric performance for the proposed system is illustrated in Fig. 16 varying different system bandwidth.

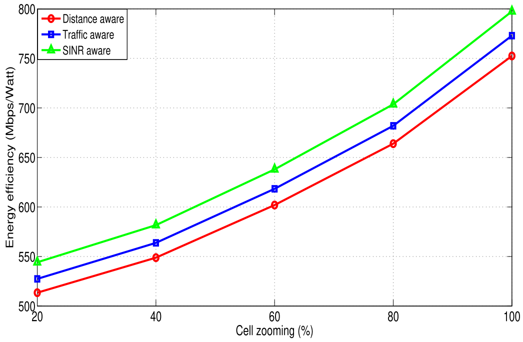

FIGURE 15. Demonstration of energy efficiency with cell zooming level for $\mathcal{BW}$=10 MHz.

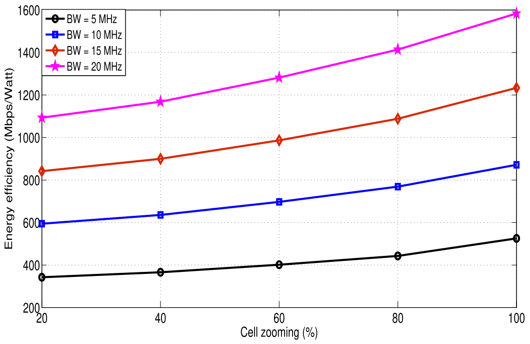

FIGURE 16. Illustration of energy efficiency with cell zooming level varying $\mathcal{BW}$.

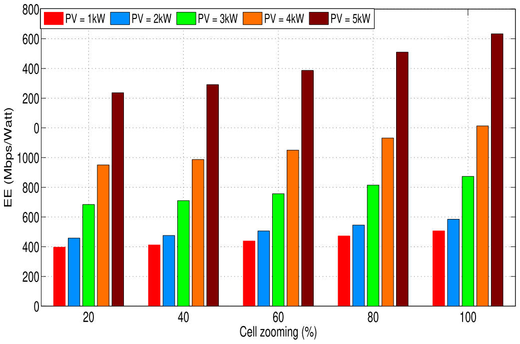

FIGURE 17. Quantitative comparison of energy efficiency varying solar PV capacity.

On the other hand, the impact of cell zooming on EE varying solar module capacity is illustrated in Fig. 17. The installment of increasing solar PV capacity to the on-site BSs demonstrates a positive impact on energy efficiency as evident from the figure. This is because additional energy production from the large array of PV panels is stored in the battery bank. This backup storage energy carries BS load during night or disasters or PV malfunctions. As a consequence, the net energy consumption by the considered BS is reduced through further curtailing the purchase of grid electricity. For example, the proposed system operating with $\mathcal{BW} = 10\text{MHz}$ offer extra 72% energy efficiency when the installed solar capacity is elevated from 1kW to 5kW. With the increment of PV capacity, storage capacity and EE metric are linearly scaled ensuring no wastage of harvested green energy.

A comparison of EEI is varying different cell zoom out levels for SINR based scheme is demonstrated in Fig. 18. It is clearly observed that the EEI graph follows the throughput pattern where the curve for full zooming out shows outstanding performance compared to others. This is because a macrocell BS enters to sleep mode entirely and thereby diminish the overall network consumption. However, the graph is simulated for SINR CoMP enabled cell zooming method of 10 MHz system bandwidth. The EEI distribution gap is less significant for the lower level of zooming as clearly identified from the figure. It can be concluded that the proposed hybrid system outperforms under higher cell zoom out for the predefined network settings.

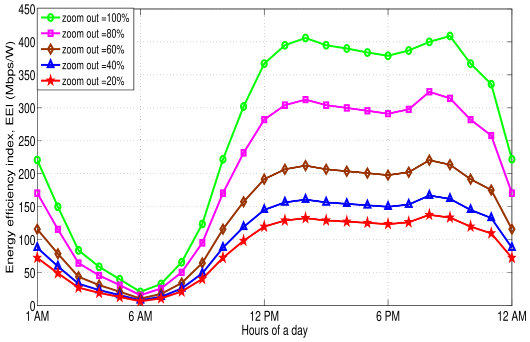

FIGURE 18. Comparison of energy efficiency index in a day for $\mathcal{BW}$=10 MHz.

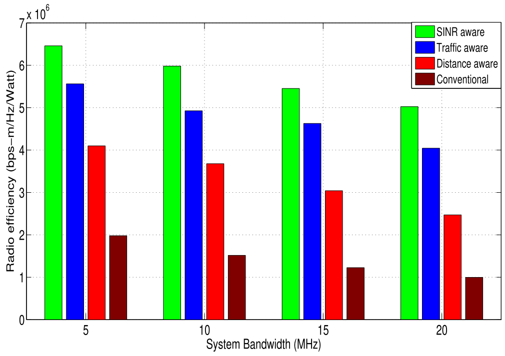

FIGURE 19. Radio efficiency for different load-balancing schemes.

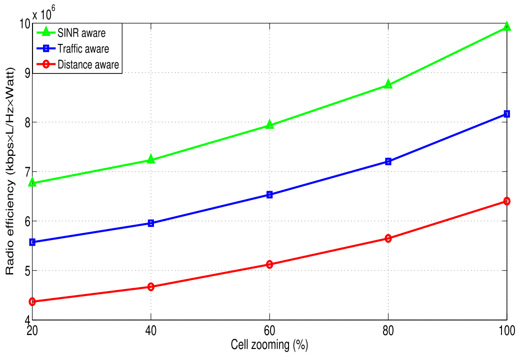

FIGURE 20. Demonstration of radio efficiency with cell zooming level for $\mathcal{BW}$=10 MHz.

An extensive comparison of radio efficiency under different bandwidth and cell zooming level is demonstrated in Fig. 19 and Fig. 20. Radio efficiency entails the achievable spectral efficiency and cell coverage range per unit power for a given bandwidth. A gradual decrement of η_{RE} has been observed with the higher system bandwidth for the specified network configuration. The higher system bandwidth results in high power consumption and thus, reduces the RE supported by Eq. (6) and Eq. (26). Nonetheless, the proposed framework attains 69% more radio efficiency than the conventional one for the given network settings. As a matter of fact, the BS operated at low bandwidth performs a lot better η_{RE} regardless of transmit power since RE predominantly depends on $\mathcal{BW}$ and input power consumption. From the above-mentioned analysis, a trade-off relation exists between energy efficiency and radio efficiency while designing a large-scale green cellular network. On the other hand, η_{RE} manifests almost identical patterns to realize peak values with the increment of load shifted parameter. It is worth mentioning that all the results presented in this section are evaluated for average solar irradiation employing Monte-Carlo based simulation. In summary, the above analysis of the aforementioned figure identifies that the green cellular system adopting DPS CoMP load balancing scheme with suitable $\mathcal{BW}$ and solar capacity achieved the best performance in terms of all predefined performance metrics.

VI. CONCLUSION

This paper examined the dynamic point selection coordinated multipoint based adaptive load balancing scheme for C-RAN networks. The primary objective of this study is to develop sustainable large-scale 5G cellular networks addressing energy efficiency and spectral efficiency aspects under existing resource availability utilizing the full advantage of renewable energy harvesting and CoMP technique. In light of this, the combined integration of CoMP enabled cell zooming method considerably reduce the utility grid consumption guaranteeing the desired signal quality as well. According to the SINR aware load balancing, users are optimally connected to actively BS offering best received signal strength and traffic carrying capability regardless of UE-BS distance. We studied the BS switching policy to assure the desired received signal quality with a minimum on-grid purchase prioritize solar energy consumption which exhibits excellent EE performance in a big-scale cellular network. Numerical results demonstrate that EE and radio efficiency predominantly depends on the cell zooming level and installed PV capacity. A profound impact of system bandwidth and load factor is noticed on the energy saving index performance for the proposed framework. Notably, the suggested system achieved additional 69% RE, 25.8% EE, and 22% energy saving performance over the conventional scheme for the particular network settings. In summary, the considered system offers an increased level energy efficiency and throughput performance addressing eco-sustainability. Future work will focus on generalized load balancing algorithms and analytical representation of CoMP enabled heterogeneous networks verified by simulation results.

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