Boost the Energy Efficiency of 5G-IoT System

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ABSTRACT

Energy efficiency techniques in ultra-dense wireless Heterogeneous 5G cellular wireless networks are intended to overcome the fundamental problems of existing cellular networks, higher data rates, superior end-to-end performance and user coverage in hot-spots and congested areas with lower latency, energy consumption and costs to transfer information. To address these challenges, IoT-5G systems will adopt a multi-layered architecture consisting of macro cells, various types of licensed small cells, relays, and device-to-device (D2D) networks to serve users with different quality of services. (QoS) spectrum requirements and in an energy-efficient manner. Starting from the visions and requirements of 5G multi-layer networks, this work outlines the challenges of interference management (power management, cell association) in these networks with shared spectrum access (when different network levels share the same licensed spectrum. In this context, our thesis presents a qualitative comparison of existing cell association and power control schemes for interference control in IoT-5G networks. Open challenges are highlighted and guidelines are given for schemes to overcome them and make them suitable for the emerging IoT-5G systems. Code division multiple access systems (MC-CDMA) and analyze the performance by examining the time-domain MC-CDMA system model to reduce the cross-correlation between the time-domain MC-CDMA waveforms and the impulse noise From the computer simulation results, it is clear that to support our analysis, the proposed MC-CDMA system can SI-CDMA in impulsive noise to provide performance an improvement of 2.5 dB at a bit error rate (BER) of 10−3 and is compared to a DS-CDMA system. The mean theoretical SINR is compared to the mean SINR measured using Monte Carlo simulations for BRAN and channel Model. It is then used to compare the sensitivities of MC-CDMA and MC-DS-CDMA systems to carrier shift in a frequency-selective channel with a zero-forcing (ZF) or minimum mean square error (MMSE) equalizer. The speed of data transmission and the spectrum efficiency of wireless mobile communications have greatly improved. Terrestrial digital television broadcasting has been developed using OFDM and CDMA technology. Most mobile communication systems transmit bits of information to the receiver through the radio space. In wireless heterogeneous networks (HetNets), spatial densification through small cells and the use of massive MIMO antenna arrays are key factors for high data throughput, wider coverage and improved energy efficiency (EE). However, the ultra-dense deployment of small cells.

Keywords: *Energy Efficiency, small cells, heterogeneous networks, Ultra-dense, MIMO antenna, 5G systems, Internet of Things.*

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1. INTRODUCTION

The so-called automation pyramid today dominates industrial communication network design thanks to the Internet of Things (IoT). With the Internet of Things, massive amounts of data are gathered and managed from a rapidly expanding network of devices and sensors. IoT nodes can connect to the Internet and communicate with one another under typical functioning settings. Every physical object has a unique digital identity, can perceive their surroundings, and can interact with other objects. The preservation of security and privacy in various applications, as well as the ongoing emergence of new vulnerabilities and threats in the Internet of Things, provide significant concerns for users when embracing this type of network. The architecture of the IoT system would be accountable for Technological, Scientific, and Industry reasons, among them the privacy and security. This is because the security reason design of IoT infrastructure collaborate key function in a logical vision. The 5G System, also known as 5GS, has three main components. One of these is the 5G core network, which provides the additional functionality of 5G networks (source). User Equipment (UE) and the 5G Access network (5G-AN) are the last two elements [1]. According to the 5G core diagram, the 5G core uses a cloud-aligned service-based architecture (SBA) to enable authentication, security, session management, and traffic aggregation from connected devices, all of which call for the intricate integration of network operations.

The components of the 5G core architecture include:

- User plane Function (UPF)
- Data network (DN), e.g. operator services, Internet access or 3rd party services
- Core Access and Mobility Management Function (AMF)
- Authentication Server Function (AUSF)
- Session Management Function (SMF)
- Network Slice Selection Function (NSSF)
- Network Exposure Function (NEF)
- NF Repository Function (NRF)
- Policy Control function (PCF)
- Unified Data Management (UDM)
- Application Function (AF)

Nodes in the wireless 5G-IoT sensor network operate on battery power with restricted power and battery life, as well as with limited storage and processing power. Nodes are typically placed in areas where human access is virtually impossible. As a result, the battery cannot be replaced. As a result, among other issues, power consumption poses a serious challenge to the development of wireless 5G-IoT sensor networks. According to studies, routing is a key component of IoT applications that affect power usage [2]. However, it is challenging for academics to create reliable, energy-efficient routing protocols for broader IoT applications. Several researchers created various techniques, yet the energy problem still exists. It is so because there is still much to learn about energy-saving routing protocols and efficient power use. For the system to boost network life and performance of the IoT applications, more and more energy-efficient routing protocols are required.

2. 5G WIRELESS TECHNOLOGY

Real-time video calls became possible with the transition from the 2G GSM to the 3G Universal Mobile Telecommunication System (UMTS), thanks to improved download and network speeds. Triple-play traffic (data, audio, and video) access is now feasible wirelessly, wherever you are, thanks to LTE and its follow-up LTE-A, which increased network capacity and decreased latency in application-server communication. In actuality, 4G is mobile broadband. While 2G was intended as the first digital mobile voice communication standard for improved coverage,
3G was the first mobile broadband standard and was initially planned for voice with some consideration for multimedia and data. From 64 kbps in 2G to 2 Mbps in 3G and 50-100 Mbps in 4G, the data rate has increased. In addition to accelerating data transmission rates, 5G is anticipated to improve the network's scalability, connectivity, and energy efficiency. It is anticipated that 50 billion devices will be linked to the worldwide IP network by 2020.
In order to satisfy de- mending needs such a 1,000 times aggregated data throughput improvement from 4G, 1 ms end to end latency, huge interconnectedness, etc., 5G will force significant changes to current wireless networks. The goal of 5G is to accommodate a range of communication needs and act as a centralized platform for numerous services and applications. Existing technologies like LTE-Advanced and wireless local area network (WLAN) are gradually changing to match new needs before 5G fully takes over.
Moreover, wearable technology's communication needs can be partially satisfied by current technologies. For instance, beam forming and multi-user multiple input multiple output (MU-MIMO) in 802.11ac can produce a throughput of more than 1 Gbps [3]. The next iteration of WLAN, specifically the IEEE 802.11 family, may offer an alternative for wearable needing high data rates. More crucially, protocols like WLAN and Bluetooth have hardware costs and power requirements that are more suited for wearable technology. The obstacles and enabling technologies in wearable communications are the main topics of this article. While the impending 5G aims to meet different communication needs, it could not have the specs needed when applied directly to wearables. We assess the design

requirements and difficulties for wearable communications and provide a communication architecture that takes into account current academic and industrial research trends. We also provide a thorough list of technologies that can make the design difficulties easier.

A well-connected core network and RAN will be features of 5G. The networked base stations should use high bandwidth wired connections, and the backbone network may even switch from fibre to mm-wave wireless communication. A typical macro-cell may be highly burdened with controlling overheads to maintain connectivity with a large number of devices as the number of connected devices rises (around 10 k per cell). In order to support an increase in signaling and payload overhead, the architecture must be less complex and more advanced. The performance of this cutting-edge 5G architecture, which uses mm-wave RAN, has been documented in the Giga KOREA 5G project [2].

The scientists also explained how the beam control mechanism enables quick handover between multiple beams and provided graphical representations of the antenna array topologies for 3D beam-forming in the report. The generation of a 3D beam is accomplished using a 2D array of patch antennas. Space division multiple access is made possible by highly directed radio transmission beams that originate from a 2D array of patch antennae and are generated in 3-dimensional spaces (SDMA).

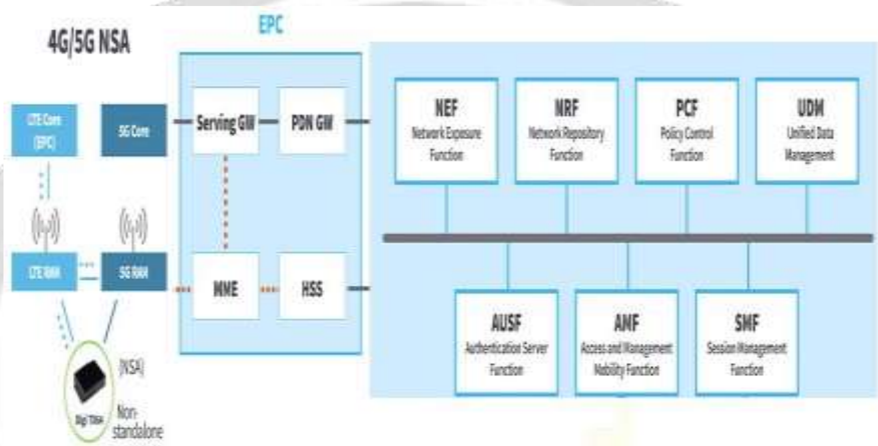

Fig. 1 NSA working model for 5G

In essence, this is beam division multiple access (BDMA). They put patch antenna arrays made up of a 2D NXM number of patch antennae in user equipment. The radio access technology is resilient, secure, and extremely reliable because it has quick handoff capabilities across several beams. Moreover, "relay" transmission is employed to overcome the mm-wave RAN's limited coverage, and the handoff procedure may no longer be managed by the core node but rather by the base station. This task of resource allocation is carried out by the base station or eNB in 4G LTE. To improve QoS in LTE, many scheduling strategies have been developed. Based on game-theoretic calculations, such an intelligent resource allocation strategy for cognitive radio connections was proposed [4]. While doing macro cell-based processes, where beam-forming would not be practicable, 5G should adopt this kind of optimal distributed resource allocation technique. It would be ideal to have an evolved core network that is flexible, intelligent, simple to deploy, and inexpensive in addition to an increase in RAN capacity. Additionally, recent advances in cloud-based networking have opened the door to the possibility of virtualized core networks.

3. RELATED WORK

The energy-efficient SSL protocol was proposed by Algimantas et al. [5] and ensured the highest bandwidth and necessary degree of security with the least amount of energy use. They outlined the SSL protocol's fundamental idea and suggested an adaptable SSL protocol. They implemented secrecy, integrity, and availability as security goals for the SSL protocol. The right cryptography approaches were used to help SSL protocols fulfil their security goal.

A thorough summary of the topology control routing protocol and data link protocol was published by Fangxin Chen et al. [6]. An effective topology structure could boost routing protocol effectiveness. The data connection protocol offered a foundation for data fusion, target placement, and other features, extending the network's overall survival time. The writers discussed energy harvesting systems like wind, sun, and vibration energy. In conclusion, the writers covered the state of the energy supply industry and wireless sensor network management strategies.

An energy-efficient strategy in both physical layer and deployment aspects was presented by Gang Wu et al. [7]. Additionally, they put forth the fundamentals of energy-efficient optimization. There are many energy-related algorithms, including bi-section algorithms for optimization and multi-level water filling.

Key technologies such encryption mechanisms, communication security, safeguarding sensor data, and cryptographic algorithms were discussed by Hui Suo et al. [8]. They examined the crucial technologies already described and implemented hop encryption security. Ultimately, they examined security requirements and features from four tiers, including the application layer, the perception layer, the network layer, and the support layer.

A method to enable heterogeneous MAC duty-cycle configuration among network nodes was put out by Julien Beaudaux et al. [9]. To put the concept into practise, the nodes were split up into disjoint subsets, each of which represented a specific duty-cycle arrangement. The authors described the routing role and sleep depth in the suggested solution. The former enabled the MAC and routing layers to work together such that every node could determine how many nodes were above it in the routing tree. The latter used applicative criteria to divide the nodes into various sleep depths, which were then represented as discrete virtual layers.

A reliable and energy-efficient data automated repetition request technique was proposed by Kyungmin Kim et al. [10] to reduce transmission delay and energy consumption simultaneously. The scheme consisted three aspects namely duplication retransmission prevention, congestion control and error notification.

For IoTs, Mallikarjun Talwar [11] described routing methods and protocols. The author began by outlining the characteristics of routing protocols and some of the major difficulties. The author concluded by explaining a variety of routing protocols, including RPL, OLSR, AODV, and PRoPHET.

A brand-new MAC protocol named PaderMAC was introduced by Marcus et al. [12] for wireless sensor networks. Tinyos and the MAC layer Architecture were used to achieve the PaderMAC principle. The purpose of this was to prolong lifespan by cutting preambles that use a lot of energy.

For M2M communication networks, Mohammed et al[13] efficient cluster-based sleep scheduling was suggested. Devices were set up in this system, and clusters were created. It was supposed that all devices had the same energy. Several gadgets were chosen to serve as Principal Cluster Heads (PCH). Many devices built as Alternative Cluster Heads (ACH) that give the PCH devices fault tolerance. The PCH determined which devices were active in each cluster. These gadgets maintained an active state and offered network coverage. The other devices stayed in an active or sleeping mode. Hence, the energy use was less when compared to other approaches.

A survey on energy-efficient routing methods in wireless sensor networks was provided by Pallavi S. Katkar et al. [14]. Without sacrificing accuracy and scalability, they explored the factors that affected routing protocols, such as fault tolerance, node placement, and energy consumption. The characteristics of some protocols, including Low Energy Adaptive Clustering Hierarchy (LEACH), Power Efficient Gathering in Sensor Information System (PEGASIS), Power Efficient and Adaptive Clustering Hierarchy (PEACH), Threshold Sensitive, Energy Efficient Sensor Network Protocol (TEEN), Energy Efficient Ant-Based Routing (EEABR), and Self-Organizing Protocol, were also elaborated (SOP). Finally, authors looked at significant routing challenges that affected sensor network design.

An activity scheduling plan for sensing coverage was demonstrated by Rongxing Lu et al. [15]. A node chose a random timeout at the beginning of each round and listened to messages from nearby nodes until it ran out. The activity decision was contained in these messages. If a connected set of a node's active neighbours' sensing ranges completely covered the node's sensing range, the node was deemed active.

Ioannis P. and others [16] Energy efficiency is becoming an increasingly crucial issue for the mobile networks of the (near) future due to the exponential growth in network traffic and the number of connected devices. More precisely, the fact that 5G is being introduced at a time when energy efficiency is becoming increasingly important for the network's capacity to consider and address societal and environmental challenges, can significantly aid sectors in achieving sustainability goals. Under this context, energy efficiency has recently taken on a more significant role as a performance indicator and design requirement for 5G communication networks, posing new problems for the future. The use of AI/ML techniques will especially improve 5G's capacity for lower power consumption and, more crucially, dynamic adaptation of the network elements to any form of energy requirements, to ensure effective functioning.

The suggested model by Osman and Zaki [17] is based on applying the Lagrange optimization technique to minimize Interference and maximize the energy efficiency and dependability of the IoT and cellular networks in fifth-generation (5G) systems. Its goal is to control interference among IoTG and BS. To accomplish the goal of the suggested model, we first establish the multi-objective optimization problem. We then extract the closed-form expressions of important quality-of-service (QoS) performance, such as system dependability, throughput, and energy efficiency, based on the optimisation technique. Lastly, the suggested algorithm has been assessed and investigated using various hypotheses and simulation situations. The findings show that our proposal is accurate and successful, and they also show that cellular and IoT network performance have significantly improved.

4. PROPOSED METHODOLOGY

In this, we suggest a radical architectural modification at the radio modem and protocol layers of the device. Using RRC message (UE capability information) signaling, the UE in our model will decide intelligently whether to perform specific radio layer functions based on the current battery level. Our suggested model focuses on radio layer modifications made by the device, including proactive network resource modification, system selection changes at the user equipment, and dynamic resource allocation at the base station. As part of the power-saving process incorporated into device software, the UE can currently only perform system-level adjustments like lowering the brightness, turning Wi-Fi on or off, and changing the screen resolution. However, the UE cannot change the protocol layer. According to our model, the device can alter the radio layer together with the system. The following proposals are based on our field trial and investigation and are illustrated in Table 4.1.

Table 1: UE Battery Report in RRC message and Proposed Mode

UE Battery	Network Allocation	Frequency Bands
>30%	Network will allocate all possible network resources (5G, MIMO, CA)	Any possible supported bands (1 GHz to 40 GHz)
20-30%	Network will remove 5G and only allocate MIMO and CA features	Block mmWave 5G (24 GHz to 40 GHz) allocation
10-20%	Network will remove 5G and MIMO, only CA will be allocated	Block mmWave 5G (24 GHz to 40 GHz) and MIMO layer
<10%	Only allocate LTE feature	Allocate only low frequency bands (< 1 GHz)

1. Every RRC message (UE capability report) that the UE sends to the network during the initial registration or attach process includes a battery measurement report. The eNode B or gNode B will decide whether or not to assign network features like 5G, MIMO, and CA to the UE based on the battery measurement value. The UE will cycle between various modes, as shown in Table 4.1.

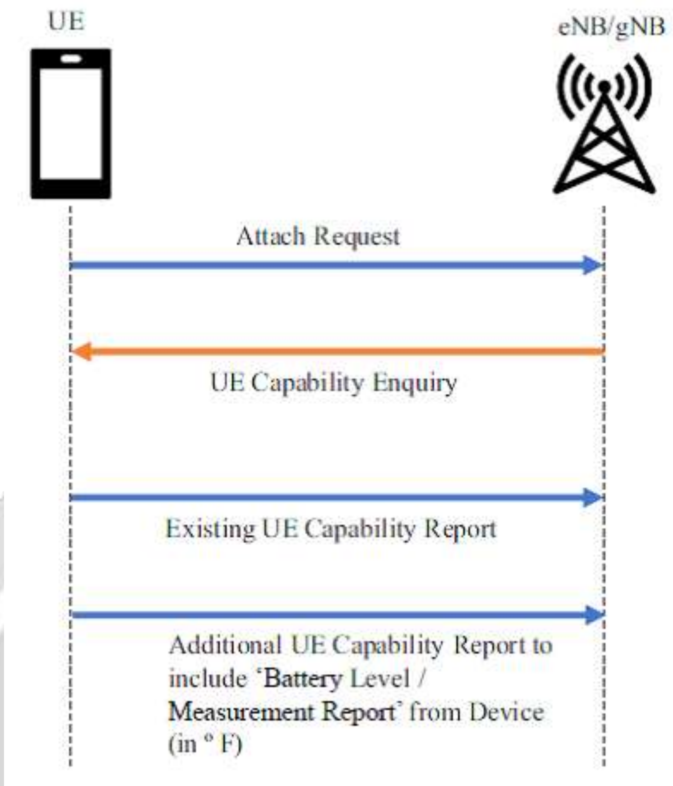

Fig.2 Proposed UE Capability Report with 'Battery Level'

2. The UE proactively adjusts the UE capability report before transmitting it to the network based on the battery level. For instance, the device might not list 5G NR, MIMO, or CA in the UE capabilities report. For instance, if the battery is low, the UE will change its capability from NR (5G) supported to not-supported and relay that information to the network. In order to prevent problems like message buffer overflow, this suggested technique also aids in lowering the size of the RRC message.

3. The UE will change the carrier frequencies between low bands (< 1 GHz) vs. mid-band (1 GHz - 6 GHz) vs. high bands (24 GHz to 40 GHz) based on battery level.

4. Based on battery level, the UE will disable the MIMO antenna configuration on devices. For instance, the device will switch to MIMO power saving mode and downgrade the user equipment to use less-aggressive radio settings if the battery level drops to between 10 and 20 percent (e.g. 4X4 to 2x2 to 1x1). The suggested UE battery levels (10%, 20%, or 30%) in Table III are merely hypothetical and are only being used for evaluation. Manufacturers of devices or network operators may change the.

5. EXPERIMENTAL RESULT

Energy Efficiency Techniques 5G networks outage ratio for HPUEs performance of the MC-CDMA system, the theoretical performance and computer simulation results are presented. TPC, TPC-GR, Prioritized TPC, Prioritized TPC,GR QAM modulation is employed for all investigated systems. For MC- CDMA and PSK 16 systems, MMSE for MC-CDMA based systems, the parameters of TPC, TPC-GR, Prioritized TPC, Prioritized TPC,GR performance versus signal-to-noise ratio (SNR) db/N0, where dbis the energy transmitted per information bit and N0 is the one-sided noise power spectral density. For comparison purposes, both theoretical performance and simulation results of the linear receivers for MC-CDMA in impulsive noise are plotted. It can be seen that the computer simulation results match the theoretical analysis perfectly. Evolution towards 5G Multi-tier Cellular Wireless Networks Higher Data Rates Transmission in MIMO Systems. In addition to setting their transmit power for tracking their objectives, the

LPUEs limit their transmit power to keep interference caused to HPUEs below a given threshold. HPUEs can notify the nearby LPUEs when the interference exceeds the given threshold.

5.1 Prioritized power control

A two-tier system (high-priority cell tier and low-priority cell tier) with same target SIR for all users 5 HPUEs per high-priority cell and 4 LPUEs per low-priority cell, each user is associated with only one BS of its corresponding tier. LPUEs employ either TPC, TPC-GR, prioritized TPC, or prioritized TPC-GR, and HPUEs use TPC (i.e., rigidly track their target-SIRs).Although outage ratio for HPUEs are improved by TPC-GR, as compared to TPC, protection of HPUEs is not guaranteed. Prioritized TPC and TPC-GR guarantee protection of HPUE sat the cost of increased outage ratio for LPUEs. Also, with prioritized OPC for LPUEs and TPC for HPUEs, protection of HPUEs is guaranteed at the cost of decreased throughput for LPUEs (compared to non-prioritized OP)

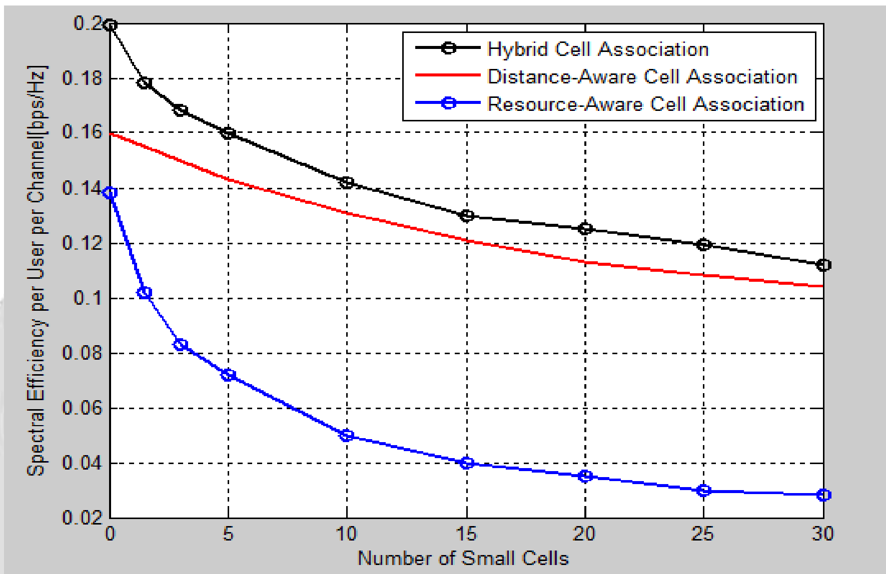

Fig. 5.3 Energy Efficiency Techniques in Ultra-Dense Wireless Heterogeneous 5G networks

5.2 Impact of the array size on the activity factor

Here, we analyze the impact of the active array size on the activity factor of the base station over 24 hours. The total bandwidth is restricted to

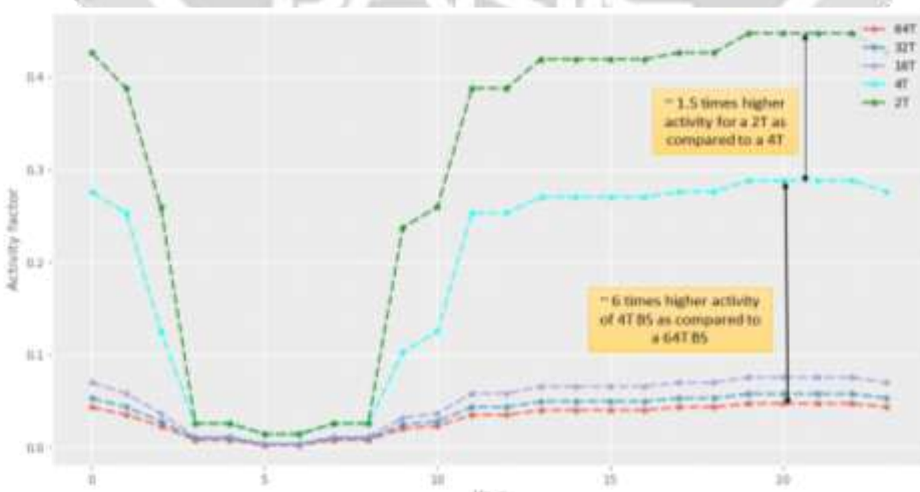

Fig. 5.4: Impact of the active array size on the activity factor

As seen in the Figure 5.4, increasing the array size reduces the activity factor of the base station. This is particularly observed during the peak hours of the day when a BS experiences much higher traffic demand due to a larger number of active users. The lower activity factor resulting from the use of large arrays can be attributed to the better performance and capacity experienced by each user in the network.

5.3 Impact of bandwidth on the activity factor

For a given active array size, we found that varying the total bandwidth available has a far greater ability in reducing the activity factor of the base station over a 24 hour period. In this simulation, we assume a peak traffic demand of 2000 Mbps=km^2. We set the active array size to 64 antenna elements and the total bandwidth is varied from 5to100MHz.

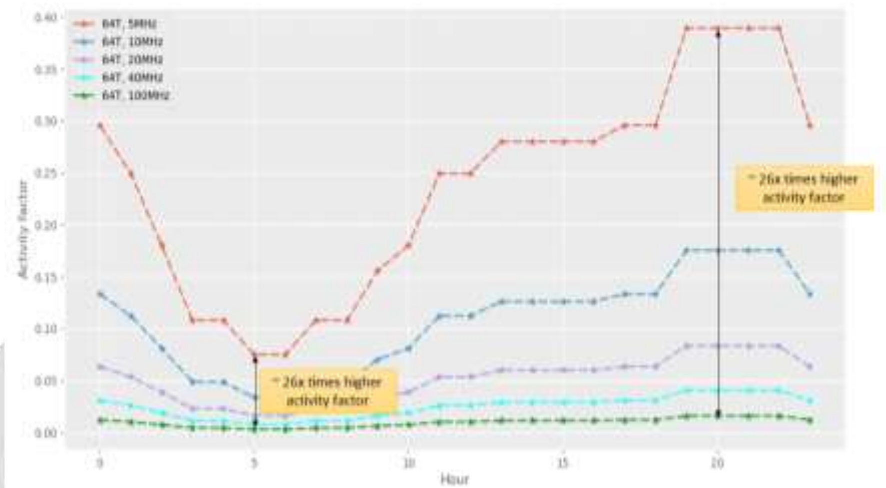

Fig. 5.5: Impact of the bandwidth on the activity factor

It was observed that at a given hour, one could achieve approximately 26 times lower activity factor by increasing the bandwidth from 5 to 100 MHz. The decrease in the activity factor mainly comes from the increased throughput experienced by the users as multiple carriers are aggregated to serve them. From the above results, one might conclude that the best way to decrease the activity factor of the base station would be by using large arrays and larger bandwidth.

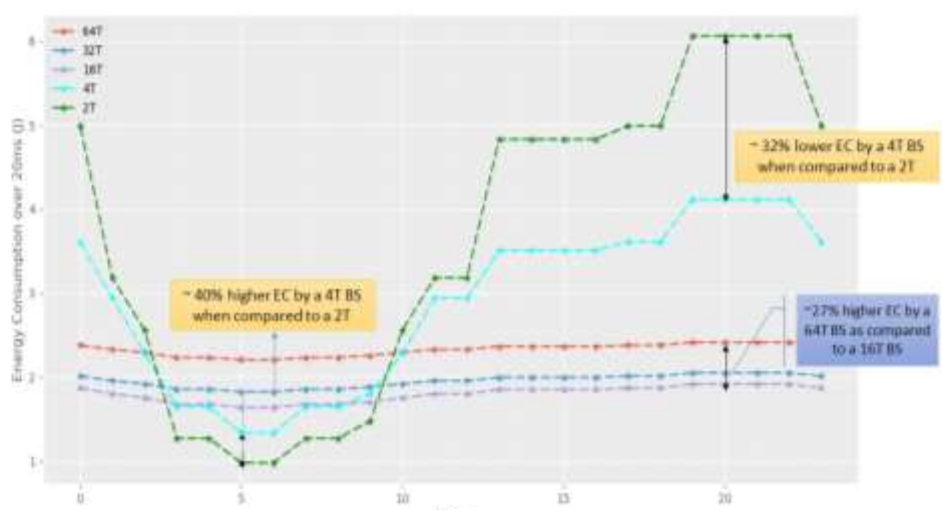

Fig. 5.6: Energy consumption variation over 24 hour period for different array sizes

The observed trend is quite interesting as we found that BSs with different active array sizes to consume a lower amount of energy during different hours of the day. During the peak hours (1800 - 2300 hrs), a 64T BS consumed approximately 34% lower energy as compared to 4T BS while the same BS consumed about 60% more energy during the off-peak hours (0300 - 0800 hours). This indicates that having a fixed array size throughout the day might not be an energy-efficient option. It also highlights the potential to save energy by adapting the array size to the variation in the traffic demand during the day.

5.4 Impact of deeper sleep modes on the energy consumption

Sleep modes help in reducing the EC of the BS during the inactive periods by turning off various hardware resources. Depending on the hardware resources that are turned off (characterized by the sleep deltas), there is a reduction in the static/idle mode.

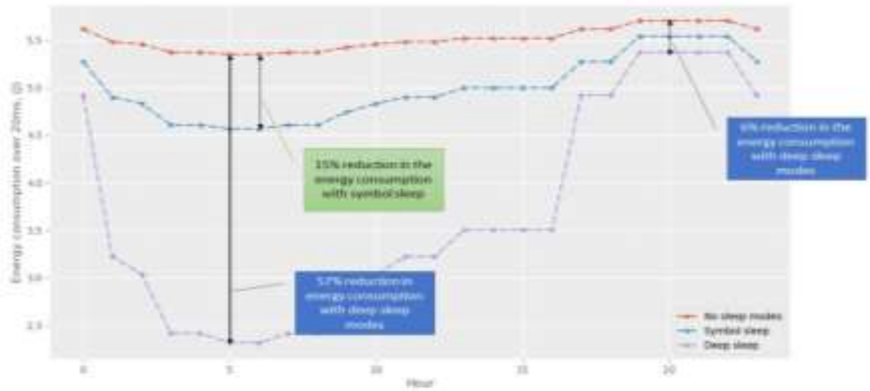

Fig. 5.7: Reduction in energy consumption with deep sleep modes

In Figure 5.7, we observe that deep sleep modes offer a great potential in reducing the energy consumption of the base station especially during the off-peak hours of the day. We observed a 57% reduction in the energy consumption during the off-peak hours by having deeper sleep modes relative to the scenario when no sleep modes are implemented.

This is 40% more energy savings than symbol level sleep. It should be noted that the depth of sleep largely depends on the traffic demand experienced by the BS. And under high traffic demands during the peak hours, it is often not possible to switch the base station to deep sleep modes. As a result, we observed that a maximum of 6% reduction in energy consumption by having deep sleep modes during the peak hours of the day.

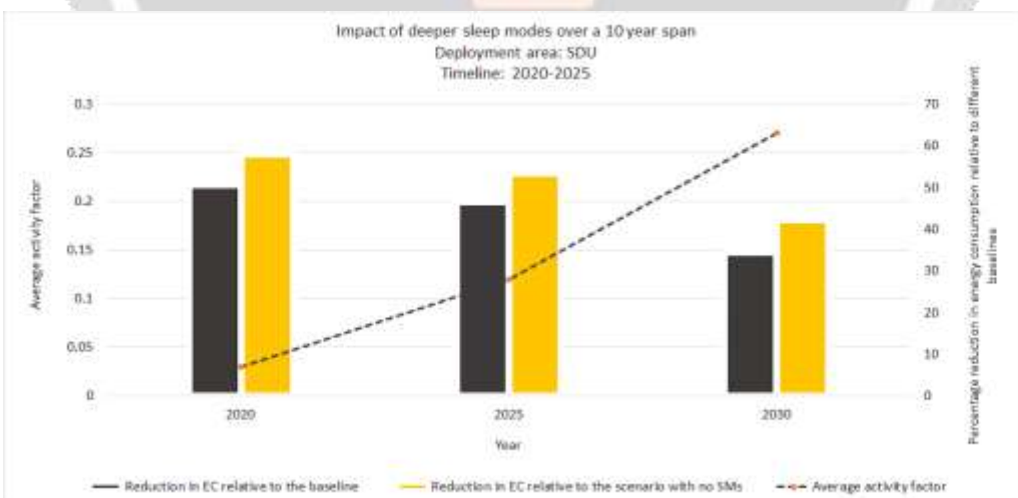

Fig. 5.8: Impact of deeper sleep modes over a 10-year span

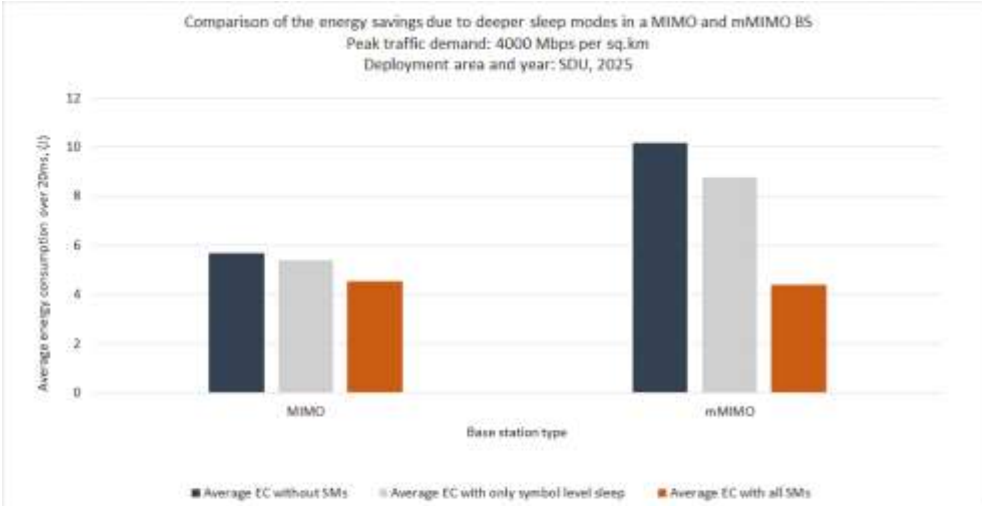

Fig. 5.9: Comparison in the energy savings due to deeper sleep modes in a 4T and 64T BS

In the above scenario, we observed an average of 15% reduction in the EC relative to the baseline with deep sleep modes in a 4T BS. This reduction is much lower when compared to the 50% drop observed in a 64T BS when deployed in the same scenario.

6. CONCLUSION

The Lagrange optimization technique is used to minimize interference and improve the quality of service by maximizing the energy efficiency and dependability of IoT and cellular networks in fifth-generation (5G) systems. This new framework, known as the interference control model, was proposed to control interference among IoT-5G and BS. We have demonstrated that the suggested model, when compared to other offered models, may demonstrate the optimum performance under a specific environmental condition based on the system throughput, energy efficiency, and reliability.

Energy efficiency is a crucial requirement for M2M communication ecosystems. In this study, we investigated the resource distribution for small, energy-efficient M2M devices over the 5G network. Our objective was to increase resource allocation autonomy for MTC devices while also increasing energy efficiency. We proposed an algorithm that splits resource blocks in accordance with the quality of service measure and the power limitations of M2M devices. The optimum method, which enhances outcomes, especially for small devices, through a succession of thresholds, has a low level of complexity and a short time delay. The solution performs faster than conventional algorithms.

The allocation of resources in this work was completed in a single instant. To further evaluate the power consumption and energy efficiency of the improved method, one might simulate a continuous allocation across time to enhance the simulation. This would increase the parallelism and timing synchronisation complexity that would be present in real-world resource allocation systems. Adding to this, employing hardware resources to transport data via a wireless channel during the simulation would support the idea that IoT devices can use less power. It would also necessitate that the algorithm complexity run within the wireless transmission's 1 ms sub frame requirement. Our research will focus on intelligent data transmission for IoT networks that accommodate numerous linked devices in the upcoming years. When considering the 5G network for Internet of Things applications, the MTC device and each gateway have constrained resources, such as computing, electricity, and spectrum.

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