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# Sleep-Wake Scheduling Scheme for Small Cell Base Stations: A Review

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***Abstract*— Energy efficiency is emerging as one of the key performance indicators for the next generation wireless communication systems. The motivation behind energy efficiency arises due to the current increasing energy cost of running access networks, which is a significant factor of operational expenditures. The total number of subscribers and the amount of traffic volume in cellular networks have increased exponentially. 5G network is aspired as the next generation wireless communication systems. In 5G networks, the width and depth of user services are expected to enhance significantly. Specifically, for this implementation to take place, the trend is towards the utilization of small cells to achieve the high data rate requirement. However, small cells can increase energy consumption if they are not equipped with intelligent power saving and distribution mechanisms. Thus, the purpose of this paper is to present a review of energy efficient (or green) ways to deploy small cells in 5G networks.**

***Keywords*— Sleep-wake mechanism, energy efficiency, sleep state**

## I. INTRODUCTION

5G is making big waves of progress around the world. Telecommunication providers and device manufacturers are both making rapid progress towards the integration of 5G wireless networks. However, with the increased number of base stations (BSs) and antennas needed to deploy the network, new energy efficient schemes must be established to counter the higher energy consumption. One such way of doing so is to maximize energy efficiency through optimizing sleep- wake scheduling. Sleep-wake scheduling works by having only selected nodes to stay active (or switched on) and the rest to stay inactive (or switched off in the sleep state).

### *A. Our Contributions*

While many energy efficient approaches have been proposed for macrocells, there is lack of similar approaches for small cells, which is the focus of this paper. Sleep mode (or the on/off mode) of small cells helps to improve energy efficiency. For instance, when the traffic load of a small cell is low, nearby or partially-on BSs can be switched off to reduce energy consumption. However, when the traffic load is high, energy-efficient mechanisms can wake up BSs for packet transmission. In order to achieve load balancing for improving energy efficiency, BSs with high traffic load must transfer traffic to neighbouring BSs. The rest of this paper presents a review of the sleep-wake scheduling scheme for small cell BSs.

### *B. Organization of this Paper*

Section II presents an overview of 5G and sleep-wake scheduling. Section III presents a taxonomy of sleep-wake scheduling. Section IV shows the state of the art of the schemes. Section V is conclusion.

## II. BACKGROUND

### *A. What is 5G?*

5G uses a control-data separation architecture (CDSA) that consists of two main layers: a) control plane, which is comprised of macrocell BSs, that provides large coverage and packet transmission commands (or instructions); and b) data plane, which is comprised of small cell BSs, that provides data transmission with high data rate following the commands given by the control plane. Fig. 1 shows the 5G architecture where macrocell is overlapping with microcell, femtocell, and picocell.

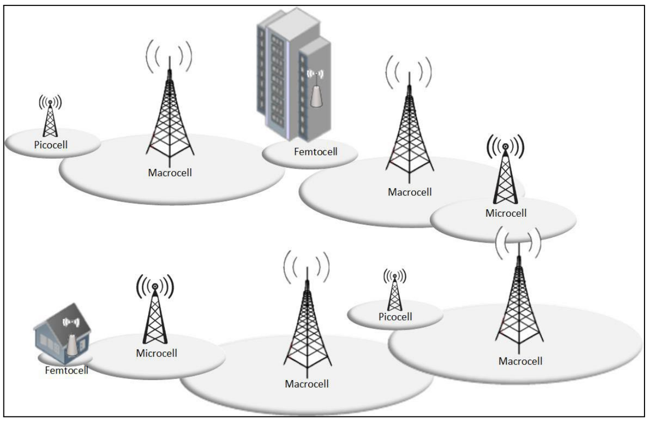

Fig. 1. 5G architecture.

Macrocell consists of BSs and nodes that operate in low frequency bands to provide large radio coverage (e.g., up to 30 km). On the other hand, small cell consists of BSs and nodes that operate in higher frequency bands to provide smaller radio coverage; specifically, up to 2 km, 0.2 km, and 0.1 km in microcells, picocells, and femtocells, respectively. While macrocell adopts a centralized control approach, small cell adopts a distributed control approach.

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In general, small cells are deployed using self-organizing algorithms, and so they are deployed without proper planning and in a random manner. Small cells have shown to provide high network capacity and to extend network coverage in indoor and hot spot outdoor environments (e.g., home and office). Small cell BSs provide data transmission and on-demand services, and so it can be switched off when they have no or low traffic load.

### B. What is Sleep-Wake Scheduling?

Sleep-wake mechanism of BSs has been proposed to reduce energy consumption in cellular networks. Sleep mode is a low-power intermediate state whereby the BSs are switched off partially, or fully, to improve energy efficiency. This is possible when they are not fully utilized. Nevertheless, there is a need for a quick transition from the sleep mode to the full operation mode when necessary. So, there is an urgent need to design a mechanism to select which BSs to sleep (i.e., when they are not in need), and to wake up (i.e., when they are required to send, receive, or handle packets).

Due to user mobility and varying traffic demand, the number of small cells changes with the quality of service (QoS) requirements, which are dynamic in nature. There are also heterogeneous users (or user equipment, UE), such as tablets, mobile phones, gaming consoles, and machine-type devices, generating a diverse range of traffic patterns. Naturally, there is an unequal distribution of traffic load among BSs, causing some BSs to incur higher energy consumption. So, there is an urgent need to design a mechanism to distribute traffic loads among BSs while taking energy consumption into consideration during the wake period.

In short, there are four main reasons why sleep-wake scheduling is needed in 5G. The main reasons are to cater for: a) increasing traffic growth; b) reducing costs (e.g., capital expenditure) whereby electricity contributes 20-30% of the network operational cost [1]; c) increasing average revenue per user; and d) reducing carbon footprint.

## III. TAXONOMY OF SLEEP-WAKE SCHEDULING SCHEMES

This section presents various aspects of sleep-wake scheduling, including objectives, sleep-wake schedulers, BS states, network characteristics, and challenges as shown in Table I summarizes the taxonomy of sleep-wake scheduling schemes.

### A. Objectives

There are three main objectives for this study:

O.1 *Determine sleep schedule* switches off hardware components, such as a small cell BS, according to network environment (e.g., low traffic load). Since macrocells and small cells overlap, traffic load can be shifted either to or from nearby BSs to enable more BSs to sleep for saving energy. Few BSs can remain in the wake-up mode to serve network traffic.

O.2 *Enable longer sleep opportunity* with less transition between active and sleep states, such as by switching off small cell BSs or keeping them in energy-saving mode for a longer period of time to save energy. During the off-peak period, the BSs can be put to a longer sleep period compared to the peak period to serve network traffic with multiple sleep level. When there is a demand, the BSs wake up from different sleep level accordingly to provide an instant network service.

O.3 *Reduce network latency* refers to a reliable network connection, which reduces the chance for a connection loss or delay. For most scheme, energy awareness is set priority while compromising the network latency. This will impact a poor Quality of Service (QoS) to the network. Thus, the objective of this study is to develop a sleep-wake scheduling scheme to enhance energy efficiency on the small cell BSs and to reduce network latency on the network traffic at the same time.

### B. Sleep-Wake Scheduler

The sleep-wake scheduler, as the decision maker, can be embedded in one of the three components as follows:

D.1 *Macrocell control center (CC)* are used in telecommunication network to provide wide area network radio coverage. It acts as a fixed transceiver at central connection point for a wireless device to communicate. The macrocell is placed on stations where the output power is higher covering a service provider's largest areas ranging from 1 - 30 km and are usually situated at high ground for a better connectivity coverage.

D.2 *Small cell BSs* are low-power BSs, capable of sending and receiving wireless signals. It covers areas where a mobile network requires additional coverage to maintain quality of service to subscribers. Microcell, picocell and femtocell are examples of small cells with decreasing in cell size.

D.3 *User equipment (UE)*, a device such as hand-held phones, laptops, and computers, which communicates with the BS. Every UE of the cellular network consists of a receiver which allows the BS to detect the position of UE for data handover. The data handover between BS and UE is dependent on the coverage area of the BS service.

### C. BS States

In order to reduce the power consumption of the BSs, the BSs can be divided into four main states as depicted in Fig. 2. The BSs will periodically move from active → idle → sleep → deep sleep whenever there is no UE request or they have served the UE and no incoming new UE. On the contrary, when there is new UE request, the BS will move from sleeping state to active state to serve the UE. Likewise if there is a sudden increase in UE requests, the BS will directly transition from deep sleep state to active state to avoid network latency. Fig. 2 shows the transition of each BS state. The characteristics of each state could be summarized as below:

S.1 *Active* state allows network entities to wake up, as well as to transmit and receive packets and serves requests (e.g., calls) from UEs.

S.2 *Idle* state allows network entities to wake up in order to wait for the arrival of new packets or user requests. At this state, the BSs is not receiving or transmitting any user traffic. In general, network entities are in this state whenever there is no data transmission.

S.3 *Sleep* state allows some components in a node to be switched off or operate under low power. Energy consumption in the sleep state is non-negligible since a network entity must enter the active and idle states immediately when necessary.

S.4 *Deep sleep* state allows the BSs to enter to prolonged sleep duration period. This state will consume the least energy or near to zero energy consumption rate.

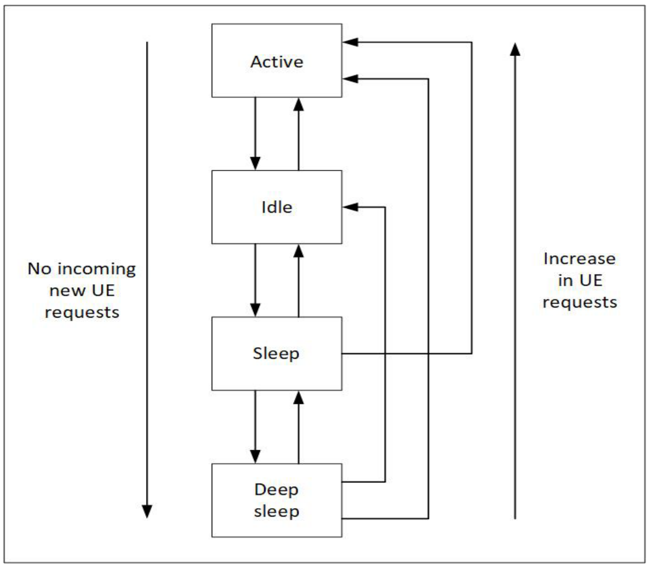

Fig. 2. The state transition of a BS.

### D. *Network Characteristics*

There are three network characteristics:

N.1 *Network heterogeneity* involves network entities with different capabilities (e.g., transmission capabilities) in a sleep-wake scheduling scheme. For instance, in [1], the small cell BS receives a wake-up control message from a central controller (CC).

N.2 *Small cell densification* refers to adding more cells in a coverage area to increase more network capacity. By increasing the number of cells, and by increasing the number of network nodes, the distance between the BS and UE will be shorter in order to improve achievable data rates.

N.3 *UE mobility* refers to a UE changing its point of attachment to the network while its communication to the network remains uninterrupted. As UE travels across different locality, the BS must be able to locate the UE within the network and automatically route the call to the UE.

### E. *Challenges*

There are five main challenges:

C.1 *Massive amount of heterogeneous traffic* is generated by a large number of heterogeneous UEs in an ultra- densified network. Network traffic is the amount of data that moves through a network at any point in time. In the heterogenous network set up, there are many UEs needed to send requests from time to time, thus this increases the network bandwidth. As a result, more BSs will need to wake up to facilitate the transfer, and this will increase the energy consumption to the BSs.

C.2 *Large deployment of small cells* can cause the overprovisioning and underutilization of resources (e.g., energy [1]), whereby energy consumption has shown to increase linearly with the number of picocells.

C.3 *Coverage constraints* refers to capability of the BS to sense the existence of UEs and to transmit data between the BS and UEs. This will also take into consideration the distance of UEs with the BS which carried out the network transmission.

C.4 *Interference* modifies a signal in a disruptive manner, as it travels along a channel between its source and receiver. It refers to the addition of unwanted signals to a useful signal.

C.5 *Switching delay* refers to difficulties for a sleeping BS to switch to active. This is because it is not aware of how much traffic is being supported by the other existing active BS, hence, it makes it hard for a sleeping BS to determine the opportune moment to switch on based on only local information that the BS has.

## IV. STATE OF THE ART

This section covers the state of the art of sleep-wake scheduling scheme. Table II summarizes the strengths and limitations of each scheme.

### A. *Traffic Load Distribution*

In [1], the sleep-wake scheduling scheme enables small cell BSs (D.2) or UEs (D.3), to determine sleep schedule (O.1) of small cell BSs according to traffic load in the presence of a large number of small cells (C.2) in a heterogeneous network (N.1). The scheme considers active (S.1) and sleep (S.3) states. Small cell BSs sleep whenever they are not needed; for instance, they overlap with a macrocell. There are three main mechanisms for a small cell BS to wake up from the sleep state to the active state. Firstly, the small cell BS uses low-power sensors, and it wakes up upon the detection of a communication between a UE and a macrocell BS. Subsequently, the UE performs handover from the macrocell BSs to the small cell BSs. Secondly, the small cell BS receives a wake-up control message from a CC in the core network. So, the CC can: a) ensure that only registered UEs can wake up small cell BSs; and b) select the small cell BS to wake up to serve the UEs based on the traffic load and traffic behaviour of the macrocell, as well as the requirement and location of the UE. Nevertheless, the control message exchange increases with the number of data transmission. Thirdly, the small cell BS receives a wake-up control message from UE. Subsequently, the UE connects to the small cell BS. In addition, the macrocell BS adjusts its energy consumption according to its dynamic traffic load because small cells can offload traffic from macrocells, and the small cells are dynamic in nature (e.g., small cells with mobile UEs). The proposed sleep-wake scheduling scheme has shown to reduce energy consumption.

TABLE I. TAXONOMY OF SLEEP-WAKE SCHEDULING SCHEME

| | **State of the Art** | | | | **Objectives** | | | **Sleep-Wake Scheduler** | | | **BS States** | | | | **Network Characteristics** | | | **Challenges** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A. Traffic Load Distribution | B. Deterministic Sleep Duration | C. Sleep Timer | D. Monitoring Area | O.1 Determine sleep schedule | O.2 Enable longer sleep opportunity | O.3 Reduce network latency | D.1 Macrocell control center | D.2 Base stations | D.3 User equipment | S.1 Active | S.2 Idle | S.3 Sleep | S.4 Deep sleep | N.1 Network heterogeneity | N.2 Small cell densification | N.3 UE mobility | C.1 Massive amount of traffic | C.2 Large deployment of small cells | C.3 Coverage constraints | C.4 Interference | C.5 Switching delay |
| [1] | √ | | | | X | | | | X | X | X | | X | | X | X | | X | X | X | | |
| [2] | √ | | | | X | X | | | X | X | X | X | X | X | X | X | | X | X | | | |
| [3] | √ | | √ | | X | | | | X | | X | | X | X | X | | | X | | X | | |
| [4] | √ | | | | X | | | X | X | | X | | X | X | | | | | | | X | X |
| [5] | | √ | | | X | | X | | X | | X | X | X | | X | | | | X | | X | |
| [6] | | √ | | | X | | X | | X | | X | | X | | | | X | X | | | | X |
| [7] | | √ | √ | | X | X | | | X | | X | X | X | X | | | X | X | | | | X |
| [8] | | | √ | | X | X | | | X | X | X | | X | X | | | X | | | | | X |
| [9] | | | | √ | X | | | | X | | X | X | X | | X | X | X | X | | X | | |
| [10] | | | | √ | X | X | | | X | X | X | X | X | X | X | | X | | X | X | | |

TABLE II. SLEEP-WAKE SCHEDULING SCHEME STRENGTHS AND LIMITATIONS

| **Scheme** | **Strengths** | **Limitations** |
|---|---|---|
| Traffic Load Distribution [1]–[4] | Maintain a balance traffic load between the BSs. | Requires two or more BSs to be located nearby to share the traffic load. |
| Deterministic Sleep Duration [5]–[7] | Systematic sleep-wake duration for each BS. Each BS will have equal time to switch on/off. | May suffer from network latency when there is an increase in UE request while BS is at sleep state. |
| Sleep Timer [3], [7], [8] | The timer ensures each BS to be switched on/off at a timely manner to avoid overloaded. | Will incur additional energy consumption for circuitry timer to work. |
| Monitoring Area [9], [10] | Suitable for areas with high UE mobility. | Lack of information from neighbouring BS will cause switching delay. |

In [2], the sleep-wake scheduling scheme enables small cell BSs (D.2) or UEs (D.3), to determine sleep schedule (O.1), particularly the sleep duration of small cell BSs to prolong the deep sleep state in the presence of a large number of small cells (C.2) in a heterogeneous (N.1) and highly dense (N.2) network. The scheme considers active (S.1), idle (S.2), sleep (S.3), and deep sleep (S.4) states. There are two types of UEs: a) idle UEs connect to macrocells in the control layer; and b) active UEs connect to small cells for data transmission in the data layer. The macrocells must be in the active state at all times to perform control functions. When the traffic load at the small cell BS is high, the traffic load is shifted from the small cell BSs to the macrocells in order to improve energy efficiency. There are three main mechanisms for a small cell BS to select the right state. Firstly, the single-level sleep strategy enables the small cell BSs to transmit and receive data in the active state, wait for data in the idle state, and sleep whenever there is no data transmission (or user requests) after a certain period of time in the sleep mode. Secondly, the multilevel sleep strategy enables the small cell BSs to estimate the sleep and operational periods based on traffic profile (e.g., the time durations of the idle and sleep states. The small cells continue to select the sleep state whenever there is no data transmission and reception with UEs. The sleep duration is optimally matched with the sleep depth (i.e., optimized deactivation, actual sleep level, and reactivation transition.

In [3], the sleep-wake scheduler scheme enables a small cell BS (D.2) to exchange information with its adjacent neighbouring BSs, and determine the sleep schedule (O.1) based on the traffic load of itself and its adjacent neighbouring traffic load in a heterogeneous network (N.1). The scheme considers active (S.1), sleep (S.3), and deep sleep (S.4) states. The scheme proposes a BS pairing mechanism that identifies pairs of BSs to maximize the number of BSs that undergo the sleep state with reduced total transmission power without affecting radio coverage. The purpose of pairing mechanism among the BSs is to enable a BS carries out transfer or share its traffic load to its nearby or adjacent BSs. The scheme has been proposed for BSs with low traffic load and high traffic load respectively. For low traffic load BS, the scheme enables a BS to transfer its traffic load to a pair of BSs with moderate traffic load, so this BS can enter to sleep state or deep sleep state to achieve energy efficiency. For high traffic load BS, the scheme enables a BS to transfer all or part of its traffic load to a single or multiple pairs of BSs with moderate traffic load to achieve load balancing among the BSs. This BS will then undergo sleep state to reduce energy consumption. For each situation, it must ensure enough BSs in the sleep state depending on the peak or off-peak period to cater for a sudden surge of traffic load and achieve load balancing, while the rest of the BSs can undergo deep sleep state. The proposed sleep-wake scheduling scheme has shown to reduce energy consumption in the network.

In [4], the sleep-wake scheduling scheme enables macrocell CC (D.1) and small cell BSs (D.2), to determine sleep schedule among the BSs by taking up the load of any new incoming UE in the presence of network interference (C.4) among the BSs and switching delay (C.5) between the BSs. The scheme considers active (S.1), sleep (S.3) and deep sleep (S.4) states. Two situations are considered. Firstly, when a new UE arrives at the nearest deep sleep BS, the CC will check for the availability of neighbouring active BS to take up the load, so the BS can continue remains at its deep sleep state to save energy. Secondly, if the UE arrives at an active BS, the CC will check if the BS is at its maximum load, otherwise the CC will wake up a deep sleep neighbouring BS to serve the traffic. Likewise, if a UE leave the BS, the CC will check the load of the neighbouring BS, if it can take the load of the remaining UE, then the UE will be offloaded to the neighbouring BS and turns the existing BS to deep sleep state. This scheme considers a distinct distance between the BSs to avoid interference among the BSs and to ensure they are near enough to carry out load distribution. The proposed sleep-wake scheduling scheme has shown to reduce energy consumption especially during low traffic load.

### *B. Deterministic Sleep Duration*

In [5], the sleep-wake scheduling scheme enables small cell BSs (D.2), particularly femtocell, to use a sleep schedule with deterministic sleep duration (O.1), which is adaptive to the presence and waiting time of requests from UEs in each time window in the presence of multiple small cell BSs (C.2) overlay with macrocell BS . The scheme considers active (S.1), idle (S.2) and sleep (S.3) states. During the sleep state, the sleep duration, which is a deterministic value, is determined based on the maximum waiting time of a request or delay the responding time to a UE request [6]. In order to reduce request loss, the UEs send requests to small cell BSs in the order of their arrivals so that: a) a request with a longer waiting time is served first; and b) a request is served before its maximum waiting time, which is a deterministic value calculated based on the number of neighbouring UEs and the sleep duration of the small cell BS. Based on the maximum waiting time of the UEs' requests, the small cell BS undergoes synchronization that adjusts its sleep-wake schedule, which allows the small cell BSs to wake up and receive requests from UEs upon waking up. For synchronization, the small cell BS sends a SS to UEs upon switching back to the active state. The proposed sleep-wake scheduling scheme has shown to increase the sleep duration of small cell BSs, as well as to reduce the loss and waiting time of requests from UEs.

In [7], the sleep-wake scheduling scheme enables small cell BSs (D.2) to sleep in different sleep modes to determine a longer sleep period (O.2) while determining the handover of data network between the BSs. The scheme considers four levels of sleep state (S.3): a) transition mode, which is a transition phase between active and sleep states, allows some transmitter subcomponents (e.g., power amplifiers) of the BS to undergo the sleep state while the rest of the subcomponents are still active so that the BS can still remain operational, such as receiving data packets from UEs; and b) sleep modes 2, 3, and 4 allows all transmitters of the BS to undergo the sleep state with reducing energy consumption and increasing sleep duration. The BS must increase or reduce the level of its sleep mode in sequence as required by the underlying transmitter subcomponents; for instance, the BS must enter sleep mode 3, followed by 2, the transition mode, and finally the active mode, in order to wake up from sleep mode 4. The BS can: a) enter the transition state whenever the BS is not actively transmitting; b) transit in between transition mode and sleep modes based on the models of the traffic load and UE requests (e.g., a burst of user requests or data); c) enter a higher sleep mode whenever the BS is idle for a longer time duration, and enter a lower sleep mode whenever the traffic is bursty in nature; d) wake up whenever there is a certain amount of user requests from UEs or a certain amount of data for transmission; and e) wake up periodically to transmit essential signals, such as synchronization signals (SS) and perform essential tasks, such as random access channel.

### *C. Sleep Timer*

In [3], the BS has two main components to improve its awareness of its operating environment. Firstly, a local timer circuitry module that collects own information (e.g., own traffic load estimate) and neighbouring BSs' information (e.g., the number of UEs) at regular intervals, and estimates the sleep duration, then dynamically decides on its state of operation based on the traffic load. Secondly, a wake-up receiver module that will wake up the BSs to check if there is any neighbouring BS which is in idle state. If there is, the BS will continue to sleep. If none, the BS will switch from sleep to idle so that it can handle requests from another BS. Through these two components to monitor the energy level of the BSs, thus it will help to reduce energy consumption on the network.

In [7], the sleep-wake scheduling scheme enables the small cell BSs enter to different sleep state level periodically, in the presence of switching delay (C.5) among the BSs. The sleep mechanism is triggered by a timer. The timer will detect the inactivation period of a BS, if it has been idle for some time, the timer will deactivate the BS to enter to the first level of sleep mode. The prolonged idle period of a BS, will cause the timer to further deactivate the BSs to enter to a higher sleep mode level, i.e. the deep sleep state to reduce energy consumption. When there is UE requests, the timer will activate the BS from sleep state to active state to serve the request. The scheme also takes into account SS periodicity between 5 ms - 40 ms. It is shown that longer SS periodicity, i.e. 40 ms will gain more energy saving as compared to shorter SS periodicity because the BSs are able to enter to deep sleep state to gain more energy saving.

In [8], the sleep-wake scheduling scheme enables the UEs (D.3) to carry out beam searching and packet served for data transmission. The scheme considers active (S.1), sleep (S.3) and deep sleep (S.4) states on the UEs. Each state is controlled by a timer, which will provide information to the UE of when to wake up to receive any incoming packets. To do this, UE will carry out a beam searching process. During this process, UE searches for beams and looks for the packets to match the transmission. Beam searching is crucial for alignment of beams between UE and BS. During traffic peak period, the UE is not able to transit to long sleep state. This results in lower power saving and delay of the served packets. On the other hand, during traffic low period, UE is able to switch to deep sleep state to improve energy efficiency. Total cycle time, total waiting time of served packets, total sleep time and sleep cycle are calculated. In order to gain more energy saving, longer sleep cycle is proposed through the implementation of longer short sleep timer to increase sleep time on the UE to improve energy efficiency. This scheme has shown to have an effective power saving at the UE.

### D. Monitoring Area

In [9], the sleep-wake scheduling scheme enables small cell BSs (D.2), to determine sleep schedule (O.1), in the presence of massive amount of traffic (C.1) in a heterogeneous (N.1) network and UE mobility (N.3) environment. The scheme considers active (S.1), idle (S.2) and sleep (S.3) states on the BSs. In order to determine whether a BS should enter the active or sleep state solely on its own information (i.e., traffic load), rather than one-hop neighbourhood information (e.g., neighbouring BSs' traffic load) in [3]. With the lack of information of its neighbouring BS, it faces a challenge where it is difficult for a sleeping BS to switch to active. This is because it is not aware of how much traffic is being supported by the other existing active BS. Hence, it makes it hard for a sleeping BS to determine the opportune moment to switch on based on only local information that the BS has. Thus, in order to put as many BSs to sleep mode to reduce energy consumption, each BS or nearby BSs need gather traffic information of each other. Based on the estimates of the distance between the active and non-active (i.e., idle and sleep) BSs, the number of active BSs in an area is estimated. To do this, the BS requires to establish a radius monitoring area, so it is sensitive enough to reach to the nearby BSs to gather information about the current load of the nearby BSs. If there is an active BS nearby and still be able to take additional traffic, two decisions could be made by the current BS. Firstly, the BS can switch from active state to sleep state to save energy. Secondly, the BS can reduce its radius monitoring area, so it does not need to serve a wide coverage to reduce energy consumption. To avoid path loss of any incoming new UEs, the BSs will continue to monitor its environment. If the UE could be covered by an existing BS or there is a redundant coverage of BS, it will reduce its monitoring area, otherwise it will extend the coverage monitoring area to serve the UE. Whenever there is a sudden hype in traffic load, the BSs will adjust their monitoring area simultaneously to ensure all the UEs could be served without path loss.

In [10], the sleep-wake scheduling scheme achieves higher energy efficiency by enabling small cell BSs to enter into longer sleep duration (O.2) in a heterogeneous network (N.1) with UE mobility (N.3) environment. The scheme considers idle (S.2) and deep sleep (S.4) states. The idle state consumes higher energy than deep sleep but can wake up more quickly than deep sleep state. On the other hand, the deep sleep state though consumes less energy but will consume more energy for a wake-up call. There are two mechanisms being considered. Firstly, neighbouring BSs can wake up a small cell BS, which is not aware of its own information, from the sleep state to the active state based on their information (i.e., traffic load and channel state information) which can be gathered from their respective UEs. Hence, neighbouring BSs know when and under what conditions the adjacent BS should be active or sleep. Secondly, a BS wakes up periodically to detect the environment, and returns to sleep when the criterion for being active is not satisfied. Two types of UE mobility levels (i.e., low and high mobility levels). In high mobility scenarios, longer idle state with shorter deep sleep state durations provides higher energy efficiency since the BS can capture the dynamicity of network and traffic load variations. On the other hand, in low mobility scenarios, longer deep sleep state with shorter idle state duration provides higher energy efficiency since it can still capture the dynamicity of network and traffic load variations in time despite shorter idle state duration. The proposed sleep-wake scheduling scheme with idle and deep sleep states in a UE mobility environment has shown to achieve better energy efficiency rate.

## V. CONCLUSION

The network traffic is facing a significant increase in the last decade due to the increase usage of mobile devices. This high usage has caused a drastic increase of the energy consumption of mobile networks. For this reason, many researches have been carried out to design the most energy efficient way to reduce energy consumption in the network traffic through the deployment of small cell BSs. This paper has reviewed some recent approaches of sleep-wake scheduling scheme in the BSs, which is an important method to reduce energy consumption on the network. This area is a promising areas of research for recent years and also years to come for a green network environment.

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