An Overview of Cell Zooming Algorithms and Power Saving Capabilities in Wireless Networks

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Abstract
Cell zooming has emerged as a potential strategy to develop a green communication system in our society and it has become an essential research area of wireless communication. Aiming to highlight the trend of existing cell zooming algorithms and their power saving capabilities, this paper reviews a number of cell zooming algorithms that have been proposed in the literature. Static cell zooming algorithms are effective for off-peak hours and their maximum power saving capability is 50% since off-peak duration is typically not more than 12 hours.Meanwhile dynamic cell zooming algorithms are applicable in full-day operation and they are useful not only for power saving but also for load balancing. However, on/off switching delay, signalling overhead due to traffic information exchange and how to attain information of traffic spatial distribution are existing challenges in dynamic cell zooming algorithms. One noticeable point is that relative power saving in dynamic cell zooming algorithm is less than 50% if traffic spatial distribution is considered. Since location management (LM) was designed for effectively servicing to customers, further researches could lead to work on location management (LM) based cell zooming algorithms for both effective servicing and energy saving.

Keywords: *Cell zooming, Green communication, Static switch-off algorithm, Dynamic switch-off algorithm, Location management*

1 Introduction

Today, two critical issues that come up with the increasing number of wired and wireless networks are larger energy demand to supply those networks and the footprint of CO_2 emission from massive energy production. In previous studies, it was reported that 3% of world's electrical energy is taken by information and communication technology (ICT) sector and it is responsible for 2% of world's CO_2 emission [1-4]. Although updated energy efficient devices are currently being deployed, the energy demand for communication is being increased by larger and larger number of communication infrastructures and customer premises. At this point, a larger portion of this energy demand is found in wireless communication networks rather than in wired networks [5]. More specifically, in a wireless network, base stations consume about two-third of total network power consumption and are logically responsible for 70% of CO_2 emission from entire network [6,7]. For this reason, management on energy consumption of wireless base stations has become an essential topic of discussion in the research society. In a wireless network, it is found that the operation of base stations regardless of traffic intensity and users' location in the network leads to unnecessary energy usage. This fact bears a conceptual strategy called "*cell zooming*" to optimize the energy consumption of base stations in a network. In a few words, cell zooming is the reduction or increment of cell size from its

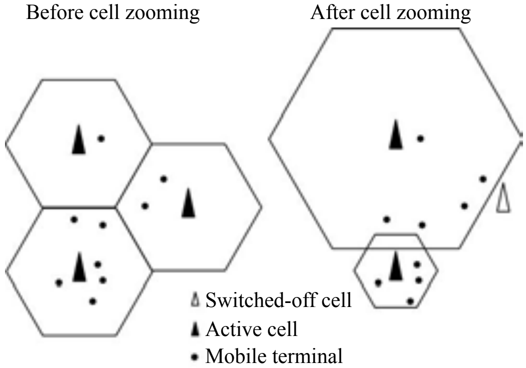


Figure 1: Conceptual scheme of cell zooming.

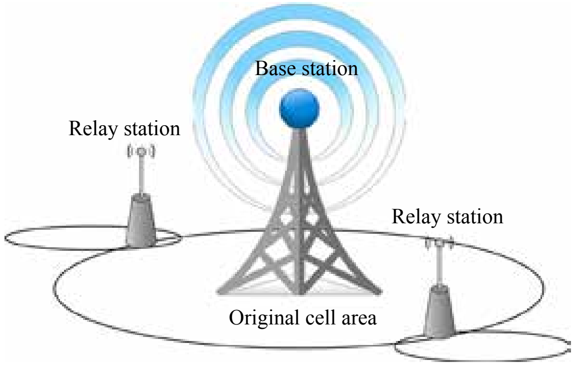


Figure 2: Relay-assisted cell zooming.

originally designed size in accordance with the traffic condition in a cell.

The advantages offered by cell zooming concept are reduction of power consumption and solving traffic congestion problem [8]. For example, as illustrated in Figure 1, the cell with light traffic load can zoom out to serve some of the users in two other cells. This reduces the traffic load in its neighbouring cells and some cells can even go switch-off, which will result in energy saving.

On the other hand, a number of challenges still exist to deploy cell zooming strategy in practical application. First, a trade-off between energy saving and effects on quality of services (QoS) occurs due to uncertainties in the forecast of traffic information in the network. Second, if awareness on traffic and QoS is taken in cell zooming, a massive information exchange among mobile terminals, base stations and central control server is required. This can lead to complexity and high cost of signalling overhead. Third, it is not so easy to practically construct an infrastructure to perform such complex cell zooming algorithms.

Thus, in the literature, many researchers have proposed with various feasible cell zooming algorithms balancing between power saving and the challenges mentioned above. Although these cell zooming algorithms have similarity as a basis, a partial diversity of those proposed cell zooming algorithms makes them different in power saving capability and complexity. Therefore, a trend of researches on cell zooming has been built from initial point to current position. Thus, the objectives of this review are 1) to present the trend of cell zooming algorithms that have been proposed in the literature and (2) to perform a comparative study on the effectiveness of cell zooming algorithms in term of power saving. This will provide a clear overview on potentiality of each of existing cell zooming algorithms and a direction for further research.

2 Conception of Cell Zooming

Although it is commonly termed as "*cell zooming*," there is a conceptual diversity. It can be explained as follows.

2.1 *Relay-assisted cell zooming*

In this concept, the originally designed cell size is not zoomed out. At the edge of original cell, a moveable or fixed relay station is applied as shown in Figure 2 so that the transmitted power of main base station is amplified and retransmitted at the same frequency to further distance. Sometimes, relaying is performed by mobile terminal [9]. Thus, this concept is also seen as "*cell zooming*" although the original cell is not zoomed out in reality [8-10].

2.2 *Multi-point coordinated cell zooming*

This concept also brings "*cell zooming*" without resizing the original cell size of each base station. Figure 3 helps in the explanation of this concept in which the designated mobile terminal is served by multi base stations at the same time. Thus, from the perspective of mobile terminal, the cell size is virtually magnified although the actual cell sizes of base stations do not change. Thus, this concept is also termed as "*virtual cell zooming*" or "*virtual MIMO system*" [8,11,12].

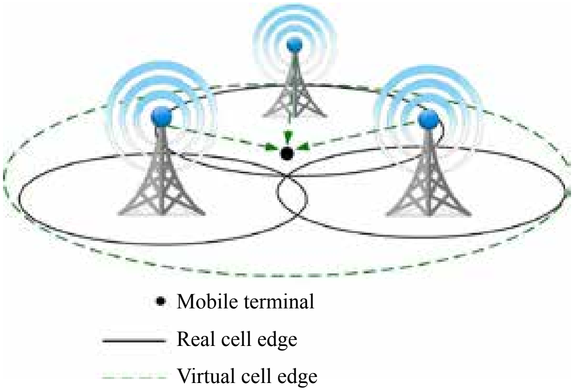


Figure 3: Multi-point coordinated cell zooming.

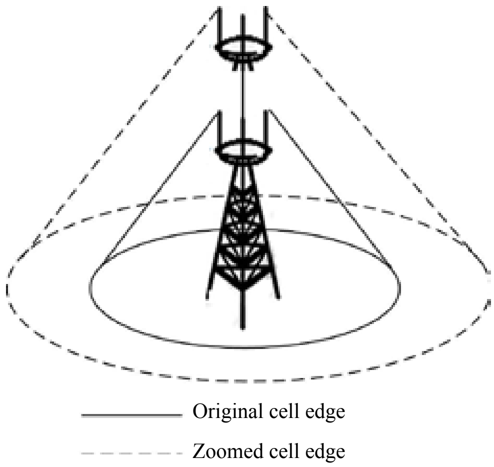


Figure 4: Physically adjusted cell zooming.

2.3 *Physically adjusted cell zooming*

In this concept, the original cell size is actually reformed by adjusting the parameters such as antenna height or transmitted power [8,13,14]. As shown in Figure 4, the cell edge of the base station can be changed by adjusting antenna height. It also should be noted that setting sleep mode and switching off the cell are included in this concept. At the same time, it should be noted that some authors [15] alternatively use "*switch-off*" and "*sleep mode*" because energy consumption in sleep mode is negligible and it is the nearly the same as switching-off.

To implement the physically adjusted cell zooming in practical operation, there are two basic requirements. These are –

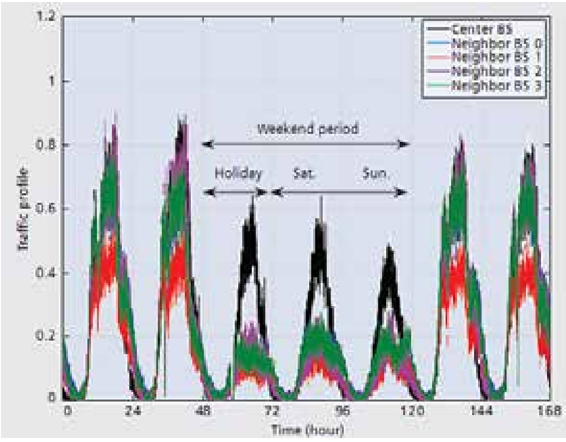
- Algorithm for gathering the traffic information in the network and cell zooming process
- Infrastructure to process the traffic information and to perform cell zooming

Here, the required infrastructure to process the traffic information can be either integrated in base stations as distributed arrangement or built as a separate system as centralized plan depending on the algorithm [8]. However, in most of previous works, only the algorithm is the focal point of research and the details of the required infrastructure are rarely discussed. Indeed, the infrastructure required for a particular algorithm can have influence on the possibility and initial investment for the algorithm in practical implementation. For instance, equipment needed for cell zooming by means of adjusting antenna height is more complicated than cell zooming by means of adjusting transmitted power. Likewise, cell zooming by means of deploying relay stations could be simpler but more expensive than that by adjusting transmitted power. Thus, the infrastructure needed for a particular cell zooming algorithm should be a performance metric to judge its potentiality.

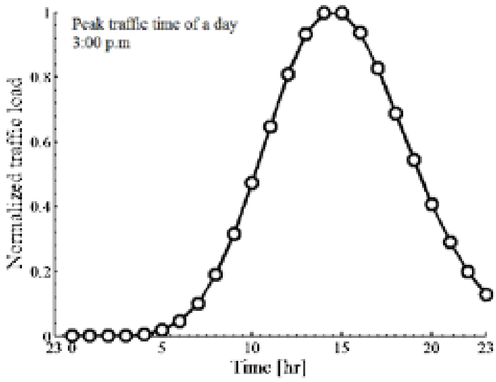
3 Traffic Arrival Pattern and Traffic Spatial Distribution used to Analyze Cell Zooming Network

In the review of cell zooming algorithms, understanding on the traffic arrival pattern and traffic spatial distribution in a network should come first since these are the most fundamental considerations in developing and discussing a particular cell zooming algorithm.

Traffic arrival pattern is basically known as the number of call arrivals to a base station or in a network during equally divided time intervals in a full-day operation. It can be manually recorded for a base station. Since a base station or a network may not receive the same number of calls every day, the traffic arrival pattern of a base station or in a network is commonly estimated by using a mathematical model called "*Poisson distribution model*" that can match with manually recorded traffic sample in a day or in a week [16]. Figure 5(a) shows the real traffic profile of a wireless access network for a week. According to the pattern, it is obvious that the calling rate at day time is higher than that in the early morning and night hours [17].



(a)



(b)

Figure 5: Traffic arrival pattern (a) real recorded pattern [17] (b) simulated pattern with Poisson distribution.

Another observation is that the traffic decreases during holidays and weekends. By using this sample, approximate traffic pattern for long term can be estimated by using *Poisson mathematical model* as follows [16].

$$\lambda(t) = \frac{p(t,\mu)}{\max\,[\;p([t],\mu)\;]}, \quad t = 1, 2, 3, \ldots \qquad (1)$$

$$p(t,\mu) = \frac{\mu^{t}}{t\,!}\,e^{-\mu} \qquad (2)$$

where, $\lambda(t)$ is normalized traffic at a time, p is Poisson distribution function, t is the specific time in a day and μ is mean value where peak number of events happened. Then, Figure 5(b) shows the approximate traffic arrival pattern in a cell or a network by using Poisson distribution with a mean value of 15. Thus, the peak traffic rate during a day occurs at 3:00 p.m and also it is changeable to match with the recorded sample from a base station. Shortly, in most of cell zooming algorithms, traffic arrival rate to a wireless base station or a wireless network at an interested time is simulated by means of *Poisson mathematical model*.

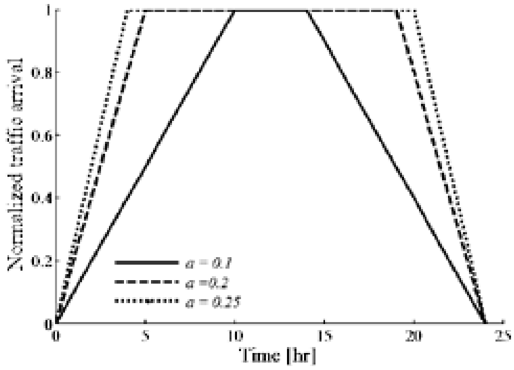


Figure 6: Trapezoidal traffic profile.

Although Poisson traffic model is very common in many works, some authors [18-20] had proposed a trapezoidal traffic pattern for more simplification. The mathematical model for trapezoidal traffic pattern can be developed as follows.

$$\lambda(\tau) = \begin{cases} a\,t & 0 \le t \le 1/a \\ 1 & 1/a < t \le T - 1/a \\ 1 - a[T - 1/a] & T - 1/a \le t \le T \end{cases} \qquad (3)$$

where, a is angular coefficient, t is the local specific time and T is the time interval. Figure 6 shows the different trapezoidal traffic profiles with different angular coefficients. The time constraints in Eq.(3) also are modifiable to obtain required trapezoidal shape.

The spatial distribution of traffic in a cell or in a network is an unpredictable phenomenon since it solely depends on the mobility of mobile terminals. Thus, in many of previous works, it is commonly assumed that the traffic is uniformly distributed in spatial domain for simplification. However, some studies had taken the spatial distribution of traffic into account to have

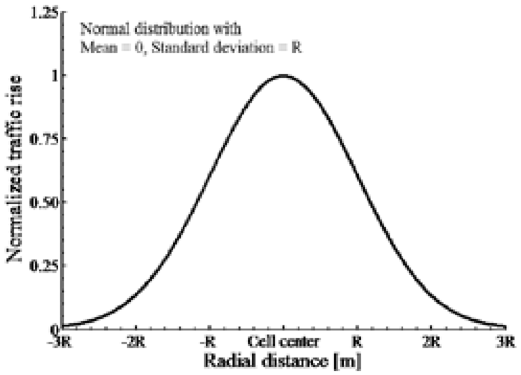


Figure 7: Spatial distribution of traffic in a cell.

a more analogue situation as practice. For instance, the authors of [8,21] considered that the traffic spatial distribution follows the normal distribution with mean at central point of each hot spot and a specified standard deviation as shown in Figure 7. A new traffic arrives to hot spot with 5-25% more probability than other areas. Here, the hot spot means the base station in busy sites such as city center. Although, no experimental sample is available, two conceptual considerations mentioned above are reasonably acceptable corresponding to the cell cluster of interest because traffic in some sites (e.g. rural areas) could be uniformly distributed and that in some places (e.g. urban area) could appear non-uniformly.

4 Cell Zooming Algorithms

4.1 *Conceptual derivation*

Although "*relay assisted cell zooming*" (see [22]) and "*multi-point coordinated cell zooming*" (see [23-24]) are conceptually accepted as "*cell zooming*," a focused discussion will be given to the scope of "*physically adjusted cell zooming*" which has been introduced in section 2.3. It has the following conceptual derivation.

Cell zooming (specifically, "*physically adjusted cell zooming*") is alternatively termed as "*cell breathing*" [6]. To the best of our knowledge, "*cell breathing*" was firstly introduced as a load balancing method in CDMA and WDMA networks in earlier works [25-27]. At that time, most of researchers mainly focused on the impact of "*cell breathing*" on the soft handoff margin shifting and call quality rather than power saving [25]. Then, the "*sleep mode*" concept was introduced as a power saving mechanism for wireless access network in IEEE 802.11 and IEEE802.16e specifications [28-30]. Although "*sleep mode*" was intended only for mobile terminals (MTs), it also has been adopted for base stations (BSs) in communication research society. Setting base stations into sleep mode can also be seen as cell zooming because the convergence umbrella is shrunk to zero. That is why cell zooming gets an advantage of load balancing from "cell breathing" concept and an advantage of power saving from "*sleep mode*" concept.

4.2 *Classification of cell zooming and related researches*

The cell zooming algorithms can be grouped into two main categories according to their basic similarity. These are –

- Regular or static switch-off algorithm
- Dynamic switch-off algorithm

4.2.1 Regular or static switch-off algorithm

The regular switch-off algorithm is simpler compared to dynamic algorithm. In such algorithm, the cells are switched off in predefined pattern by network control server during a predefined time period when low traffic arrival is expected. The active cells are managed to zoom out by increasing transmitted power or antenna height to cover the convergence umbrella over the switched-off cells. In other approach, low traffic hours are defined by setting a specified traffic threshold. Since the daily traffic distribution is mostly considered as regular and uniform throughout the network, the switched-off cell pattern will not vary time by time during cell zooming period and also day by day. Thus it is seen at static algorithm. Some of possible switched-off cell patterns and a sample of time frame for regular switch-off algorithm are shown in Figure 8 (a)-(b). All the cells work at normal mode at out of cell zooming period. The main advantages of this type of algorithm are simplicity and noticeable power saving at night hours. On the other side, the limitation of this algorithm is that it cannot be applied for full-day operation in which time-dependent traffic fluctuation and traffic spatial distribution is high. Also, it is not useful for a location where traffic arrival pattern is not consistent day by day.

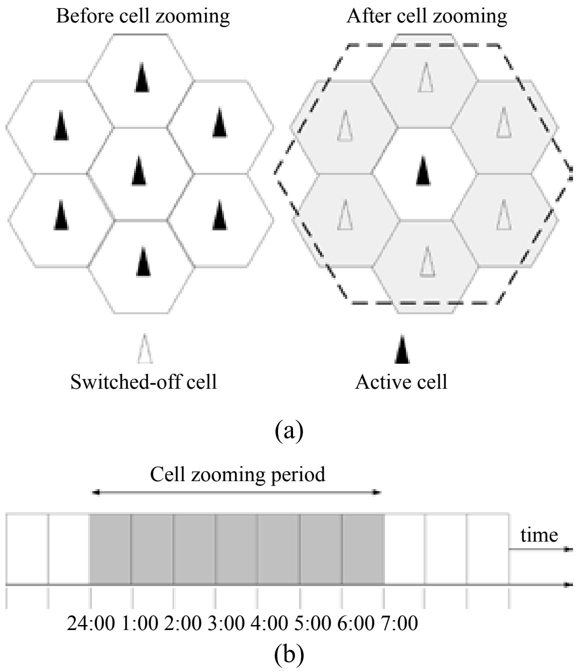


Figure 8: Basic regular switch-off algorithm (a) possible switched-off cell pattern (b) feasible time frame.

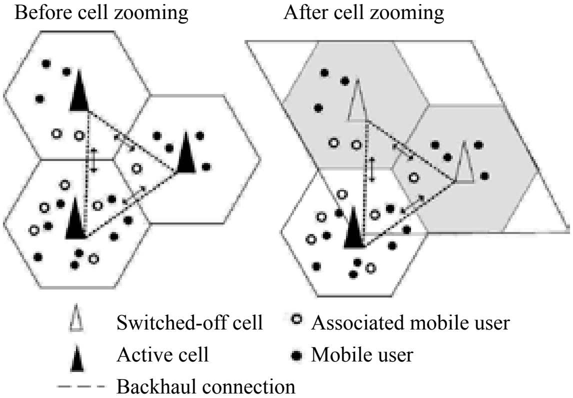
To the best of our attempt in this review, the earliest regular switch-off algorithm was proposed by Chiaraviglio et al. [31]. In this algorithm, three different site scenarios such as residential scenario, office scenario and hierarchical scenario were considered. Also, the authors considered that the peak traffic (active calls) in residential site happens during night while that in office site appears during day hours. At this point, one can realize that when the site of interest is relatively specific, a survey should be taken on corresponding traffic profile rather than following general traffic profile. For instance, as the authors considered, today mobile subscribers in urban residential area prefer social calling or data accessing during relaxing time before midnight. Then, Marsan et al. [32] proposed different switch-off patterns for different network topologies such as *Hexagonal*, *Crossroads*, *Manhattan* configurations. From this work, it was noticed that 4 out of 5 switch-off pattern from *Crossroads* configuration gave the largest percentage of power saving. In later works [21,33,34], QoS constraints were applied to adaptively choose a switch-off pattern.

However, inconvenient situation exist to perform cell zooming with a particular pattern in a given network topology. Regarding this issue, the authors of [20] explained one possible problem and solution. The possible problem is that sometimes "*insufficient cell zooming*" can occur due to large cells deployment. Thus, the solution to this issue is deploying smaller cells to overcome the "*insufficient cell zooming*". Nahas et al. [14] also stated that sleep mode with smaller cells can save more energy than using larger cells. Relating to smaller cell deployment, the authors of [19] highlighted the potentiality of "*HetNets*". HetNets are multi-tier radio access networks in which micro and/or pico/femto cells are overlaying the macros [19]. The authors discussed that deployment of pico BSs would result in more energy efficient architecture.

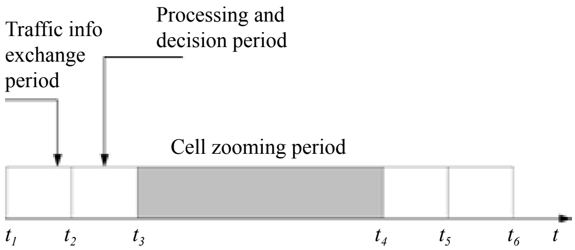
Here, a point that should be noted is that setting sleeping mode in a long period may not be always effective because energy consumption of active cells increases due to far traffic from slept cells. It is called "*network impact*" [35]. It was proved by the authors of [36] by evaluating the performance of "*Semi-Static-Sleep Mode* (*SSSM*)" concept in which the base stations were set in sleep mode in an order of one hour. It was found out that semi-static approach was less effective in power saving compared to sleep mode in minute interval (dynamic concept) but it could reduce fewer activation/deactivation times and signalling overhead. When a recap is taken, it can be noticed that two focal points in these regular switch-off algorithms are switched-off cell pattern and switch-off time frame.

4.2.2 Dynamic switch-off algorithm

The regular switch-off algorithms are no longer reliable in the networks with irregular traffic arrivals and these are limited to only off-peak hours. The dynamic cell zooming algorithms are developed to overcome these drawbacks. Thus, it is relatively more complicated than static switch-off algorithm. In such algorithm, the traffic condition in each cell or a cluster cells is dynamically inspected. This traffic load information is exchanged among collaborative base stations themselves (in distributed plan) or via central server (in centralized plan). Then, the cell zooming decision is made depending on the traffic load condition in each cell. Thus, on/off cells are not statically



(a)



(b)

Figure 9: Basic dynamic switch-off algorithm (a) conceptual scheme (b) a sample time frame.

defined. This dynamic algorithm can provide power saving and at the same time it can solve traffic congestion problem if it occurs. However, the challenge in dynamic switch-off algorithm is how to manage the requirement of massive information exchange among mobile users, base stations and control server. In addition, this type of algorithm is more acceptable for micro cells rather than in macro cells because reactivating time for switched-off macro cells is considerable to set them in fast dynamic on/off operation. Figure 9 (a)-(b) demonstrate the concept of dynamic switch-off algorithm and a sample of time frame. It should be noted that the cell zooming period in time frame of dynamic algorithm can vary according to traffic condition in each cell. For instance, if the traffic load is full in all cells, they will not perform cell zooming and there will be no cell zooming period. The information exchange period and processing period will alternatively go on.

The earliest dynamic cell zooming algorithm in wireless base stations was introduced by Saker et al. [15]. The authors proposed the sleep mode concept for 2G/3G coexisted network by giving a management on traffic allocation between 2G and 3G base stations. The authors recommended that setting sleep mode in 2G base stations would provide larger gains (energy saving and QoS) since 3G system can support high rate services that are not supported by 2G system. Since that time, the authors had considered that the infrastructure needed for sleep mode operation is an important issue to increase the possibility of the concept. The same authors [36] proposed sleep mode concept for 2G and HSPA/HSPA+ networks with dynamic and semi-static resource management. In dynamic concept, resources of base stations are activated or deactivated according to traffic load at every minute interval, meanwhile at every one hour interval for semi-static concept.

Then, Zhisheng et al. [8] proposed centralized and distributed dynamic cell zooming algorithms by taking traffic spatial distribution into consideration. According to their simulated results, centralized algorithm performs better than distributed algorithm and static algorithm. Although dynamic cell zooming algorithms show better performance, but one of the great challenges in practical implementation is dynamic shifting from active state to inactive state and vice visa. The authors of [37] explained that it is not realistic to immediately activate the resources and it can cause capacity problems in practice. Also, if activation-deactivation is performed several times, it can lead to a large signalling overhead. Thus, the authors presented the optimal control for base station sleep mode. Consequently, Xueying et al. [38] showed that setup time and close down time have impact on the energy efficiency.

In other approach to have a fast response in active-inactive shifting, the authors of [39] considered management on only power amplifier rather than all the components of base station. Following the traffic condition, the power amplifier was set into switching-on state, idle state, transmitting state and switch-off state. In accordance with traffic condition, the power amplifier was put into switch-off or idle mode to save the power consumption. The same approach was done by Ferling et al. [40].

Regarding to the ON/OFF durations in dynamic base station sleep mode algorithm, one important fact is that OFF duration can adversely affect QoS in some applications. For example, if the cellular network is connected to VoIP network, the maximum allowable delay is 20 ms. In addition, subframes that carry essential synchronization signals and automatic repeat request signals should not suddenly switched off [41]. In this regard, Wang et al. [41] developed sleep mode algorithms for LTE base stations basing on the time-domain and spatial-domain of physical layer structure. Having the same idea, Niu et al. [42] explained trade-off between energy saving and delay to the customers. The mean delay has linear relationship with the number of awaited users during startup and sleep mode.

So far it has been discussed about power consumption of base stations in various cell zooming approaches. One distinct work [43] took power consumption of customer premises into account in proposing a cell zooming algorithm. The authors stated that reducing of active cells can increase the power consumption in customer's premise that cannot be neglected by operator. The reason is that customers in switched-off cells are relatively far from active cells. The finding in [44] also showed that number of active cells need to be increased to fulfill the compromised QoS when traffic spatial distribution is considered. Finally, as far as we notice, traffic spatial distribution is likely to become the most crucial fact to be considered in developing a particular cell zooming algorithm.

Thus, in the works of Prithiviraj et al. [45] and Jie et al. [46] carefully considered traffic spatial distribution in their cell zooming scenarios. Then, Balasubramaniam et al. [47] proposed different cell zooming approaches such as "*continuous zooming*", "*fuzzy zooming*" and "*discrete zooming*". In those algorithms, the location of the users should be known. Therefore, application of movement based update was proposed for detection the user location. Consequently, Tun and Kunavut [48] evaluated the performance of those cell zooming algorithms and they pointed out the less possibility of movement-based location update in "*continuous cell zooming*" algorithm and proposed periodic location update method for user location detection in "*continuous cell zooming*" algorithm.

To sum it all up, most of dynamic cell zooming algorithms are trying to solve two great challenges. These are how to reach the fastest and most optimum switching on/off scheme and how to accurately sense the user's location. In the future, fast switching could be accomplished with far modernized control systems and "*location management (LM)*" subject could be a feasible solution for sensing user locations.

4.3 *Distinct feature and power saving capability of cell zooming algorithms*

Table 1 describes the distinct feature and power saving capabilities of selected cell zooming algorithms. It should be remembered that power saving capabilities are not comparable to each other because algorithms are different in approaching perspective, predefined constraints and reference power consumption. For example, in some works [40,41,47], energy saving is expressed by correlating maximum static transmitted power without cell zooming to variable transmitted power with cell zooming while total power consummation was considered as reference point to evaluate the effectiveness of cell zooming in other works. From all works, it can be firstly noticed that static (regular) switch-off algorithms give power saving of 50% as maximum since they can switch off not more than 12 hours. Another noticeable point is that the relative power saving is less than 50% if the traffic spatial distribution is considered in the algorithm [8,17,21, 47,48]. It can be understood that cell zooming without switch-off will not result in considerable power consumption. For instance, in our work, cells are individually shrunk to zero or extended to its maximum range according to the farthest user location in each cell without switching off. Therefore power saving is very small. However, preferable features of approaches without switching-off plan are that these are more realistic, easier to implement, no inter-cell interference and less risk of QoS degradation.

4.4 *Leading direction of researches in green communication by means of cell zooming*

Figure 10 (a)-(b) explain our perspective on the researches for the green communication by means of cell zooming. Figure 10 (a) shows the logical cyclic diagram for the development of "*cell zooming*". The basic concept of "*cell zooming*" was born from practical experience and the idea with a purpose of load balancing. Then, it was introduced in a simplified approach for power saving. After that, its performance in real filed situations was presented. Now, it is at the stage of challenges, solutions and optimization. In the near future, it is expected to appear in practical applications.

Table 1: Distinct feature and power saving capability of reviewed cell zooming algorithms

No.	Algorithm [Reference No.]	Basic category	Distinct feature	Power saving capabilities
1.	Pattern oriented sleep mode algorithm [18]	Static (Regular)	Different trapezoidal traffic pattern and different network topologies	40.8-48.7% (**)
2.	Hetnets sleep mode algorithm [19]	Static (Regular)	Hetnets topology	0.6-35% (**)
3.	Cell size dependent sleep mode algorithm [20]	Static (Regular)	Insufficient cell zooming, smaller cell deployment	50% (as maximum) (**)
4.	Site dependent sleep mode algorithm [31]	Static (Regular)	Different site scenarios, different traffic patterns	50% (as maximum) (**)
5.	Topology dependent sleep mode algorithm [32]	Static (Regular)	Different network topologies, different traffic patterns	26.16-30.13% (**)
6.	QoS constrained sleep mode algorithm [33]	Static (Regular)	Different network topologies, QoS constraints	10-80% (**)
7.	Pattern oriented sleep mode algorithm [34]	Static (Regular)	Different switch-off pattern	50% (as maximum) (**)
8.	μ-BS oriented sleep mode algorithm [21]	Static (Regular) / Dynamic	QoS constraints, non-uniform traffic spatial distribution	28% (**)
9.	QoS aware sleep mode algorithm [36]	Static (Regular) / Dynamic	QoS aware in 2G and HSPA/HSPA+	12.6% (**)
10.	QoS constrained sleep mode algorithm [7]	Dynamic	QoS constraints (per-bit delay) in different network topologies	80-95% (**)
11.	Centralized and distributed control sleep mode algorithms [8]	Dynamic	Centralized and distributed control with non-uniform traffic distribution in space domain	20-48 %, 5-32% (**)
12.	Antenna height oriented sleep mode algorithm [13]	Dynamic	Adjusting antenna height and tilt angle optimization	33% (**)
13.	Cell size dependent sleep mode algorithm [14]	Dynamic	Centralized control, smaller and larger cell deployment, QoS constraints	10.7-12.9% (**)
14.	Radio resource management sleep mode algorithm [15]	Dynamic	Traffic allocation between 2G and 3G base stations, QoS aware	30% for 3G (**) 55% for 2G (**)
15.	Dense base stations sleep mode algorithm [17]	Dynamic	Non-uniform traffic and non-uniform base station distribution	8-29% (**)
16.	Network impact aware sleep mode algorithm [35]	Dynamic	Network impact aware	80% (as maximum) (**)
17.	Optimum on/off sleep mode algorithm [37]	Dynamic	Optimum On / Off time	Energy saving depends on number of on/off states
18.	On/off delay oriented sleep mode algorithm [38]	Dynamic	Set up time / Close down time	33% (as maximum) (**)
19.	Amplifier oriented sleep mode algorithm [39]	Dynamic	On/ Off amplifier	20-80% (**)
20.	Transceiver system oriented sleep mode algorithm [40]	Dynamic	Transceiver system on/off	5.2-20.5% (*)
21.	Physical lyaer oriented sleep mode algorithm [41]	Dynamic	Time domain and spatial domain of LTE physical layer structure	90% (as maximum) (*)
22.	Energy-delay oriented sleep mode algorithm [42]	Dynamic	Energy-delay	Energy saving depends on N-policy
23.	Mobile aware based cell breathing algorithm (MA-DBCB) [43]	Dynamic	Power consumption of customer premise	6.1-56%
24.	Super density network (SDN) sleep mode algorithm [44]	Dynamic	Super density network	Energy saving depends on number of active BS
25.	Self Organized Network (SON) cell zooming algorithm [45]	Dynamic	User location based	20% (as maximum) (**)
26.	Dense cellular network sleep mode algorithm [46]	Dynamic	Non-uniform traffic distribution in dense cellular network	Energy saving depends on mode holding time
27.	I. Continuos, II. Fuzzy, III. Discrete cell zooming algorithms [47]	Dynamic	User location based	40% (as maximum) (*)
28.	I. Continuos, II. Fuzzy, III. Discrete cell zooming algorithms [48]	Dynamic	User location based	4.7-12% (**)

** Total power consumption based   * Transmitted power consumption based

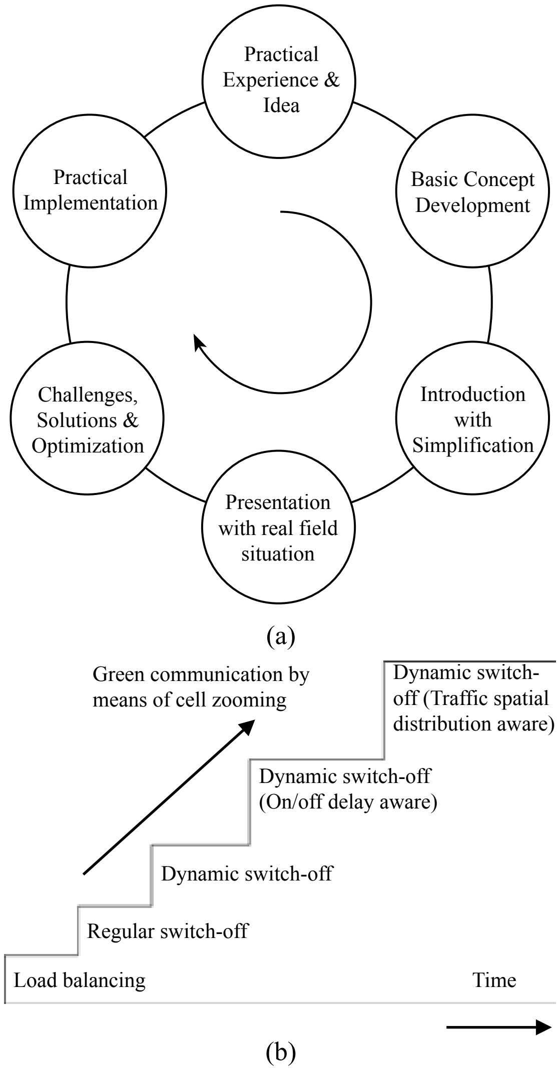


Figure 10: Current status and leading direction of researches in cell zooming (a) imaginary cyclic diagram (b) leading direction of cell zooming research.

Figure 10(b) illustrates the leading direction of researches pertaining to cell zooming. The earlier works were related to the impact of load balancing by means of cell zooming. After introducing for power saving, many researchers worked on power saving capabilities of different cell zooming algorithms in both static and dynamic approaches. However, great challenges emerged in dynamic cell zooming algorithms in which on/off delay and non-uniform traffic intensity in spatial domain must be aware to satisfy best the trade-off between energy saving and QoS effect.

Thus, current attempts are being pertinent to cell zooming algorithms with the awareness on QoS constraints. Finally, according to the two recent works [47,48], it is likely that the researchers are turning into location management to integrate it as a mechanism in developing more reliable cell zooming algorithms in the future.

5 Perspective on Location Management and Cell Zooming

In static cell zooming algorithms, it is mostly assumed that mobile terminals are uniformly distributed over the network to avoid requirement of traffic info exchange. This causes uncertainty in choosing in switch-off cell pattern and inability to provide load balancing in static algorithms.

Currently, in dynamic cell zooming algorithms, the information exchanged between base stations contains traffic intensity in each cell but not exact location of users and traffic. This leads to uncertainty in cell zooming, i.e, how far the active cell should zoom out into switch-off cells. Also, it cannot offer load balancing without knowing exact location of traffic.

These are ineffective due to lack of exact user location cell zooming. Therefore, it is worth to attain information of exact user location. The subject of location management (LM) was designed for tracing user location in the network for effective servicing and for cutting down paging cost. In LM, some strategies are applied to update the location of a user to the database of the network and the exact location of mobile terminal is known. This can fulfill the requirement of user location information in cell zooming algorithms.

Thus, it is expected that location management is the right choice to be integrated as a mechanism in cell zooming algorithms. By means of location management, incoming cell zooming algorithms are expected to be more effective and realistic.

One thing that must be improved together with location management is accuracy of distance measuring techniques to provide accurate distance of user form reference point. In this regard, future researches should give attention to cell zooming algorithm with different location update strategies and different distance measuring techniques.

6 Conclusions

This review highlights the trends of attempts for developing green communications by means of cell zooming. The earlier works on cell zooming were aimed at load balancing. Currently, researchers are trying to exploit it as an approach in developing green communication. So, a considerable extent has been attained. Yet great challenges still exist to fully guarantee compromised QoS when cell zooming is applied in a network. The static (regular) cell zooming algorithms are simple and effective for off-peak hours. The switching-off cell pattern and traffic pattern in time domain are focused points in the researches of regular switch-off algorithms. Then, the dynamic cell zooming algorithms are applicable in both off-peak and peak traffic hours and these are effective not only in power saving but also in load balancing, though far complex and far busy. The on/off switching scheme, delay in set up and close down time, user location based QoS constraints are being emphasized in the research of dynamic switch-off algorithm. One remarkable point is that cell zooming algorithms that consider spatial traffic distribution (exact user locations) and QoS constraints are more likely to become favorable and practical for real-field applications and these should be given more attention in the future. Since location management (LM) can give effective services in wireless communication, it could be an essential mechanism of cell zooming in the future.

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