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Power-aware fuzzy based joint base station and relay station deployment scheme for green radio communication

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ABSTRACT

In recent years, green wireless communication has received much attention of industrial and academic communities due to its ability to create eco-friendly power efficient networks. To support anytime-anywhere seamless broadband services to all mobile subscribers, more number of macro base stations (BSs) have to be deployed. The macro BSs are power inefficient and also responsible for large carbon dioxide (CO_2) emissions. The increase in the number of macro BSs will also increase the system cost and interference. The concept of multi-hop relay network has been widely discussed in long term evolution-advanced (LTE-A) standard, where the low power relay stations (RSs) are also deployed along with the macro BS to address the coverage and capacity issues. However, improper BS and RS deployment introduces power inefficiency, transmission delay, huge deployment cost and reduced throughput. Many of the conventional deployment schemes require iterative and complex computation. These deployment schemes are not eco-friendly and do not sustain for all channel conditions. In this work, we have proposed an eco-friendly, power-aware, fuzzy based BS and RS deployment algorithm to maximize the coverage and capacity of the system. Unlike the conventional methods, a new parameter called power consumption effectiveness ratio, which accounts for the greenness of the network is proposed and included in the fuzzy based decision making process along with the coverage ratio and traffic ratio. The simulation results prove that the proposed scheme is superior over the conventional uniform clustering and fuzzy based schemes. Further the proposed scheme is more suitable candidate for power-aware green radio communication.

1. Introduction

Wireless communication has become an indispensible part in our daily life by exchanging information reliably from anywhere, any time. The enormous increase in the number of mobile subscribers (MS) has proportionally increased the data rate demand. The MSs also demand anytime, anywhere wireless broadband services with high quality of experience. 4G standards like LTE-A and worldwide interoperability for microwave access (Wi-MAX) are ideally expected to offer gigabit internet experience to all the users [1]. This explosive growth in the wireless cellular network industry has contributed much to global power consumption. The increase in power consumption leads to higher system cost, limitation in power resources, higher greenhouse gases emission and electromagnetic pollution. However, over the last few decades, the researchers have focused on improving both the system capacity and data rate but ignored the environmental and societal impacts of wireless network. In the coming years, it is essential to consider the increase in power cost and the emission of CO_2 in wireless communication. Green wireless communication is an emerging concept that strives for improving power efficiency with reduced environmental impacts. The necessity to develop an eco-friendly green wireless communication has become more and more imperative as wireless networks are becoming ubiquitous [2].

Two basic requirements of green wireless communication are low power consumption and low electromagnetic pollution. As the number of MSs and needs of customers increases, the mobile operators are forced to increase the number of BSs. The composition of power consumption in a wireless cellular network is shown in Fig. 1. BS is the main power consumer in a wireless cellular network [3]. In Ref. [4], it is stated that the number of BSs was increased by 2 million per year between 2007 and 2012. Such an increase in the number of BSs results in uncontrollable emission of CO_2 in the global envi-

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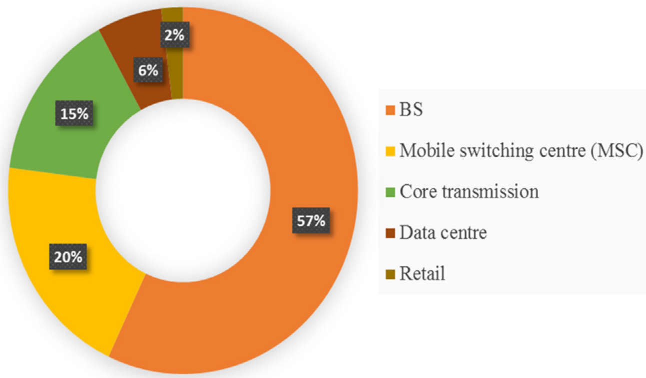

Fig. 1. The composition of power consumption in a wireless cellular network [2].

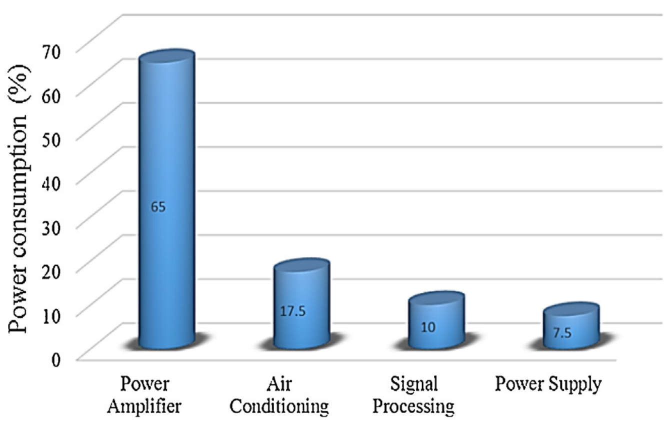

Fig. 2. The distribution of power consumption in a BS [2].

ronment. This also increases the operational expenditure (OPEX). The off-grid sites of BSs, which are used to cover remote places, are mainly powered by diesel-power generators. These electrical grids may cost nearly $3000 per year to operate. As mentioned in Ref. [2], the CO_2 emission associated with information and communication technology (ICT) was 151 $MtCO_2$ in 2002. 43% of this total is responsible by wireless communication. In 2020, the CO_2 emissions are expected to reach 349 $MtCO_2$. In Ref. [5], it is indicated that ICT consumes 600 TWh (Terawatt hours) of electrical power. This electrical power consumption is expected to reach 1700 TWh by 2030. These statistics persuade the researchers to develop the techniques to reduce the power consumption as well as the environmental impacts. In wireless communication, 57% of power is consumed by BS sites [2]. The digital signal processing transceivers, cooling units and the power back up units available in each BS site consume more power. The distribution of power consumption of a BS site is illustrated in Fig. 2.

In literature, various approaches have been discussed for green radio communication. Some of them are discussed here. The first approach is based on the usage of efficient power amplifiers (PA) in the wireless networks [6]. As indicated in Fig. 2, during wireless transmission, PA consumes more power than other elements. Therefore, highly efficient PA is essential to reduce the power consumption and cost. A special design known as Doherty design offers 30% to 35% improved power efficiency than the conventional narrow bandwidth PA designs [6]. This efficiency can be improved up to 50% by using digital pre-distorted Doherty architecture and gallium nitride amplifiers [2]. Present PA operates on high power dc supply. Since these PAs are independent of traffic load, most of the power is wasted. There exist two methods to reduce the power consumption of PA. In the first method, operating point of PA is minimized as per low, medium and high traffic loads. PAs without any signal transmission are deactivated in the second method.

In the second approach, unused blocks and resources of the cellular network are switched off periodically [7,8]. This switching off can be extended up to the cell level. The cell level switching off is done based on the traffic load conditions. The cells with low traffic load are switched off periodically and their services are handed over to the nearby active cells.

The third approach is cell zooming, where the cell size is adjusted based on the traffic load conditions [9,10]. The increase in the number of MSs in a cell increases the congestion level. In this approach, the transmission power of the congested cell is adjusted. After range adjustment, the MSs that are not covered by the congested cell are handed over to the neighbouring low traffic cells. If the neighbouring cell can provide coverage without zooming in, then the congested cell will fall into sleep mode, which reduces the power consumption. Even though this approach can improve the throughput and extend the battery life of MSs, it suffers from intercell interference, when all the neighbouring cells are zoomed out during the same time [11].

In the fourth approach, multiple input and multiple output (MIMO) based transmission schemes are used for power efficient transmission [12,13]. This mitigates the fading and increases the throughput without demanding more transmission power. S. Cui et al. proposed Alamouti's diversity based power efficient model for MIMO communication [14]. The power efficiency of the proposed scheme is also compared with various transmission schemes. The simulation results show that MIMO schemes are not always power efficient especially for low traffic load conditions. It is observed that MIMO schemes consume more power per circuit under low traffic load conditions.

Heterogeneous network deployment is the fifth approach, which improves both throughput and power consumption in wireless network [15]. A novel heterogeneous network deployment scheme for green radio communication is proposed in Ref. [16]. In heterogeneous network, macro, micro, pico, femto and RSs co-exist in the same geographic area. These cells differ in coverage range, cost, power, bandwidth and the number of users supported [15]. The different cells supported by LTE-A heterogeneous network are compared in Table 1. In heterogeneous network, portion of the traffic is offloaded to small cells. Small cells require low transmission power. It does not need cooling units. The dense deployment of small cells bring serving nodes closer to MSs [17]. This reduces the distance between the communicating nodes. The introduction of small cells reduces the total power requirement. The application of meta-heuristic algorithms for the deployment of various types of next generation network components are investigated in Ref. [18].

In LTE-A and IEEE 802.16 j standards, the concept of MHR network is introduced, where RSs are deployed along with BSs to improve the coverage and capacity [19,20]. RSs are more suited solution for the locations, where the backhaul connection is expensive or unavailable. The RSs also have other advantages like less CO_2 emission, less power consumption, easier and faster installation and low maintenance cost. Unlike BS, RS does not require direct backhaul link to the core network. Moreover, MHR network helps to improve network throughput and at the same time covers more number of MSs over a larger coverage area. Hence, MHR network is considered as one of the potential candidate to facilitate power efficient wireless communication [16]. The usage of RSs to extend the battery life was presented in an early study [21]. In Ref. [22], the possibility of a green communication using RS is presented. This paper also shows that the usage of RSs can reduce system power consumption, complexity and improve spatial reuse of radio resources.