TOWARDS GREEN HETEROGENEOUS NETWORKS-A Survey

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TOWARDS GREEN HETEROGENEOUS NETWORKS- A Survey

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Abstract— **It is the goal of researchers working in the field of future cellular networks to ensure that Heterogeneous Networks (HetNets) be far more energy efficient (EE) than their homogeneous counterparts. This drive towards reducing their energy consumption rate has led to considering HetNets as "Green networks". In this regard, lots of documents describing several research and developmental efforts are readily available. However, it remains unclear how researchers and technology developers alike intend to efficiently integrate the deployment, user association and resource allocation functions together. Consequently, this paper takes an inventory look at the state of art in green heterogeneous networks as it pertains to these key functions. Firstly, network deployment is discussed before considering user association and then, resource allocation. We conclude on advocating the need for an efficient synergy between these different functions, and also document particular future research directions in this regards.**

Keywords: Green HetNet, resource allocation, user association, network deployment

I. INTRODUCTION

In recent times, the Mobile communication industry has witnessed unprecedented and tremendous growth in the market. Mobile subscribers are constantly demanding more data to remain connected. The influx of mobile devices such as smartphones (Android, IOS, etc.), tablets, and laptops has also contributed to heightening this demand. This has caused network service providers to increase their network capacity in an attempt to meet this ever growing demand. One way of increasing their capacity is to deploy additional Base Stations (BSs) [1], [2]. However, with mobile communication technologies approaching their theoretical limit, network deployment is being replaced by an interlay of high powered BSs (HPB) and low powered BSs (LPB) [3], [4]. This new network architecture is known as Heterogeneous Network (HetNet). An analysis by OFCOM Plextek concluded that deploying HetNets could result to significant energy savings as compared to the use of additional macro BSs (MBS) for network upgrading[5]. This line of research is also driven by the high Carbon emission rate of the Information and Communication Technology (ICT) industry, which has been estimated at about 2% [6].

With specific focus on cellular networks, most research efforts in this subject are focused on reducing its overall energy consumption, which has a high emission rate in comparison to other ICT components, in order to reduce its contribution to 'Green house effect'. This trend of reducing energy consumption also extends to HetNets. However, we note that though low transmission power in HetNet might not necessarily result in an increase in energy efficiency (EEy), it could be an indication that enhanced performance can be achieved using less power. Therefore, since HetNets are conceptually the next generation networks, it is imperative that green solutions be considered for their deployment and operation. Therefore, an integration of HetNet deployment, resource allocation and user association forms a major consideration towards realizing 'Green HetNets'.

Consequently, our survey in this paper contributes to the general pursuit of Green Hetnets by discussing some factors that should be considered for the "Green" concept. In this regard, the paper is structured as follows: section II discusses HetNet Deployment, section III resource allocation section IV user association while section V concludes the paper as well as pointing out future research directions.

II. HETNET DEPLOYMENT

The deployment of HetNets is associated with many implementation challenges. These challenges give rise to a few questions such as "What is the optimal BS density and transmit power?", "How do they influence EEy?", "How can network traffic influence deployment?", among a few to mention. We note that a lot of research efforts have been invested in addresing these questions. Recently, it has been deduced that an optimal BS density and placement can improve EEy (EE) in HetNets [2]. As a follow up, additional network deployment strategies were explored in [7] to determine if it was better to increase network capacity using macrocell or picocell. It was shown that additional picocells proved to be more efficient. This EE will however saturate as the BS density increases beyond a certain threshold [5]. Furthermore, disparate transmit powers and BS placements in HetNets could impact on the overall interference level in the network. This will directly degrade the delivered Quality of Service (QoS). Therefore, to achieve an EE HetNet, an EE optimal deployment strategy must be adopted which will minimize interference.

A cellular network consists of three parts namely the core, the BS and the mobile terminals (MT) [8]. These parts contribute to the EE of the network. From literature, the BS seems to be the component of concern because of its high

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demand for energy. Core network consisting of the

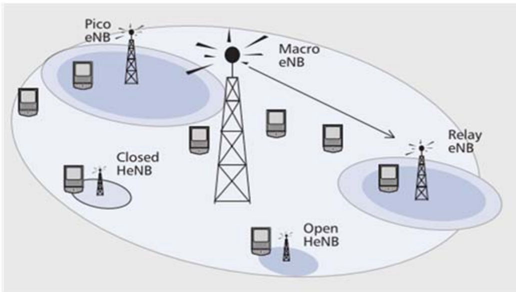

Fig. 1: A HetNet consisting of high powered and low powered cells [4]

backhaul has also received research attention especially in optimizating its performance [1], [9]. Although the least energy is expended by the MT, a lot of research has also gone into optimizing its EE for the purpose of increasing battery life [5]. The focus of this section will be on BSs. The BSs used in a HetNet deployment include macro, micro, femto, and pico BSs and relays.

Since the BS consumes the most energy, it has been proven to be more EE if they are powered down during low traffic periods. This could mean switching off the LPBs or HPBs, depending on which option is more EE during low traffic period. Consequently, BS sleep or switch off needs to be incorporated into the network plan and deployment. The network layout should be such that at least one neighboring BS will be there to receive the offloaded traffic.

An optimal SMART algorithm was proposed in [10] to determine the best position to place a new BS (micro and macro). The problem was formulated as a facility location problem with the objective of maximizing both coverage and user experience while achieving higher convergence speed. A vehicular relay node network deployment was discussed in [11]. It was argued that by placing a BS at the center of the coverage area does not guarantee the optimal EE placement in a HetNet due to the non-uniform distribution of traffic. This was further investigated in [12] where a genetic algorithm based approach was used to determine the optimal BS location based on traffic demand.

Since traffic fluctuates in both space and time dimensions, sleep has been investigated further to determine the optimal BS switching mode given certain traffic condition. These proposed algorithms can be grouped into centralized and distributed. In a centralized control, the backhaul will play a significant role in coordinating the operations of the BSs. Control signaling can be sent to nodes via the backhaul link. Therefore, the backhaul will be required to operate energy efficiently. In distributed control, the BS will make their decisions based on their perception about the network. Switching off can be further classified into full and partial switching. Full switching permits that the whole BS be switched off, while partial switching only permits that some components of the BS be switched off [13].

Obviously, algorithms that were proposed for homogeneous networks cannot be easily implemented in a HetNet because of the random and non uniform deployment of the BSs especially the LPBs [14]. Sleep algorithm for HetNet needs to consider the random deployment of the small cells, the non-uniform traffic demand distribution user behaviour, and the delivered QoS after making sleep decision. A dynamic sleep algorithm using artificial neural networks (ANN) to predict future traffic demand for a Femto Access Point (FAP) was proposed in [15]. In [16], sleep/wake function was categorized into node controlled, UE controlled and core controlled. Sleep command was sent to the FAP using the core controller interfaces. A HetNet deployment model was proposed in [17] to determine the optimal macro/micro BSs density. This model has an added advantage of choosing which BS should be powered off during off-peak traffic periods. Factors such as path loss and transmit power are to be considered for BS switch off. A social spider algorithm was adopted in [18] to decide on which BS to be switched off, while [19] groups BSs into clusters where switching is applied per cluster.

It is expected that neighboring BSs will provide coverage to the switched off region. Cell zooming and Coordinated Multi Point (CoMP) are some of the techniques that have been proposed in literature to extend coverage. These techniques requires some level of cooperation among the BSs to enhance network performance. For example, transmit power needs to be increased systematically in order to avoid interference. In addition, less power is required per BS to extend coverage to a given region.

HetNets deployment can be made more intelligent by the use of the cognitive radio techniques. This will give rise to a cognitive HetNet. Effective integration of these can lead to an EE HetNet configuration [20]. Cognitive capabilities was used in [21] to reduce cost and power consumption from the smart grid. A topological control mechanism which will allocate spectrum space to the secondary user when the spectrum slot is not being utilized by the primary user was proposed in [22]. This provides the added capability of eliminating interference between BS cells in the network.

A combination of BS cooperation and cognitive capabilities will give rise to a new generation of self-organized HetNets. These networks will have the capability to reconfigure, reorganize and decide on opportunistic spectrum usage and traffic demand [23]. They will further have the capability to enhance their EEy while maintaining enhanced performance. However, MT mobility, interference, traffic demand are some of the issues that will still need to be dealt with during network design stage. BS deployment also has to be done in such a way that users do not have to oscillate their association too frequently.

III. RESOURCE ALLOCATION

This involves the link layer control of resources among nodes to ensure that they are distributed properly across all links. Some resources for allocation include power, bandwidth, time, etc. Research efforts in this line have been classified based on factors such as centralization of control and optimization objective etc. This is shown in Fig. 2. When the objective is to minimize power for a given data rate, it is termed margin adaptive. Rate adaptive is aimed at maximizing the data rate while simultaneously trading off other QoS parameters. It is expected that an optimal allocation of resources should enhance the performance of the system. Most resource allocation (RA) research heretofore have been directed towards enhancing rate i.e. rate adaptive because of the increasing demand for improved data rates.

Recent efforts on resource allocation have focused mainly on orthogonal frequency division modulation and orthogonal frequency division multiple access (OFDM/OFDMA) systems. This is due to the wide acceptance of the OFDM/OFDMA in upcoming wireless technologies such as WiMAX, Wireless LAN and Long Term Evolution (LTE). There are however, some associated challenges with OFDM/OFDMA systems they include high peak to average power ratio (PAPR), sensitivity to Doppler Effect i.e. mobility etc. These challenges increase the complexity of RA in the systems. Consequently, a lot of research have been underway to enhance the RA in OFDMA system. With the recent interest in EEy, the research has also been poised towards enhanced RA performance while ensuring EEy.

A number of techniques have been used in literature for the allocation of resources in OFDM/OFDMA based system. Water filling [24], technique being on of the oldest means of RA, has a characteristics of filling more eresources to best channels while users at worst channel conditions will be starved of resources. The issue of fairness to users at worse channel was subsequently raised. Many techniques were consequently proposed these include Max-min, weighted proportionality [25], utility maximization [26].

The challenged of the complexity of the algorithms still remained as a fundamental problem. Techniques such as Auction approach [27], rate proportional approach [28], Ant Colony Optimization algorithm [29] Nash Bargaining [30], etc. were proposed in the literatures. Despite all the technques, the issue of complexity and optimality still remains an issue of trading off one for the other.

Future research will focus on EE resource allocation given power allocation constraint to achieve a maximum data rate requirement. These future works should consider other factors such as interference, QoS, transmission impairments, etc. The optimality of resource allocation algorithms is another area of future research, along with mobility which hasn't been given much attention in resource allocation. In our opinion, it will bring to light a whole new dimension for resource allocation.

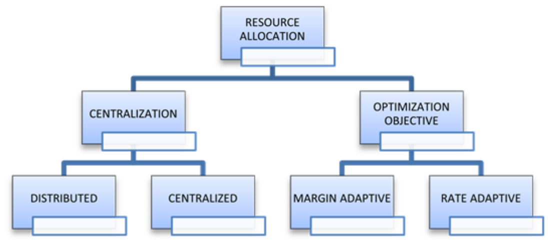

Fig. 2: Classification of Resource allocation

IV. USER ASSOCIATION

User association requires that the Mobile Terminal (MT) is able to associate with the BS for supply of the best services. In a HetNet deployment, this user association becomes a challenge because there is need to develop new user association algorithms. Obviously, the legacy highest Signal to Interference plus Noise ratio (SINR) criterion will prove to be very inefficient. Nodes transmitting at high power will be over loaded while low powered nodes will have almost no load. Therefore, new set of user association criteria needs to be put in place to cater for this random distribution of BSs in the coverage area. Also, appropriate user association algorithm can mitigate interference among the tiers of the network [31]. It has been shown from literature that resource allocation plays an important role in user association.

An improvement in network throughput can be achieved by finding an optimal combination between user association and resource allocation [32]. A joint user association and resource allocation condition was proposed in [33]. A logarithmic network utility maximization with a constraint of equal resource allocation was proposed i.e. maximization of user association with equal resource allocation. The proposed model, however, is restricted to low mobility network environments. The delay encountered as traffic traverses a network was considered in [31] to propose a delay cell association. Real world policies were considered in [34] for achieving user association decision. The objectives included balancing load distribution for minimum bit rate users, maximizing throughout for best effort user and minimizing transmission cost for the entire network. User association was modelled as a stationary point process model in [35]. The access points (AP) were assumed to be distributed according to a stationary point process. A relationship between the association area of the cell containing origin to a typical association area was derived. It was shown that the association area of an AP decreases with path-loss exponent and increases with channel gain variance.

For user association to be EE, the complex interplay between EEy and performance have to be put into consideration. When performance is the priority, EEy suffers and vice versa. In a bid to improve the EE of the BS in a cellular network, user association schemes also need to be optimized towards EEy. This often results in a trade-off between performance and EEy. It is necessary to note that a threshold value needs to applied to limit how far the trade-off can go before it impacts adversely on the network performance. In [36], a population game theoretic approach was adopted where the UEs were grouped into a finite number of classes with similar characteristics. Evolutionary dynamics was used to converge the distribution algorithm to a socially optimal point through appropriate association pricing. Reference [37] proposed an association scheme where the UE associated with a BS depending on the received EEy (Joules per bit).

The fact future of user association in HetNets will have to focus on improving EEy while maintaining a minimum threshold. Some areas still require further research efforts. These include interference mitigation, bandwidth, transmission power, cell edge user association and user mobility. MTs should also be able to associate with more than one BS to maximize throughput and minimize interference. Another area requiring further research is the frequency of dissociation of the MT with its associated BS for mobile users. This will go a long way in stabilizing the network by eliminating increased oscillation.

V. CONCLUSION AND FUTURE WORK

In this short discussion, we have presented three key functions (deployment, resource allocation and user association) which will drive the concept of green HetNet. Consequent to our review, we infer that the development of a joint multi-objective EEy algorithm, which will adequately integrate the network deployment, resource allocation and user association functions can bring about an EE HetNet. However, further research is still required in areas of user mobility, interference management, optimal resource allocation and tradeoff in order for networks to improve their EEy. Most importantly, the implementation problems mentioned here with respect to OFDM/OFDMA systems need to be addressed during resource allocation to improve EEy.

VI. REFERENCES

[1] C. H. Tang, C. E. Wu, C. W. Lin, and C. Y. Liao, “Network energy efficiency for deployment architectures with base station site model,” in *2012 1st IEEE International Conference on Communications in China Workshops, ICCC 2012*, 2012, no. 99, pp. 85–90.

[2] C. Khirallah, J. S. Thompson, and D. Vukobratovic, “Energy efficiency of heterogeneous networks in LTE-advanced,” in *2012 IEEE Wireless Communications and Networking Conference Workshops, WCNCW 2012*, 2012, pp. 53–58.

[3] D. Chee, M. S. Kang, H. Lee, and B. C. Jung, “A study on the green cellular network with femtocells,” in *ICUFN 2011 - 3rd International Conference on Ubiquitous and Future Networks*, 2011, pp. 235–240.

[4] A. Damnjanovic, J. Montojo, Y. Wei, T. Ji, T. Luo, M. Vajapeyam, T. Yoo, O. Song, and D. Malladi, “A survey on 3GPP heterogeneous networks,” *IEEE Wirel. Commun.*, vol. 18, no. June, pp. 10–21, 2011.

[5] Z. Hasan, H. Boostanimehr, and V. K. Bhargava, “Green Cellular Networks: A Survey, Some Research Issues and Challenges,” *Commun. Surv. Tutorials, IEEE*, vol. 13, no. 4, pp. 524–540, 2011.

[6] H. Zhu, S. Wang, and D. Chen, “Energy-efficient user association for heterogenous cloud cellular networks,” in *2012 IEEE Globecom Workshops, GC Wkshps 2012*, 2012, pp. 273–278.

[7] N. Miyazaki, X. Wang, and S. Konishi, “A study on homogeneous- and heterogeneous-based additional network deployments with application of coordinated multi-point operation,” in *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC*, 2012, pp. 130–135.

[8] V. Suryaprakash and G. P. Fettweis, “Modeling backhaul deployment costs in heterogeneous radio access networks using spatial point processes,” in *2014 12th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt)*, 2014, pp. 725–732.

[9] A. Awadelkarim, W. Ahmed, J. Markendahl, and C. Cavdar, “Interplay Between Cost , Capacity and Power Consumption in Heterogeneous Mobile Networks,” in *Telecommunications (ICT), 2014 21st International Conference on*, 2014, pp. 98–102.

[10] L. Hu, I. Z. Kovács, P. Mogensen, O. Klein, and W. Störmer, “Optimal new site deployment algorithm for heterogeneous cellular networks,” in *IEEE Vehicular Technology Conference*, 2011, pp. 1–5.

[11] J. Scheim and N. Lavi, “Vehicular relay nodes for cellular deployment: Downlink channel modeling and analysis,” in *2013 IEEE International Conference on Microwaves, Communications, Antennas and Electronic Systems, COMCAS 2013*, 2013, pp. 1–5.

[12] X. Li, X. Zhang, and W. Wang, “An energy-efficient cell planning strategy for heterogeneous network based on realistic traffic data,” in *2014 International Conference on Computing, Management and Telecommunications, ComManTel 2014*, 2014, pp. 122–127.

[13] A. Stavridis, S. Narayanan, M. Di Renzo, L. Alonso, H. Haas, and C. Verikoukis, “A base station switching on-off algorithm using traditional MIMO and spatial modulation,” in *2013 IEEE 18th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD)*, 2013, no. 1, pp. 68–72.

[14] J. G. Andrews, “Seven ways that hetnets are a cellular paradigm shift,” *IEEE Commun. Mag.*, vol. 51, no. March, pp. 136–144, 2013.

[15] G. Wang, C. Guo, S. Wang, and C. Feng, “A traffic prediction based sleeping mechanism with low complexity in femtocell networks,” *2013 IEEE Int. Conf. Commun. Work.*, pp. 560–565, 2013.

[16] A. Saeed, M. Dianati, and M. A. Imran, “Energy Efficiency Analysis for LTE Macro-Femto Hetnets,” in *Wireless Conference (EW), Proceedings of the 2013 19th European*, 2013, pp. 1–5.

[17] D. Cao, S. Zhou, and Z. Niu, “Optimal base station density for energy-efficient heterogeneous cellular networks,” *IEEE Int. Conf. Commun.*, pp. 4379–4383, 2012.

[18] J. J. Q. Yu, S. Member, and V. O. K. Li, “Base Station Switching Problem for Green Cellular Networks with Social Spider Algorithm,” in *Evolutionary Computation (CEC), 2014 IEEE Congress on*, 2014, pp. 2338–2344.

[19] H. Zhang, J. Cai, and X. Li, “Energy-efficient base station control with dynamic clustering in cellular network,” in *2013 8th International Conference on Communications and Networking in China (CHINACOM)*, 2013, pp. 384–388.

[20] A. De Domenico, E. C. Strinati, and M. G. Di Benedetto, “Cognitive strategies for green two-tier cellular networks: A critical overview,” in *Handbook of Green Information and Communication Systems*, Elsevier Inc., 2013, pp. 1–33.

[21] S. Bu, F. R. Yu, and Y. Qian, “Energy-efficient cognitive heterogeneous networks powered by the smart grid,” *Proc. - IEEE INFOCOM*, pp. 980–988, 2013.

[22] M. Erel, Y. Ozcevik, and B. Canberk, “A topology control mechanism for cognitive smallcell networks under heterogeneous traffic,” *2013 IEEE 14th Int. Symp. “A World Wireless, Mob. Multimed. Networks,”* pp. 1–6, 2013.

[23] C. Facchini, O. Holland, F. Granelli, N. L. S. Da Fonseca, and H. Aghvami, “Dynamic green self-configuration of 3G base stations using fuzzy cognitive maps,” *Comput. Networks*, vol. 57, no. 7, pp. 1597–1610, 2013.

[24] E. Yaacoub and Z. Dawy, “A survey on uplink resource allocation in OFDMA wireless networks,” *IEEE Commun. Surv. Tutorials*, vol. 14, no. 2, pp. 322–337, 2012.

[25] K. Sumathi and M. L. Valarmathi, “Resource allocation in multiuser OFDM systems — A survey,” in *2012 Third International Conference on Computing, Communication and Networking Technologies (ICCCNT’12)*, 2012, no. July, pp. 1–8.

[26] B. G. Kim, J. A. Kwon, and J. W. Lee, “Subchannel allocation for the OFDMA-based femtocell system,” *Comput. Networks*, vol. 57, no. 17, pp. 3617–3629, 2013.

[27] C. Comaniciu, N. B. Mandayam, and H. V. Poor, “Radio Resource Management for Green Wireless Networks,” in *2009 IEEE 70th Vehicular Technology Conference Fall*, 2009, pp. 1–5.

[28] H. Pervaiz, L. Musavian, and Q. Ni, “Joint user association and energy-efficient resource allocation with minimum-rate constraints in two-tier HetNets,” in *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC*, 2013, pp. 1634–1639.

[29] Y. Zhao, X. Xu, Z. Hao, and X. Tao, “Adaptive subcarrier and bit allocation based on ant colony optimization,” *J. China Univ. Posts Telecommun.*, vol. 17, no. 6, pp. 59–64, 2010.

[30] H. H. H. He, J. C. J. Chen, S. D. S. Deng, and S. L. S. Li, “Game Theoretic Analysis of Joint Channel Selection and Power Allocation in Cognitive radio Networks,” *2008 3rd Int. Conf. Cogn. Radio Oriented Wirel. Networks Commun. (CrownCom 2008)*, vol. 30, no. 1, pp. 70–81, 2008.

[31] J. Li, Y. Li, A. Cheng, and M. Peng, “Delay aware cell association and user scheduling in heterogeneous overlay networks,” in *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC*, 2013, pp. 106–110.

[32] D. Fooladivanda and C. Rosenberg, “Joint resource allocation and user association for heterogeneous wireless cellular networks,” *IEEE Trans. Wirel. Commun.*, vol. 12, no. 1, pp. 248–257, 2013.

[33] Q. Ye, B. Rong, Y. Chen, M. Al-Shalash, C. Caramanis, and J. G. Andrews, “User association for load balancing in heterogeneous cellular networks,” *IEEE Trans. Wirel. Commun.*, vol. 12, no. 6, pp. 2706–2716, 2013.

[34] Heli Zhang, Yongbin Wang, and Hong Ji, “User association scheme in heterogeneous networks considering multiple real-world policies,” in *National Doctoral Academic Forum on Information and Communications Technology 2013*, 2013, pp. 32–32.

[35] S. Singh, F. Baccelli, and J. G. Andrews, “On association cells in random heterogeneous networks,” *IEEE Wirel. Commun. Lett.*, vol. 3, no. 1, pp. 70–73, 2014.

[36] Sangwoo Moon, Yung Yi, and Hongseok Kim, “Energy-efficient user association in cellular networks: A population game approach,” in *Proc. 11th International Symposium on Modeling \& Optimization in Mobile, Ad Hoc \& Wireless Networks (WiOpt)*, 2013, pp. 388–395.

[37] S. Kim, S. Choi, and B. G. Lee, “A joint algorithm for base station operation and user association in heterogeneous networks,” *IEEE Commun. Lett.*, vol. 17, no. 8, pp. 1552–1555, 2013.