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On Modelling and Analysis of Small Cell Power Consumption in 5G Heterogeneous Network

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ABSTRACT – An adaptation of 5G Heterogeneous Network (HetNet) into Industry 4.0 provides a real-time information and problem-solving capacity, increase spectral efficiency and speed of data transfer. However, an increasing number of active mobile users cause a growing demand of Small Cell Network (SCN). Thus, pose a challenge in the increasing power consumption of the SCN. We design a mathematical model that able to compute an optimum number of active SCN without degrading the Quality of Service. Simulation results indicates that different traffic load have a significant impact on the power consumption of 5G HetNet systems.

1. INTRODUCTION

The fourth industrial revolution (Industry 4.0) has become a significant matter in revolutionizing the communication industry to become a borderless and automated data sharing system. With the adaptation of 5G Heterogeneous Network (HetNet) into Industry 4.0, the spectral efficiency and speed of data transfer will be increased in an impressive manner by providing a real-time information and problem-solving capacity [1]. Moreover, HetNet is a great solution for reducing the bandwidth scarcity issue to improve spectrum efficiency and quality of service (QoS).

Over the year, an increase number of mobile users contribute to an exponential growth of Small Cell Network (SCN). Thus, pose a challenge in the power consumption of the SCN in 5G HetNet systems which raised the environmental and economic concerns. Recent research direction on the 5G HetNet aim to have lesser power of consumption [2-3]. Meanwhile, an achievement in power saving is needed without degrading the QoS from the mobile users. The challenge will be on how many active SCN is needed so that the demand data rates and QoS can be satisfied by minimising the 5G HetNet power consumption. To address this challenge, in this preliminary study, the optimum number of active SCN in 5G HetNet system without degrading the QoS will be investigated. The power consumption for the single SCN requirement and the active SCN in the 5G HetNet system will be analysed.

2. METHODOLOGY

In this study, the mathematical associations of SCN in the 5G HetNet system is designed. It is based on the derivation of the total power consumption of 5G HetNet which is a total power consumption from multiple SCN, BS and the backhaul power of SCN and BS. For simplification, it is assumed that there is one macro BS and one Femto-cells as SCN.

First, we need to derive the optimum number of active SCN. Let ρ_{x} as population value on x years and A_g is the constant parameter to represent Average Annual Population Growth Rate and z is showing the increment of the years, $\rho_{x}(1 + A_g)^2\, z = \rho_{x+z}$. Let m_{t} denotes as a total number of active mobile and m_{a} is equal to the number of active mobile users, the value is given as, $0 \leq \gamma \leq 1$. The population factor for active users, γ is given by $\gamma = \frac{m_a}{m_t}$. The relationship between coverage area of BS and SCN with this population factor is used to compute the optimum number of active SCN that can be expressed as

$$S = \gamma \frac{A_b}{A_s} = \frac{m_a}{m_t}\frac{\pi r_b{}^2}{\pi r_s{}^2} \qquad (1)$$

where S represents the amount of the active SCNs, r_b and r_s denote as the coverage radius of BS and coverage radius for SCN, respectively.

Based on (1), the power consumption of SCN, Ps can be computed as

$$Ps = S(k_s P_{s\,max} + j_s) \qquad (2)$$

where $P_{s\,max}$ is the maximum output power of SCN, k_s is a slopes of the load dependent power consumption of SCN and j_s is a signal transmission power and site cooling power consumption of SCN. Let P_b is the power consumption of BS, P_{bbh} and P_{sbh} represents the backhaul power consumption of the BS and SCN, respectively. We also let $D_{port}, fg_{port}, o_{port}, S_{port}$ as a number of ports needed for DSLAM, Femto gateway, OLT, and passive splitters, respectively. P_{mod}, P_d, P_{fg}, P_{onu}, P_{olt}, P_b denotes as the power consumption of the on modern, DSLM, 1 Femto gateway, NONUs, OLT, and BS, respectively. To capture all these power consumption with its associate number of ports needed, we calculate the power consumption P_{bbh} and P_{sbh} as follows:

$$P_{bbh} = \left(\left(\gamma \frac{A_m}{A_n}\right) P_{mod}\right) +$$

$$\left(\left[\frac{1}{D_{port}}\left(\gamma\frac{A_m}{A_n}\right)\right]P_d\right)+\left(\left[\frac{1}{fg_{port}}\left[\frac{1}{D_{port}}\left(\gamma\frac{A_m}{A_n}\right)\right]\right]P_{fg}\right)(3)$$

$$P_{sbh}=\left(\gamma\frac{A_m}{A_n}\right)P_{onu}+\left[\frac{1}{S_{port}}\left(\gamma\frac{A_m}{A_n}\right)\right]P_S+\left[\frac{1}{O_{port}}\left[\frac{1}{S_{port}}\left(\gamma\frac{A_m}{A_n}\right)\right]\right]P_{olt}+\left[\frac{1}{fg_{port}}\left[\frac{1}{O_{port}}\left[\frac{1}{S_{port}}\left(\gamma\frac{A_m}{A_n}\right)\right]\right]\right]P_{fg}\ (4)$$

where the parameter, description and input value for (3) and (4) are based on [3]. Substitute (2), (3) and (4) with the power consumption of BS, we get the total power consumption of 5G HetNet as

$$P_t=P_b+P_{bbh}+P_s+P_{sbh}. \quad (5)$$

3. RESULTS AND DISCUSSION

To investigate the optimum number of active SCN in 5G HetNet system, we compute (1) by using the 24 hours system. For validation purpose, the traffic load information is based on Department of Statistics, Malaysia official portal. The parameter and its simulation settings to validate (5) are summarized in Table I. Figure 1 shows the SCNs performance that consume the lowest power at the low traffic load which is from 9pm to 8am. During a medium traffic load from 8am to 12pm at least half of the SCNs need to be in the active mode. Lastly, during the high traffic load from 2pm to 9pm, the power consuming of the SCNs will be at the highest. Hence, it is expected to have three significant different SCN performance with three different period of traffic load. Thus, indicates the trend of data usage for rural area.

Table 1 Simulation setting

Parameter	Value	Parameter	Value	Parameter	Value
P_s	0W	P_{onu}	2W	P_d	0W
fg_{port}	100	S_{port}	48	P_{fg}	0W
D_{port}	72	O_{port}	48	P_{mod}	0W
P_{fg}	100W	P_{olt}	20W		

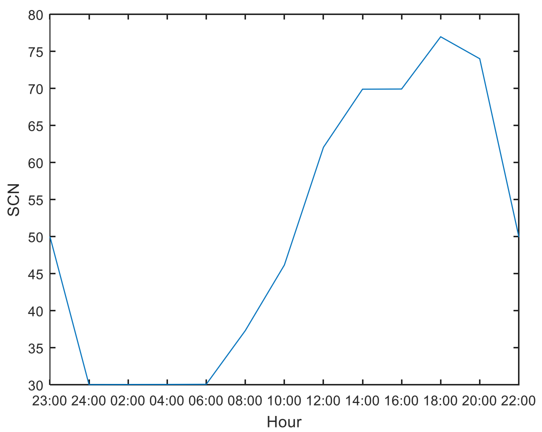

Figure 1 Number of SCN performance for various hours

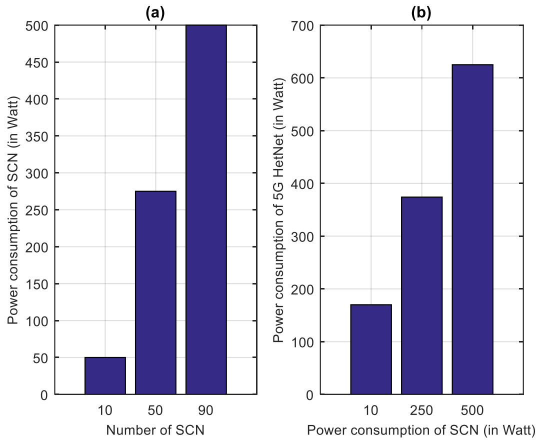

Figure 2 (a) Power consumption performance for three different traffic loads (b) 5G HetNet power consumption for three different traffic loads.

Next, we compute (2) to examine the power consumption for SCN. Here, we consider three different traffic loads that are based on result in Figure 2(a) which is 10, 50 and 90 number of SCN. Figure 2(a) shows the power consumption performance for each number of SCN that is required in 5G HetNet system. There is 275% average of increment in the power consumption for every 40 number of SCN. Based on this result, we further computes (4) to obtain the power consumption of the active SCN in the 5G HetNet system as shown in Figure 2(b). The results show that there is on average 75% increment in the total power consumption of 5G HetNet.

4. SUMMARY

In this preliminary study, the mathematical formulations of the SCN power consumption for 5G HetNet system have been validated. The simulation result shows that the SCN activation is affecting the power consumption of the 5G HetNet. This trade-off between the optimum number of active cells and power consumption of SCNs provides an effective planning aid for 5G HetNet allocation. Future work will consider the multi-BS scenario that will further enhanced a cost reduction on this 5G HetNet plan. The advancement knowledge through this study will be a reference design that could be potentially enhanced secure, energy-efficient solutions for wireless traffic in Malaysia.

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