INVESTIGATION ON POWER CONSUMPTION OF SMALL CELL NETWORK IN 5G HETNET SYSTEMS

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A report submitted in partial fulfillment of the requirements for the Bachelor of Mechatronic Engineering with Honours

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This report submitted to the Faculty of Electrical Engineering of UTeM as a partial fulfillment of the requirements for the Bachelor of Mechatronic Engineering with Honour. The member of the supervisory is as follow:

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To my beloved mother and father

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ABSTRACT

With the adaptation of 5G Heterogeneous Network (HetNet) into Industry 4.0, the efficiency and speed of data transfer will increase in an impressive manner providing real-time information. 5G HetNet represents a promising solution for next generation wireless networks, where many of small cell network or low power nodes, Small Cell Networks (SCN) are planted to support the exiting Macro-cell networks (BS) to reduce the power consumption of signal transmit and wider the coverage networking. Besides, it is able to enhance the Quality of Service (QoS) and spectral efficiency compare to traditional network which depends on the Macro-cells only. However, an increasing number of active mobile users increase the demand of Small Cell Network (SCN). Thus, pose a challenge in an increasing power consumption of the SCN in 5G HetNet systems. The present study proposes to solve this problem by designing a mathematical model that able to compute an optimum number of active SCN without degrading the QoS. Simulation results indicate that different traffic load have a significant impact on power consumption of 5G HetNet.

ABSTRAK

Dengan penyesuaian Rangkaian Heterogen 5G (HetNet) ke Industri 4.0, kecekapan dan kelajuan pemindahan data akan meningkat dengan cara yang mengagumkan yang menyediakan maklumat masa nyata dan kapasiti penyelesaian masalah. 5G HetNet mewakili penyelesaian yang menjanjikan untuk rangkaian tanpa wayar generasi akan datang, di mana banyak rangkaian sel kecil atau nod kuasa rendah, Rangkaian Sel Kecil (SCN) adalah tumbuhan untuk menyokong rangkaian makro sel keluar (BS) untuk mengurangkan penggunaan kuasa penghantaran isyarat dan rangkaian liputan yang lebih luas. Selain itu, ia dapat meningkatkan Kualiti Perkhidmatan (QoS) dan kecekapan spektrum berbanding dengan rangkaian tradisional yang bergantung kepada sel-sel Makro sahaja. Walau bagaimanapun, peningkatan bilangan pengguna mudah alih yang aktif meningkatkan permintaan Rangkaian Sel Kecil (SCN). Oleh itu, menjadi cabaran dalam penggunaan kuasa SCN yang semakin meningkat dalam sistem 5G HetNet. Kajian ini mencadangkan untuk menyelesaikan masalah ini dengan merancang model matematik yang dapat mengira jumlah SCN aktif yang optimum tanpa merendahkan QoS. Hasil simulasi menunjukkan bahawa beban lalu lintas yang berlainan mempunyai kesan yang signifikan terhadap penggunaan kuasa 5G HetNet.

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INTRODUCTION

1.1 Motivation

Global network users are exploding with no sign of retardation and it is expected to keep its rapid speed of growing. Wireless network statistics reveal that 976.4% growth from 2000 to 2017 and 51.7% among the population of the world using the wireless network [1]. Fourth generation (4G) wireless network is not able to meet this explosive growth in traffic demand. Therefore, this has giving birth to fifth generation (5G) mobile networks as decorate to this fast growing technology world.

Group Special Mobile Association (GSMA) is cooperate with its members, Huawei, and its university towards the vital shaping of 5G wireless network and they have blended the different research by industries and academia, eight major requirements of coming 5G wireless network. Firstly, 10 times increase data rates in real networks from the traditional LTE network, 100 times reduction latency, higher bandwidth, enormous number of connected devices, perceived 99%, complete coverage irrespective of users' location, higher battery life, and increase the energy of efficiency [2,3].

Today, there a lot of researchers focus their research on 5G HetNet with higher energy of efficiency or lesser power of consumption [4, 5, and 6]. Information and Communication Technology (ICT) region has consumed 4.7% of global electricity production [5] and it is estimated that 4.4 terawatt-hours (TWh) power will be consumed by 100 million of SCNs with 500 million of mobile users in 2020 [6]. In the null shell, this project have to investigate number of the active small cell networks have to be adjustable with deactivate it or minimize its power consumption during various time of the days to withstand the coming high power demand.

1.2 Problem statement

5G HetNet system is a mixed wireless infrastructure, with a combination of a few high power Macro-cells or high power nodes and many low power nodes, such as, Micro-cells, Pico-cells and Femto-cells. HetNet is a great solution for reducing the bandwidth scarcity issue to improve spectrum efficiency and QoS

An increasing number of uncoordinated and lightly loaded SCN by keeping it active during all the time might provide a maximum data rate that benefit to all users. However, this might cause in an over excess of bandwidth and increased operating's expenses such as power consumption during the times that the demand is not at its peak.

The increasing number of light loaded active SCN might increase the power consumption [2, 7, and 8]. Most of the electric power industry is used the sources renewable sources, diesel generators, renewable sources, coal-fired power station. With the high power consumption of 5G HetNet, resulting in increase of environmental and economic concerns [9]. Power consumption depends on factors such as transmission time, transmission power, channel conditions, coding and modulation [2, 10]. Therefore, energy saving has become a key design objective of 5G HetNet system.

Meanwhile, a power saving is needed to be achieved with not sacrificing or degrading the QoS from users. The question here is on how many active SCN is needed so that the demand data rates and QoS can be seen when minimising the 5G HetNet power consumption.

1.3 Objective

1. To investigate the optimum number of active small cell network in 5G HetNet system.

2. To validate the power consumption of small cell that is required in 5G HetNet system.

3. To analyses the power consumption 5G HetNet system.

1.4 Scope

This project focuses on investigation of the optimum number of active small cell network and power consumption of SCN in 5G HetNet system based on algorithm in [6].Therefore, we compare the power consumption of 5G HetNet with the traditional wireless network. There is certain type of SCN, for example Micro-cells, Pico-cells, and Femto-cell. In this project, we consider the present of Femto-cell as SCNs in Bukit Beruang, Melaka area. A network centre with a macro-cell and the radius of 1km that is surrounded with SCN as shown in Figure 1.1

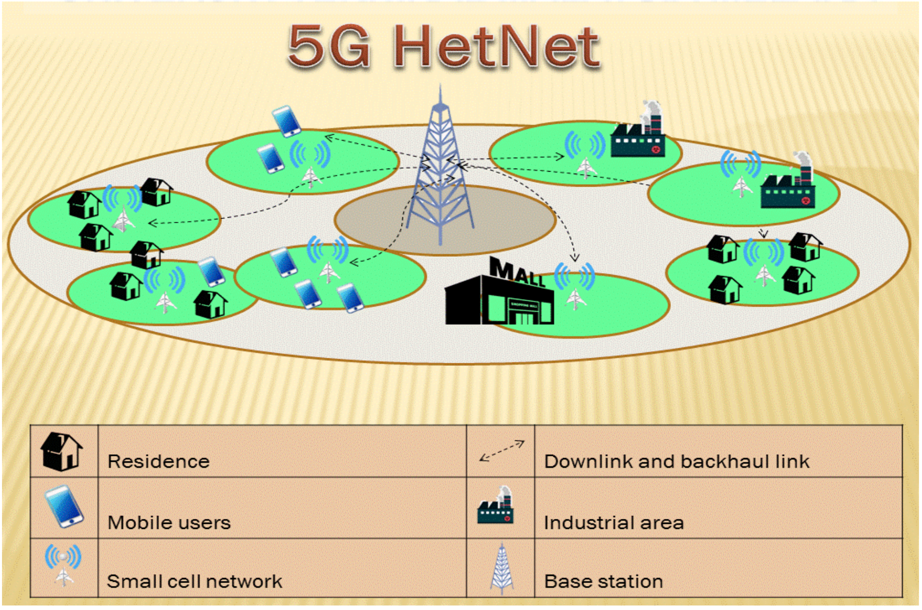

Figure 1.1 Network architeture of BS coverage with radius 1km

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the background of the project will be explained briefly for better understanding of the research. A review of previous related works will be discussed to obtain some useful information by synthesizing their work to make this research successful.

2.2 Wireless network system

First generation (1G) of the wireless network system was design in 1980s with data rates of 2.4Kbps, and is only received and transmit analogue signal, since the data transmitted is too low, the voice quantity can received by device also poor quality [14].

Next evolution in 1990s is a Second generation 2G network system transmitting the digital signal with speed 64 Kbps multi-media messages, and no able to send any video date because it is too complicated data [14].

In 2000s, the Third generation 3G networks system was a big change in history which provided 2Mbps high speed data rates and clear voice or analogue transmission. In 2015s Fourth generation 3G network system is ready to give serves which data rates of 100Mbps, which give a very high speed wireless network and highly secured [14]. The vision of next generation 5G network system should provide 8 minimums requirement as shown in Figure 2.1 [3, 13, 15].

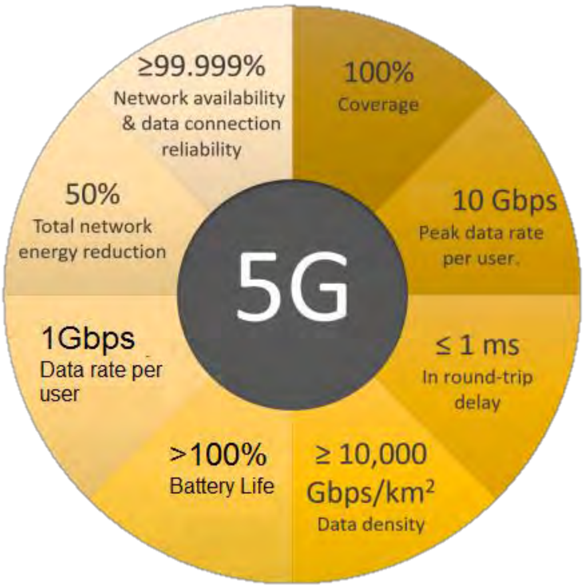

Figure 2.1: 8 Requirements to achieve 5G [3, 5]

As a conclusion, we can see an evolution of the wireless network system with expected of growing in wireless network from 1980s to 2020 as shown in Figure 2.2.

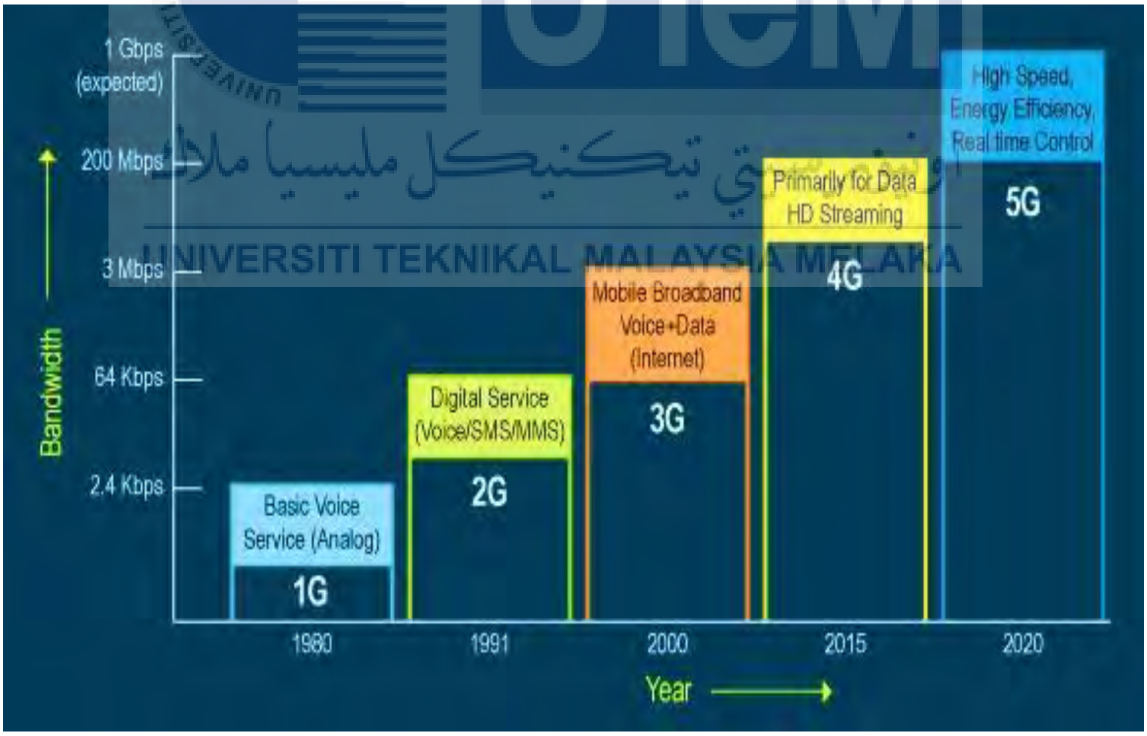

Figure 2.2: Evolution of wireless network system [3]

2.3 5G wireless network system

Recently, primary interest and discussions about a possible 5G standard have evolved into a full-fledged conversation that has took the attention and mind of researchers and engineers over the world. As the long term evolution (LTE) system embodying 4G has now been organised and is getting maturity, where only incremental developments and small amount of the new spectrum can be expected, it is natural for all the researchers to think through ―What is the next to come” [16].

The combination effect of emerging mm-wave spectrum access, hyper-connected vision and new application-specific requirements is started to trigger the next evolution in wireless network system – the 5G [15, 17, and 18]. Figure 2.3 shows that the wireless network envision greatness of increase in wireless data rates, bandwidth, coverage and connectivity, with a great reduction in round trip latency and power consumption.

GSMA is working with its allies towards the ultimate shaping of 5G wireless network system. Blending the different research advantages by industries and academe, eight major requirements [2, 3, and 23] as follows:

1. Higher data rates in real networks.
2. Reduction latency.
3. Higher bandwidth in unit area.
4. Enormous capacity of connected devices.
5. High perceived availability.
6. Coverage for anytime and anywhere.
7. Increase battery life for smart devices.
8. Reduction in power consumption.

With the 8 above requirements, wireless industries, academe and research organizations have to cooperate in 5G wireless network systems. For example, Ericsson expects 5G wireless network system should be start in backward compatible way to obtain 4G LTE network system [2]. Ericsson was also cooperating with South Korean markets leader SK Telekom, for demonstrating 5G wireless network systems in 2018 winter Olympics [2]. Huawei is work in partnership with international trade organisations, governments, academia and ecosystem partner to create crucial 5G revolutions [19].

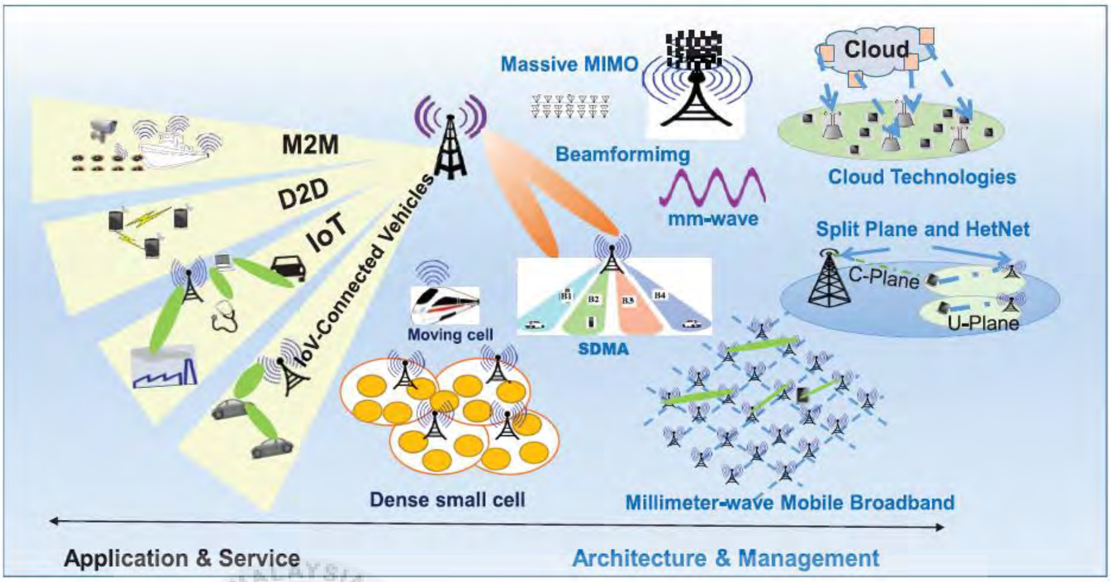

Figure 2.3: Schematic diagram of 5G wireless network system [2]

2.3.1 Data rates

Data rates in wireless network system is unquestionably the main driver in 5G network, since the global network users always requested for high speed timing in life. Data rate can be measured in three ways [2, 20]. Firstly, aggregate data rate it's refer to the total amount of data the network can be served, characterized in bit/s per unit area. The general improving is that this quantity or data rats will need to increase by roughly 100 times from 4G to 5G. Secondly, edge rate or 5% rate is the worst data rate that a user can reasonably expect to receive when in a range of the network. For the 5G edge rate from 1 Mbps to 100Mbps. Meeting 100Mbps for 95% of users will be extraordinarily challenging, even with major technological improvements. This is requires about a 100 times advance since current 4G system gave a typical 5% rate of 1Mbps [2]. Lastly, peak rate also one of the goal target in 5G network. Peak rate is the best case data rate can be reach by a user under any conceivable network configuration. For 5G is likely to be in the range of 10 Gbps peak data rate [2]. In Table 2.1 the 5G goal target for each such metric is summarised.

Table 2.1: Data rate performance between 4G and 5G [3]

Parameter \ Wireless network	***4G***	***5G***
Aggregate data rate	10 times more than 3G	100 times more than 4G
Edge rate	1Mpbs	100Mpbs
Peak data rate	100Mpbs	10 Gbps

2.3.2 Latency

Latency is the time delay from input into a system to desired outcome; the term is understood a little different in various contexts and latency issues also differ from one system to another. Latency greatly affects how usable and enjoyable electronic and mechanical devices as well as communications are. Currently, 4G round trip latencies are about of 10ms [2], and are based on the 1ms sub frame time with necessary overheads for resource allocation and access. Lastly, 5G will need to be able to provide round trip latency with 1ms, which faster than 4G.

2.3.3 Bandwidth

Bandwidth is also defined as the amount of data that can be transmitted in a fixed amount of time. For digital devices, the bandwidth is usually expressed in bits per second (bps) or bytes per second. For analogue devices, the bandwidth is expressed in cycles per second, or Hertz (Hz) [22]. 5G with higher bandwidths will able to connect with larger number of devices for longer duration in specific area.

2.3.4 Capacity of connected devices

The support of 100-1000 times the number of connected devices is depend upon a range of technologies working together, such as 2G, 3G, 4G, Wi-Fi, Bluetooth, hotspot and so on. The addition of 5G on top of this network should not define as a final solution, but just one of the additional from the wider evolution to enable connectivity of technologies. In order to realize the vision of IoT, and emerging 5G network need to provide connectivity to thousands of devices [23].

2.3.5 Perceived availability

99.999% perceived availability is required for 5G wireless network. 5G network visualises that network should practically be constantly available. This is not again unachievable by today technology. By using two sources supply might able to keep the 5G network always available and less possibility happen any power failure. For example, using the renewable sources generators and back-up by tradition diesel generators. These double sources with getting much better performs than one source of generator [3].

2.3.6 Fully coverage

On the other hand, 100% coverage is achievable using any obtainable technology, and could be done by any network operator. Operators select where to plant the small cells based on the cost to prepare the site to launch a cell to cover a specific area balanced against the profit of the cell providing coverage for a specific area. This in turn makes certain cell sites and coverage areas like rural areas and indoor coverage area.

Docomo network has acknowledged two important trends of, which is pervasive wireless connectivity and extensive high content delivery in real time. In fact, it can plant the huge amount of SCN is the key of 5G to get 100% coverage anytime and anywhere [24].

2.3.7 Battery life

Battery life in this topic stands for the power consumption by devices. It is also one the requirement for 5G wireless network system. The tradition BS (Macro-cells) directly transmits it data or information toward the devices hence it is consuming a lot of power by devices in order to receive the data. In 5G developing, researcher tried to find the key in saving the power used by consumer [24] by planting the SCNs around all the area to lower down the power used by devices users.

2.3.8 Power consumption

To improve the data rate in the 5G communication chain, we aim to maintain the power consumption or to reduce the power consumption further. In tradition 4G LTE, BS (Macro-cell) required a lot of energy and power to send its data toward the device users. However, for the next generation of network 5G it is required to reduce the power consumption due to the coming explosive global mobile users' demand.

To face the increasing demands of mobile users, 5G cellular operators are placing huge amount of SCNs (Femto-cells) to pair the Macro-Cell network (BS) so that can provide the biggest bandwidth to all the devices. However, the large number of SCNs will caused oversupplied bandwidth and increased power consumption during the period that is not at its peak [6]. It is estimated in [6, 25] that a typical SCN consumes about 0.05W.

2.4 5G HetNet system

Heterogeneous networks (HetNet) denote a capable solution for the next generation wireless network, where many low power, low cost small- cell are placed to support the existing Macro-cell networks (BSs) as shown in Figure 2.4. HetNet is to decrease the over the air signal and power consumption, and thereby improve the spectral efficiency compared to Macro-cell network (BSs) only [6].

5G HetNet system is expected to support the evolution of current applications and the highly increasing demand of the internet users. These demands and high performance, improved data rate, enhanced QoS, energy and cost efficiency. In order to succeed the goal, cellular network operators have positioned a large number of base stations (BSs). Therefore, over-the-air signal and power consumption of next generation wireless networks have increased rapidly, such as 4G networks. However these have highly increased the consumption of power energy. Currently, Information and Communication Technology (ICT) organisation has consumed 4.7% of global electricity production [5]. Hence, 5G HetNet system are to full fill these demands and enhance the overall power consumption by placing numerous low power, low cost of SCNs such as, Micro-cells over Macro-Cell networks (BS).

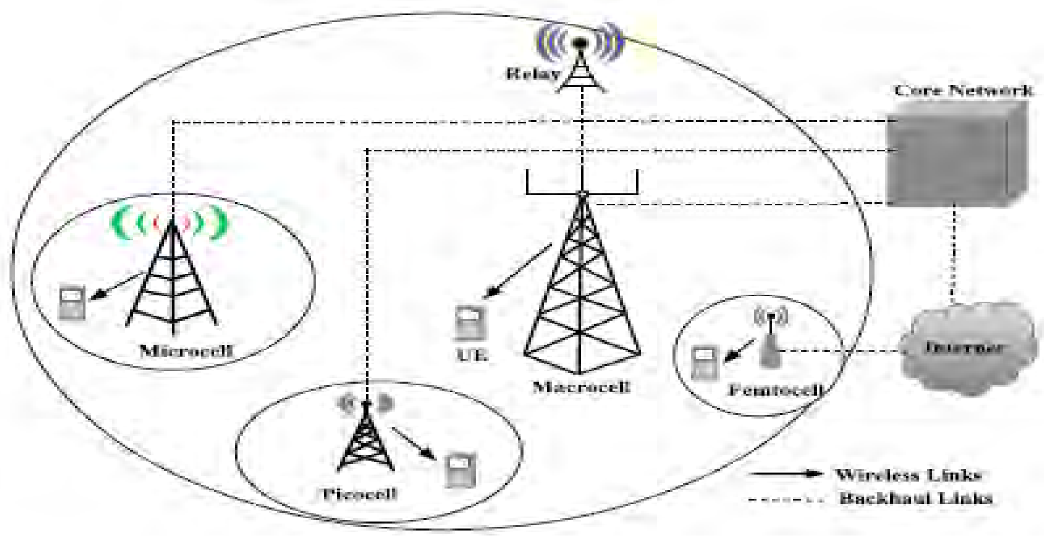

Figure 2.4: Network Architecture of a 5G HetNet [6]

2.4.1 Base stations

Base stations are usually envisioned as big high-power towers or cell sites. The most important characteristics of a BS are; it must be able to initiate and provide accommodations impulsive requests for communication channels with mobile users in its coverage area. Secondly, it has to give a dependable backhaul connection to the core network. Thirdly, BSs need to have a supportable power source. Commonly, this is a traditional wired power connection system, but it could in principle be renewable solar energy, wind-powered, or fossil fuel generated [26]. It is vital to know that traditional tower-mounted BSs —Macro-cells which is a type of BS.

In 5G HetNet, Macro-cell (BS) always held on the centre of the networks and surround the by SCNs. For example in Figure 2.5, Macro-cells are modelled with a hexagonal grid, with closely six SCNs per Macro-cell, which are each placed exactly on the boundaries among neighbouring BSs [27].

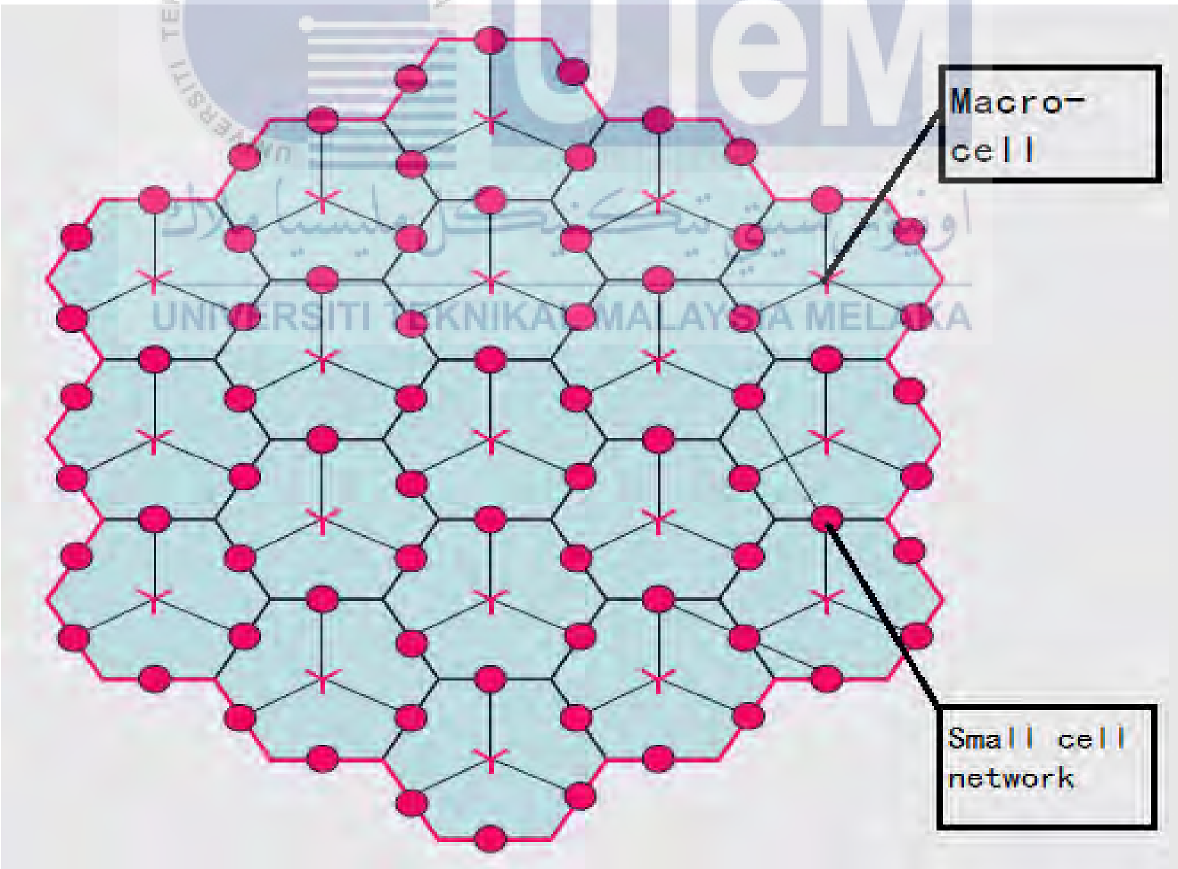

Figure 2.5: HetNet with hexagonal grid [4]

Finally, Macro-cell plays important role in 5G HetNet or we can call it as main drive in the network. To attain the coverage of a 1500 m Macro-cell, and surrounded with Femto-cell which has a power consumption of 50-100 W. the increased amount of Macro-cells with consumed more energy, increases the cost of wireless operators, and also generates more greenhouse gas productions. Hence, minimize the power consumption has become one of the important design objective of wireless network systems [4].

2.4.2 Small cell networks

The exponentially increasing demand for wireless data services requires a massive network densification that is neither economically nor ecologically viable with the current cellular system architectures. A promising solution to this problem is the concept of SCN [28].

A small cell is essentially a miniature base station which breaks up a Macro-cells site into smaller pieces, for examples in Figure 2.6, Pico-cells, Micro cells, Femto-cells which can consist of of indoor and outdoor systems. With Macro-cells base station, there's one pipe going into the network; with small cells, it breaks the pipe into many other pipes. The main objective of SCNs is to increase the Macro-cell's data capacity, speed, reduces power consumption and overall network efficiency. Small cells were new in Release 9 of the 3GPP LTE in 2008 [29].

Small cells are usually used in very densely populous urban areas, such as shopping centre, sports venues, cities area and train stations – basically anywhere you have many people using data at a given point in time. Most small cell infrastructure deployments are targeted for outdoor use. In contrast, indoor small cell systems can or cannot incorporate Wi-Fi or unlicensed LTE bands [25].

In 5G HetNet, SCNs provide wider data capacity. Secondly, it helps service providers reduce costly rooftop systems and installation or rental budgets, which cuts the cost expenses. Besides, it also helps increase the QoS of mobile handsets. If your phone is closer to a SCN, it transmits at lower power levels, which efficiently lowers the power output of the mobile cells and efficiently increases battery life of the devices [6].

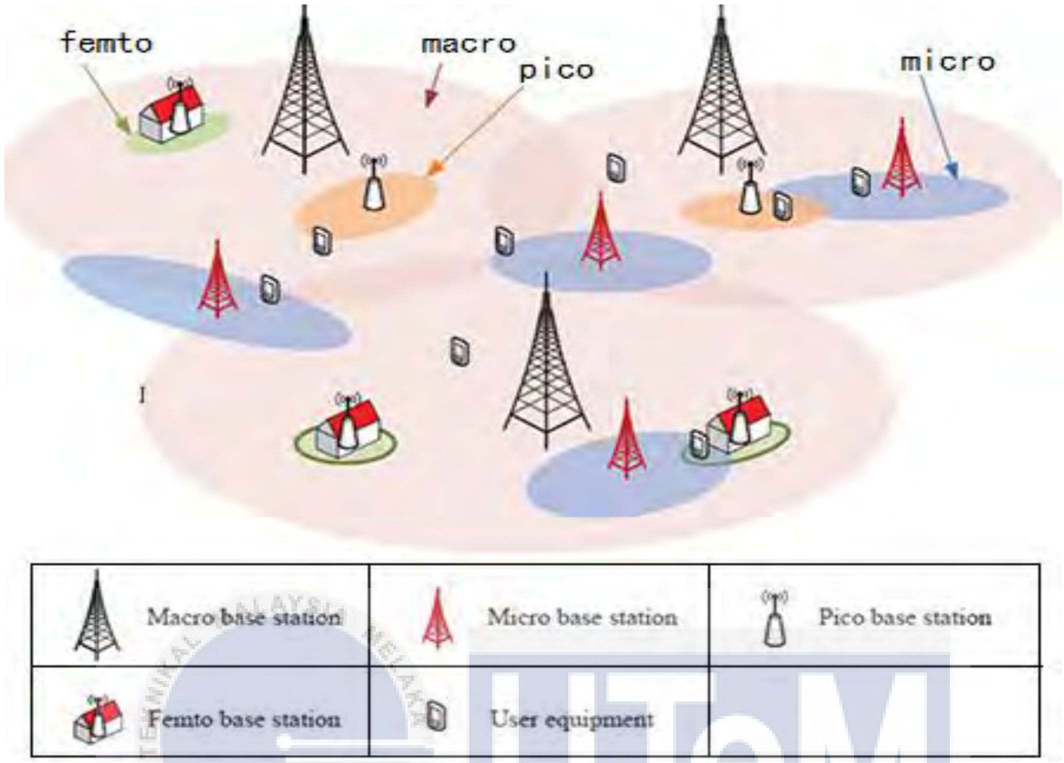

Figure 2.6: Small Cell Networks Architecture [29]

2.4.2.1 Femto-Cell Network

Femto-cells are a low-power wireless access points that operate in licensed spectrum to connect standard mobile devices to a mobile operator’s network using residential DSL or cable broadband connections. Femto-cells playing an important role in the 5G HetNet system which located at home base station or home access point. Output powers of Femto-cells are in between 0.001W to 0.05W [30].

2.4.2.2 Pico-Cell Network

Pico-cells offer greater capacities and coverage areas than Femto-cells, it is supporting up to 100 users over a range of less than 250 yards. Pico-cells are commonly installed indoors to increase poor wireless and cellular coverage within a building, like office floor or retail space. Power output of Pico-cell is between 0.25W to 1.0 W. It is almost 40 times less power consuming than macro-cells (BS) [31].

2.4.2.3 Micro-Cell Network

Micro-cells are difficult to exactly distinguish from Pico-cells, but their coverage area is the principal delineator. Microcells can coverage the areas which less than a meter in diameter and uses power control to limit this radius. Microcells can be installed temporarily in anticipation of high-traffic in a specific area, such as a sporting event, but are also installed as a lasting feature of mobile cellular networks. Power output of Micro- cell is between 1W to 10W [31].

In HetNet, SCNs work in conjunction to provide endless coverage for its end users. HetNet Wireless provides continuous wireless coverage solutions that are seamlessly adjusted to the physical space and requirements of our clientele, which vary from commercial developers to public safety officials. In Table 2.2 shows the summarized the property of SCNs as presented in [30, 31].Thus, for the thesis we consider the Femto cell as the SCN.

Table 2.2: Sizing- up SCNs [30, 31]

Cell type	**Output power, W**	**Cell radius, km**	**Amount users**	**Plant location**
Femto-cell	0.001- 0.050	0.2	1- 30	Indoor/ Outdoor
Pico- cell	0.050- 1.000	0.2- 0.5	30- 100	Indoor/ Outdoor
Micro-cell	1.000-10.000	0.5- 2.0	100- 2000	Indoor/ Outdoor
Macro-cell	10- >50.000	8.0- 30.0	>2000	Outdoor

2.4.3 Comparison between 5G HetNet and traditional cellular

Table 2.3: Comparison between 5G HetNet and traditional cellular [26]

Aspect	Traditional Cellular	5G HetNet
Coverage area	Macro- cell network (BS) as base station, have limited coverage areas. Hexagonal Grid is a ubiquitous model for BS locations.	SCNs (Pico or Femto- cells) inside Macro-cells. BSs are placed opportunistically and their locations are improved Model as a random process.
Cell Association	Connecting in between all Macro-cells to a BS.	Using all SCNs and connect to BS to provide the peak data rate, signal strength.
Backhaul	BSs have heavy-duty wired backhaul, are linked into the main network.	BSs often will not have high speed wired connections. BS to core network (backhaul) link is often the bottleneck in terms of QoS and cost.
Power consumption of BS	Data and signal sent from BS to devices. High energy is needed.	Data and signal sent from BS to SCNs and hence receive by devices. Less energy consumption at BS
Battery life	Required a lot energy to receive the data or signal from the huge distance BSs	Receiving the data and signal from close SCNs.

From Table 2.3, traditional cellular networks can be expedient by increasing the number of BSs with widely to raise its coverage area whereas the 5G HetNet coverage area was depends on plant location of SCN. 5G HetNet is using all the SCNs and connected with BSs to provide the data transmission service to all devices. However the traditional cellular network build up with all Macro-cell (BS) and the all devices are receive the information via BS. Besides that, power consumption for BSs is between 10W to 50W which is 5 times more than the Micro-cell network, hence the power consumption in traditional cellular higher than the 5G HetNet. At the same time, all the devices were required high power or energy consuming to receive the data or information from huge distance of BSs. However, battery life of the devices in 5G HetNet system might last longer compared to traditional cellular network due to the closer data transmitter.

2.5 Demography

2.5.1 Population

Population in simpler terms is the number of people in a city or town, region, country or world [35]. In this sub chapter will scribe about the effecting of population on 5G HetNet. Population is concerned with virtually everything such as [35]:

1. Population size, which is the total size in a given place. And the amounts of people are classified into 2 group; urban area and rural area.
2. Population growth or decline. The annual growth rate of a people in that place. For example annual growth rate of Melaka in year 20 is 2.3%
3. Population process, the level and trends in fertility, mortality, and migration that are determining population size and change and which can be thought of as capturing life's three main moments: hatching, matching, and dispatching.
4. Population distribution, the amount of the people in the location and what facility they have. For example, the 5000 people in a place might require at least 500 Femto cells.
5. Population structure, the amount of males and females there are of each age.
6. Population characteristics, in term of variables such as education, income, occupation, family and household relationship, immigrant and refugee status and the many other characteristics that add up to who we are as individuals or groups of people.

2.5.1.1 Urban area

An urban area can refer to towns, cities, and suburbs. An urban area includes the city itself, as well as the surrounding areas. Most inhabitants of urban areas have non-agricultural jobs. Urban areas are very developed, meaning there is a density of human structures such as houses, commercial buildings, roads, bridges, and railways [36]. In 1991, qualification of population size of urban centre was expanded to 10,000- 24,999 per 1 km^2[37].

2.5.1.2 Rural area

A rural area is an area that is located outside towns and cities. The Health Resources and Services Administration of the U.S. Department of Health and Human Services define the word *rural* as encompassing. All population, housing, and territory not included within an urban area. Whatever is not urban is considered rural. Typical rural areas have a low population density and small settlements. Agricultural areas are commonly rural, as are other types of areas such as forest. Different countries have varying definitions of *rural* for statistical and administrative purposes [36].

2.5.2 Relationship between the population and 5G HetNet

In this chapter, we are relating the population with the 5G HetNet. This is because the population was affecting the number of active user which is direct effecting with power consumption of 5G HetNet. As an urban area, of cause need to be install more SCNs in order to maintain the QoS for internet users. In our research, we are selected Bukit Beruang, Melaka to run our simulation. And Bukit Beruang, Melaka is a rural area according to reference [36, 37].

2.6 Power consumption by 5G HetNet

Saving the usage of power will be another major feature of 5G HetNet. Power consumption and transmitting data and information to all devices is forecast to increase significantly in future [11]. In 5G HetNet system, SCNs can be considered as sources of bandwidth, users' demand for data dictates the demand curve and the communication network makes sure that the available bandwidth provided required QoS [6]. It is obviously that maximum of bandwidth able to provide by turning all the SCNs in active mode during all the time. However, the will resulting in oversupplied of bandwidth and increase power consumption during the period of the day when demand not the highest.

To overcome the challenge of increasing power demand, researchers have focused on saving the power consumption and develop energy- efficient solutions for 5G wireless network system [4, 5, and 6]. There are few examples by numerous researchers, such as:

1. Evolving new power amplifier technologies to design energy efficient BSs.
2. Reducing the power consumption by deactivating the SCNs while there is under low demand and low traffic load.
3. Profiting from renewable energy sources.

2.6.1 Activate and deactivate small cell network

This thesis will focus on reduction of the power consumption by deactivating the SCNs while there is under demand and low traffic load as a main idea to reduce the power consumption. In 5G HetNet smart switching are the main factors for the improvement of power aware device platforms [32]. Most of the power consumption are caused by factors such as transmission power, transmission time, and channel conditions [2]. So, by deactivating the SCN during not peak demand might minimize the power consumption.

We assume that when the traffic load is at high demand the SCN set as ACTIVATE mode (AM). In this state, all the small cells in HetNet are fully switched ON. During AM all allowed users in coverage area are served with high bandwidth and high speed data rate. However, when all the traffic load is served under the constraints of the SCN maximum capacity, DEACTIVATE mode (DM) is switched ON. In this state, not all small cells will be deactivated but majority of it will undergo DM.

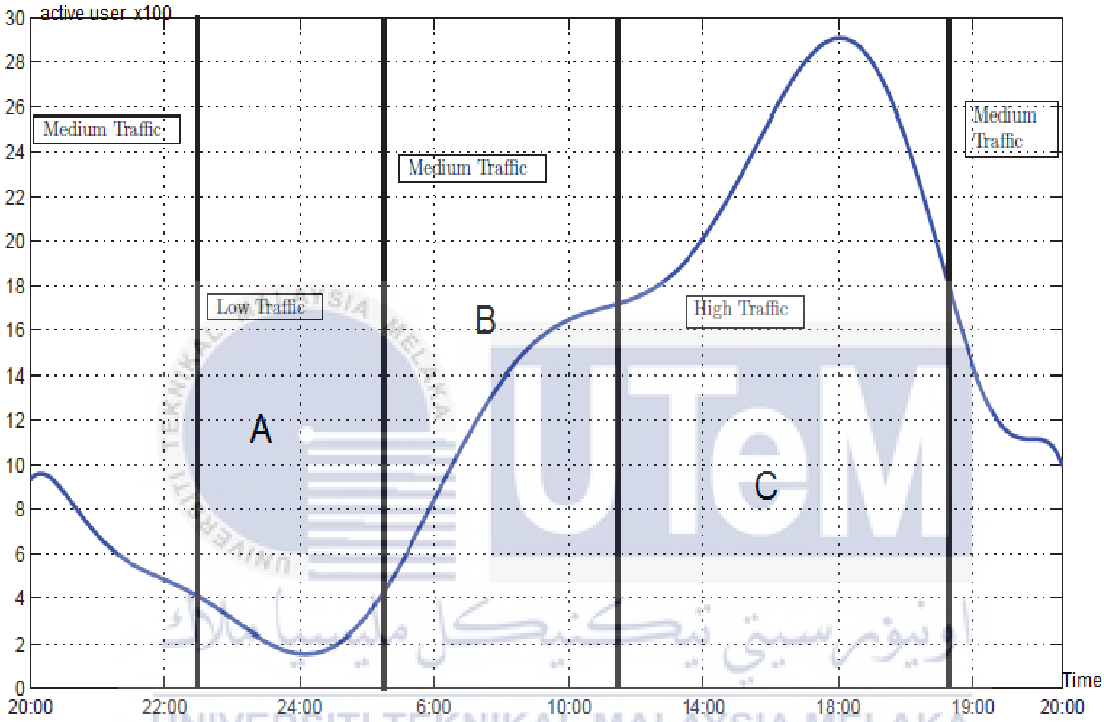

Figure 2.7: Time versus active users [6]

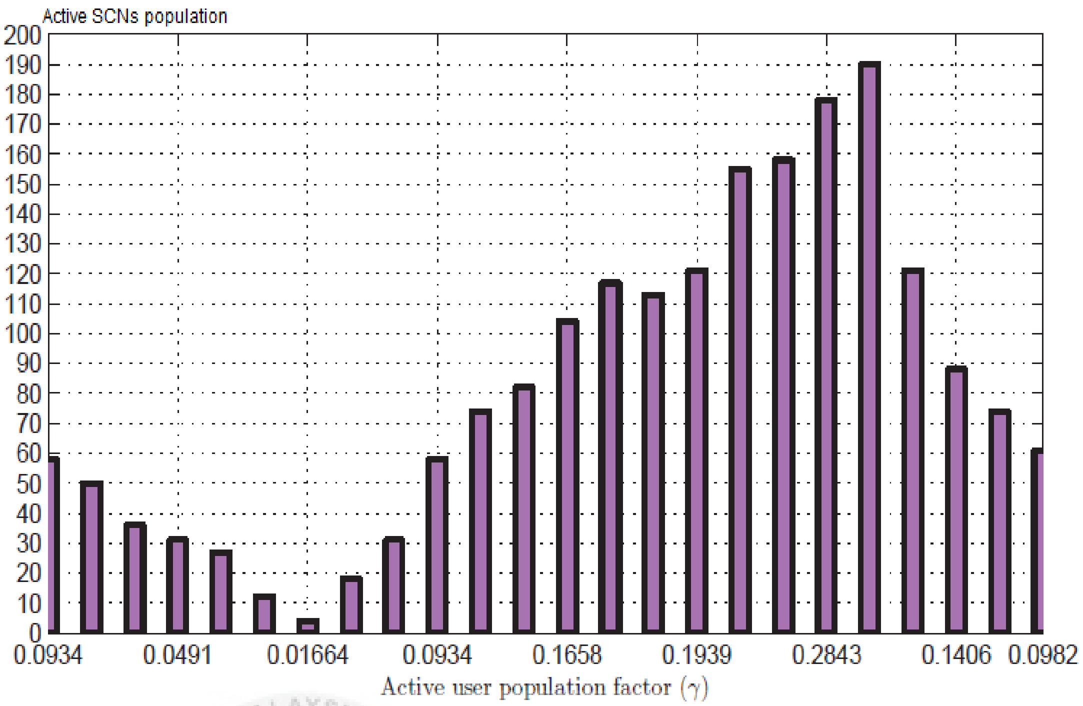

Figure 2.8: Active SCNs population versus active user population [6]

Figures 2.7 and 2.8 show that there are different levels of traffic which is a load, low, medium and high traffic. In period between of 1900 hour to 0600 hour there are less active users, so the population of active SCNs demand also low. Hence during that time majority of SCNs undergo DM in order to save the power consumption. Besides, after 0600 hour the traffic and SCNs demand increased significantly since the active users raised. In this state half of the SCN will be turn to AM. After that, in time 1400 hour to 1900 hour there is a peak hour demand in SCN during the moment all the SCNs will be turned to AM to maintain the QoS since the active users is rapid growth.

2.7 Summary

From the previous studies in [2, 3, 15, 17, 18], we can conclude that the 8 major requirement is needed to achieve next generation wireless network. Besides that, the power consumption is the main focus in 5G HetNet wireless network [4, 5, 6]. To minimize the power consumption in 5G HetNet, we used probabilistic distribution analysis as proposed in [6] by reducing the number of active SCN. We assume the Femto-cell and Macro-cells as our SCN and BS, respectively. We consider an area at

Bukit Beruang, Melaka as our research target area. So, this project emphasis on investigation the power consumption of SCNs and the optimum number of active SCNs in Bukit Beruang, Melaka per day. In addition, the full analysis of information related to this Chapter can be found in **Appendix B**.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter provides the overall plan to achieve the objectives for this research. The method and tool use to analyse the power consumption of the active small cell network in the 5G HetNet system is discussed.

3.2 Power Consumption Process for 5G HetNet

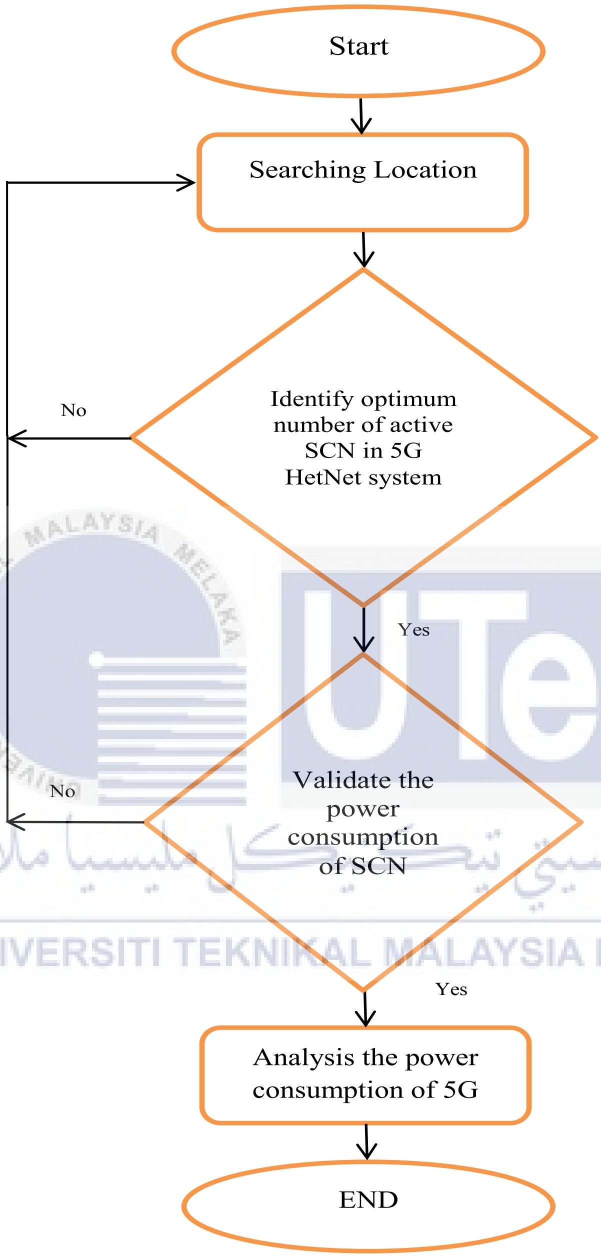

Figure 3.1: Process Flow Chart

Figure 3.1 shows a flow chart to reduce the power consumption of 5G HetNet. As we know 5G was a big evolution in age band, to achieve 5G wireless network Group Special Mobile Association (GSMA) is cooperate with its allies towards the ultimate shaping of 5G wireless network systems. They have come out with 8 requirements. In this paper, we have focused on one of the requirement reduce the power consumption of 5G wireless network. In 5G HetNet, SCNs and BSs occupy the most in the network architecture. Therefore, the project is started by selecting the SCNs as our experiment objects, since the SCNs have several types, so we just choose one type as ours object, Femto-cells. After that, draw the network architecture of 5G HetNet, which located at Bukit Beruang, Melaka. Next, the power consumption of SCN in 5G HetNet is calculated by using an analytical mathematical formula [11]. And then, validate the optimum number of SCNs that should be in active mode is validated. After the simulation and calculating we will compare the result power consumption of 5G HetNet with the traditional 4G wireless network.

3.2.1 Population and Network architecture of 5G HetNet

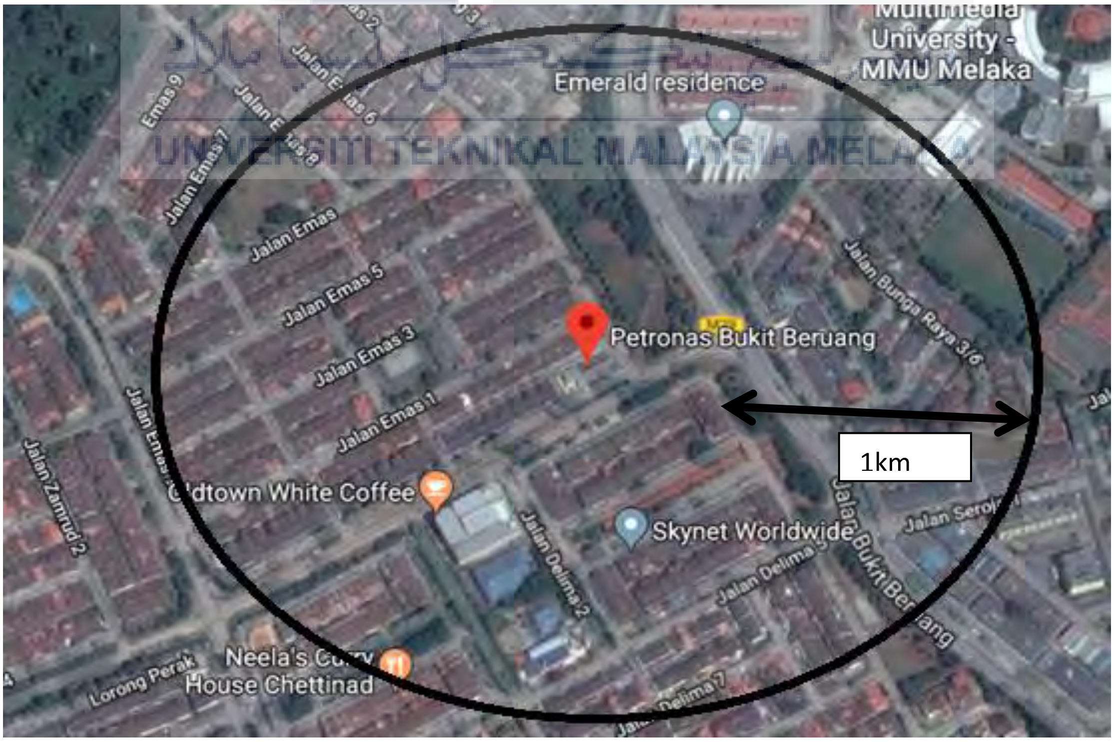

Figure 3.2: Network architecture for 5G HetNet

To start our research we have chosen Bukit Beruang, Melaka as our targeted area, as shown in Figure 3.2. We have set Petronas Bukit Beruang as BS, the centre of the network and the radius of the network is 1km.

Table 3.1: Population of Bukit Beruang, Melaka [34, 35]

Population of ethic group	**1991**		**2000**	
	Number	Percentage	Number	Percentage
Chinese	302	21.7	305	17.5
Malay	1016	73.1	1319	75.5
Indian	54	3.9	71	4.1
Other	18	1.3	51	2.9
Total	**1390**	**100**	**1746**	**100**

According to Table 3.1, the population of Bukit Beruang Melaka is 1747 people in year 2000. Let ρ_x as population value on year x and A_g is the constant parameter to represent Average Annual Population Growth Rate of Melaka g. In order to calculate the population of Bukit Beruang year 2018, the mathematical expression of population for year x with increment y can be defined as

$$\rho_x (1 + A_g).y = \rho_{x+y} \tag{1}$$

The vital reason we would like to find out the number of total population is to estimate the number of total mobile users, m_t which we assumed that 1 people equally to 1 mobile user.

3.2.2 Number of active SCN

In 5G HetNet system, the SCN is assume to be distributed within the Macro-cell network homogenously where each SCN can serve up to ten users simultaneously [30, 31]. From Figure 3.2, we located the BS at the Petronas, Bukit Beruang which is the centre of the network system. The circular BS of radius denoted by r_b, and contain circular SCN of radius, r_s. The optimum of active SCN per BS can be calculated as below [6]:

$$S = \gamma \frac{A_b}{A_s} = \frac{m_a}{m_t}\frac{\pi {r_b}^2}{\pi {r_s}^2}, 0 \leq \gamma \leq 1, \tag{2}$$

Where N represents the amount of the active SCNs, γ is a random variable which denotes the population of active mobile users per BS. The factor γ is the ratio of number of active mobile users m_a, and number of total mobile users m_t, A_b and A_s stand for areas of BS and SCN. Furthermore, the active or inactive SCNs based on the probability that mobile user is active in the neighbourhood of SCNs by using a daily traffic profile. Figure 3.3 shows the input and output for the Algorithm to compute the number of active SCN.

Algorithm 1 Optimum number of active SCN

Input :

A_m= coverage area for BS

A_n = coverage area for SCN

m_a= number of active mobile users

m_t = number of total mobile users

Output 1:

N =Required number of active SCNs to maintain the QoS

Figure 3.3: Algorithm for optimum number of active SCN

To simplify the notation, m_a and m_t denotes a random variable, and its values, respectively. So for instance the notation $f_{m_a}(m_a)$ has become $f(m_a)$and so on. Besides that, the joint distribution of m_a and m_t, is given by

$$f(m_a, m_t) = f(m_a|m_t)f_{m_t}(m_t) \tag{3}$$

And the marginal probability mass function (PMF) can be calculated as [6]:

$$f(m_a) = \sum_{m_t} f(m_a, m_t) = \sum_{m_t} f(m_a|m_t)f_{m_t}(m_t) \tag{4}$$

The distribution of $\gamma = \frac{m_a}{m_t}$ can be assessed as

$$\gamma = \sum_{\gamma=\frac{m_a}{m_t}} f(m_a, m_t) = \sum_{m_t} f(\gamma m_t | m_t) f_{m_t}(m_t) \tag{5}$$

The total amount of active mobile users $m_t$is devoted to be binomial distributed. It is assumed that $m_{T_{max}}$ is maximum possible number of the mobile users and it is a constant. Therefore, $f(m_t) = 1$, where $m_a$is a random variable with $m_a | m_t \sim B(\cdot,\cdot)$. By considering that $f(m_a | m_t)$is binomial distributed such that $m_t > 0$ and $0 \leq p \leq 1$, where we have

$$f(m_a | m_t) = \binom{m_t}{m_a} p^{m_a} (1-p)^{m_t - m_a}, \tag{6}$$

where, p is the probability of having an active mobile user. Hence by substituting, $f(m_t) = 1$ and into (6), we get

$$f(m_a) = \binom{m_t}{m_a} p^{m_a} (1-p)^{m_t - m_a}, m_a = 0, \dots, m_t \tag{7}$$

Using (7), one can express the population factor, γ, as follow:

$$\gamma = \binom{m_t}{\gamma m_t} p^{\gamma m_t} (1-p)^{m_t - \gamma m_t} \tag{8}$$

Hence, substituting (8) into (2) the optimum of active SCN, *S* under this case can be expressed as follows:

$$S = \frac{A_b}{A_s} \binom{m_t}{\gamma m_t} p^{\gamma m_t} (1-p)^{m_t - \gamma m_t} \tag{9}$$

3.2.3 Power consumption of a SCN

The power consumption of SCN [6]can be written as

$$Ps = S(k_s P_{s\,max} + j_s) \tag{10}$$

where

Pn = total power consumption of SCN

S = Number of active SCN

P_s = Maximum output power of SCN

k_s = Slopes of the load dependent power consumption of SCN

j_s = signal transmission power and site cooling power consumption of SCN

Algorithm 2 Power consumption of SCNs

Input :

N = Number of active SCN (**Output 1**)

P_s = Maximum output power of SCN

k_s = Slopes of the load dependent power consumption of SCN

j_s = signal transmission power/ site cooling power consumption of SCN

Output 2:

Pn = total power consumption of SCN

Figure 3.4: Algorithm for power consumption of SCNs

The number of the active SCNs, S can be calculated by using (9). Figure 3.4 summarized the input and output of the algorithm.

3.3 Power consumption of 5G HetNet

In this section, simulation result is presented to analysis the power consumption of 5G HetNet. In the simulation, we use r_m = 1km and r_n= 10m, $m_{T_{max}} = m_t = 2008$ as shown in Table 3.2. Here, the power consumption of 5G HetNet is decomposed into two components, which is BS power consumption and SCN power consumption. The total power consumption of 5G HetNet as below [6]:

$$P_t = P_b + P_{bbh} + P_s + P_{sbh} \tag{11}$$

Pn denotes the power consumption of BS. $P_{bh}^M, and\ P_{bh}^n$ represent the backhaul power consumption of the BS and SCN, respectively, can be written as

$$P_{bh}^{M} = \left(\left(\gamma \frac{A_m}{A_n}\right) P_{mod}\right) + \left(\left[\frac{1}{D_{port}}\left(\gamma \frac{A_m}{A_n}\right)\right] P_d\right)$$

$$+ \left(\left[\frac{1}{fg_{port}}\left[\frac{1}{D_{port}}\left(\gamma \frac{A_m}{A_n}\right)\right]\right] P_{fg}\right) \tag{12}$$

$$P_{bh}^{n} = \left(\left(\gamma \frac{A_m}{A_n}\right) P_{onu}\right) + \left(\left[\frac{1}{S_{port}}\left(\gamma \frac{A_m}{A_n}\right)\right] P_S\right) + \left(\left[\frac{1}{o_{port}}\left[\frac{1}{S_{port}}\left(\gamma \frac{A_m}{A_n}\right)\right]\right] P_{olt}\right)$$

$$+ \left(\left[\frac{1}{fg_{port}}\left[\frac{1}{o_{port}}\left[\frac{1}{S_{port}}\left(\gamma \frac{A_m}{A_n}\right)\right]\right]\right] P_{fg}\right) \tag{13}$$

Where, the parameter, description and input value for equation (12) and (13) input value has listed in **Appendix A**

CHAPTER 4

RESULT & DISCUSSION

4.1 Introduction

This chapter cover the simulation result for population, optimum number of active SCN, *S*, power consumption of SCN, and power consumption of 5G HetNet based on Chapter 3.X. The complete simulation coding by using MatLab is shown in Appendix C.

4.2 Simulation set-up

4.2.1 Simulation for total number of active mobile users

From Table 4.1 we substitute the value into (1) hence we have a simulation line graph as shown in Figure 4.1. As expected, there is an exponential growth in the population performance over various years by 1.5% every year.

Table 4.1: Active mobile users' parameter

Algorithm A: To calculate the total number of active mobile users		
Input [34,35]		Value
P_{2010}	population of Bukit Beruang Melaka in year 2000	1747 people
A_g	Average Annual Population Growth Rate	1.5%
Output 1	$P_{2017} =$ population of Bukit Beruang Melaka in year 2017	

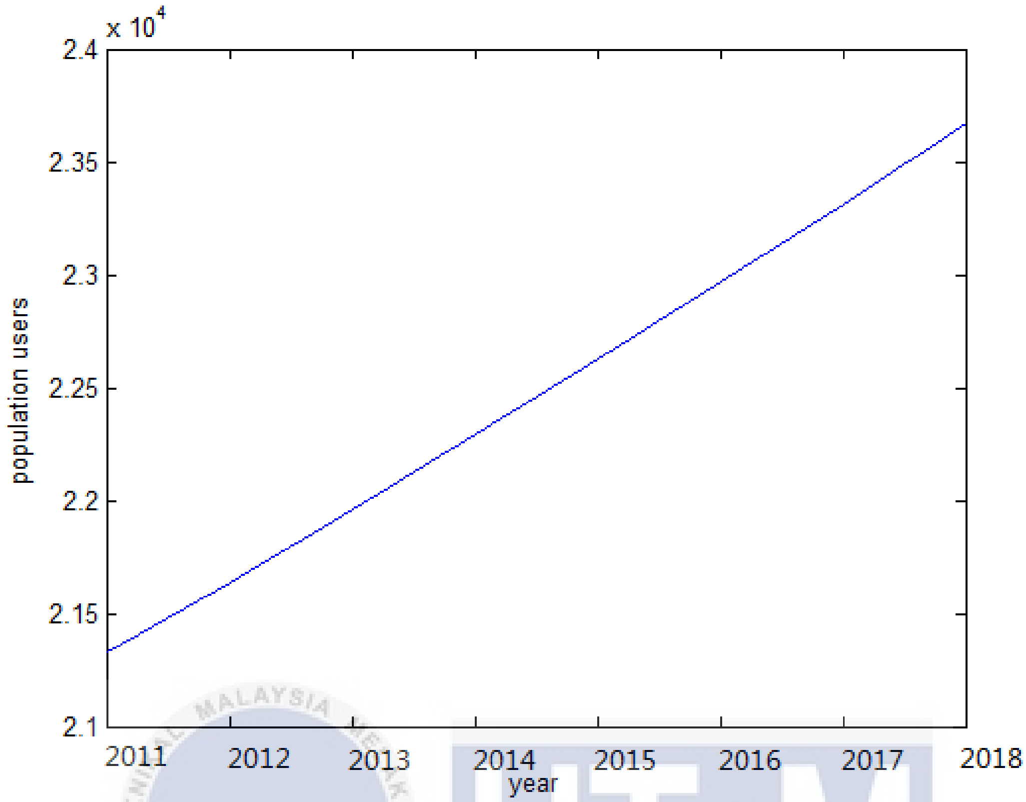

Figure 4.1: Population performance of various years

To find the optimum number of SCN, we first have to compute the number of total mobile users in Bukit Beruang, Melaka. Figure 4.1 clearly shows that the population of the users increasing significantly with increasing with the various year. There are 2142 of people in year 2011 which later increase to 2352 in the year 2018. The result was collected by computing equation (1). The vital issues we would like to simulate the number of total population are to estimate the number of total mobile users, m_t which we have assumed that 1 people equally to 1 mobile user.

4.2.2 Optimum number of SCN

To investigate the optimum number of active SCN in Bukit Beruang, we first compute (10) by using 24 hours system. The result as show in Figure 4.2,

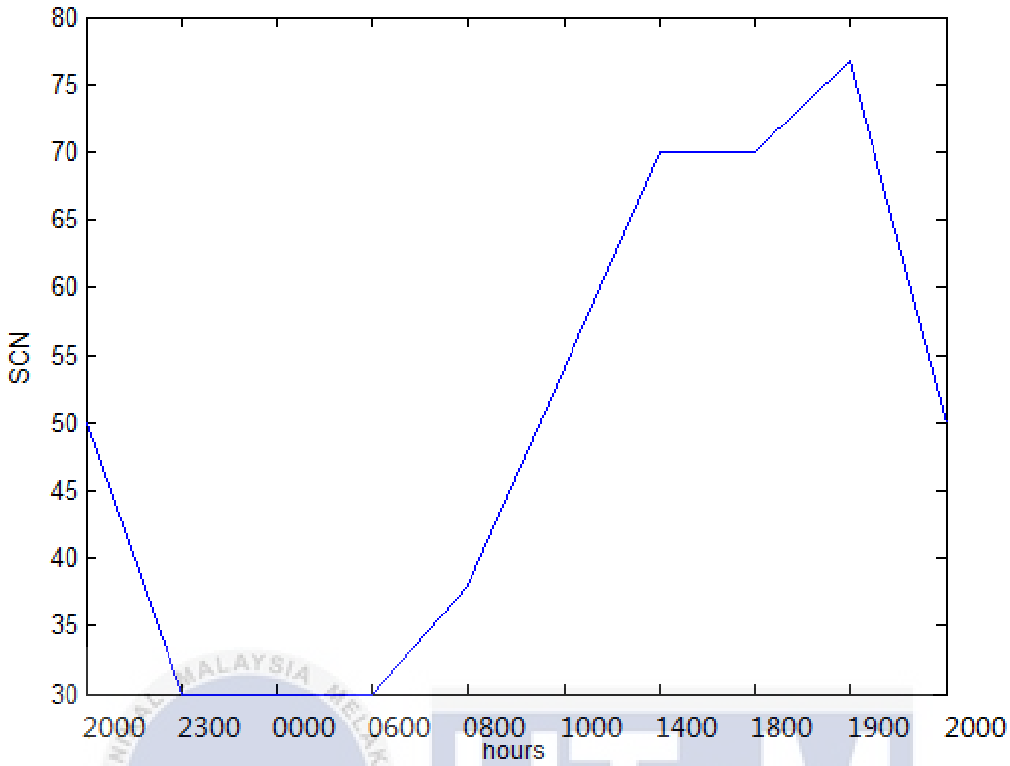

Figure 4.2: Number of SCN for various hours

From Figure 4.2 and Table 4.2 are showing the demand of SCN in various hours. We can clearly see that the number of SCN demand were different and changing for every periods. From here, we would like to classify it into 3 categories: low traffic load, medium traffic load and high traffic load.

Firstly low traffic load were consumed at the lowest power during the period from 9pm to 8am.In the low traffic load the amount of SCN needed is 10 in the range of 1km. During the medium traffic load from 8am to 12pm, it is needed at least haft of the SCN to be in the active mode, and 50 SCN is required in order to maintain the QoS. Last but not least, during the high traffic load from 2pm to 9pm, the demand of the SCN will be at the highest which it is needed 90 SCN. Hence, it is three significant different SCN performances with three different period of traffic load.

Table 4.2 Optimum number of SCN performance of various hours

Time	***Optimum number of SCN***
8:00pm	50
11:00pm	30

12:00am	30
06:00am	10
08:00am	38
10:00am	54
02:00pm	70
06:00pm	90
07:00pm	76.667
08:00pm	50

4.2.3 Power consumption of SCN in 5G HetNet

Next, we compute (10) to examine the power consumption for SCN. Here, we consider three different traffic loads that are based on result in Figure 4.2 which is 10, 30 and 90 number of SCN. In Figure 4.3 we can significant increment in the power consumption performance for each number of SCN that is required in 5G HetNet system. Based on this result, we further computes (11) to obtain the power consumption of the active small cell network in the 5G HetNet system as shown in Figure 4.4. We can see the increment in Figure 4.4. Thus it is an urgency to identify the optimum number of SCN to satisfy the 5G HetNet system in order to reduce the energy wastes.

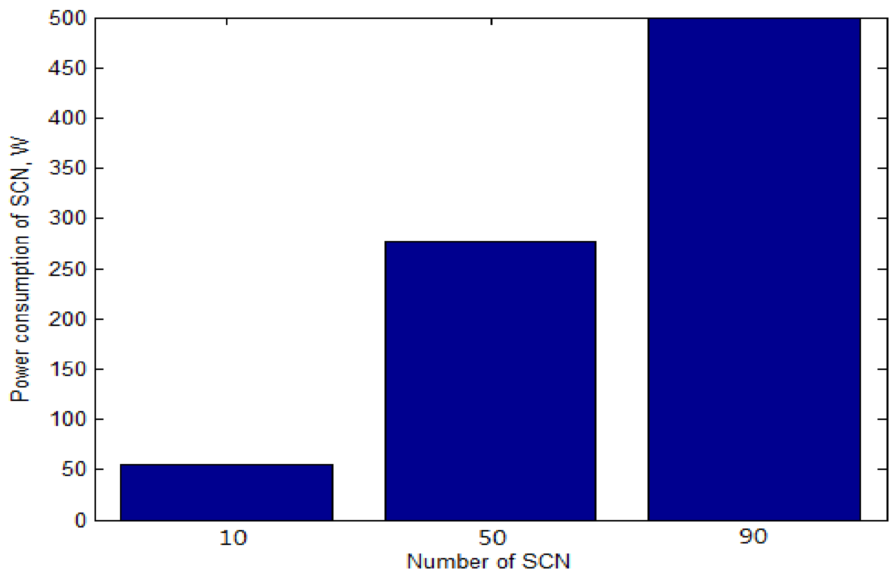

Figure 4.3: Power consumption performance for three different traffic loads

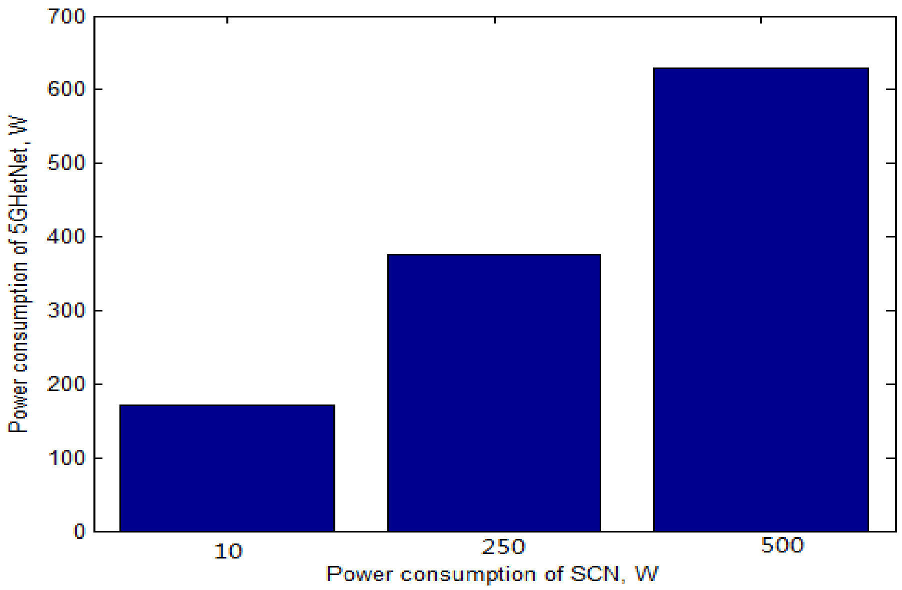

Figure 4.4: 5G HetNet power consumption for three different traffic loads

CHAPTER 5

CONCLUSION & RECOMMENDATION

SCNs in 5G HetNet bring a significant impact in the total power consumption of 5GHetNet. In this thesis, we have clearly show that activate and deactivate of SCNs will affect the power consumption of 5G HetNet. The investigation of the active and inactive SCNs is validated based on the mathematical formula, from (2) to (13) in Chapter 3. The numbers of total mobile users in Bukit Beruang are also determined. We have collected the data for an optimum number of active cells and power consumption of SCNs and also in 5G HetNet.

It is expected to have three different simulation results during three different period of traffic load. During the low traffic load from 9pm to 8am, the SCNs consume at the lowest power. During a medium traffic load from 8am to 12pm at least haft 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.

The proposed solution from this study can be upgraded into software that applicable to data processing system for telecommunication base station. This aim is to have future collaboration with telecom industrial in Malaysia to the way of successful industry-leading in wireless communication systems. 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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APPENDICES

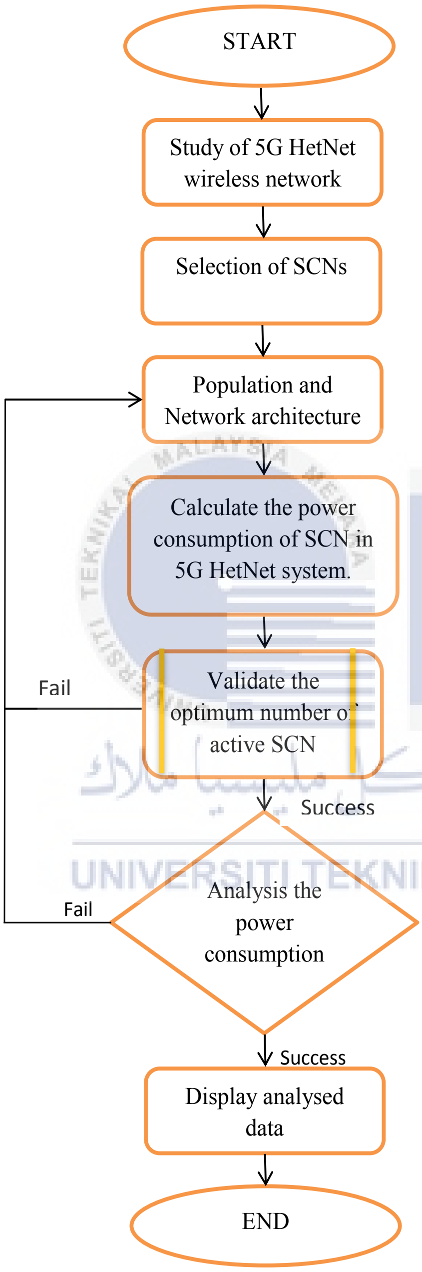
A. RESEARCH GANTT CHART (FYP 1 & 2)

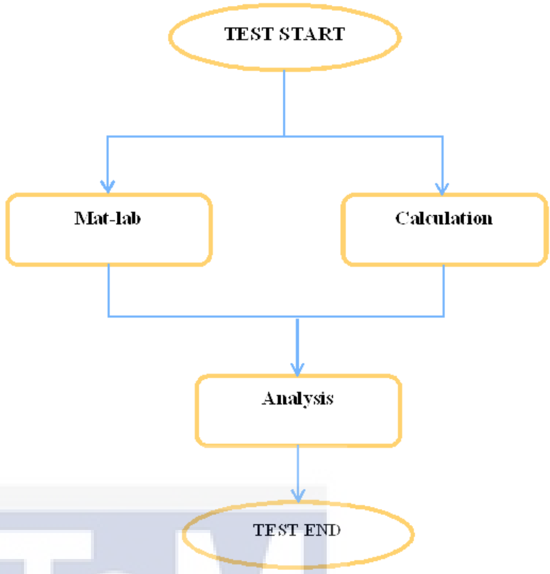
Project Activity	**2017**															**2018**														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Development of study tool	**BP Briefing**					**Mid Sem Break**																		**Mid Sem Break**						
Topic selection																														
Discussion with supervisor																														
Literature review																														
Prepare proposal																														
Submit proposal																														
Data collection																														
Selection of subject to test																														
Research briefing																														
Baseline study																														
Data collection																														
Data processing & analysis																														
Data entering& Pre-Post analysis																														
Final report & dissemination of research findings																														
Project presentation																														
Submitting project																														

Table 3.2: Power consumption parameter [6]

Cell type	$P_{(\cdot)}$,W	$k_{(\cdot)}$	$j_{(\cdot)}$,W	P_{mod}	D_{port}	a_{port}	fg_{port}	P_d	P_{fg}	P_{onu}	P_{olt}	S_{port}	O_{port}	P_s	P_{sw}	P_{ul}	P_{dl}
BS	50	21.45	354.44	N/A	N/A	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1000	2	1
SCN	0.05	7.5	4.8	2	72	N/A	100	60	100	2	20	48	48	0	N/A	N/A	N/A

B. RESEARCH PROGRESS CHART





C. CODING FOR MATLAB

```
rho_a = 100;
rho_b = 1000;
rad_scn = 1; % in meter
rad_BS = 1000;
for i=1:100
    rho_a = 100+rho_a;
    Sn(i) = (rho_a/rho_b)*(rad_scn^2/rad_BS^2);
end

figure(1)
plot(Sn)
      end
end
rho_a2 = [50 30 10 10 50 50 70 90 90 50]; % 3 values morning>3 values
evening> 3 value night
% rho_b = 1000;
% rad_scn = 1; % in meter
% rad_BS = 1000;

for t=1:length(rho_a2)
    rho_ = rho_a2(t);
    S(t) = (rho_/rho_b)*(rad_scn^2/rad_BS^2);
      End
End
S = [10 50 90];
Ks = 7.5;
Psmax = 0.1;
Js = 4.8;
for i =1: length (S)
    s_= S(i);
    Ps(i) = s_*(Ks*Psmax+Js);
end
Figure (6)
bar (Ps)
xlabel ('Number of SCN')
ylabel ('Power consumption of SCN')
    end
end
Ps= [50 250 500];
Pb = 100;
Pbbh = 20;
Psbh = 0.02;
for i = 1 ; length (Ps)
    ps_ = Ps;
    Pt = Pb + Pbbh+ ps_+ Psbh*ps_
end
Figure (9)
bar (Pt)
xlabel ('Power consumption of SCN')
ylabel ('Power consumption of 5GHetNet')
```