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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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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I hereby, declared this report entitled "Investigation on power consumption of Small Cell Network in 5G HetNet" is the results of my own research except as cited in references.

Signature : …….

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Date : ……

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

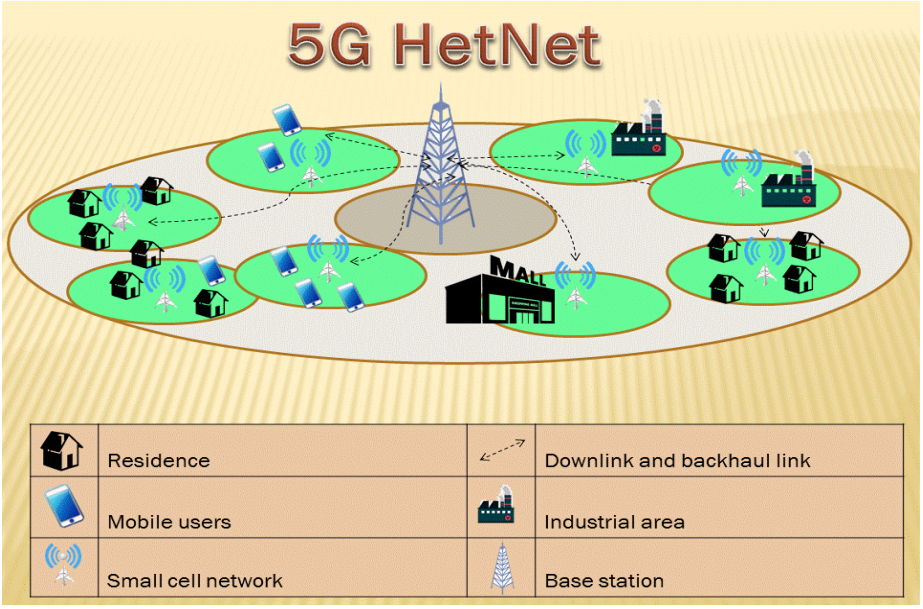

Figure 1.1 Network architeture of BS coverage with radius 1km

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].

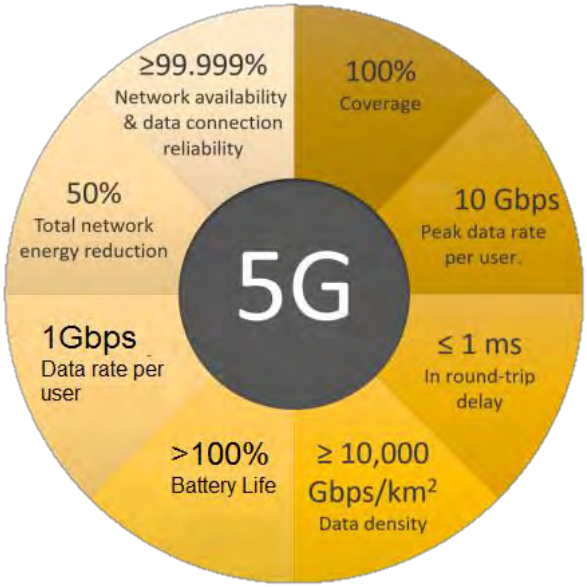

Figure 2.1: 8 Requirements to achieve 5G [3, 5]

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].

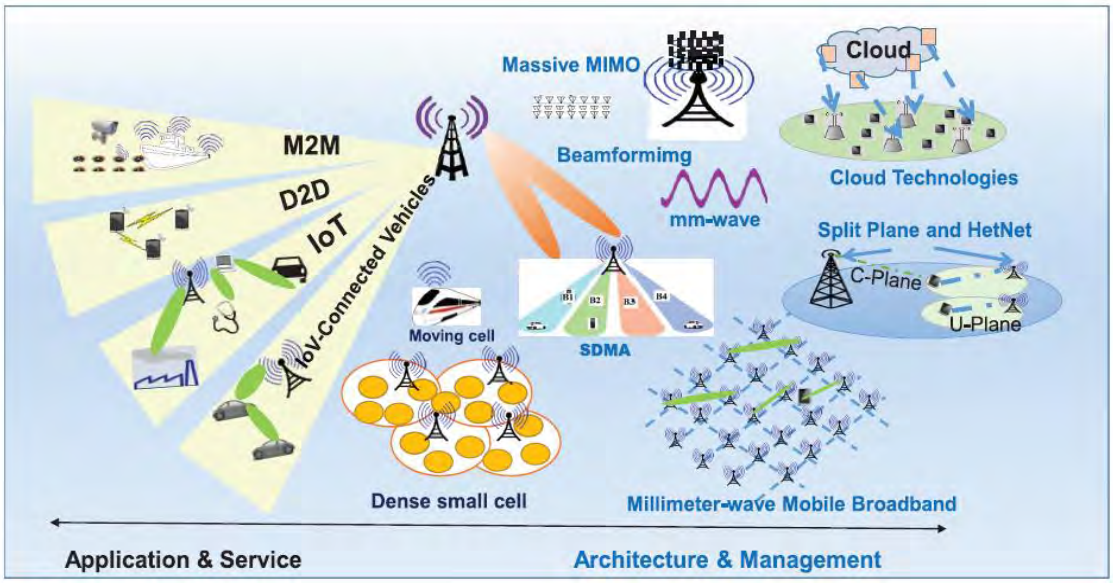

Figure 2.3: Schematic diagram of 5G wireless network system [2]

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).

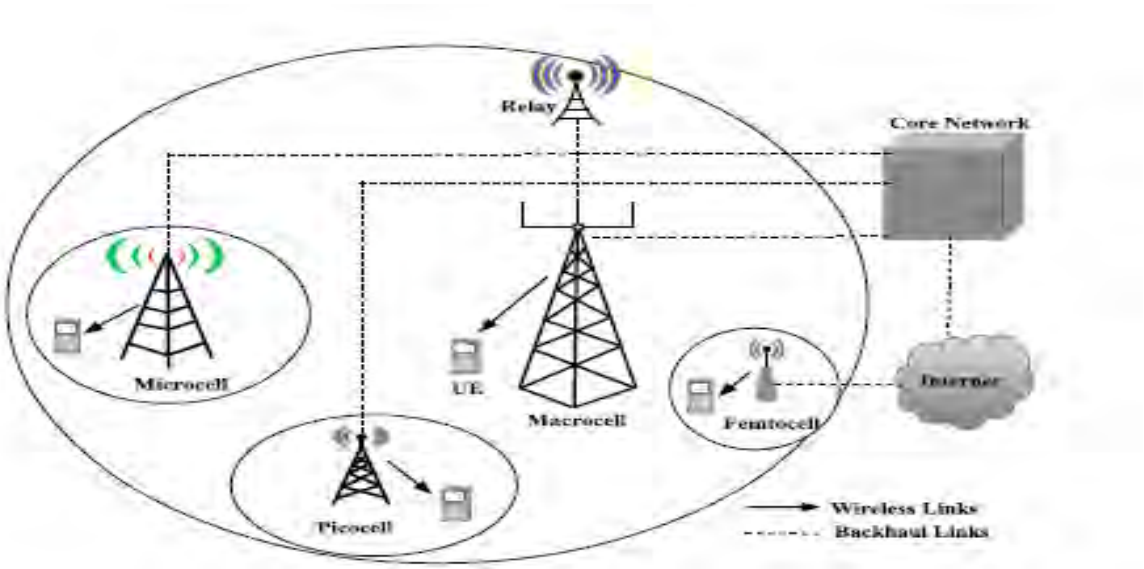

Figure 2.4: Network Architecture of a 5G HetNet [6]

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].

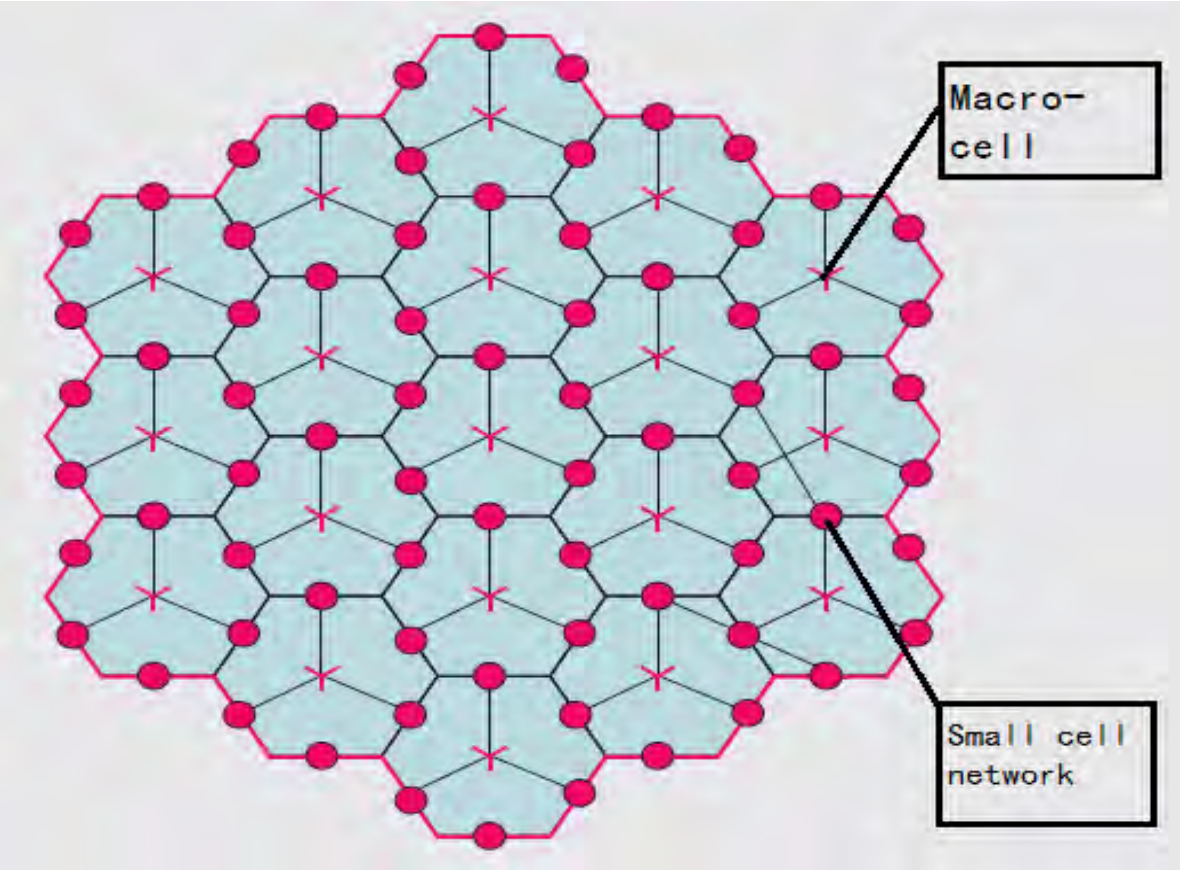

Figure 2.5: HetNet with hexagonal grid [4]