

## **MALAYSIA TOWARD 4G MOBILE SYSTEM THROUGH MINI BACKBONE RADIO ACCESS NETWORK RADIO OVER FIBER, CHALLENGES, SOLUTIONS AND KEY TECHNOLOGIES REQUIREMENTS**

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**Abstract.** Mobile system evolution is a wireless revolution through wireless communications systems. Because of the need of higher data rate of the data transmission like video streaming, also, the improvement of signal quality, 4G mobile system will be the future mobile system. It will be the integration of the other mobile wireless systems. This work will be a contribution in order to forwarding Malaysia toward 4G mobile system. In this paper, the challenges and solutions have been presented through a proposed radio access network to 4G mobile system access to the internet, some useful results and optimized parameters obtained.

*Keywords* : Mobile system; evolution; back bone optical fiber; RoF; Malaysia toward 4G mobile system

### **1.0 INTRODUCTION**

One of the fastest growing and most demanding communication industries is mobile telecommunications. The stages of evolution and development of these systems are known as “generations”. The first generation was an analogue system started in the early 1980’s called Nordic Mobile Telephone (NMT), which offered speech and related services, and whose modulation was Frequency Modulation (FM). Roaming was not possible with first generation systems, due to the lack of efficient use of the frequency spectrum. Low security also limited the services and compatibility of the first generation systems, The need for a mobile communication system offering more compatibility resulted in the creation of the second generation mobile system [1], known the Global System Mobile ( GSM ), which uses digital modulation via the technique of Gaussian Minimum Shift Keying (GMSK), In addition, the GSM system has two phases, 2G and 2.5G: 2G

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lacks internet connection and the system data rate is lower ( 9.6 kbps ) because it uses a circuit switching technique, meanwhile 2.5G has some added units in the architecture such as a General Packet Radio Service ( GPRS ) unit for connecting the system, and a higher data rate (384 kbps) using packet switching.

Next, to accommodate the higher data rate demands of applications like video transmission, a third generation (3G), known as the Universal Terrestrial Mobile System (UMTS), was generated. In 3G networks, mobile equipment is able to establish and maintain multiple connections simultaneously; the network also allows efficient cooperation between applications with diverse Quality of Service (QoS) requirements, as well as adaptive applications that will function within a wide range of QoS settings [1]. The 3G system has a data rate higher than 384 kbps (about 2 Mbps), and the network architecture of a 3G mobile system differs from that of GSM, because the overall system uses a single frequency. The multiplexing of 3G is Code Division Multiple Access (CDMA), which means that all base stations use the same frequency with different codes. Through 3G, voice and video can be transmitted at the same time that an internet connection is maintained, facilitating the user to have email capability as well as Multi Media Services (MMS). This system also uses packet service. One of the 3G system applications is Wide-Band CDMA (WCDMA), which supports the higher data rate of 5MHz band width, and because of fewer predicted requirements and applications, in the future the systems should be much cheaper for consumers.

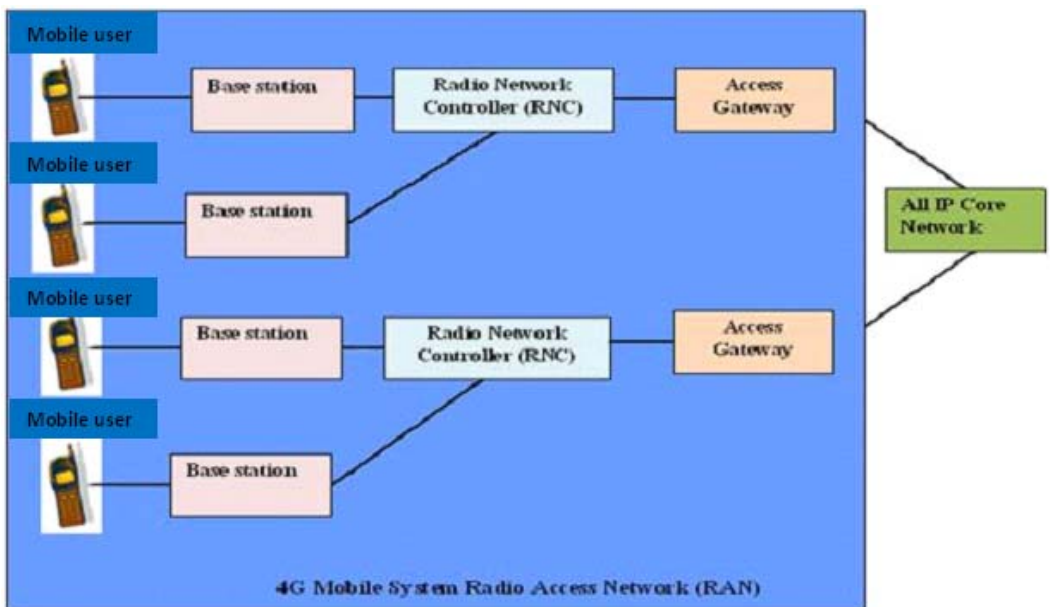
The next wireless system to be designed was the fourth generation (4G) mobile system, the future mobile system which integrates all the other mobile systems as well as other wireless systems like WiMAX. 4G mobile system architecture will be different from the previous generations, according to the frequency band used, the radio access network, and even in the software part of the system which will be all IP (Internet Protocol): fourth generation uses IPv6 (Internet Protocol version 6), and the data transmission will be based on Session Initial Protocol (SIP). This system has higher band width, therefore, the coverage of the base stations will be smaller than that in 3G system, but at the same time the data rate will be higher than 3G (more than 100 Mbps).

## **2.0 4G MOBILE SYSTEM KEY TECHNOLOGIES**

4G mobile system proposed band width is 2 – 8 GHz, and this higher bandwidth causes smaller cell radii, requiring more base stations. Higher interference also causes the signal level to be lower, therefore decreasing signal quality. The expected interference effect will be high, especially Co-Channel Interference (CCI) and Adjacent Channel Interference (ACI), which encourages researchers to design a model to minimize the CCI and ACI effects.

A new Radio Access Network (RAN) model is needed, one with reduced carrier frequencies, an overall system cost reduction, higher quality of service, and higher capacity for supporting the services of the coming decade. These requirements will make the 4G RAN different from current RANs and will innovate its architecture [2].

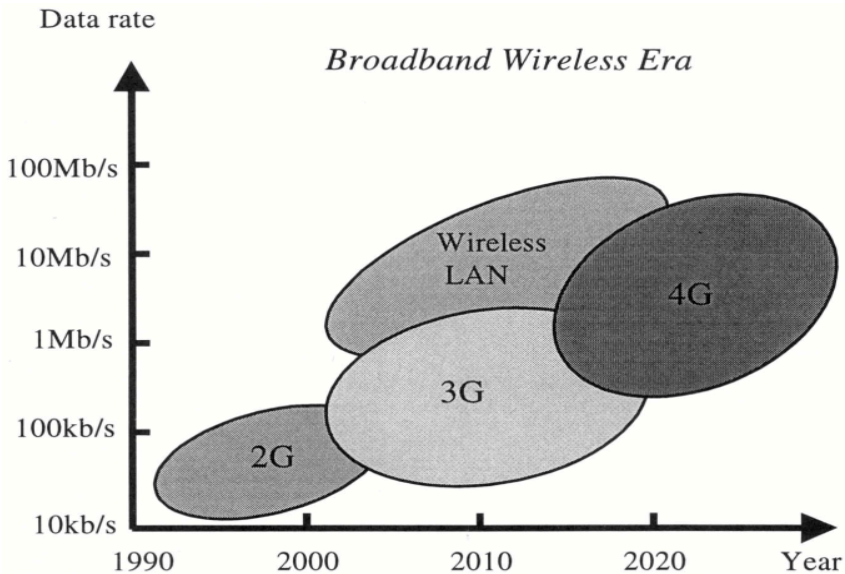
In order to achieve high capacity with reasonable frequency bandwidth, a spatial frequency reuse strategy is the key, therefore, cell planning for the system is also an important procedure [3] because the 4G will be the integration of the other wireless systems, handover also will be another challenge which must be managed. In this case, when employing radio entrance links, a higher frequency band such as the millimeter wave band will be used to transmit broadband signals; however, the higher frequency bands suffer from rain attenuation and the signal transmission range is limited to less than a few kilometers, a proposed 4G radio access network is presented in [4], therefore, radio repeaters are necessary for Base Stations (BSs) far from the Radio Network Controllers (RNCs), and to solve this problem, a new model of RAN will be necessary for the system, a simplified 4G radio access network shown in Figure 1, and the major mobile standards given in Table 1, Figure 2 is the data rate for different generations as a function of year.



**Figure 1** Simplified 4G RAN architecture

**Table 1** Major mobile standards [5]

Generation	Year of service	Major systems	Peak data rate
1G	1983	AMPS	
2G	1991	GSM, PDC, IS-54, IS-95	13 kbps 8 kbps 9.6 kbps
3G	2001-2004	WCDMA, CDMA2000, EDGE	2M bps
4G	2015 or after	OFDM-based?	> 20 Mbps?



**Figure 2** Data rate for different generations as a function of year [5]

Due to the increased number of devices and types of devices accommodating more geographic areas and users, scalable fault management solutions are desirable. Devices are likely to generate more event reports (including problems), as they will be involved in handoffs, roaming, charging, etc., and thus there will be a lot more event reports to be processed than in the traditional networks.

Some new challenges in 4G design can be summarized as follows:

- Multi-access interface, timing and recovery.
- Higher frequency reuse leads to smaller cells that may cause intra-cell

- Interference or higher noise figures due to reduced power levels.
- The Digital to analog conversions at high data rates, multiuser detection and estimation (at base stations), smart antennas and complex error control techniques as well dynamic routing will need sophisticated signal processing.
- Issues in the interface with the ad hoc networks should be sorted out.
- 4G systems are expected to interact with other networks like the Bluetooth, hyperlan, IEEE802.11b, etc.
- Voice over multi-hop networks is likely to be an interesting problem because of the strict delay requirements of voice.
- Security will be an important issue.
- A new IP protocol might be needed because of the variable QoS services and the network should do “ better than best “ effort.
- Networking protocols that adapt dynamically to the changing channel conditions.
- Seamless roaming and seamless transfer of services.

### 3.0 GLOBAL BACK BONE OPTICAL FIBER

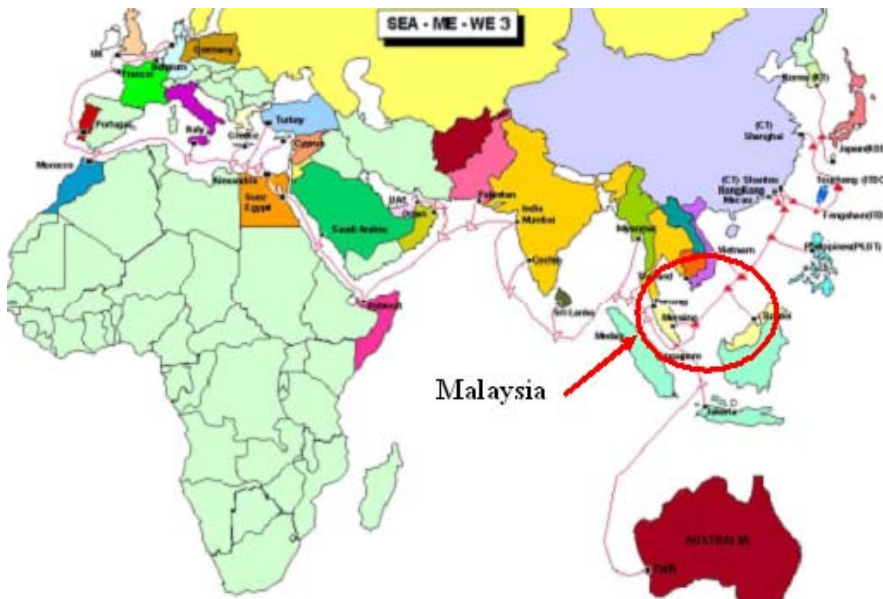
Long haul backbone networks (1.55 $\mu\text{m}$ ); metro area networks (1.3 $\mu\text{m}$ ) and local area optical networks (0.85 $\mu\text{m}$ ) are the three major applications of fiber optic telecommunications. Domestic intercity systems based on optical fibers have now been widely implemented. These use digital transmission with pulse rates ranging from a few hundred Mbps to about 2Gbps. Single mode fibers using repeater spacing of up to 40 km or more achieved since 1984.

The fiber type will be multi mode fiber because for short distances this type is suitable, unlike single mode which is better for long distances. Radio over Fiber technique which is the conversion from electrical to optical (E/O) and from optical to electrical (O/E) will be used for transmission and reception of signals, by the employment of RoF technique utilized in this work for the connection between base stations. Wave Division Multiplexing (WDM) technique was used to connect each group of base stations to their central base station [6].

By the end of that decade high capacity optical fiber cables using a carrier wavelength of 1.31 $\mu\text{m}$  (corresponding to the second lowest fiber attenuation window) were laid under the Atlantic Ocean (TAT-8) and the Pacific Ocean (TPC-3) respectively. TAT-8 and TPC-3 have the capacity to transmit data at a rate of 280 Mbit/s per fiber pair. Thus, these formed part of the so-called first generation digital light wave systems [7].

The second generation cables (TAT-9 to TAT-11 and TPC-4), with enhanced capabilities such as 560 Mbit/s per fiber pair and using a carrier wavelength of  $1.55\mu\text{m}$  (corresponding to the lowest fiber attenuation window), are now in operation.

The third generation cables (TAT-12 and 13 and TPC-6) are now in their installation/operation stages; these have a capacity of 5 Gbit/s transmission rate per fiber pair employing the first fully optical regeneration techniques in the repeaters. They also use dispersion shifted fibers and carriers with a  $1.55\mu\text{m}$  wavelength. The second and third generation cables have extended digital connectivity to the South Pacific, South East Asia and other points. Two of such global submarine cable networks that are in the vicinity of Bangladesh are the “South East Asia, Middle East and Western Europe (SEA-ME-WE)” and the “Fiber Link Around the Globe (FLAG)” long haul backbones respectively. For example, Figure 3 shows the 39,000 km long route taken by SEAME-WE-3 cable network that was started in early 1997 and took two and a half years to complete. It is an SONET cable system that uses the latest wavelength division multiplexing (WDM) technology and provides the platform to launch innovative wideband services [6].



**Figure 3** The global route taken by SEA-ME-WE-3 optical fiber cable system-3 connecting South East Asia, Middle East and Western Europe [6]

#### 4.0 MALAYSIAN MOBILE SYSTEMS

The major mobile companies in Malaysia are Maxis, Celcom, Digi, TimedotCom and TM. Of the five, three (that is, Celcom, TimedotCom and TM) are offshoots from Telekom Malaysia, which was originally a government department and which has been privatized and listed in the Kuala Lumpur Stock Exchange or Bursa Malaysia. The Directors of these three companies, that is, Celcom, TimedotCom and TM have strong links to Telekom Malaysia and the Government of Malaysia. In the case of Maxis and DiGi they also have been judicious in appointing former senior government officials and officials of the fixed liner monopoly, that is, Telekom Malaysia to sit on their board. This is to reduce their transaction costs when dealing with the regulator or the Minister, Mobile phone companies in Malaysia in 1995 given in Table 2.

**Table 2** Mobile phone companies in 1995 [8]

Mobile phone company name	Parent company	Type of cellular phone license
Mobikom	Telekom Malaysia joint venture With Sapura Holdings	800 MHz GSM1800
Celcom	Technology Resources Industries	900 MHz
Maxis	Binariang	900 MHz
Mutiara Swisscom	Berjaya	900 MHz
Sapura Digital	Sapura Holdings	GSM1800
Time Wireless	Time Engineering	GSM1800

#### 5.0 MALAYSIA TOWARD 4G MOBILE SYSTEM

Forwarding Malaysia toward 4G mobile system needs radio network architecture that must be suitable and match with other mobile and wireless systems in the country given in table 2, for example handover procedure between these mobile systems and 4G mobile system, this leads to design an architecture to the system adaptable for the handover procedure.

The second requirement is to increase the data rate because the data rate for 4G mobile system will 100 Mbps and 1Gbps for indoor and outdoor communications respectively, this can be done with a new base stations interconnections for the radio access network, The proposed RAN architecture employs grouping the overall coverage base stations into groups, interconnection group numbers equal to the cluster size as shown in Figure 4. For example, for cluster size  $N = 3$ , there will be three groups, and seven groups when  $N = 7$ , etc.

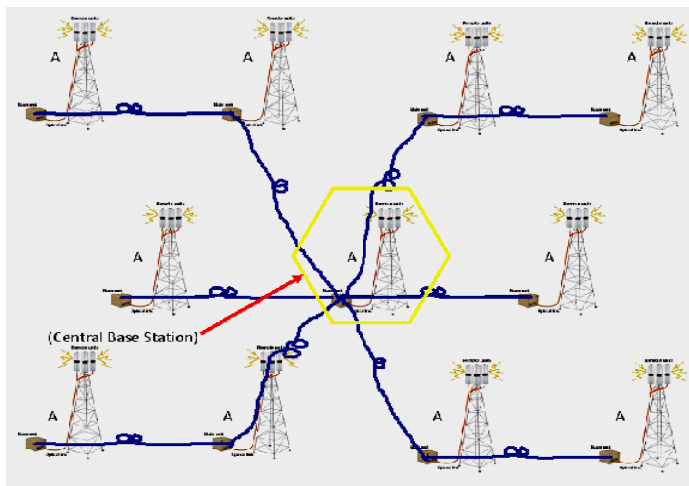
The contribution of this work is that the 4G mobile system will have Central Base Stations (CBSs) for each group connected to these central base stations, unlike the GSM system which has many Base Transceivers (BTS). In the GSM system, each group of these BTSs is connected to a Base Switching Control (BSC), and these BSCs are connected to the Mobile Switching Center (MSC), with all of these connections between BTSs, BSCs and the MSC made via microwave link.

Furthermore, in 3G mobile systems, there are base stations named Node-B, and each group of these Node-Bs is connected to Radio Network Controllers (RNC), also through microwave links like the GSM system, and then these RNCs are connected to the core network through SSGN and GSGN using microwave links.

In this paper, each group of base stations will be connected directly to CBSs through the use of the Radio over Fiber (RoF) technique, using a fiber optic channel instead of a microwave link. Figure 5 shows the connection of one group of base stations to their central base station (the black nodes represents base stations, and the red lines are fiber optic links using RoF technique).

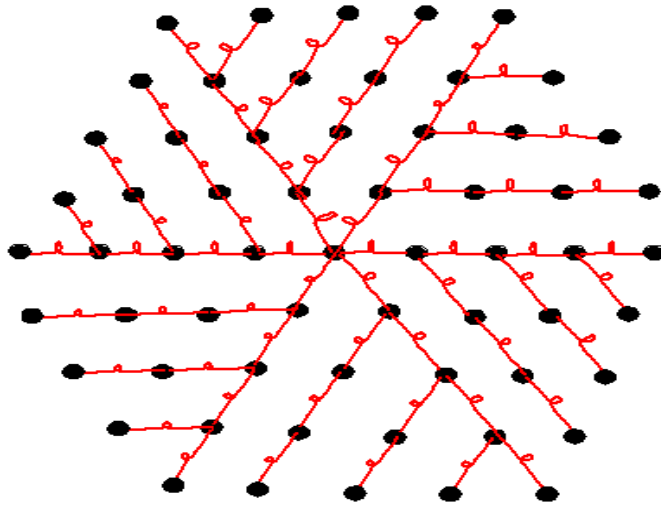
Optical fiber link is an underground link, unlike microwave link, which has many disadvantages such as atmosphere effects, and interference with other signals, especially C-band satellite signals, because the C-band is (4-8) GHz. Thus if microwave linkage were used for a 4G mobile system which has the frequency band (2-8) GHz, the interference with C-band signals would be a problem, but using fiber optics, this problem is solved.

The length of the fiber optic cable between each two adjacent base stations must be greater than twice the reuse distance  $D$  of each base station for cluster size  $N$ , using equations.



**Figure 4** The new proposed topology ( $N = 3$ ), practical view [9]



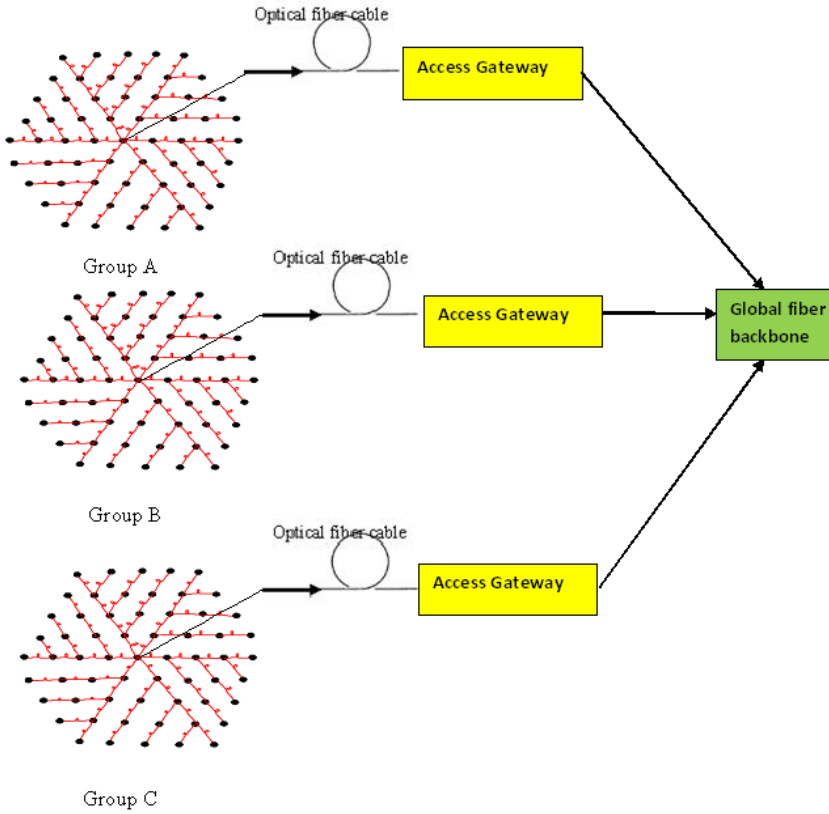


**Figure 5** The new proposed topology ( $N = 3$ ), practical view for each group [9]

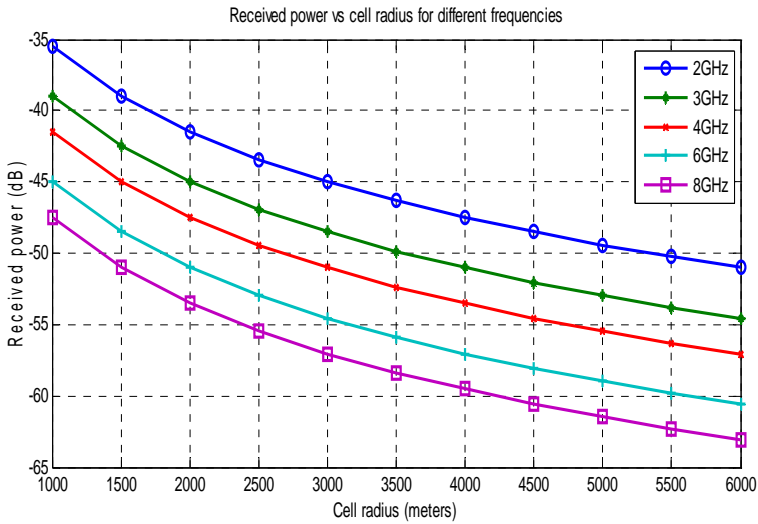
After the overall radio access network architecture design, replacing the satellite microwave link, this can be done by connecting the central base stations to access gateways, then to the internet through the global fiber backbone (i.e. with the global route taken by SEA-ME-WE-3 Optical fiber cable system-3 connecting South East Asia, Middle East and Western Europe), as shown in Figure 6.

## 6.0 RESULTS

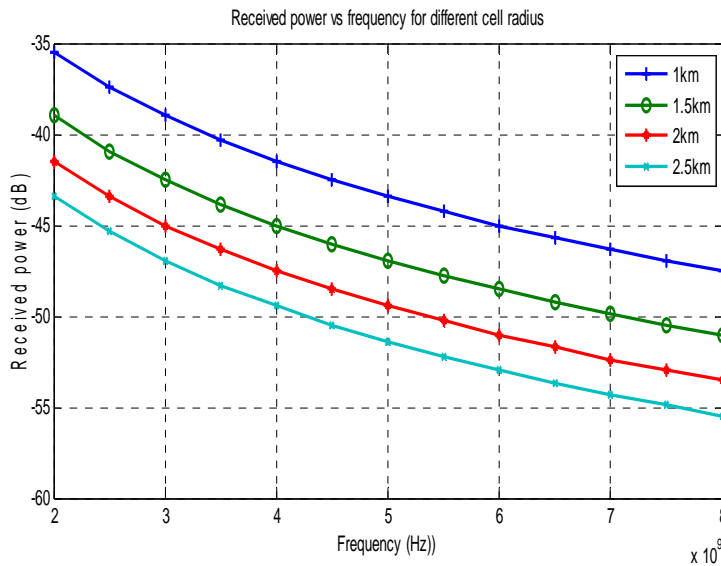
The proposed access toward 4G mobile system to Malaysia needs some optimized parameters, for example, the received power dependence on the cluster sizes with difference carrier frequencies for 4G band width which is (2 - 8) GHz (Figure 7), the base stations coverage versus the frequency (Figure 8), the fiber length between each two base stations, the total fiber length for each group, in this work some of these useful results has been obtained for this purpose, it is shown that for minimum 4G frequency ( 2 GHz ), the received power for each cell will be between (-36 to -51 dB), but for the maximum 4G carrier frequency ( 8 GHz ), the received power will be between (-48 to -63 dB ) for the cell radius between (1km to 6km), but 4G mobile system coverage is about one third of that in 3G mobile systems, therefore, the coverage area for 4G will 2-3 km, therefore the received power will be between ( - 42 to -53 dB) for the 4G frequency band ( 2 - 8 ) GHz.



**Figure 6** The proposed 4G access to the internet



**Figure 7** Received power versus cell radius



**Figure 8** Received power versus carrier frequency

The fiber length for different cluster sized are shown in Table 3, it depends on the cell radius, by optimization, practically, as the cluster size increased, the fiber length increases and the tiers increases, for different cluster sized, the total fiber length and the coverage area are given in Table 4.

**Table 3** The fiber length and cluster size calculation

Cluster size (N)	L (fiber length, km)
1	$>2R$
3	$>3R$
4	$>3.4R$
7	$>4.5R$
12	$>6R$
13	$>6.2R$

Where

R = the cell radius in km

N = the cluster size

L is the fiber length in km

The area of hexagonal cell can be calculated as:

$$A = \frac{3\sqrt{3}}{2} R^2 \dots\dots\dots (1)$$

For the proposed RAN, for each group of base stations and additional central base station, the first tier base station number = 6, second tier = 12, third tier = 18, i.e. 6 base stations will be added for each subsequent tier. Now the total number of base stations needed for a certain coverage area and cluster size can be obtained, after calculation for each group as shown in Table 4.

**Table 4** The fiber length and cluster size calculation

Cluster size (N)	No. of tiers	No. of base stations (BSs)	Coverage area (km <sup>2</sup> )	L (fiber length, km)
1	6	127	(2.6*R <sup>2</sup> )*127	>2R
3	6	381	(2.6*R <sup>2</sup> )*381	> 3R
4	6	508	(2.6*R <sup>2</sup> )*508	> 3.4R
7	6	889	(2.6*R <sup>2</sup> )*889	>4.5R
12	6	1,524	(2.6*R <sup>2</sup> )*1524	> 6R
13	6	16,51	(2.6*R <sup>2</sup> )*1651	>6.2R

If N = 3, the number of BSs = 381, R = 2 km, and the overall coverage area = 3,962.4 km<sup>2</sup>. The fiber length must be greater than 6 km between each two base stations; if the overall fiber length (126 part of fibers) = 756 km for each group and the number of groups = 3, then the fiber length equals 2,268 km for all the three groups.

If N = 7 and the total coverage area = 9,245.6 km<sup>2</sup>, the fiber length between each two base stations must be greater than 9.165 km; if the total fiber parts for each group (126 parts of fibers) = 1,154 km, the fiber length for the three groups is 8,083.66 km.

After the radio access design, calculations for the network parameters were done, especially for the fiber optic parameters like dispersion, numerical aperture, relative refractive index, the difference between Brillouin and Raman powers as threshold minimum and maximum powers launched to the fiber, and calculation of data rates with different fiber lengths can be optimized for optimum signal quality.

## 7.0 CONCLUSIONS

The future mobile system is 4G mobile system, it will be the integration of the other mobile and wireless systems like GSM, UMTS and WiMAX. This work is

an attempt to contribute forwarding Malaysia toward 4G mobile system, a proposed access network presented for Malaysia toward 4G mobile system, considering this proposed work, there will be replacement of satellite microwave system by the optical fiber system through the use of fiber optic system as an interconnection between the base stations and the global fiber optic, some optimized results and parameters has been obtained, this work will be a useful contribution for the future mobile development in Malaysia.

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