

Full Length Research Paper

# Radio access network (RAN) architecture development for a 4G Mobile system with reduced interference

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The fourth-generation wireless network communications technology standard is called 4G. Users of 4G devices will have the ability to access applications ranging from basic voice communication to seamless real-time video streaming. This paper proposes new techniques for the 4G mobile system, which include base station and cell distribution, channel allocation, and carrier frequencies. In addition, the connection between cells with a new topology using the fiber optic system instead of the microwave link in the air interface is proposed. The results show that there is very good improvement in terms of signal strength, data rate, and quality of service by using the proposed radio access network, the fiber length depends on the cluster size, also, co-channel and adjacent channel interferences has been further reduced. The fourth generation system requires accessing and air interface at higher data rates, which can be achieved by these new proposed techniques as shown in the results.

**Key words:** 2G, 3G universal mobile telecommunications system (UMTS), long term evolution (LTE), 4G, cell planning, frequency, channel allocation.

## INTRODUCTION

Frequency assignment and channel allocation are the main procedures in the planning process for mobile systems. Each mobile system has a frequency band assigned by the International Telecommunications Union (ITU) and the Federal Communications Committee (FCC). The initial channel allocation for GSM provides 124 carriers with frequency division duplex uplink and downlink sub-bands with a width of 25 MHz, duplex spacing of 45 MHz, and frequency spacing between carriers of 200 kHz. One carrier is used for the guard-bands, giving the following (Jalal, 2008):

Total number of carriers Absolute Radio Frequency Channel Number (ARFCN) =  $(25 - 0.2)/0.2 = 124$

$$f_u(n) = 890 + 0.2n \quad (1)$$

Where,  $(1 \leq n \leq 124)$

$$f_d(n) = f_u(n) + 45 \quad (2)$$

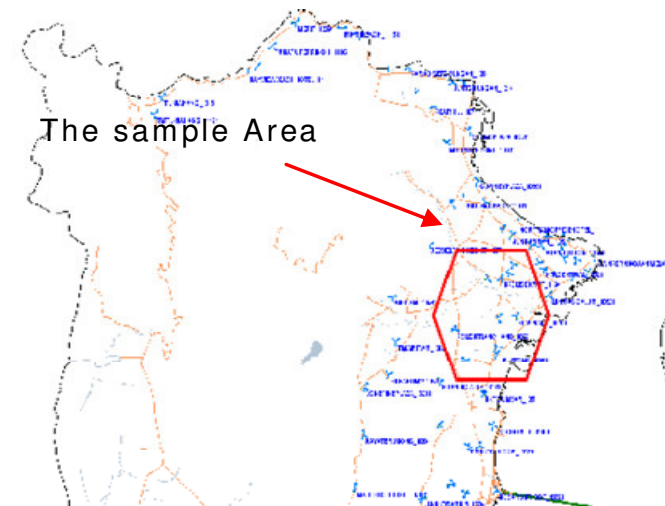
Where  $f_u(n)$  and  $f_d(n)$  are the up and down carrier frequencies, respectively, and ARFCN stands for absolute radio frequency carrier number (Jalal, 2008).

For other mobile systems, the above parameters are calculated as shown in Table 1. In second-generation mobile systems, detailed planning is concentrated strongly on the coverage planning. On the other hand, in third-generation systems, more detailed interference planning and capacity analysis, rather than a simple coverage optimization, are required. The planning tool should aid the planner in optimizing the base station configurations, antenna selections, antenna directions, and even site locations such as real networks. The uplink and downlink coverage probability is determined for a specified service by testing the service availability in each location of the plan. The coverage of a sample geographic area according to 3G UMTS mobile is shown in Figures 1 and 2, which is covered by 13 base stations (CELCOM mobile communication system in Malaysia,

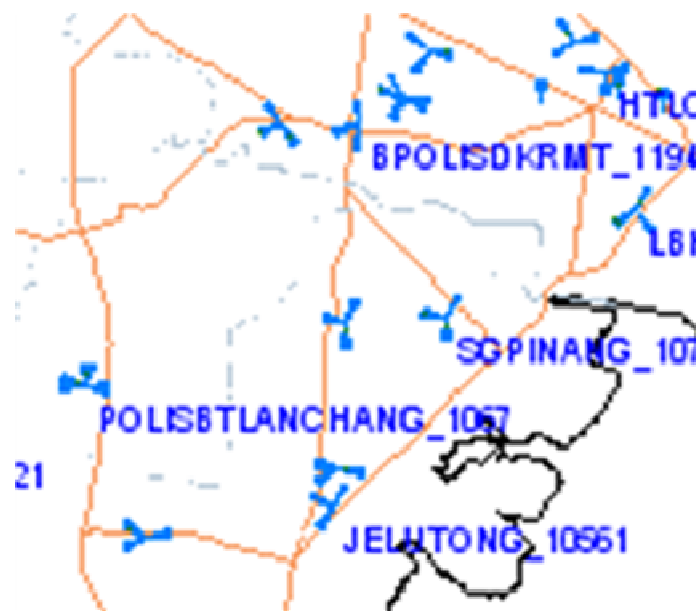
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**Table 1.** Frequency Related Specifications of Mobile Systems

System	Uplink frequency band (MHz)	Downlink frequency band (MHz)	Bandwidth (MHz)	Channel spacing (kHz)	No. of channels	Duplex distance (MHz)
P-GSM900	890 to 915	935 to 960	25	200	125	45
E-GSM900	880 to 915	925 to 960	35	200	175	45
GSM1800	1710 to 1785	1805 to 1880	75	200	375	95
GSM1900	1850 to 1910	1930 to 1990	60	200	300	80
UMTS	1920 to 1980	2110 to 2170	60	5000	12	90
LTE	2110 to 2170	2300 to 2360	60	5000	12	190



**Figure 1.** Sample area.



**Figure 2.** Maximized view of the sample area.

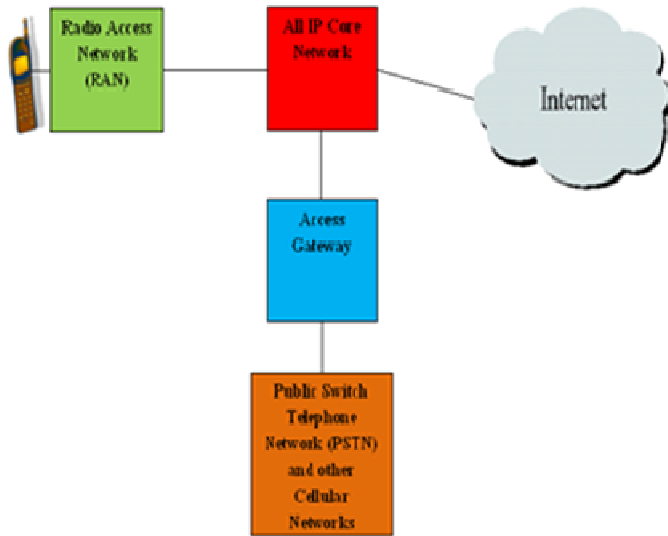


Figure 3. Simplified 4G RAN architecture.

Penang section).

## CO-CHANNEL AND ADJACENT CHANNEL INTERFERENCE

Co-channel interference (CCI) is one of the major limitations in mobile systems, and it is caused mainly by frequency reuse spectrum allocations, especially when frequency planning has not been optimized. This type of interference decreases the ratio of carrier-to-interference (C/I) powers at the periphery of the cells, causing a diminished system capacity, more frequent band-offs, and dropped calls. Adjacent channel interference (ACI) is another type of interference that affects a mobile system's signal strength and quality. This type of interference occurs when two channels are assigned with two adjacent carriers. For example, in a GSM system, two channels are separated by 200 kHz; thus, without cell planning, ACI will affect the signal quality in this case. CCI can be expressed as follows (Arango, 2001):

$$C/I = 10 \log (P_C/P_I) \quad (\text{dB}) \quad (3)$$

Where  $P_C$  = wanted signal power  
 $P_I$  = signal power from the interfering transmitter

- i) The GSM specification recommends that the C/I ratio should be greater than 9 dB.
- ii) Ericsson recommends that 12 dB should be used as the planning criterion.
- iii) Operators generally plan for higher C/I values.

ACI can be expressed as follows:

$$C/A = 10 \log (P_C/P_A) \quad (\text{dB}) \quad (4)$$

Where,  $P_C$  = power from a wanted signal  
 $P_A$  = power from an adjacent channel

- iv) The GSM specification states that the carrier-to-adjacent (C/A) ratio must be greater than -9 dB.
- v) Ericsson recommends that a C/A ratio higher than 3 dB should be used as the planning criterion.

## 4G MOBILE SYSTEM

A 4G mobile system is the future mobile system beyond 3G, which may have the following specifications (Arango, 2001):

- i) High-speed transmission (peak of 50 to 100 Mb/s and average of 200 Mb/s).
- ii) Larger capacity (~10 times greater than 3G systems).
- iii) Next-generation Internet support (IPv6, QoS).
- iv) Seamless services.
- v) Flexible network architecture.
- vi) Use of microwave band (2 to 8 GHz).
- vii) Low system costs (1/10~1/100 of 3G systems).

A simplified radio access network (RAN) architecture for 4G mobile is shown in Figure 3. The proposed frequency band for this type is 2 to 8 GHz. Owing to the higher frequency carriers, the coverage of the base stations will be smaller than that of 3G. To cover large geographic areas, the number of base stations will be increased, which causes a larger interference (both CCI and ACI).

## THE PROPOSED 4G CHANNEL ALLOCATIONS AND CARRIER FREQUENCY ASSIGNMENT

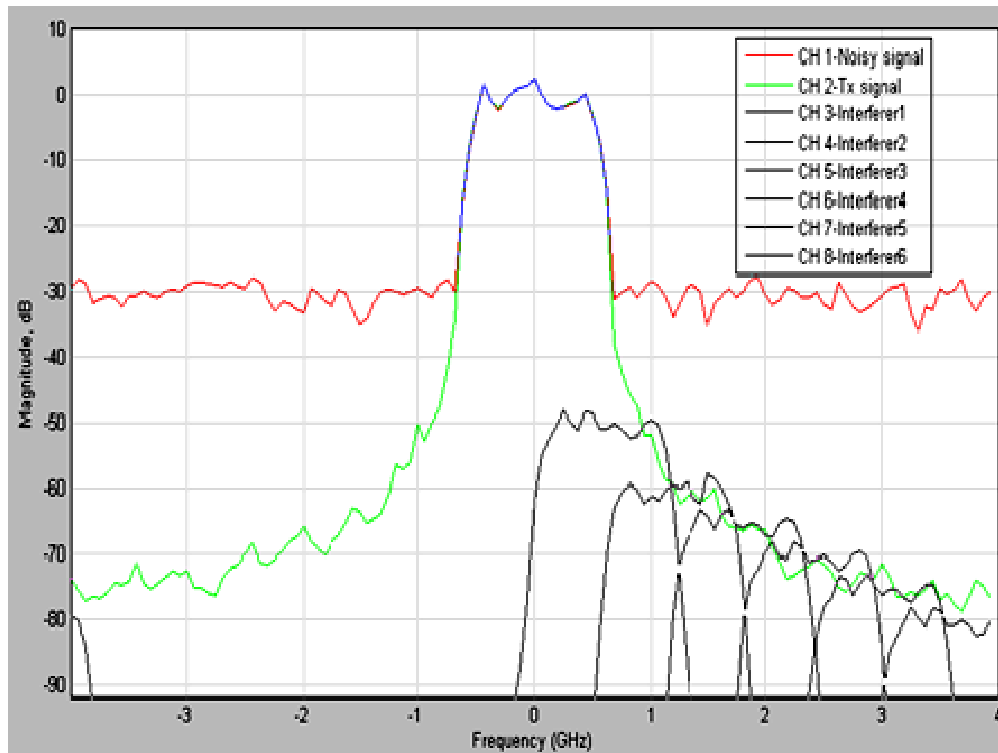
In this paper, a proposed channel allocation scenario and carrier frequencies have been presented, as shown in Table 2. The proposed allocation shows that after cell planning using the proposed channel allocation, when the C/I ratio increases, the signal strength also increases. The coverage of a certain sample area is obtained, and CCI and ACI will be reduced as shown in Figure 4 and Figure 5.

## RELATED WORK

After proposing the channel allocation and carrier frequencies assignment as shown in Table 2, the next

**Table 2.** The proposed frequency and channel allocation for 4 g mobile system.

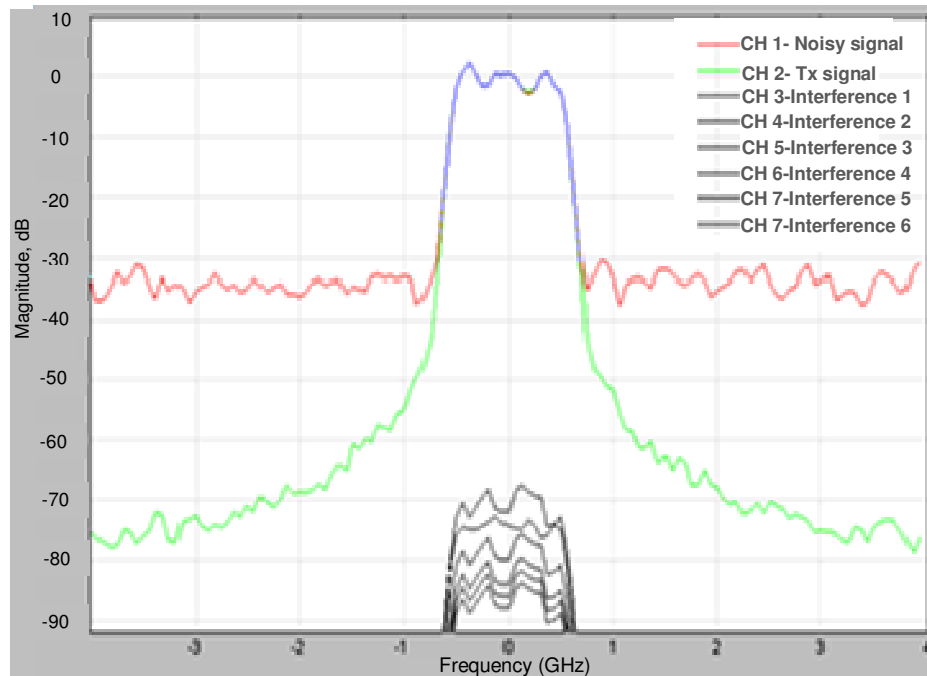
Sub-band no.	Uplink frequency band (GHz)	Downlink frequency band (GHz)	Sub-band band Width (MHz)	No. of sub-channels	Channel spacing (MHz)
1	2.0 to 2.2	2.3 to 2.5	200	40	5
2	2.6 to 2.8	2.9 to 3.1	200	40	5
3	3.2 to 3.4	3.5 to 3.7	200	40	5
4	3.8 to 4.0	4.1 to 4.3	200	40	5
5	4.4 to 4.6	4.7 to 4.9	200	40	5
6	5.0 to 5.2	5.3 to 5.5	200	40	5
7	5.6 to 5.8	5.9 to 6.1	200	40	5
8	6.2 to 6.4	6.5 to 6.7	200	40	5
9	6.8 to 7.0	7.1 to 7.3	200	40	5
10	7.4 to 7.6	7.7 to 7.9	200	40	5

**Figure 4.** ACI effect on the transmitted signal power spectrum (8PSK) modulation.

step is to develop the base stations topology with a new connection model. As a survey for the work, in (Kwansoo, 2005), radio over fiber has been shown between the radio access unit with the antenna and the switching unit for the base station. Also, (Yasushi et al., 2000) has proposed cluster-cellular radio access network but also using microwave link not fiber optic link. The same for (Halim et al., 2008) and (Seungwan et al., 2004). In (Noureddine et al., 2008), ring topology has been proposed but cell with Wireless Local Area Network (WLAN). Whereas, (Toru et al., 2001; Gary et al., 2009;

Afaq et al., 2009) are for the cell radius versus frequency relationship, the interference effect and some 4G expected specifications.

Finally, (Istivan, 2004) has proposed a double-multiple access (MA) wireless network and a two-service wave division multiplexing (WDM) optical transfer network using fiber optic link for cellular wireless networks realized via radio over fiber composing two-sub layers : conventional wireless layer and below it the optical layer. In this new developed model of connection, there will be central base stations (CBS), such as radio network



**Figure 5.** CCI effect on the transmitted signal power spectrum (8PSK) modulation.

controllers (RNCs) in 3G mobile. Each CBS represents a center for a group of base stations connected to it. Each group of these base stations connections will pass through fiber optic links instead of microwave links. In this case, there will be no free space losses because of the use of the fiber optic channel. Although the installation cost is high, but the running cost will be low. Also, all the base stations are grouped according to the cluster size, then the topology is tree unlike Toru et al. (2001) from which ring topology has been proposed, in ring topology, any fault between two adjacent base stations causes overall disconnection, also there will be no central base station to control its base stations group, in our proposed technique in this paper is tree topology, fault between base stations link will not affect the others, also there will be central base stations as a controller for the base stations group connected with it.

## RESULTS

Figures 4 and 5 show the CCI and ACI effects without using the proposed technique, while Figures 6 and 7 shows the effects of using the new technique. This indicates that there will be no interference when CCI and ACI are removed, so the signal-to-interference ratio (SIR) will be increased. Also, the length of the fiber optic depends on the cluster size, as shown in Table 3. The fiber length increases if the cluster size increases, which in turn raises the total dispersion and data rate. After

optimization, the cluster size of  $N = 3$  and  $7$  will have the best cases, as shown in Figures 8 and 9. Figures 10 and 11 show the practical view of connection for the proposed topology.

This new proposed topology for the base station connection results in reduced free space losses and an improvement in signal strength, although, the installation cost is high using this proposed technique, but the running cost is very low because fiber optic system running cost is low. Whereas, microwave link system has very high installation and running cost. Also the atmosphere effects on microwave link, but fiber optic link is under ground, so the atmosphere effect is negligible. Meanwhile, the red color refers to the fiber optic, the black nodes refer to the BSs and blue colored node for central base station (CBs). It is shown that for the same sample area, the number of BSs for 3G is 13, while that for 4G is 36 (that is approximately three times that of 3G). This is because of the higher frequency bandwidth for 4G mobile, resulting in a smaller cell radius.

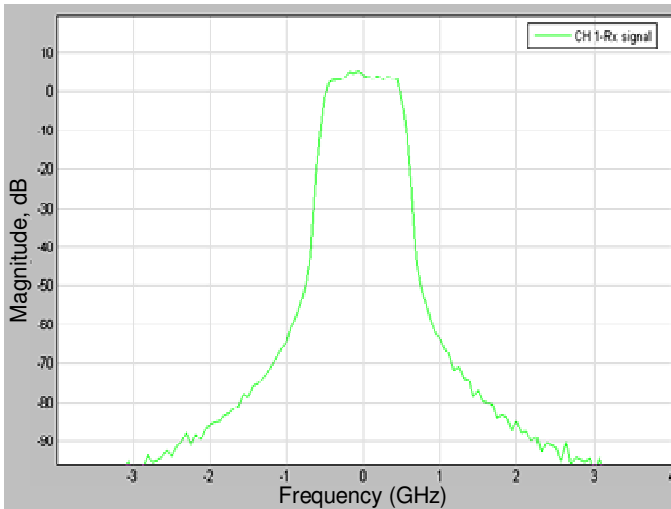
## CONCLUSIONS

This paper describes 4G mobile base station distribution, connection, and channel allocation. A new channel allocation and carrier frequencies for the system cells with new cell connection and distribution are also introduced, yielding some measured results. It is shown that the new allocation and connection increases the SIR

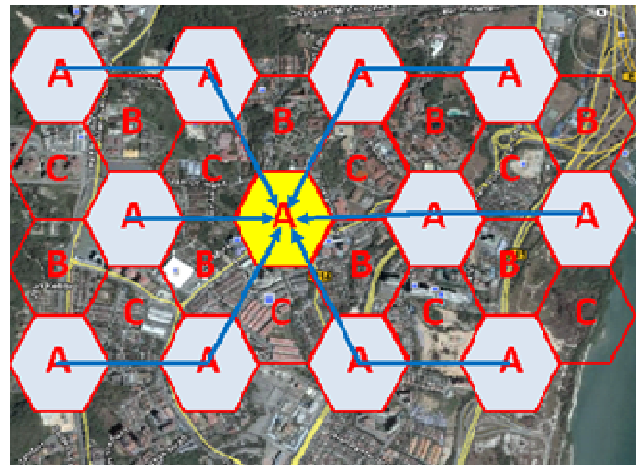
**Table 3.** Summary of coverage planning and fiber length

Cluster size (N)	No. of tiers	No. of base stations (BSs)	Coverage area (km <sup>2</sup> )	L (fiber length, km)
1	6	127	$(2.6 \cdot R^2) \cdot 127$	$> 2R$
3	6	381	$(2.6 \cdot R^2) \cdot 381$	$> 3R$
4	6	508	$(2.6 \cdot R^2) \cdot 508$	$> 3.4R$
7	6	889	$(2.6 \cdot R^2) \cdot 889$	$> 4.5R$
12	6	1,524	$(2.6 \cdot R^2) \cdot 1524$	$> 6R$
13	6	1,651	$(2.6 \cdot R^2) \cdot 1651$	$> 6.2R$

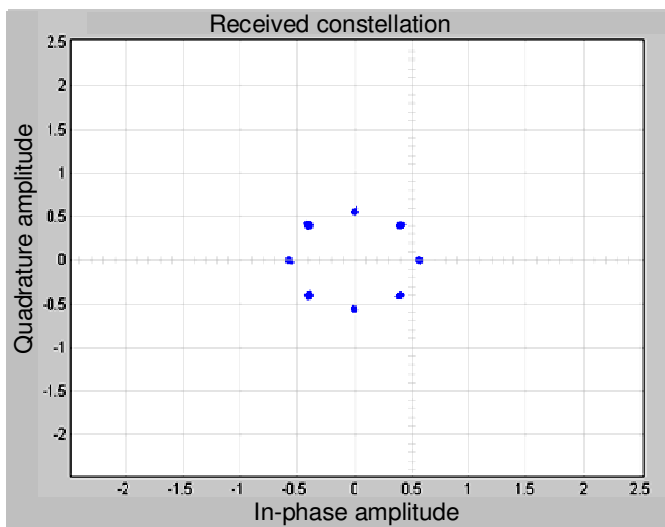
Where, R is the cell radius in km, and BSs are the base stations. If N = 3, the number of BSs = 381, R = 2 km, and the overall coverage area = 3,962.4 km<sup>2</sup>, the fiber length must be greater than 6 km between each two base stations; if the overall fiber length (126 part of fibers) = 756 km for each group and the number of groups = 3, then the fiber length equals 2,268 km for all the three groups. On the other hand, 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 part of fibers) = 1,154 km, the fiber length for the three groups is 8,083.66 km.



**Figure 6.** Received signal power spectrum (8PSK) using the new proposed technique.



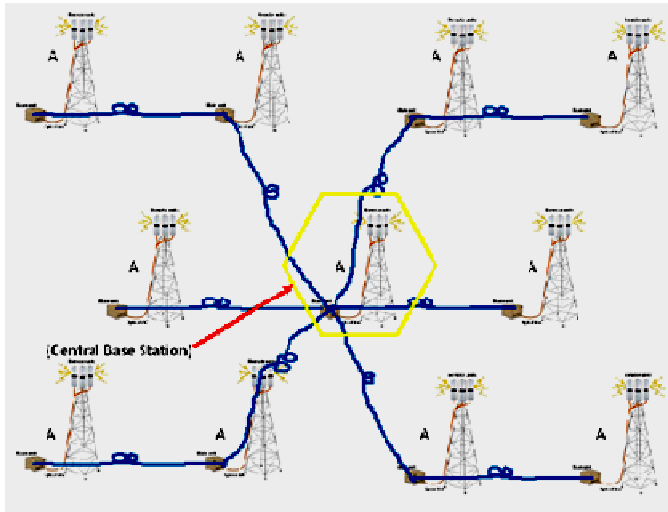
**Figure 8.** The new proposed topology (N = 3) for the same sample area shown in Figure (2). There will be the same step and connection for cell groups B and C because N = 3; the yellow-colored cell is the CBS for this cell group.



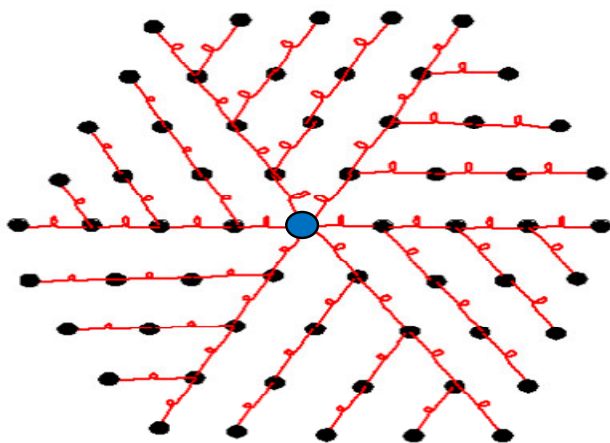
**Figure 7.** Received signal constellation (8PSK).



**Figure 9.** The new proposed topology (N = 7) for the same sample area as shown in Figure (2). There will be the same step and connection for cell groups B, C, D, E, F, and G because N = 7; the yellow-colored cell is the CBS for this cell group.



**Figure 10.** The new proposed topology ( $N = 3$ ), practical view.



**Figure 11.** The new proposed topology ( $N = 3$ ), practical view for each group.

and reduces the interference because the carrier frequencies are allocated with minimum interference. Moreover, the connection between the cells with the newly introduced technique improves the data rate and QoS. The signal strength also improves because there are no free space losses, and the fiber optic has very small losses of approximately 0.02 dB/km.

The proposed new techniques improve the quality of 4G services and the signal quality as given in the results, the results shows the proposed radio access network gives more suitable network for 4G mobile system by increase in data rate to about more than ten times that for 3G mobile system, although the installation cost is

higher. Nevertheless, the running cost is very small because of the use of the fiber system.

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