The Seybold Report
ISSN 1533-9211
DOI 10.5281/zenodo.7124744

DESIGNING A CELLULAR NETWORK USING MULTIPILE ACCESS TECHNIQUE IN THE CITY IPOH, PERAK, MALAYSIA

[1]ALI OTHMAN ALBAJI, [2]ROZEHA BT. A. RASHID and [3*]AHMAD SHAHIDAN ABDULLAH

[1]Dept. of Electronics and Telecommunications, the Higher Institute of Science and Technology, Suk Algumaa Tripoli, Libya.
[2,3]Dept. of Telecommunication Software and Systems (TeSS) Research Group Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.
E-mail: [1]ahmedali@graduate.utm.my, [2]rozeha@fke.utm.my, [3*]ashahidan@utm.my

Abstract:

The design and construction of a cellular network are complex processes that involve the selection and configuration of various components and the support infrastructure. This study aims to provide a net revenue maximizing model for network designers. The integer programming model takes into account various factors such as the cost of doing business, the availability of bandwidth, and the revenue potential of each customer area. It then takes into account the locations and sizes of each cell and the channels that it will be allocated. The research provides design and solutions for cell planning and cellular network building. It is specific research and given the spectrum (20 MHz), channel bandwidth (200 kHz), and C/I = 15 dB rate, a select city will need coverage by cells. So, for our research, we chose the startup point, network type, "duplex distance", Multiple Access (MA), TDMA, and control principles, by knowing our frequencies band for frequency reuse and frequencies' table building, the cells planning will be based on frequency division (GSM) and code division (WCDMA) because in code division case adjacent base station sites use the same frequencies and the different base stations and users are separated by codes rather than frequencies. We chose GSM 900 and based on our choice provide our solution.

Keywords: DUPLEX DISTANCE, MA, TDMA, GSM, WCDMA

1. INTRODUCTION

In terms of tackling spectral congestion and user capacity, the cellular concept was a major development. It packed a lot of capacity into a little amount of spectrum and didn't necessitate any significant technical advancements A group several A single high-power transmitter1 is replaced with a series of low-power transmitters (small cells), each of which covers a piece of the service area in the cellular concept (large cell) [1][2]. Adjacent base positions are given different sets of channels, subsequent in only an insignificant number of base stations getting all the available channels. By allocating separate sets of channels to neigh boring base stations, interfering between base zones (and the cellular users under their control) is abridged. Ipoh is a 643-square-kilometer city with a population of 660,000 people. As an RF planning engineer for a single local operator with a 20MHz spectrum allocation and a 200KHz full-duplex channel bandwidth Propose cell planning with 6 tier-one co-channel cells and a minimum operational C/I of 15dB, assuming the cost of building one base station is RM500K, and one sector is just RM50K. The number of channels given to a cell becomes insufficient to supply the needed number of clients as the demand for cellular networks expands. Cellular design solutions now demand a greater number of channels per unit of the service area to increase the

The Seybold Report
ISSN 1533-9211
DOI 10.5281/zenodo.7124744

capacity of cellular networks, techniques such as cell splitting, sectoring, and coverage zones are utilized., designs are utilized in practice. The cellular system may increase in a regulated manner because of cell splitting [3] [4] [5]. Directed Sectoring employs projection to prevent channel interference and frequency reuse [2] [6]. The notion of zone microcells expands the cell boundary and stretches out the coverage of a cell. To hard-to-reach locations. In a cellular radio system, the geographical area is split into several areas called cluster which use all frequency channels, and each of which is split again into cells. Each cell has one base station, and neigh boring base station is assigned different groups of channels so that the interference between base stations is minimized. This technology is frequency reuse, and if the frequency is reused M times, then it increase the capacity of the system M times. In addition to that, the cellular network employees sectoring and cell splitting. In sectoring, it replaces a single omnidirectional antenna at the base station by several directional antennas so that decrease the co-channel interference and improved SIR. In cell splitting, it splits one cell into several sub cells, and increase the number of base station so that, it increases the number of subscribers in the cellular system. As the result, of increasing base station, each base station can decrease the height of the antenna tower and the power of transmit. The cellular system was used in 2G/3G mobile system as well as 4G/5G system. By fundamentally altering the mechanism, cell excruciating boosts capacity. Cell splitting improves Reduce the cell size R while keeping the co channel reprocess ratio D/R constant to increase the figure of channels per unit zone. Another strategy to enhance the purpose of capacity is to maintain the cell size constant and look for new ways to expand it, for smaller cells [4]. As we've seen, sectoring increases SIR, enabling the cluster to expand, which lowers the D/R ratio2. There's a chance the size will be reduced. The SIR is first enhanced with turning projections, and then it is improved again. The number of cells in a cluster can be reduced by lowering the number of cells in the band, the capacity of the cluster can be improved. Repeat the process regularly. However, the relative risk must be minimized to be effective. By decreasing the transmission power, interference may be avoided. Co-channel interference can be decreased in a cellular structure by substituting only channels. One directional antenna is surrounded by several directional projections at the base station, each emitting within a defined range and industry [7] [8] [9] [10].Ipoh population is 660,000. The network has at least an operating C/I of 15 dB, Spectrum 20MHz, full-duplex channel bandwidth 200KHz. Network is based on GSM, stations (St, S) and run in the 900 MHz diapason, which parcelled out into two scopes of 20 MHz (each canal 200 kHz), for downstream to the mobile St (BS to MS) make use of 890 to 910 MHz, for upstream to base St (MS to BS) apply 935 MHz - 955 MHz After the network boundaries defined, the work will go through the below steps:

- Build our clusters with determinate the spectrum length and bandwidth for each channel, which will be done through the co-channel interference and co-channel tiers in hexagonal cellular system, “finding” cluster size, build clusters topology and determinate/find the positions of co-channel cells. Then apply it in the directional radio propagation case.
- Build frequencies table, calculate cell size in the sites, capacity and BTS count.
- Carry out financial calculations.
- Provide nominal cell plan.

The Seybold REPORT

ISSN 1533-9211

DOI 10.5281/zenodo.7124744

2. PROPOSED DESIGN

In this part, discuss our suggested monitoring and roaming decision method for cellular network interoperability. The suggested plan is a decision-making process. The connection manager (CM) of the end user's device performs this operation. Because the UE has altitude is in a unique position to receive both the operator's stated policies and real-time network data. The state of the neigh boring area, as a result, it is best to delegate roaming to the Earther than any other entity in the network, this entity makes the selection choice. As a result, the proposed strategy is a good one. Station with network assistance and host control. It's worth emphasizing that we don't think about handoffs. It fully follows the 3GPP Standard single local operator with a 20MHz spectrum allocation range between macro-cell BSs. The suggested design must not obstruct the macro-cell handoff strategy of the proposed plan:

A. Interconnectivity

An operator can allocate a portion of the base station's traffic to the regions served by the repeater by changing the coverage of a serving cell. The repeater, on the other hand, has the purpose is to reradiate the base station signal to areas, not to increase capacity to the system. Repeaters are increasingly being utilized to extend coverage inside and around buildings, which has historically been a weak point [Rap96], [Mor00]3. Many carriers have chosen to do so. Put microcells outside of huge structures to allow in-building wireless penetration, and then, within the buildings, multiple repeaters with DAS networks are installed. This method is advantageous since it has quick coverage into selected locations but does not allow for capacity upgrades. As a result of increased outdoor and interior user traffic, problems will occur. Dedicated base stations will be implemented in the future. To support the high number of in-building cellular users, additional infrastructure will be required within buildings.

B. Dynamic and Circulated mobility

The same channel is maintained while a mobile moves from one zone to the next inside the cell. As a result, unlike sectoring when the mobile moves between MSCs, no handoff is necessary. Zones that exist inside the cell the base station merely changes the zone location for the channel. In this case, in this method, a specific because the channel is only active in the area where the mobile is moving, the base station's radiation is limited, and interference is reduced. In the normal condition, all three zones distribute the channels in time and space, and they are also used in co-channel cells. On highways and in urban traffic corridors, this strategy is extremely useful. Because the cell features a large central antenna, zone cell technology decreases co-channel interference in the cellular system while maintaining a specified coverage radius. The channels are dispersed in time and space in all three zones, and they are reused in co-channel cells as normal. On highways and in urban traffic corridors, this strategy is extremely useful. The advantage of zone cell technology is that it decreases co-channel interference while keeping a particular coverage radius in the cellular system. Replace the base station on the outskirts. The inside of the cell Reduced co-channel interference increases signal quality while simultaneously lowering costs. Increased capacity without the loss of trunking efficiency that sectoring causes.

ISSN 1533-9211
DOI 10.5281/zenodo.7124744

C. Network Coverage

It has thoroughly covered the region to finally reach a 100 percent coverage level. Network Configuration is a shrinking coverage over the area and others have extensively covered the area to finally reach a 60 percent coverage level. Every cell is in a distinct environment, and as a result, they operate differently and have diverse impacts on one another. The minimum signal level inside the coverage region is -97dBm, which is sufficient for receiving a perfect quality signal. In general, the signal near the BSs is strong enough to offer a -80dBm level with minimal loss of coverage, and the signal farther away is reflected until it reaches an acceptable level5. As a final correction, the network created in this exercise is made up of 15dBand six-cell clusters. Cell splitting and zone microcell approaches avoid the trunking inefficiencies that sectored cells suffer from, allowing the base station to operate more efficiently.

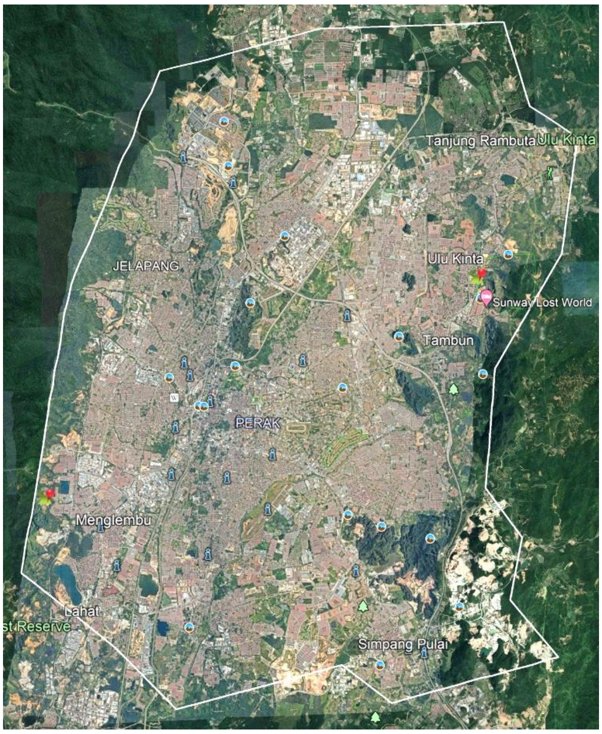
3. MAP AND OPERATOR'S NETWORK BORDERS

Ipoh Telecom LLC network service zone is divided as can be seen below:

- Has an area of about 643 km^2
- Number of people - 660,000.

First drawing the zone's border where should be provided the services.

Figure 1: Services' zone border



ISSN 1533-9211

DOI 10.5281/zenodo.7124744

A. Build our clusters "Frequency, spectrum length and bandwidth for each channel"

Our stations (St, S) will run in the 900 MHz diapason, which will be parceled out into 2 scopes of 20 MHz (each canal 200 kHz):

- For downstrm to the mobileSt (BS to MS) make use of 890 to 910 MHz
- For upstrm to baseSt (MS to BS) apply 935 MHz - 955 MHz

In GSM fruition the Frequency Division (FD) and Time Division (TD) for cell/cluster planning (FD), duplex gear (FD), and for multiple access (Figure 2 and Figure3). Duplex distance for 900 MHz band is 45 MHz [11].

Figure 2: Frequency division and Time division in GSM

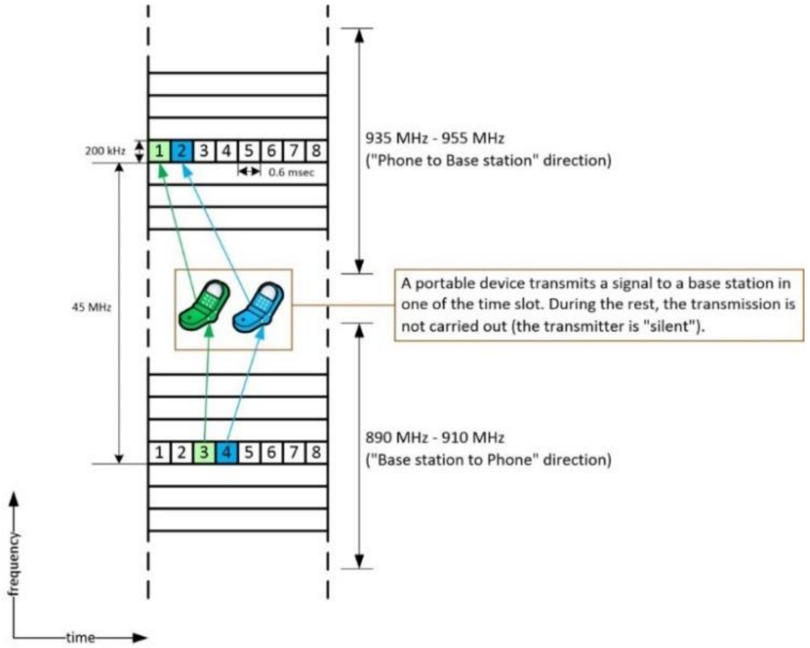
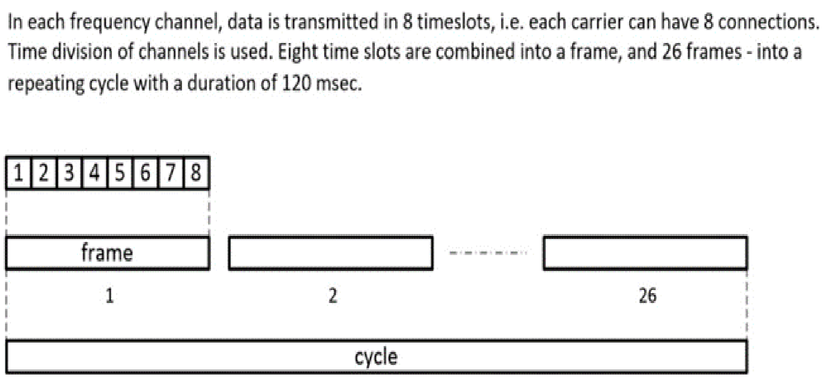


Figure 3: Time division in GSM



ISSN 1533-9211

DOI 10.5281/zenodo.7124744

B. Co-channel interference and co-channel tiers in hexagonal cellular system

When doing design and building a cellular or any other wireless system, we should not only take care of radio coverage but support the needful capacity also [12]. Frequency reuse increases the capacity of the system. But, the downside to that is the interference in the same (co-channel) and from adjacent frequency channel. In recommendations and requirements pointed out the co-channel (C/I) and adjacent frequencies (C/A) interference rates.

- C/I ≥ 9 dB; + additional 3 dB (allowance in engineering), so, C/I ≥ 12 dB
- C/A ≥ -9 dB; + additional 3 dB, so, C/A ≥ -6 dB

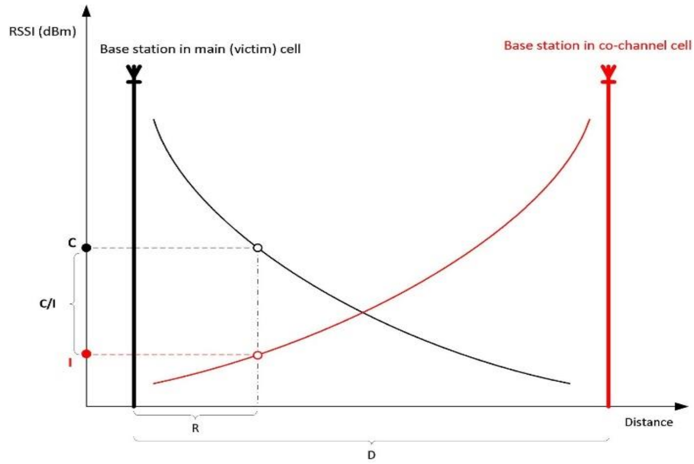
In our research, for the co-channel sites in tier 1, we should have C/I ≥ 15dB.

C/I (carrier-to-interference rate) visualization can be seen in Figure 4

D – Distance between co-channel cells

R – Radius of main (victim) site/cell

Figure 4: C/I (carrier-to-interference rate) visualization

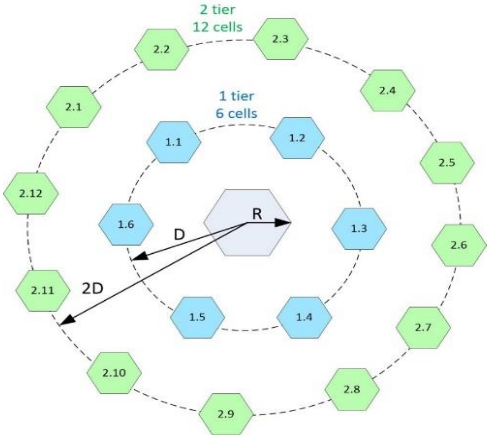


To reduce interference, the contiguous sites/cells do not operate on the same frequencies. All sites/cells with different frequencies are grouped in a cluster.

In hexagonal architectures on each “n” tier exist “6 x n” co-channel sites/cells [13][14], and it does not depend on the count of cells in the cluster. I.e., on the first-tier, as the source of interference are six (6 x 1 =6) co-channel sites/cells, on the second-tier – 12, and so on.

The Seybold Report
ISSN 1533-9211
DOI 10.5281/zenodo.7124744

Figure 5: Co-channel tiers in hexagonal cellular system



C. Finding cluster size

Increasing transmitter (TX) RSSI will not help to decrease the interference in all system. More TX RSSI maybe will increase the C/I ratio for this site/sell, but the co-channel site/cell will have the opposite effect. The cluster size based on C/I necessary rate and depend on the ratio of D (distance between co-channel sites/cells) to R (main (victim) site/cell radius) [15].

$$\frac{D}{R} = \sqrt{3 \times N}$$

Equation 1_Co-channel reuse ratio

N – Is a cluster size, i.e., is the count of sites/cells in the cluster.
Now we will calculate cell count in one cluster.

$$\frac{C}{I} = \frac{\left(\frac{D}{R}\right)^{\alpha}}{6}$$

Equation 2_C/I (carrier-to-interference rate) on R distance

$$C/I = 15\ \text{dB} = 31.6228$$

α is a path-loss exponent, it can take below values [16]:

Table 1: Path-loss exponent value

Environment	Path-Loss exponent, α
Free space	2
Urban area cellular	2.7 to 4.0
Shadowed urban cellular	3 to 5
In building LoS	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

ISSN 1533-9211

DOI 10.5281/zenodo.7124744

So, in our case, α = 2.7 to 4, we will use "4" value

$$\frac{C}{I} = \frac{\left(\frac{D}{R}\right)^4}{6}$$

$$\frac{D}{R} = \left(\frac{6 \times C}{I}\right)^{1/4}$$

Equation 3_Cluster size calculation - part1

We know that $\frac{D}{R} = \sqrt{3 \times N}$

So, we get the following

$$N = \frac{1}{3} \times \left(\frac{6 \times C}{I}\right)^{2/4}$$

$$N = \frac{1}{3} \times (6 \times 31.6228)^{0.5} = \frac{1}{3} \times 189.7381^{0.5} = \frac{1}{3} \times 13.775$$

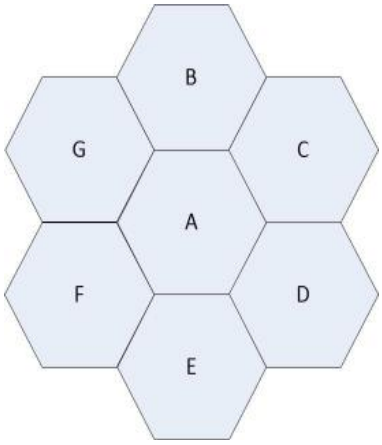
N =4.592

Equation 4_Cluster size calculation - part2

N can be 3, 7 or 12 (Tipper, n.d., p. 5)[1].

Finally, our cluster will have minimum 7 sites/cells. Our choice is N=7

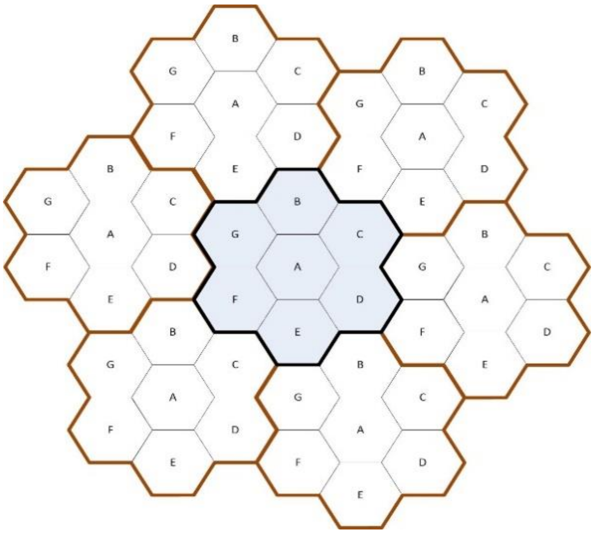
Figure 6: One cluster diagram



A, B, C, …, G are the frequencies in the site/cell. As we know, the cells in the same cluster use different frequencies. So, we can use the whole 20MHz in one cluster and reuse the same frequency many times in other clusters.

ISSN 1533-9211
DOI 10.5281/zenodo.7124744

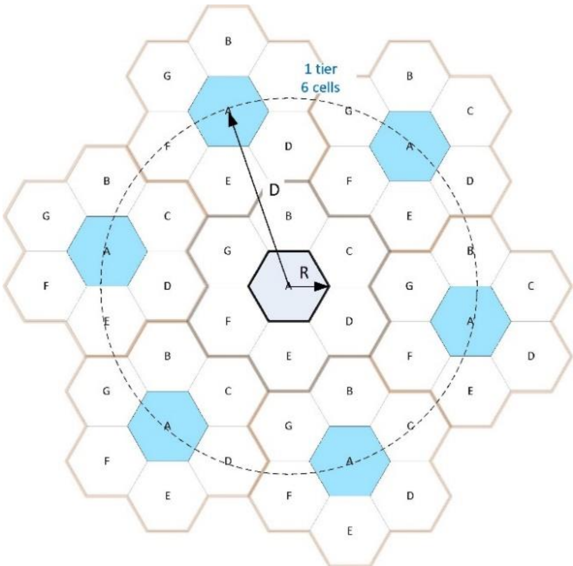
Figure 7: Main cluster with six contiguous clusters



D. Build clusters topology and determinate/find the positions of co-channel cells

As wrote before, assuring the required capacity and continuous radio coverage are always important factors to pay attention to. Our cluster will have 7 sites/cells. We can set additional clusters and increase our cellular network if one cluster fails to cover the required zone during design and radio propagation calculations. Main cells and tier 1 co-channel 6 cells disposition preview in Figure 8.

Figure 8: Main cluster's cell and tier 1 six clusters' co-channel sites/cells



ISSN 1533-9211

DOI 10.5281/zenodo.7124744

During the design and build of the cellular network, we should determine the positions of the co-channel cells in contiguous clusters. Where is it should be? In the same place as the observed cell, for example, in the center of the cluster? Or at the junction of clusters?

To find it we must from our observed site/cell shift "i" cells in any direction, then rotate 60° counter clockwise and continue moving through "j" cells.

"i" and "j" values depend on cluster size ("N") [14].

$$D = \sqrt{(i^2 + i \times j + j^2)} \times \left(R \times \sqrt{3}\right)$$

Equation 5_Calculation the distance between co-channel sites/cells

We know that $\frac{D}{R} = \sqrt{3 \times N}$

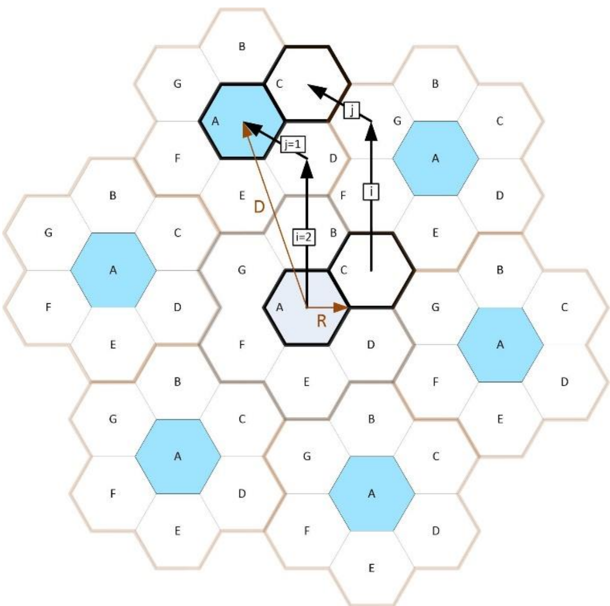
"N" value can preview as in Equation 6.

$$N = i^2 + i \times j + j^2$$

Equation 6_"N" value preview via "i" and "j"

In our case N=7, so, we have N=7 (i=2, j=1)

Figure 9: Co-channel cell position determination



4. SECTORING" FROM OMNIDIRECTIONAL TO DIRECTIONAL RADIO PROPAGATION"

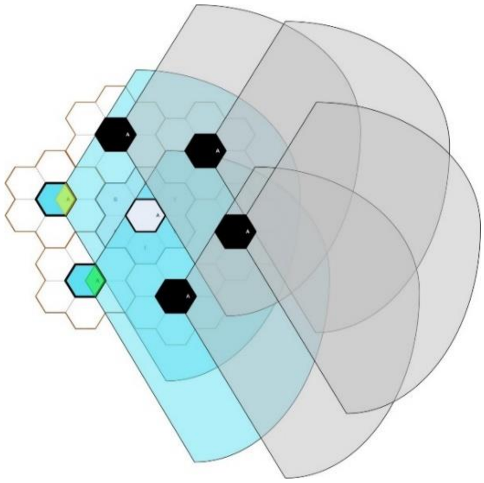
Base Station Systems (**BSS**) provides for mobile customers access to the provider's services. Each BSS consists of Base Station Controller (BSC) and Base Transceiver Station (BTS). BTS includes radio devices (transceiver, receiver, etc.) and antennas. BSC manages the BTS and

ISSN 1533-9211

DOI 10.5281/zenodo.7124744

whole radio network [12]. We can set up in each BTS omnidirectional antenna and via one antenna will cover 360^0. But we can split our 360^0 directions into 3 (120^0 sectoring). What do we have in this case?

Figure 10: Sectoring decrease interfering co-channel cells from 6 to 2



5. BUILD CLUSTERS TOPOLOGY FOR CELLS WITH SECTORING RADIO PROPAGATION

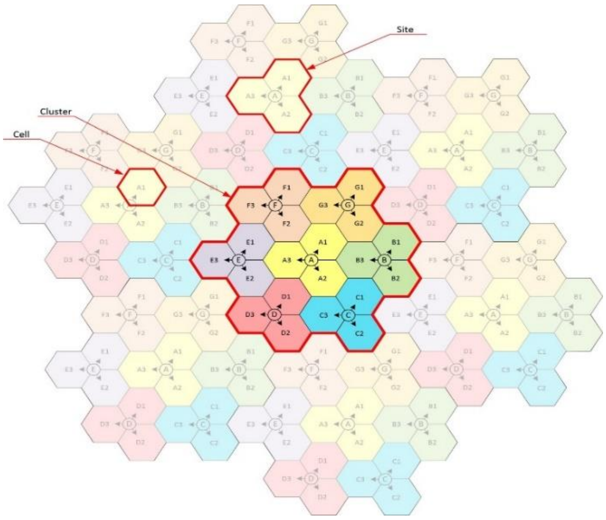
For cells with sectoring radio propagation, we will apply other techniques for building our clusters, other than cells with omnidirectional radio propagation. We will not place BTS in the center of the cell and divide the cell into three zones. We will place BTS on the junction point of three cells. Each cell will be covered by a 1200 directional antenna, for each cell coverage will use its frequency (group of frequencies). So, from three cells will build one site, then from seven sites will build the cluster. We will use the following cluster notation – X/Y.

X – Sites count in the cluster.
Y – Cells count in the cluster.

We already calculated our cluster size (page 7). Our cluster will have 7/21 pattern. It means that each cluster will have 7 three-sector sites which will cover/support 21 cells [12].

The Seybold Report
ISSN 1533-9211
DOI 10.5281/zenodo.7124744

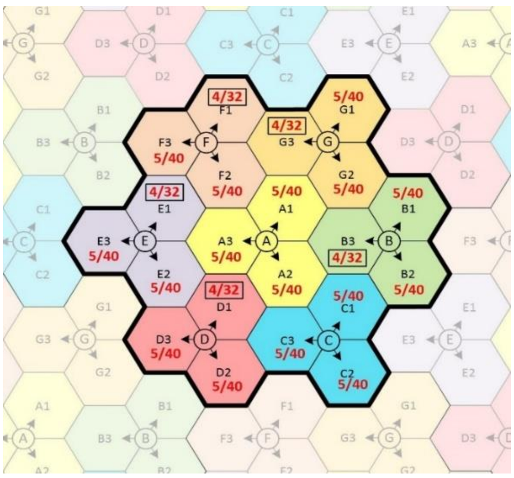
Figure 11: Clusters topology for cells with sectoring radio propagation



6. FREQUENCIES TABLE, CELLS SIZE IN THE SITES, CAPACITY, BTS COUNT "USING BAND AND CHANNELS COUNT"

As mentioned above, for BTS to MS will use frequencies from 890 MHz to 910 MHz, for MS to BTS from 935 MHz to 955 MHz, i.e., for each direction we have 20 MHz spectrum (for each canal 200 kHz). So, we will have 20 MHz/200 kHz = 100 carriers for duplex canals in each cluster. As we can see in Figure 2, each carriers provided multiple accesses, 8 connections canal per one carrier. So, our capacity for each cluster is 8 x 100 = 800 calls in a zone covered by one cluster. Our cluster will have a 7/21 pattern. If we assume that the subscribers' load is evenly distributed in the cluster, then in the cluster we will have for 16 cells the 5carriers/40canal per cell, for the remaining 5 cells the 4carriers/32canal per cell.

Figure 12: Channel/connections count in cells



ISSN 1533-9211

DOI 10.5281/zenodo.7124744

But in the real network, one cell maybe will need more channels, another one has fewer channels, it depends on subscribers' loads in the cell. I.e., we can “withdraw” channels from one cell to another one, as required.

Channels/frequencies table for our cluster can see in Table 2.

Table 2: Frequencies. Channels list

Channel	BS-MS/MS-BS MHz	Cell	carriers/ canal	Channel	BS-MS/MS-BS MHz	Cell	carriers/ canal
Ch 1	890/935	A1	5/40	Ch 51	900/945	B2	5/40
Ch 2	890.2/935.2	B1	5/40	Ch 52	900.2/945.2	C2	5/40
Ch 3	890.4/935.4	C1	5/40	Ch 53	900.4/945.4	D2	5/40
Ch 4	890.6/935.6	D1	4/32	Ch 54	900.6/945.6	E2	5/40
Ch 5	890.8/935.8	E1	4/32	Ch 55	900.8/945.8	F2	5/40
Ch 6	891/936	F1	4/32	Ch 56	900/946	G2	5/40
Ch 7	891.2/936.2	G3	4/32	Ch 57	901.2/946.2	A3	5/40
Ch 8	891.4/936.4	A2	5/40	Ch 58	901.4/946.4	B3	4/32
Ch 9	891.6/936.6	B2	5/40	Ch 59	901.6/946.6	C3	5/40
Ch 10	891.8/936.8	C2	5/40	Ch 60	901.8/946.8	D3	5/40
Ch 11	892/937	D2	5/40	Ch 61	902/947	E3	5/40
Ch 12	892.2/937.2	E2	5/40	Ch 62	902.2/947.2	F3	5/40
Ch 13	892.4/937.4	F2	5/40	Ch 63	902.4/947.4	G1	5/40
Ch 14	892.6/937.6	G2	5/40	Ch 64	902.6/947.6	A1	5/40
Ch 15	892.8/937.8	A3	5/40	Ch 65	902.8/947.8	B1	5/40
Ch 16	893/938	B3	4/32	Ch 66	903/948	C1	5/40
Ch 17	893.2/938.2	C3	5/40	Ch 67	903.2/948.2	D1	4/32
Ch 18	893.4/938.4	D3	5/40	Ch 68	903.4/948.4	E1	4/32
Ch 19	893.6/938.6	E3	5/40	Ch 69	903.6/948.6	F1	4/32
Ch 20	893.8/938.8	F3	5/40	Ch 70	903.8/948.8	G3	4/32
Ch 21	894/939	G1	5/40	Ch 71	904/949	A2	5/40
Ch 22	894.2/939.2	A1	5/40	Ch 72	904.2/949.2	B2	5/40
Ch 23	894.4/939.4	B1	5/40	Ch 73	904.4/949.4	C2	5/40
Ch 24	894.6/939.6	C1	5/40	Ch 74	904.6/949.6	D2	5/40
Ch 25	894.8/939.8	D1	4/32	Ch 75	904.8/949.8	E2	5/40
Ch 26	896/940	E1	4/32	Ch 76	905/950	F2	5/40
Ch 27	895.2/940.2	F1	4/32	Ch 77	905.2/950.2	G2	5/40
Ch 28	895.4/940.4	G3	4/32	Ch 78	905.4/950.4	A3	5/40
Ch 29	895.6/940.6	A2	5/40	Ch 79	905.6/950.6	B3	4/32
Ch 30	895.8/940.8	B2	5/40	Ch 80	905.8/950.8	C3	5/40
Ch 31	896/941	C2	5/40	Ch 81	906/951	D3	5/40
Ch 32	896.2/941.2	D2	5/40	Ch 82	906.2/951.2	E3	5/40
Ch 33	896.4/941.4	E2	5/40	Ch 83	906.4/951.4	F3	5/40
Ch 34	896.6/941.6	F2	5/40	Ch 84	906.6/951.6	G1	5/40
Ch 35	896.8/941.8	G2	5/40	Ch 85	906.8/951.8	A1	5/40
Ch 36	897/942	A3	5/40	Ch 86	907/952	B1	5/40
Ch 37	897.2/942.2	B3	4/32	Ch 87	907.2/952.2	C1	5/40
Ch 38	897.4/942.4	C3	5/40	Ch 88	907.4/952.4	A2	5/40
Ch 39	897.6/942.6	D3	5/40	Ch 89	907.6/952.6	B2	5/40
Ch 40	897.8/942.8	E3	5/40	Ch 90	907.8/952.8	C2	5/40
Ch 41	898/943	F3	5/40	Ch 91	908/953	D2	5/40
Ch 42	898.2/943.2	G1	5/40	Ch 92	908.2/953.2	E2	5/40
Ch 43	898.4/943.4	A1	5/40	Ch 93	908.4/953.4	F2	5/40
Ch 44	898.6/943.6	B1	5/40	Ch 94	908.6/953.6	G2	5/40
Ch 45	898.8/943.8	C1	5/40	Ch 95	908.8/953.8	A3	5/40
Ch 46	899/944	D1	4/32	Ch 96	909/954	C3	5/40
Ch 47	899.2/944.2	E1	4/32	Ch 97	909.2/954.2	D3	5/40
Ch 48	899.4/944.4	F1	4/32	Ch 98	909.4/954.4	E3	5/40
Ch 49	899.6/944.6	G3	4/32	Ch 99	909.6/954.6	F3	5/40
Ch 50	899.8/944.8	A2	5/40	Ch 100	909.8/954.8	G1	5/40

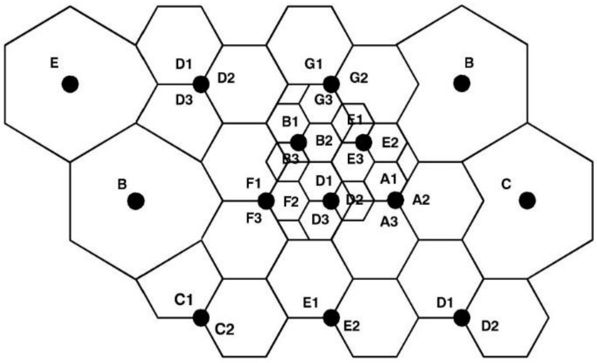
A. Cell size, transition regions

In some cases traffic intensity varies depending on the area and during the day. So, the cell can have different sizes. When traffic is high in a region, small cells are placed, and when traffic is low, large cells are placed, as shown In Figure 13.

ISSN 1533-9211

DOI 10.5281/zenodo.7124744

Figure 13: Cells of different sizes



To determine the radius of the cell (R), in addition to radio coverage calculation, the following data are analyzed:

- direction and congestion of roads and highways;
- the density of the subscriber load;
- capacity requirements.
- Cells by size qualified as [11]:
- "MACRO" cell (up to 35 km);
- "**MICRO**" cell (up to 2 km);
- "PICO" cell (up to 100 m).

When building clusters with small cells, totally will have more capacity, but cars, trains, any object moving at high speed, will frequently jump from one cell's BTS to another one BTS. When building clusters with big cells, we will have another problem, total capacity will be lower.

Thus, the topology of the BTS should be adapted to the value, density, and territorial distribution of the subscriber load.

B. Transition regions

If our clusters have assorted sizes of cells, it provides problems in channel planning because the reuse distance D is will be different for cells with different sizes. The small cells with half the D are interfering in the large cell. So, we will have the buffer zone where the small and big cells do not use the same frequencies.

If we apply all frequencies in our cluster, we will not have a reserve for buffer zones, and will not reserve for additional BTS for future installation also. Additional BTS will need if will need increase capacity in the existing cluster. So, for cells we will not provide 5/40 and 4/32, we can for some channels, for example, Ch85-Ch100, Ch79, Ch67-Ch70, not use and reserve those for the future (Table 2).

In another way, for the expansion of capacity, we should do our cells small, which will decrease cluster size. So, we should be building additional clusters. If our cellular network cannot be

The Seybold Report
ISSN 1533-9211
DOI 10.5281/zenodo.7124744

covered by one cluster, for example, it is covered by “Z” count clusters, our system capacity will be = Z x 800 connections (traffic canal).

C. Grade of Service (GoS)

Cellular network capacity depends on the count of the available canal and grade of service (GoS). The probability of blocking calls (GoS) is the percentage of unsuccessful attempts at the establishment of a connection caused by network congestion. For simplicity of cell’s capacity calculations, the results of calculations are usually presented in the form of an Erlang B table [12]. Rows (n) – number of traffic canal

Columns (GoS) – function of the GoS.

Table 3: Erlang B table

n	.007	.008	.009	.01	.02	.03	.05	.1	.2	.4	n
1	.00705	.00806	.00908	.01010	.02041	.03093	.05263	.11111	.25000	.66667	1
2	.12600	.13532	.14416	.15259	.22347	.28155	.38132	.59543	1.0000	2.0000	2
3	.39664	.41757	.43711	.45549	.60221	.71513	.89940	1.2708	1.9299	3.4798	3
4	.77729	.81029	.84085	.86942	1.0923	1.2589	1.5246	2.0454	2.9452	5.0210	4
5	1.2362	1.2810	1.3223	1.3608	1.6571	1.8752	2.2185	2.8811	4.0104	6.5955	5
6	1.7531	1.8093	1.8610	1.9090	2.2759	2.5431	2.9603	3.7584	5.1086	8.1907	6
7	2.3149	2.3820	2.4437	2.5009	2.9354	3.2497	3.7378	4.6662	6.2302	9.7998	7
8	2.9125	2.9902	3.0615	3.1276	3.6271	3.9865	4.5430	5.5971	7.3692	11.419	8
9	3.5395	3.6274	3.7080	3.7825	4.3447	4.7479	5.3702	6.5464	8.5217	13.045	9
10	4.1911	4.2889	4.3784	4.4612	5.0840	5.5294	6.2157	7.5106	9.6850	14.677	10
11	4.8637	4.9709	5.0691	5.1599	5.8415	6.3280	7.0764	8.4871	10.857	16.314	11
12	5.5543	5.6708	5.7774	5.8760	6.6147	7.1410	7.9501	9.4740	12.036	17.954	12
13	6.2607	6.3863	6.5011	6.6072	7.4015	7.9667	8.8349	10.470	13.222	19.598	13
14	6.9811	7.1154	7.2382	7.3517	8.2003	8.8035	9.7295	11.473	14.413	21.243	14
15	7.7139	7.8568	7.9874	8.1080	9.0096	9.6500	10.633	12.484	15.608	22.891	15
16	8.4579	8.6092	8.7474	8.8750	9.8284	10.505	11.544	13.500	16.807	24.541	16
17	9.2119	9.3714	9.6171	9.6516	10.656	11.368	12.461	14.522	18.010	26.192	17
18	9.9751	10.143	10.296	10.437	11.491	12.238	13.385	15.548	19.216	27.844	18
19	10.747	10.922	11.082	11.230	12.333	13.115	14.315	16.579	20.424	29.498	19
20	11.526	11.709	11.876	12.031	13.182	13.997	15.249	17.613	21.635	31.152	20
21	12.312	12.503	12.677	12.838	14.036	14.885	16.189	18.651	22.848	32.808	21
22	13.105	13.303	13.484	13.651	14.896	15.778	17.132	19.692	24.064	34.464	22
23	13.904	14.110	14.297	14.470	15.761	16.675	18.080	20.737	25.281	36.121	23
24	14.709	14.922	15.116	15.295	16.631	17.577	19.031	21.784	26.499	37.779	24
25	15.519	15.739	15.939	16.125	17.505	18.483	19.985	22.833	27.720	39.437	25
26	16.334	16.561	16.768	16.959	18.383	19.392	20.943	23.885	28.941	41.096	26
27	17.153	17.387	17.601	17.797	19.265	20.305	21.904	24.939	30.164	42.755	27
28	17.977	18.218	18.438	18.640	20.150	21.221	22.867	25.995	31.388	44.414	28
29	18.805	19.053	19.279	19.487	21.039	22.140	23.833	27.053	32.614	46.074	29
30	19.637	19.891	20.123	20.337	21.932	23.062	24.802	28.113	33.840	47.735	30
31	20.473	20.734	20.972	21.191	22.827	23.987	25.773	29.174	35.067	49.395	31
32	21.312	21.580	21.823	22.048	23.725	24.914	26.746	30.237	36.295	51.056	32

Is acceptable GoS = 2% (in table 2% = .02) [12].

D. Per cells subscribers count calculation

We can calculate traffic by subscriber (Asub) (Arefín, et al., 2010, p. 42).
Traffic is measured in Erlangs (E).
n – Count of connection during the 1 hour
T – Average talk time during connection (sec)
3600 – 1 hour (3600 sec)
A_sub = (n×T)/3600

ISSN 1533-9211

DOI 10.5281/zenodo.7124744

Equation 7_Subscriber traffic calculation

Researches showed that Asub typically = 15-20 m. We will choose Asub = 20 mE = 0.02 E.

GoS = 2% = 0.02

For our cluster with 7/21 pattern, in case of for cell 4/32 (4 carriers/32 canals), cell's traffic channels = 32 – 2 (control channels) = 30, i.e., n=30

Traffic value for our cell in cluster with 7/21 pattern will find in the Erlang B table (Table 3) [16].

Figure 14: Traffic value for cell in cluster with 7/21 pattern

n	.007	.008	.009	.01	.02	.03	.05	.1	.2	.4	n
1	.00705	.00806	.00908	.01010	.02041	.03093	.05263	.11111	.25000	.66667	1
2	.12600	.13532	.14416	.15259	.22347	.28155	.38132	.59543	1.0000	2.0000	2
29	18.805	19.053	19.279	19.487	21.039	22.140	23.833	27.053	32.614	46.074	29
30	19.637	19.891	20.123	20.337	21.932	23.062	24.802	28.113	33.840	47.735	30
31	20.473	20.734	20.972	21.191	22.827	23.987	25.773	29.174	35.067	49.395	31
32	21.312	21.580	21.823	22.048	23.725	24.914	26.746	30.237	36.295	51.056	32

So, Acell = 21.932 E

The subscribers count per cell = Acell ÷ Asub = 21.932 ÷ 0.02 = 1096 subscribers per cell.

E. BTS count and R calculation

The finally count of BS is determined by two parameters:

- provide ongoing (continuous) radio coverage;
- provision of the required capacity.

First, keeping the requirements for signal strength and quality, we need to provide ongoing radio coverage of a given area.

Second, the count of BTS should be enough to service the required number of subscribers and support the required capacity.

Ipoh:

- Has an area of about 643 km^2
- Number of people – 660 000.
- Density - 1,023/km^2

The services' zone border already drew. It is around 16 km x 21 km zone = 336 km^2 area.

Nearly 400 000 - 500 000 potential mobile users are available in Ipoh. Approximately in the next 5 years, we will occupy 20% of the mobile services market. We can assume that we will have around 92,000 subscribers.

ISSN 1533-9211

DOI 10.5281/zenodo.7124744

We can provide service for 1096 subscribers per cell. So, we will need 92000 ÷ 1096 = 84 cells to provide service for 92 000 subscribers.

In our 7/21 cluster, we have 21 cells and 7 BTS with 3 sectors to provide coverage for 3 cells per each BTS. For 92 000 subscribers, we should have 84 ÷ 21 = 4 clusters.

So, in total, for 92 000 subscribers, we should have 4 x 7 (or 84÷3) = 28 BTS.

If we assume that the load on the network will be uniform across the entire service area, take into account that we have 84 cells across the entire service area, take into account that services an area of about 336 km^2, so, each cell will have near 336 ÷ 84 = 4 km^2 area.

Now we can calculate cell's radius (R).

$$
\begin{aligned}
&S = \pi \times R^2 \\
&4 = 3.14 \times R^2 \\
&R^2 = 4 \div 3.14 = 1.27 \\
&R = \sqrt{1.27} \\
&R = 1.13 \text{ km}
\end{aligned}
$$

Equation 7_Cell's radius calculation

F. Financing "Initial investment for deployment of our cellular network"

Already have calculation for one BS (BSS = BSC+BTS). BSS = 500K. It includes one BSC and one BTS with 3 sector TX (antenna + transmitter) (each sector cost = 50K) + all working which need to mount stations on the necessary places. For our start up network, we need 28 BTS, i.e., 28 BSS. Investment for cellular station will be = 28 x 500K = 14000 K.

We will deploy a fiber-optic (FO) network to connect the BSS to the MSC (Mobile Switching). It is expected that 100 km of FO cables will be laid, 30 FOSCs (FO splice closures) and 5 ODFs (optical distribution frames) will be installed/spliced, and so on.

1 m FO cable with mounting/installing work (includes works, cable, fittings, clamps, etc.) = 9.

For 100 km = 9 x 100000 = 900K.

For mount 30 FOSC and 5 ODF = 35 x 230 = ~ 12K

Startup investment for deployment of our cellular network will be = 14000 K + 900K + 12K = 14912K

First 5 years we will need to occupy 20% of the mobile services market and will have around 92000 subscribers.

So, per user our cellular network cost = 14912K ÷ 92K = 162K

To recoup our investment in, say, 20 years, we must have an annual income of at least = 162K ÷ 20 = ~ 8K per one subscriber.

Our tariff plans must charge subscribers about 660 each month to provide such amounts. It is not real, so, if we provide voice services only, it is not possible to recoup even after 20 years.

ISSN 1533-9211

DOI 10.5281/zenodo.7124744

We should provide other services and deploy other networks based on existing own FO infrastructure, for example, build GPON network in Ipoh city.

G. Additional investment when will have growth in the number of subscribers

When we have growth in the number of subscribers by 20%, we can increase our network in a few ways:

- Every time, for every 20% growth in the number of subscribers, we will install additional BTS in those places where the overload is. Will need to use the additional frequencies or bring it from reserved (3.2.2 Transition regions). Or reduce necessary cells' R, then will mount in the emerging "black holes" new BTS.
- Once increase capacity by 100% and in future will not do anything, so far, the count of subscribers will be = 92000 x 2 = 184000.

Investment in deploying new FO cables will be insignificant.

a) Every time will install additional BTS

If the number of stations is to be increased by 20%, in this case, we will not mount a new BSC, new BTS and new sectoring will be managed by available BSC. So, we will mount new 6 BTS, i.e., 6 x 3 = 18 new sectors.

Additional investment in this case will be = 18 x 50K = 900K.

b) Once increase capacity by 100%

In this case, we will not mount a new BSC also, we will reduce the size of our clusters by half and install additional 28 BTS, i.e., 28 x 3 = 84 new sectors.

Additional investment in this case will be = 84 x 50K = 4200K.

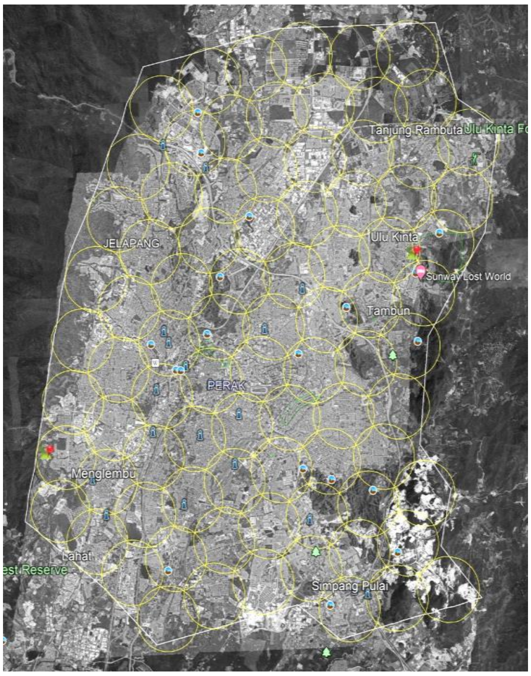
7. NOMINAL CELL PLAN

f we assume that the load on the network will be uniform across the entire service area, that our cell's R = 1.13 km, that we should provide ongoing (continuous) radio coverage, so we will divide the selected area into circles with r = 1.13 km.

ISSN 1533-9211

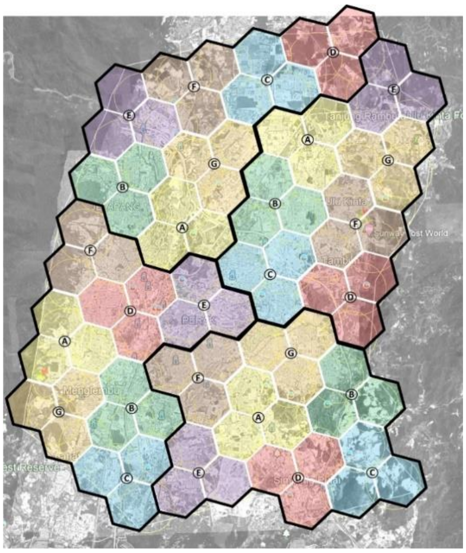
DOI 10.5281/zenodo.7124744

Figure 15: Services' zone divided into 84 circles



Based on Figure 15 we will draw nominal cell plan.

Figure 16: Nominal Cell Plan -1

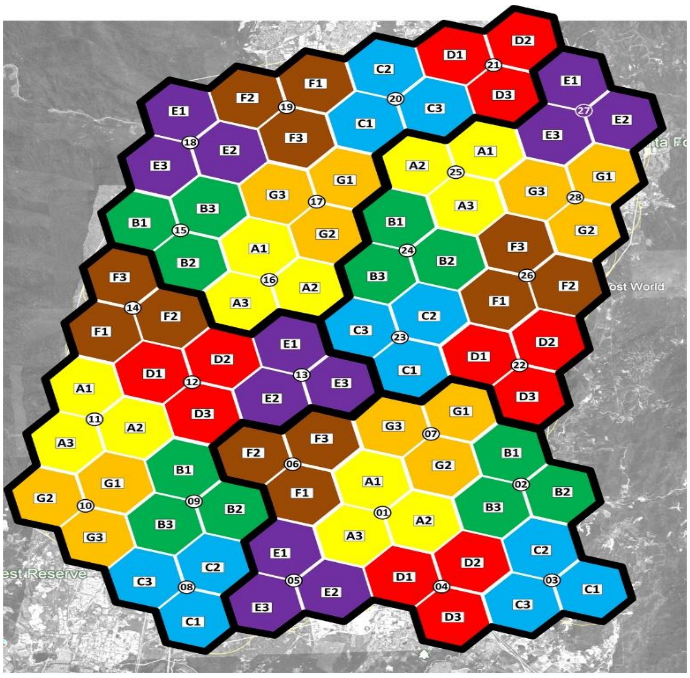


Now we will draw a nominal cell plan with distribution of working frequencies.

ISSN 1533-9211

DOI 10.5281/zenodo.7124744

Figure 17: Nominal Cell Plan -2



8. CONCLUSION

In this research, we designed a cellular network for Ipoh city with 643 square kilometres and a 660,000 population. There are about 83 clusters, and each cluster has 12 cells and 100 radio channels. The cell has 3 sectors, each of which has 4 directional antennas. Also, we provided a solution for the cellular network in Ipoh city, all the stages of GSM mobile network design, MA, TDMA, carry out up to “nominal cell plan”, radio propagation/coverage, simulation/calculation, final cell plan (final design) implementation, and so on. We used frequency reuse and sectoring to increase the capacity of the system and improve SIR.

9. ACKNOWLEDGEMENT

The authors wish to express their gratitude to Ministry of Higher Education (MOHE) Malaysia and Universiti Teknologi Malaysia for the financial support of this project under Collaborative Research Grant (Vot number R.J130000.7351.4B458).

REFERENCES

1) Cellular Network Alliance; Hotspot 2.0 Technical Specification Package (Release 2);V1.0.0.

2) Doug W, Announcing the Cisco Visual Networking Index Mobile Forecast, 2010-2015, Available Online: Http://Blogs.Cisco.Com/Tag/Mobile-Data-Forecast (Access On December 27th, 2014).

3) Hagos, D.; Kapitza, .R; Study on Performance-Centric Offload Strategies for LTE Networks, 2016 6th Joint IFIP Wireless and Mobile Networking Conference (WMNC), Pp.1-10, April 2016.

ISSN 1533-9211

DOI 10.5281/zenodo.7124744

4) Hugues, S.; Figueiredo, L.; Rabadão, C.; Pereira, A.; Wireless Networks Interoperability-Wifi Wimax Handover. ICSNC'09. Fourth International Conference On, Pp. 100-104. IEEE, 2019.

5) Kassar, M.; Kervella; B.; Pujolle G. An Overview of Vertical Handover Decision Strategies In Heterogeneous Wireless Networks, Journal of Computer Communications, Vol.37, No.10. 2018.

6) Noroozi, N.; Abbasfar, A.; Adaptive Load Balancing In LTE-Advanced Networks with Base Station Coordination, NICT, ISSN: 1882-5621/13, 2019.

7) Voyiatzis; Artemios; a Survey of Delay-And Disruption-Tolerant Networking Applications, Journal of Internet Engineering 5, No. 1, 2018.

8) Zekri; Mariem; Badii J.; Djamal Z. A Review on Mobility Management and Vertical Handover Solutions over Heterogeneous Wireless Networks. Computer Communications 35, No. 17, 2055-2068, 2018.

9) 3GPP. 3rd Generation Partnership Project; Architecture Enhancements for Non-3GPP Accesses (Release 12); Technical Specification 3GPP TS 23.402; March 2016.

10) 3GPP. 3rd Generation Partnership Project; Access Network Discovery and Selection Function Management Object (Release 12); Technical Specification 3GPP TS 24.312; V12.4.0; March 2016. 4G Americas; Integration of Cellular and Cellular Networks; Sep, 2015.

11) Montelius, J., N.D. GSM Network and Services 2G1723. [Online] Available At: Https://People.Kth.Se/~Johanmon/Attic/2g1723/Lectures/Network.Pdf [Accessed December 2021].

12) ERICSSON - STUDENT TEXT EN/LZT 123 3314 R3A, 1998. CELL PLANNING PRINCIPLES. [Online] Available At: Https://Fdocuments.In/Document/Radio-Cell-Planning-Principles.Html,[Accessed December 2021].

13) Teletopix, Web Site, 2013. Requirement for Interference and Carrier to Interference Ratio in GSM. [Online] Available At: Http://Teletopix.Org/Gsm/Carrier-To-Interference-Ratio/ [Accessed December 2021].

14) Girma, S. T., Konditi, D. B. & Maina, C., 2019. Frequency Re-Use Distance Calculation In Cellular Systems Based On Monte-Carlo Simulation. [Online] Available At: Https://Www.Ncbi.Nlm.Nih.Gov/Pmc/Articles/PMC6407157/ [Accessed December 2021].

15) Ankitpandey, 2019. Co-Channel Interference. [Online] Available At: Https://Www.Ques10.Com/P/40163/Co-Channel-Interference-1/ [Accessed December 2021].

16) Decibel Conversion Http://Www.Mogami.Com/E/Cad/Db.Html

17) Rappaport, T., Blankenship, K. & Xu, H., 1997. Propagation and Radio System Design Issues in Mobile Radio Systems for the Glomo Project. [Online] Available At: Https://Www.Researchgate.Net/Publication/247282643_Propagation_And_Radio_System_Design_Issues_In_Mobile_Radio_Systems_For_The_Glomo_Project [Accessed December 2021].

18) Tipper, D., N.D. Fundamentals of Cellular Fundamentals of Cellular Networks. [Online] Available At: Https://Sites.Pitt.Edu/~Dtipper/2720/2720_Slides4.Pdf [Accessed December 2021].

19) Arefín, U. A. Et Al., 2010. A Study of Cell Site Planning of GSM System. [Online] Available At: Https://Www.Researchgate.Net/Publication/271587738_A_Study_Of_Cell_Site_Planning_Of_GSM_System [Accessed December 2021].