[1]Nyoman Gunantara
[2]Nyoman Pramaita
[3]Satria Mandala
[4]Linawati
[5]Made Niama Dwi Susila
[6]Afif Zuhri Arfianto
[7]Yulindon

Planning and Implementation 5G System Cellular Network in Urban Areas Utilizing Local Wisdom

Journal of Electrical Systems

Abstract: - The rapid delivery of information and the increasing number of users on mobile services is a big problem. This problem occurs in urban areas. The case taken is the city of Denpasar, Bali-Indonesia. The solution to this problem is through cellular technology. Currently, 5G mobile technology is developing. With 5G cellular technology, fast information delivery and an increasing number of users on mobile services can be overcome. So this research is about technical studies of 5G systems. The technical study is in the form of an analysis of the planning and implementation of 5G cellular technology in the Denpasar city area. The technical study still maintains local wisdom in the form of using banjar halls to place towers. The results achieved in the planning and implementation are determining the area of Denpasar City, specifying 5G system frequency bands, designing a rooftop tower, calculating cell coverage distance, farthest receiving power, cell capacity, and cell mapping. Next, cell mapping was carried out in the banjar hall with antenna heights of 13 m, 18 m, and 22 m respectively. The number of cells obtained was 35, 33, and 2. Meanwhile, by making the antenna height 22 m at the banjar hall, the number of cells will be 70. So the total number of cells to cover the Denpasar city is 139 cells placed in banjar hall and the other 69 cells are placed at outside the Banjar hall.

Keywords: 5G system, Denpasar city, coverage, capacity, mapping

I. Introduction

The rapid delivery of information and the increasing number of users on mobile services is a big problem. This problem occurs in urban areas. The case taken is the city of Denpasar, Bali-Indonesia [1] . To overcome this problem, an increase in information and communication networks is needed that can serve all customer needs in quantity and quality, one of which is the availability of a 5G system.

The introduction of 5G cellular technology to the younger generation in welcoming the new era through pre and post-tests [2], [3][4]. The implementation of cellular technology from 1G to 4G in Indonesia is always late, so this research is expected to provide an initial description of the preparation of 5G technology in Indonesia. Indonesia needs to map out the main requirements for the 5G system according to the conditions and situation in Indonesia so that a 5G system roadmap can be prepared [5] [6]. An analysis of Indonesia's readiness to face 5G technology through developing strategies using the SWOT method [7], [8] [9]. 5G cellular technology is one of the applications that can be used in the high altitude platform station (HAPS) system as an alternative telecommunication technology to complement existing terrestrial and satellite systems. Communication between devices (device to device, D2D) aims to distribute traffic loads to communication between devices and reduce the load on the main network [10]. The development of the fifth generation (5G) has been driven by many new breakthroughs in various fields such as carrier aggregation (CA), licensed assisted access (LAA), massive MIMO (MaMi), cooperative spectrum sensing (CSS), compressive sensing (CS) and others [11], [12] [13].

Through a review of several studies, it is clear that the 5G system is only in the introduction, preparation, and development stages. In this research, a technical study of the 5G cellular technology implementation in the

[1] *Corresponding author: Department of Electrical Engineering, Universitas Udayana, Indonesia, Email: gunantara@unud.ac.id
[2] Department of Electrical Engineering, Universitas Udayana, Indonesia
[3] Department of Information Engineering, Faculty of Engineering, Universitas Telkom, Indonesia
[4]Department of Electrical Engineering, Universitas Udayana, Indonesia
[5]Ngurah Rai Airport Engineer, Indonesia
[6] Marine Electrical Engineering, Politeknik Perkapalan Negeri Surabaya, Indonesia
[7]Department of Electrical Engineering, Politeknik Negeri Padang, Indonesia

Denpasar city will be carried out. In technical studies on the 5G system, we always maintain the preservation of Balinese culture. Technical studies in the form of cell coverage, tower design, number of cells needed, minimum acceptability for the farthest areas, and cell capacity are mapped to service areas using Google Earth. Cell mapping in the Denpasar city by maintaining local wisdom using banjar halls.

The structure of the presentation in this paper is to explain the 5G system and research literature review, the steps and parameters of the 5G system, results and analysis, and conclusion.

II. RESEARCH METHOD

A. 5G System Architecture

The 5G network architecture consists of a cloud radio access network (C-RAN), transport layer, and core network [14], [15]. This architecture can be seen in Figure 1 [16].

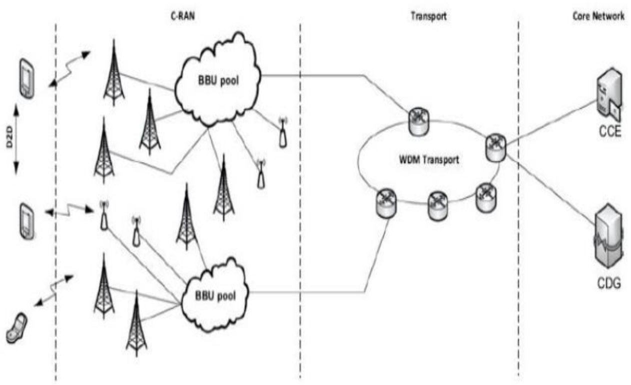

Fig. 1 5G system architecture

C-RAN is a radio access network that allows large-scale networks supported by collaborative radio networks and a collection of several ports connected to all devices on the base transceiver station (BTS) . Next, there is the transport layer is today's wireless communications and uses the latest common public radio interface (CPRI) standard, coarse or dense wavelength division multiplexing (CWDM / DWDM) technology [12], [17]. Finally, there is the core network, a network that can be divided into 2, namely combined control entity (CCE) and combined data gateway (CDG) [18].

B. ERC Report 68 Radio Propagation

Propagation is the process of propagating electromagnetic waves from one place to another. The propagation model suitable for the 5G system is the European radio communications committee Report 68 [19]. ERC Report 68 is a modified Hata radio propagation model. The path loss for the ERC Report 68 radio propagation model in the urban area are:

$$L = 69{,}6 + 26{,}2\log(f) - 13{,}82\log(max \{30, H_b\}) + [44.9 - 6.55\log(\max(max \{30, H_b\}(log(d))^{\alpha} - a(H_m) - b(H_b)] \quad (1)$$

where:

f	:	frequency between 150 - 1500 MHz
H_b	:	transmitter antenna height (BTS) between 1 - 200 m
H_m	:	receiver antenna height (MS) between 1 - 200 m
d	:	distance between Tx-Rx between 1 - 100 km
$a(H_m)$	:	correction factor for MS antenna height
$b(H_b)$	:	correction factor for BTS antenna height

While the correction factor for MS and BTS antenna height can be calculated by the following equation:

$$a(Hm) = (1{,}1 \log(f) - 0{,}7) \min\{10, Hm\} - (1{,}56\log(f)\text{-}0.8) + \max\{0, 20\log (Hm/10)\} \quad (2)$$

$$b(Hb) = \min\{0, 20 \log (Hb/30)\} \quad (3)$$

C. Fade Margin

Fade margin is the acceptable reserve power level, which must be or exceed the value required for the minimum level of performance of the specified system. Fade Margin is determined by the following equation [11][20]:

$$F_m = P_r - R_x \quad (4)$$

where:

F_m : fade margin (dB)

P_r : received signal power (dBm)

$P_{R,min}$: minimum received signal power (dBm)

D. Cell Area and Cell Capacity

If it is assumed that the cell shape is hexagonal, with R is the cell distance, then the cell area can be calculated by the following equation [21][22]:

$$A_{cell} \approx 2{,}6R^2 \quad (5)$$

where:

A_{cell} : cell area (km^2)

R : cell distance (km)

Meanwhile, the cell capacity needed to cover the service area is determined by the[21] [22]

$$M_{cell} = A_{area}/A_{cell} \quad (6)$$

where:

M_{cell} : cell capacity

A_{area} : coverage area (km^2)

A_{cell} : cell area (km^2)

E. Cell Mapping in Service Areas

In cell mapping, cells are made to coincide with each other so that communication runs well (no drop calls) and has high reliability. To find out the need for the number of cells in the service area, it is necessary to map cells using Google Earth software. Google Earth is a virtual globe program which is actually called Earth Viewer and was created by Keyhole, Inc.

Steps And Parameters of the 5G System

The development of the 5G system cellular network starts with defining the parameters of the 5G system, determining the location of service areas, and the methods used in planning. The next step is to determine the propagation model, namely ERC Report 68. Next, calculations are carried out, namely calculating the farthest received power, cell coverage, and cell capacity for service areas. The next step is to map the cells in the service area. After these steps, an evaluation and analysis are carried out. These steps can be seen in Figure 2.

From Figure 2, at the define 5G parameters and service area stage, the 5G system parameters used in the technical study are determined. After that, determine the service area and always maintain the local wisdom that is applied. In the radio propagation model stage, a review of the appropriate radio propagation model is carried out. Selected ERC Report 68 radio propagation model. The calculation and analysis stage involves calculating the number of banjar halls in the service area, rooftop tower design, calculation of cell coverage distance, receiver power, cell coverage area, and cell capacity. The cell mapping stage involves mapping the number of cells using Google Earth software. The final stage is to draw conclusions from the results achieved.

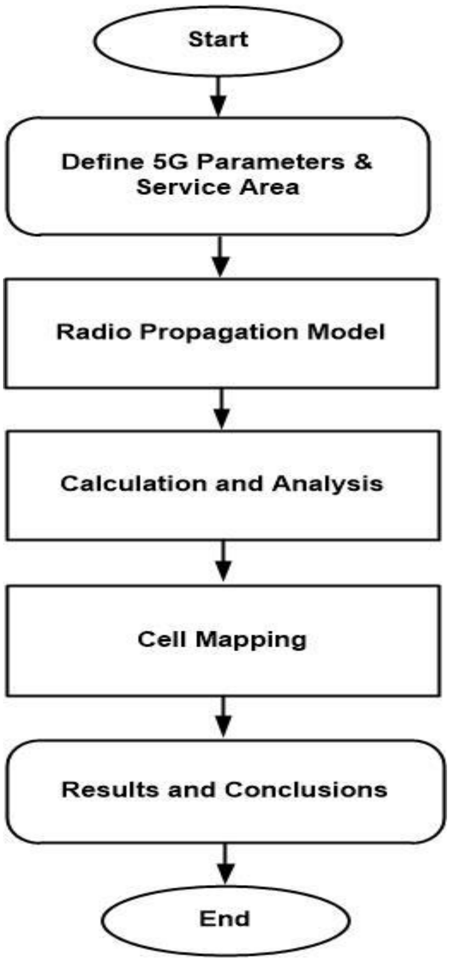

Fig. 2 5G system implementation steps

The 5G system has not been implemented in Indonesia until now. Thus, in this study, the 5G system specifications issued by 3GPP were used. The specifications for frequency bands and devices used in the 5G system can be seen in Table 1.

TABLE I
DEVICE SPECIFICATIONS OF THE 5G SYSTEM

Parameter	*Nilai Uplink*	*Nilai Downlink*
Frequency Band (MHz)	824 – 849	869 – 894
Data Rate	256 Kbps	
Transmitter (Tx)		

Tx *Antenna Gain*	0 dBi	8 dBi
Cable Loss	1 dB	3 dB
Receiver (Rx)		
Antenna Gain *Body Loss* *Receiver Noise Figure* *Receiver Implementation Margin* *Receiver Sensitivity for Data Channel* *Shadow Fading Margin for Data Channel Penetration Margin*	8 dBi 3 dB 5 dB 2 dB -96,93 dBm 4,89 dB 9 dB	0 dBi 1 dB 7 dB 2 dB -93,35 dBm 4,89 dB 9 dB

III. Results and DISCUSSION

The results achieved in this study are the geographical conditions of Denpasar City, rooftop tower design, 5G system specifications, ERC Report 68 radio propagation model, calculation of coverage distances for uplink and downlink directions, calculation of reception power, coverage area, 5G system cell capacity, and cell mapping in service area.

A. *Geographical Conditions of Denpasar City*

The administrative area of Denpasar City is 130.48 km^2 and is divided into 4 sub-districts which include West Denpasar (24.13 km^2), East Denpasar (22.54 km^2), South Denpasar (49.99 km^2) and North Denpasar (31.12 km^2) [23]. The sub-district area is divided into several villages, each consisting of several hamlets. Besides the official village, there are also traditional villages, each of which consists of several traditional banjars. There is no overlapping between official villages and traditional villages, on the contrary, there is harmony and mutually supportive cooperation. The number of villages and banjars in the Denpasar City government can be seen in Table 2 [5].

Table 2 shows that there are 399 official banjars and 322 traditional banjars. By utilizing the location of the banjar hall as a place to place a rooftop tower for cellular system antennas, the advantage that the banjar hall gets is to receive contract fees from the provider which can later be used for the maintenance or development of the banjar hall. Or it can be used for traditional ceremony fees at the banjar hall. Another advantage that will be obtained by the community is that by placing the tower at the banjar hall, later it can be negotiated with the provider to provide free internet at the banjar hall as a form of corporate social responsibility (CSR) provided by the provider. If this can be realized, then in the future children, youth or adults will come to the banjar hall with laptops or gadgets. On the government side, regular towers will be developed according to predetermined coordinates to make it easier to arrange them later. Meanwhile, on the provider side, there will be guarantees for a healthier communication business, because the coordinates offered by the government have been mutually agreed upon.

TABLE II
NUMBER OF SUB-DISTRICTS/OFFICES/BANJARS IN THE GOVERNMENT OF DENPASAR CITY

No	Districts	Capital	Sub-district	Villages		Banjar	
				Official	Traditional	Official	Traditional
1	Denpasar Utara	Peguyangan	3	8	10	98	75
2	Denpasar Timur	Kesiman	4	7	12	85	95
3	Denpasar Selatan	Sesetan	6	4	11	104	87
4	Denpasar Barat	Pemecutan Kaja	3	8	2	112	65
Denpasar City			16	27	35	399	322

B. Rooftop Tower Design

The Denpasar City is located on the island of Bali, which is a tourist destination. Under these conditions, the construction of physical facilities and infrastructure must always be considered and still maintain local wisdom and comply with regional/government regulations [24]. The Mayor of Surabaya Regulation of 2008 and the Regional Regulation of the Province of Bali concerning spatial planning number 16 of 2009 article 95 paragraph 2 point b states that the height of buildings that utilize air space above the earth's surface is limited to a maximum of 15 (fifteen) meters, except for public buildings and special buildings that require a height requirement of more than 15 (fifteen) meters, such as telecommunication towers. In addition, the area of Denpasar City has an area that is not wide and dense with buildings. So that the towers used in this plan are towers that are placed on top of a building.

This tower is called the rooftop tower. Under these conditions, in planning for the rooftop tower, use the banjar hall in Denpasar City. A rooftop tower with three heights where the height includes the poles on the rooftop tower. The three rooftop tower heights for the Denpasar City area are as follows [25] :

a. The height of 13 meters is used for buildings with 1 floor.

b. The height of 18 meters is applied to buildings with 2 floors.

c. The height of 22 meters is used because of the maximum height limit for buildings in Denpasar City.

The rooftop tower that stands at the banjar hall can be seen in Figure 3.

C. Calculation of Cell Coverage Distance in 5G Systems

To calculate the cell coverage distance of the 5G system, we must first know the frequency band, rooftop tower equipment specifications, and the maximum allowable path loss (MAPL) value. In implementing the 5G system so that communication runs well, uplink and downlink communication are taken into account. Calculation of the MAPL value for 5G systems based on 3GPP device specifications can be seen in Table 3.

Fig. 3 Rooftop tower at banjar hall

TABLE III
MAPL IS BASED ON 3GPP DEVICE SPECIFICATIONS

Parameter		*Uplink*	*Downlink*
Transmitter – NR			
a.	Tx Power	23 dBm	23 dBm
b.	Tx Antenna Gain	0 dBi	8 dBi
c.	Transmit Array Gain	0 dB	15 dB
d.	Data Channel Power Loss Due to Pilot	0 dB	0 dB
e.	Cable Loss	1 dB	3 dB
f.	EIRP	22 dBm	66,11 dBm
Receiver – UE			
g.	Antenna Gain	8 dBi	0 dBi
h.	Body Loss	3 dB	1 dB
i.	Receiver Noise Figure	5 dB	7 dB
j.	Thermal Noise Density	-174 dBm/Hz	-174 dBm/Hz
k.	Receiver Interference Density for Data Channel	-165,7 dB/Hz	-169,3 dB/Hz
l.	Total Noise Plus Interference Density for Data Channel	-164,03 dBm/Hz	-164,99 dBm/Hz
m.	Occupied Channel Bandwidth for Data Channel	5760000 Hz	18360000 Hz
n.	Effective Noise Power for Data Channel	-96,43 dBm	-92,35 dBm
o.	Required SNR for the Data Channel	-2 dB	-2,5 dB
p.	Receiver Implementation Margin	2 dB	2 dB
q.	H-ARQ Gain for Data Channel	0,5 dB	0,5 dB
r.	Receiver Sensitivity for Data Channel	-96,93 dBm	-93,35 dBm
s.	Hardware link budget for Data Channel	141,98 dB	159,46 dB
t.	Log Normal Shadow Fading Deviation	6 dB	6 dB
u.	Shadow Fading Margin for Data Channel	4,89 dB	4,89 dB
v.	Diversity Gain	0 dB	0 dB
w.	Penetration Margin	9 dB	9 dB
x.	Other Gain	0 dB	0 dB
MAPL		**125.09 dB**	**144.57 dB**

Based on calculations with the equipment specifications contained in Table 3, the MAPL values for the uplink and downlink directions are 125.09 dB and 144.57 dB.

After the frequency band, rooftop tower device specifications of the 5G system, and MAPL are known, the 5G system cell coverage distance is calculated using equation (1).

From equation (1), we will look for the value of d.

Before calculating the *d* value, it is necessary to calculate the *a(Hm)* and *b(Hb)* values which are the correction factors for the MS and BTS antenna heights using equation (2) and (3).

From the planning of the 5G system, there are three BTS antenna heights using the banjar hall, namely 13 m, 18 m and 22 m. The calculation for the BTS antenna height correction factor of 13 m is -7.2636 dB. For BTS antenna heights of 18 m and 22 m, correction factors of -4.4370 dB and -2.6940 dB are obtained, respectively. The results of this calculation indicate that the BTS antenna height correction factor increases in proportion to the increase in antenna height.

1) Calculation of 5G System Cell Coverage Distance in Uplink Direction

After the parameters are known, then proceed to calculate the value of *d* which is the cell coverage distance for a BTS antenna height of 13 m is 0.5793 km. For BTS antenna heights of 18 m and 22 m, the cell coverage distance obtained are 0.6969 km and 0.7809 km respectively.

2) Calculation of 5G System Cell Coverage Distance in Downlink Direction

In addition to the uplink direction, the calculation of the 5G system cell coverage distance is also carried out in the downlink direction. After the parameters are known, then proceed to calculate the value of d which is the cell coverage distance for a BTS antenna height of 13 m is 2.0703 km. For BTS antenna heights of 18 m and 22 m, the cell coverage distance obtained are 2.4905 km and 2.7910 km respectively.

D. Calculation of Cell Coverage Distance in 5G Systems

Radio communication, especially cellular systems, in its electromagnetic wave propagation is affected by fading. Fading is a natural phenomenon of information signal propagation due to the influence of the surrounding environment. Fading will cause fluctuations in the power of the received signal or may cause radio communication failure. In order to increase the reliability of the received signal power, the communication planning for the 5G system is given a fade margin. So that the calculation of the received signal power after adding the fade margin can be calculated by using equation (4):

$$F_m = P_r - R_x$$

The fade margin and receive sensitivity values of the 5G system to be implemented can be seen in Table 3. So that the received signal power in the uplink direction is as follows:

$$P_r = -96.93 + 9$$

$$P_r = -87.93 \text{ dBm}$$

In the same way, the received signal power in the downlink direction is -84.35 dBm.

E. Calculation of Cell Coverage Distance in 5G Systems

Figures The area of cell coverage in a 5G system is affected by the shape of the cell and the distance of the cell coverage. The cell coverage is assumed to be hexagonal in shape. So that the calculation of cell coverage area in a 5G system can be calculated by using equation (5):

$$A_{cell} \approx 2{,}6R^2$$

From the previous calculation, the cell coverage distance has been calculated for both the uplink and downlink directions. The cell coverage distance values for the uplink direction are 0.5793 km, 0.6969 km and 0.7809 km. While the cell coverage distance values for the downlink direction are 2.0703, 2.4905 km, and 2.7910 km. In planning this 5G system, the uplink direction, the cell coverage distances of 0.5793 km, 0.6969 km and 0.7809 km are used (which are shorter distances than the downlink direction). This is based on the consideration that 5G system communications have high reliability. Thus, the area of cell coverage in a 5G system can be calculated as follows:

$$A_{cell} \approx 2.6(0.5793)^2$$

$$A_{cell} \approx 0.8725 \text{ km}^2$$

In the same way, the cell coverage area in the 5G system for cell coverage distances of 0.6969 km and 0.7809 km is obtained respectively 1.2627 km^2 and 1.5855 km^2.

F. Calculation of Cell Capacity in 5G Systems

The cell capacity in a 5G system is the number of cells or rooftop towers needed to cover the Denpasar City area. In the previous subsection, it was known that the area of Denpasar City is 130.48 km^2. The calculation to determine the cell capacity using equation (6):

$$M_{cell} = A_{area}/A_{cell}$$

Next, calculating the cell capacity for the cell coverage area in the 5G system of 0.8725 km^2 150. In the same way, the cell capacity of the 5G system for a cell coverage area of 1.2627 km^2 and 1.5855 km^2 is obtained as 103 and 82 respectively. These results indicate that to cover the Denpasar City area, the number of cells needed is 150 cells (for height 13 m), 103 cells (for height 18 m), and 82 cells (for height 22 m). Thus, the cell coverage distance, cell coverage area, and cell capacity in the 5G system for the Denpasar City area can be seen in Table 4.

TABLE IV
CELL CAPACITY IN THE 5G SYSTEM FOR THE DENPASAR CITY AREA

Tower Height (m)	Distance (d) (km)	Coverage Area (A_{cell}) (km^2)	Cell Capacity (M_{cell})
13	0.5793	0.8725	150
18	0.6969	1.2627	103
22	0.7809	1.5855	82

G. Cell Mapping in the 5G System in Denpasar City

Through calculations it has been obtained that to cover the Denpasar City area, the number of cells or towers required is 150 units (for a height of 13 m), 103 units (for a height of 18 m), and 82 units (for a height of 22 m). Apart from going through calculations, to find out the need for the number of cells in the Denpasar City area, it is necessary to map cells using Google Earth software. In cell mapping, cells are made to coincide with each other so that communication runs well (no drop calls) and has high reliability. The cell that is applied is the rooftop tower which is prioritized to be placed in the banjar hall. It is known that there are 399 banjar halls in Denpasar City with coordinate points for each. Mapping the number of banjar halls as many as 399 banjar halls that already have coordinate points on Google Earth can be seen in Figure 4.

Fig. 4 Mapping banjar hall through coordinate points

From Figure 4 it can be seen that the position of the banjar halls is that some are too close and some are too far from other banjar halls and do not yet cover the entire area of Denpasar City Thus, it is necessary to select the banjar hall which will be used as a rooftop tower. So that in planning the 5G system, priority is given to the use of banjar hall as a rooftop tower, so in this mapping, we will start from Banjar Hall "Balun" which is located at longitude 115.186828º and latitude 8.64875º and Banjar Hall "Sari" which is located at longitude 115.20205º and latitude 8.652116º. This is because the two banjar halls are existing banjar halls that have been installed with rooftop towers.

The steps for cell mapping to find out the need for the number of cells in the Denpasar City area are:

- Counting the number of cells in Denpasar City.
- Mapping the number of banjar halls through their coordinates.
- Choose a banjar hall according to the desired coverage distance. The reference point used is the existing banjar hall (a rooftop tower has been installed).
- Changed the height of the cell antenna to 22 m and mapped the cell again.
- Increase the number of cells outside the banjar hall to cover the Denpasar City area and map the cells again.

From these steps, the results of cell mapping for cell coverage in the Denpasar City area can be seen in Figure 5. From Figure 5 it can be seen that the mapping still has many blank spot areas. From the existing 393 banjar halls, 70 banjar halls were obtained which could be used for rooftop towers. From 70 banjar halls, there are 35 banjar halls with a height of 13 m (shown by white cells), 33 banjar halls with a height of 18 m (shown by green cells), and 2 banjar halls with a height of 22 m (shown by blue cells).

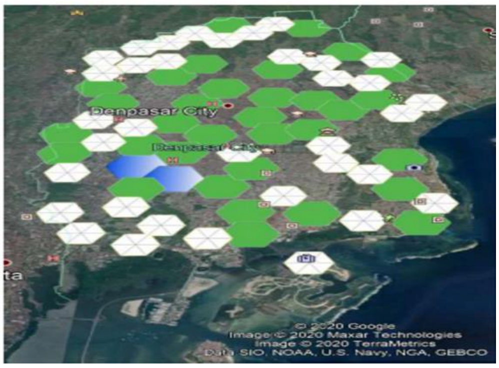

Fig. 5 Cell mapping in the Denpasar City area

To reduce the blank spot area, a solution is needed to cover the Denpasar City area. The solution that can be done is to increase the height of the antenna from each cell to a height of 22 m in order to produce greater coverage. By increasing the antenna height to 22 m, the mapping results can be seen in Figure 6.

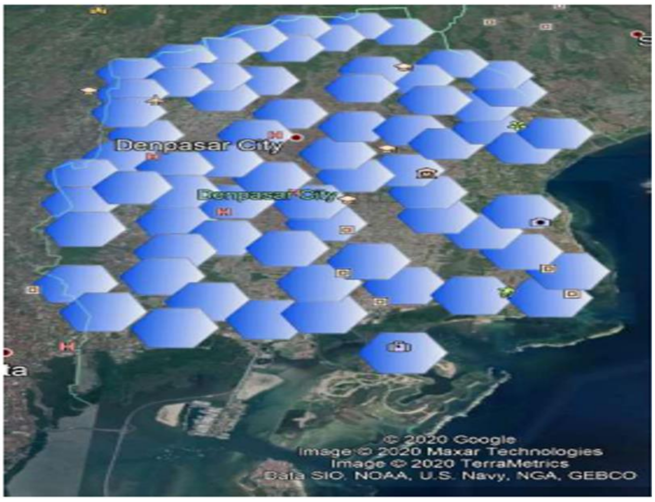

Fig. 6 Cell mapping by increasing the height of the antenna

From Figure 6 it can be seen that there are still blank spots so that they do not yet cover the Denpasar City area. In planning for the 5G system to cover the Denpasar City area, it is necessary to add cells outside the banjar hall. Next, a new cell mapping was carried out outside the banjar hall. The results of the cell mapping can be seen in Figure 7.

From Figure 7 it can be seen that there are no blank spots and the cell coverage covers the Denpasar City area. The mapping results show that the number of cells outside the banjar hall is 69 cells. Of the 69 cells there are 32 cells with a height of 13 m, 20 cells with a height of 18 m and 17 cells with a height of 22 m. So that the total number of cells needed both in the banjar hall and outside the banjar hall to cover the Denpasar City area is 139 cells. For more details on the total number of cells needed can be seen in Table 5.

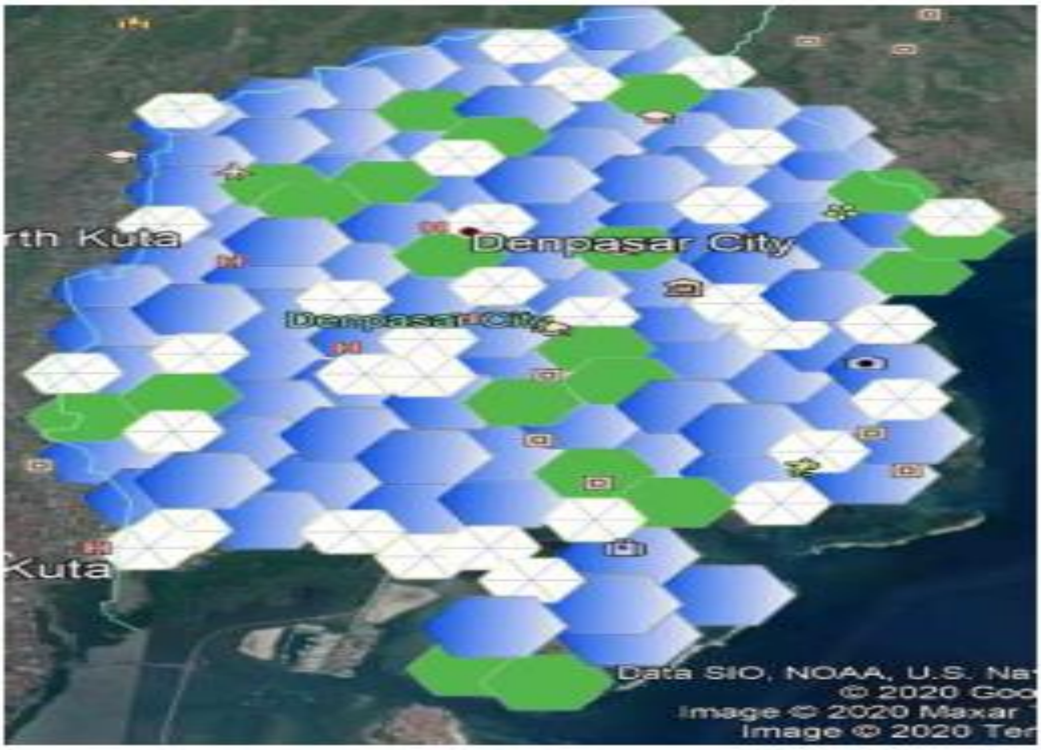

Fig. 7 Cell mapping after adding outside the banjar hall

TABLE V
CELL CAPACITY IN THE 5G SYSTEM FOR THE DENPASAR CITY AREA

Parameter	**Cell With Antenna Height**			**Cell Site**
	13 m	**18 m**	**22 m**	
The cell at the banjar hall	35	33	2	70
Cells in the banjar hall by increasing the height of the antenna	0	0	70	
Cells outside the banjar hall	32	20	17	69
Total of Cell site	32	20	87	139

IV. CONCLUSION

The improvement after analyzing the planning and implementation of the 5G system cellular technology in the Denpasar city area, the results obtained can be concluded that first, calculation of cell coverage distance in the uplink direction obtained 0.5793 km for an antenna height of 13 m, 0.6969 km for an antenna height of 18m and 0.7809 km for an antenna height of 22 m. While in the downlink direction, the cell coverage distance is 2.0703 km for an antenna height of 13m, 2.4905 km for an antenna height of 18m and 2.7910 km for an antenna height of 22m. Second, calculation of the signal receiving power in the uplink direction is -87.93 dBm and in the downlink direction is -84.35 dBm. The cell coverage area for the 5G system is 0.8725 km^2. Third, cell capacities in the 5G system were 150, 103, and 82. These results indicate that to cover the Denpasar City area, the number of cells required is 150 (for a height of 13 m), 103 cells (for a height of 18 m), and 82 cells (for a height 22 m). Lastly, the results of cell mapping to cover the Denpasar City area are 139 cells where 70 cells are placed in the banjar hall by increasing the height of the antenna and 69 cells are placed outside the banjar hall.

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References

[1] N. P. N. E. Lestari, M. K. S. Budhi, and I. M. Suidarma, "The role of subak as culture capital to develop community based tourism village (case study in Pinge Village, Bali Province, Indonesia).," 2019.

[2] G. M. Zebari, D. A. Zebari, and A. Al-zebari, "Fundamentals of 5G cellular networks: A review," *Journal of Information Technology and Informatics*, vol. 1, no. 1, pp. 1–5, 2021.

[3] M. Agiwal, A. Roy, and N. Saxena, "Next generation 5G wireless networks: A comprehensive survey," *IEEE communications surveys & tutorials*, vol. 18, no. 3, pp. 1617–1655, 2016.

[4] B. Alfaresi, F. Ardianto, M. Hurairah, T. Barlian, and R. Noverianty, "Introduction of Telecommunication Technology to the Young Generation in Welcoming the New Era of Fifth Generation Technology (5G)," *Jurnal Gema Ngabdi*, vol. 2, no. 2, pp. 161–169, Jul. 2020, doi: 10.29303/JGN.V2I2.88.

[5] A. Febian and S. Admaja, "5G Technology Research Mapping," 2018.

[6] S. Hutajulu, W. Dhewanto, and E. A. Prasetio, "Two scenarios for 5G deployment in Indonesia," 2020, *Elsevier*.

[7] F. Dahmir *et al.*, "Strategy for Strengthening the Ecosystem to Accelerate the Application of 5g Technology for Industry 4.0 in Indonesia," *Available at SSRN 4681632*.

[8] S. Andromeda, B. Amal, and N. L. B. Dwijaksara, "Machine to Machine (M2M) Connectivity Business Feasibility Analysis and Strategy Development Case Study of PT XYZ, a Company in Indonesia, with SWOT Analysis," *Nusantara Hasana Journal*, vol. 3, no. 8, pp. 318–330, 2023.

[9] D. Estining, T. Lufianawati, C. Adipura Wicaksana, and I. Artikel, "Analysis of Indonesia's Readiness in Facing 5G Technology," *Setrum : Sistem Kendali-Tenaga-elektronika-telekomunikasi-komputer*, vol. 9, no. 1, pp. 17–23, Jun. 2020, doi: 10.36055/SETRUM.V9I1.8191.

[10] R. Abdurrahman Mulyadi and dan Uke Kurniawan Usman, "Device-to-Device Communication on 5G Cellular Networks using mmWave," *AVITEC*, vol. 2, no. 1, 2020, doi: 10.28989/avitec.v2i1.614.

[11] A. Hilt, "Availability and fade margin calculations for 5G microwave and millimeter-wave anyhaul links," *Applied Sciences*, vol. 9, no. 23, p. 5240, 2019.

[12] X. Liu and N. Deng, "Emerging optical communication technologies for 5G," in *Optical fiber telecommunications VII*, Elsevier, 2020, pp. 751–783.

[13] Y. Huo, X. Dong, W. Xu, and M. Yuen, "Enabling Multi-Functional 5G and beyond User Equipment: A Survey and Tutorial," *IEEE Access*, vol. 7, pp. 116975–117008, 2019, doi: 10.1109/ACCESS.2019.2936291.

[14] X. Wang *et al.*, "Virtualized cloud radio access network for 5G transport," *IEEE Communications Magazine*, vol. 55, no. 9, pp. 202–209, 2017.

[15] J. Wu, Z. Zhang, Y. Hong, and Y. Wen, "Cloud radio access network (C-RAN): a primer," *IEEE Netw*, vol. 29, no. 1, pp. 35–41, 2015.

[16] S. Z. Asif, *5G Mobile Communications Concepts and Technologies*. 2018. doi: 10.1201/9780429466342.

[17] X. Liu, *Optical communications in the 5G era*. Academic Press, 2021.

[18] L. H. Campbell, "Approaching the Promise of 5G," *Journal of Telecommunications and the Digital Economy*, vol. 9, no. 3, pp. iii–v, Sep. 2021, doi: 10.18080/JTDE.V9N3.453.

[19] ERC Report, "R-REP-SM.2028-1-2002-PDF-E," 2002.

[20] Campbell Scientific, "The Link Budget and Fade Margin," 2016. Accessed: Apr. 08, 2024. [Online]. Available: https://s.campbellsci.com/documents/us/technical-papers/link-budget.pdf

[21] Rappaport, "Wireless Communications: Principles and Practice: Rappaport, Theodore S.: 8601419420230: Amazon.com: Books." Accessed: Apr. 10, 2024. [Online]. Available: https://www.amazon.com/Wireless-Communications-Principles-Practice-2nd/dp/0130422320

[22] A. R. Mishra, "Fundamentals of Cellular Network Planning and Optimisation," *Fundamentals of Cellular Network Planning and Optimisation*, Apr. 2004, doi: 10.1002/0470862696.

[23] I. K. A. K. Wirayuda, P. Widayani, and A. B. Sekaranom, "Urban green space analysis and its effect on the surface urban heat island phenomenon in Denpasar City, Bali," *Forest and Society*, vol. 7, no. 1, pp. 150–168, 2023.

[24] A. A. P. Agung, I. M. Tamba, and I. B. Brata, "Building A Traditional Village-Based Tourism Destination Management System (Pandawa Beach Tourism Destinations, Kutuh Village, South Kuta, Bali)," *Revista Turismo Estudos E Práticas-RTEP/UERN*, no. 2, pp. 1–18, 2020.

[25] R. K. Putri, Y. D. R. Widhi Astuti, A. K. Wardhany, and C. Hudaya, "Building Integrated Photovoltaic for Rooftop and Facade Application in Indonesia," *Proceedings - 2018 2nd International Conference on Green Energy and Applications, ICGEA 2018*, pp. 171–175, May 2018, doi: 10.1109/ICGEA.2018.8356283.