Feasibility Study

PENERAPAN BTS MINI Mi-Fi 4G BERBASIS CO-OPERATIVE WIRELESS RADIO SELULER DI KAWASAN KARST WISATA RAMMANG-RAMMANG

Ringkasan

Penelitian ini dilatarbelakangi oleh adanya blank spot area di Kawasan karst Rammang-rammang. Permasalahan utama karena letak base transceiver station (BTS) oleh operator eksis seluler dibangun diluar jauh kawasan karst. Solusi yang ditawarkan berupa penerapan BTS-mini (Mi-Fi 4G) menggunakan metode perancangn berdasarkan arsitektur RF-upconverter yang telah terbukti memiliki kestabilan dalam BTS cell coverage. Mi-Fi 4G dirancang dengan konsep access point. Kelebihan Mi-Fi 4G adalah karena dilengkapi dengan teknologi antenna Tx/Rx multiple input multiple output (MIMO) sehingga menguatkan interference reduction dan distortion cancellation disetiap proses transmisi signal pada BTS. Sasaran feasibility study report Tahun ke-1 ini adalah pemodelan desain terukur dengan key performance indicator (KPI), jenis parameter radio yang tepat *access point* dengan perhitungan budget link dan cost instatalasi yang akan diterapkan. Saat ini validasi produk terapan Mi-Fi 4G melalui test bench di lingkungan laboratorium menggunakan frekuensi real 4G-5G dan optimasi jaringan dengan Drive/Walking Test.

Hasil penelitian telah diperoleh beberapa temuan sebagai berikut:

1. Data lapangan di lokasi mitra dengan melaksanakan Drive Test jaringan eksis 4G (operator Telkomsel dan XL).
2. Hasil analisi data lapangan berupa logfile dan telah diperoleh hasik pengukuran sesuai dengan Key Performnace Indicator (KPI).
3. Test Bench pengukuran skala laboratorium pada wilayah tempat uji coba telah dilakukan untuk memastikan lokasi tempat test bench dinyatakan layak.
4. Perancangan Filter LPF pada Repeater/Penguat.

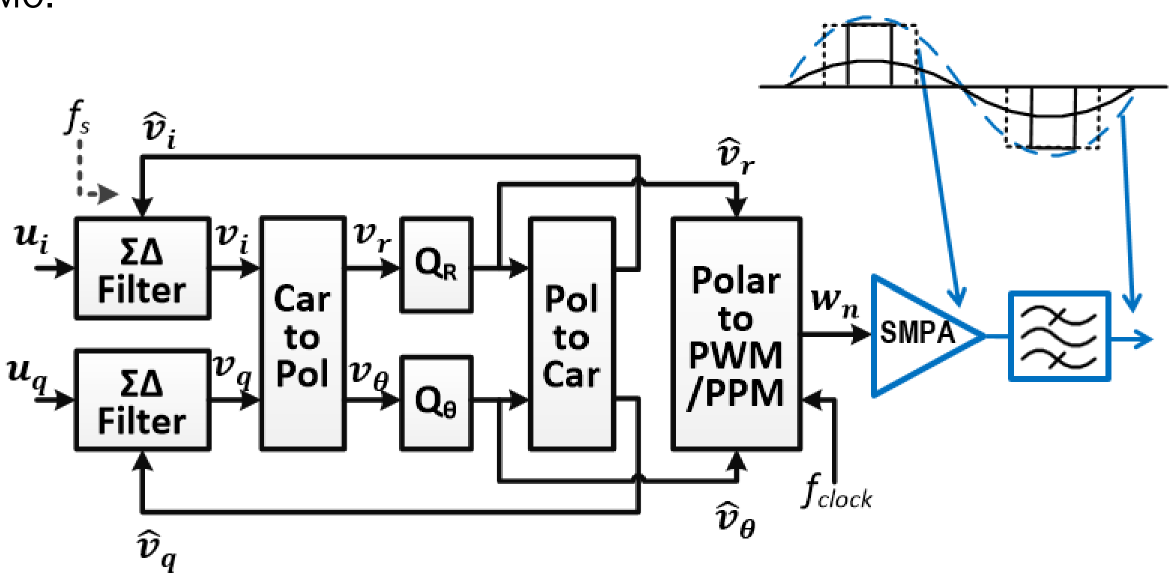
Strategi yang akan dijalankan bagi keunggulan produk ini menjalin Kerjasama kemitraan dengan operator seluler dalam uji coba lapangan secara real dan penggunakan solar cel dengan biaya yang murah untuk kestabilan infrastruktur yang akan dibangun.

Pasar Produk/Layanan

Produk BTS mini (Mi-Fi 4G) dibuat dalam bentuk *access point* (AP) yang target jangkauannya meliputi wilayah kampung Berua. Luas wilayah kampung Berua adalah kurang lebih 2 Ha atau setara dua kali lapangan sepak bola, dengan hanya ada 15 kepala keluarga dan 15 bangunan rumah panggung tetap yang bermukim di wilayah ini. Test bench yang telah dilakukan adalah pemodelan *Femtocell access point* (FAP) pada Gedung Sekolah Kampus 1 dan Kampus 2 PNUP sebagaimana FAP ini akan diimplementasikan pada wilayah target.

Hasil produk dan jasa yang telah dilaksanakan pada tahun-1 ini adalah:

a. Test bench pada struktur upconverter-RF menggunakan parameter radio di BTS eksis sekitar wilayah karst Rammang-rammang. Skenario ini akan menggunakan satu frekuensi carrier yang digunakan sama dengan frekuensi kerja celluler 4G. Hasil data yang telah dimiliki saat ini selanjutnya akan diimplementasikan pada blok struktur upconverter-RF dengan resolusi metode kuantisasi joint-Q. Tujuan produk pemodelan pengukuran ini adalah untuk menguji ketahanan efisiensi low power dan noise. Bagan desain BTS Mini Mi-Fi 4G menggunakan struktur upconverter-RF seperti yang terlihat pada Gambar 1. Luaran variable *wn* merupan sinyal waveform RF dan kemudian akan dihubungkan dnegan filter dan antenna MIMO.



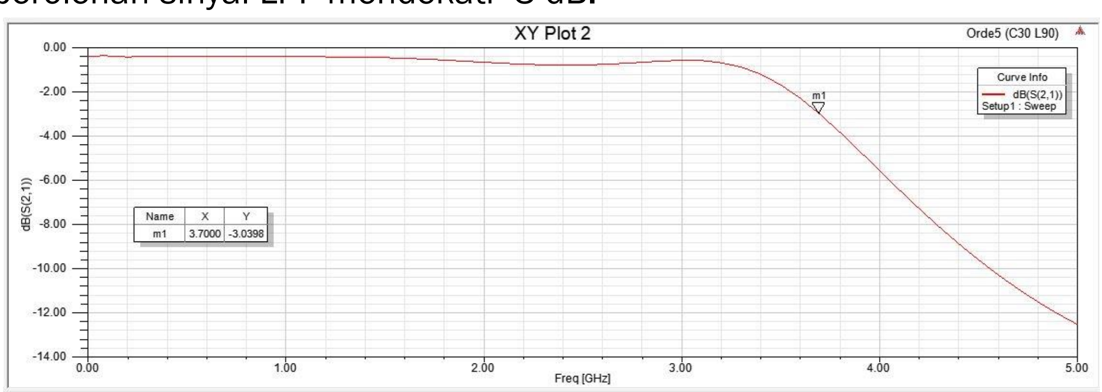
Gambar 1. Konseptuan struktur Mi-Fi 4G.

Terdapat tiga tahapan proses dalam pemodelan ini yaitu:

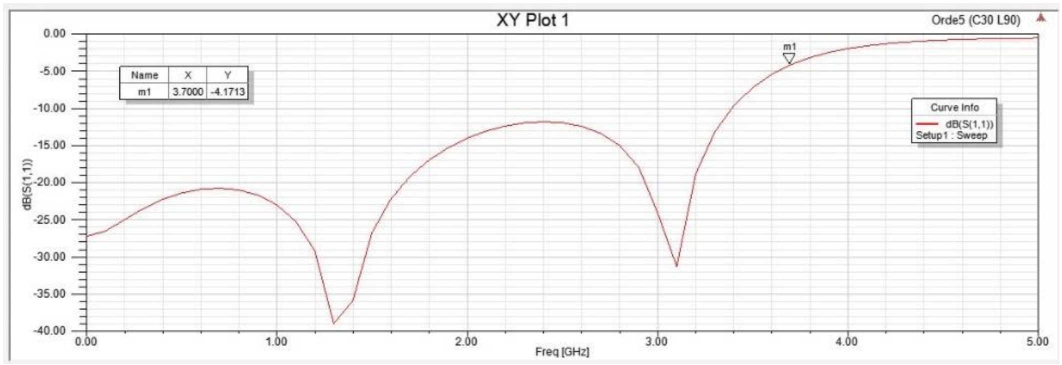
1) Blok ΣΔ filter berstruktur low-pass ΣΔ MOD2. Baseband I-Q akan melalui ΣΔ filter $[u_i, u_q]$. Output variabel $[v_i, v_q]$ format koordinat Cartesian.
2) Blok Quantiser-Q adalah fungsi kuantisasi sinyal polar. Baseband $[u_i, u_q]$ harus dikonversi (blok Car-to-Pol) ke format polar dan menghasilkan $[v_r, v_\theta]$. Metode konversi dapat dilakukan dengan persamaan umum $R = \sqrt{I^2 + Q^2}$ dan $\theta = \tan^{-1}\left(\frac{Q}{I}\right)$. Proses kuantisasi akan dilakukan secara terpisah baik yaitu untuk amplitude (blok QR) dan fasa (blok Qθ) menghasilkan $[\hat{v}_r, \hat{v}_\theta]$. Penggunaan pre-distorsi dan post-distorsi bertujuan membuat noise palsu (amplitude dan fasa serupa dengan distorsi asli) dari spectrum signal yang dihasilkan. Pre-distorsi yang ditempatkan di bagian depan ΣΔ-driver untuk solusi image cancellation. Sedangkan post-distorsi ditempatkan pada bagian akhir blok transmiiter dengan harapan untuk menghitung posisi noise dalam spektrum dan sebagai solusi noise cancellation.
3) Blok "Polar to PWM/PPM' adalah fungsi menghasilkan sinyal waveform RF (w_n). Luaran blok Quantiser format polar $[\hat{v}_r, \hat{v}_\theta]$ akan diteruskan ke dalam blok ini, sedangkan format Cartesian $[\hat{v}_i, \hat{v}_q]$akan diteruskan ke unit feedback ΣΔ filter.

Keunggulan system ini adalah perolehan sinyal waveform RF murni tanpa noise (distortion cancellation) dimana ancaman image distorsi dapat dikendalikan. Sistem ini dapat menguatkan perancangan BTS mini yang akan diimplementasikan.

b. Desain Co-operative wireless radio menggunakan source Tx, source Rx dan Relay. Setiap relay akan difungsikan sebagai Amplify-and-Forward (AF) dan/atau Decoding-and-Forward (DF). Jumlah hopping dapat disesuaikan dengan jarak antar repeater dari rasio luas karst yang ditargetkan sebagai coverage BTS Mi-Fi 4G. Desain LPF sudah selesai 100% dan telah diuji dalam pengukuran. Keunggulan system ini adalah perolehan sinyal LPF mendekati -3 dB.

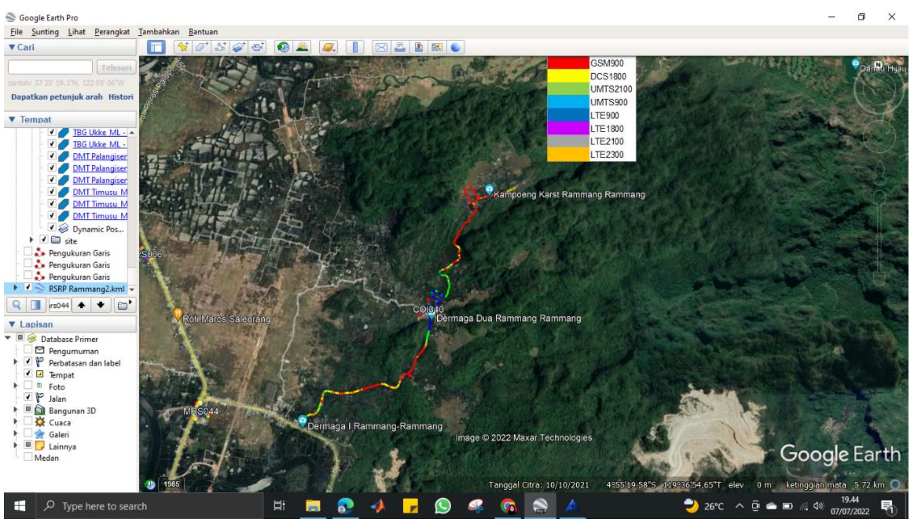


Gambar 2. Plot S11 LPF orde 5, hasil aktual -12.3 dB

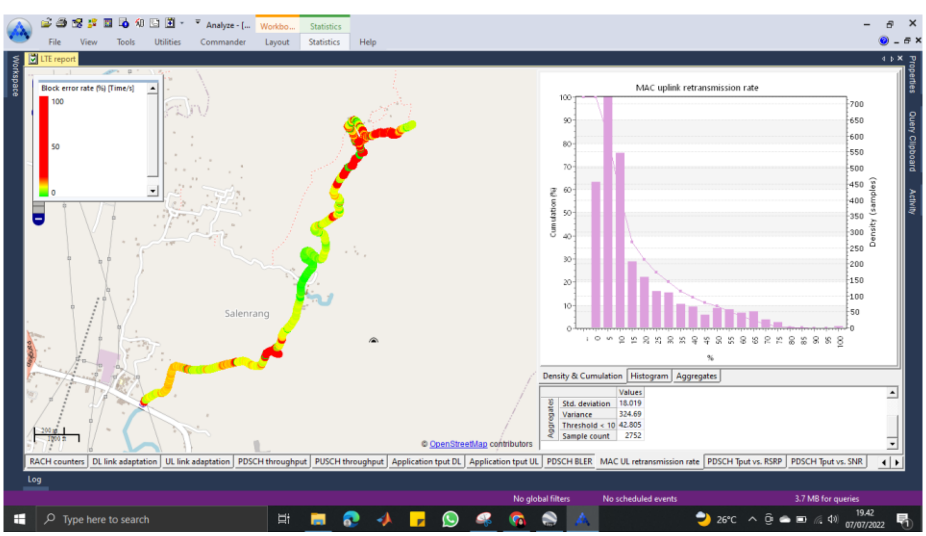


Gambar 3. Plot S21 LPF orde 5, hasil aktual -2.7 dB

c. Optimasi jaringan BTS eksis melalui pengukuran Drive/Walk Testing. Metode ini berupa site audit dan pengukuran kualitas radio yang digunakan menggunakan tool DT dan analisis menggunaka Nemo Handy. Data sudah ada dan telah ditentunkan KPI yang cocok.



Gambar 4. Tampilan Google Earth kualitas sinyal Operator Telkomsel



Gambar 5. Tampilan kualitas sinyal BER

Strategi yang akan dijalankan bagi keunggulan produk ini adalah:

- ✓ Menjalin Kerjasama kemitraan dengan operator seluler dalam uji coba lapangan secara real. Konsep ini dapat berupa compact Mobile BTS (COMBAT) yang biasa digunakan oleh operator dalam membuka akses konektivitas di daerah-daerah terpencil.
- ✓ Mi-Fi 4G dapat dirancang untuk wilayah-wilayah lain seperti kepulauan dan wilayah terpencil lainnya. Diperlukan ujicoba pada wilayah ini jika memungkinkan.

Harga jual yang akan diterapkan masih memerlukan pertimbangan dalam hal supply power listrik daya tetap PLN. Langkah strategis yang akan dipertimbangan untuk memasuki harga pasar ialah penggunakan solar cel dengan biaya yang murah.

Pertimbangan Teknologi/Sosial

Setelah dilakukan pengukuran kualitas sinyal bahwa sistem akses radio seluler disekitar kawasan karst Rammang-rammang sangat buruk. Hal ini terjadi karena kondisi wilayah dihalangi pegunungan karst dan antar karst inilah yang menjadi penghalang sinyal gelombang langsung dari base transceiver station (BTS) terdekat.

Pemasangan FAP di lokasi target memerlukan beberpa titik penempatan. Idelanya, FAP ditempatkan dititik tengah wilayah dan dianggap sebagai lokasi sentral yang dapat menjangkau merata diwilayah target.

Beberapa aspek yang perlu dipertimbangkan, antara lain:

1) Aspek Teknologi
   Perlunya sumber daya energi seperti supply PLN yang tetap atau tersedianya solar cel yang memadai.
2) Aspek Lingkungan
   Perlunya lokasi strategi menempatkan FAP pada beberapa titik lokasi. Penggunaan lahan warga perlu didiskusikan lebih lanjut.
3) Aspek Sosial
   Perlu pendekatan kepada warga target pentingnya pemeliharaan insfrastrutur FAP yang akan diimplentasikan. Dengan demikian, perlu dipikirkan strategis pemeliharaan melalui system remote dan monitoring jarak jauh.
4) Aspek Hukum
   Penggunaan frekuensi kerja memerlukan ijin penggunaan frekensi dari Kominfo. Solusi yang bisa dilakukan adalah bekerjasama dengan operator seluler aktif sehingga dapat menggandeng konektifitas dalam base controller LTE 4G. Aspek hukum ini terkait impelementasi standar pelayanan system seluler.

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Penelitian Produk Vokasi Unggulan Perguruan Tinggi (P2VUPT)
PENERAPAN BTS MINI Mi-Fi 4G BERBASIS CO-OPERATIVE WIRELESS RADIO SELULER DI KAWASAN KARS WISATA RAMMANG-RAMMANG
Program Studi Teknologi Rekayasa Jaringan Telekomunikasi
Politeknik Negeri Ujung Pandang


2022.07.03 16:31

Nama/Judul Luaran

PENERAPAN BTS MINI Mi-Fi 4G BERBASIS CO-OPERATIVE WIRELESS RADIO SELULER DI KAWASAN KARST

Deskripsi Luaran

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Periode Uji

Tgl. Awal

08/19/2022

Tgl. Akhir

11/12/2022

Link video luaran (jika ada)

-

Unggah Dokumen

Dokumen hasil uji produk lapangan/lingkungan sebenarnya

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Article

Optimalization Femtocell 4G-LTE Deployment Placement in Multifloor Buildings

Sirmayanti Sirmayanti [1,*], Winnie Patiung[1], Sahbuddin Kadir, and Lidemar Halide1[1]

[1] Department of Electrical Engineering, Politeknik Negeri Ujung Pandang, 90245, Indonesia
* Correspondence: Sirmayanti.sirmayanti@poliupg.ac.id

Abstract: Indoor cellular network system is a solution to overcome the weak signal received by the user. Buildings with heavy cellular communication traffic levels, such as in the airport, schools or campuses, etc require an indoor network system to ensure the continuity of cellular communication by all users. Therefore, it is necessary to plan an indoor network using Femtocell LTE, a popular solution for the existed 4G network. The aim of this research is to design an LTE indoor network, case in the School Building Campus 1 and the Electrical Building Campus 2 PNUP based on the COST231-Multiwall Indoor Propagation model using the radiowave propagation simulator (RPS) application. The size of the wall-building and the type of construction material are necessary inputs for this design in order to determine the number of Femtocell access points (FAP) required to reach and provide a strong signal to every room. Based on the results of the coverage calculation, it is showed that the number of FAPs that can be placed are 2 FAPs for the 1st floor and 3 FAPs for the 2nd and 3rd floors of each building.

Keywords: mobile communication; Femtocell; 4G-LTE; Indoor Cell; network design; wireless communication; cellular design.

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1. Introduction

The development of data communication in the Internet user sector in Indonesia in 2021 has increased significantly by 11% from about 175.4 million to approximately 202.6 million users. This value is equivalent to 73% from 274.9 million people of the Indonesia's total population [1]. Furthermore, in broadband wireless access (BWA) technology where 4G long term evolution (4G-LTE) cellular operators are required to serve telecommunications needs with high data access rates. Wide access coverage and guaranteed high data transfer are the maximum service standards both indoors and outdoors [2,3].

Considering the indoor Femtocell area has a smaller range cell nodes than the outdoor microcell, so taking the selection suitable path loss character is of great importance. The path loss is a pattern of measuring the value of the amount of attenuation caused by soil contours, weather, slope, walls, and others [4,5]. Later, the transmitted signal behavior with a radio propagation model also still needs to be analyzed. 4G-LTE advantages in indoor networks because it has a sending component (Tx) and signal receiver (Rx) which is located inside the building so that it is not disturbed by outside coverage penetration to get high data rate access inside the building [6,7].

The existing 3G-Macrocell network access if emitted by base station (BTS) for Indoor users will be less optimal due to coordinate inter-cell interference problems and channel estimation of neighbor cell searches [8, 9]. Besides that, it needs a minimum connection between the Femtocell and Macrocell on each base stations. Thus, a special indoor technology system is needed for indoor or building users through 4G-LTE technology. Femtocell network on 4G-LTE is one of the alternative solutions to increase 4G service coverage in buildings. The advantage of this system is that Femtocell can work by reducing the distance between user equipment (UE) and BTS [10,11]. Strong network coverage and mobility management for Femtocell is possible [12] and less costly [13,14] when compared to the addition of BTS to reach all parts of the Indoor.

This research focuses on the Femtocell modeling to the buildings which have high density levels in the existing cellular service areas. This modelling had taken sample cases at School Building Campus 1 (GS-K1) and Electrical Building Campus 2 (GE-K2) of the State Polytechnic of Ujung Pandang (PNUP). These two buildings consist of 3 floors which are used as classroom facilities. The density of Internet access in this building is very high especially when all students use their smartphone devices to access the Internet simultaneously then reach high traffic so that communication services require a longer waiting time to be accessed by users.

The novelty of this research that the indoor radio network design applies the radiowave propagation simulator (RPS) and G-NetTrack Lite modeling methods in the real existed cellular provider. RPS is a desktop-based application program that is useful for analyzing radio wave propagation performance and predicting the coverage of BTS in cellular areas. The results study in [13, 15] which only discussed the different scenarios for Femtocell access points (FAP) placement for their steps in Femtocell indoor network planning. It displays their effect on system behavior after comparing different propagation models then resulting the best scenario. So therefore, this paper had explored more the specific research founding in determining the signal strength from the 4G/LTE key performance indicator (KPI) measurement using Nemo Analyst that will be the initial parameter reference so as to create the best scenario for the installation of Femtocell antennas. The Nemo application was chosen as a supporting instrument that serves to assist the process of measuring signal strength at the object of the research location.

2. Material and Methods

2.1 LTE Technology

LTE is a standard from the 3rd generation partnership project (3GPP) for wireless access on GSM/EDGE and UMTS/HSPA networks. For decent performance, LTE must be operated over a separate wireless spectrum [16].

3GPP has made LTE technology criteria including reduced latency up to 10 ms, peak downlink rate reaching 100 Mbps when the user is on the move and 1 Gbps when the user is idle. Meanwhile, the peak uplink rate is 50 Mbps. LTE technology must have a flexible frequency range from 1.4 MHz to 20 MHz, the spectrum efficiency is increased by two to four times. 3GPP also makes a cost-effective system migration qualification from 3.5G release 6 technology so that it can work on various frequency spectrums, both paired and unpaired, in other words 3GPP and non-3GPP technologies can work together [3, 7, 17].

2.2 COST231 Multiwall

COST231 Multiwall is one of the propagation calculations models that considers all aspects of the vertical plane in the building that is between Tx and Rx. This model also considers the type of material in the building. The amount of attenuation will be greatly influenced by the signal beam received after passing through walls and other components [18]. The types of division of building walls are listed in the following Table 1, Table 2 and Table 3.

Table 1. Wall Types [19]

Wall Type	Description
Thin Wall (Lw1)	Walls that do not have additional bearings and have a thickness rating of 10cm
Thick Wall (Lw2)	Walls loaded by a bearing or additional type of wall so that the wall thickness is > 10 cm

Table 2. Wall Attenuation Variable [19]

Building Condition	**Lw1 (Light Wall) (db)**	**Lw2 (Heavy Wall) (db)**	**Lf (Loss per Floor) (db)**	**B (empirical parameter) (db)**
Congested	3,4	6,9	18,3	0,46
Open	3,4	6,9	18,3	0,46
Large	3,4	6,9	18,3	0,46

Table 3. Environmental Category Explanation [19]

Category	**Description**
Category	Types of buildings such as offices with permanent occupants in the room
Open	The type of building is open with non-permanent occupants
Large	The type of building is a large type of factory, airport or shopping center

This calculation will produce a model that is very similar to room conditions [6]. The COST 231 Multiwall equation used in this design analysis is as follows:

$$LT_{Multiwall\ Model} = \text{FSL} + \text{LC} \sum_{i=1}^{M} nwi, Lwi + n^{\left[\frac{nf+2}{nf+1} - b\right]} Lf \quad (1)$$

where i = (1 or 2), *LC* is constant loss, *nwi* is the number of walls crossed by the path, *b* is empirical parameter, *nf* is number of floors crossed by the path, and *LSF* is free space loss.

2.3 *LTE Key Performance Indicator (KPI)*

2.3.1 Reference Signal Received Power (RSRP)

RSRP is power received value on the user side based on a certain frequency [20]. The RSRP parameter received on the user side will be influenced by the distance between the user and the site, where the greater the distance between the user and the site, the smaller the RSRP received on the user side will be [21, 22]. For the range of RSRP values, see Table 4.

Table 1. RSRP Value Range [23]

Signal Criteria	Range (dBm)	Color
Excellent	-85	
Good	-92 RSRP < -85	
Fair	-102 RSRP < -92	
Poor	-120 RSRP < -102	

2.3.2 *Signal To Interference Ratio (SIR)*

SIR is a ratio to compare between signal strength and signal interference from other cells. This parameter indicates the user viability to make a call even in the smallest power level [21]. Table 5 shows the SIR range in different signal criteria.

Table 2. SIR Value Range [23]

Signal Criteria	Range (dBm)	Color
Excellent	10 SIR < 30	
Good	3 SIR < 10	

Fair	0 SIR < 3	
Poor	-20≤ SIR < 0	

2.4 *Femtocell*

2.4.1 Femtocell Concept

Femtocell is a micro-Tx technology structure (home base station) with large coverage and capacity even at low power levels. Femtocell is also referred to as a small low-powered wireless access point that operates on a licensed frequency spectrum [24]. It can be said that Femtocell is a mini-sized BTS that is placed in a location that gets a low signal. Femtocell's goal is to improve mobility, availability, connectivity and performance of network services with low power requirements. Femtocell is now becoming popular as an alternative to mini BTS outside the range of certain existed BTS, especially in indoor areas (houses, buildings, schools, etc.) [15].

2.4.2 Femtocell Architecture

Femtocell-device management system (FMS) and security gateway (SeGW) are the three main Femtocell elements that are present in every network architecture [15]. Access Point (AP) is the main element is FAP which is on the user side of the femtocell network, FMS is a system located on the operator's network and SeGW is a network element that functions to protect the Internet connection between users and the network of the cellular operator.

2.5 *Coverage Area Calculation*

To analyse the number of FAPs based on the coverage area, commonly it is necessary to calculate the cell radius [25]. In this calculation, it is necessary to calculate the Link Budget which consists of Free Space Loss, namely the decrease in the power of radio waves as long as the signal propagates in free space. The FSL formula will then be used to find the radius which can be seen in Equation 1.

$$Lp = FSL = 32.45 + 20 \log f + 20 \log d \quad (2)$$

where d is the range between Tx-Rx (km).

After obtaining the results from the radius calculation, the cell area calculation can be carried out using Equation 2 and continued by counting the number of cells in Equation 3.

$$L\ (Cell\ Area) = 2.6\ x\ d^2 \quad (3)$$

$$Number\ of\ Cells = Area/Cell\ Area \quad (4)$$

2.6 *Attenuation of Various Room Dividers*

Buildings have different shapes and materials of different types of barriers or insulation – different components. For example, a house has a room divider that uses wood insulation for Walls in its interior space. At the same time, office space partitions generally use movable space partitions [26]. Meanwhile, the types of attenuation for each building material can be seen in Table 6.

Table 3. Materials Attention Value

Material	Attenuation (db)
Concrete Wall	8
Glass window	2,8
Wooden door	4

2.7 Radiowave Propagation Simulator (RPS)

RPS is software program that is often used to measure and analyze radio wave propagation and predict the coverage of a telecommunication BTS. This program is created by a software development organization [4].

2. 8 Modell Planning

The research design is the entire research process from the beginning to the end, and is presented in the form of research diagram in Figure 1.

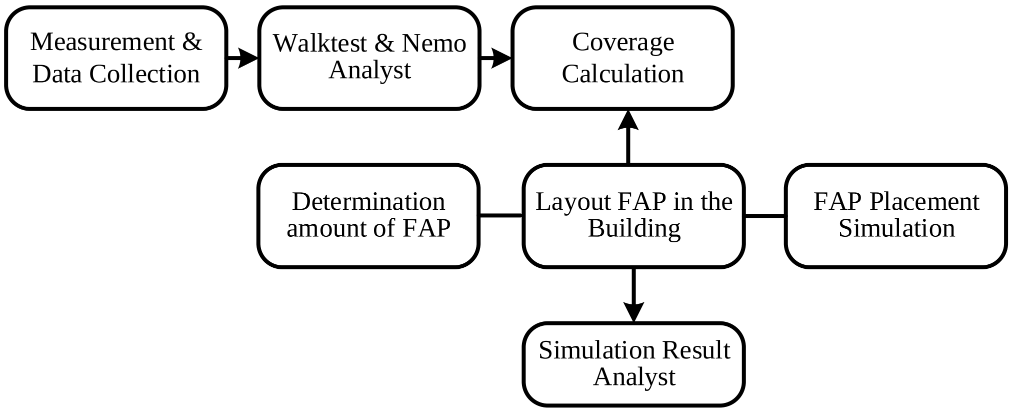

Figure 1. Research Diagram.

As shown in Figure 1, site audit is the first step of the measurement data collection, and then loading floor plans of the GS-K1 and GE-K2. The next step is pre-walking test mode by Nemo handy tool to capture the accurate real-world data of the radio frequency (RF) environment. Drive/walk test (DT/WT) procedure would assess the quality of experience (QoE) of 4G mobile networks such as signal strength, the mobile network latency, voice call KPIs etc. This processing tool must support the analysis on the floor map-based view. Data collected states are stored in the log files. In planning to determine the number of FAPs, calculations are applied using Cost 231 multi wall indoor propagation in both the buildings. From these calculations, the maximum number of FAPs was selected in the simulation based on the scenario plans. Moreover, the link budget calculation is carried out to maintain the balance of gain and loss in order to achieve the desired SIR on the receiving side. After laying out and placing the FAPs based on coverage calculations, an analysis of the parameters of the RSRP and SIR had been carried out in each scenario based on the number of FAPs. To obtain the best decision, each scenario will be compared with one another and then look at the most optimal results.

2.9 Building Location Information

Table 4. Building Area Details

Floor	Building Area (m2)	
	GS-K1	GE-K2
1st	829.44	1.305
2nd	829.44	1.305
3rd	829.44	1.305

GS-K1 has 3 floors with 29 classrooms, 12 toilets, 1 warehouse and 1 OHP service room. Meanwhile, GE-K2 has 3 floors consisting of Lobby, Classroom, Laboratory Room, Tools and Materials Room, Head School Office and Meeting Room, Living Room, Instructor Room and Toilet. In this study, the network design will be carried out on all floors, namely from the 1st floor to the 3rd floor. This is because GS-K1 and GE-K2 are buildings that become a means to carry out the teaching and learning process with a high level of Internet data access usage. For details of the building area, see Table 7.

2.10 Walktest (WT)

Walktest (WT) is a method of measuring signals that are carried out without using a means of transportation, in this case it is done by walking with a drivetest device. In this study, the Walktest was conducted by measuring the signal from the Telkomsel operator.

2.11 Calculation Flow

At this stage, the number of FAPs is calculated based on coverage planning using Cost 231 Multi Wall Indoor propagation which includes material loss parameters for GS-K1 and GE-K2. From the calculation, the number of FAPs with the maximum results will be chosen for the simulation later. The results of the calculation of the number of FAPs show that the number of FAPs for the 1st floor of each building is 2 FAPs and 3 FAPs for the 2nd floor and 3rd floor for each building.

2.12 FAP Scenario

There are 5 scenarios in the Femtocell-TX design with RPS application, namely where the FAP is positioned: (1) In the middle of the building, (2) FAP is positioned on the North side (3) On the South side, (4) Zigzag Type 1 and (5) Zigzag Type 2.

To determine the number of FAPs in terms of coverage, each uses the equation as stated in equation (1). After this design is completed, then proceed with inputting into the RPS and it is ready to be tested for its performance.

3. Results and Discussion

3..1 Walktest Measurement Result

Good network conditions according to KPI standards is -70 dBm [6, 8, 10]. After exchanging the network, the measurement results from the floor of each building can be seen in Table 8 for RSRP and Table 9 for the SIR value. Figure 2 is the Walktest plot for GS-K1 where the top image is the RSRP result and the bottom image is the SIR plot. The colors displayed represent the values in accordance with those in Table 4 and Table 5. Figure 3 is a plot of the results of the GE-K2 Walktest.

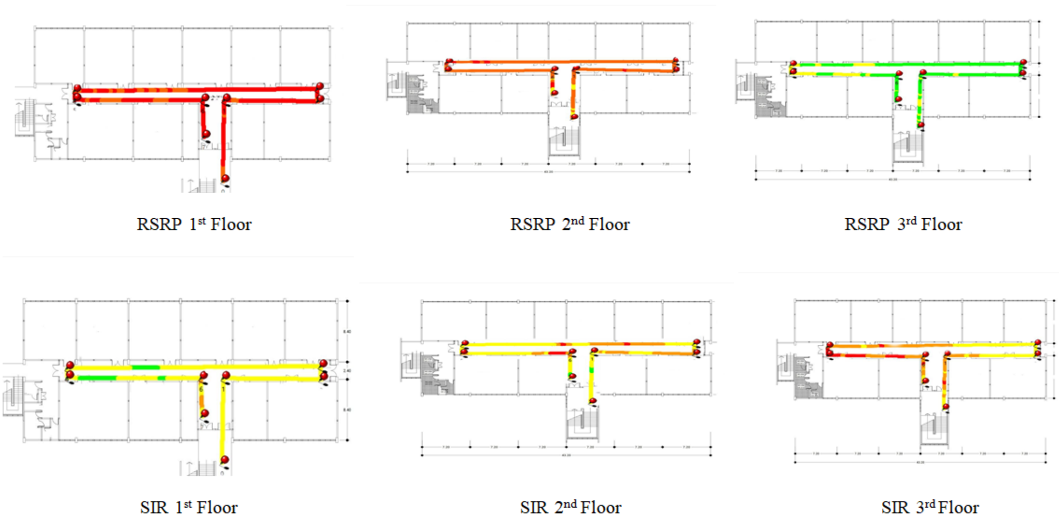

Figure 2. GS-K1 Walktest Plot Results

Table 5. RSRP Building Walktest Results

Signal Criteria	GS-K1(%)			GS-K2 (%)		
	1	2	3	1	2	3
Excellent	5.29	5.48	0	3.94	0	0
Good	89.84	64.78	36.28	58.08	30.97	1.01
Fair	4.88	26.55	42.32	30.57	31.31	26.16
Poor	0	3.19	21.41	7.40	37.71	72.84

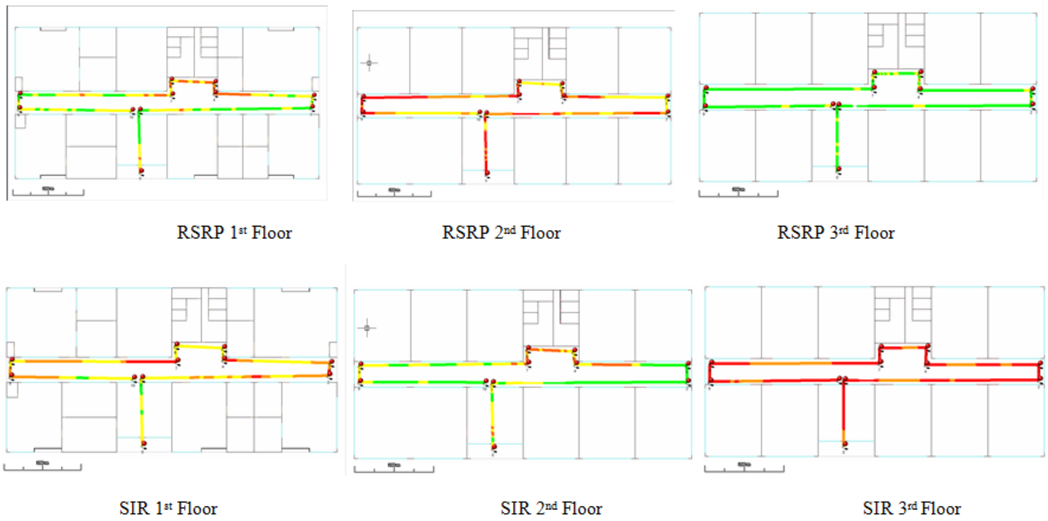

Figure 3. GE-K2 Walktest Plot Results

Table 6. SIR Building Walktest Results

Signal Criteria	GS-K1(%)			GS-K2 (%)		
	1	2	3	1	2	3
Excellent	5.29	5.48	0	3.94	0	0
Good	89.84	64.78	36.28	58.08	30.97	1.01
Fair	4.88	26.55	42.32	30.57	31.31	26.16
Poor	0	3.19	21.41	7.40	37.71	72.84

3.2 *Link Budget Results*

The link budget is targeted to obtain the maximum legitimate path loss (MAPL) value. As we can see from the Table 10, the results of the MAPL-uplink calculation obtained a value of 394,16 dB and the MAPL-downlink 391,16 dB. The difference between MAPL uplink and 3db dB downlink. Based on the result in [7] if the value of the difference between uplink and downlink is <5 dB then signal amplification is feasible.

Table 7. MAPL Uplink Downlink Calculation Results

	Variable Name	Equation	Up	Dw
a	Maximum mobile Tx-power (dBm)		23	20
b	Mobile antenna Gain (dBi)		0	0

c	Body/orientation Loss (dB)		0	0
d	EIRP (dBm)	$(d = a+bc)$	23	20
e	Thermal noise density (dBm/Hz)	KTB=(1.38x10- 23x290) = -240 dBW = -174	-174	-174
f	BS receiver noise figure (dB)		4	4
g	Receiver noise density (dBm/Hz)	$(g = e+f)$	-170	-170
h	Receiver noise power (dBm)	$(h = g + 10log\ (14.4x\ 10\text{-}6\ ))$	-218.42	-218.42
i	Interference margin (dB)		3	3
j	Noise & interference (dBm)	$(j = h+i)$	-388.42	-388.42
k	Processing gain (dB)	(k = 10 logs(14.4 Mbps/384))	-14.26	-14.26
l	Required Eb/No	384 kbps data	1	1
m	Receiver sensitivity (dBm)	$(m = l – k + j)$	-373.16	-373.16
n	Base station antenna gain (dBi)		0	0
o	Fast fading margin		2	2
p	Maximum path loss (dB)	$(p = d\text{-}\ m + n\ \text{-}\ o)$	394.16	391.16

3.3 *Indoor Loss*

The Indoor loss in the form is loss wall material. This type of loss considers the contribution of building materials such as types of walls, floors, room dividers, wooden doors, ceilings, glass, and others, see in Table 11.

Table 8. Building Loss Calculation Results

Floor	Total Indoor Attenuation (dB)	
	GS-K1	GE-K2
1	232	284
2	228	244
3	228	248

3.4 *FAP Amount*

The results of calculating the number of FAPs based on coverage on building objects are in the Table 12.

Table 9. FAP Total

Floor	FAP Total	
	GS-K1	GE-K2
1	2	2
2	3	3
3	3	3

3.3 Scenario Placement Results

Table 10. Building Composite Coverage Results

Scenario	GS-K1 (dBm)			GS-K2 (dBm)		
	1st Floor	2nd Floor	3rd Floor	1st Floor	2nd Floor	3rd Floor
1	-72.87	-56.26	-55.55	-63.72	-46.19	-47.18
2	-76.74	-58.71	-58.26	-67.38	-58.87	-57.43
3	-92.12	-64.88	-64.39	-75,48	-49.75	-51.75
4	-91.76	-59.45	-58.86	-71.48	-47.26	-48.53
5	-75.43	-54.85	-54.34	-70.68	-48.81	-48,88

Table 13 is the composite coverage data obtained after performing a simulation using RPS. The data is used as a comparison to see and decide the best scenario. The best scenario is chosen through the highest mean value in the data in Table 13. It can be seen that scenario 1 (FAP in the building floor centre) is the best scenario. Thus this scenario is then used to place the FAP on the measured object. Table 14 is a complete description of the results of the RSRP while Table 15 is a complete description of the results of the SIR from the first scenario. Figure 4 and Figure 6 are the results of the histogram coverage of the RPS for RSRP. While Figure 5 and Figure 7 are the results of the SIR histogram on the measured object.

Table 11. RSRP Best Scenario Results

Signal	GS-K1(%)			GS-K2 (%)		
Criteria	1st Floor	2nd Floor	3rd Floor	1st Floor	2nd Floor	3rd Floor
Excellent	64.88	95.18	95.47	72,20	98.28	98.44
Good	12.73	2.21	1.98	10.49	0.621	0.59
Fair	4.99	0.44	0.41	7.37	0.14	0.12
Poor	14.94	2.12	2.09	9.88	0.95	0.84

Table 12. SIR Best Scenario Results

Signal	GS-K1(%)			GS-K2 (%)		
Criteria	1st Floor	2nd Floor	3rd Floor	1st Floor	2nd Floor	3rd Floor
Excellent	69.84	83.76	84.32	85.54	71.21	68.02
Good	20.18	9.03	8.75	10.03	9.55	8.94
Fair	5.63	5.95	5.76	4.14	14.86	19.16
Poor	3.33	1.19	1.15	2.29	4.37	3,876

Figure 4 is a plot of the RSRP GS-K1 results obtained from the RPS application. The image shows the plot of the first simulation result, namely the placement of the FAP which is placed in the center of the building (hallway). The 1st floor of GS-K1 obtained an RSRP value in the Excellent category covering an area of 5.29%, 2nd floor of 5.48% and 0% of 3rd floor. The average value of RSRP on the 1st floor is -72.87 dBm, the 2nd floor is -56.26 dBm and the 3rd floor is -55.55 dBm. Optimization results after FAP placement at several points which resulted in a significant improvement. Floor 1 which initially had an RSRP with a category of Excellent 0% now gets a score of 64.88%, Floor 2 which was originally

0% has now become 95.18% and Floor 3 which was originally 67.35% has now become 95.47%.

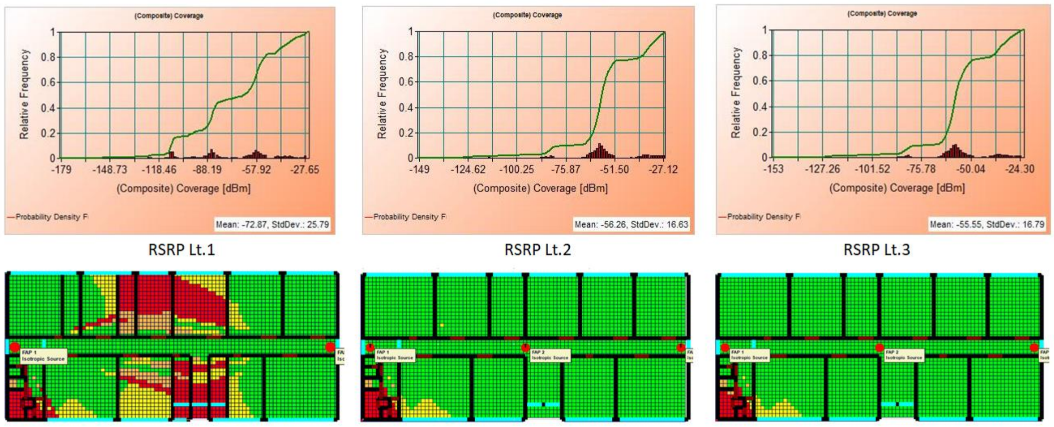

Figure 4. GS-K1 RSRP Plot Results

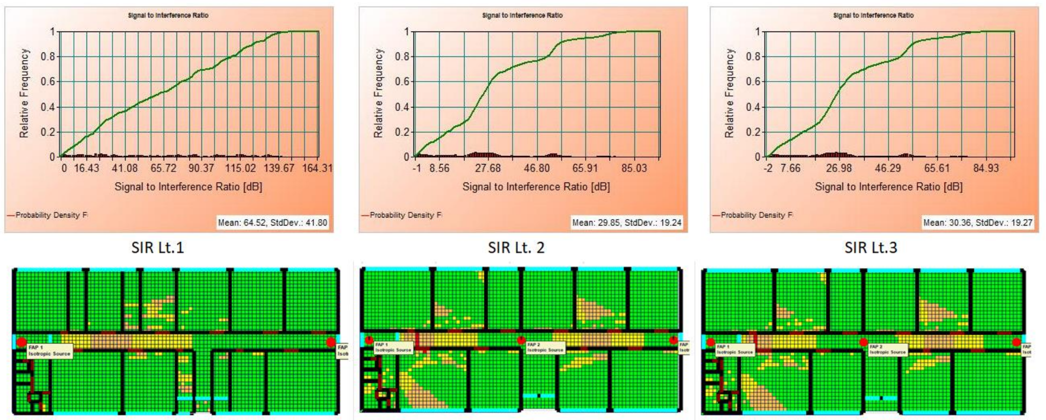

Figure 5. GS-K1 SIR Plot Results

Figure 5 is a plot of the results of the SIR GS-K1 which was also obtained from the RPS application. The average SIR value obtained on the 1st floor is 64.52 dB, the 2nd floor is 29.85 dB and the 3rd floor is 30.36 dB. After optimization with FAP placement, the results obtained in the Excellent category which initially only covered 5.29%, 5.48%, 0%, now become 69.84%, 83.76% and 84.32%.

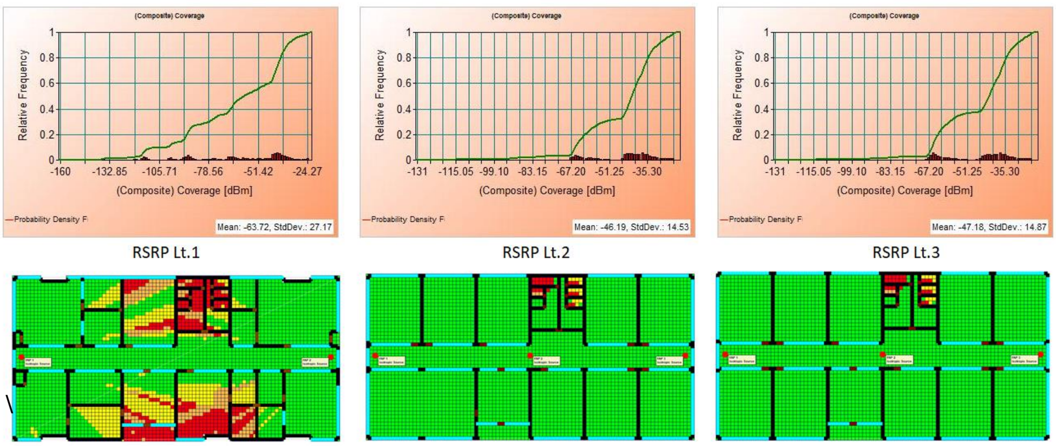

Figure 6. GE-K2 RSRP Plot Results

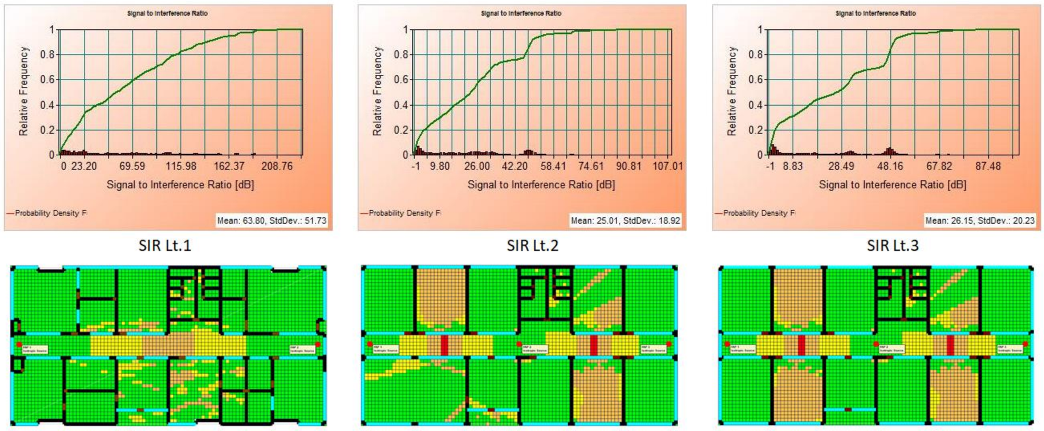

Figure 7. GE-K2 SIR Plot Results

RSRP measurements were also carried out on GE-K2 which is shown in Figure 6. The initial results obtained that the average RSRP value for the 1st floor was -63.72 dBm, the 2nd floor was -46.19 dBm and the 3rd floor was -47.18 dBm. To be more specific, the RSRP in the Excellent Category which initially was only 3.94% increased from 68.36% to 72.2%, the 2nd floor which was initially 0% increased to 98.28% and the 3rd Floor which was originally 0% increased to 98 ,44%.

SIR calculation is also carried out where the data is shown in Figure 7. The average value of SIR obtained on 1st floor is 63.00 dB, 2nd floor is 25.01 dB and 3rd floor is 26.15 dB. After the placement of FAP the results obtained are on 1st floor , the Excellent category which initially only covers 3.94% now becomes 85.54%, 2nd floor which was originally 0% has now become 71.21% and 3rd floor which was originally 0% has now become 68.02%.

Scenario simulation results on GS-K1 and GE-K2 show that the entire area is covered and the signal quality is good. The placement of the FAP with the best results is the placement of the first scenario, which is in the middle of each floor (in the middle of the hallway). The number of obstacles that are passed is the least compared to other scenarios so that the FAP can transmit the signal with the smallest attenuation.

4. Cconclusions

The number of obstacles that the signal passes through will affect the amount of power that will be received by the user. That is why the placement of FAP in the mid-center of the building gets the best composite results than other placement scenarios. The best composite coverage results obtained from each scenario are for GS-K1 1st floor of -72.87 dBm, then the results for 2nd floor composite coverage are -56.26, and for 3rd floor the resulting composite coverage is -55.55 dBm. Meanwhile, the best composite coverage result for GE-K2 1st floor is -63.72 dBm, then the composite coverage result for 2nd floor is -46.19, and for 3rd floor the resulting composite coverage is -47.18 dBm. In the calculation based on coverage, the number of FAPs that can be placed is 2 FAPs for the 1st floor and 3 FAPs for the 2nd and 3rd floors of each building. FAP in this study has a transmit power of 20 dBm. So that the Maximum Allowable Path Loss is 394.16 dB from the uplink direction and 391.16 dB from the downlink direction. After adding FAP at several points, it is known that the optimization was successfully implemented because the results before and after optimization experienced a significant increase.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Directorate General of Informatics Applications, the Ministry of Communication and Informatics of Indonesia, Indonesia Needs to Increase Cultural Values on the Internet. Availabe online: https://aptika.kominfo.go.id/2021/09/warganet-meningkat-indonesia-perlu-tingkatkan-nilai-budaya-di-internet/ (accessed on 26 May 2022).
2. Chen, S.; Zhao, J. The requirements, challenges, and technologies for 5G of terrestrial mobile telecommunication. *IEEEmcom* **2014**, *52*, 5, 36–43.
3. Krasniqi, F.; Maraj, A.; Blaka, E. Performance analysis of mobile 4G/LTE networks. In Proceeding of the IEEE South-Eastern European Design Automation, Computer Engineering, Computer Networks and Society Media Conference (SEEDACECNSM*)*, Kastoria, Greece, 22-24 September 2018.
4. Chong, C.; Poh, K.; Daeyoung, K. Surface-level path loss modeling for sensor networks in flat and irregular terrain. *TOSN* **2013**, *9*, 2, 1-32.
5. Usman, U.K. Radio Wave Propagation in Cellular Technology. In Proceeding of the National Information Systems Conference (KNSI), STMIK Atma Luhur Pangkalpinang, Indonesia, 8 – 9 March 2018.
6. Syam, A.M.; Junianto, D.; Anggreani, D.; Suganda, I .F.; Rahayu, Y. Designing a Femtocell Network on a 4G LTE Network at the Riau University Rectorate Building. *Simteris* **2020**, *11*, 1, 313–324.
7. Rappaport, T.S. et al. Millimeter wave mobile communications for 5G cellular: It will work!. *IEEEAcc* **2013**, *1*, 335–349.
8. Bashar, A. An Efficient Cell Selection Approach in 4G Networks. *TCSST* **2020**, *2*, 4, 188–196.
9. Rajesh, M. Streamlining radio network organizing enlargement towards microcellular frameworks. *Wipecomm* **2020**, *113*, 4, 2463-2475.
10. Utami, F. K.; Hikmaturokhman, A. Planning of Femtocell 4G LTE 1800Mhz Case Study of Telkom Purwokerto ST3 New Building. In Proceedings of FORTEI, Electrical Deparment Dipenogoro University, Indonesia, 20 October 2016.
11. Saeed, M.A.; Saeed, M.U.; Hassan, M.A.S.; Javed, T. Impact of Propagation Path Loss by Varying BTS Height and Frequency for Combining Multiple Path Loss Approaches in Macro-Femto Environment. *Ajscieng* **2022**, *47*, 2, pp.1227-1238.
12. Maswood, M.M.S., et al. Improving System Performance in Indoor Environment by Designing Femtocell Considering Interference and Mobility Management. In Proceeding of CCWC, Las Vegas, USA, 27-30 January 2021.
13. Sinaga, B. Indoor Network Planning for LTE Technology in the Faculty of Applied Sciences Building Telkom University. Thesis, Bachelor Degree-Telkom University, Bandung Indonesia, 2016.
14. Al-Turjman, F. *Smart Things and Femtocells: From Hype to Reality*, 1st ed.; CRC Press: New York, 2020; pp. 181-198.
15. Hikmaturokhman, A.; Ni'amah, K.; Nugraha, E.S. Designing Indoor 4G LTE TDD 2300 Mhz Network using Radiowave Propagation Simulator. In Proceeding of the SENIT, Tegal, Indonesia, April 2016.
16. Gemiharto, I. 4G-LTE Technology and the Challenges of Media Convergence In Indonesia. *JKK* **2015**, *3*, 2, 212–220.
17. Ariyanti, S.; Perdana, D. Feasibility Analysis of 1.8 GHz LTE Technology Implementation for Cellular Operators in Indonesia. *PTM* **2015**, *13*, 1, 67-78.
18. Amanaf, M.A.; Nugraha, E.S.; Azhari, L. Optimization Analysis of Wifi Access Point Re-planning Using Pathloss Model COST 231 Multi Wall and Method of Offered Bit Quantity (OBQ) Case Study of ITTP Telematics Building. *JTECE* **2019**, *1*, 1, 32–42, 2019.

19. Imansyah, F.; Yacoub, R.R. Design and Loss Program for Indoor Network Radio Waves Based on Graphical User Interface (Gui) Matlab. *JEE* **2017**, *l*, 1, 1-11.
20. Hidayat, L.; Fauzi, H. Analysis of Optimizing Radio Frequency Access on Long Term Evolution (LTE) Networks in the Bandung Region," *ePE* **2012**, *3*, 2, 1669–1676.
21. Ulfah, M.; Tadung, N. P. Designing Indoor Network 4G LTE1800 Mhz Building Electronic Building Polyteknik State Balikpapan Using Radiowave Propagation Simulator 5.4. *JEcotipe* **2019**, *6*, 1, 40-48.
22. Milanović, J.; Šimac, G.; Mazor, K. Performance analysis of empirical propagation model for long Term Evaluation (LTE) network. In Proceeding of SST, Osijek, Croatia, 12-14 October 2016.
23. Sitindjak, H.G.; Hadikusuma, R. S.; Saragih, Y. Comparison of Software Drive Test in 3G Network Quality Test Using Telkomsel Provider Comparison of Software Drive Test in 3G Network Quality Test Using Telkomsel Provider. *JETT* **2021**, *8*, 2, 1104–1115.
24. Pratama, R.; Fahmi, A.; Arseno, D. Cognitive-Based Interference Management Analysis in Femtocells with Distributed Carrier Selection," *ePE* **2017**, *4*, 1, 239-246.
25. Hassan, R. S.; Rahman, T. A.; Abdulrahman, A. Y. LTE Coverage network planning and comparison with different propagation models," *JTelkomnika* **2014,** *12*, 1, 153–162.
26. Hikmaturokhman, A.; Berlianti, L.; Pamungkas, W. Analysis of the 231 Multi Wall Cost Propagation Model in the Design of an Indoor Femtocell HSDPA Network using a Radiowave Propagation Simulator. In Proceeding of SNATi, Yogyakarta, Indonesia, 6 Jun2 2015.