Wireless Local Area Network Planning Methodology for Indonesian Rural Area

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Abstract

Wireless telecommunication networks have been widely implemented in Indonesia. However, the planning methodology hasn't been intensively studied. In this paper, we proposed a novel methodology for wireless local area network planning in Indonesian rural area. Our proposed method consists of eleven steps of work emphasizes the ease of implementation, market survey consideration, Indonesian Government standard application, and free tools usage optimization. At the end, an example of a network design created by following the proposed methodology for Sebira Island is presented.

Keywords: Methodology, Network, Planning, Rural, Wireless

1. Introduction

The existence of telecommunication infrastructures is one of the most influential aspects that prompted the development of one region. Roller and Waverman stated in [1] that from 21 members of the Organization for Economic Co-operation and Development (OECD) countries, all countries experienced a boosted economic growth over 20 years caused by telecommunication infrastructure. Unfortunately, the deployment of telecommunication infrastructure heavily relied on the telecommunication service providers' investment. Rural areas that have few residents and lack of facilities seems not a right spot for investment. Therefore an alternative solution for bringing telecommunication in rural areas is needed.

Wireless telecommunication has been long known for its numerous advantages. It is fast in deployment, less equipment required than wired technology, and able to deliver various services [2]. Indonesia has widely implemented this technology for decades. Its flexibility in deployment is one of the reasons why wireless telecommunication can be deployed in a country that has a diverse environment, like Indonesia.

Even though wireless telecommunication has been extensively researched, study about network planning received attention much later. There are still limited publications discussing wireless telecommunication planning for the rural area, especially for Indonesia. Therefore this paper proposed a methodology for wireless network planning in Indonesia's rural area.

Sen S. and Raman B. in [3] explained about problem formulation to plan long distance wireless mesh network. They stated that network throughput is influenced by four aspects: antenna type, transmit power, link length, and tower height. It also stated that tower takes the most budget. However this paper gives only problem formulation for radio link calculation, not for the whole planning steps.

Jean Louis Ebongue, Kedieng Fendji, and Jean Michel Nlong in [4] discussed the methodology to design a wireless mesh network in the rural area. The paper proposed ten steps of design. The method started by analyzing the region profile, coverage requirement, application and services, Quality of Services (QoS) requirement, and elevation profile. Then the step is continued by selecting network technology, outdoor and indoor node position determination, node selection, routing application, network plan and components determination, then cost estimation. This methodology presented a good flow of work. However, this methodology didn't consider the availability of the component in the market. Whereas the components used in the network determined the parameter values for the link budget calculation.

From two works mention above, there are two main conclusions: 1. Market survey is essential to avoid design changing caused by device unavailability, 2. Tower is the most costly components thus the position and numbers must be considered wisely. There for we proposed a method to plan wireless network in rural area of Indonesia emphasizing the ease of implementation, market survey consideration for checking the device availability and tower's type and cost, Indonesian Government standard application, and free tools usage optimization.

2. Research Methodology

By modifying methodology mentioned by [4] and adding parameters considered by [3], we propose a novel methodology as shown in figure 1. This methodology is arranged in such a way by prioritizing the ease of implementation, market survey consideration, Indonesian Government standard application, and free tools usage optimization. Therefore, the desired quality of service can be satisfied.

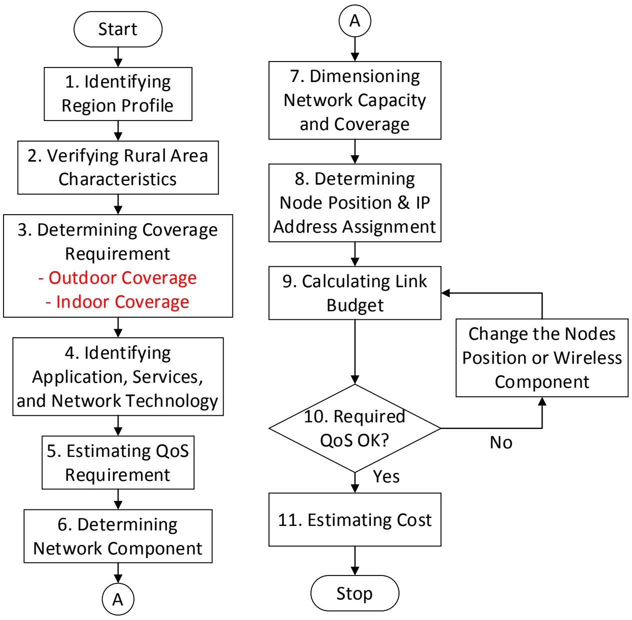

Figure 1. Planning Methodology

3. Result and Discussion

3.1 Identifying Region Profile

Identifying region profile is required in order to obtain information about the area. The information needed are as follows:

1) Total Population
2) Total Area
3) Total Residential Area
4) Population Growth Rate
5) Population Age Ratio
6) Public Facilities Availability
7) Population Type of Work
8) Elevation Profile

Information about parameter (1) to (7) can be acquired from Badan Pusat Statistik (BPS) website. While information about (8) can be obtained from Google Maps. By knowing the region profile, the network designer can start planning how the network will be.

Beside those technical data, non-technical data such as culture, religion, and regulation of specific area are also needed. People living in the same natural environment could behave differently because of the different culture.

3.2 Verifying Rural Area Characteristics

In this step, the rural area characteristics are verified. It is essential to verify the characteristics to ensure the area that will be designed is a rural area. In telecommunication, the definition for rural area isn't clearly defined. Masaharu Hata in [5] gave an empiric formula to calculate propagation loss in the rural area. But the characteristics for the rural area didn't describe in the formula. [6] in COST 207 GSM Model defined that rural area is an area where the delay is between 0-0.6 µs. However, this definition is complicated to be used as a standard. Hence a more practical definition is needed.

Based on the regulation made by Head of BPS number 37 year 2010 about urban-rural area classification [7], an area is characterized as a rural area when the total score is less than 10 in three categories: population density per Km, agricultural area percentage, and public facilities access. Table 1 and Table 2 shows the variable for urban-rural area classification. This definition is then used to verify rural area characteristics due to its convenience and data availability for every area in Indonesia from the National Statistics Center website.

Table 1 Urban Rural Classification Variable based on Population Density and Agricultural Area Percentage

Population Density	Score	Agricultural Area Percentage
<500	1	>70.00
500-1249	2	50.00-69.99
1250-2499	3	30.00-49.99
2500-3999	4	20.00-29.99
4000-5999	5	15.00-19.99
6000-7499	6	10.00-14.99
7500-8499	7	5.00-9.99
>8500	8	<5.00

Table 2 Urban Rural Classification Variable based on Public Facilities Access

Public Facilities Access	Score
Kindergarten Junior High School High School	1 (Exist or ≤ 2.5 Km) 0 (>2.5 Km)
Market Shopping Complex	1 (Exist or ≤2 Km) 0 (>2 Km)
Cinema Hospital	1 (Exist or <5 Km) 0 (>5 Km)
Hotels/Billiards, Discotheques/ Massage Parlour/Beauty Salons	1 (Exist) 0 (Non-exist)
Land Line Phone Ownership Percentage	1 (≥8.00) 0 (<8.00)
Electrical Power Connection Percentage	1 (≥90.000) 0 (<90.00)

In some cases, a rural area does not always have agricultural culture. Remote islands, recreational villages, and fisheries community exist in some region. Such areas could be considered rural for having few residents and lacks of facilities, but have no agriculture aspect. For such regions, agricultural area percentage variable can be ignored. Therefore, region profile identification is the most essential step in starting network planning.

3.3 Determining Coverage Requirement

In the rural area, it isn't necessary to cover the whole region. It because most of rural area is open spaces and not many people gathered in those spots for a long time. Total area and total residential area data acquired in the first step plays a significant role in this step. That data gives information about how big the coverage area required. Visual data presented by Google Earth/Maps also takes an important part. It shows where the residential area, public facilities, and open space are located. Public facilities such as government office, public hall, hospital, market, and bus station may need indoor coverage because there will be many people gathered there in some time. By combining the statistical data from Badan Pusat Statistik (BPS) and visual data from Google Earth/Maps, the planning process can be optimized by prioritizing which areas need outdoor only or with indoor coverage, and which areas didn't need to be covered.

3.4 Identifying Services, Application, and Network Technology

In this step, what service will be provided for the resident is identified. People living in the different environment have a different need. Residents of an agricultural village may need less various service than residents of a recreational village. Population age distribution data can also help to determine what service is required. An area where many old people resides may prefer voice communication than text. Later it can be decided what application will be used to deliver the service. Each application has different bandwidth requirement. Table 3 shows bandwidth required per user for different application. This information will be needed for calculating network capacity.

Table 3 Application's Requirement per User

Application	Requirement/User
Text Messaging	< 1 Kbps
Electronic Mail	1 – 100 Kbps
Voice over Internet Protocol	24 – 100 Kbps
Website Browsing	50 – 100 Kbps
Audio Streaming	96 – 160 Kbps
Video Streaming	64 – 200 Kbps
Peer to Peer (PtP) sharing	0 - infinite

Users' preferential devices also influenced the application's determination. People who have high mobility use their mobile phone more than fixed line phone. So suitable applications for such area are the ones that can work in mobile phone, such as text messaging, e-mail, and streaming application. After knowing the application's requirement, the network designer can determine what network technology can accommodate such a demand.

Deploying a mesh network consists of 802.11 working based devices is a promising option for rural area implementation. 802.11 technology is also known as Wireless Fidelity (Wi-Fi). Based on definition given by [8], a mesh network comprises of a group of nodes connected wirelessly and able to self-configure when communication link disrupted. A mesh network doesn't need central switching node because the nodes do all the routing activities. Therefore, when a communication link down, the node can find another route to deliver the information. This flexibility in routing can't be seen in the conventional cellular network. 802.11 devices provide connectivity with lower prices when compared to the conventional cellular network. Table 4 shows specification for 802.11 families. The network designer later can decide which 802.11 protocol that is suitable for the area.

Table 4 802.11 Protocol Specification [9]

802.11 Protocol	Freq (GHz)	Data Rate per Stream (Mbit/s)	Indoor Range (m)	Outdoor Range (m)
a	5	Up to 54	35	120
b	2.4	Up to 11	35	140
g	2.4	Up to 54	38	140
	5	Up to 200		
ac	5	Up to 866.7	46	92

3.5 Estimating Quality of Service (QoS) Requirement

Quality of Service (QoS) is a set of parameters that determines the level of network's performance. Every organization can have different QoS for their network. The most important things that need to be considered in determining QoS parameters is make sure the required parameters have important impact on the network performance. In Indonesia, the government provides a standard parameter for some telecommunication application. Table 5 shows parameters standard for VoIP and wireless internet parameter. This standard can be used as a reference for planning the network. Other parameters that can be used as QoS requirements are coverage area, received signal level, received signal quality, and capacity.

Table 5 Application Parameter Standard

Application	Parameter	Allowed Value
VoIP [10]	Delay	≤ 300 ms
	Jitter	≤ 10 ms
	Packet Loss	≤ 2%
	MOS	≥ 3
Internet [11]	Throughput	≥ 1024 Kbps
	Latency	≤ 750 ms
	Packet Loss	≤ 2%

3.6 Determining Network Component

Before deciding what components to be used, the network designer should do a research/survey to know what devices available in the market. It's trifling to design a network without considering the device's availability in the market.

There are four main components that build wireless network. Those components are:

A. Wireless Nodes

Wireless nodes here are wireless router or wireless access point. For rural area a mesh network is a better option than a conventional hotspot network. Because in mesh network, each node acts as coverage's area extension. This is very suitable for rural area where coverage is more important than capacity.

When choosing the devices, there are some factors that need to be considered such as:

a) **Interoperability**: the device capability to work with devices made by different manufacturers
b) **Specification**: device's ability to accommodate the required service and application
c) **Coverage Range**: transmit power information provided by the manufacturer will be used to calculate the link budget
d) **Sensitivity**: the lower the sensitivity, the better the quality
e) **Throughput**: determine how fast the device can transfer the data
f) **Availability**: the convenience to find the spare part replacement or similar devices when the device is damaged or broken
g) **Power consumption**: the lower power consumption, the lower the overall budget
h) **Environment**: the equipment that will be put in the outdoor area should have water resistance
i) **Other Factors**: required accessories, external antenna supportability, Power over Ethernet (POE) support, provide encryption, etc.

B. Antenna

Without the existence of antenna, the communication can't happen. Important factors when choosing antenna are gain and directivity. The bigger the antenna gain, the stronger the emitted energy. Antenna directivity decides the direction of the signal beam. If the antenna is put in the middle of the intended coverage area, then omnidirectional antenna should be use.

C. Tower

In rural area, tower existence is essential for putting the wireless device. Tower's height and type must be decided carefully since the installation cost is very high. When installing the tower, grounding equipment must also be installed. This equipment can protect the mounted device from damage because of lightning attack.

D. Server

Every service provided by network needs a server for storing the configuration. For example, VoIP application needs Session Initiation Protocol (SIP) server software such as Asterisk or Kamailio. For website browsing proxy server is needed to manage network's security.

3.7 Dimensioning Network Capacity

When designing a network, the network designer should remember that the network isn't made to work only for a short time. The network should able to accommodate the user's necessity for a certain period. Therefore, the population growth rate and settlement distribution should be considered to calculate network capacity.

To calculate network capacity, multiply the expected number of users with the application's required throughput. For example, if there are 100 users of G.711 codec VoIP, based on [12], the network capacity should be 100 x 64 kbps. The network should provide this capacity to be able to accommodate the expected number of users.

If the network is expected to work for some years, it's important to forecast the total population in the expected years. Based on [13], this equation is used to calculate the number of population in the following several years.

$$P_t = P_0 \, (1 + r)^t \quad (1)$$

Where:
Pt = total population in the expected year
P_0 = total population in the basic year
r = population growth rate
t = difference between expected year and basic year

3.8 Determining Node Position and IP Address Assignment

For helping the network designer to decide where to put node, [14] can be used. This tool is web-based, free, and provides terrain information. It can simulate how big one node's coverage area by inputting its technical specification, such as transmit power, sensitivity, and antenna gain. It also shows signal strength information. Figure 2 shows an example of five nodes coverage area. After knowing which area needs to be covered, the network designer can quickly determine where the best place to put the node. So, it can be decided how many access points required to cover the whole area.

After that, the network designer can start the IP address assignment for each device. It's important to plan the IP allocation because there are many problems can occur because of mistake in addressing, such as congestion, high packet loss, and address conflict. Proper IP address planning can also help the designer to easily find unused IPs and allocate them for new devices when there's network expansion.

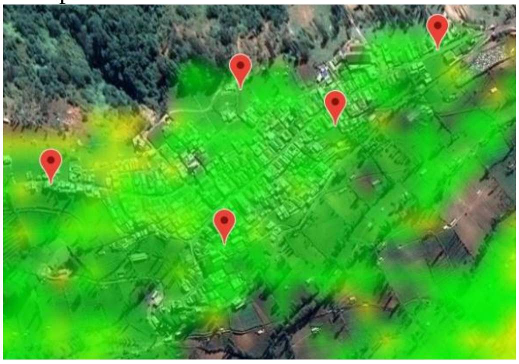

Figure 2. Five Nodes Coverage Area Simulation Result

3.9 Calculating Link Budget

For making two nodes communicate, the received signal must be above the specified threshold unless the connection won't happen. Therefore, it is essential to calculate the link budget when designing a wireless network. Essential parameters in link budget are:

Transmit Power (Tx Power): this parameter shows how strong the signal is emitted by the device and is expressed in milliwatts or dBm. A device from different manufacturers can have different maximum Tx power. This information must be provided in the device's technical document. Based on standard determined by Ministry of Communication and Informatics, maximum transmit power for telecommunication device working on frequency 2.4 and 5.8 GHz is 100 milliwatts [15].

Antenna Gain: it is expressed in dB. The higher the antenna gain, the stronger the signal will be. This parameter must also be included in the device's technical document.

Minimum Received Signal Level (RSL): this parameter shows the minimum allowable signal received by the device. If the received signal is below RSL, then the connection won't happen. It is expressed in negative dBm (-dBm).

Cable Losses: usually between the device and the antenna is connected by the cable. And when propagating the cable, there's some energy loss. This parameter is expressed in dB.

Free Space Loss (FSL): this parameter shows the loss value when the transmitted signal propagates at a certain distance. This equation is used to calculate FSL [9]:

$$L_{fsl} = 30.24+20*\log_{10}(D)+20*\log_{10}(f) \quad (2)$$

Where:
D = distance, in Km
f = frequency, in MHz

To calculate the link budget, adds Tx power and antenna gain then subtracts by all losses. The result from the calculation must be higher than RSL value unless the communication will not connected.

Environment condition also influenced the loss calculation. Many mathematical models have been made to give a more accurate prediction, such as the Longley Rice model, Durkin's model, Okumura-Hata model, Walfisch and Bertoni model [16].

Radio Mobile provides the link calculation by entering antenna height, frequency, transmit power, line loss, and sensitivity. It also uses elevation data provided by Google for calculation. Then by using Longley Rice model [17], it provides the calculation result alongside the link's picture.

When the calculation has completed, the QoS can be verified. If the link calculation shows a bad result, then adjustment can be done by changing the node's position or wireless components. Changing the nodes position means the link calculation also changes. Therefore, the link calculation must be repeated. If the wireless components are changed, then the parameter such as Tx power, antenna gain, etc also change. So, the link calculation also be repeated. The adjustment process is repeated until the satisfactory results are obtained.

3.10 Verifying Network Performance

Verifying network performance is important to ensure the required QoS is achieved. If not, then optimization is required to improve it. Change nodes' position or the wireless components are two options that can be done to improve QoS value.

For example, to verify whether the received signal from link budget calculation has met the minimum required received signal. If the received signal is higher than receiver equipment's sensitivity, then the required QoS for received signal level is achieved.

3.11 Estimating Cost

The costs that need to be taken into account are the costs of purchasing, installation, operation, and maintenance. The purchasing cost consists of the cost of every components. Tower purchasing takes the most budget. Based on our survey from tower provider, the tower cost from Rp.850.000 to more than Rp.300.000.000. Table 5 shows the price range for different tower type.

Table 6 Tower Price

Type	Price
Triangle Painting 20cm x 20cm x 20cm (per 5m)	Rp.850.000 - Rp.1.000.000
Triangle Galvanize 20cm x 20cm x 20cm (per 5m)	Rp.1.250.000 - Rp.1.350.000
Triangle Painting 30cm x 30cm x 30cm (per 5m)	Rp.1.400.000 - Rp.1.550.000
Triangle Galvanize 30cm x 30cm x 30cm (per 5m)	Rp.1.750.000 - Rp.1.850.000
Square Galvanize 30cm x 30cm x 30cm (per 5m)	Rp.2.200.000 - Rp.2.750.000
Monopole 6m	Rp.1.400.000 - Rp.2.150.000
Monopole 12m	Rp.5.400.000 - Rp.8.750.000
Monopole 20m	Rp.7.000.000 - Rp.13.500.000
Monopole 30m	Rp.28.250.000 - Rp.31.000.000
Self-Supporting Tower 42m	Rp.140.000.000 - Rp.175.000.000
Self-Supporting Tower 52m	> Rp.200.000.000
Self-Supporting Tower 62m	> Rp.240.000.000
Self-Supporting Tower 72m	> Rp.300.000.000

Purchasing the wireless device that consumes lower power, resulted in lower overall budget. If the nodes are installed in area where the electrical power availability stable, then it's unnecessary to purchase solar panel. Therefore, the network designer should choose the network component wisely.

3.12 Network Design Example

By using the proposed methodology, a network is designed for Sebira Island. It is a small island located in Kepulauan Seribu DKI Jakarta. Table 6 shows the designed network for this rural area.

Table 7. Network Design for Sebira Island

Region Profile	Based on BPS data [18]
- Total Population	523 people
- Total Area	0.0882 km^2
- Residential Area	0.059 km^2
- Agricultural Area	0 km^2
- Population Growth Rate	1.43%
- Productive Age Population Percentage	69.76%
- Public Facilities	Public School, Harbour
- Elevation Profile	3-9 meters above sea level
Target User for 5 Years	392 User
Coverage Area	0.0059 km^2
Service	Voice Call, based on [19]
Application	Voice over Internet Protocol (VoIP) - SIP Server Software: Kamailio - Audio Codec : GSM
Network Technology	Wireless Mesh Ad-hoc with 802.11n Protocol - Frequency : 2.4 GHz - Transmit power: 20 dBm (100 mW) - Channel Number: 1 - Channel Width: 20 MHz - Routing Protocol: B.A.T.M.A.N Advanced
QoS	- Coverage Area - Received Signal Level - Eb/No - Capacity
Network Components - **Server : Raspberry Pi** Type : Raspberry Pi 3 Model B Processor : Quad-Core 1.2GHz Broadcom BCM2837 64bit CPU RAM : 1 GB Power Supply : 2.5 A/3.7 W Hard disk : Micro SD 16 GB Operating System : Ubuntu Mate 16.04 - **Wireless Node : Ubiquiti Pico Station M2** Power Supply: 15V/0,8A Tx Power: 20 dBm Power Consumption: 8 Watts Antenna Gain: 5 dBi Sensitivity: -96 dBm - **Tower: Triangle** Height: 5m	
Required Capacity	13.64 Mbps

Table 8. A Network Design for Sebira Island

Node	Longitude	Latitude	Ground Elevation	Tower Height	Device
1	106.4612	-5.2045	6.4 m	2 m	Ubiquiti Pico Station M2
2	106.4602	-5.2050	9.1 m		
3	106.4609	-5.2054	6.2 m		
Server	106.4605	-5.2055	4.2 m	-	Raspberry Pi

The position for the nodes can be seen in Figure 5.

Figure 5. Nodes Position for Sebira Island

4. Conclusions

In this paper, a planning methodology to design a wireless local area network in Indonesia rural area is presented. The proposed method is designed with emphasizes the ease of implementation, market survey consideration, Indonesian Government standard application, and free tools usage optimization. The method consists of eleven steps, starting from identifying the region profile, verifying rural area characteristics, determining required coverage, identifying services application and network technology, estimating quality of service, determining network component, dimensioning network capacity, determining node position and IP address assignment, calculating link budget, verifying network performance, and conclude it with cost estimation. By following the proposed method, a wireless network is designed to cover Sebira Island.

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