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# Public Protection and Disaster Relief Planning Using Terrestrial Trunked Radio in West Java

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*Abstract*—This research aims to implement Public Protection and Disaster Relief (PPDR) planning using Terrestrial Trunked Radio (TETRA) in the West Java area. This plan will work at frequencies 806-821 MHz and 851-866 MHz (bandwidth of 15 MHz). PPDR planning study using TETRA in West Java with a total area of 37,315 Km2. This TETRA planning study uses the simulation method. Simulation using ATOLL software using parameters used by the West Java Regional Police (Polda) because it follows the conditions of the province of West Java. This plan does three things, firstly plans the coverage area to determine the number of base stations by looking for the link power budget and MAPL, followed by finding the cell radius value, secondly planning the network capacity to be used by following the assumptions and predictions of the TETRA mobile station (ms), and the third is planning the frequency spectrum. The three methods are tested and validated using Atoll software simulation. The planning results for the West Java region required 58 sites (base station). The required channels are 94 channels, while from 15 MHz, TETRA digital radio trunking bandwidth provides 600 channels so that TETRA digital trunking radio can be implemented in West Java. In the future, this TETRA radio trunking plan can be implemented in other provinces in Indonesia and even be expanded to all regions in Indonesia to handle disasters.

Keywords— PPDR; GRN; frequency; TETRA.

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## I. INTRODUCTION

Indonesia is prone to disasters, such as earthquakes, tsunamis, erosion, and volcanic eruptions. Because vast oceans surround Indonesia, it has many active mountains and expansive hills so that the contours are not flat and hilly and are at an intersection of active plates in the world. To the south, there is the Indo-Australia plate; to the north, there is the Euro Plate, and the Asia and Pacific Plate is in the east. West Java is one of the provinces in Indonesia. Based on the official website of the West Java provincial government, geographically, West Java is at 5050'-7050 'South Latitude and 104048'-108048' East Longitude, with a land area of 3,710,061.32 hectares. West Java Province has 26 districts/municipalities, of which 17 are regencies. The remaining 9 are cities with 625 sub-districts and 5,877 villages/wards. The central part of West Java is a mountainous area. In contrast, the north coast area is a lowland area and has an active fault, namely the Lembang fault, so from the position and location of West Java province, it is a disasterprone area [1].

West Java Province for handling natural disasters is the Regional Disaster Management Group of West Java Province (BPBD West Java Province). Apart from BPBD, some agencies help with disasters in West Java, such as the West Java Regional Police, SAR, TNI, etc. BPBD, as the leading sector in disaster management, must coordinate with parties who help handle disasters so that they can be held more quickly in the event of a disaster.

Looking at the current conditions in West Java province and several groups that handle disasters/PPDR, each of which uses different frequencies and technologies in communicating, it is undoubtedly challenging to communicate coordinate and among disaster agencies/institutions. Here is an opportunity to conduct further research on PPDR Planning Using TETRA Radio in the West Java Region. This research aims to study the PPDR implementation plan using TETRA, which can reach all regencies and municipalities in West Java province to implement and use TETRA in West Java.

Previous research focused on existing rules and the application of PPDR using a frequency of 409 to 417 MHz,

then 422.5 to 426.6 MHz. Here the researcher uses PPDR to communicate and does not research implementing these frequencies [2], [3]. In addition to the above study, there is research related to the frequency requirements used for PPDR in the 400 MHz bands and the 800 MHz band, which is  $2 \times 10$  MHz for ordinary events and 2x20 MHz is used in emergency cases [4]–[6].

Then, research related to TETRA technology on various specific needs of service, such as being used at the Soekarno Hatta Airport location using the operating frequency 410-420 MHZ and the frequency 420-430 MHz [7]. The VANET network can use TETRA technology, so this TETRA technology supports high-speed and reliable data in mobile communications, making it suitable for use in emergency conditions and natural disasters, where this condition has limitations in communicating [8]. Then the sensor-based network [8][9] and the United Kingdom (UK) Police [10] also use TETRA technology [11], [12].

Apart from being used by police services, the government can also use it, are in research that analyzes the use of GRN for PPDR services in the city of Bandung using GRN with TETRA technology. This research explains the advantages of TETRA technology and carries out the implementation in the city of Bandung [13], [14]. So based on previous studies, researchers surveyed the implementation of TETRA technology in emergency services (PPDR) for an area more expansive than the city of Bandung, which is the area of West Java Province, a continuation of previous research [15].

### II. MATERIALS AND METHOD

In the current research, the study of PPDR implementation with the application of TETRA technology in the West Java Region uses the following method.



Fig. 1 TETRA Network Planning Flowchart

# A. Planning and Analysis

In this planning, the Province of West Java in disaster management (PPDR) involves the following groups/institutions:

- BNPBD (National Group for Regional Disaster Management) West Java,
- BASARNAS Region West Java,
- West Java Regional Police (POLDA),
- West Java Fire Service,
- "Satpol PP" ("Pamong Praja") West Java,
- Regional Work Units (SKPD) involved in disaster management,
- PMI, health medical personnel.

Then to use the PPDR communication system is divided into seven agencies/institutions (groups), so this requires an integrated communication system in PPDR communication, so the solution offered is the use of the TETRA system. Figure 1 below is a flow chart of stages in the TETRA network planning study.

The TETRA network planning review process is different from planning for a cellular network or other commercial networks because TETRA serves customers who require specific coverage areas and low investment costs. The TETRA network planning process is as follows:

1) Coverage Area Planning: The power link budget is a parameter that is calculated when planning the radio coverage distance. After obtaining the power link budget, calculate the Maximum Allowable Path Loss (MAPL) parameter value. MAPL is the most significant amount of loss allowed within a specific range. In the coverage, distance planning calculates the power link budget parameter. Then we can calculate the MAPL parameter, which is the maximum allowable loss over a range.

2) Network capacity planning: Network capacity planning ensures and minimizes blocking during peak hours. TETRA trunk radio used in this study is at agencies/institutions serving disasters in the West Java region, spread throughout the West Java region.

*3) Frequency Planning:* Indonesia has two trunk radio working frequency blocks: the 400 MHz frequency block and the 800 MHz frequency block.

#### B. Simulation

After the three plans are complete, the next step is testing the Atoll simulation. Simulations related to distance, network capacity, and frequency then validate the sound quality by looking at the signal level parameters, overlapping zones, and BTS number. The assumptions used in the simulation use the West Java Regional Police (Polda) data. This data has been implemented in the West Java area.

## C. Conclusion

Provide conclusions on the Terrestrial Trunked Radio (TETRA) design results in West Java. Then in this research, apply the restrictions as follows:

- The operational area coverage needs in the analysis are all areas of West Java province.
- The attenuation prediction model used is the Okumura-Hatta Model.

# III. RESULT AND DISCUSSION

The timing is fast when there is a call set up efficiency in using the frequency of security features, all of which are the advantages of the features that have and offer TETRA. Besides these features, TETRA also provides packages and circuit data as one of the services offered [16]:

## A. Radio Coverage Planning Results

The following are the specifications of the devices used for the installation of the TETRA network in the West Java area:

1) Determine the Base Station Class: In determining the Base Station Class in planning, use existing equipment and installations used by the West Java Regional Police (Polda).

2) Antenna type: In this research, the type of antenna used by the Regional Police (Polda) antenna, the Katherine 738 192 antenna, works at 806-894 MHz.

3) Cable use: The cable used by the police to connect the base station to the antenna is a type of 7/8 inch coaxial cable with a loss of 4 dB per 100 meters at a frequency of 800 MHz, with a tower height of 80 meters, so a line of about 100 meters is needed, so that cable loss is 4 dB.

4) Power Link Budget: The objective of calculating the power link budget is to find MAPL. Other parameters are based on regular use of radio trunking systems. EIRP and MAPL calculations by looking at the following table:

TABLE I		
POWER LINK BUDGET	[17]	

	BS & MS Receiver	MS tx dan MS Rx	Unit	Formula
Power Tx	46	45	dBm	Z
Transmitter cable and receiver loss filter	5	0	dB	Y
Receiver Antenna Gain	11	1	dBi	Х
Peak EIRP	52	46	dBi	W=Z- Y+X
MAPL	-157	-136	dB	V
Receiver Antenna Signal Level	-105	-90	dBm	U=W-V
Receiver Antenna Gain	1	11	dB	Т
Receiver Cable Loss	0	-5	dBi	S

Then from table 1 above, the calculations are detailed as follows:

PTx = 46 dB

Gantenna = 11 dB

Lcable = 4 dB

There is a connector in the EIRP calculation, and the connector attenuation is calculated as 1 dB. EIRP = PTX - Lcable - Lconnector - Gantenna = 46 dBm - 4 dB - 1 dB + 11 dB EIRP = 52 dBm MAPL = EIRP - PR<sub>sensitivity</sub>

= 52 dBm-(-105 dBm)

MAPL = 157 dB

Then proceed with finding the cell diameter using the Okumura Hatta propagation model used in urban areas [18], [19]:

$$L_u = 69.55 + 26.16 \log(f) - 13.82 \log(hb) - a(hm) + [44.9 - 6.55 \log(d)]$$
(1)

Where:

Lu is the attenuation of urban areas

hb is the height of a Base Station antenna

hm is the size of a mobile station antenna

f is the frequency

d is the distance between the base station and the mobile station (km).

a (hm) is the Correction Factor for the antenna height

The following is used in large cities with a frequency  $\geq$  150 MHz [18]:

$$a(hm) = 3.2[\log(11.75 hm)]2 - 4.97$$
 (2)

If the loss value for an urban area is the maximum value, then the attenuation is referred to as MAPL, then the d obtained is the maximum d or the radius (R) of the range. Then determined the height of the antenna BS (hb) = 80 m and the height of the Mobile Station antenna (hm) based on general standards (referring to human size) = 2 m, and using frequency = 800 MHz, then equation (2) is:

$$a(hm) = 3.2[\log(11.75 hm)]2 - 4.97$$
$$a(hm) = 3.2[\log(11.75 (2))]2 - 4.97$$

 $a (hm) = 23.5 = 1.045446665 \, dB \approx 1.045 \, dB$ 

Then put into equation (1), obtained:

 $57 = 69.55 + 26.16 \log(800) - 13.82 \log(80) - a(hm) + [44.9 - 6.55 \log(80)] \log(d)$ 

 $157 = 69.55 + 26.16 \log(800) - 13.82 \log(80) - 1.045 + [44.9 - 6.55 \log(80)] \log(d)$ 

$$157 = 69.55 + 26.16(2.91) - 13.82(1.91) - 23.5 + [44.9 - 6.55(1.78)]\log(d)$$

$$157 = 118.1498 + 32.435 \log(d)$$

$$157 - 118.149 = 32.435 \log(d)$$

$$38.8502 = 32.435 \log(d)$$

$$Log (d) = (\frac{38.8502}{32.4347})$$

$$Log (d) = 1.197829598$$

$$d = log_{-1}(1.197829598)$$

$$d = 15.76992392 Km \approx 15.77 Km$$

From the above calculation results, the maximum radius value of an urban area that can cover the base station is 15.77 Km. Calculation of the Number of Base Stations. Calculation of the coverage distance using an omnidirectional antenna used by the West Java Regional Police (Polda) to determine the number of base stations (BS) needed is as follows:

$$L = 2.6 (d)^2$$
  
 $L = 2.6 (15.77)^2$   
 $L = 646.5953007 \text{ Km}^2$ 

From the calculation of L above, to serve the West Java region with 37,315 square kilometers. Number of BTS needed in West Java area = (West Java area): (BS coverage area) = (37.315 Km square): (646.5953007. Km square) = 57.7099771 site = 58 sites.

This site means that the West Java region needs 58 Base Stations (BS) to serve everything. The placement of BS cannot be arbitrary because there are regulations on West Java and local rules for each city/district in West Java that regulate it. Still, the placement of the BS must also be optimal. In planning the coverage area above using an omnidirectional antenna (11 dB) and several parameters that have been determined in the trunk radio plan, such as antenna height, frequency, and area in the figure below, as follows:



Fig. 2 Total TETRA Radio Trunking Sites

Then, after mapping 58 sites for the West Java region, analyze the signal strength throughout the West Java region as follows:



Fig. 3 Coverage by Signal Level TETRA

Then the histogram results from the coverage planning results are based on the signal level as follows:



Fig. 4 Histogram Coverage with TETRA Signal Level

The histogram coverage with the signal level of the TETRA image above shows that the lowest signal level is -70 dBm to -105 dBm.

## B. Network capacity planning results

The following is a scenario in this research. PPDR is an institution that handles disasters divided into seven groups. For the PPDR group in Surabaya, East Java, for example (because Surabaya is a big city in Indonesia), each institution has at least 200 users (people) as a team. Hence, the number of users = seven teams x 200 users = 1400 users, assuming each user uses 50 mE traffic. The traffic in one base station cell =  $1400 \times 50 \text{ mE} = 70 \text{ Erlang}$  (This is a minimal requirement in using radio trunking technology communication in the form of grouping, where channels in one group can be used together).

The priority user grouping is the emergency call group consisting of the chairman and members of the emergency group using the Erlang B traffic modeling. The priority is classified into the second priority using Erlang C traffic modeling.

In the TETRA technology system, users can share existing channels in the same group (grouping), limiting the number of users in the group. With 700 users, the traffic intensity (A) is 1400 x 50 mE = 70 E. If you want a B (Blocking Probability) to be a maximum of 1%, then at least you need a channel (N) following Erlang B; below, the parameter connection is as follows [18]:

ł

$$B(N,A) = \tag{3}$$

The above mathematical calculations are in traffic intensity A and Grade of Service (GoS) tabulation. In the GoS table, traffic is 70 Erlang, and Blocking Probability is 1%, so 94 channels are needed. Then the call for the second priority using Erlang C modeling, with 94 channels, if the probability level is delayed for 1 second, the traffic will experience failure approaching 0%.

### C. Frequency Planning Results

The working frequency of radio trunking in Indonesia is provided with two frequency blocks, at 400 MHz and 800 MHz.

 TABLE II

 TRUNKED RADIO FREQUENCY IN INDONESIA [20][21][22]

Туре	Transmitter	Receiver	Channel Spacing
Trunking	380 - 389 MHz	390 - 399 MHz	12.5 KHz
400 MHz	407 - 409 MHz	417 - 419 MHz	12.5 KHz
	419 - 422.5 MHz	426.5 - 429.75 MHz	12.5 KHz
	412.5 - 414 MHz	422.5 - 424 MHz	12.5 KHz
Trunking 800 MHz	806 - 821 MHz	851 - 866 MHz	25 KHz

Following the picture above, the West Java regional police (Polda) frequency is 806 to 821 MHz and 851 to 866 MHz. Several types of interference occur in TETRA network planning: adjacent and co-channel. Adjacent interference arises because of adjacent frequencies, and Co-channel interference is interference due to the same frequency. Therefore, the frequency placement must be appropriately regulated so that interference does not occur [20].

With the standard TETRA technology, the carrier frequency distance of 25 kHz consists of 4 channels, with three channels used for voice/data and one channel for signaling control, it requires a carrier on the uplink or downlink) is (94 channel / 3 carrier) = 32 carrier (25 kHz), so it takes uplink or downlink spectrum = (32 carrier x 25) KHz = 800 KHz, so it takes spectrum for 2 directions, for uplink and downlink directions = 2 x 800 kHz = 1600 KHz. Meanwhile, the frequency is obtained by calculating the available channels: 15 MHz: 25 KHz = 600 channels. Then it can be compared that the need for canals is 94 channels while the available channels are 600 channels, far from sufficient for the essential requirement

# IV. CONCLUSION

The results of PPDR planning and analysis using digital radio trunking can be implemented and reach all districts and municipalities in West Java Province with a need for 58 sites (Base Station). The TETRA used uses frequencies 806 to 821 MHz and 851 to 866 MHz with a bandwidth of 15 MHz or 600 channels, while the need for the number of channels is 94 channels which can serve as many as 1400 mobile station (MS) users with a traffic size of 70 Erlang. Then the TETRA signal quality is at a reasonable level, is -70 dBm to -105 dBm, so this is feasible to be implemented in the West Java region.

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