FORECASTING DATA TRAFFIC DEMAND FOR RURAL AREAS USING MULTI-DIMENSIONAL PARAMETERS

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ABSTRACT

Deploying network in rural is not attractive for commercial based broadband network providers. However, it is important to provide internet access for villagers since internet may give positive impacts on social development. A failure to forecast traffic demand might lead to a sloppy network design which is inefficient and costly. The mobile traffic demand forecast method needs wider perspectives other than technical records of network providers only. This research introduces a multidimensional model to predict data traffic demand in the future, by combining government spatial planning, demography statistics, and network records. Two different areas were studied and analyzed: Panimbang and Leuwidamar districs, in Banten Province, Indonesia. The main parameter to compare single- and multi-dimensions model is the areal traffic demand. For Panimbang, the areal traffic demand for multi-dimensions model has 24 Mbps/km^2 higher, compared to the single-dimension model. For Leuwidamar, the demand for multi-dimension is 10 Mbps/km^2 lower, compared to the single-dimension. In case of Panimbang, a pessimistic forecasting might not be a big problem since adding cells in a dense area is not costly, however for the case of Leuwidamar, multi-dimensions models could help to design a more efficient network since the single-dimension model is too optimistic and leads to a high capital investment for providers. This multidimensional model suits best for remote and sparsely distributed users (Leuwidamar). However, it might give no high impact for residential or urban areas (Panimbang).

Keywords: Traffic modeling, Mobile Broadband, Data Traffic, Rural, Remote

INTRODUCTION

Traffic forecasting is the initial step to plan an efficient cellular network. Forecasting the trend helps worldwide telecom companies to form corporate strategies globally. Reports such as [1] and [2] are successfully taking pictures of global, continental and national growth of mobile subscribers. One of the methods is by using historical data, such as regular traffic measurement of hundreds of live networks in major regions. Since the network subscribers are mostly live in urban areas, the global data is more suitable for big cities. What about other types of areas, such as rural and remote areas?

A published global forecast might not be useful for local situation, especially for marginal areas such as rural or remote areas. The argument is that there are so many differences between rural and urban areas in terms of population density, demography, social economy, geography, politics and others. Therefore, to understand data consumption behaviour in rural areas, the study of other potential parameters should be included to predict the traffic in the future.

A failure in forecasting a suitable traffic in rural area may leads to a sloppy infrastructure development planning and would cause financial loss for the network providers. In most cases, after the network being deployed, the generated income might be way smaller than the investment cost. The network providers may relocate the installed network if that certain area does not generate profitable income for them. That relocation needs additional cost. Consequently, we need new approach to measure network planning in rural areas that differs in urban ones. In addition, we need to find an efficient solution to deploy a rural network to minimize the capital cost. There are studies to measure the techno-economic impacts of new technologies, with aim to maximize the technical aspects and minimize the capital and operational expenditure, e.g. for LTE Deployment [3][4] and porspective 5G [5].

However, deploying a telecommunication network is not only about generating profit. A socio-economic analysis shows that such service would improve people welfare [6]. In rural area, villagers can access information to educate themselves, enable remote health-services, and enable small business (e.g. rural banking, smart-farming). As telecommunication network could help many kinds of sectors, it is important to consider the multidimensional aspect that this paper aim to contribute to. The first and main aim of providing rural connectivity is to improve people welfare, so all effort should be centralized to society. The Ministry of ICT of Republic of Indonesia has a nation-wide project, to provide fiber optic connection that aims to serve as a backbone [7]. Yet, to reach the "last-mile", we need to address the needs of it carefully

Techno-economics and socio-economics analysis of broadband development has been studied. However, there is lack of study that combine them all: technical, economical, and social aspects. This research aims to answer: 1) What parameters that important to be considered when modeling a traffic demand?; and 2) What are the impacts of using multidimensional-based data traffic modeling compared to a single dimensional (e.g. commercial values) model?. The traffic model is simulated by using case studies in Indonesia rural districts: Leuwidamar and Panimbang Area, in Banten Province, Java Island.

This paper is structured as follows: In Section II, we discuss related works and literature research to address current knowledge of related topics. In Section III, we provide research method that includes the parameters and assumptions. In Section IV, we provide the simulation based on cases study. Lastly in Section V, we summarize and conclude the research results.

LITERATURE REVIEW

Generally, researchers and engineers use existing traffic records to model the traffic which leads to a detailed measurement-driven model [9][11]. Such measurement-driven model successfully captured a traffic characteristic (mostly dense urban) to forecast global future traffic demands. In [10], they characterize future traffic by: number of sessions, inter-arrival time, volume of traffic, and session duration. With around 1 billion sessions, it is highly possible to model traffic with the advantage of a big amount of data, which mostly were generated from urban areas. However, the number of subscribers in rural areas is very limited, and the gathered data might not be enough to capture the generic trends.

If we look closely to social impacts of telecom technology, studies show that there are behavior relations between traffic generated to several factors, e.g. age, gender, human behavior of using spaces, etc [11][12]. Since a big amount of data could depict human behavior, it can be used in other sectors to make their strategic planning in the future. For example, in [12], the traffic records were used for future strategic planning in tourism. Specifically, research in [11] could help the municipality to address people movement in urban districts. In other words, if the recorded data could be interpreted to several factors, we could say that there is causality between mobile traffic to those factors. Thus, it is important to deploy network considering those factors, to have an efficient network with high impact to society.

However, most of traffic modeling studies uses urban areas cases. Yet, the behavior and characteristics between urban and rural areas are different in many factors. Thus, the published, generic, and common traffic model (such as in [1]) could not be adapted for rural. There are several efforts to modeling traffic demand specifically for rural. For example, Energy Aware Radio and Network Technologies (EARTH) research teams introduce a traffic model for Europe, corresponds to a specific area: dense urban, urban, suburban, rural, and wilderness areas [13]. Rural characteristic with the case of Europe areas was defined as follow: 100 citizen/km^2 on average for rural, 25 citizens/km^2 on average for sparsely populated and wilderness; rural has less heavy users i.e. few users who need a data-heavy app such as streaming; Steady daily traffic variation, i.e. peak hours has no significant difference compared to normal hours.

EARTH uses population density as a parameter to classify areas of study and to define traffic profile based on UMTS forum's mobile traffic forecast to see a variation of users. EARTH model shows that traffic modeling should be different regarding population density, devices capability (normal user, heavy user), and daily traffic profile. The more data that is considered to, the more suitable the model to realistic cases.

For this paper, firstly we address the impacts of providing data service in rural, to find an opportunity for additional parameters that need to be considered for the traffic model. Then, we study realistic cases current condition as a pilot project.

A. Addressing Rural Condition in Indonesia

Three main social aspects that related to ICT which are Social Welfare, Social Bonding, and Social Culture [14]. In terms of social welfare, the local governments in Indonesia have designed a Long-Term Development Plan of the Region (*Rencana Pembangunan Jangka Panjang Daerah*/RPJPD). RPJPD is a government's strategic planning for about 20 years span, with the main aim is to address natural and human resources to develop the area, from spatial usage to economic growth.

Traffic modeling is used to map a telecommunication infrastructure network in the future, so it also depends on the mapping of people, or spatial planning. RPJPD has been the main reference for further strategic actions, one of them is Regional Spatial Plans (*Rencana Tata Ruang Wilayah*/RTRW). Based on this RTRW, we could know whether the area is meant to develop as industrial areas, habitation, plantation, etc. Such spatial utilization will highly affect the traffic forecasting model.

B. Technology Indicators in Rural

There is wide social and technological gap between urban and rural. Among 34 provinces in Indonesia, Banten is located nearby to Jakarta the capital city. However, the gap between two provinces remains exist. We study two samples of South Banten area: Panimbang in Pandeglang Regency, and Leuwidamar in Lebak Regency. The main reason is that both regencies have quite a large area (28% and 35% of total area), and lowest population density compared to other regencies (435 and 371 people/km^2 respectively). The Ministry of CIT (the MCIT)'s survey research shows that only 32% of the rural population using an internet. However, based on a provider's record in the studied area, the mobile data users might be way smaller than that.

METHODS

The main workflow and process of this research are discussed in Subsection III-A, and the parameters used for simulation is in Subsection III-B.

A. Framework and Work Diagram

For the main framework, we adopt the EARTH model to classify rural traffic demand and add several parameters as considerations to mimic the real situation in Indonesia. The traffic forecasting accounts four main processes: Population density and its growth, Device Capability, User Type, Average Subscription. The flow process diagram can be seen in Fig.1.

A.1 Population density and growth of users:

We investigate population density records for past years to estimate the expected number of population in the future. The increase in population growth might differ from the increase in the number of users, for user penetration might sharply increase because of cheaper devices or other reasons. As the situation between Leuwidamar and Panimbang is different, statistical data from the regional Central Bureau of Statistics (*Badan Pusat Statistik*/BPS) shows a different population increase. Statistics and local current conditions are gathered from the yearly report of regional BPS, both province, and district. The YoY Population growth in Pandeglang District (Which Panimbang located) is 0.55%, and in Lebak District (Leuwidamar) is 0.83% (*Kabupaten)*, details can be seen in Table 2 [18]–[20].

A.2 Device capability

It represents a total number of users that capable to access 2G, 3G, and/or 4G in the area. We consider only 3G and 4G users that have a high possibility to access mobile data. Device capability records can be gathered from the core network of telecommunication providers. Data records that used in this research were from one provider only, thus to mimic actual users, we study current market-share and found that 60% of fishermen and farmer users nation-wide are using our studied providers [21],[22]. We took this specific job title, as most people in Panimbang and Leuwidamar work in fishery or agriculture. Next, we calculate Total User by using Eq. 1

$$Total\ User = \frac{Subscribers}{0.6} \qquad (1)$$

To define the growth of users (in percentage), we need to study the spatial planning, main occupation (major job title), and other potential aspects (such as tourism area) that might relate to data access. According to RTRW of Banten, Panimbang would mostly develop as residential areas, and Leuwidamar mostly planned as plantation area, and

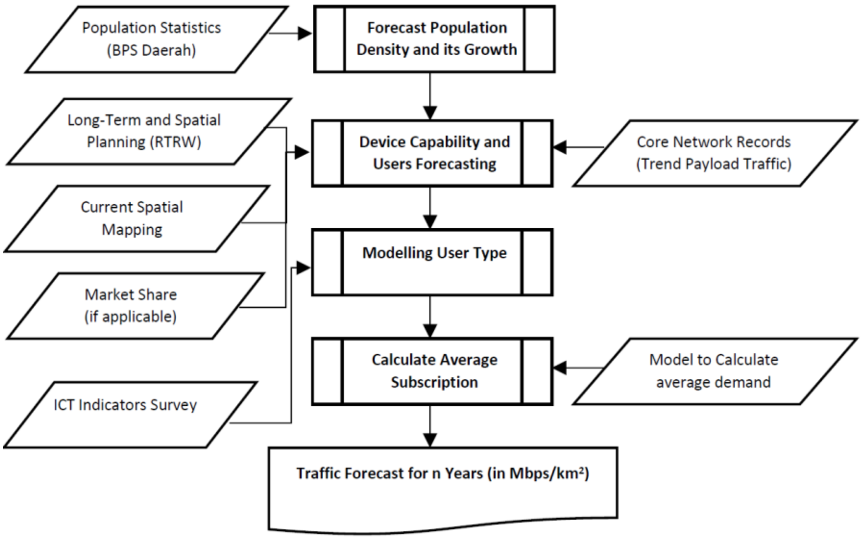

Figure 1. Workflow of Traffic Forecasting

Table 1. Conditions and Local Potential Aspects

Area	Land Use	Job Sectors	Potentials
Panimbang	Residential Areas	Fishery, Aqua-culture	Tourism (Tanjung Lesung Beach)
Leuwidamar	Nature preservation, Production Forests	Agriculture, Farming	Tourism (Entrance of Baduy)

partly for nature preservation and production forests. Moreover, both areas are potential to develop their tourism sector. In Panimbang, there is Tanjung Lesung beach. Leuwidamar is also the main entrance to Baduy village, a historical and cultural attraction. The summarized aspects that need to be consider is depicted in Table 1 [15]–[17].

A.3 User type

The type of users represents typical devices that would be accessed by a user to surf the internet. We consider three types of devices. The first device is a mobile phone which considered as normal-user, second and third devices considered as heavy-user: Mobile PC/Laptop, and Tablet. Considering situations in Panimbang and Leuwidamar, the number of heavy users in Panimbang is higher compared to Leuwidamar, for Panimbang is planned to be a residential area. The base data is mobile phone users that taken from "device capability" data from the core network. For Panimbang, Mobile PC users are 20% of mobile phone users, and Tablet users are 10% of mobile phone users. For Leuwidamar, we take 10% and 5% for Mobile PC and Tablet respectively, based on the number of mobile phone users.

A.4 Average subscription

The Average Subscription is able to give us a picture of overall traffic demand. We adopt the EARTH model, that enables us to mix the traffic which generated from several types of terminals. The Ericsson Mobility Report for South East Asia and Oceania Region shows that the average subscription for mobile is 1.2 GB/Month [23]. However, a survey from providers and sales report shows that the subscription of a user in the studied area is around 2 GB/Month. As there is no clear classification between the normal or heavy user, we assume that Mobile PC user has 1.5 times subscription, and Tablet has 1.25 times, compared to mobile phone subscription. The average traffic demand per subscriber can be calculated by Eq. 2. The r_k represents the monthly data demand and s_k is the ratio of subscribers for type k device.

$$r_{av} = \sum_k r_k s_k \text{ in [GB/month/subscriber]} \quad (2)$$

Assumptions were taken by considering data gathered from BPS, reports from companies (such as Ericsson), and survey result. To forecast, we take a sample of five years span. The reason is that normally the time of telecom technology is 10 years span (1G in 1990, 2G in 2000, 3G in 2010, etc). Thus forecasting for 5 years is reasonable, since the next 5 years, we need to prepare for the future technology that might not yet be discovered.

The detail parameters which consider multidimensional aspects are summarized in Table 1. To model the generalized traffic for a particular area, we calculate the traffic demand Ω_i by using Eq. 3.

$$\Omega_i = (r_{av})_i \frac{8 \, x \, 10^3}{30 \, x \, 12 \, x \, 3600} \, Mbps \quad (3)$$

We first need to define a busy hour which represents traffic usage during a time unit. In this research, we assume that the traffic is spreading uniformly in 12 hours for 30 days, as in rural area most people not having exact office hours such in dense urban. Usually, urban areas have a shorter busy hour, e.g. 8 hours in 20 days. The traffic demand also dependent to $(r_{av})_i$, which previously calculated in Eq. 3. Lastly, the Ω_i is used to calculate areal traffic demand in Mbps/km^2, as shown in Eq. 4.

$$\tau_i = \frac{\rho_i \, \Omega_i}{A} \text{ in Mbps/ km}^2 \quad (4)$$

ρ is number of users for year i, $\$(r_{av})_i$ is the average subscription per user for year i, and A is a total area understudied. Panimbang has a total area as 132.8 km^2, and Leuwidamar has 176.61 km^2.

B. Parameters

The main references to set parameters in Table 2 are from regional BPS yearly reports and Regional Spatial Planning reports. This table is used as the foundation to set other parameters which shown in Table 3.

Single-dimension means that we neglect government spatial planning or other potentials. We set a flat increase for the number of users and amount of subscription, regardless of either Panimbang or Leuwidamar area. The Multi-dimensions means that we consider all the aspects that discussed before, as in Table 1.

For Panimbang multidimensional scenario, the number of users has accelerated by 1% yearly. It means that if year 1 increase 2%, then year 2 increase 3%, year 3 is 4%, etc. The reason is that Panimbang is planned to be a residential area, so a higher number of users is expected. On the other hand, Leuwidamar is planned to nature reservation and forest products, thus the increase is quite steady. The subscription in- creases for both areas is the same, except in multidimensional scenario for Leuwidamar.

Table 2. YOY Increase Parameters

	Singledimension		**Multidimensional**	
Parameters	Panimbang	Leuwidamar	Panimbang	Leuwidamar
Population	0.55%	0.83%	0.55%	0.83%
Users	2%	2%	Increase of prev. year + 1%	1%
Subscription	2 GB	2 GB	2 GB	2 GB (bi-yearly)

Table 3. Traffic Estimation of Multi-Dimensions Scenario

Details	2019	2020	2021	2022	2023
Panimbang Subscriber					
Population Density	397	400	404	408	412
Total Population	52,722	53,120	53,652	54,183	54,714
Mobile Phone User	21%	26%	32%	39%	47%
Mobile PC User	4%	5%	6%	8%	9%
Tablet User	2%	3%	3%	4%	5%
Subscription (GB/Month per Subscribers in Panimbang)					
Mobile Phone	6	8	10	12	14
Mobile PC	9	12	15	18	21
Tablet	7.5	10	12.5	15	17.5
Leuwidamar Subscriber					
Population Density	373	376	379	382	384
Total Population	65,876	66,406	66,936	67,466	67,819
Mobile Phone User	6%	7%	8%	11%	16%
Mobile PC User	0%	1%	1%	1%	1%
Tablet User	0%	0%	0%	0%	0%
Subscription (GB/Month per Subscribers in Leuwidamar)					
Mobile Phone	4	4	6	6	8
Mobile PC	6	6	9	9	12
Tablet	5	5	7.5	7.5	10

The same reason as the number of users background. The single-dimension is set to be a baseline of comparison, and the increase is the same for Panimbang and Leuwidamar (2% per year), neglecting the government spatial planning [15]–[17].

Detail parameters that used for traffic estimation are shown in Table III.

The population density and number of subscribers are calculated based on reference in [18]–[23].

As we can see in Table III, the increasing of several parameters for Panimbang and Leuwidamar case are different. The detail increase of each parameter is shown in Table 2. Noted that in Table 3, it is written 0%, yet it still accounts for the number of users but less than 1% of total population i.e. 0.5% of the population.

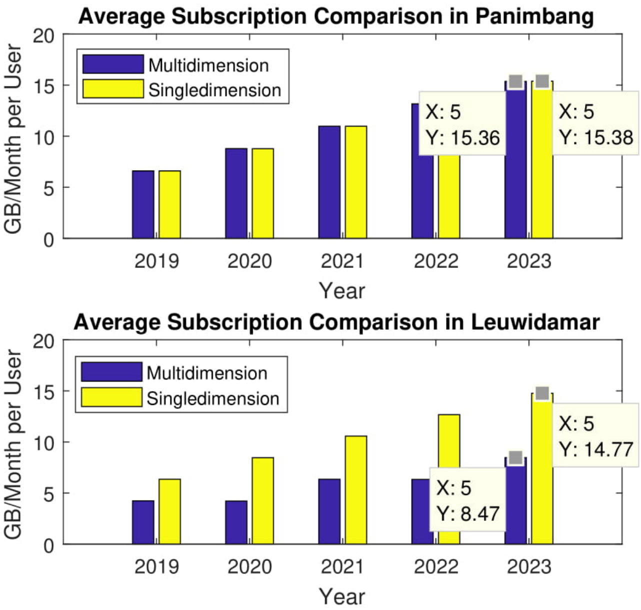

Figure 2. Average Subscription Comparison

RESULT AND DISCUSSIONS

In this section, we discuss the result of traffic forecasting simulations and compare the multidimensional scenario and single-dimension.

A. Average Subscription

The average subscription for Multi-dimensions scenario and Single-dimension scenario are depicted in Fig. 2. The description of the average subscription is described in Section III-A4.

For Panimbang case, the area that planned to be resi- dential, are not having much difference in terms of aver- age subscription, 15.38 GB/Month/User for single-dimension and 15.36 GB/Month/User for the multi-dimensions scenario. Yet in Leuwidamar, the difference is quite significant, 14.77 GB/Month/User for single-dimension and 8.47 GB/Month/User for the multi-dimensions scenario.

The slight difference in Average Subscription of users in Panimbang is mainly because of the almost similar amount of subscription. Although the number of mobile users is increasing, it is followed by the same subscription scenario for both single- and multi-dimensions: 2 GB/Month/User. Thus, the different increase in population and user does not significantly influence the amount of average subscription.

In Leuwidamar, however, shows a relatively difference be- tween single- and multi-dimensions scenario. The main reason is that in the multi-dimensions' scenario, we took an increase of 2 GB/user/month bi-yearly when in single-dimension we took 2 GB/user/month each year. For the multi-dimensions scenario in Leuwidamar, the area is not planned to be residential, thus the increasing amount of subscription will not as significant as Panimbang. The scenario of using data traffic in such area is might be meant for researchers, engineer, or local people that only use the network for basic communication.

B. Areal Traffic Demand Comparison

By using (4), we calculate an areal traffic demand for single- and

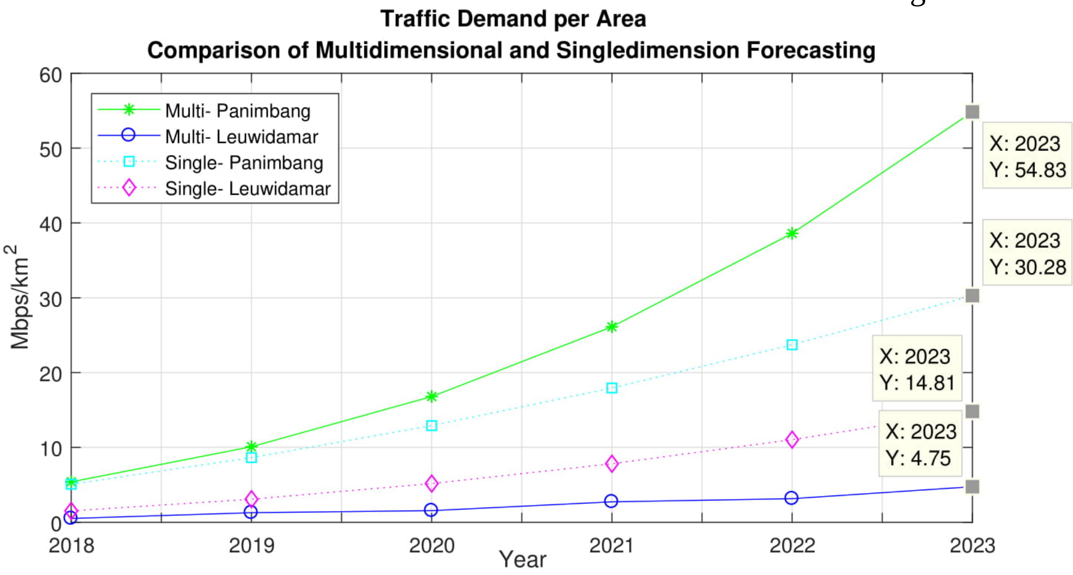

Figure 3. Traffic Forecasting Comparison

multi-dimensions scenarios. Noted that the busy hour of both scenarios are the same, 12 hours each day and accounts for 30 days. The comparison of areal traffic demand between single- and multi-dimensions scenarios is depicted in Fig. 3.

For the multi-dimensions scenario in Panimbang, the areal traffic demand sharply increases up to about 54 Mbps/km2 in 2023, while for the single-dimension scenario is only reach 30 Mbps/km2. The big difference is because the single-dimension scenario only takes a flat increase of the number of users, which is 2%, while in the multi-dimensions scenario, the increase is adding 1% more each year. In 2023, the multi- dimensions scenario has 47% mobile phone users among the population, yet for another scenario only account for 26% of users. The subscription between single- and multi-scenarios in Panimbang is the same. Thus, the higher impact of a big difference in areal traffic demand for Panimbang is the increasing percentage of users.

In Leuwidamar case, the areal traffic demand for the multi- dimensions scenario remains steady with a slight increase up to 4 Mbps/km2 in 2023. Yet, the single-dimension scenario has climb gradually and reach 14 Mbps/km2. The reason for the steady increase of areal traffic demand in the multi-dimensions scenario is that the regional spatial planning, which stated that the Leuwidamar area is mostly for nature preservation and forest. Thus it is reasonable to account less subscription per user. Moreover, the increase of population density for the multi-dimensions scenario is only 1%, rather than 2% as in single-dimension scenario.

We can see that, if we took the single-scenario in a populated area, we might forecast less traffic compared to real future demand. However, this scenario might not be too problematic since adding more cells in a densely populated area might need small capital investment, e.g. no need to build such high tower individually to cover a wide area.

However, for a remote area such as Leuwidamar, consid- ering a single-dimension scenario to forecast network, might leads to a high loss of profit. When we take a single-dimension scenario and neglecting local spatial planning, we might have a miss-forecasting and invest too much in deploying a network to fulfill high demand. Then, providers need to expend addi- tional cost to relocate the installed network. On the other hand, when we take RTRW as consideration, we might not expect high subscription and a high number of users. By using this model, we could combat the high investment cost of covering wide, low-utility and low-income area.

CONCLUSIONS

The aim of this research is to study what kind of parameters that need to be considered when forecasting traffic and sim- ulate the impact of using the multi-dimensions traffic model compared to single-dimension.

In terms of parameters needed, we first need to address the impact of an Internet on rural society. Internet or telecommu- nication network is provided to support social welfare, and the development planning usually has been formulated by the regional government, as in RPJPD, RPJMD, and RTRW. Thus, to simplify of accounting social aspect for this research, we use Regional Spatial Planning (RTRW) for modeling future traffic. Aside from the social aspects, we surely need the technical records that can be gathered from providers network (usually from core network). To support in modeling future traffic, we also use survey records or reports from companies and government. To summarize, there are plenty of parameters that could support traffic forecasting. However, the main step of parameter processing is: Forecast population density, study the device capability, define user type, and calculate average subscription. There are also other data needed to support this process, which depicted in III-A.

The impact of using the multi-dimensions traffic model is that we could decrease the opportunity of deploying a network that not suitable for futuristic traffic demand. For rural that planned to be a residential area, the single-dimension scenario might look too pessimistic, because we are neglecting the possibility of a sharp increase in the number of users that might come from the transmigration program. However, to make a denser network in high utilization area is easier because generally for a densely populated area, the generated income could outweigh the investment cost of network providers.

Yet, for Leuwidamar area, which most villages are remotely located, the single-dimension scenario might be too optimistic. In single-dimension, we assume a steady increase, neglecting the fact that the area is meant to be nature preservation and product forests.

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REFERENCES

[1] Ericsson, ”Ericsson Mobility Report, June 2018” Ericsson, 2018.

[2] GSMA, ”Today , tomorrow and the future – managing data demand in Asia Pacific” GSM Association, 2014.

[3] A. Jha and D. Saha, "Techno-economics behind Provisioning 4G LTE Mobile Services over Sub 1 GHz Frequency bands," Commun. Syst. Networks, vol. 10340, no. September, pp. 284–306, 2017.

[4] C. Ovando, J. P e´rez, and A. Moral, "LTE techno-economic assessment: The case of rural areas in Spain," Telecomm. Policy, vol. 39, no. 3–4, pp. 269–283, 2015.

[5] G. Smail and J. Weijia, "Techno-economic analysis and prediction for the deployment of 5G mobile network," 2017 20th Conf. Innov. Clouds, Internet Networks, no. 2015, pp. 9–16, 2017.

[6] R. L. Katz, "The economic and social impact of telecommunications output: A theoretical framework and empirical evidence for Spain," Intereconomics, vol. 44, no. 1, pp. 41–48, 2009.

[7] Dwijayanto, A "Menkominfo: Proyek Palapa Ring Tuntas Akhir Tahun Ini", Kompas [Online]. https://ekonomi.kompas.com/read/2018/03/14/133000726/menkominfo – proyek-palapa-ring-tuntas-akhir-tahun-ini

[8] S. Ariyanti and K. Kautsarina, "Kajian Tekno-Ekonomi pada Telehealth di Indonesia," Bul. Pos dan Telekomun., vol. 15, no. 1, pp. 43–54, 2017.

[9] C. Qi, Z. Zhao, R. Li, and H. Zhang, "Characterizing and Modeling Social Mobile Data Traffic in Cellular Networks," 2016 IEEE 83rd Veh. Technol. Conf. (VTC Spring), pp. 1–5, 2016.

[10] E. Mucelli, R. Oliveira, A. Carneiro, K. P. Naveen, and C. Sarraute, "Mobile Data Traffic Modeling : Revealing Temporal Facets," vol. 112, pp. 176–193, 2016.

[11] R.M. Pulselli, et. al, "Computing Urban Mobile Landscapes Through Monitoring Population Density Based on Cell-Phone Chatting," Int. J. Des. Nat. Ecodynamics, vol. 3, pp. 121–134, 2006.

[12] F. Girardin and A. Gerber, "Towards Estimating the Presence of Visitors from the Aggregate Mobile Phone Network Activity They Generate," pp. 1–11, 2008.

[13] G. Auer and O. Blume, "EARTH Project D2.3 - Energy efficiency analysis of the reference systems, areas of improvements and target breakdown," Energy Aware Radio Netw. Technol. (EARTH), INFSO-ICT-247733, ver. 2.0. [Online]. Available http//www.ict-earth.eu/, 2012.

[14] Puslitbang Kemkominfo, "Survey Penggunaan TIK," Badan Penelit. dan Pengemb. SDM, 2017.

[15] Badan Perencanaan Pembangunan Daerah Provinsi Banten,"RPJPD Provinsi Banten". [Online].Available: https://bappeda.bantenprov.go.id/id/archive/rpjpd-provinsi-banten/1.html

[16] Badan Perencanaan Pembangunan Daerah, Provinsi Banten, "RPJMD Provinsi Banten 2017-2022". [Online]. Available:https://bappeda.bantenprov.go.id/read/rpjmd-2017-2022/576/Rancangan-RPJMD-2017-2022.html

[17] Badan Perencanaan Pembangunan Daerah, Provinsi Banten, "Album Peta RTRW Provinsi Banten". [Online]. Available: https://bappeda.bantenprov.go.id/read/albumpeta/13/Album-Peta-RTRW-Provinsi-Banten.html

[18] Badan Pusat Statistik Provinsi Banten, ”Statistik Daerah Provinsi Banten 2017,” 2017.
[19] Badan Pusat Statistik Kabupaten Lebak, ”Statistik Daerah Kabupaten Lebak 2016,” 2016.
[20] Badan Pusat Statistik Kabupaten Pandeglang, “Statistik Daerah Kabupaten Pandeglang 2016,” 2016.
[21] Kementrian Komunikasi dan Informatika RI, ”Provider yang Digunakan oleh Petani Tahun 2015” [Online]. Available: https://statistik.kominfo.go.id/
[22] Kementrian Komunikasi dan Informatika RI, ”Provider yang Digunakan oleh Nelayan Tahun 2015” [Online]. Available: https://statistik.kominfo.go.id/
[23] Ericsson, ”South East Asia and Oceania Ericsson Mobility Report,” June, 2016.