Feasibility of LTE 700 MHz Digital Dividend for Broadband Development Acceleration in Rural Areas

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Abstract. The need of broadband services to reduce digital divide in rural areas had increased in the recent years. The government of the Republic Indonesia shared similar intention and had set guidance of ICT development in its "economic master plan" and "medium term development plan". This paper addressed feasibility and suitability of its implementation in Indonesia, by conducting assessment of possible solutions. Using mixed method, the study was started with qualitative approach to identify possible options, conducted benchmarking and case study analysis to narrow down the options and finally conducted quantitative calculation for the two remaining options and measure performance of the solutions. The results of analysis concluded that early implementation of LTE in 700 MHz Digital Dividend would be feasible in certain geographical areas to fasten the broadband plan development in Indonesia.

Keywords: *broadband; digital dividend; HSPA 900 MHz; LTE 700 MHz; Rural.*

1 Introduction

Indonesia, with around 240 million people, is the world's fourth largest populated country, with nearly 2 million km2 land separated over 17.000 islands [1]. However, its population is not evenly distributed, as more than half of them concentrated in the Java island. Similar case applied for the availability of physical infrastructures, such as road and electricity, in dense areas, which are much better than those in the sub-urban and rural area. This also applied to the broadband technologies' availability in Indonesia.

Currently, wireline and wireless technology telecommunication services are provided by licensed operators such as Telkom, Telkomsel, XL and Indosat. Number of mobile and fixed wireless access services has reached more than 100% of population in Q2-2010 [2]. Unfortunately, development of broadband service is far behind voice services and video broadcast; available in about only 30 cities counted for around 1% Wireless Broadband, 0.7% Fixed Broadband and 4% PC household penetration [3].

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The digital dividend would be a viable opportunity to extend the coverage of wireless broadband networks in sparselypopulated areas, as well as indoors, which would be very important for developing countries such as Indonesia. The digital dividend refers to the spectrum which is released in the process of digital television transition. When television broadcasters switch from analog platforms to digital only platforms, part of the electromagnetic spectrum that has been used for broadcasting will be freed up because digital television needs fewer spectrums than analog television.

Most of Band IV/V (470-806 MHz), allocated to analog television broadcasting services in Asia Pacific, as also applied in Indonesia and the rest of the world, will not be used after switchover to digital TV transmission.

Re-planning of broadcasting networks will exhibit the so-called digital dividend, the frequencies no more necessary for DVB-T (SD and HD) transmissions [4][5]. APT Wireless Group identifies the 694 MHz to 806 MHz band plan for Mobile Broadband in Asia Pacific [5].

As broadband service is considered as one of country's strategic sectors, the government of Republic Indonesia step in and set guidance through "Master Plan for the Acceleration and Expansion of Indonesian Economic Growth in the year 2011-2025 (MP3EI)" [6] and the "Medium term of National Development Plan in the year 2010 – 2014 (RPJMN)"[7]. It demonstrates strong Government intention and policy support for the development of mobile broadband services as economic infrastructure and to reduce digital divide, ensuring service reachability up to rural area.

Mobile broadband technologies, such as HSPA 900 MHz and LTE 700 MHz, can do for broadband availability what GSM did for voice [4]. In this paper we explored the feasibility of these mobile broadband technologies as the possible solution to provide broadband service in rural areas of Indonesia.

Given both private and government support them, studies on broadband systems and services become increasingly important. The broadband services will meet the following key requirements [3]:

- 2 Mbps throughput when required by subscribers, although best effort internet is supported.
- 9 kilometers coverage from district capital to ensure most of rural areas would be covered.
- Speed of roll-out, project completion by the end of 2014 to fulfill the Government target of National Broadband Plan.
- The availability and the affordability of the broadband wireless solution.

The above-mentioned challenges motivate authors to conduct a study for the development of wireless broadband to accelerate the deployment of broadband in Indonesia. More specifically, this study is conducted to answer several questions. First, the feasibility of technology implementation option and whether LTE 700 MHz is the qualified one. Second, the performance of the technology options, and finally, in which geographical area the solution would be feasible.

2 Proposed Method

Digital divide involves social and technical issues; therefore both human interpretation and scientific calculation is required in conducting study for digital divide. Walsham [8] suggests interpretive approach as appropriate method for case requiring human interpretation. On the other side, quantitative analysis provides more precise measurement on performance of the technology. Therefore, mixed-method, which is an approach to inquiry that combines both qualitative and quantitative forms [9], is proposed for this study. Feasibility of technology implementation options and whether LTE 700 MHz is the qualified one will be analyzed by qualitative approach; while performance of the technology options and Geographical area the solution would be feasible will be analyzed by quantitative approach.

In the first approach, the study focused on identification of solutions options both wireline and wireless technology, then interpretive analysis is used to interpret possible solutions meeting key requirements in terms of bandwidth delivery, distance, and speed of delivery. Constraint, such as detailed economic analysis, is not in the scope and excluded from analysis of this study.

On the second approach, both conventional calculation and planning tools are used to measure numeric performance of the solutions in bandwidth, subscriber capacity and coverage. Next step is to continue with analysis of guard band requirements, and finally determine the feasible areas of early LTE implementation taking into account the map of spectrum utilization of 698 - 806 MHz in Indonesia. The following hypotheses are developed as basis of measurement:

- H1: system performance, deliver 2 Mbps throughput services for the whole 30% population in 30% land (about 650 thousands km^2) at cell edge 9 km away from antenna.
- H2: guard band requirements are achievable.
- H3: geographical areas feasible for implementation.

2.1 Qualitative Analysis

This analysis starts with identification of solution options, both wireline and wireless solutions in term of technology characteristics, bandwidth and evolution path; then continues with benchmarking and best practice on speed of implementation from one of the operator's FTTx project and concludes with analysis of digital dividend spectrum utilization.

2.1.1 Solutions Identification

Two major solutions are identified to deliver broadband services, for wireline access namely FTTx and xDSL, while on wireless solutions three major access technology namely CDMA 2000 1X EV-DO, HSPA, and LTE.

FTTx and xDSL: FTTx stands for Fiber-To-The-X, where X refers to physical end-point location such as home, building, and curb. The FTTx rely on physical media of fiber optic cable. The system can deliver very high bandwidth (up to 100 MHz) and in some cases, up to 1 GBps today. xDSL is another way to deliver broadband services. It uses copper cable instead of fiber optic cable. It supports typically up to 20 MHz bandwidth for about 3 km distance and exceed 50 MHz for shorter loop. The FTTx technology is evolving toward higher bandwidth of 10 Gbps, while xDSL is evolving toward hundreds of Mbps.

Code Division Multiple Access (CDMA) 2000 1-X EV-DO: CDMA2000 1xEV-DO (Evolution-Data Optimized) is 3G wireless technology (which) works in 1.25 MHz of spectrum, offering more than 2 Mbps throughput per cell. Typically, the system supports spectrum efficiency of 1.04 bit / Hz [10]. Currently, this 800 MHz band is allocated for four operators, that is Telkom, Indosat, Bakrie Telecom and Smartfren, with allocated frequency of 3.75 MHz, 2.5 MHz and 3.75 MHz band and 5 MHz respectively as described in Figure 1 [11].

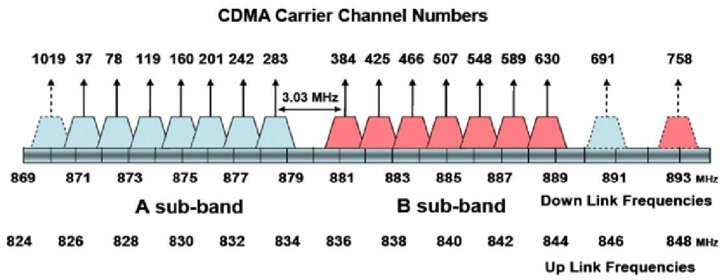

Figure 1 Frequency band plan of CDMA-800 MHz.

EV-DO is designed to co-exist with CDMA2000 1X. EV-DO can be deployed in the same cell sites as 1X, using the same antenna. Also, the EV-DO channel cards fit in the 1X channel card enclosures. Working frequency for this system is 850 MHz, in 869-879 MHz for sub-band A and 883-893 MHz for sub-band B with 1.23 MHz channel raster. This technology evolves to LTE for 4G services

High Speed Packet Access (HSPA): High Speed Packet Access (HSPA) is a 3G technology and combination of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) which extends and improves the performance of existing WCDMA protocols. HSPA networks capable of delivering peak bit-rates of 14.4 Mbps. The next level, HSPA+, use higher order 64 QAM modulation which offers 21 Mbps, latest version use 64 QAM dual carriers system to achieve even higher cell throughput of 43 Mbps per cell today. Typically, the system supported spectrum efficiency of up to 0.7862 bit/Hz [10].

3GPP recommends 900 MHz and 2100 MHz band for HSPA. In 900 MHz band in Indonesia, the operating frequency for uplink is 890-915 MHz while for downlink is 935-960 MHz. Although 900 MHz band is not originally allocated for HSPA services, but system upgrade would be technically possible. In this band, spectrum blocks are allocated for three operators namely Telkomsel, Indosat and XL-Axiata with 7.5 MHz, 10 MHz and 7.5 MHz band respectively as described in Figure 2 [11].

Figure 2 Frequency band plan of GSM/HSPA-900 MHz.

Although some technology developers are trying to enhance HSPA supporting higher frequency, mainstream evolution of this technology will also converge to LTE for 4G services.

Long Term Evolution (LTE): LTE (Long Term Evolution) is a 4G wireless technology introduced by 3GPP (3rd Generation Partnership Project). This technology is able to support bandwidth ranging from 1.4 MHz to 20 MHz, both FDD (Frequency Division Duplex) and TDD (Time Division Duplex) and working band from 700 MHz to 3500 MHz. Supported downlink speeds can reach 100 Mbps and uplink up to 50 Mbps in 20 MHz channel bandwidth [12]. The higher speed (up to 1 Gbps) will be supported by LTE Advanced. The use of frequency spectrum in LTE has increased quite significantly when compared to the technology of HSDPA (High Speed Downlink Packet Access). LTE also support MIMO technology to increase data rate and keep lower order of modulation. Hence LTE provides double gain of higher throughput and longer distance benefit. Further detail quantitative calculation will be elaborated in the next part of this paper.

In the 11th Asia Pacific Telecommunity Wireless Group (AWG-11) meeting in September 2011, the meeting adopted the Report of Implementation Issues Associated with the use of the Band 698-806 MHz by Mobile Services [5]. It was defined in the band of 698 MHz - 806 MHz as working frequency band, allowing flexible allocation of up to 2 x 45 MHz FDD block for FDD LTE as shown in Figure 3 below [5].

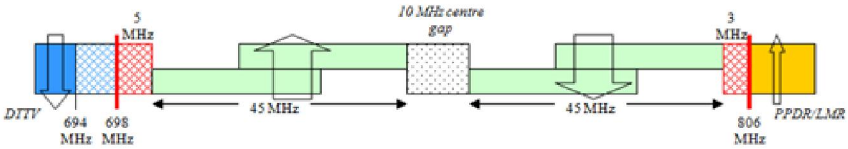

Figure 3 Harmonized FDD arrangement of 698-806 MHz band.

2.1.2 Comparison of Broadband Implementation Speed of FTTx Project

In order to assess the feasibility of other technology alternatives providing broadband especially in rural areas in Indonesia, benchmarking and analysis with current FTTx project of "Nusantara Superhighway" [13] is worthwhile to be done. This analysis would provide solid understanding of implementation speed for FTTx and xDSL technology as compared with wireless broadband in the next part of this paper. In the "Nusantara Superhighway" project, Telkom Indonesia had the intention and plan to rollout the true broadband services, deliver 100 MHz bandwidth to its customer premises, and to serve nearly 14 million subscribers by the end of year 2015 [13]. Comparison of this project with key requirements to serve nearly 80 million subscribers would be considered to compare the feasibility of FTTx as solution to provide broadband in Indonesia to reduce the digital divide. Additionally, the current fiber optic backbone government project of "Palapa Ring" [13] to rollout 50 thousands kilometers fiber optic cable is also included in the assessment.

2.1.3 Digital Dividend Spectrum Utilization

Currently, this spectrum is allocated for Terrestrial Broadcast TV services. This technology needs to be reviewed to qualify coexistence with wireless technology for digital divide solution. Terrestrial analog broadcast TV services operated in VHF-high band (174-216 MHz) and UHF band (470-806 MHz). Although at present, it does not overlap with CDMA and HSPA frequency band, the use of upper UHF band of Broadcasting TV would potentially interfere with LTE in 700 MHz band (694 - 806 MHz). Therefore, properly defined spectrum policy and planning and the determination of technical operational limitation such as guard band would be very important.

In Indonesia, currently all broadcasting TV stations are still using analog technology, while nationwide switchover to digital technology would not be completed before year 2018 [14]. Typical TV station operates in very high power transmission, in order of tens of kilowatts up to Megawatts, required high-investment and operational cost, resulting in very challenging business case of deploying TV station.

This situation has impacted to the low utilization of 694-806 MHz spectrum in less profitable and less dense area, especially outside Java island, where most of that band is identified as still unused. Detailed geographical occupancy of 694-806 MHz utilization is provided in Table 1.The information is developed based on the database of use of frequency of analog TV in Indonesia from Ministry of Communications and Informatics**.**

Table 1 Spectrum utilization of 698 - 806 MHz by analog TV in Indonesia.

Province	No of TV channels	Channels													
		Ch.49	Ch.50	Ch.51	Ch.52	Ch.53	Ch.54	Ch.55	Ch.56	Ch.57	Ch.58	Ch.59	Ch.60	Ch.61	Ch.62
		Freq Center (MHz)													
		698	706	714	722	730	738	746	754	762	770	778	786	794	802
Sumatera Islands															
North Sumatera	1	1													
West Sumatera	5	1	1	1			1				1				
Jambi	2	1					1								
Bangka Belitung	1		1												
Riau Island	4	1		1				1						1	
South Sumatera	2		1		1										
Java Islands															
DKI Jakarta	5	1		1		1		1				1			
West Java	8		1		1		1		1		1	1		1	1
Central Java	9	2	1	1		1	1	1				1		1	
East Java	17	2	1	1	1	1	1	1	1	1	2	1	2		2
Banten	5				1			1		1		1	1		
Kalimantan															
East Kalimantan	3	1		1		1									
South Kalimantan	1				1										
Sulawesi															
Central Sulawesi	1	1													
South Sulawesi	1	1													
Bali Nusa Tenggara															
Bali	2	1			1										
NTT	1			1											
NTB	1														1
TOTAL	69														

The geographical map of spectrum utilization of 698 - 806 MHz band by Analog TV in Indonesia is depicted in the Figure 4 below

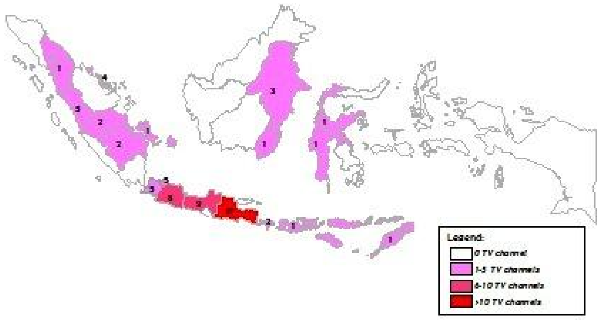

Figure 4 Geographical map of 698 - 806 MHz spectrum utilization.

2.2 Quantitative Analysis

This approach focuses on performing calculation to measure how solution options meet requirements in terms of how much bandwidth, subscriber capacity and coverage area supported; whether guard band requirement is achievable in some areas; and to determine areas where implementation of digital dividend is feasible as formulated in hypothesizes above.

2.2.1 System Performance

As a starting point, necessary parameters such as services-mix and respective downlink and uplink bandwidth as well as overbooking factors must be defined and be used for entire calculation. The Broadband Service Parameters used in this study as provided in Table 2 [10].

Table 2 Broadband Service Parameters [10].

	VoIP	2-ways video	PS1	PS2	PS3
UL Data Rate	64.0 kbps	256 kbps	512 kbps	256 kbps	128 kbps
DL Data Rate	64.0 kbps	256 kbps	2 000 kbps	1 000 kbps	512 kbps
% Subs/ Service	35%	5%	7.5%	12.5%	40%

Additional characteristics such as latency and jitter related to more advance performance of the system are not taken into account in this detail analysis to keep this study focused on key requirements.

2.2.1.1 Propagation Model

This model focused on measurement of cell coverage of LTE 700 MHz and HSPA 900 MHz. Both LTE 700 MHz and HSPA 900 MHz band is supported by 3GPP [15]. Propagation model calculation is required to calculate either the cell radius or MAPL (Maximum Allowable Path Loss) in rural areas.

First, we calculate Maximum Allowable Path Loss (MAPL) [16] as shown in the equation 1 as follow:

$$\text{MAPL (dB)} = P_t - L_c + G_{ant} + \text{Margin} - \text{Receiver Sensitivity} \quad (1)$$

where:

- $P_t$is the BTS transmit power
- L_c is the feeder loss
- G_{ant} is the sum of BTS antenna gain and UE antenna gain
- Margin is an expression for how much dB there is between the received signal strength level and the receiver sensitivity of the radio that provides for sufficient system gain or sensitivity to accommodate expected fading and interference for the purpose of ensuring that the required quality of service is maintained. For most mobile systems, a margin of 6 to 10 dB is acceptable. [17]

Okumura-Hata is the most widely used wireless cellular propagation model and we can use it as an approximation for radio wave propagation model for LTE. Okumura-Hata propagation model [16] is used to calculate cell radius in rural area as shown as Eq. 2.

$$\text{MAPL} = 69.55 + 26.6 \log f - 13.83 \log h_{tx} - a(h_{rx}) + (44.9 - 6.55 \log h_{tx}) \log d + 4.78(\log f)^2 + 18.33 \log f + 40.98 \quad (2)$$

whereas,

$$a(h_{rx}) = (1.1 \log f - 0.7)h_{rx} - (1.56 \log f - 0.8) \text{ dB} \qquad \text{for small/medium area}$$

$$a(h_{rx}) = 3.2 (\log 11.75 h_{rx})^2 - 4.97 \text{ dB} \qquad \text{for large area}$$

2.2.1.2 Throughput

Throughput is important to know the performance from the network. Document3GPP suggests LTE supported downlink speeds can reach 100 Mbps(in cell center) [12], it isdetermined from equation (4) based on frame structure [18]

$$C = M \times N_{PRB} \times N_{Subcarrier/PRB} \times N_{Sym/TTI} \times N_{Subframe/Sec} \quad (3)$$

where:

- C is the maximum data rate
- M is the number of bits per symbol
- N_{PRB} is the number of physical resource blocks
- Nsubcarrier/prb represents the number of subcarriers per resource block
- Nsym/TTI represents the number of symbols per TTI
- Nsubframe/sec represents the number of subframes per second

In this scenario, simulationmodeled within 3 cells [19] as shown as in Figure 5

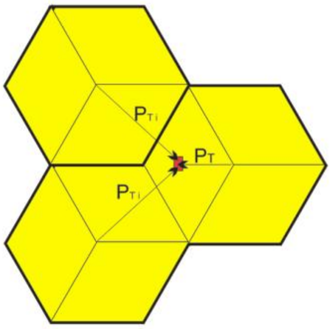

Figure 5 Re-use of factor 1 configuration.

In the figure above, the red dot is the location of User Equipment and there are 3 BTSs located at the center of each hexagonal cell. The one to the right of UE (P_T) is the serving BTS while two others (P_{Ti}) are the interfering BTSs.

The main goal of this calculation is to obtain SINR value which is needed to calculate throughput at that particular SINR value. The SINR formula is shown below:

$$SINR = \frac{Pt + Gt - MAPL}{No + BW + \sum (Pti + Gti - MAPLi)} \quad (4)$$

SINR is defined as the ratio of the received strength of the desired signal to the received strength of undesired signals (noise and interference). In this case, the source of the desired signal is the serving BTS while the sources of interferences are the two interfering BTSs.The received strength of the desired signal can be calculated by summing up transmitted signal power from the serving BTS with gain from BTS and UE antenna, then subtract it with MAPL

(Maximum Allowable Path Loss). MAPL can be calculated by using Okumura-Hatta propagation model because we already know the distance from serving BTS to UE, that is 9 km.

In the denominator part, No + BW represents Noise Power in the logarithmic scale. No is the Noise Density and given by $N_0 = kT$, where k is Boltzmann's constant in joules per kelvin, and T is the receiver system noise temperature in kelvins. BW is the amount of bandwidth; in LTE case, the utilized bandwidth can reach up to 20 MHz.

$\sum(Pti + Gti - MAPLi)$ is the sum of interferences power caused by those two interfering BTSs, just like the calculation of received signal power from serving BTS. However, to calculate MAPL from each interfering BTS, we take a quite different approach because we have not known the distance from interfering BTS to UE yet.

First, we calculate cell radius of serving BTS from known MAPL using Okumura-Hata propagation model. Subsequently, we use phytagoras formula to calculate the distance from interfering BTS to UE by using known cell radius and distance from serving BTS to UE (9 Km). Finally, we can calculate MAPL for each interfering BTS by using Okumura-Hata propagation model again.

Using all of these known parameters, we can calculate the value of SINR. SINR is needed to calculate throughput using formula below:

$$C = BW \log_2 (1+SINR) \tag{5}$$

However, correction factor is necessary for both downlink and uplink throughput as shown in table below:

Table 3 SINR correction factor.

	BWeff	**SINReff**	**SINRmin**	**SINRmax**
DL	0,56	2,0	-10 dB	32 dB
UL	0,52	2,34	-10 dB	35 dB

The result is a slight change in the formula:

$$C_{DL} = 0{,}56\ BW \log_2 (1+(SINR/2)) \tag{6}$$

$$C_{UL} = 0{,}52\ BW \log_2 (1+(SINR/2{,}34)) \tag{7}$$

2.2.1.3 Subscriber Capacity

In this paper there are two scenarios to find out the comparison of number of users between HSPA and LTE.

Scenario 1 :UL is ¼ of the DL rate.

The parameter of scenario 1 is shown in Table 4.

Table 4 Capacity parameters of scenario 1.

	VoIP	2-ways video	PS1	PS2	PS3
UL Data Rate	64.0 kbps	256 kbps	512 kbps	256 kbps	128 kbps
DL Data Rate	64.0 kbps	256 kbps	2000 kbps	1000 kbps	512 kbps
% Subs/Service	35%	5%	7.5%	12.5%	40%
Overbooking	20 mErl	100 mErl	10	30	50

Scenario 2 :UL is 1/2 of the DL rate.

The parameter of scenario 2 is described in Table 5.

Table 5 Capacity parameters of scenario 2.

	VoIP	2-ways video	PS1	PS2	PS3
UL Data Rate	64.0 kbps	256 kbps	1 000 kbps	512kbps	256 kbps
DL Data Rate	64.0 kbps	256 kbps	2 000 kbps	1000 kbps	512 kbps
% Subs/Service	35%	5%	7.5%	12.5%	40%
Overbooking	20 mErl	100 mErl	10	30	50

In providing broadband access to rural areas, cell coverage is the main factor. The selection of operating frequency for the provision of broadband access also must consider other factors, such as the use of 4G spectrum of global and market conditions and development of the ecosystem. It should be the basis of consideration to benefit from economies of the global industry.

In this study, we assume that the use of broadband in rural areas mainly in fixed location. The following parameters are taken into account.

Table 6 LTE 700 MHz and HSPA 900 MHz assumption parameters [10].

Bandwidth	LTE 20 MHz, HSPA 15 MHz
UL Air Interface Feature	1 x 2 Rx Div
DL Air Interface Feature	LTE: MIMO 2x2, MIMO 4x2
BS Antenna Height	40 m
BS Antenna Gain	17 dBi
UE Antenna Height	4m
UE Antenna Gain	6 dBi
Additional loss (connecting antenna to UE unit)	3dB
Indoor Penetration Loss	0 dB (Antenna mounted outside the building)
UL Load	50%
PA Tx power per path	LTE : 2 x 40 W for MIMO 2x2
	LTE : 4 x 40 W for MIMO 4x 2
	HSPA: 40 W per carrier (5 MHz)
Coverage Probability	98%
Standard Deviation	7dB
	(Parameter for Fixed Wireless Design)

2.2.1.4 Guard Band between Terrestrial Broadcast TV and Mobile Broadband Systems

Guard band between terrestrial broadcast TV and mobile broadband is an important factor. This analysis focused on calculating guard band requirements to ensure co-existence of terrestrial broadcast TV and LTE 700 MHz.

Depending on the television planning arrangements established by national administrations, a guard-band of at least 5 MHz or 9 MHz will exist between the uppermost television channel and the lower end of the FDD uplink block [5]. In case of Indonesia, which current analog TV based on 8 MHz PAL-G bandwidth channel raster, while the Digital Terrestrial Broadcasting TV would be based on 8 MHz bandwidth DVB-T channel raster also, a guard-band of 9 MHz would be available between 694 MHz (uppermost frequency of Ch.48) and 703 MHz (lowermost frequency of harmonized FDD LTE 700 MHz Asia Pacific band plan). Meaning that it would be 2 x 45 MHz FDD LTE 700 MHz

Digital Dividend spectrum available in case of frequency 698 - 806 MHz by Analog TV was not used in certain areas in Indonesia.

The availability of 9 MHz guard band gives several advantages over 5 MHz one. Including the additional 4 MHz ‘external’ guard-band below 698 MHz will further relax the minimum isolation requirements of both possible interference cases, DTV Tx interference into IMT base station Rx and IMT UE Tx interference into DTV receivers, by about 7~8 dB (around 50% reduction in required separation distances) [20].

Moreover, there is a suggestion to adapt ‘reverse duplex’ arrangement, where the mobile transmit function (uplink) is allocated to the upper spectrum block of the FDD pair and downlink is allocated to the lower spectrum block of the FDD pair. However, in the event that a ‘reverse duplex’ arrangement is adopted, for the 2 x 45 MHz structure being proposed for the 700 MHz IMT band in Region 3, there is serious potential impact on a range of important satellite navigation, location and precision timing applications. This impact is not just on RNSS applications integrated within IMT terminal devices but, perhaps more significantly, also on a wide range of critical public safety and infrastructure systems. Recognizing the increasing prevalence and importance of RNSS systems likely to be operating in close proximity to IMT user devices, the APT Wireless Forum agreed on adoption of a ‘conventional duplex’ arrangement of the 2 x 45 MHz structure proposed for the 700 MHz band in Region 3.

On the contrary, guard band calculation for HSPA 900 MHz is not required in this study since there is no overlapped frequency and out-of-band emission problems between different operators and services in such particular band.

2.2.2 Feasible Area for Implementation

In this study, we analyze the areas in Indonesia where the digital dividend spectrum would be feasible to be used by taking into account the mitigation of interference with the Broadcast TV services, such as areas where minimum guard band 5 MHz between Broadcast TV and Mobile Broadband is available.

3 Results and Analysis

Study results are presented in a way to responds research questions.

3.1 Rural Broadband Options

Potential solutions include wireline solutions namely DSL, FTTx and Cable, while wireless mobile broadband solutions include HSPA, LTE and CDMA EV-DO and IP-Satellite technology.

The most important parameter to be considered is the roll-out speed of those several technology options in order to fulfill the National Broadband Plan by the end of 2014. From the reference of deployment plan of wired broadband of FTTx [13], it was clearly defined that it would be difficult to provide broadband plan in the targeted timeline of Master Plan for the Acceleration and Expansion of Indonesian Economic Growth in the year 2011-2025 (MP3EI)" [6] and the "Medium term of National Development Plan in the year 2010 – 2014 (RPJMN)"[7] by the year 2015. It would be nearly at least 5 years needed to rollout 14 million FTTx lines. The "Palapa Ring" fiber optic project in unprofitable areas would show even longer implementation to rollout 50 000 km fiber optic backbone. Both cases proved that the wireline solution cannot be used as solely solution and must be combined with wireless solution. With this consideration, this study of providing Broadband Wireless solution would be urgently necessary.

From an economic point of view, lower population densities in rural areas create significantly elevated cost for deploying wireline broadband facilities. Wireless broadband solutions are, however, less sensitive to population density. The deployment of high quality wireless network that afford broadband capability to be more economically attractive, especially for private sector investment, than wireline solutions [21].

Terrestrial wireless solution , on the other side, would be the only remaining possible solution. It is understood that available spectrum for CDMA is very limited. Spectrum efficiency 1.04 bit/Hz resulting from 1.25 Mbps per 1.25 MHz speed per cell which would be practically lower compared to HSPA and LTE [10]. Furthermore, its evolution path toward LTE do not justify this technology to be used as a long term solution, therefore it was concluded that CDMA would not become feasible solution.

HSPA 900 MHz and LTE 700 MHz had better spectrum allocations, total of 2 x 25 MHz and 2 x 45 MHz respectively. With better spectrum efficiency support, the two systems had better position to be the solution for digital dividend. Both technologies had also evolution path to 4G, although majority of technology provider support converged evolution toward 4G.

In summary, based on qualitative analysis, it was concluded that only HSPA 900 MHz and LTE 700 MHz left as possible solutions and will be further analyzed using quantitative approach as follow:

3.2 Performance Measurement

3.2.1 Coverage

The coverage and cell radius of LTE 700 MHz and HSPA 900 MHz were calculated by Okumura-Hata propagation model. The result is shown as in Table 7 below.

Table 7 Cell Range LTE 700 MHz And HSPA 900 MHz.

UL Cell Edge Bit Rate (kbps)	LTE 700 MHz (km)	HSPA 900 MHz (km)
UL128	18.79	12.91
UL256	15.40	10.56
UL384	13.93	9.32
UL512	13.24	8.63
UL1000	11.38	5.93
UL2000	9.72	4.10

The result can also be presented in the chart in Figure 6 below:

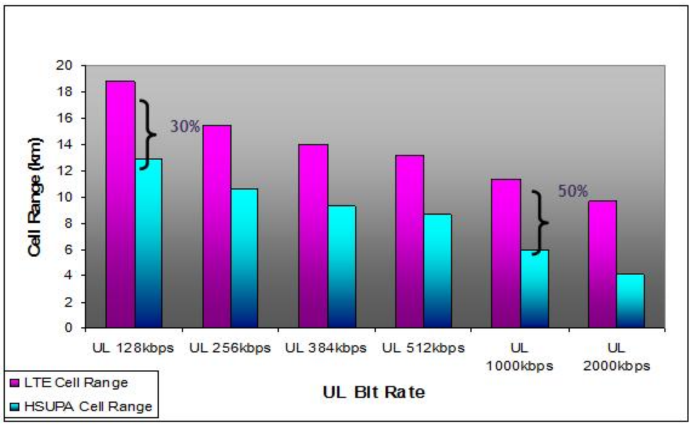

Figure 6 UL cell range LTE 700 MHz toward HSPA 900 MHz.

The study results showed that with a distance of 9 km, UL bit rate at the edge of the cell to 700 MHz LTE is 2 Mbps for whereas HSPA only 384 kbps. For UL greater bit rate equal to 1 Mbps, the LTE cell range 700 MHz is much greater than 900 MHz HSPA. The difference reached 50%. In general, it could be concluded that LTE 700 MHz provides greater range of cells from HSPA UL 900 MHz on the same bit rate.

In Figure 6, the cell radius of LTE 700 MHz had 30% more efficient than HSPA 900 MHz in uplink bit rate 128 kbps and 50% in uplink bit rate 1 000 kbps. According to preliminary studies had been conducted, LTE FDD technologies operating in the frequency of 700 MHz would be feasible to be implemented to address the needs of 2 Mbps broadband service with a range of at least 9 km. Figure 7 shows the magnitude of the range of cells that could be obtained with the prerequisite UL data rate to be achieved at the edge of the cell and the type of configuration with user equipment (UE) specific.

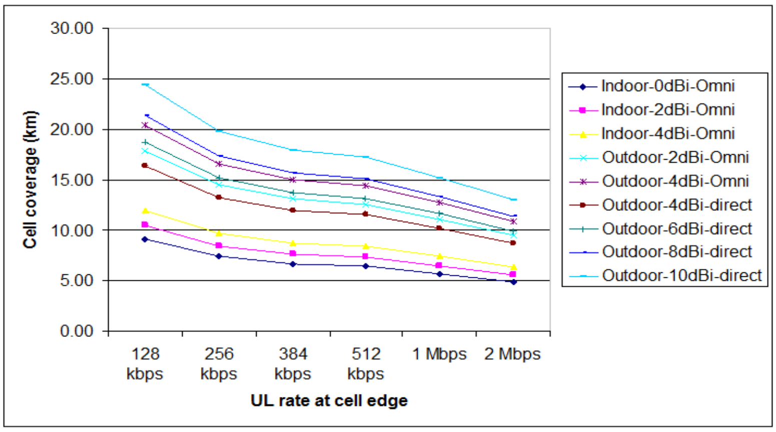

Figure 7 Influence of uplink rate (UL at cell edge) and the configuration of user equipment (UE) toward cell coverage.

From Figure 7 above, it was concluded that in case of eNodeB placed in the Capital of Sub-District to provide wireless broadband access services based on LTE FDD frequency of 700 MHz for rural areas within 9 km of Capital District, it would be appropriate to use UE with an outdoor antenna with minimum of 6 dBi directional gain.

3.2.2 Subscriber Capacity

In scenario 1, by comparing the capacity of base stations and user traffic, it can be determined number of users in one cell and one site as described in the Table 8.

Table 8 Number of subscribers With Scenario 1.

Technology	Cell Capacity (Subs)	Site Capacity (Subs)
HSPA	53	477
LTE MIMO 2 x 2	896	2688
LTE MIMO 4 x 2	968	2904

In scenario 2, by comparing the capacity of base stations and user traffic, number of users in one cell and one site can be determined as described in Table 9.

Table 9 Number of subscribers With Scenario 2.

Technology	Cell Capacity (Subs)	Site Capacity (Subs)
HSPA	36	324
LTE MIMO 2 x 2	731	2193
LTE MIMO 4 x 2	946	2838

3.3 Feasible Service Areas of Early Implementation of LTE 700 MHz in Indonesia

Based on analysis of the spectrum utilization of 698 - 806 MHz by Analog TV in Indonesia in Table 1 and Figure 4 above, assuming there would be no new Analog TV license would be issued in that particular sub-band, and 5 MHz guardband between LTE 700 and analog television, the feasible service areas of early implementation of LTE 700 MHz in Indonesia were described in the Table 10.

It is concluded that the 700 MHz band for Analog TV is heavily used in Java island and major commercial areas, while outside those areas, the 700 MHz is relatively unused. Out of total 33 provinces, the 700 MHz spectrum is idle in 14 provinces, and less than 5 channels are occupied in other 12 provinces. In other words, guard band requirements can be met in those areas. Therefore, LTE 700 MHz can be easily deployed in those 14 provinces without having to complete the transition to Digital TV first, while deployment in another 12 provinces would be still feasible with the need of very careful technical limitation and arrangement to minimize interference.

Table 10 Feasible service area of early implementation of LTE 700 MHz.

Provinces	Available Bandwidth For LTE	Uplink Frequency	Downlink Frequency
D.I Aceh	2x45 MHz	703-748 MHz	758-803 MHz
Riau	2x45 MHz	703-748 MHz	758-803 MHz
Bengkulu	2x45 MHz	703-748 MHz	758-803 MHz
Lampung	2x45 MHz	703-748 MHz	758-803 MHz
Kalimantan Barat	2x45 MHz	703-748 MHz	758-803 MHz
Kalimantan Tengah	2x45 MHz	703-748 MHz	758-803 MHz
Sulawesi Utara	2x45 MHz	703-748 MHz	758-803 MHz
Gorontalo	2x45 MHz	703-748 MHz	758-803 MHz
Sulawesi Barat	2x45 MHz	703-748 MHz	758-803 MHz
Sulawesi Tengara	2x45 MHz	703-748 MHz	758-803 MHz
Maluku Utara	2x45 MHz	703-748 MHz	758-803 MHz
Maluku	2x45 MHz	703-748 MHz	758-803 MHz
Papua Barat	2x45 MHz	703-748 MHz	758-803 MHz
Papua	2x45 MHz	703-748 MHz	758-803 MHz

4 Conclusion and Recommendation

This paper suggested the use of LTE 700 MHz as the most feasible solution to reduce digital divide in Indonesia. Other solutions shall be co-exists in geographical specific area or different market segment.

Performance measurements were conducted through conventional calculation and simulation that shows that within 9 km cell radius, the achievable UL bit rate at Cell Edge was 2 Mbps with LTE, and only 384 kbps with HSPA. LTE shows significant benefits for higher UL bit rate, more than 50% better cell range performance for UL bit rate more than 1 Mbps. If eNodeB located in the center of sub-district to provide wireless broadband access services based on LTE FDD frequency of 700 MHz for rural areas within 9 kms of Capital District, it would be appropriate to use UE with an outdoor antenna with minimum of 6 dBi directional gain.

In this study, we found out that from total of 33 provinces in Indonesia, the 700 MHz spectrum is totally idle in 14 provinces, and less than 5 channels occupied in other 12 provinces. In other words, guard band requirements can be met in those areas. Therefore, we believe that in order to facilitate and fasten the implementation and roll-out of broadband plan in Indonesia particularly in the above mentioned areas, the early implementation of LTE 700 MHz would be very important and recommended.

For further study, it was recommended to conduct detail of LTE 700 MHz Digital Dividend implementation started from several areas outside Java island. It would be worthwhile also to further study the relationship between the LTE 700 MHz Digital Dividend implementation with the acceleration and widespread of broadband developments, as in case of Indonesia, this broadband plan target was already stipulated in the master plan of accelerating economic growth in Indonesia and the medium term of national development plan year 2010 - 2014.

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