Analysis of Mobile Spectrum Management in Thailand to Move Towards a Knowledge Based Economy: A Regulatory Review

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***Abstract*—The objective of this study is to analyze and determine the challenges on transition from 3G to 4G while incorporating the lesson learnt from the 3G auction. This paper provides a brief picture of the Thai telecommunications industry in terms of the extent of liberalization it has undergone. Qualitative case study method is adopted where a variety of credible secondary sources are applied in this research focusing on evidence-based approach. The qualitative research provides an overview of Thai mobile market and a brief account of its development. This paper further discusses the current changes brought about by the 2.1GHz 3G auction on the traditional concessionaire regime. It is followed by discussion on spectrum management challenges in the current Thai regulatory regime. In doing so, the pros and cons of some key regulatory issues are discussed and analyzed by taking into account both national and global viewpoints.**

***Index Terms*—spectrum management, concessionaire regime, licensing regime, telecommunication regulation**

I. Introduction

Mobile communication has had a bigger impact on mankind in a shorter period of time more than any other invention in the history of mankind. It not only empowers individuals but has had important cascading effects as evidenced in exponential growth of new technological devices, birth of new forms of business and increase in productivity afforded by new innovative solutions as seen in global economy.

However, unlike developed countries where mobile communications have added value to legacy communication systems and have supplemented and expanded existing information flows, developing countries are following a different path. Developing countries are increasingly well situated to exploit the benefits of mobile communications due to the fact that levels of access are high and rising and that the mobile sector has become a significant economic force in developing economies [1]. Contrary to developed countries that have adequate and outstanding geographical reach in terms of their fixed broadband, the void in inadequate geographical reach on fixed broadband can be fulfilled by mobile broadband instead. Hence, developing economies stand to gain more from mobile broadband than developed countries.

The mobile wireless landscape is undergoing a transformation and is an infrastructure supporting economic growth and innovation in wide-ranging, consumer-focused areas such as health care, public safety, education, and social welfare. Ensuring that sufficient spectrum is available to satisfy the growing demand for mobile broadband services is a global challenge [2]. Global mobile data traffic will increase 13-fold between 2012 and 2017 and there will be over 10 billion mobile-connected devices in 2017 [3].

Thailand is not an exception to such global trends. The number of Thai mobile users was expected to grow from 3,959 million Baht in 2010 to 5,799 million Baht in 2011, representing growth from 8.8 to 11.6% of the total market value of the software industry. The growth rate in this sector is expected to be more than 30% per annum [4]. An expansion of network capacity to accommodate exponential growth of mobile and internet traffic will call for an upgrade of 3G networks to Long Term Evolution (LTE), the so-called 4G networks which are already deployed in many countries. The roadmap to the early deployment of 4G networks may be difficult for Thailand, and particularly the NBTC, because many issues have to be taken into account, not only technical but also regulatory issues.

The objective of this research is to determine the challenges on transition from 3G to 4G networks while incorporating the lesson learned from 2.1 GHz 3G auction conducted in Thailand in October 2012. Further this reveals regulatory challenges NBTC has to undergo for Thailand's transition from 3G to 4G networks. This paper provides an analysis of the extent that Thailand can respond to the challenges in implementing 4G networks, in terms of potential spectrum to be assigned for 4G deployments.

Manuscript received May 30, 2013; revised July 31, 2013.

doi: 10.12720/joams.1.3.288-298

II. Literature Review of Thailand and its Market Structure

A. Facts and Figures

Thailand is located in South-East Asia, and is one of ten of ASEAN countries. In 2011, it had about 68 million inhabitants; the percentage of urban population is 36 percent [5].

As for economic data, Thailand's GDP per capita has increased more than two-fold since 1994 (166,769 THB in 2011) [5]. Though facing political turmoil, and significant flooding in 2011, the Thai economy is forecasted to rebound at a growth rate of 5.5 percent (within a range of 5.3 - 5.8 percent). "Public consumption and public investment still play important roles in boosting economic recovery" [6].

The contribution of the ICT sector to GDP is still very low in percentage terms. It was only 1.62% in 2008, 1.6% in 2009 and 1.48% in 2010 [7]. The decreasing numbers may have been caused by several factors, among them low investment and constraint in spectrum supply in telecommunications sector brought about by concessionaire regime.

There is a strong correlation between the development and maturity of a country's ICT infrastructure and economic growth [8] and this correlation more prominent in emerging economies. The ICT Development Index (IDI) is measures national ICT development, progress in ICT development and Thailand has increased its IDI score from 3.03 in 2008 to 3.41 in 2010 but it is still lower than the average for developing countries. Moreover, Thailand's global ranking in terms of IDI has fallen from 80 in 2008 to 92 in 2011 of 153 nations [8].

B. Telecommunications Market Structure

In the past, telecommunications services in Thailand were provided exclusively through two state enterprises, i.e. TOT and CAT. The TOT's primary responsibility was to provide domestic telephone service while the CAT focused on international services. Prior to 1997, the ownership of spectrum lies with the government. Before NTC's existence, state-owned CAT and TOT were authorized to issue licenses to incumbents to use the spectrum license. After the Parliament enacted a new Constitution of Thailand in 1997, article 40 states that spectrum are "national assets and should be used for the benefit of the public and not for any specific government agency". The structure of the market is constrained by the legacy concession contract arrangements, which have been in place for many years – long before the existence of the NBTC and its predecessor the NTC. Therefore, the spectrum ownership was transferred from being state-owned or specific government agency owned to being rightfully owned by the general public. After 1997, TOT had formed a concessionaire agreement to allocate frequency block of 17.5 MHz of 900 MHz spectrum to AIS for provision of telecommunications services. CAT had formed concessionaire agreements with DTAC, True and DPC. DTAC has 10 MHz of 850 MHz and has 25 MHz of upper band and 25 MHz of lower band of 1800 MHz, True has 12.5 MHz of 1800 MHz spectrum and DPC 12.5 MHz of 1800 MHz spectrum. Additionally, DTAC is not permitted to use 25 MHz of upper band of 1800 MHz unless 10 MHz of 850 MHz spectrum and 25 MHz of 1800 MHz are not utilized at a full capacity. Today, the Thai telecommunications industry features the most complex environment in the world with two main incumbent public operators (CAT and TOT) and three main large private mobile or mixed operators (AIS, DTAC and TrueMove). The private sector could only operate within the industry if they worked in conjunction with one of the state enterprises through collaborated partnership in form of Build-Transfer-Operate (BTO) contracts. Mobile operators in Thailand including AIS, DTAC, True Move and DPC all operate under this type of contract, started during early 1990s with the terms of 25-27 years (end 2013-2018)

In 2000, to comply with the provision of constitution in relation to allocation and management of frequency, the Parliament enacted the Act on the Organization for Allocation of Frequencies and for Supervising Radio and Television Broadcasting and Telecommunications. The Frequency Allocation Act came to force on 8th March 2000. This had led to the establishment of National Radio and Television Broadcasting Commission (NBC) and National Telecommunications Commission (NTC). As a result of the National Frequency Masterplan to be created jointly by NBC and NTC, the government's monopolistic role in frequency allocation will be eradicated. Due to a political hindrance, NBC could not be formed therefore National Frequency Masterplan could not be created, hence NTC alone without the existence of NBC is not authorized by law to allocate frequency. While spectrum demand has been exponentially increasing simultaneously for vital industries including broadband, telecommunications and broadcasting, spectrum supply could not be injected into these industries since 2000 due to legal constraint arising from the absence of NBC. While the demand for spectrum has been increasing at an exponential rate, Thailand has been experiencing artificial spectrum scarcity due to its complex telecommunication industry. As spectrum has not been injected into the Thai telecommunications industry since 2000, Thailand has faced unnecessary constraints which impeded the development of its telecommunications industry, resulting in a primitive telecommunications industry in comparison with other countries worldwide.

Present day, the Radio Frequency Allocation Act (2010) redefines NTC and NBC by requiring them to consolidate into one whole and authoritative organization called National Broadcasting and Telecommunications Commission (NBTC). The NBTC has full rights to allocate spectrum under the legislation and the 11 board members of NBTC elected in October 2011 are authorized by law to process and create the National Frequency Allocation Masterplan, Telecommunication Masterplan and Broadcasting Masterplan. Therefore the spectrum auction of 2.1 GHz for 3G services was commenced on 16th October 2012. Particularly before the 2.1 GHz auction, the structure of the mobile market has been constrained by legacy concession contract

arrangements as mentioned above. Six (6) mobile network operators are in place with AIS, DTAC and TrueMove having major market share. The structure prior to 2.1 GHz distorted the regulatory and market incentives for new entry and hinder further investment and development By number of network operators, Thailand is not extremely competitive, although liberalization was introduced to the Thai market in 2005.

C. 2.1 GHz 3G Auction Design: Liberalization of the Thai Telecommunications Industry

The 3G auction concluded on 16th October, 2012 was the first milestone towards transforming Thailand's mobile telecommunication industry from concessionaire regime to a more liberalized market-based licensing regime. In designing the auction method and setting up the guidelines for the auction, NBTC has used and applied the guidelines set by the International Telecommunications Union meeting on the topic of Licensing of Third Generation (3G) Mobile which was in Geneva from 19-21 February 2001. The meeting involves a discussion of variety of topics including significant aspects such as issuing license, technical aspects on telecommunications. Prior to the auction design, NBTC acknowledges that the objective of most spectrum auction is threefold. The objective of any auction is 1) spectrum efficiency, 2) the outcome of the auction should stimulate competition resulting in beneficial and healthy rivalry within telecommunications industry 3) encourage entry to induce effective demand and supply leading in optimal prices and benefits incurred to consumers from competitive market structure and lastly 4) maximum auction revenue without compromising other auction objectives. Therefore measures and standards that NBTC has set for the auction complies with international standards that promotes transparency and mitigates risks of unfairness. The 2.1 GHz auction was conducted for IMT2000/IMT advanced services and the number of operators remains unchanged since the three licensees were awarded to Advanced Wireless Network, DTAC Network, and Real Future, which are subsidiaries of the three largest operators, AIS, DTAC, and True Move, respectively. Further the auction design for 2.1 GHz spectrum auction is explained in this section.

1) Flexible packaging

The total of 2.1 GHz spectrum auctioned was 45 MHz. The 45 MHz of spectrum were divided into 9 slots of 5 MHz spectrum. All bidders that are participating in the auction of 2.1 GHz were permitted to bid for no more than 3 blocks of 5 MHz spectrum so spectrum cap is set at 15 MHz. Flexible packaging of spectrum provides an opportunity for small players or new entrants that need lesser than 15 MHz to have the chance to bid and compete in the telecommunications market. By dividing the spectrum into small blocks to motivate both large and small players, it accomplishes the main purpose of an auction which is encouraging competition within auction process and also in the telecommunications market after the auction has already taken place.

2) Reserve price

Reserve price in a spectrum auction is the minimum acceptable payment the government should tax such that it reflects the spectrum value. As a protocol in all auctions conducted globally, a reserve price must be set to deal with the possibility of low bidding competition. NBTC and the researchers are in agreement that the reserve price or floor price should be set such that it ensures that NBTC at least earns the applicable value required for the spectrum. If the reserve price is not set, NBTC may not earn a deserving value for the spectrum hence; reserve price should eliminate the possibility of attaining spectrum for anti-competitive purpose by ensuring it is utilized efficiently by winners who will be motivated to earn more than the value paid for the spectrum. However, it is pertinent that the reserve price is at an optimal level and should not be set at an extremely high value because a skyscraping value can also discourage even incumbents that are determined to use the spectrum efficiently. Therefore, reserve price set must reflect the spectrum value as if too low, the nation is at a disadvantage and if too high the general public is at a disadvantage by not being able to utilize the best possible service that can be achieved from the spared spectrum not assigned by the auction. High reserve prices set for the purpose of generating high revenue for the spectrum increases the risk that all of the available spectrum may not be assigned.

"Valuation is often instrumental in determining threshold or reserve prices in spectrum auctions or tender processes, and bidders can be expected to estimate spectrum value in designing their bidding strategies" [9]. The spectrum value for 2.1 GHz was calculated by economists in Chulalongkorn University where a value of 6440 million per 5 MHz was concluded. While the economists at Chulalongkorn University recommended that the floor price or reserve price should not be lesser than 67% of the spectrum values, the board of NBTC have agreed to set the reserve price at 70% of the spectrum value calculated hence, 70% of Bht 6440 million per 5 MHz is 4500 million per 5 MHz of spectrum. Therefore, reserve price is BT 4500 million per 5 MHz of spectrum.

3) Artificial spectrum scarcity

Sometimes spectrum scarcity is imposed artificially particularly to limit the number of mobile licenses to fewer than what is permitted by amount of spectrum available. "Limiting the number of spectrum licenses might be to gauge incrementally the number of operators to reach the optimum level of competition, controlling the risk of excessive network overbuild and fragmentation. (N-1) is imposed only in this case" [10]. Although N-1 is an auction tactic to increase competition within the auction in order to earn highest revenue possible for the spectrum, it can have drastic and unwanted effect on the competition after the auction has ended. Particularly in the case of Thailand, mobile communications is served by three big operators including AIS, DTAC and TrueMove. Due to the oligopoly market structure, if N-1 is applied in a market with three giant operators it could result in only two giant competitors competing against each other as a

result of the auction outcome. The worst case scenario could be that consumers will have only two giant operators to choose from for the next 15 license period years. As a consequence, this will result in unhealthy competition where consumers' choices of operators and services are limited, which can further lead to monopolistic behavior. Although the auction design had made it easier for entry of new entrants, there were only three bidders which are AIS, DTAC and TrueMove, hence if n-1 were to be adopted, it could have resulted in a duopoly market structure which will hinder innovation and consumer benefits.

4) Spectrum cap

According to ITU, "Spectrum is adopted to preclude spectrum hoarding and some governments have imposed caps on the size of individual operators' spectrum holdings" [10]. NBTC 2.1 GHz working group came to an agreement that spectrum cap of 15 MHz is appropriate especially when auctioning 45 MHz of spectrum in total. As Thailand currently has three big operators within the market as mentioned earlier, if 20 MHz spectrum was to be permitted it could result in two giant operators buying 20 MHz each and leftover of 5 MHz is not enough for quality 3G services for consumers. Spectrum cap at 20 MHz could be seen as a strategy to create higher barriers for small operators that are not financially capable of competing with large operators. If two incumbents can bid for 20 MHz each summing up to 40 MHz, 5 MHz will be left for the third operator thereby leading to unfair competition as the quality of service provided by the operator with 5 MHz will be worse than the others. License period of 15 years also makes it extremely difficult to increase competition after that occurs. On the other hand, it can be argued that three bidders do not have to compete as 3 blocks of 5 MHz is equivalent to 15 MHz for each operator. However, we expect competition for the most optimal slot that requires the lowest investment hence, competition within the auction is was expected.

5) Spectrum price

Thailand has not injected the supply of the spectrum since 2000. Auction design is not one fits all, but should be designed explicitly to achieve results that are beneficial to the general public. The first priority of the 2.1 GHz spectrum auction is to ensure all of the spectrum must be assigned to support the exponential demand for mobile broadband. Developing countries such as Thailand that do have sufficient national coverage in terms of fixed broadband stand to gain more from mobile broadband than developed countries. Therefore, the first priority of this spectrum auction is to assign all available to fulfill the demand from the general public. According to ITU, under these conditions, spectrum auctions should be implemented for the further of expanding the capacity of the telecommunications services and should be less driven to focus on taxing highest revenues and more focused on maximizing the use of the available spectrum as an asset to increase economic benefit for the general public [10]. "The emphasis would be on efficient allocation of a scarce resource for the purpose of alleviating network bottlenecks." [10]. Further Roberto Viola, President of Radio Spectrum Policy Group (RSPG), states that "in presenting spectrum policy, we should look at what is the ultimate goal of allocating spectrum. When thinking especially of telecoms and broadcasting, the ultimate goal is not to make money with the award of licenses, as sometimes the financial value of spectrum seems to imply, but to make sure that our broadband communication system works efficiently along the entire value chain and supports the whole economy." Countries that have collected high revenues in terms of per price per MHz per pop such as India and Thailand are expected to undergo a massive expansion in data services both in capacity and penetration. The recent 2.1 GHz spectrum auction shows that there is great variability in auction prices of spectrum which is dependent on a wide variety of complex market and technical conditions. "Such conditions also influence the degree to which economic rent, efficiency of distribution, advancement of broadband access or other policy objectives best govern the design of an auction process." [10]

Therefore as stated by ITU, "it may be more important in evaluating the success of spectrum auctions to focus on qualitative aspects (benefits to industry and impact on economic growth and social development) rather than on the revenue collected from the auction" [10]. "If revenue benchmarks were the primary measure for determining a success rate, then India and Thailand might be considered as relatively successful in their recent 2.1GHz auctions." The assignment of all licenses has deemed 2.1 GHz 3G auction in Thailand as having achieved its main objective. Thomas W. Hazlett supports by stating "High auction prices are reported to be the sign of a successful auction. While this is clearly true for a private asset owner, the sale of government-created licenses is another story. Wireless licenses are inputs into businesses providing services to the public." [11]. Bloomberg further extends that excessive prices of auctioned frequencies have translated into excessive charges for fast mobile internet" [12]. Therefore, the optimal price per MHz per pop in Thai auction is due to the massive data growth expected in telecommunications however, if prices were to be higher, it could translate into negative consequences for the general public.

III. Methodology

The research methodology adopted in this study is qualitative case study research to explore the lesson learned from Thai 3G auction, evaluation of its auction design and regulatory challenges of transitioning from 3G to 4G networks. This type of research methodology facilitates exploration of a subject by using variety of data sources [13]. This ensures that the issue at hand is not explored through one source but through variety of sources allowing multiple views of the subject to be revealed and understood. This case study sources data from secondary sources and expert input focusing on adopting the evidence-based approach. The evidence based approach is such that information within this research is sourced from variety of credible sources and further analysis is conducted.

IV. Analysis

A. Moving towards 4G Mobile Networks: Key Considerations

Much research has found a positive relationship between broadband penetration and economic growth, particularly in developing countries [14]. Mobile broadband has a higher impact on GDP growth than fixed broadband, because of the reduction of inefficiencies [15].

The delay of 3G network deployments resulted from the flaw posed by the concessionaire regime which led to complex legal obstacles resulting in Thailand lagging behind many countries in terms of telecommunications network developments. A relatively high mobile phone penetration rate (126% in 2012, comparing to 116% in 2011) together with high ICT usage will evolve progressively toward increased access to mobile data. By 2015, it is expected that approximately 40% of the population will be able to connect to the Internet, mainly through mobile, up from about 27% in 2012. This creates a sizeable opportunity for mobile device vendors, network equipment vendors (in particular 3G, LTE, small cell and Wi-Fi hotspots) and applications providers.

From analysis of 3G and 4G auctions around the world, spectrum is a scarce resource which is critical to the development of industries vital to a country's development and advancement. Governments should tax for spectrum in order to convey to incumbents the value of spectrum to eradicate the possibility of spectrum being used inefficiently or hoarded for anticompetitive purposes. However, a leading priority of any spectrum auction is to ensure healthy competition still exists after the spectrum auction outcome. Further the utmost priority that cannot be compromised for the sake of auction revenue is that all spectrum blocks should be sold in order to ensure that spectrum available is fully injected into critical industries to serve the general public and further develop the country.

After 2.1 GHz auction completed in Oct 2012, 3G is expected to be deployed as a commercial service from middle 2013 onwards. Increasing Internet traffic as a result of high usage will soon lead to the necessity of having a new high capacity mobile network, 4G in particular. Moving towards 4G networks in Thailand, either LTE or LTE-Advanced, needs careful considerations and long term planning. According to the ITU (2012a), the four essential and interrelated dimensions that are needed to support mobile technologies are: spectrum, marketplace, technology and regulatory [16]. This paper addresses spectrum and marketplace dimensions in detail.

Since 2000, the first family of standards derived from the IMT concept – IMT-2000 (commonly referred to as 3G), has been introduced by the ITU.

"Pursuing its initiative to lead international efforts to produce global standards for mobile communications, ITU's Radiocommunication Sector (ITU-R) completed in 2011 the assessment of candidate submissions for the next generation global mobile broadband technology, otherwise known as IMT-Advanced".[10] IMT-Advanced brings major improvements, including, but not limited to, "increased spectrum efficiency – more users at higher data rates per radio channel and fully packet-based architecture – reduced costs, comprehensive support for broadband wireless data, and lower latency" [10].

Among the critical technical features of IMT-Advanced technologies, the frequency allocation improvement is particularly important. With the conclusion of the WRC 12, a three-year period of debate, the frequency bands for IMT services have been identified

Though a wide range of spectrum bands are identified for IMT services, availability of spectrum may become a bottleneck to the development of mobile broadband networks in many countries, for several reasons [1].

- *Cost-efficient technologies:* Technologies are designed to be more efficient in specific spectrum bands. To facilitate rapid network deployment, operators need spectrum that is technically adapted to the most cost-efficient mobile broadband technologies. International harmonization provides the benefits of economies of scale for the provisioning of network equipment. As a result some bands are much more commercially attractive than others. If operators have to opt for other less efficient options, which can result in more limited investments or no investments at all.
- *Availability of quality spectrum:* operators need spectrum bands that are most effective for deploying mobile broadband technologies. Particularly, "LTE can operate in multiple frequency bands, but the lower bands (such as700 and 800 megahertz, or MHz) can be more cost-effective, allowing for both wider coverage from fewer radio base stations (an important consideration for rural area deployments) and higher powers to support building penetration (an important consideration in urban areas)" [17]. According to ITU report, 700 MHz is proving to be most effective for deployment in rural or high-cost regions. It is also economically viable – an LTE network at 700 MHz would be 70 per cent cheaper to deploy than an LTE network at 2.1 GHz (GSM Association). Two to three times fewer sites are required for initial coverage at 700 MHz as compared to 2.1 or 2.5 GHz bands [16].
- Third, blocks of spectrum must be sufficiently large to allow cost-efficient provision of mobile broadband, with multiple operators. LTE allows operations with different-sized blocks of spectrum (from 1.4 to 20 MHz); the size of the spectrum blocks and the pairing of frequencies determines the maximum broadband speed and the cost of deploying mobile broadband networks based on this technology. Because data traffic and bandwidth are growing rapidly, "operators may need larger blocks of spectrum to cope with demand and avoid congestion, particularly in urban areas" [17]. To minimize bottlenecks in the availability of spectrum, policy-makers and

regulators should assess spectrum needs and available cost-efficient technologies and release to the market spectrum of suitable and sufficient quality for these technologies. Spectrum needs may differ from country to country due to different market environments. However, with increasing internet traffic and demand for bandwidth, many studies have been conducted with different methodologies to estimate spectrum bandwidth requirements for IMT service:

- A study by the ITU in 2006 (ITU-R M.1078) estimated total spectrum bandwidth requirements ranging from 1,280 MHz to 1,720 MHz (including spectrum already used, or planned to be used), which represented a lower and higher market setting as developed from the data in report ITU-R M.2072. It should be noted that the lower figure (1,280MHz) is higher than the anticipated requirements for some countries which may have a need for less additional spectrum. In addition there are some countries where the requirement is larger than the higher value (1,720 MHz).
- A study by the ITU in 2012 also suggests allocation targets for wireless spectrum until 2020 for Asia Pacific region. It is recommended that the minimum spectrum allocation for cellular mobile services should be at least 760 MHz by 2020 and preferably 840 MHz. However, many countries in the Asia region are significantly below this target [9].
- A study by FCC in 2010 stated that mobile data demand will exhaust spectrum resources within the next five years. As existing US spectrum allocations are currently comparatively low, the paper goes on to state that a spectrum deficit approaching 300 MHz is likely by 2014 and that the benefit of releasing additional spectrum is likely to exceed USD 100 billion. To this end the FCC asked to look at more spectrally efficient ways of providing the distribution of TV broadcast services using wireless broadband.

As for Thailand, to deploy 4G network, currently there are two major concerns on spectrum allocation. Firstly, most of frequency bands which are identified for IMT services by ITU are not available.

Most of frequency bands are assigned with different expiry dates. Approximately, the amount of 50 MHz in 1800 MHz will be released in September 2013 due to its license expiration which creates an opportunity for 4G assignment. Secondly, apart from expiry date issue, There is inconsistency between ITU suggested bands and Thailand allocation, in particular 700 MHz and 2.6 GHz.

- 700 MHz: currently, this frequency band is allocated to broadcasting service. Given the fact that the passing of a Royal Thai Government Gazette in December 2012 allowing allowed digital broadcasting in the 510-790MHz band by adopting DVB-T2 standard, no official confirmation has been provided on how the band will be used after analogue switch off.
- 2.6 GHz: this frequency band has been assigned to MCOT and is utilized for MMDS technology. However, MCOT, a broadcast company, is a not a 100% privatized company and a large part of its shares are held by the Ministry of Finance (MOF), negotiations for the return of the spectrum has proven to be extremely challenging.

LTE trial was approved on 2.3 GHz by the NBTC: TOT partnered with its concession holder AIS to trial 2.3GHz LTE TDD in 20 MHz of its total 64 MHz allocation, using 20 base stations in central Bangkok. Digital Phone Co joined with CAT Telecom to test LTE1800 from mid-January 2012 in Mahasarakham. Additionally, Softbank has formed a partnership with TOT which will focus on joint development of a 2.3 GHz LTE TDD network using TOT's bandwidth. It is likely that the LTE network will be used for mobile backhaul for Wi-Fi access points and mobile cell sites.

B. Regulatory Aspects

Regulatory aspects are vital for mobile broadband deployment. Though the regulatory framework is under national jurisdiction, it is unavoidable to raise regulatory concerns at the global level due to seamless and borderless connectivity resulting from Internet connectivity. At the Global Symposium for Regulators 2005, a set of best practice guidelines for spectrum management to promote broadband access were drafted. Many regulatory issues regarding IMT services have been addressed in [1] and [9]. Some major issues affecting the development of mobile broadband network in Thailand are raised:

- *Harmonization:* In order to encourage growth and rapid deployment of infrastructure and services, adopting harmonized frequency plans defined by ITU-R recommendations is an important issue. To make spectrum available for affordable wireless broadband services, spectrum bands assigned should harmonized with global or, at least, regional standards in order to get cost-effective deployment and facilitate global roaming. Though developing countries are emerging economies with specific needs, to deploy mobile broadband networks in spectrum bands that are not compatible with global standard would result in a high cost of network deployment and spectrum waste.

As a member of ITU, Thailand has followed ITU-R to ensure compatibility and harmonization unless there have been some legal difficulties at the national level. For example, the decisions from WRC-2000 on 2.6 GHz and WRC-12 on 700 MHz to be allocated for IMT services, though these two bands are crucial for mobile network development and are deployed in many countries; due to the complex concessionaire regime, it will be a challenging to assign those two bands for IMT in Thailand.

- *Spectrum assignment method:* There are several methods for awarding spectrum rights, the most common ones being auctions such as the 3G and

4G auctions held in many countries, beauty contests such as spectrum assignments in Japan and Myanmar, and hybrid methods of these two such as in Chile, Germany or Sweden. Although auctions are generally considered more efficient than beauty contests, auction designs aimed at increasing up-front revenues for the government do not achieve the highest social welfare benefits (Hazlett and Munoz 2008, 2010). High up-front spectrum costs may limit the capital available for operators to invest in coverage beyond the most affluent areas (EC, 2002; Delian, 2001; Bauer, 2002) . In addition, for developing countries, it may not be possible to use an auction as the process for determining the price for spectrum. Proposals for the pricing of, for example, 3G or 4G spectrum should be consistent with global and regional benchmarks. Some countries may need to use benchmarking studies to determine appropriate prices for 3G or 4G spectrum [9].

The award of spectrum licenses in Thailand is restricted only to auctions. This restriction is stated by the Act on Organization to Assign Radio Frequency and to regulate the Broadcasting and Telecommunications Services B.E. 2553 Section 45 in which it is stipulated that:

Any person who wishes to use spectrum for the purpose of telecommunications business operation shall obtain a license under this Act by means of *spectrum auctions* in accordance with the criteria, procedures, duration, and conditions as prescribed by the NBTC

Since this law came into force, the 3G auction for 2.1 GHz spectrum in October 2012 was the first auction under this law in Thailand. Issues regarding bidders, spectrum pricing and transparency have been criticized by the public, though the auction design and processes were set out clearly. As a result, the restriction on method stipulated under the law is questionable, as is whether it could give utmost benefit for network deployment under current market environment and regulatory practices. This issue is not discussed in this paper but it is a good example to be reviewed by legislators if 4G networks are to be deployed, because the same problems may be repeated.

- *Spectrum sharing:* Since spectrum is a scarce resource but which has increasing importance in mobile broadband environment, one of the best practices for Spectrum Management to Promote Broadband Access suggested by GSR (GSR, 2005, 2008) is to adopt flexible measures for the use of spectrum for wireless broadband services, i.e., spectrum sharing.. Though spectrum-sharing models are fairly diverse worldwide, its implementation can be seen in some countries, such as, Brazil for 3G network deployment and Sweden for LTE deployment.

To encourage deployment by promoting spectrum sharing is not impractical due to legal hindrance. Under the Act on Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services B.E. 2553 Section 46, it is stated that:

Section 46A spectrum license for telecommunications business is the exclusive rights of the licensee and is not transferable.

The licensee who has been authorized to use spectrum for telecommunications services shall carry out the services by himself or herself. Business management either in whole or in part shall not be rendered or permitted to other to act on his/her behalf.

A reason behind the statutory restriction is to prevent the resurrection of the old concession regime employed in the past. However, it does not attract new entrants to enter into the market and in fact hinders the deployment of mobile broadband networks.

- *Imposing spectrum caps*: In order to ensure a level playing field, consideration should be given to imposing spectrum caps and to creating rules to avoid spectrum hoarding by one or two major mobile operators, taking into consideration the total frequency owned by the mobile operators for LTE and broadband. Spectrum caps are a mechanism used by regulators in a number of foreign jurisdictions to improve market competition, secure benefits for users, and avoid hoarding of spectrum. Such markets include Asia as well as Australia, Europe and North America. For example, operators with a disproportionate share of 900/1800 MHz spectrum should be precluded from securing more than 20 per cent of future 2.3 and 2.6 GHz spectrum auctions unless they are willing to hand back and/or trade existing spectrum blocks. Likewise a single operator should not be entitled to hold more than one-third of the major cellular spectrum band allocations (i.e. in the key IMT bands – namely700, 800, 900, 1800, 2100, 2300 and 2600 MHz spectrum bands) [9].

Imposing a spectrum cap regime has been reviewed and discussed by the NBTC (and the NTC) for many years; however, spectrum caps have not yet been imposed on any operators on total spectrum but have been imposed in the 2.1 GHz auction design. A difficulty in implementing such a regime comes from the past concession arrangements and monopoly structure, in which privates operators were not allowed to provide telecommunications services on their own, therefore, most spectrum in UHF bands is owned mostly by government institutions today.

C. Technology Aspects

There are many bands in the Radio Regulations that are primarily allocated for mobile communications but which are not available for mobile broadband applications because they are not compatible with available equipments. Compatibility of spectrum bands with equipments available, create economies of scale and lead to lower-cost devices. In order to create these ecosystems, an identification of spectrum for IMT is required.

Consequently, international "mature" spectrum bands - for example, the GSM bands (900 and 1800 MHz), or W-CDMA (2100 MHz bands) bands where there are multiple vendors offering network infrastructure and equipment, are typically more valuable than undeveloped or new spectrum bands where the future availability of network infrastructure and consumer devices is dependent on extensive research and where the cost-intensive design, testing, and production of new components and facilities is still needed [9].

Because this is the same for LTE, to assign any bands for LTE deployment, considerations should be given to the ecosystem of that band to make sure that regulatory decisions will facilitate network deployment and encourage investment. As a result of the World Administrative Radio Conference, a wide range of frequency bands are identified for IMT services. However, not all bands are cost-effective deployment LTE deployment.

Nevertheless, where cost considerations warrant the installation of fewer base stations, such as in rural and/or sparsely populated areas, bands below 1 GHz are generally suitable for implementing mobile systems including IMT. Therefore, given the fact that the frequency band 470-806/862 is allocated to the broadcasting service on a primary basis, studies will be taken to study the compatibility between the mobile service and other services currently allocated in the frequency band 694-790 MHz. The results of ITU-R studies, in accordance with Resolution 232 (WRC-12), on the use of the frequency band 694-790 MHz by the mobile, except aeronautical mobile, service in Region 1 will be examined in WRC-15.

According to the GCF report in 2013 (GCF, 2013), the 2600 MHz band and the 800 MHz European Digital Dividend band were the most frequently implemented LTE bands – with 31 and 30 devices respectively. The 2100 MHz band, which is being allocated to LTE in Japan and Korea, was the third most frequently implemented LTE band – with 20 devices. The 750 MHz band (US Upper SMH C band) was implemented in 19 devices while the 1800 MHz band, widely allocated to GSM operators across Europe, Africa, the Middle East and Asia and increasingly being re-farmed to LTE, was implemented in 18 devices.

It is interesting to note that there remain only a few devices which are certified for LTE in the 900 MHz band. However, in 2012, Telstra has sought to begin conversations with global chip makers, manufacturers and other carriers in the Asia Pacific to raise support for building devices that support Long Term Evolution technology over the 900 MHz frequency (IT news, 2012). Since then vendors such as Nokia have released LTE 900 phones.

Therefore, if a country plans to use the 900 MHz band for LTE technology, it may be hampered by the currently poor take-up by other carriers and lack of interest from other parties, resulting in a shortage of compatible devices, base band chips and mobile base stations equipment required to make it possible. However, within the next 6 months there will be clarity on the support of the use of this band for LTE.

V. Research Results

From previous sections, several issues need to be taken into account if Thailand is proactively facilitating the move toward a knowledge based economy which is underpinned by wireless broadband services.

A. A Proactive Plan for the Future

Like most developing countries, mobile penetration surpasses fixed line penetration in Thailand. While numbers of fixed line subscribers are decreasing, Internet users and number of mobile broadband have been increasing. The growth of mobile Internet is accelerated by two major factors: technological development whereby smartphones and tablets substitute for featured phones, and the rapid uptake of applications and content markets, in particular social networks. Thailand ranks number 1 of the most users in some social networks even though Thailand only has a population of 68 million people.

As social and economic development in the future will rely on more and more on telecommunication infrastructures, it is foreseeable that demand for bandwidth will drastically increase due to increase in Internet traffic. .

The total bandwidth which Thailand has is very low in comparison with ASEAN countries, for example, 735 MHz of Malaysia, 480 MHz of Indonesia, or 435 MHz of Cambodia in 2012. Those countries are now planning to release more frequencies to prepare for the demand of bandwidth and LTE networks in the future.

Although there is limited research on demand for spectrum in next 5 and 10 years for Thailand, a study by ITU for APT indicates that demand for bandwidth in APT economy can be ranged between 760 to 840 MHz in 2020 depending on the size of market. Advanced OECD markets are aiming for 1,000+ MHz allocation to wireless services.

Given the fact that some part of spectrum in frequency band 1800 MHz, 900 MHz and 800/1800 MHz will be released in 2013, 2015 and 2018 respectively, Thailand needs short-term and long-term strategic planning on how to deal with the released spectrum and how to secure more spectrum in other frequencies band such as 700 MHz and 2.6 MHz.

From ICT Development Index in 2011 (provided in Section 2), Thailand is rank number 5 among 10 ASEAN countries and another 5 countries behind Thailand are planning for wireless broadband economy. An early strategic movement to 4G network can support the national economy and economic growth; however, to get there without the delay which characterized the 3G spectrum allocation, a proactive plan which has the support of all stakeholders is needed.

B. Multi-Band Radio Frequencies and Harmonization

To deliver a nationwide mobile broadband

infrastructure in Thailand, a multi-band radio frequency strategy may be suitable due to the terrain. Given the fact that mountains cover most part of the northern region down to the southern region and some part of the northeastern region, to make broadband available for every people cannot rely solely on fixed network. Nevertheless, different frequency bands have different capability. Frequencies below 1 GHz have greater capacity in terms of coverage and need less radio towers while frequencies above 1 GHz have high penetration but need more radio tower to repeat signals. Six criteria are suggested to determine the optimal new spectrum bands: a) Signal propagation characteristics, b) Whether spectrum band is allocated internationally (or regionally) for a particular use, c) Availability of network equipment and consumer devices (including handsets), d) Availability of paired bands for uplink and downlink transmissions (assuming the band is to be used for FDD) or a large contiguous spectrum block if the TDD use is proposed (or single TDD band), e) Whether the band is cleared (or clean) of incumbent users, f) Need for coordination or other complex negotiations with other users and neighboring countries [18]. If applying those criteria to LTE case in Thailand, the scores on the preferred spectrum are detailed in Table I.

TABLE I. ANALYSIS OF PREFERRED SPECTRUM BANDS FOR LTE DEPLOYMENT (ADAPTED FROM ITU, 2012C)

Criteria	Frequency band							
	700 MHz	800 MHz	900 MHz	1800 MHz	1900 MHz	2.1 GHz	2.3 GHz	2.6 GHz
a) Signal propagation characteristics	1	1	1	2	2	3	4	6
b) Whether spectrum band is assigned internationally (or regionally) for LTE	2	2	3	1	5	4	2	1
c) Availability of network equipment and consumer devices (including handsets)	3	1	6	3	5	3	4	2
d) Availability of paired bands for uplink and downlink transmissions (assuming the band is to be used for FDD) or a large contiguous spectrum block if the TDD use is proposed (or single TDD band)	1	1	3	2	3	2	1	1
e) Whether the band is cleared (or clean) of incumbent users	3	2	2	1	2	2	2	3
f) Need for coordination or other complex negotiations with other users and neighboring countries	1	2	2	2	1	2	2	1
Total	11	9	17	11	18	16	15	14

The ideal score is set at 6, the 700, 800 and 1800 MHz bands are the highest ranking spectrum band to be allocated for 4G LTE systems. It should be highlighted any listing of any preferred bands for allocation needs to be considered in a holistic way. This is because the radio frequency plan of a cellular communication system revolves around two principal objectives, namely coverage and capacity. Coverage relates to the geographical footprint within the system that has sufficient radio frequency signal strength to provide for a call/data session while capacity relates to the capability of the system to sustain a given number of subscribers. In most systems, including 4G LTE systems, both capacity and coverage are interrelated. To improve quality some coverage and capacity has to be sacrificed, while to improve capacity, coverage will have to be sacrificed [18]. As such, to offer spectrum which comprises a mix of coverage and capacity, it can be done by using two frequency bands (e.g. 800 MHz and 2.3 GHz).

VI. DISCUSSION

In this study, we have demonstrated that in Thailand the complex telecommunications industry and the lack of real competition in the past have deterred real development in this industry consequently affecting end users. The most obvious major consequence resulting from a combination of legal challenges and dominant players have impeded Thailand's ability to bring about the 3G auction, which finally commenced about a decade after Japan.

The path towards liberalizing the Thai telecommunications industry will gradually transform the industry and bring about a complete form of market-based licensing regime. Under this new regime, radio frequency using for telecoms and broadcasting business will be allocated under market-based approach, i.e. auction for 2.1 GHz band. Pursuant to the liberalization concept, all sectors (incumbents, existing sectors, new entrants) will be treated equally under the similar regulation without any special privilege. This is expected to eliminate the preventable and uncalled-for uncertainty and challenges that impede the development in the Thai telecommunications industry hence, permitting elevating a faster transition into the 4G era.

Nevertheless, the analysis in this research suggests that the major issue to deploy 4G LTE in Thailand is spectrum availability. If optimal spectrum bands could be released, efficiency and effectiveness of 4G LTE deployment is not guaranteed anyway. This is caused by very restrictive legal regimes which make Thai mobile market less attractive to new entrants. Particularly, spectrum assignment method and unpermitted spectrum sharing are the major ones.

These two hindrances could decrease investor

confidence in LTE market and do not facilitate new business model for 4G LTE network. However, to remove those two main barriers are not solely within the ambit of the NBTC authority. Legislative changes are arguably needed and have a lead-time. In addition, strong supports from stakeholders such as Ministry of ICT, providers, manufacturers or NGOs are required.

Nevertheless, it does not mean that there is no hope for the market as there is competition among operators persists. Nevertheless, NBTC should take cautious steps where any decisions to be made require support from regulatory data and research.

VII. Conclusion

The issuance of 3G licenses in October 2012 proved a positive step in regulatory and policy frameworks, as private telecom operators' move away from concession schemes which have been prone to regulatory, policy and legal uncertainties. These include the pending reviews of concession amendments, tighter restriction on foreign-ownership laws and concession expiration.

Despite the fact that 3G networks on frequency band 2.1 GHz just have been deployed in Thailand in 2013, Internet traffic has been drastically increasing due to technological and market developments. The research results indicate that mobile network with greater capacity namely, 4G LTE is required and must be deployed quickly. As mobile network is an efficient solution to making broadband available throughout the country to fill in the void created from insufficient fixed broadband.

Thailand needs quality broadband network to integrate into the world economy and to increase national competitiveness. Sufficient availability of quality spectrum to deploy cost-effective mobile broadband networks must be ensured. In addition, harmonization and maintaining competition in the market must be considered.

Therefore, a proactive plan to release more spectrums for wireless services is necessary. Though fostering spectrum sharing and opening opportunity to assign spectrum through various methods can facilitate market innovation and attract new entrants, it is prohibited by law and makes Thai mobile market less attractive as a result hence, this seems to be the biggest challenge Thailand must face.

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