VALUATING COLLECTIVE USE OF SPECTRUM: THE CASE OF WI-FI IN THAILAND

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Abstract

In Thailand, the band of 2400–2500 MHz was initially assigned by the command and control approach to the fixed service for point-to-point or point-to-multipoint microwave link service. After that, the administrator/regulator decided to additionally allow everyone to use this band as collective use of spectrum (CUS) with some limitations. The major use for CUS is Wi-Fi service. The additional service will increase the benefit and value to society of this frequency. This paper estimates the value of this frequency by an original method. In order to valuate the use of the frequency for microwave link service and Wi-Fi service, the business model approach will be used to estimate the costs and revenues to provide these services including the licence fee, frequency usage fee, equipment cost, operating cost, installation and maintenance cost, etc. In particular, the possibility to extend the use of Wi-Fi service as complementary to the other existing telecom services including the fixed line telephone and cellular mobile phone will be investigated. This study will have implications for regulators, in particular to increase the collective use of spectrum, either as complementary or as additional services in other frequency bands.

Keywords

Wi-Fi, Business model, Spectrum valuation

1   INTRODUCTION

1.1   Approaches to valuating frequencies

In general, the value of a specific range of frequency depends on how many applications or services can be used in the same band. If they can share the same range, the value of spectrum can be the combination of their benefits. If there are some limitations in both technical and non-technical respects that preclude sharing the frequencies, a tradeoff between services needs to be faced. By comparing the value of selecting one service with that of denying other services, the higher-value service(s) should be chosen. In other words, the value of spectrum can be derived from the opportunity cost in terms of implementing or not implementing the services. The value of spectrum can be seen from the benefit and the cost of denying spectrum to alternative services by other spectrum assignments.

In order to address the opportunity costs, the value of spectrum in a specific range of frequencies can be valuated by its actual use from a supply and demand point of view, thus representing the opportunity costs from the society's point of view. The demand and supply surplus represents the society's welfare as a whole. If there is more than one specific use of the service, a comparative analysis needs to be completed, addressing the supply and demand for each service.

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On the supply side, the value of using the frequency can be represented by the revenues generated from the specific services. Alternatively, if there are no revenues, the value can be represented by the cost to provide the specific services. These revenues or costs should be compared with other services, which can be used in the same specific range of frequencies. For example, the band of 2400–2500 MHz can be used for the fixed service as point-to-point or point-to-multipoint microwave link, and it can also be used for Wi-Fi service. A comparison between the two services involves establishing the revenues and costs for each service and finding the most beneficial service.

On the demand side, the use of the frequency can be found in the willingness to pay for the specific service. Similarly to the demand side, the consumer has choices of selecting services in the specific frequency. For example, the frequency band 2400–2500 MHz can provide both microwave link and Wi-Fi service. The willingness to pay for the two services can be compared in order to find the most beneficial.

In Thailand, the band of 2400–2500 MHz was initially assigned by the command and control approach to the fixed service for point-to-point or point-to-multipoint microwave link service. After that, the administrator/regulator decided to additionally allow everyone to use this band as collective use of spectrum (CUS) with some limitations. The major use for CUS is Wi-Fi service.

This paper estimates the value of this frequency by an original method. In order to value the use of the frequency for microwave link service and Wi-Fi service, the business model approach will be used to estimate the costs and revenues to provide these services including the licence fee, frequency usage fee, equipment cost, operating cost, installation and maintenance cost, etc. In particular, the possibility to extend the use of Wi-Fi service as complementary to the other existing telecom services including the fixed line telephone and cellular mobile phone will be investigated. This study will have implications for regulators, in particular to increase the collective use of spectrum, either as complementary or as additional services in other frequency bands.

1.2   History of spectrum management in Thailand

On August 4, 1883 [2], the Post Department and the Telegraph Department were established. However, on April 21, 1883[3], Siam (former name of Thailand) filed application for membership of the International Telegraph Union (which changed its name to International Telecommunication Union (ITU) in 1932) and made Thailand obliged to obey its conventions and constitution.

On July 19, 1898, the Post Department and the Telegraph Department were merged to form the Post and Telegraph Department (PTD) and mainly provided post and telegraph services. On February 18, 1955, the Radio Act 1955 was enacted; all of the radiocommunication equipment had to be licensed by the authority (Director General of the Post and Telegraph Department under the Ministry of Communication and Transport). This was the first step of spectrum management in Thailand in terms of a command and control approach.

In 1975, the cabinet approved formation of the National Frequency Management Board (NFMB) chaired by the Minister of the Ministry of Communication and Transport in order to assign frequency to users. The Director General of the PTD served as a member of NFMB. NFMB operated until October 2002. The highlight of this NFMB period regarding spectrum management occurred in December 1999, when the NFMB approved the first National Table of Frequency Allocation 1999 according to the ITU Radio Regulation (1998), and this table has been used up to now. The NFMB used the command and control approach to assign frequencies to the users on a first-come, first-serve basis. At that time, only the government agencies and state enterprises could use the frequencies.

Since 1982, the NFMB granted the right to PTD to assign frequency for use under 1 watt of power. In 1993, the PTD allowed the general public to use radiocommunication devices without licences under the Ministerial Regulation No. 24 (1993) including low-power devices such as wireless microphone with power up to 10 milliwatts in the bands of 33–50, 88–108, 165–210 and 470–490 MHz and with power up to 30 milliwatts in the band of 902–960 MHz, wireless phone with power up to 10 milliwatts in the bands of 1.6–1.8, 30–50 and 54–74 MHz, etc. There are several amendments of this regulation. It was finally changed to a Ministerial Regulation with the exemption of some radiocommunication equipment licences and radiocommunication station licences (2004). This could be considered as the collective use of spectrum.

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[2] The history of the Post and Telegraph Department (Thai language) is available on http://203.121.175.10/history_post/P1.html, (URL access in May 2009)

[3] Date of entry on ITU website, available on http://www.itu.int/cgi-bin/htsh/mm/scripts/mm.list?_search=ITUstates&_languageid=1. (URL access in May 2009)

In 2000 and 2001, the act of establishment of the National Broadcasting Commission and the National Telecommunications Commission (2000) and the Telecommunications Business Act (2001) were passed. However, two commissions were not established in the time stated in the provisions enacted.

On October 1, 2004, the National Telecommunications Commission (NTC) was established and the liberalization of the telecommunication market began. In order to change the authorization to the licensing scheme, the NTC has launched many regulations in order to regulate the telecommunication market in Thailand. However, in the spectrum management, the command and control approach has been mainly used on a first-come, first-serve basis and adopted the use of low-power devices from the PTD (Ministerial Regulation of exemption of some radiocommunication licences and radiocommunication station licences (2004)).

Unfortunately, the National Broadcasting Commission (NBC) has not been established and thus the new National Table of Frequency Allocation has not been approved. Therefore, the National Table of Frequency Allocation from 1999 is still valid.

During 2009, the NTC would like to introduce the market-based approach for 3G spectrum; however, the process is ongoing and expected to finish within this year.

2.4 GHz Fixed service or microwave link service

All of the microwave link services have been assigned by the command and control approach on a first-come, first-serve basis. The channeling plan of the fixed service mostly complied with the ITU-R recommendations. It was approved by NFMB since 1999 and is still valid up to now. In the band of 2.4 GHz, 2.3–2.5 GHz, the ITU-R Recommendation F.746-1 is used and has been revised to F.746-9 without change in the channeling plan of 2.4 GHz.

The 2 MHz channel spacing is selected with 40 channels each for go and return. Examples of channeling pairs are 2308/2402, 2310/2404, … , 2384/2478 and 2386/2480 MHz. [4] Polarization is used for the adjacent channel in order to avoid harmful interference.

Wi-Fi service

In 1996, the PTD announced that the band of 2400–2500 MHz was available for the general public, in order to allow people to use radiocommunication equipment in that band with power (effective radiated power: ERP) up to 100 milliwatts. The users have to obtain licences for possession and use. The use of this radiocommunication equipment is allowed indoors only.

In 2003, the PTD amended the use of radiocommunication equipment in the band of 2400–2500 MHz for the general public. The limitation of place for use was removed in order to allow both indoor and outdoor application. However, the users still need to obtain licences for using and possessing radiocommunication equipment [5].

In 2004, the PTD successfully launched the Ministerial Regulation on the exemption of some of radiocommunication equipment licences and radiocommunication station licences (2004) in order to allow the use of lower-power devices. This included the use of the radiocommunication equipment in the band of 2400–2500 MHz with power (effective isotropically radiated power: EIRP) up to 100 milliwatts without any licences, designated as Wi-Fi service.

On June 20, 2005, the NTC announced regulations [6] in order to determine the nature and categories of telecommunication business and provide clear and unambiguous criteria and conditions for Internet service licence application. The Wi-Fi service falls into the "Type 1" Internet licence, with one licence by this notification.

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[4] The channelling plan is extracted from the 2.4 GHz Microwave link Channel Plan.

[5] The person who has radiocommunication equipment needs to obtain a possessing licence and the person who is using the equipment needs to obtain a using licence.

[6] The Notification of the National Telecommunications Commission Re: Nature and Categories of Telecommunications Business (2005) and The Notification of the National Telecommunications Commission Re: Criteria and Procedure for Internet Service Licence Application (2005) came into force on June 22, 2005.

In 2007, the NTC announced regulation [7] in order to update the regulation by replacing the previous regulation [8].

1.3 Current situation

2.4 GHz Fixed service or microwave link service [9]:

There are six existing users for 2.4 GHz microwave link service. First, the TOT Public Limited Company was authorized by PTD on May 15, 1996 for 10 pairs and on January 20, 2000 for 6 pairs for the rural telephone project. Second, CAT Telecom Public Limited Company was authorized by PTD on May 16, 1996 for 1 pair and on May 16, 1997 for 1 pair. Third, the Provincial Electricity Authority was authorized by PTD on May 15, 1996 for 4 pairs and on January 22, 1997 for 1 pair. Fourth, the PTT public limited company and its subsidiary were authorized by PTD for 4 pairs and by NTC on September 12, 2007 for 1 pair. Fifth, the Samart Telcom Public Limited Company was authorized by PTD for 3 pairs. Sixth, the Digital Research and Consulting company (DRC) Limited was authorized by NTC on October 9, 2007 for 20 MHz in the band of 2402–2422 MHz.

Table 1 shows a summary list of existing users and number of stations.[10]

Name	Frequency (MHz)	Bandwidth (MHz)	Frequency Usage Fee (Baht) [11]	Base station	Repeater	Terminal
TOT	2307–2369/2401–2463	128	3,200,000	215	932	60,000
CAT Telecom	2307–2313/2401–2407	16	400,000	3		
PEA	2335–2349/2429–2443 2367–2369/2461–2463	40	2,000,000	74		
PTT and subsidiary	2351–2365/2445–2459	29.66	1,856,500	120		
Samart Telcom	2319–2321/2413–2415 2327–2329/2421–2423 2335–2337/2429–2431	21	525,000	106		
DRC	2402–2422	20	500,000			

Table 1: List of existing microwave link service

Wi-Fi service

Since June 22, 2005, the NTC has granted more than 92 Type 1 Internet licences but the valid ISP licence is 84. [12] The condition of Type 1 Internet licence allows the ISP to provide Wi-Fi service. However, there are a few operators providing public Wi-Fi service. The number of Type 1 Internet licenses in each year is shown in Table 2.

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[7] The Notification of the National Telecommunications Commission Re: the exemption of radio communication equipment licences and radio communication station licences (2007).

[8] The Ministerial Regulation on the exemption of some radio communication equipment licences and radio communication station licences (2004).

[9] This information comes from the office of the NTC frequency fee database and was updated on December 29, 2008.

[10] The number of stations is summarized from the interview of an official of the Office of NTC in May 2009.

[11] Information from Office of the NTC frequency fee database updated on December 29, 2008.

[12] Information from http://www.ntc.or.th/license/index.php (URL access on May 20, 2009).

Year	2005	2006	2007	2008	2009	Total	Valid
ISP	21	18	23	25	4	91	83
Public Wi-Fi[13]	15	9	11	16	3	54	50
Active [14]	5	1	1	1	0	8	8

Table 2: Number of Type 1 Internet licences

From the table above, the active Public Wi-Fi providers which have some information available on Internet are 8 companies: True Internet, KSC commercial Internet, TOT, Acumen, Milcom, JCMR , FTTH and Kirz.

True Internet and KSC commercial Internet provide 138 service areas excluding Bangkok and 145 service areas, more than 15,000 and more than 16,000 hotspots, and price plans for pre-paid and post-paid service, respectively. On the other hand, TOT and Milcom provide 63 service areas and 73 service areas, and price plan for pre-paid service, respectively. JCMR provides only 35 service areas but Acumen provides more than 500 hotspots. The remaining two, FTTH and Kirz, provide a Wi-Fi solution for implementation upon request. Table 3 shows the detailed information [15].

Name of ISP	Service areas	No. of hotspots	Price plan	Wi-Fi solution
True Internet	138 excluding Bangkok	16,000 +[16]	Pre-paid/post-paid	
KSC commercial Internet	145	16,000 +	Pre-paid/post-paid	
TOT	63		Pre-paid	
Milcom	73		Pre-paid	
JCMR	35			
Acumen		500 +		
FTTH				Yes
Kirz				Yes

Table 3: Summary of Public Wi-Fi hotspot providers

2   METHODOLOGY

The literature regarding the related regulation on frequency management in Thailand has been investigated extensively in order to get the correct information. The interview in April to June 2009, either telephone or e-mail to both the official of the office of the NTC and the ITU, has been conducted in order to get the information since 1975 and 1883, respectively, Most of the information is available on the Internet as can be seen in the reference list.

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[13] Information from Office of the NTC frequency ISP Wi-Fi database updated on May 21, 2009.

[14] Information from their website (URL access on May 21, 2009).

[15] The details of information including the accessible websites of companies, the number of hotspots and service areas can be found in the Annex.

[16] Information from e-mail of the company on May 25, 2009.

The reason why the 2.4 GHz band has been chosen for this case study is the experience of the use of Wi-Fi, which has been globally increasing and easily found in day-to-day activities. After specifying the frequency of 2.4 GHz, the next step is to look at the table frequency allocation of Thailand to identify which services are allowed to be used in this band. There are three blocks of frequency related. First, the band of 2300–2450 MHz is for FIXED, MOBILE, RADIOLOCATION, and Amateur service. Second, the band of 2450–2483.5 MHz is for FIXED, MOBILE, and RADIOLOCATION service. Third, the band of 2300–2450 MHz is for FIXED, MOBILE, MOBILE-SATELLITE (space-to-Earth), RADIOLOCATION, and Radiodetermination-satellite (space-to-Earth). Figure 1 shows excerpts from Table Frequency Allocation of Thailand 1999.

2 300 – 2 450	FIXED T17 T21
	MOBILE
	RADIOLOCATION
	Amateur
	S5.150 S5.282 S5.396
2 450 – 2 483.5	FIXED T21
	MOBILE
	RADIOLOCATION
	S5.150
2 483.5– 2 500	FIXED T22
	MOBILE
	MOBILE-SATELLITE (space-to-Earth)
	RADIOLOCATION
	Radiodetermination-satellite (space-to-Earth) S5.398
	S5.150 S5.402

Figure 1: Table Frequency Allocation of Thailand 1999: 2 300–2 500 MHz

After getting the services from Table Frequency Allocation 1999, the spectrum utilization chart has been investigated. [17] There are fixed service or microwave link, NGSO-MSS (Globalstar) and Wi-Fi service. In order to update the latest information, the telephone interview to the official in charge at the Office of the NTC has been conducted. The existing services are only fixed service or microwave link and Wi-Fi service.

2.1   Fixed service or microwave link service

As for microwave link in the band of 2.4 GHz, the frequency plan has been explored in order to check the frequency channeling. Moreover, the official of the Office of the NTC has manually investigated the details of authorization in order to collect the number of assigned stations one by one. The authorization evidence from the NFMB is not available in electronic form or on Internet. The information relies on the hard copy, which has been stored since 10 years ago.

Fortunately, the frequency usage fee [18] can be obtained from the database and is available electronically. The number of stations of users has been investigated from the database of licence holders and traced back to type approval number in order to get the importing licence. After getting the importing license, the cost of importing equipment can be found.

The assumption of the installation, operating, and maintenance costs will be based on the actual equipment cost in order to estimate the cost to provide the service. The cost of microwave link will represent the value of spectrum under command and control in this specific frequency band.

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[17]   The spectrum utilization 2.2–2.7 GHz can be found at http://www.ntc.or.th/uploadfiles/ 1195792068_spec_utili%202.2-2.7%20G.pdf (URL access on May 24, 2009).

[18] The person who uses the frequency has to pay the frequency usage fee annually.

2.2   Wi-Fi service

The person providing the Public Wi-Fi service has to obtain the Type 1 Internet licence from the NTC. The information of the existing licence details can be found in the NTC website including the duration of licence, date of licensing and type of licence. However, not all of Type 1 Internet licence provides the Public Wi-Fi service – it is necessary to obtain a short list from NTC. After that, searching the websites of ISP providers gives more information about the Public Wi-Fi service including number of hotspots, number of service areas and the price plan.

At the same time, the interview by e-mail to several operators has been conducted in order to get the details of cost to provide the service. However, the available information is only the number of hotspots and the revenue of the Public Wi-Fi. The details of cost cannot be disclosed.

The assumption of the equipment, installation, operating, and maintenance costs will be based on the number of hotspots in order to estimate the cost to provide the service. The cost of Public Wi-Fi will represent the value of spectrum under a commons or collective use regime of spectrum in this specific frequency band.

3   COMPARISON OF RESULTS

3.1   Fixed service, microwave link

The overall cost to provide the 2.4 GHz microwave link can be divided into two parts. First, the information from Office of the NTC includes frequency usage fee and possessing licence fee. This information shows the actual number of transmitters and receivers which are registered in FMS and frequency usage fee database of NTC. Second, unfortunately, the equipment cost is not obtainable from either the importing licence or the database. The extrapolation of the equipment cost, installation cost, operating cost and maintenance cost will be assumed.

The information regarding equipment cost is excerpted from the interview of the vendor in Thailand in June 2009. The range of equipment cost includes omni-direction, two sectors and three sectors. The average of equipment cost is about 42,000 USD per station.

In addition, the installation cost including the civil work of tower setup and electricity varies from 35,000 to 90,000 USD depending on the type of tower – self-supporting or guide-wired. The information is excerpted from the interview of the subcontractor in Thailand in May 2009. In order to make calculation easier, the amount of 58,000 USD per station is chosen.

The operating and maintenance costs are also excerpted from the interview of the subcontractor in Thailand in May 2009. The assumption of operating and maintenance costs is 20% of the combination of equipment cost and installation cost annually. The total cost of a new tower, including equipment cost (EC), installation cost (IC), operating cost (OC) and maintenance cost (MC) is 120,000 USD (58,000 + 42,000 + 20,000 USD).

In the case of TOT, the assumption of a new tower is 10% of the number of possessing licences. The remaining 90% of the number of possessing licences use the existing tower and building.

Table 4 shows the summary of cost estimation to provide the 2.4 GHz microwave link service.

Name	Bandwidth in 2.4 GHz (MHz)	Frequency Usage Fee (Million Baht/year)	Possessing licence [19]	Possessing licence fee (Million Baht) [20]	EC + IC [21] (Million Baht)t	OC + MC [22] (Million Baht)	Total (Million Baht)
TOT	64	1.6	8,709	4.3545	3,048.15	609.63	3,663.7345
CAT Telecom	8	0.2	87	0.0435	304.500	60.9	365.6435
PEA	20	1	120	0.060	42	84	505.06
PTT and subsidiary	14,83	0.92825	54	0.027	189	37.8	227.75525
Samart Telcom	10.5	0.2625	106		371	74.2	445.4625
DRC	20	0.5					0.5
Total	**123**	**4.49075**	**9,076**	**4.485**	**4,332.650**	**866.53**	**5,208.2**

Table 4: Summary of cost estimation of 2.4 GHz microwave link service [23]

The fee that the Office of NTC has received from the operator is the frequency usage fee, possessing licence fee and installation licence fee (in the case of building a new station); it is only the frequency usage fee that operators have to pay annually. The possessing licence fee and installation licence fee are paid one time and valid for their equipment lifetime.

The overall estimation cost of 2.4 GHz microwave link in Thailand is 5,208.2 million Baht representing the supply side, and could be used as the value of spectrum under the command and control approach.

3.2 Wi-Fi service

The available information of the operator website only provides either service areas or number of hotspots. In addition, the revenue of True Internet who has the biggest market share in this business is 100 million Baht (end of 2008) [24].

In order to estimate the value of spectrum in Public Wi-Fi service, the cost structure of this service has been examined. The cost providing Public Wi-Fi service includes the equipment cost, the installation cost, operating cost and maintenance cost. The equipment cost is the cost of access point and internal network. The installation cost is the cost of placing the access point at the service area, which includes civil work, electricity work and the communication part. The operating cost is the rent of the Internet connection and the billing system, both pre-paid and post-paid. The maintenance cost of Internet connection is included in the rental. Only the maintenance of internal network and billing system are included.

The assumption of the cost to provide Wi-Fi service is 8,000 Baht per hotspot with 50% equipment cost and 50% operating cost. Also the Internet connection to the hotspot is available with the market price.

From the information of True Internet, the average revenue per hotspot is 6,250 Baht per year. With the assumption of 50% equipment cost and 50% operating cost, and 12% loan interest, the return on investment is 1.7 years per hotspot with the assumption of constant revenue of 6,250 Baht for 2 years consecutively.

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[19] This information comes from Office of the NTC FMS database updated on June 3, 2009.

[20] The possessing license fee is 500 Baht each and valid for the lifetime of equipment.

[21] The sum of equipment and installation costs.

[22] The operating and maintenance cost.

[23] The exchange rate of 1USD is 35 Baht and excludes the business licence fee.

[24] This information comes from e-mail of the company on May 25, 2009.

If the same assumption is applied to all operators, the overall cost to provide Public Wi-Fi hotspots in Thailand represents the value of spectrum of Wi-Fi service. Table 5 shows the number of hotspots, cost to provide service, and revenue.

Name of ISP	No. of hotspots	Cost to provide service	Revenues
True Internet	16,000 +	128 million Baht	100 million Baht
KSC commercial Internet	16,000 +	128 million Baht	
TOT			
Milcom			
JCMR			
Acumen	500 +	4 million Baht	
Total	**32,500 +**	**260 million Baht**	**100 million Baht**

Table 5: Summary of cost and revenue estimation of Public Wi-Fi hotspot

The additional value of 2.4 GHz spectrum from Wi-Fi service could be 260 million Baht for the initial cost to provide service and additional growth of the revenue 100 million Baht per year.

Thus the additional allowance for spectrum commons in 2.4 GHz Wi-Fi band creates the additional value of spectrum apart from the existing 2.4 GHz microwave link service.

4   BUSINESS MODEL

4.1   Fixed service, microwave link

Existing business model:

There are three operators providing the service to the public: TOT, Samart Telcom and Digital Research and Consulting (DRC). CAT Telecom, PEA, PTT and subsidiaries are using it for their own business.

TOT has used the 2.4 GHz microwave link to provide the rural telephone project with an access channel. Its business model is the complement of fixed telephone service in rural areas where copper cable cannot reach. The 2.4 GHz microwave link is used for the backhaul, repeater and base station to carry the telephone traffic from the user terminal, physically fixed wireless access to the Public Switch Telephone Network. The subsidy has been used in order to charge at the same rate as urban and sub-urban areas despite the higher cost of providing the telephone service.

Samart Telecom used the 2.4 GHz microwave link as the distribution channel from the satellite hub station to the corporate users. Its business model uses the 2.4 GHz microwave link as the access point of the Very Small Aperture Terminal (VSAT) service. The service provides the communication from the headquarters to the regional office via satellite in order to connect real time business such as banking system etc. It uses a small number of VSAT as hub stations in order to minimize the overall cost; the 2.4 GHz point to multipoint microwave link is the last mile or access channel from the users to the hub station. The price of service depends on the corporate deals, which vary from time to time.

DRC is the new player in the 2.4 GHz microwave link market. It is using 2.4 GHz microwave link for point to multipoint service. Its business model seemed to be similar to Samart Telecom's except with different customers. Its customer is the oil rig or floating platform of the petroleum company in the Gulf of Thailand. DRC can use either satellite or long-range microwave link to carry the traffic from the platform to the shore. Between the platforms, it can use the point to multipoint microwave link to connect each platform. Within the platform, it can use the Wi-Fi access point to distribute the signal as access channel.

4.2   Wi-Fi service

Existing business model:

The Wi-Fi service can be used for both public and private or complementary service. There are at least 6 operators – True Internet, KSC, TOT, Milcom, JCMR and Acumen provide the service in public places including cafés, hotels, airports, hospitals, conventions or conferences, department stores, cinemas, theatres and so on. The price of service can be both pre-paid and post-paid. The format of pre-paid can be pre-paid card or pre-paid account with limitation of usage time, per hours, per day. The post-paid can be monthly with unlimited access.

Moreover, the Wi-Fi can be used as a complementary service to broadband or high-speed Internet as wireless routers from either the operator or the end user. The broadband operator uses xDSL or FTTx technologies to provide service.

The mobile operator can take advantage of the Wi-Fi technology as complementary service to the 2G phone for high-speed data access. (Note that 3G has not yet been launched in Thailand.) For the high-end terminal equipment with Wi-Fi module such as IPhone or PDA, the mobile operator can use intelligent software to hand over the GPRS/EDGE/HSPA to Wi-Fi for the higher bit rate up to 54 MHz. Furthermore, the aircard with SIM card in a laptop or NETBook providing unlimited access to Internet via GPRS/EDGE/HSPA network of 2G can be used; the Wi-Fi module can be used as the primary channel if the higher bit rate is available. An additional charge per package or bundled package may be offered to the customer.

Possible business model:

After deployment of 3G networks or WiMax, the Wi-Fi service could be used as the access technology to the end users. The tariff of the service could be charged separately or bundled with the data package, which depends on the market conditions and demand of users.

5   IMPLICATIONS FOR THE REGULATOR

2.4 microwave link service

From the above cost analysis of 2.4 GHz microwave link, the regulator might revise the Radio Act 1955 in order to charge for the possessing licence annually, the same as the frequency usage fee. This might help to keep tracking the quality of equipment after installation and use in parallel with the licence condition.

Wi-Fi service

The additional secondary service for Wi-Fi in the band of 2.4 GHz is increasing the spectrum efficiency. The value of spectrum of 2.4 GHz Wi-Fi hotspots is represented by the cost to provide service and revenue generating from the service.

This is a good sign of secondary allocation for spectrum commons with primary existing service, and encourages the regulator to allow more spectrum under commons use in order to increase spectrum efficiency.

However, the difficulty of obtaining information is an important problem. The regulator will need to create a database of cost and revenue of the telecommunication market to analyze this issue further.

6   SUMMARY

In Thailand, the band of 2.4 GHz has been assigned for fixed service or microwave link service since 1996 representing the command and control approach. In 2004, PTD successfully approved the 2.4 Wi-Fi for unlicensed application with the maximum power E.I.R.P. 100 mW, representing collective use of spectrum. Up to now, there are at least eight Type 1 Internet licences with public Wi-Fi hotspots throughout Thailand at hotels, airports, department stores, cafés etc.

The evaluation of spectrum in the band of 2.4 GHz in the case of Thailand is using a business model. The model has estimated the cost to provide the service and the revenue generating from the service representing the value of spectrum. As a result, the 2.4 GHz microwave link has the value of spectrum of 5,208.2 million Baht and the additional public Wi-Fi hotspots have the value of spectrum of 260 million Baht.

The paper has shown that, in the case of Thailand, the microwave link service and additional Wi-Fi hotspot service could increase spectrum efficiency. The regulator might consider allowing more spectrum commons in other frequency bands in order to make use of frequency as much as possible.

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Annex

No	Name	License number	Date of authorization and expiration	No of hot spot	URL	Date of access	No of service area	Prepaid	Post paid/month
1	KSC commercial internet co. Ltd.	NTC/MM/INT/ISP/I/001/2548	June 23, 2008 - June 22, 2009	16000+	http://www.ksc.net/TH/Products-Hotspot-Whatis.html	21-May-09	145	1/5/20 hr 1 day	500
2	TOT plc.	NTC/MM/INT/ISP/I/002/2548	August 4, 2008 - August 3, 2009		http://www.tothotspot.com/th/location.htm	21-May-09	63	1/3 hr 1/3/5 day	
3	Cattelecom plc.	NTC/MM/INT/ISP/I/003/2548	August 4, 2008 - August 3, 2009		http://www.cattelecom.com/site/th/list_service.php?cat=195&subcat=200				
4	ISSP co. Ltd.	NTC/MM/INT/ISP/I/004/2548	August 18, 2008 - August 17, 2009		http://www.issp.co.th/site/?q=content/internet-package				
5	Otaro co. Ltd.	NTC/MM/INT/ISP/I/005/2548	August 18, 2008 - August 17, 2009		http://www.otaro.co.th/index.html				
6	TT&T sub service co. Ltd.	NTC/MM/INT/ISP/I/006/2548	August 18, 2008 - August 17, 2009		1103 Maxnet call center				
7	Proen co. Ltd.	NTC/MM/INT/ISP/I/007/2548	August 18, 2008 - August 17, 2009	not Wi-Fi	http://www.proen.co.th/internet_access_mpls_sp1.php	21-May-09			
8	Kirz co. Ltd.	NTC/MM/INT/ISP/I/008/2548	August 25, 2008 - August 24, 2009	not provide on web	http://www.kirz.co.th/index.php?option=com_content&view=category&layout=blog&	21-May-09			
9	True Internet co. Ltd.	NTC/MM/INT/ISP/I/009/2548	August 18, 2008 - August 17, 2009	15000+	http://www.truewifi.net/th/promotion/green_bangkok.htm	21-May-09	136 exclude bangkok		
10	Acumen co. Ltd.	NTC/MM/INT/ISP/I/010/2548	August 25, 2008 - August 24, 2009	500+	http://www.acumen.co.th/TH/PRODUCTS_CYBERPOINT.html	21-May-09			
11	101 global co. Ltd.	NTC/MM/INT/ISP/I/012/2548	September 1, 2008 - August 31, 2009	no info	http://101g.smesme.com/product.php	21-May-09			
12	Free Internet co. Ltd.	NTC/MM/INT/ISP/I/013/2548	September 1, 2008 - August 31, 2009	no info	http://auction.freei.co.th/aboutus-3.php	21-May-09			
13	CS loxinfo plc.	NTC/MM/INT/ISP/I/014/2548	September 8, 2008 - September 7, 2009	no info	http://www.csloxinfo.com/index_large.asp	21-May-09			
14	NTT communication (thailand) co. Ltd.	NTC/MM/INT/ISP/I/015/2548	September 15, 2008 - September 14, 2009	no info	http://www.ntt.co.th/th/product_service.html	21-May-09			
15	Pacnet internet (thailand) co. Ltd.	NTC/MM/INT/ISP/I/016/2548	September 8, 2008 - September 7, 2009	not Wi-Fi	http://www.pacific.net.th/en/services_nectDetail.asp?id=7	21-May-09			
16	Infonet (thailand) co. Ltd.	NTC/MM/INT/ISP/I/017/2548	September 21, 2008 - September 20, 2009	no info	http://www.infonetthailand.com/index.php?page=product&cont_id=7&item=14&lang	21-May-09			
17	Lenso co. Ltd.	NTC/MM/INT/ISP/I/018/2548	October 13, 2008 - October 12, 2009						
18	Worldweb co. Ltd	NTC/MM/INT/ISP/I/019/2548	November 3, 2008 - November 2, 2009		no website	21-May-09			
19	Wise communication co. Ltd.	NTC/MM/INT/ISP/I/020/2548	December 19, 2008 - December 18, 2009						
20	ADC co. Ltd.	NTC/MM/INT/ISP/I/022/2548	December 19, 2008 - December 18, 2009	no info	http://www.buddybb.net/prodcut_service.asp	21-May-09			
21	Thai tradenet co. Ltd.	NTC/MM/INT/ISP/I/023/2548	December 19, 2008 - December 18, 2009						
22	Mandala communication co. Ltd.	NTC/MM/INT/ISP/I/001/2549	February 16, 2009 - February 15, 2010	no info	http://www.inet.co.th/eng/product/bizaccess/	21-May-09			
23	Milcom co. Ltd.	NTC/MM/INT/ISP/I/002/2549	March 16, 2009 - March 15, 2010		http://www.wlannet.net/area.html	21-May-09	73	1 hr	
24	Thai system integration co. Ltd	NTC/MM/INT/ISP/I/003/2549	March 23, 2009 - March 22, 2010	no info	http://www.thaiit.com/english/index.htm,http://www.truechonburi.com/about.php	21-May-09			
25	All telecom co. Ltd.	NTC/MM/INT/ISP/I/005/2549	April 27, 2009 - April 28, 2010						
26	A-net co. Ltd	NTC/MM/INT/ISP/I/006/2549	June 25, 2008 - June 26, 2009						
27	Sawasdee shop co. Ltd.	NTC/MM/INT/ISP/I/007/2549	May 19, 2008 - May 18, 2009	no info	http://www.sawasdeeshop.com/th/home.php	21-May-09			
28	Portalnet co. Ltd.	NTC/MM/INT/ISP/I/011/2549	July 4, 2008 - July 3, 2009						
29	Jasmine internet co. Ltd	NTC/MM/INT/ISP/I/015/2549	July 28, 2008 - July 27, 2009	no info	http://www.jasmine.com/jasmineweb/html/business.html	21-May-09			
30	Plannet commerce co. Ltd.	NTC/MM/INT/ISP/I/016/2549	August 3, 2007 - August 2, 2008						
31	Samart infonet co. Ltd	NTC/MM/INT/ISP/I/017/2549	August 15, 2008 - August 14, 2009	no info	http://www.samarts.com/2008/main/content_view.php?contentdata_cat=4&content	21-May-09			
32	Dtac network co. Ltd.	NTC/MM/INT/ISP/I/019/2549	August 30, 2008 - August 29, 2009						
33	Sipphone (thailand) co. Ltd.	NTC/MM/INT/ISP/I/021/2549	September 5, 2008 - September 4, 2009						
34	Toki net co. Ltd	NTC/MM/INT/ISP/I/022/2549	September 7, 2008 - September 6, 2009						
35	Plus one poer co. Ltd.	NTC/MM/INT/ISP/I/023/2549	September 14, 2008 - September 13, 2009		no website	21-May-09			
36	Shin broadband internet (thailand) co. Ltd	NTC/MM/INT/ISP/I/025/2549	October 18, 2008 - October 17, 2009						
37	Worldness & Service co. Ltd	NTC/MM/INT/ISP/I/026/2549	Novebber 1, 2008 - October 31, 2009	not Wi-Fi	http://www.pacific.net.th/en/services_nectDetail.asp?id=7	21-May-09			
38	TCC technology co. Ltd.	NTC/MM/INT/ISP/I/027/2549	December 7, 2008 - December 6, 2009						
39	ISP co. Ltd.	NTC/MM/INT/ISP/I/028/2549	December 25, 2008 - December 24, 2009						
40	Asia Infonet co. Ltd	NTC/MM/INT/ISP/I/001/2550	February 5, 2009 - February 4, 2010	True group	http://www.truecorp.co.th/tha/contact/contact_voc.jsp	21-May-09			
41	Max premium co. Ltd.	NTC/MM/INT/ISP/I/003/2550	February 1, 2008 - January 31, 2009						
42	Global link (thailand) co. Ltd	NTC/MM/INT/ISP/I/004/2550	April 9, 2007 - April 8, 2008						
43	Trans Pacific Telecom (thailand) co. Ltd	NTC/MM/INT/ISP/I/005/2550	April 9, 2008 - April 8, 2009						
44	CAT satcom link co. Ltd	NTC/MM/INT/ISP/I/006/2550	April 10, 2008 - April 9, 2009						
45	Softphone co. Ltd.	NTC/MM/INT/ISP/I/007/2550	April 24, 2007 - April 23, 2008						
46	BB broadband co. Ltd.	NTC/MM/INT/ISP/I/008/2550	April 23, 2009 - April 22, 2014						
47	Callthaidotnet co. Ltd.	NTC/MM/INT/ISP/I/009/2550	May 9, 2007 - May 8, 2008						
48	Access convergence management co. Ltd.	NTC/MM/INT/ISP/I/010/2550	June 18, 2008 - June 17, 2009		no website	21-May-09			
49	TTT broadband co. Ltd.	NTC/MM/INT/ISP/I/011/2550	June 20, 2008 - June 19, 2009	Jasmine group-TTT sub	http://www.jasmine.com/jasmineweb/html/business.html	21-May-09			
50	Boston broadband consultant co. Ltd.	NTC/MM/INT/ISP/I/013/2550	July 24, 2008 - July 23, 2009						
51	EZ system telecom co. Ltd.	NTC/MM/INT/ISP/I/014/2550	August 3, 2008 - August 2, 2009						
52	Integration communication technology (asia) co. Ltd	NTC/MM/INT/ISP/I/015/2550	August 16, 2007 - August 15, 2008						
53	Samart broadband service co. Ltd.	NTC/MM/INT/ISP/I/016/2550	August 17, 2008 - August 16, 2009	no info	http://samartdsl.com/prod_serv-01.htm	21-May-09			
54	FTTH co. Ltd.	NTC/MM/INT/ISP/I/017/2550	August 27, 2008 - August 26, 2009	not provide on web	http://www.ftth.co.th/pages/package-detail.php?package_id=3	21-May-09			
55	Soundwell communication co. Ltd.	NTC/MM/INT/ISP/I/018/2550	September 27, 2008 - September 26, 2009						
56	Aware corporation co. Ltd.	NTC/MM/INT/ISP/I/019/2550	October 1, 2008 - September 30, 2009	no info	http://www.aware.co.th/product_awareinternet.htm	21-May-09			
57	Ice Johnson co. Ltd.	NTC/MM/INT/ISP/I/021/2550	October 8, 2007 - October 7, 2008						
58	SBN co. Ltd	NTC/MM/INT/ISP/I/022/2550	October 10, 2008 - October 9, 2009	not Wi-Fi	http://www.sbn.co.th/services.html	21-May-09			
59	Money talk for me co. Ltd.	NTC/MM/INT/ISP/I/023/2550	October 19, 2007 - October 18, 2008						
60	UT tel co. Ltd	NTC/MM/INT/ISP/I/024/2550	October 30, 2008 - October 29, 2009		no website	21-May-09			
61	AIS plc.	NTC/MM/INT/ISP/I/025/2550	Novebber 23, 2008 - October 24, 2009	not Wi-Fi	http://www.ais.co.th/th/ServiceExcellence/ServiceExcellence.html	21-May-09			
62	Solution one holding co. Ltd.	NTC/MM/INT/ISP/I/027/2550	December 6, 2007 - December 5, 2008						
63	Nipa technology co. Ltd.	NTC/MM/INT/ISP/I/001/2551	January 3, 2009 - January 2, 2010						
64	Bluedot communication co. Ltd.	NTC/MM/INT/ISP/I/002/2551	February 3, 2009 - February 2, 2010		no website	21-May-09			
65	A-connect co. Ltd.	NTC/MM/INT/ISP/I/003/2551	March 27, 2009 - March 26, 2010						
66	TGT (2551) co. Ltd.	NTC/MM/INT/ISP/I/004/2551	April 24, 2009 - April 23, 2014						
67	System advisor group co. Ltd.	NTC/MM/INT/ISP/I/005/2551	April 24, 2008 - April 23, 2009						
68	Media partner international co. Ltd.	NTC/MM/INT/ISP/I/006/2551	May 20, 2008 - May 19, 2009						
69	CodeTech co. Ltd.	NTC/MM/INT/ISP/I/007/2551	May 30, 2008 - May 29, 2009						
70	JCMR co. Ltd.	NTC/MM/INT/ISP/I/008/2551	June 3, 2008 - June 2, 2009		http://www.thai-fi.com/wifiinfo/locations.php	21-May-09	35		
71	Budget communication co. Ltd.	NTC/MM/INT/ISP/I/009/2551	July 8, 2008 - July 7, 2009						
72	MT everest trading co. Ltd.	NTC/MM/INT/ISP/I/010/2551	August 6, 2008 - August 5, 2009		no website	21-May-09			
73	Wide Access co. Ltd.	NTC/MM/INT/ISP/I/011/2551	August 11, 2008 - August 10, 2009		no website	21-May-09			
74	Revolution network co. Ltd.	NTC/MM/INT/ISP/I/012/2551	August 8, 2008 - August 7, 2009		no website	21-May-09			
75	SMC communication service co. Ltd.	NTC/MM/INT/ISP/I/013/2551	August 15, 2008 - August 14, 2009		no website	21-May-09			
76	TCB supply intertrade co. Ltd.	NTC/MM/INT/ISP/I/014/2551	August 22, 2008 - August 21, 2009						
77	TTT global net co. Ltd.	NTC/MM/INT/ISP/I/015/2551	September 15, 2008 - September 14, 2009	not Wi-Fi	http://www.102globalnet.com/info.php?#%E0%B9%81%E0%B8%99%E0%B8%B0%	21-May-09			
78	Net three co. Ltd.	NTC/MM/INT/ISP/I/016/2551	September 17, 2008 - September 16, 2009		no website	21-May-09			
79	AWN co. Ltd.	NTC/MM/INT/ISP/I/017/2551	September 17, 2008 - September 16, 2009		no website	21-May-09			
80	BlissTel plc.	NTC/MM/INT/ISP/I/018/2551	October 28, 2008 - October 27, 2009	not Wi-Fi	http://www.blisstel.com/2008/catalogs/Dphone.html	21-May-09			
81	Setta byte co. Ltd	NTC/MM/INT/ISP/I/019/2551	November 5, 2008 - November 4, 2009						
82	Chokecharoenkit construction co. Ltd.	NTC/MM/INT/ISP/I/020/2551	November 5, 2008 - November 4, 2009		no website	21-May-09			
83	Justel network co. Ltd.	NTC/MM/INT/ISP/I/021/2551	November 6, 2008 - November 5, 2009						
84	POS technology co. Ltd.	NTC/MM/INT/ISP/I/022/2551	November 7, 2008 - November 6, 2009						
85	IEC technology co. Ltd.	NTC/MM/INT/ISP/I/023/2551	November 20, 2008 - November 19, 2009	not Wi-Fi	http://www.iectechnology.co.th/wwwiect/fixpage.php?l=2	21-May-09			
86	One-to-all co. Ltd.	NTC/MM/INT/ISP/I/024/2551	November 27, 2008 - November 26, 2009	not Wi-Fi	http://www.12call.ais.co.th/th/Content/Service/mobileLife.html	21-May-09			
87	Hi-work system co. Ltd.	NTC/MM/INT/ISP/I/025/2551	December 26, 2008 - December 25, 2009		no website	21-May-09			
88	BPL asia co. Ltd.	NTC/MM/INT/ISP/I/001/2552	January 27, 2009 - January 26, 2010		no website	21-May-09			
89	2S1N co. Ltd.	NTC/MM/INT/ISP/I/002/2552	January 29, 2009 - January 28, 2010		no website	21-May-09			
90	Vith Telcom (thailand) co. Ltd.	NTC/MM/INT/ISP/I/003/2552	February 27, 2009 - February 26, 2010		no website	21-May-09			
91	Teleglobal co. Ltd.	NTC/MM/INT/ISP/I/004/2552	March 11, 2009 - March 10, 2010						

not provide public Wi-Fi service