SPECTRUM REQUIREMENT ESTIMATION FOR IMT SYSTEMS IN DEVELOPING COUNTRIES

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ABSTRACT

In this paper we analyze the methodology developed by the International Telecommunication Union (ITU) for estimating the spectrum requirement for International Mobile Telecommunications (IMT) systems. The International Telecommunication Union estimates spectrum requirements by following ITU-R-Rec.M1768. Although this methodology is adopted by ITU-R, there are discrepancies for estimating the spectrum requirement for developing countries. ITU estimates the spectrum requirement by considering technical and market parameters that were provided by the most developed countries with high income and high development index. Developed countries have a very rapid expansible telecom market due to the high level of penetration, dominant user density and usage of high-volume multimedia services. In contrast, developing countries use less bandwidth-intensive services such as voice communication, low rate data, low and medium multimedia. However, while the input parameters are adequate for developed countries, they do not reflect the status of developing countries. For this reason the ITU spectrum estimation overestimates the exact requirements of spectrum for IMT systems for developing countries. This paper presents an approach based on the technical and market related parameters, which is thought to be applicable for overcoming the shortcomings of the current ITU methodology in estimating the spectrum requirement for developing countries like Bangladesh.

KEYWORDS

International Mobile Telecommunications (IMT), Radio Access Technique Groups (RATGs), Spectrum Estimation, Spectrum Management.

1. INTRODUCTION

To estimate the radio spectrum for IMT Systems, International Telecommunication Union adopted the methodology described in ITU-R Rec M.1390 [1]. Spectrum requirements for the terrestrial components of IMT-2000 were estimated in Report ITU-R M.2023 [2] prior to WRC-2000 by using this methodology. ITU-R.M1390 has been considered to be a framework focusing on a single system and market scenario based on blended 2G and 3G networks. In addition, this methodology was essentially based on the paradigm of circuit switching. But this approach is no longer suitable for meeting the current requirements set by ITU for IMT Systems, since packet- based traffic now dominates as the switching scheme in current and conventional wireless networks. The methodology ITU-R Rec M.1390 [1] does not properly consider packet-based traffic. As stated in Rec. ITU-R M.1645 [3] the majority of traffic has been shifting from voice oriented communications to multimedia communications with Internet Protocol-based packet switching. To consider the changes in wireless service environment a new methodology, ITU-R Rec.M1768 has been developed by ITU for planning and calculating spectrum use in IMT Systems [4]. This new method specifically emphasizes the capacity of a cell of wireless system that needed to fulfill Quality of Service (QoS) requirements of an arbitrary number of different

service classes offering packet traffic. The methodology is applicable to both circuit and packet switch-based traffic and can accommodate multiple services. The Report ITU-R M.2072 [4] provides a summary of the market analysis and forecast for the evolution of mobile markets and services for the future development of IMT systems and derives market related parameters for the years of 2010, 2015 and 2020. To calculate the spectrum requirements, the report analyzed data from thirty countries and organizations and provided typical data. Bangladesh was one of the developing countries analyzed. In 2004, the cellular mobile penetration rate in Bangladesh was only 3.7%, compared to 68% in Japan and 86% in Republic of Korea in roughly the same time frame.

It is obvious that spectrum requirements for cellular mobile communications are directly proportional to the size of the telecommunication market. The market size of IMT systems can be estimated from many kinds of parameters. For example, the total population is an important driver of cellular penetration: higher population density lowers the cost of service delivery. Telecommunication growth is also highly correlated with economic indicators such as the GDP, GNP and the overall economic development of a country. Income and literacy rate are the key market parameters for market estimation, since they can be used to approximate the average citizen's ability to buy mobile telecommunication services. The technology available to users at a certain point of time also influences the market because new technologies lead to new services and create demand.

ITU-R-Rec.M1768 estimates the spectrum requirements based on technical parameters such as the cell area, application data rate, radio parameters, population coverage percentage and market parameters like user density, session arrival rate per user, mean service bit rate, average session duration, market settings and mobility ratio are considered in Reports ITU-R.M2072, ITU-R.M2074 and ITU-R.M2078. These parameters are typically based on the data provided in the most developed parts of the world where the saturation level of market development may be reached earlier than the global market and where user expectations are continually increasing for their consuming capability with regard to the variety of multimedia services and applications. Due to differences in market development, the input parameters should be interpreted differently for developing countries at different time intervals. Thus the technical and market parameters have to be changed to estimate the spectrum requirements for developing countries. This paper presents an acceptable approach to overcome the shortcomings of the available ITU spectrum estimation methodology that can be applicable to developing countries in order to avoid overestimating the requirements. It also proposes a scenario for spectrum planning for IMT Systems for a developing country like Bangladesh in terms of increasing wireless communication traffic.

The remainder of this paper is organized as follows. Section 2 gives an overview of the ITU-R spectrum estimation methodology and its technical and market parameters. Section 3 presents an approach for estimating the spectrum requirement for developing countries by using relevant technical and market data for Bangladesh. Section 4 explains the spectrum requirement estimation for Bangladesh and compares the obtained result with the spectrum requirements forecasted by ITU. Finally, the proposed method and its results are summarized in section 5.

2. LITERATURE REVIEW

In 2000, ITU estimates 530.3 MHz spectrum to be required for IMT systems (Methodology ITU-R Rec M.1390). But this methodology does not properly consider broadband data and multimedia traffic. To overcome this problem ITU has been developed a new methodology ITU-R Rec.M1768 through IST-WINNER project (Marja Matinmikko1, Tim Irnich, Jörg Huschke, Antti Lappeteläinen, and Jussi Ojala). This methodology forecasted 1720 MHz spectrum to be required

for IMT 2000 and IMT advanced systems. According to Chung, Lim, Yook and Park (2007) who forecasted spectrum requirement based on the Korean communication environment, they have shown that in the case of spectral efficiency using higher modulation and coding schemes, the spectrum requirement of IMT advanced is approximately 2700 MHz. When applying 2x2 multiple-input multiple output (MIMO) antenna system, it is approximately 1500 MHz. When applying 4x4 multiple-input multiple output (MIMO) antenna system, it is approximately 1050 MHz. In 2013, a new model for spectrum estimation has been commissioned by the GSM Association to estimate future spectrum requirements for different countries and mobile markets by taking a theoretical approach, the starting point of the model is the existing number of base station sites within a given market and scope for future site densification. By this methodology they estimate spectrum requirement for four countries and the preliminary results indicate a total spectrum of 1939 MHz will be required for USA, 2074 MHz for UK, 2080 MHz for Brazil and 1844 MHz for China.

3. SPECTRUM REQUIREMENT CALCULATIO METHODOLOGY OF ITU-R:

A generic flow chart of the ITU spectrum requirement estimation methodology for IMT systems is shown in Fig.1. This methodology follows a deterministic approach starting from the market expectations and ending in the final spectrum requirements of IMT systems. The terms service category, service environment, radio environment, radio access technique group and related parameters are described in this section.
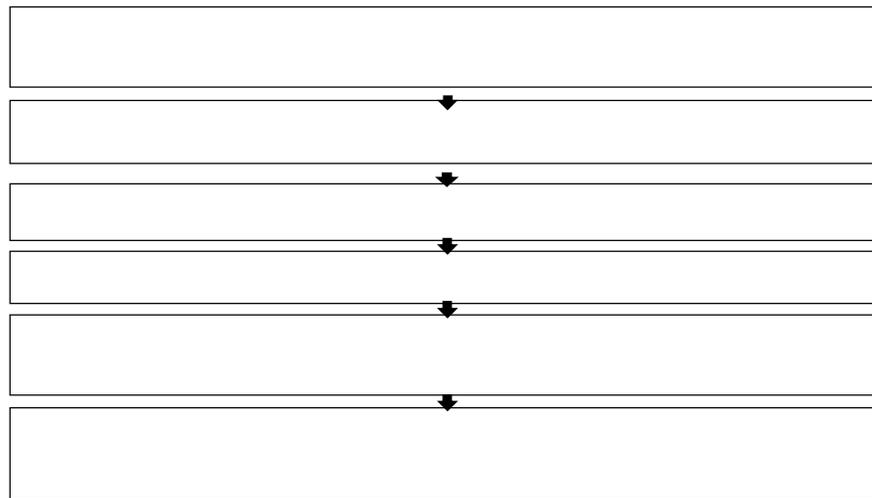

Fig.1. Flowchart of ITU spectrum estimation methodology

3.1. Technical Parameters

3.1.1 Service categories

A service category (SC) is defined as a combination of service type and traffic class as shown in Table1. The traffic class concept is based on the IMT systems QoS classes as defined by ITU-R Rec. M. 1079-2. Based on this recommendation, the conversational and streaming classes are served with circuit switching while the interactive and background classes are served with packet switching. The combinations of service types and traffic classes lead to the 20 service categories.

Table 1. Service categorization

Traffic Class/Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	SC1	SC6	SC11	SC16
High multimedia	SC2	SC7	SC12	SC17
Medium multimedia	SC3	SC8	SC13	SC18
Low rate data &low multimedia	SC4	SC9	SC14	SC19
Very low rate data	SC5	SC10	SC15	SC20

3.1.2. Service environment

A service environment is a combination of the teledensity and a service usage pattern. Teledensities describe the user density in different areas. Three types of teledensities are considered : dense urban, sub-urban and rural. Service usage patterns such as home, office and public areas are categorized according to areas where users get services. Six service enviornments are used in this methodology as listed in Table 2 [4].

Table 2. Identification of service environments

Service usage pattern	Teledensity		
	Dense urban	Sub-urban	Rural
Home	SE1	SE4	SE6
Office	SE2	SE5	
Public area	SE3		

3.1.3. Radio environments

Radio environments are characterized by two parameters: cell area and population coverage percentage. The cell area of a radio environment may vary depending on the teledensity [7]. A cell is the area covered by a base station. The cells can be classified according to their size as macro, micro, pico and hotspot cells. The cell area largely depends on the user density, type of service and transmitter output power and has a direct impact on the traffic volume and spectrum requirements. It is also closely related to other radio parameters such as the application data rate and the minimum deployment per operator per radio environment.

3.1.4. Radio access technique groups

●RATG 1: Pre-IMT systems, IMT-2000 and its enhancements. This group covers the digital cellular mobile systems, IMT-2000 systems and their enhancements.

● RATG 2: Systems beyond IMT-2000 (e.g., new mobile access and new nomadic/local area wireless access), but not including systems already described in any other RATGs [4].

3.1.5 Area spectral efficiency

The spectral efficiency is an important parameter for converting the capacity requirements in terms of bit/s/cell to the spectrum requirements in Hz. If the spectral efficiency is increased, the unadjusted and final spectrum requirements decrease and vice versa [7].

3.2. Market data analysis

This step analyzes the market data that have been obtained from Report ITU-R M2072 [5]. The collected market data are categorized and calculated in order to obtain the market attributes.

3.3 Traffic calculation and distribution over RATGs

In this step, five different set of market parameters are used. Offered traffic is the required input for calculating the spectrum requirement. The conversational and streaming classes (SC1-SC10) have a more conventional nature and they serve with circuit switching, while the background and interactive classes (SC11-SC20) are serve with packet switching. For the circuit switched service categories, the average traffic per cell in each teledensity for each service category can be calculated by multiplying the session arrival rate per cell by corresponding mean session duration. This product is equivalent to the offered traffic and measured in Erlangs. The capacity calculation for packet switched service categories requires the offered traffic in bits/s/cell which is calculated by multiplying the corresponding elements of the area traffic volume, distribution ratios and cell area. The offered traffic is the total traffic of all users of the same service category [6].

3.4. Required capacity calculation

The fifth step in the methodology flow chart is calculating the required system capacity. Separate algorithms are applied to calculate the circuit switched and packet switched traffic.

3.4.1 System capacity for circuit switched traffic

The capacity is calculated by using the multi-dimensional Erlang B formula Kleinrock et al., 1975 [11].Input parameters for determining the required number of service channels for circuit-switched sessions are the offered traffic in Erlangs per cell ρ_n, service channel data rate r_n and the maximum allowable blocking probability π_n. We assume that a session of N_{cs} different circuit switched service categories shares a set of v channels with an associated service channel rate of 16 kbit/s and that each session of class n requires v_n channels simultaneously ($1 \leq n \leq N_{cs}$). If an arriving service request of service category n finds less than v_n idle channels then it is blocked and lost. The one-dimensional recursive algorithm by Kaufman [12] and modified algorithm by Takagi [Takagi *et al.*, 2006] [13] are used to compute the blocking probability for each of N_{cs} service categories when the total number of channels, v, is given. Then the required number of channels per cell is determined by the smallest v that satisfies the conditions $B_n(v) < \pi_n$. The system capacity is obtained by multiplying the required total number of channels by the bit rate per channel.

3.4.2 System capacity for packet-switched traffic

The M/G/1 queuing model with non-pre-emptive priorities or head-of-the-line queuing system [Klienrock, 1976] is used to determine the mean delay requirement. The input parameters such as the offered base traffic per service environment per cell $T_{d,t,n,rat,p}$ (bit/(s · cell)), the mean packet size s_n (bits/packet) and the second moment of packet size $s_n^{(2)}$ (bits²/packet) of the IP packet and the required mean delay D_n of each service category are used to determine the system capacity for packet switched service categories [8]. The arrival rate of IP packets refers to the average number of IP packets that are transmitted per unit time per cell λ_n (packets/(s · cell)). Thus the packet arrival rate per cell is

$$\lambda_{d,t,n,rat,p} = \frac{T_{d,t,n,rat,p}}{s_n}.$$

(1)

Let C (bit/s) be the capacity of the channel. Then the mean b_n (s/packet) and the second moment of $b_n^{(2)}$ of the transmission time for an IP packet of service category n are given by $b_n = \frac{s_n}{C}$ and $b_n^{(2)} = \frac{s_n^{(2)}}{C^{(2)}}$ The mean delay of an IP packet of service category n is given by

$$D_n(C) = \frac{\sum_{i=1}^{N_{ps}} \lambda_i s_i^{(2)}}{2\left(C - \sum_{i=1}^{n} \lambda_i s_i\right)\left(C - \sum_{i=1}^{n-1} \lambda_i s_i\right)} + \frac{s_n}{C}$$

(2)

This equation is derived from Cobham's formula for the mean waiting time in a single arrival M/G/1 non-pre-emtive priority queue [Cobham et al., 1954] [14], [Kesten and Runneberg et al. 1957] [15], [Inrich and Walke et al., 2004] [16]. If the QoS requirement for IP packets of class *n*, is given in terms of a required mean delay *Dn*, the required system capacity *Cn* is defined as the capacity satisfying the condition *D(Cn) = Dn*. Given a certain value for *Dn*, the system capacity *Cn* required to achieve *Dn* can be calculated by solving (2) for C. Among the three roots of this equation there is always one that satisfies the stability condition

$$\sum_{i=1}^{n} \lambda_i s_i < C_n$$

(3)

This value is chosen as the solution to the problem of dimensioning the system capacity so that IP packets of service class *n* have the required mean delay *Dn*. The system capacity that fulfills the mean delay requirements of all classes, denoted by *C*, is obtained by determining the set {*C1, C2…….CN}* of system capacity values required to fulfill the QoS requirements of classes *n* = 1-- *N*, and selecting the maximum value from this set, i.e. *C= max (C1, C2…….CN)*.

3.5 Spectrum results calculation

3.5.1 Determination of spectrum requirement

The resulting capacity requirements for circuit and packet switched service categories are added together to get the total capacity requirement

$$C_{d,t,rat,p} = C_{d,t,rat,p,cs} + C_{d,t,rat,p,ps}$$

(4)

The capacity requirements are now converted to the spectrum requirements by dividing the area spectral efficiency factors. The spectrum requirement is obtained by

$$F_{d,t,rat,p} = \frac{C_{d,t,rat,p}}{\eta_{d,rat,p}}$$

(5)

Then, the total required spectrum for all operators is

$$F_{d,t,ra} := N_0.F_{d,t,rat} + (N_o - 1)F_{rat}^G$$

(6)

where F_{rat}^G (Hz) is the guard band between operators. The total spectrum requirements of RATG1 and RATG2 are taken as the maximum over the teledensities (dense urban, suburban, rural) [4].

4. APPROACH TO ESTIMATE SPECTRUM REQUIREMENT FOR DEVELIPING COUNTRIES

This section presents a scenario and a set of input parameter values to overcome of the shortcomings of current ITU methodology, which delivers a significantly better founded estimation of the spectrum requirement for developing countries and compared to the spectrum estimation by ITU derive in Rep. ITU-R M.2078 [7].

4.1. Cell area

The cell area of a radio environment may vary depending on the teledensity [7]. The cell area that is proposed by ITU for macro and micro cells seems to be too small compared to deployment scenarios in the real world [9]. This cell area is applicable for the most developed countries that have large dense urban/urban cities with high rise buildings, increasing traffic due to the high level of penetration and usage of high-volume multimedia services. Radio propagation is highly dependent on the terrain and other obstacles. Path loss, shadowing and multi-path fading all affect the cell coverage of an area. In urban areas where there is no direct line-of-sight path between the transmitter and the receiver, the presence of high-rise buildings causes severe diffraction loss. In the case of Bangladesh the sub-urban and rural areas are flat terrain; a LoS (Line of sight) path between the base and mobile stations is guaranteed due to the absence of high rise buildings or obstacles. Further a macro base station can cover a wide area due to the small propagation loss and low user densities. The dense urban areas are growing with many high rise buildings and attract large volume of commerce and industries. The base station covers a small area because the LoS paths may be seldom available; moreover a high capacity cellular network is required to carry the larger traffic due to the higher user densities and rich multimedia service demands in the dense urban areas. To increase the network capacity in these dense urban areas, micro cells, pico cells and hotspots can be installed in addition to macro base stations. Currently, the deployment of cellular networks is complex and requires installation of base stations and supporting infrastructure. The installation cost is high and it remains difficult for operators to establish a profitable network in developing countries with low gross national income. If the ITU proposed cell areas of macro and micro cells are applied to developing countries, more base stations would be required for network coverage, which would increase the capital expenditure and operating cost of network expansion. To estimate the present and future traffic, the proposed cell area for macro and micro cells from Table 3 are used in the calculation, with information for developing countries obtained from the Bangladesh network deployment scenarios.

Table 3. Cell area per RE (km^2).

Cell area proposed by ITU				Cell area proposed for developing countries			
Radio Environment	Teledensity			Radio Environment	Teledensity		
	Dense urban	Sub-urban	Rural		Dense urban	Sub-urban	Rural
Macro	0.1	0.15	0.22	Macro	0.25	0.5	1.5
Micro	0.07	0.1	0.15	Micro	0.07	0.15	0.2
Pico	1.6E-3	1.6E-3	1.6E-3	Pico	1.6E-3	1.6E-3	1.6E-3
Hotspot	6.5E-5	6.5E-5	6.5E-5	Hotspot	6.5E-5	6.5E-5	6.5E-5

4.2. Population coverage percentage

The traffic distribution follows the principle of using the radio environment with the lowest mobility support that satisfying a service category's requirement. According to this principle all stationary/pedestrian traffic would go to macro, micro and pico cells, all low mobility to macro

and micro cells and all high mobility to macro cells. The respective radio environment should be available, otherwise the traffic would go to the radio environment with the next higher mobility support. Some radio environments can be supported in all service environments. In practice, the total area of a service environment is covered by a certain radio environment, only up to a certain percentage, which is defined as the population coverage percentage [7]. For the years of 2010, 2015 and 2020, ITU proposed population coverage percentages for different radio environments in different service environments in Table 4 [7]. This is satisfactory for service environments included in the dense urban area but not harmonious for service environments in sub-urban and rural areas of a developing country. They can be covered under a cellular mobile network by using macro or micro cells because of the absence of high rise buildings and other obstacles. In addition to macro and micro cells, pico cell can be installed in office and public area where large capacity is required. According to the ITU methodology, pico cells and hotspots are proposed for rural areas, but this is not appropriate for developing countries. The base station antenna height of pico cells and hotspots may be much lower than the average rooftop height, so pico cells and hotspots are not feasible for rural areas. Network coverage is often lacking in low population density and low income rural areas of the developing world because of the expense of infrastructure. To solve this coverage gap, we propose using only macro cells for rural and remote areas. In some special cases micro cells can be installed in village areas that often feature a single community center where schools, hospitals and markets are located.

Table 4. ITU proposed population coverage percentage.

Service Environments	Radio environments				
	Year	Macro Cell	Micro Cell	Pico Cell	Hot Spot
SE1	2010	100	90	0	80
	2015	100	90	10	80
	2020	100	90	20	80
SE2	2010	100	90	20	80
	2015	100	90	20	80
	2020	100	90	20	80
SE3	2010	100	95	20	10
	2015	100	95	30	25
	2020	100	95	40	40
SE4	2010	100	15	0	80
	2015	100	35	0	80
	2020	100	35	0	80
SE5	2010	100	40	35	20
	2015	100	50	35	20
	2020	100	50	35	20
SE6	2010	100	0	10	50
	2015	100	0	10	50

4.3. Radio parameters

 Recent developments in technologies and deployments indicate the importance of small cells. Heterogeneous networks have become a standard approach in mobile broadband communication networks where small cells co-operate with macro cells, and the hotspot radio environment is a feasible deployment scenario for RATG 1. The radio parameters of the hotspot radio environment are similar to those of the pico cell radio environment. Therefore, the same radio parameter values should be used for the two radio environments. But hotspot radio environments in RATG1 were not considered in the ITU spectrum estimation methodology. In this paper hotspot radio

environments are included in RATG 1 for indoor coverage in dense urban areas. Network capacity and spectrum requirements largely depend on the application data rate and the mean service bit rate. The application data rate proposed by ITU for RATG 1 is acceptable but it is not typical for RATG 2 in developing countries. ITU estimated the application data rate for spectrum as 50 Mbit/s for macro cell, 100 Mbit/s for micro cell and 1 Gbit/s for pico cell/hotspot for RATG 2 [5]. Data rates of 30 Mbit/s to 100 Mbit/s or 1Gbit/s are required only for super high multimedia services. "However overall multimedia services such as high quality video conferencing, multimedia phone, mobile HDTV, video streaming and downloading, high volume business applications and collaborative working, mobile internet and data transfer etc. are visible into the high multimedia service type that supports a peak bit rate of up to 30 Mbit/s." Moreover, for the average subscriber in developing countries, the medium multimedia service categories with peak bit rate up to 2 Mbit/s are the most affordable multimedia services.

Table 5. ITU proposed radio parameters of RATG 1and RATG2

| Attribute | | RATG1 | | | RATG2 | | | |
| | | Value | | | Value | | | |
		Macro Cell	Micro Cell	Pico Cell	Macro Cell	Micro Cell	Pico Cell	Hot spot
Application data rate (Mbit/s)	2010	20	40	40	0	0	0	0
	2015	20	40	40	50	100	1000	1000
	2020	20	40	40	50	100	1000	1000
Max supported velocity-Km/h		250	50	4	250	50	4	4
Guard band between operators (MHz) -		0						
Minimum deployment per operators and RE (MHz) --					40		120	120
Granularity of deployment per operator per RE (MHz) -		20						
Number of overlapping network deployment-		1						
Support for multicast		yes						

To ensure a high bit rate, operators need to install more base stations with radio frequency or optical fiber based high capacity backhaul with supporting infrastructure. Since radio frequency is a very scarce and limited resource, an optical fiber based transmission /backhaul network is prepared to carry the required traffic of super high and high multimedia services. Apart from its very high installation cost, operation and maintenance are also challenging in rural environments. Since developing countries don't have a very big market, it remains difficult for operators to establish economically viable and profitable network for IMT systems. Thus, for developing countries we propose the application data rates for RATG 2 as given in Table 6 which can ensure the optimum use of the network and reduce the capital expenditure needed.

Table 6. Proposed application data rate of RATG 2

| Attribute | | Value | | | |
		Macro Cell	Micro Cell	Pico Cell	Hotspot
Application data rate [Mbit/s]	2010	0	0	0	0
	2015	30	50	100	100
	2020	30	50	100	100

4.4. Market data analysis

4.4.1. Market attributes settings for Bangladesh

In this step we analyze market parameters that have been obtained from Report ITU-R M2072, which derives market related parameters and provides forecasts for the mobile market for 2010, 2015, and 2020. ITU has collected market data from the most economically developed countries from the different parts of the world. This market data shows the great weight of the highest developed countries where multimedia traffic is increasing far more rapidly than speech, and will increasingly dominate traffic flows due to the higher mobile phone penetration. They have high data rate wireless network in every environment. Reports ITU-R M.2072 and ITU-R M.2078 present the market size of different countries, with penetration assumption for each service category along with service environment and technical data.

Bangladesh is a developing country in South Asia with an area of 147570 sq. km and a population of about 160 million with a low per capita gross national income of US$ 1000 and a 55.08% functional literacy rate. The Majority of the population are living in rural areas and engaged in farming activities. In terms of occupation 63% of the total population of Bangladesh is engaged in agriculture, 11% is in industry and 26% is in service based employment. Bangladesh is densely populated and also has a flat and easily extendable coverage. The demand for voice communication is very high and the subscriber base is very large but the investment needed is low because of the topographic layout. There are six licensed mobile operators in Bangladesh. The number of mobile connections has increased from 3.8 million in 2004 to over 100 million at the mid of 2013. Penetration rates are reported as 62.5% and network coverage extends to over 99% of the populations. The cellular mobile phone operators provide voice, SMS and low rate data service by using their EDGE (Enhanced Data rates for GSM Evolution), GPRS and CDMA 2001X compatible 2.5G networks. It can be assumed that 2G and beyond cellular mobile penetration rate will reach 75% at the end of 2020. Figure-2 shows that a significant growth has already taken place in voice communication through the 2G cellular mobile networks but the internet and personal computer penetration rate in Bangladesh is still not inspiring. In Bangladesh Broadband Wireless Access (BWA) was launched commercially at the end of 2008 but the penetration rate for the new service is much slower than that of the 2G service. 3G market in Bangladesh commenced commercially at the end of 2013.
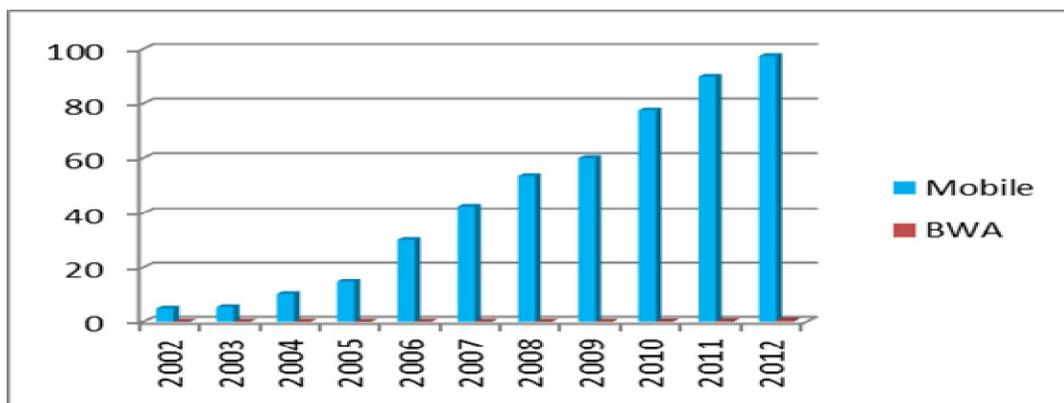
Fig.2 Growth of the telecommunications market of Bangladesh

The people of Bangladesh predominantly rely on traditional and relatively low- tech ICT (Information Communication Technology) options to access information. In the ICT development index released by ITU, Bangladesh ranked 138 out of 154 countries. Furthermore, a large portion of the population suffers from digital divide and there is a big difference in socio-

economic conditions between the urban and rural populations. Due to the lack of basic literacy, financial insolvency, computer skills and training in the use of ICT applications, it remains a significant challenge to proliferate telecommunication services included in the IMT systems in the rural areas of Bangladesh. Language barriers and the complexity of personal computer operation are hindering the internet based service diffusion further. Moreover the relatively high price of the 3G/4G/LTE terminal devices and the comparatively higher tariffs of high speed data, multimedia and video telephony services may discourage lower and lower middle income people from migrating from 2G to 3G/4G/LTE. It can be deemed that 40% of the total cellular mobile subscriber will enter the 3G/4G/LTE network within the year of 2020. So there is a genuine need to determine the spectrum requirements for Bangladesh that can accommodate not only the new services of IMT systems but also the new radio transmission technologies being developed.

To estimate the spectrum requirement for IMT systems, the related market parameters are provided in Report ITU-R M2072 for the years of 2010, 2015 and 2020. Those forecasts present the extreme volume of the strongest and aggressive market of developed countries but cannot be an example for spectrum estimation for IMT systems of a developing economy like Bangladesh. ITU has applied market attribute settings on the forecasted user density, session arrival rate, mean service bit rate and mean session durations [7]. For the years of 2010 and 2015 the user density is 5% in lower user density market settings and 25% for higher user density market setting while for 2020 the user density is 25% in lower user density market settings and 50% for higher user density market setting for all service categories. Even after applying the lower user density market setting on the market parameters of the Report ITU-R M2072, the ITU forecasted user density is above the limit of the expected user density of Bangladesh for the years 2010, 2015 and 2020. For example we compare some typical market data of the most usable service categories included in the conversational traffic class provided by ITU and the actual data that have been collected from Bangladesh telecom market for the year 2010 in the Table 7. ITU forecasted user density is 45 in the SE2 and 7 in the SE5 of the SC2 whereas the actual user densities are 20 and 3. Moreover there is quite a difference in the user density of the SC3 and SC5. This example is also applicable for all other service categories and service environments for the years 2010, 2015 and 2020. For this reason the ITU forecasted spectrum estimation does not match with the spectrum requirements of developing countries. Furthermore the session arrival rate per user and average session durations of each service category in the sub-urban and rural environments are larger than in the dense urban environments which indicate that the consumption rates in the sub-urban and rural environments exceed those of the dense urban environments for voice, data and multimedia service. For this reason the spectrum demand is dominated by the sub-urban teledensity in RATG1 [8]. This is another major limitation of the ITU spectrum estimation methodology. The dense urban environment represents a central business and highly populated area. Most users may use high-speed broadband data and multimedia services They also make many phone calls from home, office and public areas. Hence in a dense urban environment, a larger spectrum requirement holds than in a sub-urban environment. This scenario is also applicable for Bangladesh because the user density of its dense urban areas is approximately twenty times higher than the user density of sub-urban areas. So the market parameters have to be changed to get reliable spectrum estimation results for IMT systems for Developing countries.

Table7. Typical market data (user density, session arrival rate mean service bit rate and average session duration) for the year of 2010 (BGD indicates Bangladesh)

SC	SE	User Density		Session Arrival Rate		Bit Rate (Kbps)		Average Session Duration	
		ITU	BGD	ITU	BGD	ITU	BGD	ITU	BGD
2	2	45	20	0.299	0.199	20000	10000	53	41
2	5	7	3	0.299	0.1	20000	3000	51	16
3	1	6107.7	3637.5	0.2437	0.2129	496.2	496.2	113.5	105.75
3	4	1387.5	757.5	0.3738	0.158	290.2	290.2	109.2	45.5
5	5	8095.5	2228.5	1.688	0.511	16	16	227.1	128.9
5	6	677	380	1.3484	0.2506	16	16	207.5	95.6

Note that the 2G/2.5G cellular mobile communication market of Bangladesh is in a saturation state. For this reason we consider these service categories (SC4, SC5, SC9, SC10, SC14, SC15, SC19 and SC20) with the higher user density market settings. To calculate the spectrum requirement of Bangladesh we propose the user density parameter as shown in Table 8 based on the cellular mobile, computer and internet penetration rates. Table 8 shows that user density parameter denoted by U is equal to a certain percentage for different service categories. The market setting for session arrival rate per user is denoted by Q, the average session duration by μ and the mean service bit rate by R are equal to 30% for the year of 2010 and 2015, and 40% for the year of 2020 in all service categories. The market setting for the mobility ratios presented in this table assumes the middle mobility scenario for all service categories except for SC11. Because SC11 is a very high data rate service category with more than 100 Mbit/s data rate requirements.

Table 8. Market attributes settings for Bangladesh for the year of 2010, 2015 and 2020

SC	U in %			Q/R/ μ in %		Mob-ility ratio	SC	U in %			Q/R/ μ in %		Mobi-lity ratio
	10	15	20	10/15	20			10	15	20	10/15	20	
1	5	8	25	30	40	2	11	5	8	25	30	40	2
2	5	10	25	30	40	2	12	5	10	25	30	40	1
3	5	15	40	30	40	2	13	5	15	40	30	40	2
4	25	25	40	30	40	2	14	25	25	40	30	40	2
5	25	25	40	30	40	2	15	25	25	40	30	40	2
6	5	8	25	30	40	2	16	5	8	25	30	40	2
7	5	10	25	30	40	2	17	5	10	25	30	40	2
8	5	15	40	30	40	2	18	5	15	40	30	40	2
9	25	25	40	30	40	2	19	25	25	40	30	40	2
10	25	25	40	30	40	2	20	25	25	40	30	40	2

4.4.2 Mean service bit rate for Bangladesh

The overall spectrum demand mostly depends on the mean service bit rate. The ITU proposed peak bit rate is up to 30 Mbit/s for high multimedia and 30-100 Mbit/s or1Gbit/s for super high multimedia services. To meet the peak data rate up to approximately 1Gbps, a system bandwidth of around 100 MHz will be needed. But it is impossible for a telecom operator in Bangladesh to assign 100 MHz frequency continuously from a particular frequency band when competition between multiple operators is too high. In the wide-area cellular case for continuous coverage the system assumes a consistent and ubiquitous data rate per link of 5 Mbps as a minimum

requirement at the cell edge. In that case two carriers could be deployed; one providing basically the minimum ubiquitous service of 5 Mbps for all users and the other providing the access to services demanding higher data rates as up to 50 Mbps per service. As an example two carrier bandwidths of 2 x 20 MHz and 2 x 40 MHz are considered. 2x20 MHz operation could provide an aggregate peak throughput between 40 – 60 Mbits, which would be sufficient to deploy basic services in future wireless mobile systems. The 2 x 40 MHz carrier bandwidth could be deployed in environments where users request services demanding higher data rates. The carrier bandwidth of 2 x 40 MHz would allow a minimum of 80 Mbps that could guarantee mobility between cells for the high data rate services [10]. The Asia Pacific Telecommunity (APT) spectrum information database indicates that most of the countries in the Asia Pacific region have assigned 2x15 MHz or 2x20 MHz spectrum to each operator for IMT systems, which can provide a minimum ubiquitous data rate of 5 Mbps for all users in a full mobility radio environment.

5. SPECTRUM REQUIREMENT ESTIMATION FOR BANGLADESH AND COMPARISON WITH THE FORECASTED RESULT OF ITU

The complete algorithm developed by Hideaki Takagi and Bernhard H.Walke [8] and the calculation tool package "SPECULATOR" [17] are used for traffic and spectrum requirement estimation that has been described briefly in section 3 and 4. Calculations of spectrum requirement estimates for Bangladesh are presented in Table-9 and demonstrated in fig.3 & 4. These calculations were based on Bangladesh's telecom market trends, cellular mobile and internet penetration rates. ITU presents the results of the calculation of spectrum requirements for IMT systems in the Report ITU-R.M 2078 and the values are listed in Table-9 and illustrated in fig. 5 & 6. In the present telecom scenario, most traffic has been shifting from voice oriented communication to multimedia communication, so the spectrum requirement for RATG2 should be higher than RATG1 for the year of 2020. But in table 10 & Fig.8, the ITU spectrum estimate indicates that the spectrum requirement for RATG 2 is lower than RATG1. Moreover the spectrum demand is dominated by the sub-urban teledensity of RATG1 instead of the dense urban teledensity. These are the major shortcomings of the ITU methodology. In contrast, the results of the spectrum estimate for Bangladesh show in table 8 & fig.7 that the spectrum requirement for dense urban area is almost double than the spectrum requirement for sub-urban areas for every forecasted year and that the spectrum requirement for RATG 2 is higher than RATG1 for the year of 2020.

Table 9.Spectrum requirement estimation Result

RATG	Teledensity	Spectrum requirement estimation for Bangladesh			Spectrum requirement forecasted by ITU		
		2010	2015	2020	2010	2015	2020
RATG1	Dense Urban	520	700	540	720	720	760
	Sub-urban	300	360	340	840	880	880
	Rural	160	220	200	560	360	440
RATG2	Dense urban	0	340	680	0	420	840
	Sub-urban	0	200	400	0	380	700
	Rural	0	140	180	0	220	280
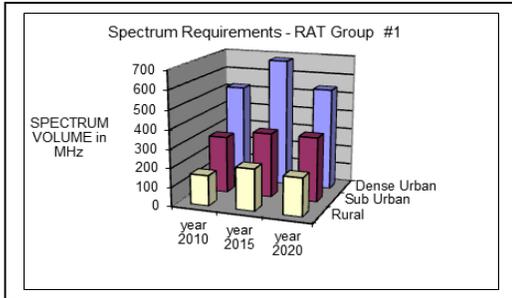
Fig.3 Spectrum requirement for Bangladesh
for RATG 1
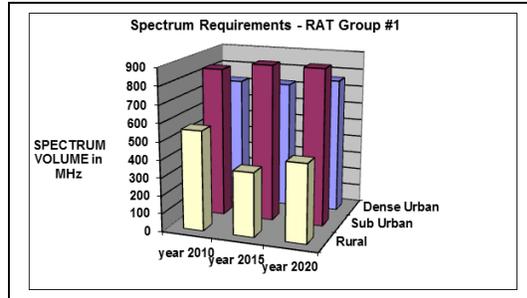
Fig.5 Spectrum requirement forecasted by
for RATG 1
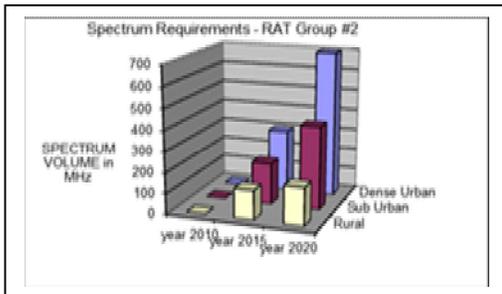

Fig.4 Spectrum requirement for Bangladesh
for RATG 2
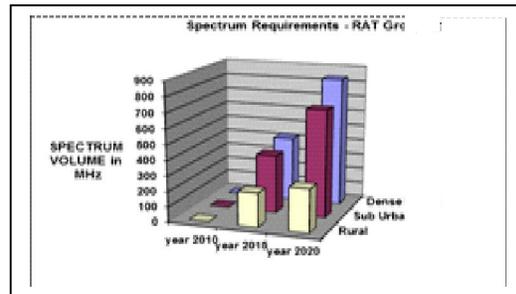
Fig.6 Spectrum requirement forecasted by
for RATG 2

Table 10.Final spectrum requirement estimation Result

| RATG	Spectrum requirement estimation for Bangladesh			Spectrum requirement forecasted by ITU		
	2010	2015	2020	2010	2015	2020
RATG1	520	700	540	840	880	880
RATG2	0	340	680	0	420	840
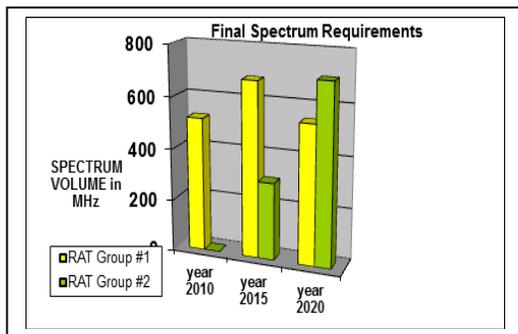
Fig.7 Final spectrum requirement for Bangladesh   Fig.8 Final Spectrum requirement forecasted by ITU
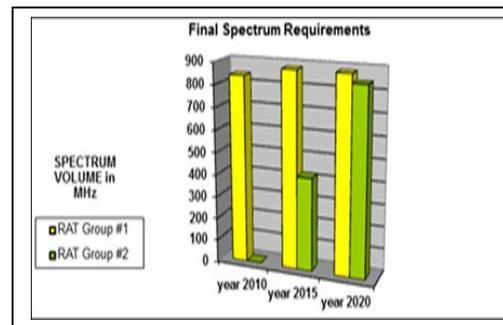
6. CONCLUSIONS

In this paper, we analyzed the algorithm underlying ITU's methodology for calculating of spectrum requirements of IMT systems. We proposed an alternate approach for estimating the spectrum requirements for a developing country like Bangladesh to deploy IMT systems in the three forecast years 2010, 2015 and 2020. We have pointed out the unsuitability of the ITU

methodology of applying spectrum estimation for developing countries and proposed the market setting, cell area, population coverage percentage, application data rate, market parameters like user density, mean service bit rate, session arrival rate and average session durations based on the Bangladeshi mobile communications environment and market. According to the ITU-R spectrum estimation methodology, the spectrum requirements of IMT systems for lower and higher user density settings are 1160 MHz and 1720 MHz respectively for the year of 2020 [8].The predicted total spectrum bandwidth requirements of Bangladesh for both the RATG 1 and RATG 2 for the year 2020 are calculated as 1220 MHz. It should be noted that this figure (1220 MHz) is little higher than the spectrum requirements of the lower market setting (1160 MHz). These consequences indicate quite difference between the forecasting marks of ITU-R and the outcomes based on the input parameters of Bangladesh telecom network deployment scenarios. Which direct ITU spectrum estimation overestimates the approximate requirement of developing countries.

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