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CRYSTAL BALL, TEA LEAVES OR MATHEMATICS - FORECASTING DATA TRAFFIC FOR MOBILE SERVICES

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ABSTRACT

The purpose of this paper is to contribute to a critical examination of the mobile spectrum requirements as put forward by the mobile industry in the Report ITU-R M.2290. A number of erroneous elements have been identified in this report leading to the conclusion in this paper that the spectrum requirements for IMT are greatly overestimated.

The mobile industry, supported by some national administrations, has formally proposed the estimated amount of spectrum in the Report ITU-R M.2290 to be allocated to mobile services at the WRC-15. No cost/benefit analysis and no impact assessment on the existing spectrum users have been provided to support this proposal.

If the WRC-15 decides to satisfy these requirements, the incumbent users of the affected frequency bands will have to be displaced. This would most certainly have an adverse impact on terrestrial broadcasting, satellite services, the cultural and content industries, and society in general.

INTRODUCTION

Major decisions on the use of radio spectrum are taken by national governments. In some cases such decisions have to be negotiated and coordinated internationally, in particular when the spectrum users seek global harmonisation of spectrum allocations. In principle, harmonisation helps to ease technical compatibility, ensure global interoperability and benefits from economies of scale.

The International Telecommunication Union (ITU) is a global forum where such negotiations take place. Spectrum planning decisions are agreed at the World Radiocommunications Conferences (WRC) that the ITU organise every 3-4 years. The next WRC will be held in November 2015.

Global spectrum negotiations are costly, lengthy and complicated. Once the spectrum has been harmonised, a number of years may pass before networks are rolled out to provide the services planned for that spectrum. It is, therefore, essential that this work takes into account the anticipated future demands for services and their impact on network capacity and spectrum requirements.

One of the main challenges that spectrum regulators have been facing in recent years is to ensure a sufficient allocation of spectrum for terrestrial mobile communications services in the future.

Forecasting future developments is necessary in any business and it constitutes an important pillar on which decisions are based regarding future investments and availability of resources. This is especially important when considering access to scarce, and thus highly demanded resources, such as the radio spectrum.

However, at the same time, forecasts always have to be taken with some scepticism. Depending on the circumstances, the probability of false prognosis may be very high. Thus, forecasting is always a very delicate and risky endeavour.

The mobile industry has collectively formulated their future spectrum requirements considering the results from work undertaken in ITU-R Study Group 5. Their most recent publication is the Report ITU-R M.2290, published in January 2014, estimating the spectrum requirements for the year 2020 [1]. More specifically, this Report quantifies the spectrum requirements for IMT-Advancedⁱ services to be accommodated at the WRC-15. These requirements are substantial and considerably exceed earlier estimates.

Up to now (i.e. March 2014) it has not yet been decided which frequency bands will be proposed for additional mobile allocation at the forthcoming WRC-15. However, the candidate bands under consideration are already used for a number of other radiocommunications services. As mobile communications networks are not capable of sharing spectrum with other users, this means that the new mobile spectrum requirements can only be fulfilled if the incumbent users are displaced from the spectrum bands they currently use. Economic and social costs of such displacement would be very high.

It is therefore very important, before taking any decision on new spectrum allocations to mobile services, to ensure that:

1. the mobile spectrum requirements are realistic, taking into account the technical and economic viability of the foreseen market developments in the time frame under consideration (e.g. until 2020), and
2. it can be reliably assumed that the incremental benefits for society of providing new spectrum for mobile use will exceed the costs and inconvenience of displacing the existing users.

The authors are not aware of any such analysis being carried out at a European or global level.

ⁱ International Mobile Telecommunications - Advanced (IMT-Advanced) is a set of ITU-R specifications for the next generation mobile communications systems.

ITU WORK ON SPECTRUM REQUIREMENTS FOR IMT

The new Report ITU-R M.2290 is in fact an update of an earlier Report produced in 2006ⁱⁱ. Both Reports are based on a method of calculating spectrum requirements that is described in Recommendation ITU-R M.1768-1 [2]. The key inputs for this method are:

- the assumptions on technical capabilities of radio access networks and their respective network configurations; and
- the assumptions about the future market demands and user behaviour.

The spectrum requirements are then quantified using a spreadsheet-based calculation tool that incorporates the methodology defined in Recommendation ITU-R M.1768-1.

While Report ITU-R M.2290 explicitly states that the input parameter values have been updated in order to reflect the recent developments in mobile telecommunication markets, some input assumptions appear to be arbitrary and unrealistic. This is described in more details in the sections below.

The conclusion of Report ITU-R M.2290 is that between 1340 MHz and 1960 MHz will be required to carry the traffic on mobile networks (3G and LTE) by 2020. This does not include traffic on wireless LAN (e.g. WiFi) for which separate spectrum requirements have been put forward.

Although the results in [1] are not representative of any particular country or territory, they have been interpreted to represent the amount of spectrum required globally for IMT and have been put forward as spectrum requirements to be accommodated by the WRC-15, as mentioned above.

In addition, the Report ITU-R M.2290 provides a forecast for global mobile data traffic until 2020. The forecasting method is rather controversial as shown in the examination and critique below.

Furthermore, it remains unclear what relation has been assumed between the global traffic levels and the amount of spectrum required to carry this traffic.

A study has recently been submitted to the ITU-R that examines whether the spectrum requirements in the Report ITU-R M.2290 match the assumed data traffic levels [3]. That study correctly points out that the spectrum requirements are determined by traffic density in a given area rather than by an aggregated traffic volume. Therefore, the predicted global traffic figures from the Report ITU-R M.2290 were used to determine corresponding traffic densities (measured in petabytes per month per km²). The study concludes that the ITU model overestimates the mobile traffic density by a factor of 100 or more when compared with those which would normally be expected in urban and suburban areas of any developed or developing country in 2020, leading to greatly exaggerated spectrum requirements.

Furthermore, it is well known that for any given data traffic volume, the spectrum requirements depend on the network configuration and size as well as on the transmission system. An increase of data traffic does not necessarily imply that more spectrum is needed. As network deployments and distributions of user demand are different in different countries the spectrum requirements will also be different. The Report ITU-R M.2290 fails to take this into account.

CRITICAL EXAMINATION OF THE INPUT ASSUMPTIONS IN REPORT ITU-R M.2290

The prediction of data traffic and the calculations of the spectrum requirements are highly sensitive to the values of the input parameters used in the calculations. It is, therefore, essential to ensure that these input values are realistic and as accurate as possible.

We aim to explain the perceived shortcomings of the approach taken by ITU Study Group 5 to estimate the future spectrum requirements for IMT. Firstly, the assumptions used by ITU SG5 to calculate the spectrum requirements are critically examined, and then the inadequacy of the

ⁱⁱ ITU-R Report M.2078

forecasting methodology for the future mobile data traffic is addressed. In particular, those issues where fundamental revisions are needed are highlighted.

GEOGRAPHICAL VARIATION OF SPECTRUM REQUIREMENTS

Depending on how mobile networks are implemented, similar data traffic levels may result in different spectrum requirements in different geographical regions. Undoubtedly, there are regions in the world with an extremely high demand growth for mobile services; but in other areas of the world this process is slowing down or has even reached a plateau. However, spectrum requirements will depend on the absolute traffic volumes and traffic densities and not on the rate of growth.

Therefore, areas with a high demand for mobile services are likely to require more spectrum than areas where the demand is low; but there is no correlation between geographically separated areas in terms of their respective spectrum requirements. For example, whatever the spectrum requirements may be in sub-Saharan Africa, they have no relevance for European services. It is crucial for the calculation of spectrum requirements to allow for such differentiation.

No such differentiation has been considered in Report ITU-R M.2290. Instead, it relies on mobile data traffic forecasts provided in Report ITU-R M.2243 [4], which gathers traffic and usage predictions from various sources in order to generate an overall global forecast until the year 2020. This global data traffic forecast is then used in Report ITU-R M.2290 to estimate the future spectrum requirements, which are interpreted as the amount of spectrum to be allocated to mobile services on a global basis. Obviously, such an approach is flawed as it does not reflect geographical variations and may lead to inefficient use of the spectrum. Therefore, the figures put forward in Report ITU-R M.2290, as currently proposed by the mobile industry, cannot be taken to represent the realistic spectrum requirements.

NETWORK TOPOLOGY AND SPECTRUM REQUIREMENTS

The calculation methodology applied in Report ITU-R M.2290 does not consider the relationship between the configuration of a mobile network and its overall capacity.

Adding more spectrum helps to increase the network capacity but this is certainly not the only possibility. Other possibilities include adjusting the network configuration and making a transmission system more efficient.

It is well known that within a given amount of spectrum the network capacity can be greatly improved by adapting the network topology. This means, for example, reducing the inter-site distance between mobile base stations, essentially making the network denser. Furthermore, indoor coverage can be achieved by deploying indoor access points, as opposed to serving the indoor users from outdoor base stations, which requires more spectrum. Whilst these and other network optimisation approaches are available and widely used in practice, none of them are reflected in Report ITU-R M.2290.

Furthermore, future IMT systems will be able to make use of carrier aggregation of already available spectrum bands to create wider channels in order to increase their spectral efficiency. This is not taken into consideration in the spectrum requirement calculations in Report ITU-R M.2290 either.

This is why the Report ITU-R M.2290 does not properly capture current trends in technological and network evolution. Consequently, the derived spectrum requirements cannot be considered reliable.

REDUNDANT SPECTRUM REQUIREMENTS

The mobile industry around the world postulates that societies are confronted with exponential data traffic growth. This is repeated like a mantra over and over again and serves as *the* justification for requesting more spectrum for IMT.

The alleged exponential growth of mobile data traffic is largely attributed to the increasing consumption of audio-visual content. However, most of this consumption takes place indoor, either in the home or at work. Usually, fixed broadband networks extended by WiFi are used as the principal means of delivery of such content. This is often because the users are cost sensitive and WiFi is less expensive than cellular networks.

More and more, media consumption takes place on tablets rather than on smartphones. Interestingly, the market figures showⁱⁱⁱ that 80% of the tablets are WiFi only. Of the remaining 20% one half never gets connected to a cellular network. With regard to traffic volumes, there are indications^{iv} that wireless data traffic delivered to smartphones and tablets over Wi-Fi connections already exceeds the total traffic delivered over mobile broadband networks and the difference is set to further increase. To some extent this is actively promoted by the mobile network operators as the WiFi offload is invariably factored into the design of mobile networks.

Report ITU-R M.2290 explicitly states that the spectrum requirements are calculated only for IMT. However, it remains obscure what assumptions have been made about the distribution of traffic between cellular networks and WiFi. This distribution should be a crucial factor used to balance the spectrum allocated to cellular networks with respect to that for WiFi.

ASSUMPTIONS ON DATA RATES

It is assumed in Report ITU-R M.2290 that services delivered over mobile networks can be classified into several service types. One of the assumed types is called '*super-high multimedia*'. According to § 3.4.1.1 of Recommendation ITU-R M.1768-1, this service type includes high data rate applications, such as multimedia video streaming with a peak data rate of 30 Mbit/s to 100 Mbit/s, or even up to 1 Gbit/s. In Annex 2 of Report ITU-R M.2290, which contains the assumed real values of market attributes used in the spectrum requirements calculation, a number of entries are found in Tables B.1 and B.2 with the mean service bit rate in excess of 400 Mbit/s, without giving any further explanation.

It is unclear what kind of application would require such high data rates in practice. For comparison, a multimedia application with one of the highest known data rate requirements is a full HDTV signal (1080p/50) which requires a data rate of less than 10 Mbit/s using the H.264/AVC compression standard. With the recently approved H.265/HEVC standard the required data rate will be much lower. Furthermore, even the emerging new Ultra HDTV services (4k) are likely to require less than 30 Mbit/s per programme^v. It can be expected that in the future the data rate requirements will further decrease.

The above mentioned applications are already well covered by the service type '*high multimedia*' that assumes a peak data rate of < 30 Mbit/s.

It is not realistic to assume that new, currently unknown multimedia services with extremely high data rate requirements will be widely deployed on wireless networks by 2020. In addition, new compression standards such as H.265/HEVC will considerably reduce bit rate requirements for video applications.

Consequently, the assumptions used in the Report ITU-R M.2290 unavoidably result in overestimated spectrum requirements of IMT.

ASSUMPTIONS ABOUT USER DENSITIES

User density is one of the key input parameters for calculating data traffic and the corresponding spectrum requirement. It was explained in Section 4.1.2 of Report ITU-R M.2290 that unique values for market parameters have been selected from the ranges given in another Report, ITU-R M.2072 [5].

ⁱⁱⁱ <http://allthingsd.com/20130710/why-bother-with-wireless-tablet-owners-stay-tethered/>

^{iv} http://europa.eu/rapid/press-release_IP-13-759_en.htm.

^v http://ateme.com/IMG/pdf/4k_delivery_to_the_home_-_pierre_larbier_-_ateme.pdf

It is observed that the values for user density given in Report ITU-R M.2072 differ substantially between different countries even for similar use cases. Furthermore, Report ITU-R M.2072 does not provide specific guidance concerning the user density values to be used in calculations. Instead, the values are described with a range on the basis of the submission by individual administrations (see §8.3 and Table 55 in [5]). In some cases the assumed values for user density appear rather excessive.

The values used in the spectrum requirements calculation are given in Annex 2 of Report ITU-R M.2290. Tables B.1 and B.2 in Annex 2 contain a number of entries with user density in excess of 100,000 users/km², some even higher than 200,000 users/km². No explanation has been provided to justify the assumption of such extremely high user densities.

However, the above-mentioned values significantly exceed the population densities encountered in practice, which even in the most densely populated urban areas rarely exceed 30,000 inhabitants/km².^{vi}

Obviously, using such unrealistic values of the user density in the calculation of the future spectrum requirements for IMT cannot lead to realistic results.

Furthermore, while specific provisions may be required for urban spots with exceptionally high user density for a limited period of time (e.g. sport venues, train stations), their geographical size is normally rather small and therefore such cases should not be used to determine the global spectrum requirements.

ASSUMPTIONS ABOUT MOBILITY

Spectrum requirements also depend on the state of motion of the mobile terminals. As a general principle, everything else being equal more spectrum will be required to serve fast moving terminals than the stationary ones.

A set of specific mobility classes are used in Report ITU-R M.2290. Indeed, they are the same as those used in the earlier Report ITU-R M.2072. Four different cases are distinguished and defined as follows:

- Stationary: no movement, i.e. a velocity of 0 km/h is assumed.
- Low mobility: velocities between 0 km/h and 4 km/h.
- High mobility: velocities between 4 km/h and 100 km/h.
- Super-high mobility: velocities between 100 km/h and 250 km/h.

In the calculations of the spectrum requirements these different mobility classes are not used explicitly. Rather, a combination of different mobility classes is assumed by defining the so-called "mobility ratios". Report ITU-R M.2290 states in §4.1.2 that *'for market parameter "mobility ratios" three scenarios are considered: lowest (1), medium (2) and highest mobility scenario (3)'*. However, no explanation has been provided as to how the values for the mobility ratios have been derived. This information is necessary as it may well be that the value of this parameter is different in different countries or changes depending on the coverage target of the mobile networks.

^{vi} See <http://demographia.com/db-worldua.pdf>

In addition to mobility classes and the concept of mobility ratios, service environments (SE) are defined which are given in Table 6 in Recommendation ITU-R M.1768-1 as follows:

Teledensity Service Usage Pattern	Dense urban	Suburban	Rural
Home	SE1	SE4	SE6
Office	SE2	SE5	
Public area	SE3		

Service environments and mobility ratios are among the input parameters included in Tables B.1 and B.2 in Annex 2 of Report ITU-R M.2290 (“*Real values of market attributes used in the spectrum requirements calculation*”).

The treatment of mobility up to this point seems to be plausible, even though as mentioned above, the selected values for mobility ratios have not been explained. However, there are a number of entries to those tables where the home and office service environments are associated not only with the stationary use but also with the low, high and even super-high mobility. It can be argued that low mobility is indeed relevant in home and office environments as people certainly are using their devices while walking in their homes or offices. However, high and super-high mobility classes are highly improbable in the home or in the office.

As previously explained, the spectrum requirements for services grow with increasing mobility. Thus assumptions based on high or super-high mobility in the home or in the office leads to overestimated spectrum requirements.

ECONOMIC CONSIDERATIONS

The traffic predictions on which Report ITU-R M.2290 is based have apparently been made without taking account of some key economic aspects and market developments that have significant impact on the actual demand and, consequently, the spectrum requirements.

Therefore, assuming that:

- In order to support the estimated growth of mobile data traffic (e.g. the 44- to 60-fold increase) large investments in network capacity would be required within the considered time frame (e.g. until 2020). Otherwise, the assumed traffic growth will not be possible.
- Investments will be justified only if they generate new revenues, save costs or ensure better market positioning.
- Demand for mobile data services is sensitive to pricing of these services. Readiness to pay is strongly influenced by the purchasing power of the consumers and the availability of equivalent services from other providers (e.g. fixed broadband and WiFi). Therefore, there will be limited possibilities to increase the charges to users.
- Mobile operators' revenues are increasingly under pressure in some countries. It seems unlikely that the average revenue per mobile user (ARPU) will increase substantially until 2020.

Based on these observations, it is appropriate to ask how the rapid increase in the network capacity will be financed. Without investments, traffic growth will be lower than predicted; therefore the corresponding spectrum requirements will also be lower.

Large investments without a sustainable revenue potential are not commercially viable. However, some mobile operators have already indicated that the investments in network capacity outpace the additional revenues from data services and it is difficult to reverse this trend. It is therefore uncertain how much spectrum will be possible to bring into use in the considered time frame.

Operators also use pricing as a tool to moderate the user demand. But this may curb the demand and consequently lower the spectrum requirements.

Economic considerations are normally not part of the studies carried out by the ITU. It is for the operators to carry out this kind of analysis as part of their business plans.

The conclusion is therefore that the estimated future spectrum requirements in the Report ITU-R M.2290 cannot be taken at face value. Even if the input assumptions are rectified, the mobile traffic growth will strongly depend on market circumstances and will not be uniform around the world. Therefore, a single set of global spectrum requirements is not appropriate.

FUTURE TECHNOLOGICAL DEVELOPMENTS

The current mobile networks carry a substantially higher amount of data within the available spectrum than was considered feasible in the past. For example: Verizon Wireless in the USA has stated that about two-thirds of its data traffic is carried on its 700 MHz LTE network^{vii}. This means that roughly 20% of all mobile data traffic in the USA is being accommodated within less than 40 MHz of spectrum. It is therefore hard to see how the requirement for more than 1900 MHz of spectrum for mobile services can be justified.

In addition, substantial developments in mobile network technology will enable much higher data rates than it is currently possible. For example, one global technology vendor has recently announced^{viii} that by aggregating 3 frequency channels (presumably each 20 MHz wide), an LTE network would be able to deliver up to 460 Mbit/s which is far beyond the capabilities of the commercial networks today.

Another significant factor is the recent adoption of a new compression standard H.265/HEVC. The increasing capabilities of such compression technologies as products mature will considerably reduce the capacity requirements of individual video applications.

None of these considerations have been reflected in the Report ITU-R M.2290.

CRITICAL EXAMINATION OF THE FORECAST METHODOLOGY

FORECAST OF THE DATA TRAFFIC GROWTH

Report ITU-R M.2290 sets out two graphs to illustrate the results of the data traffic growth predictions. For the sake of completeness they are reproduced here.

^{vii} <http://www.businessweek.com/articles/2013-12-06/verizon-wireless-4g-blitzkrieg>

^{viii}

http://www.fiercewireless.com/tech/story/ericsson-debuts-new-software-products-solve-capacity-issues-offer-new-servi/2014-02-11?utm_medium=nl&utm_source=internal

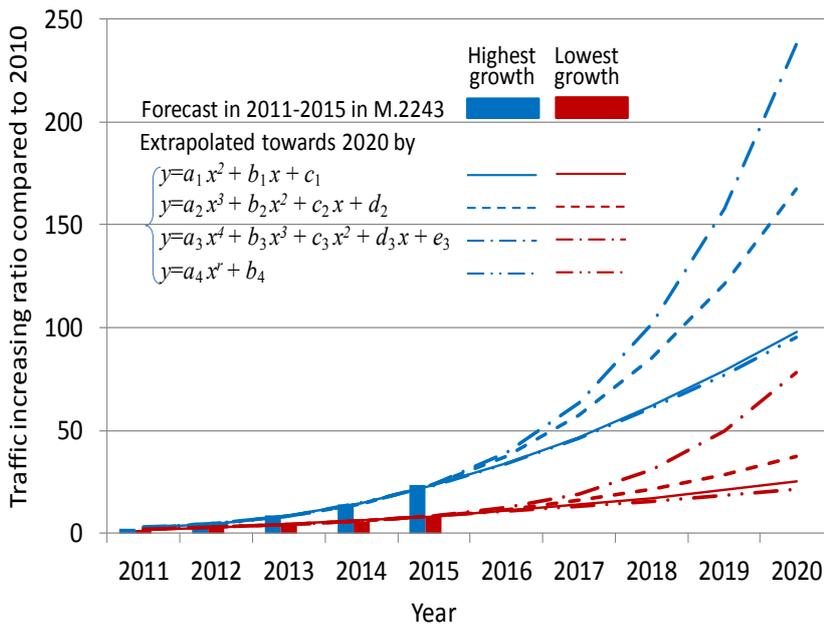


Figure 1: Mobile traffic forecast used in Report ITU-R M.2290 including employed extrapolation functions.

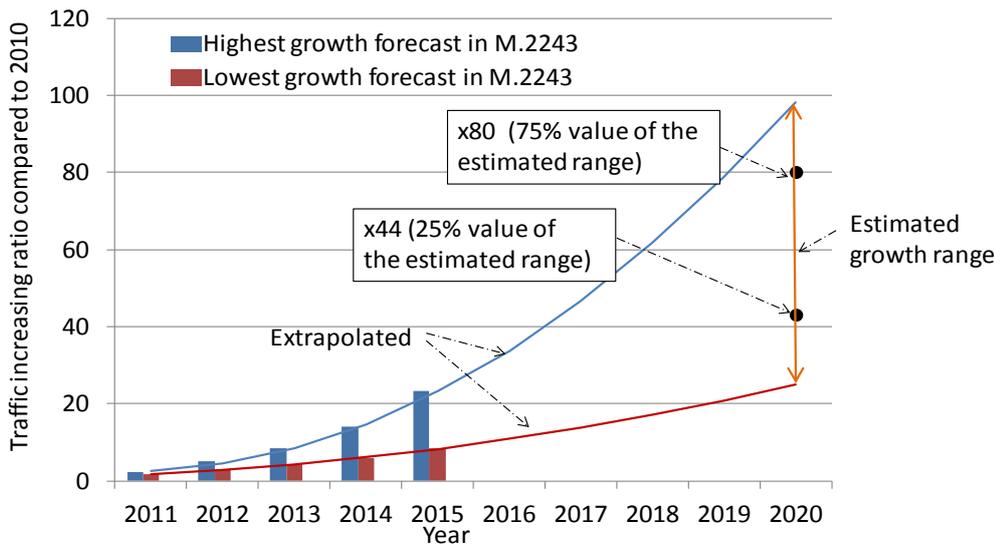


Figure 2: Mobile traffic forecast used in Report ITU-R M.2290.

The traffic predictions for the year 2020 shown in Figure 1 extend from a growth factor of 25 as the most conservative value to about 240. From these figures an estimated growth factor range between 44 and 80 is derived in Figure 2.

CRITIQUE

Forecasting the future traffic growth factors for IMT falls into the mathematical field of time series analysis. The basic idea is to predict future evolution of given variables on the basis of their known behaviour within a defined time interval. To this end, it is assumed that there is an intrinsic dynamics which drives the evolution and that the change from one time to another is not subject only to chance.

In most cases, the dynamic behaviour comprises two elements. The first one is a deterministic part which in principle could be described by corresponding equations such as differential evolution

equations. In addition, there is usually an unpredictable element at work as well which then is modelled by statistical means. A dynamic process which combines deterministic and statistical forces is usually addressed as a stochastic process.

Several mathematical methodologies are in place to deal with these kinds of problems [6]. They require more or less sophisticated mathematical techniques, but many of them are applied successfully in very different areas of science, engineering and economics.

The time series dealt with in Figures 1 and 2 constitute discrete data sets, i.e. for a finite set of discrete points in time a corresponding value of the data traffic growth is given. In such a case time series analysis is usually based on discrete models. If a set of data values D_n is given ($n = 1, \dots, N$), then a typical model would predict the next data point by assuming a relation of the form

$$D_{n+1} = F(\{D_n\}) + S_n, \quad n = 1, \dots, N$$

This means that the data value D_{n+1} at the instant $n + 1$ can be calculated from all previous data values $\{D_n\}$, $n = 1, \dots, N$ plus a statistical term S_n which represents either noise or fluctuating external forces. The function F can be any linear or nonlinear combination of the data values D_n . However, the crucial point is that defining a particular form of the function F corresponds to making assumptions about the internal dynamics of the time series. Well-known linear examples of such models go under the name ARMA (“auto-regressive moving average”) model and are widely applied in economics [7].

Turning to the analysis that underlies the results given in Figures 1 and 2 several issues stand out, such as:

- No evidence is given about the assumed dynamic structure of the time series for traffic evolution.
- Consequently, no stochastic model is presented according to which the forecast is carried out.
- Instead, polynomial functions up to fourth order are fitted to the available data.
- The data employed to fit the polynomials functions are forecast values themselves stemming from Report ITU-R M.2243.
- The evolution of the traffic growth is given by the shape of the polynomial functions outside the fitting interval.

Fitting polynomials to data is a well-known technique which is justified when it comes to interpolation of data. Quite often Spline-Functions are used for such a purpose, particularly if no further information is available about the underlying structure of the data set, i.e. whether it follows a polynomial or exponential behaviour.

Any interpolation applies by definition to the range between the first and the last data point. There the precision of approximation is under complete control. However, when fitting is used to extrapolate beyond the data set interval then the forecast is associated with growing error probabilities for increasing distance to the fit range. Beyond certain distances the error can no longer be controlled [8].

Consequently, the data traffic forecast in Report ITU-R M.2290 is highly unreliable. It is indeed surprising that such kind of analysis enters into ITU-R documentation as such an approach does not possess any mathematical justification.

The approach chosen for the forecasts of Figure 1 and 2 has to be considered even more unacceptable when looking on the data set on which the forecasts are based. These data are partially forecasts in themselves. Indeed, these facts reduce the statistical level of confidence in these estimations to virtually zero.

To illustrate how misleading such an approach can be, it is applied here to forecast two well-known time series. Figure 3 and Figure 4 show the time series together with a fitted 4th order polynomial

function.

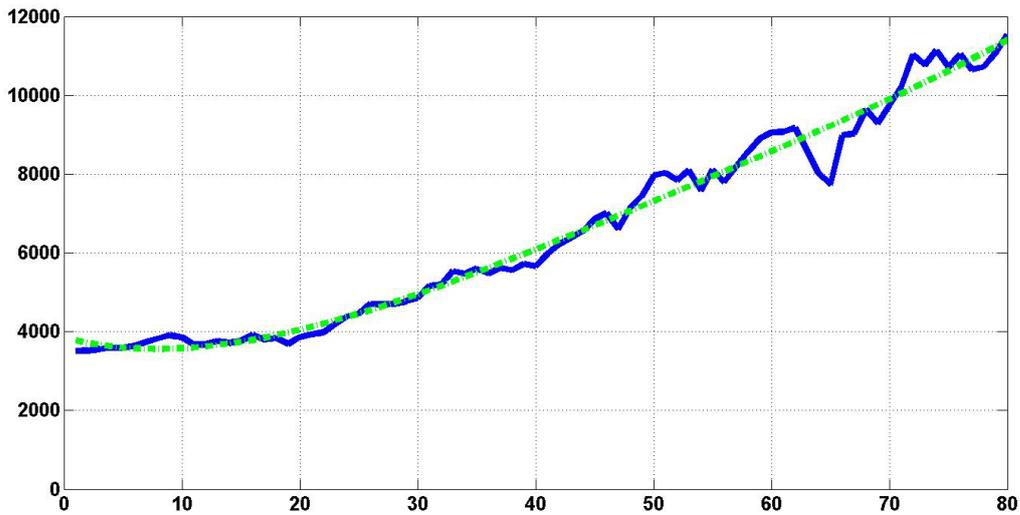


Figure 3: First example of a fourth order polynomial fit to a set of raw data. The raw data are given by the blue solid line while the dashed, green curve is the fitted fourth order polynomial.

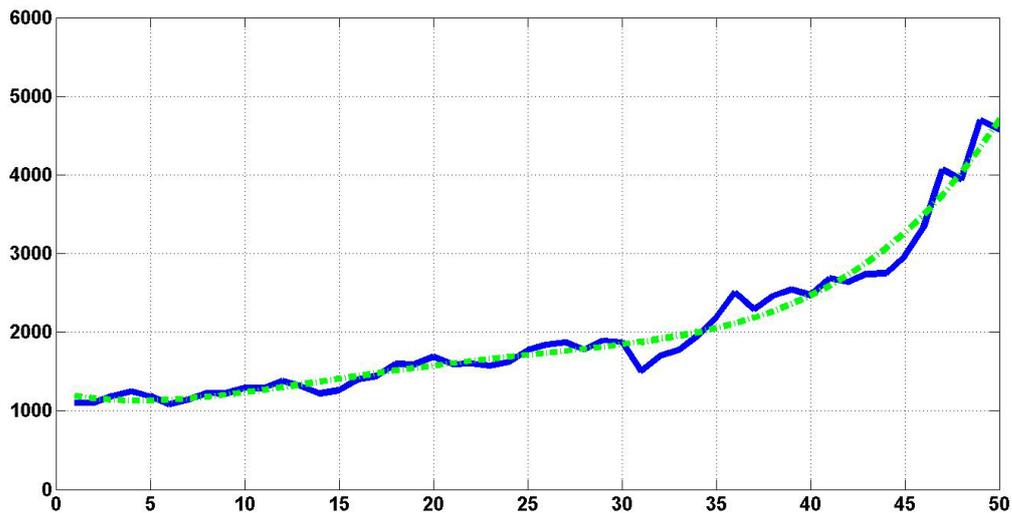


Figure 4: Second example of a fourth order polynomial fit to a set of raw data. The raw data are given by the blue solid line while the dashed, green curve is the fitted fourth order polynomial.

As indicated before, these time series are in fact very familiar to us. Indeed, Figure 3 shows the Dow Jones Industrial Index between 21 May 1993 and 9 December 1999, while Figure 4 displays the NASDAQ Composite Index between 5 February 1996 and 1 February 2000. Over these periods, both indices very much resemble the evolution of the data sets of Figures 1 and 2. Applying the same extrapolation approach to the Dow Jones and the NASDAQ time series, reveals the fundamental inadequacy of forecasting by polynomial extrapolation. Figures 5 and 6 illustrate the problem.

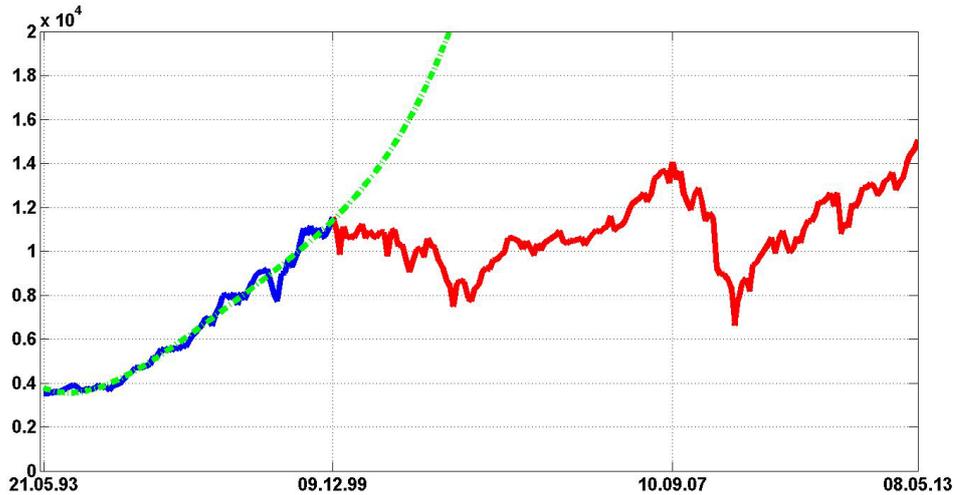


Figure 5: Same data as in Figure 3, only for a larger interval. The blue solid line corresponds to raw data set to which the fourth order polynomial was fitted; the red solid line is the real continuation of the raw data set. The green dashed line is the fourth order polynomial used to extrapolate from the blue line.

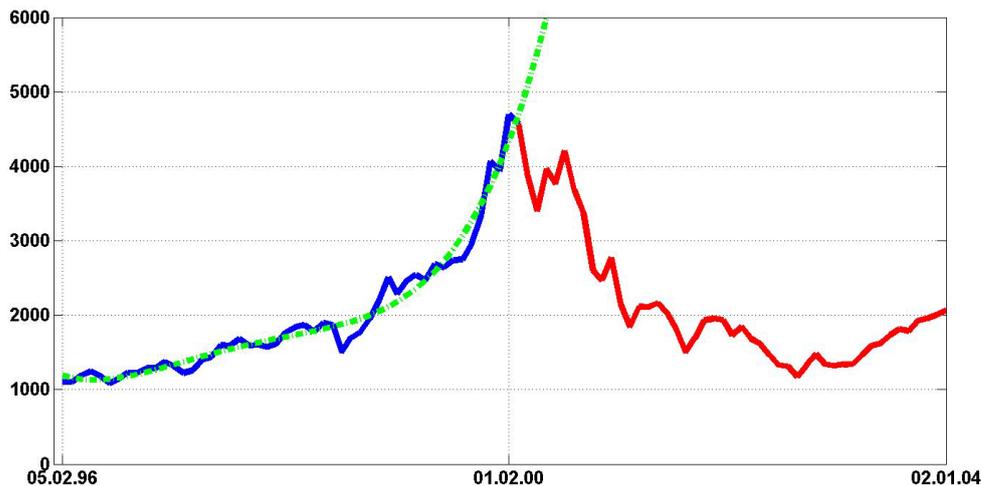


Figure 6: Same data as in Figure 4, only for a larger interval. The blue solid line corresponds to raw data set to which the fourth order polynomial was fitted; the red solid line is the real continuation of the raw data set. The green dashed line is the fourth order polynomial used to extrapolate from the blue line.

Between May 1993 and December 1999, the Dow Jones exhibited continuous growth. Without further analysis taking into consideration external factors the same approach as in ITU-R Report M.2290 would have suggested ongoing growth. Based on this, stock market analysts would probably have advised the public to continue investing in stocks. As everyone knows, at the end of 1999 the economic wind started to shift. This can be seen when looking at the NASDAQ graphs. At the beginning of 2000, the Internet bubble burst and the NASDAQ crashed.

From a mathematical point of view the analysis of the mobile data traffic growth and the evolution of the Dow Jones and NASDAQ Index are very similar. In both cases, the underlying dynamics are not known in mathematical terms. Consequently, stochastic process modelling is the only viable option to grasp, at least in statistical terms, the future behaviour of the time series. However, as is illustrated here, any attempt to forecast the evolution of such time series on the basis of polynomial extrapolation is doomed to failure.

CONCLUSIONS

WRC-15 will decide on new spectrum allocations for mobile services. One of the key issues addressed in the preparatory work for the WRC-15 is to establish future spectrum requirements for IMT, and to identify suitable frequency bands where these requirements can be accommodated.

Report ITU-R M.2290 is the key document on which mobile spectrum requirements are based. This Report has been published in order to substantiate the request of the mobile industry for additional spectrum for IMT. However, it has been shown here that this Report is flawed, both with respect to the input assumptions for calculating the spectrum requirements, and the mathematical approach used for the prediction of data traffic evolution. As such, the conclusions taken in this Report are wrong and should not be relied upon in the current debate about spectrum requirements of IMT systems.

Furthermore, the traffic predictions have been made without taking account of economic aspects or market developments that will have significant impact on the actual demand and, consequently, the spectrum requirements. These factors may well prove to be decisive in determining the future evolution of mobile data traffic.

As the work in the ITU continues, the EBU and ARD/ZDF have brought to the attention of the relevant ITU committees^{ix} all the above mentioned issues, with a request to rectify the input assumptions and revise the mobile spectrum requirements accordingly. At the time of writing, the information provided has not been taken into account.

Instead, the mobile industry and a number of national administrations strongly support the proposal to allocate the requested amount of spectrum at the WRC-15, despite the fact that the requirements are greatly exaggerated.

If the Conference decides to satisfy the current requirements of the mobile industry, the incumbent users of the affected frequency bands will have to be displaced. This would result in significantly adverse impacts on terrestrial broadcasting, satellite services, the cultural and content industries, and society in general.

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- [8] <http://en.wikipedia.org/wiki/Extrapolation>

^{ix}See document 5D/68 of WP5D (<http://www.itu.int/md/R12-SG05-C-0068/en>) and document 4-5-6-7/526 of JTG4-5-6-7 (<http://www.itu.int/md/R12-JTG4567-C-0526/en>)

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Roland Beutler studied Physics at the University of Stuttgart, Germany, and went on to receive a Ph.D. in Mathematical Physics from the Max-Planck-Institute for Metal Physics, also in Stuttgart. Between 1995 and 1996 he worked at the *Università degli Studi di Lecce*, Italy, under a Fellowship of the European Commission. In 1993 he joined SWR to work in the frequency planning department and is currently responsible for strategy of programme distribution and international frequency management issues.

Dr Beutler has been participating in EBU Technical activities for more than 10 years and has chaired several EBU groups dealing with the future of radio (S/FOR and S/FB2). He was chair of the Strategic Programme on Terrestrial Broadcasting (SP-TB), Currently he acts as chairman for the Strategic Programme on Cooperative Terrestrial Networks (SP-CTN) and the focus team SMR-SDB.

Roland Beutler is also involved in ITU and CEPT work and has been responsible for several of their working groups. He participated in WRC-12 and RRC-06 and was heavily involved in the preparation of the latter conference. Moreover, he has published several articles and three books on frequency and network planning for digital terrestrial broadcasting systems and the Digital Dividend.



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