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SPECTRUM FOR MOBILE[1]

COMMUNICATIONS IN THE WORLD

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[1] **TERRESTRIAL**

EXECUTIVE SUMMARY

Terrestrial wireless is evolving very rapidly around the globe. Despite efforts of regulators, especially those who allocate radio spectrum, different approaches continue to appear and to grow in ways that are not converging toward an « everybody's worldwide phone ». Many of the developments interact in ways that cannot be understood except by looking at the whole picture. This paper will provide a working global overview of the currents in mobile telephone technology, business growth and regulation, with special emphasis on spectrum aspects.

Since the origins of radiocommunication, in the early years of the 20th century, government has played a key role in managing radio spectrum ; and international coordination – through what was already called *ITU*, or otherwise – was an early preoccupation, mainly because radio was the only practical way to communicate while extensively mobile, be it on a ship or a plane.

In the last two decades, public cellular radio enjoyed such an exponential development, virtually everywhere, that the frequency harmonization which would have been advisable in a global mobility perspective could not follow pace. Also, technical conception took place « bottoms up », fairly independently within each leading geographic domains such as the U.S., Europe and Japan, giving birth to otherwise incompatible « air-interface » standards. This has not subsequently prevented the dozen key manufacturers from addressing the world market, at least in appearance, as if they were selling PC's or digital cameras ; the operators' camp, for its part, remaining extremely fragmented along geographic lines, even though consolidation looms.

Labeled GSM (***Global*** *System for Mobiles)* or UMTS (***Universal*** *Mobile Telecommunications System*), a cell-phone could be assumed by its owner to be **basically** working at any reasonable place in the world. This, however, is not the case because in large areas of the Americas, where GSM is now deployed, it is so in radio frequency bands different from those GSM uses on other continents. As to UMTS - also a Europe-driven effort but for the following generation - it is difficult at this point to tell if and when it is going to be deployed in America ; and if it ever is, it will make use particularly in the U.S. of bands again largely incompatible with UMTS elsewhere. *CDMA 2000*, on the other hand, a fairly advanced system on a significant growth path in various parts of the world, largely uses bands which had been allocated to - and used by - older generations.

Especially if they concern applications as important as public mobile communications, radio frequency decisions are for the long haul; and the reality may still give them a longer life than expected . The original 1970 *Federal Communications Commission* allocation to analog cellular will remain a key piece of the spectrum landscape for many more years, much beyond the U.S. In a vast multi-country area of the globe, another specific band which was considered obsolete a year or two ago, becomes important again « in a digital future » perspective : frequencies in that band do not only have the advantage of being available there for mobile use, they also have very appropriate propagation characteristics. As to China, an extremely important market in several ways, it understands the long-term bearing of spectrum decisions for the next generation and has therefore delayed them to 2004.

Hence, as established in this report, the number of cellular bands is on the increase worldwide ; this not only generates complexity (with costs and delays) for the manufacturers and for the operators, but more importantly, inconvenience for the end-user especially if he travels between continents. Indeed, today a cell-phone typically handles only two bands, maybe three.

Adding to that cellular multi-band environment, is the more recent *hotspot* phenomenon with its own bands. *WI-FI* broadly speaking becomes a segment of mobile communications which will sooner or later compete with cellular, particularly – but not only – on the data and image applications front, where the cellular operators have been keen to invest in order to increase average revenue per subscriber. A significant orientation now, on key markets, is the WI-FI / cellular combination, both in terms of service and of device, like a communicating digital assistant having both capabilities.

It is clear that the *International Telecommunications Union* – or rather the world community – has failed in its task, well defined already in the late 1980's ; namely to create the conditions, particularly in terms of spectrum, enabling the man in the street's cell-phone to place and receive voice calls virtually anywhere in the world. Some fifteen years later, the current and planned situations in terms of mobile bands make such capability still a remote and moving target ; though an *everybody's worldwide phone* remains highly desired in our perception by a large number of people, including but not only the corporate traveller. (One may note that all fixed-line phones have worldwide call and receive capability, technically speaking).

Many will retort that the multiplicity of standards – air-interfaces – is at the heart of the incompatibility problem as much as the multiplicity of bands ; indeed, and in this respect things do not improve : *ITU*'s *IMT-2000* edifice for the *Third Generation* of mobile communications incorporates today half-a-dozen such standards, incompatible with each other. But the two troubling factors are of a very different nature : not only are band allocations to services immutable in practice, but the spectrum an operator has at his disposal constitutes his core-asset and he has an extremely limited possibility to change it, even if spectrum trading is being introduced. The same does not apply to standards : large as well as small operators have migrated their infrastructure – within their available bands - from one air-interface to another, possibly in two or three years (e.g. from analog to digital, from *NA-TDMA* to CDMA*one* or to *GSM*) ; and such migrations will continue to take place in a variety of environments at each operator's initiative, if judged advantageous.

There are a number of angles to the harmonization debate. A static look today concludes that the mobile communications world is harmonized to over 70% on GSM, essentially in two or three bands. But one cannot ignore the dynamics towards more advanced and diverse services, the licenses awarded to existing or new operating entities for next generation deployment in new bands, nor the strong wish of influential governments to maintain and develop technology competition, thus also allowing new facility and service innovations to emerge. Our conviction is that a proper degree of worldwide spectrum harmonization negatively impacts **neither** one of these drives ; nor should it be opposed by *open spectrum* advocates. Actually technology competition works best in harmonized bands : if each major technology is attached to a specific band, what is at stake is convincing – actually lobbying - the pertinent authority in the concerned country to allocate one's preferred band, with the objective of freezing out the competing technologies.

The analysis in this report, of a worldwide scope and focusing on the end-user advantage, leads to remarkable intertwined challenges which industry and government are probably not currently addressing with the proper level of priority.

Technology challenge. The proponents of each mobile system type - we mean essentially the *GSM, CDMA, UMTS* and *Wi-Fi* families, a somewhat mixed bag - make maximum efforts to develop the performance, the economics and the features offered by the related products and services, within the spectrum resources available to them. In our view, more needs to be done towards multi-band capabilities and the latter's adequation to a multiplicity of continuously evolving standards, both on the device and on the infrastructure side. Software radio, cognitive radio, nanotechnologies, MEMS, smart antennas, frequency-agile base stations and others, certainly constitute interesting tracks ; but they are likely to take many years until they bear fruit in cell-phones and other portable devices on the street ; or within the extensive infrastructures. They imply R&D efforts beyond the possibilities of individual manufacturers (of devices, components or systems) who increasingly find themselves in a tough competitive row, often cash strapped and with other priorities to pursue.

Intercontinental mobility challenge. While waiting for ubiquitous radio technologies, the operators, assisted by the manufacturers, will have to give special attention to those of their customers who travel occasionally or frequently between continents, admittedly generating only a marginal proportion of their total traffic : they demand a reasonably global coverage for their personal communicating device, with corresponding seamless roaming capability. The operators, on their part, when formulating their spectrum requirements, must encompass this dimension to match the increasing complexity of the environment.

Granted, there are other, non-technical hindrances to the development of international and intercontinantal cellular traffic, such as the level of charges generally considered too high.

Regulatory challenge. Scope of regulation and spectrum policy for the mobile sector heavily intersect. Fixed telephony is still associated with the notion of « public service », which is not the case with cellular. But as the fixed carriers increasingly lose ground versus the mobile services, the question of the regulatory goals for the latter area, including in a travelling end-user perspective, cannot be indefinitely avoided : just making sure that there is competition is not enough. Notwithstanding international agreements, most countries have substantial latitude in spectrum management on their territory, which they can use as a leverage towards such goals.

On the other hand, spectrum decisions blessed by the highest levels of government as they appear rational at the outset, may later prove incoherent in their application and generate drifts disadvantageous to large slices of the user population. This is the case when spectrum is granted to one class of operators at a high cost – e.g. through auctions – and virtually free of charge to another class of operators, both offering, after some time, services perceived as similar by the marketplace. The couples *wide area mobility / limited mobility* or *cellular / Wi-Fi* will probably illustrate this concern.

ITU's challenge. Among the many areas in which ITU is currently active, all relating in one way or another to the exploding information society, spectrum coordination for global mobility constitutes a unique mission which the organization can by no means elude. (The same is true for satellite orbit slot management). It is apparent that this mission is now as important for the less developed as for the developed world.

Provided it continues to receive adequate support from the leading member states and regional organizations, ITU is uniquely positioned to put prime focus on pertinent areas of spectrum harmonization. Specifically, it is in harmonized bands that competition between mobile technologies – if it is desired – can thrive best.

Skepticism about whether a « spectrum commons » could work most likely springs from the way we've been trained to think about « spectrum ». A hundred years of careless talk has led many to think that spectrum is a thing. Worse, a hundred years of careless talk has led most people to think that when radios suffer « interference » it is because the radio waves have, in some sense, collided. Both notions are simply wrong. There is no such thing as « spectrum » that gets « used » the way a pasture gets used. Spectrum is not a thing. And what we think of as « interference » is not an issue of radio waves ; it's an issue in the receiver. Clarifying these two misconceptions will go a long way toward a greater understanding of a spectrum commons.

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This report aims at organizing some facts, observations, thoughts and issues regarding radio spectrum (i.e. radio frequencies) used or to be used for terrestrial mobile communications. It does not examine spectrum as a scarce commodity, nor as infinitely layered « plots of land » ; but focuses on the allocation of specific frequency bands to various mobile systems and applications, in different parts of the world. What are the implications for the prime stakeholders ? The manufacturers, the operators and the more or less mobile end-users ?

Four important assumptions are worth mentioning at the outset :

a. Beyond basic instinctive needs, talking is more than anything else in mankind's nature, by necessity or for pleasure. This is why, during the 20th century, traditional telephony went from nothing to « universal service ». And why, in the past quarter of a century, mobile telephony has followed a growth pattern unmatched by any other evolution, or rather revolution. We assume therefore that the preeminence of **voice communications,** especially in a global perspective, is unlikely to be threatened by exchanges of text, data, image, sound or video ; via internet or otherwise.

b. A few years ago, many expected that satellites – geostationary or rather orbiting constellations – would play a prime role in future mobile communications. Though there definitely is an important role for satellites, we assume that terrestrial mobile will continue to very largely dominate, in particular in terms of numbers of users. As in addition, the issues of frequency allocation to satellite systems are quite different, the scope of this report is limited to spectrum for **terrestrial** mobile.

c. There is a long history of **private** mobile radio systems devoted to communications within companies, government entities or within other bodies like those in charge of defense, security or emergency assistance ; spectrum is typically allocated to private systems on an individual basis. The history of **public** mobile communications, like cellular services open to all citizens, small companies and any other organization, is much shorter. We can assume that such public services will continue to dominante the scene ; they are therefore the only ones to be addressed here.

d. A time may come when there will no longer be a need to refer to spectrum, frequencies, bands or interference : transmitters / receivers will, at least in a certain sphere, intelligently exchange signals, hence information, through the « ether », without being constrained to uniform electromagnetic waveforms. This time has clearly not come and we assume here that, for a significant number of years, bands will have to be allocated to applications or assigned to operators serving defined geographical areas.

A key difficulty in attempting to produce the hopefully pertinent picture which follows, resides in the fact that spectrum decisions, taken at national or international level mostly for the long-term, are overlaid by a rapid and dense flow of relevant events materializing short-term policy, business or technological evolutions.

INTRODUCTION

Nearly everyone today – not only in the developed world – has some notion of what are *airwaves*[3] and of the vagueries of their propagation, even without having ever heard of Maxwell's equations or of Hertz's or Popov's initial esperiments over a century ago. The increasingly pervasive mobile phones certainly contributed to this awareness. However, the multitude of applications depending on « wireless » transmission of signals – as well as their significance to the economy - is often underestimated and so is the complexity of managing the invisible asset consisting of *radio frequencies*, customarily referred to as *spectrum*[4].

Simplistically, spectrum management is required because satisfactory wireless transmission of information from one point to another at some frequency, normally implies that it not be interfered by another transmission « nearby » at the same frequency. Hence, the essential elements of spectrum management are rather physical dimensions like space and time ; and technical like transmission power and the specific characteristics of the involved frequencies, particularly in terms of propagation. Even though legal and economic considerations are also very important ingredients. Spectrum management is generally seen as the main substance of *radiocommunications regulation*, whoever is in charge of that regulation.

Early in the history of *wireless* – in its broadest sense – it was realized that spectrum needed to be managed by a public authority. In fact, in every country of the world today, the state still exercises this prerogative in one form or another (even though efforts are deployed here and there towards decreasing that role[5]). On the other hand, as borders between contiguous countries generally are lines on maps, sometimes rivers or fences, they can easily be crossed by radio signals : hence, there is an intrinsic international dimension in spectrum management, not mentioning airwaves which propagate across continents. Some see this dimension as essential, some others as marginal, depending on the size and degree of insularity of their country and on the types of applications they are considering.

One application characteristic affecting heavily the task of spectrum management is the mobility of the transmitter / receiver[6] and the scope of this mobility. It was fairly obvious already in the earlier part of the 20th century, that the spectrum requirements of transatlatic merchant vessels had for instance little in common with those of most radio broadcasters (for information or entertainment).

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[3] Airwaves, radiowaves, electromagnetic waves or hertzian waves are equivalent designations. And so is to some extent the more popular, though confusing, term « wireless ».

[4] We will in this report use the terms *(radio) frequencies* and *(radio) spectrum* interchangeably. The former though is in many cases preferrable as it better implies that various frequencies have different characteristics, especially in terms of propagation ; whereas *spectrum* may be understood as an homogeneous commodity which can be uniformly « sliced » and distributed.

[5] The governments' task of spectrum regulation can be gradually reduced in scope, for instance :

1. By letting the market forces intervene more through authorizing *spectrum trading*, typically between operators.
2. By qualifying large slices of spectrum as *unlicensed* : technology driven or other coordination mechanisms allow a multiplicity of users, even if they are not registered.
3. By having a supra-national authority acquire real spectrum management powers : the European Union is going in this direction.

As to ITU's role at a global level, we will examine it later in this report.

[6] As the purpose is to avoid – or in some way to limit – (harmful) interference, one is primarily concerned by the transmitter. This report naturally focusing on *two-way* mobile communications, transmitters generally also are receivers.

Thus, at the core of this report, is the logical assumption that the administration of spectrum used by transmitters which move significantly, say at international, continental, intercontinental or global scale, needs some special attention. Ships, aircraft, many ground vehicles as well as non-geostationary satellites fall to a significant extent in this category : their ability to communicate depends on garanteed access to specific frequencies, within their geographic domain of mobility.

But our main focus here is on spectrum used by small, pocket-size, or other portable devices : typically *cellphones* and their derivatives, *PDA's* and portable computers like *laptop PC's*. The mobile communications revolution of these last 10-15 years justifies this apparently narrow scope within the vast field of spectrum management and spectrum policies : early 2003 there were well over one billion mobile phones in use in the world ; and this scene continues to evolve quickly both quantitatively and qualitatively. Spectrum for mobile access to the internet – at more or less broadband speeds – is of course part of subject scope, though we have not put that aspect in the very center of our investigation.

The essential question addressed in this report is this : in a worldwide perspective, what are the main issues related to spectrum used for or allocated to mobile communications ?

CHAPTER 1 : THE HARMONIZED SPECTRUM VISION AND ASSET

HISTORIC BACKGROUND

The history of *radio* or *airwave transmission* is significantly over 100 years old : the « radio boom » of the 1890's has recently been paralleled with the internet explosion of the 1990's[7] ! Guglielmo Marconi managed to transmit signals effectively over increasing distances : from yards in 1894 to 80 miles five years later. And finally over the Atlantic Ocean in December 1901[8] ; a date generally considered as ***the*** radio history landmark.

It is probably the early conception of *mobile radio communications* which explains that Marconi could thrive in England, the then leading maritime power, and not in his home country, Italy : *ship-to-shore* telegraphy was to be the prime application of airwaves.

After the inevitable progress triggered by World War I, the most visible use of radio became broadcasting of voice or *spoken radio*[9] as it was called : the general public was now concerned. In the U.S. in particular, radio broadcasting stations mushroomed already in the early twenties and the ensuing interference problems made it clear – to those who were not yet convinced - that the new channels of communications had to be under public control.

Rapidly, at least in the industrialized countries, transmission of any radio signals had to be authorized by the government and some form of national spectrum mangement was put in place. Legal frameworks were created to this effect, like the *1913 Radio Telegraph Act* in

[7] *The Guardian* (UK daily paper) dated December 11, 2001 – Article titled « Faking the waves ».
[8] From Cornwall to Newfoundland.
[9] Brodcasting of music also came early ; but its perceived impact was probably inferior.

Great Britain or the *1927 Radio Act* in the U.S. which « established the public ownership and regulation of the new channels [10]».

But quite early on, the international implications were recognized : this was imperative in the context of ship-to-shore telegraphy, leading to the *International Radiotelegraph Conference* held in Berlin in 1906 (which in particular adopted the SOS emergency distress signal). Note that by then the *International Telegraph Union* (ITU) founded in Paris, was already 41 years old ! In Berlin, the first regulations governing radiotelegraphy were agreed ; they later became the *Radio Regulations*, expanded and revised by numerous radio conferences held since.

More broadly, it subsequently became apparent that national control was not sufficient. Upon the initiative of the USA[11], an international conference attended by delegates of 26 nations was held in Washington in October 1927. Thus the radio arm of the ITU was borne, under the name of *International Radio Consultative Committee* (CCIR)[12] ; it was relabeled *ITU-R* at the occasion of a vast reorganization[13] in 1992 of the grand body which had become a UN specialized agency in 1947, still base in Geneva, Switzerland.

ITU's GENERAL ROLE IN WORLDWIDE FREQUENCY HARMONIZATION

The precise functioning of ITU-R is fairly complex as it reflects the formal interactions between a number of constituent bodies, the roles of which will not be described here: *World Radiocommunications Conference* (WRC), *Radiocommunications Assembly, Radiocommunications Bureau, Frequency Registration Board, Radio Regulations Board, Radiocommunications Advisory Group, Study-Groups.*

« The international framework for radio-regulation exists primarily to protect against harmful interference »[14]. In this spirit, ITU's *Radio Regulations* (RR's) are the essential piece of that global framework. They have the status of international treaties once ratified by the member states (numbering close to 200 by year-end 2002). The RR's include *International Frequency Allocations*[15] which allocate spectrum to broad categories of *services* like *fixed, mobile, broadcasting, aeronautical, mobile satellite, radionavigation, meteorological aids, amateur radio.*….etc. The RR's are revisited and updated or enhanced by *World Radiocommunications Conferences* (WRC's) held now every two or three years[16]. The ITU furthermore divides the

[10] « Development and control of of radio broadcasting » by Herbert Hoover – In *The Political Economy of the Media* (1952).
[11] Herbert Hoover, here agin, played a key role ; like in the initiation of the US legislation (Radio Act of the same year).
[12] The CCIT and the CCIF had been founded a couple of years earlier. These two were merged in 1956 to become CCITT.
[13] ITU was streamlined into three *Sectors*, corresponding to its three main areas of activity : Telecommunications standardization (*ITU-T*), Radiocommunications *(ITU-R)* and Telecommunications Development *(ITU-D)*.
[14] *Review of Radio Spectrum Management* by Professor Martin Cave, for the DTI (UK's Department of Trade and Industry) and for Her Majesty's Treasury – March 2002.
[15] Allocations can be on a *primary* or on a *secondary* basis. Current systems operating on a primary basis are protected from all future systems.
[16] For a long period in the latter part of the 20th century, they were held every four years only and were called *World Administrtaive Radiocommunications Conferences* (WARC's). The WARC's or the WRC's, the location of which varies, typically bring together thousands of experts - some representing their governments in a diplomatic capacity - for several weeks. Note that at WRC-03 held in Geneva during June/July 2003, it was decided to hold the next WRC only in 2007.

world into three geographic *Regions*[17] and the allocations can differ from one Region to another.

In simple words, a sovereign state can authorize the use of a certain frequency band[18] (or part threof) for a certain *service* – we would rather say *application* today – if this band is allocated to this *service* in ITU's *International Frequency Allocation Table* (which is an integral part of the RR's). This may sound like an extremely constraining provision ! There are though several attenuating factors. First, the RR's are a concensus, the result of a fairly continuous collaborative work over long periods (involving, beyond ITU staff, national experts, regulatory bodies and other government agencies, not mentioning industry). Second, ITU's frequency allocation tables are quite open and have built-in flexibility in several ways. This can be illustrated as follows.

During the 1992 WARC which took place in Torremolinos, Spain, 62 frequency bands (in the wide and highly important 148 MHz – 3 GHz range) were examined and received some amendment – often quite minor – in the Frequency Allocation Table. Among the services to which such bands can be allocated, *FIXED*[19] and *MOBILE* are of course quite important. Examination shows that among these 62 bands, all of those allocated to *MOBILE* were also allocated to *FIXED*[20]. And this is basically true in all three ITU Regions, mostly on a primary allocation basis. This means that individual countries (or regional bodies like the EU) had considerable latitude in their allocation of spectrum to terrestrial mobile communications services.

Similarly, nothing in the RR tables concerning the 2.4-2.6 GHz band, could let us expect that this band will be intensively used for RLAN's[21] (*RadioLans*), starting at the end of the last decade ; not only by private entities for their own use, but also by operators offering « mobile » high-speed access services to the Internet. (Spectrum for RLANs will be addressed later, in the chapter titled « The WI-FI phenomenon »).

These observations could lead to believe that the ITU has not fully played its role of worldwide mobile band harmonization which many expect it to assume. By 1992, and probably much earlier, it was already quite difficult to get worldwide agreement on allocating any specific band - primarily - to one important service. National interests, the weight of incumbants (in terms of spectrum occupancy) and the cost of *relocation* (i.e. converting existing infrastructures to new bands) largely tend to freeze de facto situations. Strangely, even some insiders within the ITU see the organization still heavily embedded in the wired and fixed communications past, thus giving the more recent *wireless* revolution a place less important than it deserves

Another dimension of flexibility of the RR's consists of the *footnotes*, the importance of which should not be underestimated. Most frequency allocation tables (each table, say one page, referring to a specific band and its possible subbands) – if not all – are followed by

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[17] Note that for some elections (like of the 12 members of the *Radio Regulations Board*), the world is divided in five regions : Americas, Western Europe, Eastern Europe, Asia and Australasia, Africa.

[18] The f(1) – f(2) frequency band comprises all frequencies between f(1) and f(2).
The 606-614 MHz (Megahertz) band, for example, is dedicated in the UK to astronomy (until further notice).

[19] Fixed wireless services are to a significant extent *microwave links*.

[20] Precisely, among the 62 bands, 46 are allocated to ***fixed*** **and to** ***mobile*** ; and none of the remaining 16 bands is allocated either to *fixed* or to *mobile*.

[21] *RadioLans* or *Wireless LANs (WLANs)* are *Local Area Networks* in which transmission over cables is replaced by radio.

footnotes which qualify to a more or less significant extent the content of the table as such. They may, for instance, reposition a set of countries with respect to an allocation formally appearing in the table ; or exempt a country from complyance with one or another listed provision. For example, the table for the 148-150.05 MHz band (comprising two subbands) is followed by four footnotes. The third one[22] states :

> « Stations from the mobile-satellite service in the band 148-149.9 MHz shall not cause harmful interference to, or claim protection from stations of the fixed or mobile service from the following countries that operate in accordance with the Table of Frequency Allocations…… ». Follows a list of 77 countries ranging from Swaziland to the Russian Federation and including all 15 EU member-states. Clearly, exception is taken with the mobile-satellite service using that band, by a substantial part of the world.

Let us provide another example. The 2290-2483.5 MHz table is followed by four footnotes, the third one saying :

> « In France, the use of the band 2310-2360 MHz by the aeronautical mobile service for telemetry has priority over other uses of the mobile service ». Note that the aeronautical mobile service is not within the allocations of subject table (and *telemetry* does not appear to be a service in the ITU sense).

In other words, everyone has to comply with the RR's, except where he has made it clear at a WRC conference that he cannot or will not comply with a given provision.

The ITU has of course become a complex organization which, though basically intergovernmental, also strongly associates a large private sector ; and some may well label it bureaucratic. Beyond telecommunications as such, it is involved in more general « information society » questions, especially with regard to the less developed world. As such, it has been criticised for some time already and the support it receives from its key contributors, i.e. the leading richer countries, is rather declining. In their common position paper, two European industry organizations pointed out in 1998, following the WTO agreement on telecommunications :

> « The global liberalisation of the sector provided for in this agreement raises a number of questions about the long-term mission of a specialized body of the United Nations responsible for telecommunications » [23]

A more explicite formulation of the concern :

> « As government ownership and control of telecommunications has diminished through waves of privatization and liberalisation, this has long been acknowledged as a problem for the ITU, whose membership comprises government signatories to the Charter. While once these were the only people that mattered, now they matter less and less »[24].

The fact is though that in the area of spectrum management, the governments still matter very much, as stressed earlier ; and we see no alternative to a worldwide organization – and why not an independent U.N. Agency - particularly when it comes to achieving agreements to

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[22] Designated ADD 608 / WARC 92.

[23] « *Tough Times Ahead for the ITU* » - An article in the March 1998 issue of *PNE* (Public Networks Europe) The two industry organizations are *ETNO* and *ECTEL*.

[24] Excerpt from the same article in *PNE*

harmonize spectrum for worldwide mobile communications (or to coordinate satellite positions on orbits with their relevant radiocommunications needs).

The U.S. certainly values the role of the ITU in spectrum management. The head of the U.S. delegation at a WRC – and this is unique - has Ambassador status, nominated by the President. In 2002, the *Assistant Secretary for Communications and Information*[25] (who reports into the U.S. Department of Commerce and also heads NTIA) stated before the *Center for Strategic and International Studies* :

> « I would like to say a few words on……..our goal of improving our effectiveness at international conferences. The name of the game is advantage. Our goals at the World Radiocommunications Conferences are not only to reach agreement on spectrum use that benefits U.S. customers, but also to protect U.S. commercial and national defense interests »[26].

This does not reduce ITU's need to adapt, which it appears to be doing. Reform was the prime topic at the 2002 *Plenipotentiary Conference*[27], including amending the essential *International Telecommunications Regulations* which, in their current status, date back to 1988. A *Working Group on Reform* has been active for some years and a *World Conference on International Telecommunications* is envisaged in 2007 or 2008 to that effect.

SPECTRUM CURRENTLY EXPLOITED FOR MOBILE COMMUNICATIONS WITHIN THE U.S.

Public cellular radiotelephony is undoubtedly an American invention and the credit generally goes to the Bell Lab's and to Motorola. In the late 1940's, AT&T made several technical proposals towards a service offering ; but only in 1970 did the FCC formally allocate 40 MHz of spectrum nationwide in the 800 MHz band. And it then took another thirteen years of political wrangling among the stakeholders until cellular service could actually be offered, initially in Chicago in October 1983. (Note that by then there already was some public service in Scandinavia and in Japan).

This original allocation[28] was dedicated to the analog technology AMPS of that time, a standard designed under the auspices of the FCC, which remains an important foundation of the American mobile communications edifice (stretching actually quite beyond the U.S.). A large number of private entities[29] were licensed to offer service, local in scope, with the aim of having two operators compete[30] at any location worthwhile throughout the country, each with 25 MHz[31]. Numerous transfers and mergers followed – the general trend being

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[25] Michael Gallagher, on July 8, 2002. Formally he was only « acting » in this position at that time, because he had not been confirmed by Congress.
[26] Remarks at the second meeting of this Center's *Commission on Spectrum Management*, July 8 2002.
[27] Held in Marrakesh, Marocco, from September 23rd to October 18 2002.
[28] Extended to 50 MHz in 1986.
[29] The selection by the FCC among the enormous number of candidates took place initially through comparative hearings, but then essentially through lottery.
[30] One of the two competitors was a *wireline* operator, i.e. he was owned by the local telephone company.
[31] The precise bands are 824-849 MHz and 869-894 MHz. Each of the two operators owns half of each band, as he needs in FDD mode an *uplink* separate from the *downlink* (i.e. from mobile to base-station and from base-station to mobile).

geographic consolidation of the licencees – but without impact on this basic scheme, spectrum-wise. Roaming between areas covered by different operators implied technical and administrative interworking mechanisms, but constituted no fundamental problem as there was a single air-interface standard and a « single band », both accommodated by all mobile handsets and all base-stations.

A new wave of cellular development – though under a different name – was initiated by FCC's *PCS* ruling of September 1993 : a more important chunk of spectrum was to be auctioned, again to a large number of geographically fragmented licencees for *Personal Communications Services*[32], which the FCC defined rather loosely as:

> « Radiocommunications that encompass mobile and ancillary fixed communications services that provide services to individuals and business and can be integrated with a variety of competing networks ».

Rapidly, PCS became in fact mobile voice not really different, for the user of a suitable handset, from already well entrenched *cellular*. While PCS actually pursued several aims[33] beyond the auction proceeds for the Federal Budget, we can say in retrospect that it mainly meant one thing for the growing mobile service provision industry : 120 MHz of additional spectrum, hence a great relief. That new spectrum was in a fairly different range – around 1900 MHz [34]– where the incumbants could be convinced to free it ; but with propagation characteristics unlike those of signals in the 800 MHz band, thus requiring more (though smaller) base-stations, this being logically in line with higher traffic capabilities. The PCS frequencies are better suited to urban and suburban coverage where the capacity strain appeared, and less to rural areas.

The PCS auction scheme was not simple and the actual unfolding of the auctions, starting in 1994, is even less : it spun over a long period because of various financial convulsions and it is barely completed after nine years ; in particular, the high-profile *Nextwave*[35] case has been settled by a Supreme Court ruling only in January 2003, tending to establish that a licence – or the associated spectrum ?[36] – is, like any other property, part of the licencee's assets, even if he goes bankrupt. Essentially, 120 MHz[37] divided into three 30 MHz and three 10 MHz

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[32] The total PCS scheme was actually more complex (and the FCC vocabulary rather misleading) : there were *narrowband licences* (for paging) and *broadband licences* (for mobile voice). We only give consideration here to the latter.

[33] (a) Increase competition by having up to five PCS operators coexisting in any area (in addition to the two existing *cellular*service providers)

(b) Offer higher spectrum efficiency and improved service through digital technologies (without any FCC role, this time, in the definition of technical standards which proliferated)

(c) Allow much higher end-user and traffic densities as they were going to result – mainly in urban areas – from the explosive mobile penetration

(d) Introduce from the start both small and large service areas ; the latter allowing a broader scope of end-user mobility without *roaming* into the area of another operator than his own.

[34] The quote which precedes as well as the detail of the six pertinent PCS bands (in the 1850-1910 and 1930-1990 MHz ranges) can be found in *Wireless Spectrum Finder*, by Bennett Z.KOBB – Mc Graw-Hill 2001.

[35] *Nextwave* won a number of PCS licences (with bids totaling 4.74 B$), paid the first instalment due, but was unable to pay the following ones. A legal scramble followed between the FCC, courts and other stakeholders.

[36] Unlike many other countries of the world, obtaining a licence in the U.S. is not much different from acquiring spectrum, as the licence includes few constraints as to the way in which the spectrum is to be used (like application, technology or standard).

[37] Previous users of this spectrum were in a large part private microwave link owners.

licences were auctioned in a large number of areas[38]. The aggregate revenue for the Federal Treasury from the PCS auctions is impressive but generally not considered unreasonable : well over 20 B$[39].

For the U.S. market today, PCS and cellular are equivalent services, now labelled *wireless*[40], though in various flavours. Thus, in view of the many acquisitions and mergers between mobile operators having taken place, one can no longer talk about *cellular* versus *PCS* service providers. *Digitization* occurred in both the PCS and cellular bands, but quite slowly, one of the reasons being the multiplicity of digital standards used, as the FCC had left to the licencees, at PCS introduction time, the « free choice » of technology. In practice, two American digital standards took the lead (NA-TDMA and CDMA[41]) in the 1900 MHz and - later – in the 800 MHz bands. More recently, the European digital standard GSM started to penetrate the U.S. significantly, essentially in the 1900 MHz band; but in 2003 also in the 800 MHz band .

The fact that geographical coverage is easier to realize in the 800 MHz band than in the 1900 MHz band, on one hand, the slow penetration of digital (with multiple standards) on the other hand, have justified the 800 MHz analog AMPS back-up as a regular feature of U.S. cellular service and mobiles. This is indeed a regulatory obligation which the FCC has revisited only in September 2002, deciding formally to phase it out over a five years period.

The overall thriving public cellular service provision industry as such is now dominated, within the U.S., by five giants (two of which are partly controlled by European groups) which coexist with many medium-sized and small operators ; in total, a complex and highly competitive landscape continuing to evolve in many ways ; the hunt for more spectrum, better and wider coverage – in one word : better service - being a key driver. The reasons why cellular penetration in the U.S. is significantly lower than in Europe or in the Far East are probably multiple. The spectrum situation is though a regularly expressed concern which led in May 2003 to what is considered as a major breakthrough :

> In a major policy shift, federal regulators voted to allow wireless carriers to lease their airwaves to others – a bid to ease a capacity crunch that has clogged cellphone networks and limited service in rural areas. The 4-1 vote by the FCC lifts a 40-year-old rule requiring airwave license holders to tightly control services that use that spectrum. …..[The] FCC Chairman……has called for a more market-based approach…..His view has gained traction largely because of a shortage of spectrum that has led to busy cell phone signals and slowed

[38] 51 *Major Trading Areas (MTA's)* and 493 smaller *Basic Trading Areas (BTA's)*. Neither ones are related to the *MSA's* or *RSA's*, the geographical division used originally for cellular licensing.

[39] As we will see in a following chapter, several 3G auctions held some time later in Europe lead to bidding levels considered – a posteriori – as completely unreasonable and damaging to the telecom sector as a whole. In fact, the amount paid per MHz and per head (of population) at significant PCS auctions in the U.S. (4.2$) is of the same order than the price reached in the « top-level » European 3G auctions (3.8$ and 4.4$ per MHz per head, in the UK and in Germany respectively). This comparison – which we could not validate in detail - was presented at a Palo Alto briefing in June 2001 by David Cleevely, managing director of *Analysis Consulting*, a respected consultancy based in Cambridge, UK.

[40] The introduction during the early nineties, in a systematic way, of a term as general as *wireless* to designate cellular broadly speaking, is unfortunate. This opinion is validated by the following observation : starting 2002, when the media mention *wireless*, they refer increasingly to *WI-FI* or *hotspots*, quite a different concept in regulatory, geographic, economic, spectral and other technical terms, as well as from the point of view of user perception. Much confusion in the marketplace is likely to result, not only in the U.S.

[41] Detail is available in « Standards for Personal Communications in Europe and in the United States » published by the *Center for Information Policy Research*, Harvard University, April 1998.

> the rollout of wireless internet services[42]. « Today's marketplace demands that we provide license holders with greater flexibility to respond to consumer wants, market realities and national needs without *getting FCC's permission* » [the FCC Chairman] said recently.

Imperfect roaming capability within the huge country is probably also a factor ; it is still being improved, including for more advanced data services, as evidenced for instance by actions taken not so long ago by *AT&T Wireless* to expand its footprint:

> « On the heels of announcing a major roaming accord with *Cingular Wireless*, *AT&T Wireless* said that, in the past year, it has signed domestic GSM/GPRS roaming agreements with another 22 USA based GSM network operators. The agreements further expand AT&T Wireless' next generation[43] roaming capabilities in mostly rural areas of 30 states. Roaming service is targeted to be available in most of these areas by the end of 2003…….We have signed a number of important GSM roaming agreements as a cost-efficient way to supplement our own new nationwide next generation network and further enhance the coverage we offer our customers »[44]

While CDMA (including its multiple flavours : *CDMA 2000*, *CDMA 2000 1X*, *CDMA 20001X rtt*, and *CDMA 2000 1X-EV-DV* or *EV-DO*[45] versions) has become the leading air interface standard in the U.S., three out of the five service providing giants are in the process of migrating to GSM and a fourth one is controlled by the most global operator worldwide, UK based and largely committed to GSM[46] worldwide. This appears to reflect a contradiction between the spectrum tense situation of the U.S. and the often quoted superiority of CDMA in terms of spectrum efficiency.

In summary, taking a « North-Atlantic » view : North America (actually beyond Nafta) has basically two cellular bands exploited with a patchwork of standards ; Europe also basically has two cellular bands – though different – exploited with a single standard, GSM. Both of these richest areas of the world have benefitted, it seems, from harmonized spectrum – at the internal level – for the development of their mobile communications market.

We must however, still in the U.S., address another category of terrestrial mobile communications companies, which in practice also offer mobile service to the public : *Specialized Mobile Radio* operators. SMR's[47] essentially serve markets like transportation, utilities, emergency services, construction and have received a lot of attention from the FCC over the last decades, particularly regarding spectrum allocation. What makes them worth mentioning here is strangely the posture of the largest one, *Nextel*[48], created in 1987 under the name *Fleetcall* (and renamed in 1993).

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[42] Excerpt from a May 16th 2003 *USA TODAY* release.
[43] We interprete here *next generation* as meaning GSM (to which AT&T is migrating its network) and/or GSM/GPRS, the wireless data service, in the 1900 MHz band.
[44] Excerpt from a release posted on March 24th 2003 by *cellular-news.com.*
[45] *EV* stands for enhanced version, *DV* for data and voice, *DO* for data only.
[46] *Vodaphone*
[47] SMR's derive from *trunking* (i.e. sharing private networks) on one hand ; but also from the important use and history, specific to the U.S., of *two-way radio* and *walky-talkies*. The latter represent the initial market opportunity of SMR's, in particular of *Nextel*.
[48] Nextel is controlled since 1995 by Craig McCaw, generally considered as the founder of the U.S. cellular industry.

Nextel has nationwide coverage[49] and offers to professionals and companies – and now even to private individuals - pocketphones with a range of services very similar to those of the cellular (or PCS) operators, including even access to the Internet web. But its system (*iDEN*, with its particular air interface, developed by Motorola) has a unique feature allowing through the push of a button[50] to communicate **immediately** with one or several colleagues of a team.

SMR's use spectrum in the 800 MHz (and 900 MHz) band, in part obtained through auctions. Nextel grew through acquisitions of smaller SMR's and has now access to 10 MHz[51] across the U.S., which no other wireless operator has, to our knowledge. Nextel's spectrum is close to – but outside – the bands allocated to true *cellular* as described above.

Though its 11 million end-users early 2003 represent less than 10% of the total U.S. wireless subscriber population, the company has an increasingly high profile, including internationally. It offers now dual-mode sets (iDEN / GSM) and, as the other major wireless service providers, has roaming agreements with operators abroad, specifically in 80 countries by early 2003. It advertizes with the catchphrase : « One phone. One number. Worldwide ». One therefore talks increasingly about the six « large wireless operators, which have [virtually] nationwide coverage in the U.S.», one of them being Nextel[52] .

As Nextel fares well, business-wise, compared to its wireless competitors, it could become a factor on the global scene, enhancing the importance of its special band exploited in the U.S. (and in some other countries in the Americas).

THE GSM STANDARD AND SPECTRUM HARMONIZATION DRIVE IN EUROPE

Spectrum management is in Europe – as elsewhere – a national prerogative, until further notice[53]. The organizational set-up varies considerably from one country to another : a specialized body may be devoted to the mission, like the *Radiocommunications Agency* in the UK or the *Agence Nationale des Fréquences* in France ; but even then, spectrum matters regarding telecom's may be more or less in the hands of the independent telecom's regulator, which is the case e.g. with the *Autorité de Régulation des Télécommunications* in France. In Sweden *Post & Telestyrelsen* (PTS) combines both spectrum management and telecom's regulation.

When it comes to spectrum auctions, it is usually a strong government arm which « calls the shots », like the *Department of Trade and Industry* in the UK or the *BundesMinisterium fuer Wirtschaft* in Germany ; and matters have typically gone higher up.

Telecom's and postal technical cooperation at European level takes place essentially through *CEPT*, a multi-committee body with 44 members (i.e. states, by YE 2002), historically dominated by what formerly were the national postal and telecom monopolies.The

[49] The other SMR's are local in scope, regional at best.
[50] Large U.S. cellular operators also start in 2003 to offer such a service.
[51] 896-901 and 934-940 MHz
[52] The five other ones are : *Verizon Mobile, Sprint PCS, AT&T Wireless, Cingular, D-Telecom.*
[53] The trend is clearly towards increased influence and weight, in policy matters, of the *European Commission* and of the *European Parliament*, with a goal of more effective coordination and harmonization. In this spirit, the *EP* and the *Council* issued in March 2002 a *Radio Spectrum Decision* which provides a regulatory framework with proper tools to establish a common spectrum policy. (It contains no reference to specific services like mobile communications).

organization, now assisted for spectrum matters by the small *European Radiocommunications Office* (ERO)[54] and linked by a dotted line to the *European Commission*, has adapted to the new environment and is a key player in European spectrum coordination and harmonization[55].

Automatic cellular telephone systems – truly speaking – emerged in Europe first in Scandinavia in the early 1970's and some years later gradually in all member states of what became the European Community. These were the *PTT* times when, to a very large degree, telecom's was a monopoly in the hands of the governments and when corresponding R&D was carried out in state labs in close conjunction with « national » manufacturers.

This situation led – except in Scandinavia where the countries cooperated around *Televerket*[56] and *Ericsson* towards the *Nordic Mobile Telephone* (NMT) system – to different national solutions like : *TACS* in the UK (largely based on US's *AMPS*), *C-NETZ* in West-Germany, *RADIOCOMM 2000* in France, and *RTMS* in Italy. Most of these systems used frequencies in the 450 and 900 MHz bands, probably inspired by the successful NMT-450 and NMT-900 networks. The Radiocomm 2000 frequencies were though in the 200, 400 and 900 MHz bands. Note that all these networks were based on analog technology : voice was not digitally coded for transmission.

Even with some homogenization in the 1980's (TACS came to Italy, NMT to France), intra-European roaming could not be seriously considered - except again within Scandinavia - because the systems were basically incompatible ; and handsets, if they were not costly installations of carphones, remained very expensive. Following an aborted Franco-German development project, a wider team was assembled in the early 1980's under the auspices of CEPT. It was labeled *Groupe Spécial Mobile* (which led to *GSM* i.e. *Global System for Mobiles*) and had the mission of designing standards for a digital system which would replace the networks mentioned above. Spectral efficiency and inter-operator roaming were important consi-derations from the outset ; the latter extending the scope of the work to a full network architecture. As to the air-interface, TDMA was selected (however different from the North-American NA-TDMA standard).

In parallel with this technical teamwork (which took first place autonomously in Paris and was later transferred to ETSI), awareness of what was at stake built up at the *European Commission* level. An *EC Council Directive*[57] was thus issued in 1987, setting aside two slices of spectrum totalling 30 MHz, in the 900 MHz band[58]. This initial GSM dedicated spectrum was later augmented with contiguous 40 MHz[59].

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[54] Based in Copenhagen

[55] This includes the establishment of common positions for key events and negociations like the WRC's.

[56] The Swedish national telecom's operator (including important R&D facilities) ; now a company called *Telia.*

[57] Directive 67/372 – A piece of binding *European Community* legislation.

[58] 890-905 MHz and 935-950 MHz – As is still typical today, this spectrum was to be used in *FDD* mode, i.e. a part dedicated to the *uplink* (i.e. from mobile to base-station) and another part to the *downlink*.

[59] The total GSM spectrum in the 900 MHz band, consists early 2003 (and unchanged for some years), in formal terms of :

- The GSM 900 band : 2x25 MHz (890-915 / 935-960)
- The E-GSM (Extended GSM) band : 2x10 MHz (880-890 / 925-935).

It is convenient and customary now to call the conjunction of these bands « the GSM 900 » band i.e. 70 MHz of spectrum (880-915 / 925-960).

The historic telecom's operators - the PTT's or their derivatives – were largely leading the first phase of the GSM game, while further licensing of operators selected through « beauty contests » was carried out by the national authorities. In spite of initial difficulties, serious doubts and delays[60], the first system and service were launched in the UK in 1990[61] and the mushrooming effect was then beyond expectations : in 1993 the one million GSM subscribers milestone was reached.

The pressures of increasing traffic and the desire to introduce more effective competition by having several nationwide GSM operators in each European country - three, four or five is now typical - generated a few years after the initial launch a need for much additional spectrum, in a different range of frequencies ; in most cases over 100 MHz were rapidly found in the 1700-1800 MHz range[62]. The corresponding adaptation of the existing 900 MHz GSM standard was called *DCS[63] 1800* for some time ; but now the term GSM encompasses both GSM 900 and GSM 1800.

The end result is that by 2003, 35 European countries are served by 110 national GSM operators[64] which are associated through bilateral roaming agreements, making the whole space virtually seamless.

The landscape of the precise frequency bands awarded exclusively to each operator through its licence is in fact not simple : virtually all GSM operators in Europe have by now both 900 and 1800 MHz spectrum ; but even for a small operator, this spectrum may be in as many as eight slices, with boundaries involving fractions of a MHz[65]. This has no impact on the mobile phone design : cell-phones now marketed in Europe all have the *dual band* capability and can function at any frequency within the Europe-wide, formally defined GSM900 and GSM 1800 bands. In fact, « at home » a GSM handset only has access to the frequencies belonging to the operator of which the owner is a subscriber ; while in another country served by GSM operators, this same handset is able to take advantage of the operator which has the best coverage, at a given place and time ; because of the large number of effective roaming agreements. (The GSM roaming agreements graph in Europe is largely « any-to-any »).

GSM has gradually spread outside of Europe to Africa, the Middle-East as as well as to some important countries in the Far East and in the South Pacific region ; again in the 900 and 1800 MHz bands. Central and South American countries were fewer to adopt it and significantly later, generally making use of the 900 MHz and 1900 MHz bands ; that process is still going on. And finally the U.S. adopted it in part, as indicated earlier, in the 1900 MHz band (and now also gradually in the 800 MHz band). By early 2003, the GSM geographic spread was by no means over, affecting close to 200 countries and of the order of 500 operators[66].

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[60] The prevailing joke in the industry went like this : GSM means « God send mobiles ! »

[61] Actually not by the historic operator but by *Racal Vodafone* (now just called *Vodafone*), the system being supplied by *Ericsson.*

[62] The so-called GSM-1800 band, as formally defined at European level, consists of 150 MHz (1710-1785 / 1805-1880). In most concerned countries it is only partially assigned.

[63] For *Digital Communications System*

[64] We count here the national operating entities. Some though are part of international groups devoted to mobile communications. The leading such groups are UK based *Vodafone* and (now) France based *Orange.*

[65] *Mobilkom Austria*, for example, has eight non contiguous slices : 2x7.6, 2x2.2, 2x2.1 and 2x1.0 MHz.

[66] The statistics published by the (UK/Ireland based) *GSM Association* do not provide clear operator figures.

Though this has no direct implication – so far – in terms of spectrum, there is a different cellular coverage philosophy in Europe versus many other countries. Only European countries (and possibly a few others like South Africa, Thailand, Marocco) have close to « blanket coverage », because of evident population density, physical geography and standard of living factors ; but also because of public policy measures (implemented through constraining coverage requirements associated with the licences) implemented in Europe, aimed at avoiding the poorest, most rural areas being left out[67].

With some 850 million subscribers representing over 70% of the world's cellular population (early 2003) and the extensive associated roaming facilities, the history of GSM can clearly be viewed as a success story, much beyond Europe. The more recent explosion worldwide of *short-messaging* (a standard GSM feature but no longer a GSM unique) adds to the positive perception by the general public of GSM's adaptability. On the other hand, this view has probably strengthened the « harmonization » syndrom, in opposition to the diversity and rapid evolution of the technologies, needs or marketplace ; and to the possibilities of the real world[68]. Spectrum is among the main factors which will – and has started to - shape the « post-GSM » future ….if such a future ever comes about in sizable terms.

We understand though that the number of countries affected still went from 179 in April 2002 to 195 in April 2003 (some having both GSM and non-GSM operators). Though many operators are *dual band*, the 900 MHz band prevails substantially.

[67] This matter still remains somewhat an issue, in 2003, even in some rich highly populated, early and well penetrated European countries. (Note that intra-country / inter-operator roaming has been rarely envisaged on a substantial scale – for obvious pro-competitive reasons - ; though in Scandinavia one government has given it consideration). In France for example, the regulatory body had to intervene to broker with the three operators a joint solution – involving some local authority funding – to assure proper coverge in areas complaining that they were negatively impacted in economic terms by its absence.

[68] The GSM industry has drawn huge benefits from subject harmonization. Not only the visible European heavyweights like Ericsson, Nokia, Alcatel and Siemens ; but also their North-American competitors like Motorola, Nortel and even Lucent, not mentioning those of the Far East (like Samsung, Panasonic or LG). The same applies to component and chip-set manufacturers, large (e.g. TI, Intel, STM) or small (e.g. Wavecom or Enfora). More recently though, the *realpolitik* has found its place : even the most GSM committed entities are now competing in the expanding CDMA markets. As to the large GSM operators, they are – cautiously ? – embracing the Wi-Fi horse, with no less enthusiasm – to say the least - than the CDMA players.

CHAPTER 2 : THE END-USER's VIEW

THE VERY BASIC REQUIREMENTS

What the vast majority of the wireless subscribers want, is fairly well established and will still apply through a large part of this decade. Basically, they want to be able to make and receive voice calls, to hear the other party well and to be clearly heard, to finish a conversation without being subreptitiously cut off ; associated voice messaging is generally also seen as a must. They want this service to be available first in the places where their normal life takes them : outside, on the move or inside buildings they visit. For the vast majority of the people, again, most of the time, their work, leisure, socializing, driving, use of public transportation takes place within miles, at most, from their home. This is where they require permanent seamless coverage, associated with sufficient traffic capacity even during peak hours, even at jammed locations – like Trafalgar Square at 5 p.m. – so that they can reliably count on their calling ability and the possibility to be reached. They more or less understand, however, that the network cannot be designed to handle traffic surges due to extreme, catastrophic circumstances.

Satisfying these basic requirements[69] implies, on the operator's side, that infrastructure deployment be sufficient (essentially in number of base-stations) and appropriate (in terms of their location). It further implies that he has enough spectrum at his disposal, compatible with the mobile devices being used by his customers[70]. Clearly, more spectrum helps, especially in view of the increasing reluctance of the inhabitants, especially in affluent areas, to see new base-stations being set up[71].

Some readers may at this stage think that all this goes without saying and that in « cellular developed » countries, such worries do no longer exist or are marginal by now. Unfortunately, there are many signs, particularly in the U.S., that such a view would be substantially incorrect. For example, a November 2002 news release says :

> « Can you hear me ? That is what Senator Charles Schumer is asking the FCC in order to improve New York City cellphone service, which is the worst in the country. While New York City is the largest cell-phone market nationwide, customer complaints jumped 1400 percent from 2000 to 2001, and even more during the past year.
>
> New-York City and Long Island also have 200 dead zones and cell-phone services currently charge customers per minute even when the connection is not made.

[69] Some organizations, like banks in important cities, compell their branch employess when needing to reach customers to use provided cellphones. The reason lies in the economics resulting from queer rate arrangements or special deals struck with mobile operators. Not mentioning the necessary tricky building coverage, we do not consider such use of public cellular service as reflecting a « basic requirement ».

[70] This is maybe an obvious point, but worthwhile to be illustrated : if a 2G operator for instance acquires 3G spectrum, that spectrum will be of no use for his existing 2G subscriber population ; it can represent a relief to the operator once there are enough 3G devices out there.

[71] This reluctance results from growing health and environmental concerns, though the reality of the risk has, to our knowledge, never been scientifically proven in spite of the huge number of studies carried out. To some extent, there is a balance between spectrum and number of base-stations : with a given technology, doubling the amount of spectrum available in an area also doubles the number of channels or total traffic capacity ; doubling the number of cells (which often means increasing the number of base stations) has roughly the same effect. A futher degree of compexity is due to the fact that increasing the number of base-stations does not necessarily mean increasing the number of « towers », the most visible element of the infrastructure.

> With more than 150 million cell-phone users nationwide – and 10.5 million in New-York City – Schumer is calling for new regulations »[72].

While Manhattan's unique architectural high-rise profile may present particular difficulties, more or less similar complaints have been reported in other U.S. urban areas. As to service in U.S. rural areas, it is often mentioned as being insufficient.

In Europe – a very different geography and population spread - the wireless performance seems overall to be perceived by the end-users as satisfactory or at least acceptable. In some countries there are systematic quality of service measurements designed and initiated by the telecom's regulator (though carried out by an independent third party), the results of which are made public per operator, thus allowing comparisons. One cannot deny, though, that troublesome coverage « holes » exist - even in some highly developed areas – and are leading to special steps involving local government, national regulator and operators ; nor can one deny that one's conversation may happen to be broken, especially while in a moving car or train.

We are not in a position to judge how much the above perceived « difference » between the two sides of the Atlantic, could be the result of dissimilar spectrum situations in quantitative terms. Two American experts put it bluntly :

> « …….wireless services have 159 MHz of spectrum available for use [in the U.S.], but most European nations have about 250 MHz of spectrum». Adding that :
> « An FCC goal to allocate another 100 MHz to wireless uses in the next ten years is not very ambitious »[73].

THE SUPPOSED NEED FOR ADVANCED MOBILE SERVICES

There is no doubt that in the fixed communications sector, a certain amount of traditional voice-calls have been replaced by electronic mail[74], even before the astonishing spread of the Internet and its common use for e-mail. Hence the question is open as to what extent the same trend applies to wireless : will cell-phone owners use them substantially to exchange mail or access the Internet ? Or for other non-voice applications like taking/sending pictures or for video transmission ? Such developments which have been « around the corner » for years have started substantially in Korea and Japan ; in the U.S. and in Europe, early 2003, they were still ardently awaited by the operators as a means to increase the ARPU. If we limit our

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[72] November 26, 2002 *New York Post* release titled : « Chuck's cell-phone wake-up call ».

[73] These quotes are taken from a May 1, 2003 release by *Computerworld / IDG News Service* titled : « Wireless experts : give us broadcast spectrum ». The experts are : Thomas Hazlett, former economist at the FCC and now with the Manhattan Institute ; and Steve Berry, senior vice-president at CTIA. We assume w*ireless* is to be understood here as cellular, broadly speaking (a worthwhile precision, as we will see in a later chapter that the term is increasingly used now to designate *Wi-Fi ,hotspots and IEEE 802.1 ;* a different world in quantitative spectrum terms).
However, we have difficulties to reconcile these comparative figures with our data. It appears that these experts include, on the European side, at least some 3G/UMTS spectrum indeed awarded, but very marginally in use in 2002-2003 ; as to the not included 3G spectrum on the U.S. side, it is indeed only planned (for release in 2008). It would be more significant to compare spectrum of *cellular* plus *PCS* in the U.S. with GSM spectrum in Europe, and then the totals are at the advantage of the U.S. (170 versus 156 MHz) ; not even encompassing *Nextel.*

[74] In the 1970's-1980's the computer industry marketed fairly successfully intra-company electronic mail systems which were then opened up to customers or suppliers ; carefully in some areas because of regulatory concerns at that time.

scope to what pocket-phones can do, spectrum consumption associated to such applications can be quite low or quite substantial. On the other hand, many non-voice applications are less sensitive to link-quality problems than voice calls.

As stated earlierr, we believe that voice will remain the leading traffic on cellular networks for many years to come. This is evidently so in the less developed countries (e.g. China, India, South America, Africa) which continue to contribute an important share of the cellular growth ; but also in the advanced countries where cellular voice traffic continues to increase, notwithstanding the explosive «short text messaging craze » of the younger generation (so-called SMS in GSM language[75]). Text messages are cheap and millions per day do not constitute big business for an operator with millions of subscribers ; and they mean even less in terms of spectrum use[76]. In the longer term though and with the generational change, growth of short-messaging could constitute a spectrum relief for the operators.

This being said, there is probably a strong potential requirement on behalf of the cellular subscriber - primarily in the developed countries – to use his device to access information, be it practical[77], professional or for leisure. As the argument goes, he is increasingly used to do so via his internet station at home or at the office ; even if the parallel between a mobile phone and a desk-top PC should not be pushed too far, the ergonomics being different in so many ways. It may be recalled that, at least in the U.S., the « mobile data » history is well over 15 years old[78] and that many investigations have shown that there is a vast segment of the working population mostly or often on the move, which would need access to remote computer data on the spot, in the interest of productivity, customer service or convenience.

To develop this « mobile data » opportunity, the cellular industry has invested in several systems, actually derivatives from the mobile voice base. The most successful so far is *i-mode*[79], a PDC derivative which in Japan is said to have over 30 million subscribers ; several operators are introducing i-mode into Europe (France, Netherlands….) ; the commercial results, though less convincing so far, are said to be promising. Similarly, *WAP* (Wireless Access Protocol) was aiming at easy access to Internet Web pages, via a circuit-switched cellular network and a cell-phone ; but it is, after some three years, largely considered as a

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[75] The « short messages » - in text form – application exists on non-GSM systems but was developed and expanded mostly in the GSM world, under the SMS label, starting early 1999. We have figures for SMS messages within the GSM world : the *GSM Association* estimates that some 24 Billion such SMS messages were exchanged on the average per month in 2002. Concerning the U.S., an *IDC* study released in May 2003 indicates that there were 21 million SMS subscribers at the end of 2002 ; it forecasts that there will be 75 million in 2007, corresponding revenues topping 1.9 B$ over the next four years. Next to SMS, there also are « instant messaging services » which make the short-messaging topic less clear.

[76] In a keynote presentation on May 22nd 2003, the CEO of AT&T Wireless, John Eglis, appeared to confirm the necessary focus on voice : « The challenge facing companies in the wireless technology industry is to stop talking about whiz-bang future offerings and start generating cash…….Too often in the hype about next-generation services and other advanced offerings is the reality that wireless companies need to do a better job of profitability selling the products they already have available ». He seemed though to include text messaging , an existing service, within the offerings to be capitalized upon. AT&T Wireless scaled back its 3G plans, citing lack of market demand. « ….Better marketing, no fancy new services, will be the key to expanding wireless penetration. ». (As reported by an *Infoworld* release with the same date).

[77] A simple example among thousands: when driving to the airport to welcome someone, finding out if the plane is on time or how much it is delayed.

[78] *ARDIS* (Advanced Radio Data Information Service) was an IBM-MOTOROLA joint venture created in the early eighties and aimed at the mobile populations employed by large corporations within the U.S. A private network spectrum allocation had been granted. Coverage was limited to areas where there was a significant density of business locations. The data terminals had been specifically designed.

[79] *i-mode* introduced by *NTT DOCOMO* early 1999 in Japan, is largely based on the Internet / Intranet protocols.

unrecoverable marketing failure. *GPRS* (general packet radio service) is being implemented by a large number of GSM operators ; an « always on » packet-switching system, it allows over 170 kbps while making it possible to share the radio channel between several users ; data can be sent or received even during a voice call. There also is *EDGE*, an alternative to GPRS, with three times higher bit-rates ; it is being implemented by a number of GSM operators in 2003, accross the world, within their GSM spectrum.

Furthermore, on a fairly successful path to fast internet access - judging from 2002 / early 2003 results - are the CDMA 2000 data versions, generally labelled « 3G » ; they are though using 2G spectrum, like *cellular* and *PCS* in the U.S.[80] There is no doubt, anyhow, that some of CDMA's success in a number of countries, can be attributed to its performance in data applications (as well as to various delays affecting UMTS).

Except that they are designed to use the existing channels as well as possible and that they are expected to generate **additional** or **more valuable** end-user traffic, all these systems are 2G variations which, simply said, piggyback on voice channels and use spectrum allocated in the past largely in a mobile voice context.

The big jump is expected to come from true 3G systems in new bands, the introduction of which, e.g. in Europe, has been well planned but is taking place with much delay and at a reduced tempo. By mid-2003, one operating company (called « *3* ») had introduced such service, including video capabilities, in four countries there ; attracting tens to hundreds of thousands of subscribers, numbers very far in order of magnitude from the existing GSM populations. Several other operators, about at the same time, announced their true 3G plans.

Note that the debate on wireless access to the Internet has changed significantly since 2001/2002 with the increasing focus on wireless LANs and on unlicensed spectrum, along with the emergence of the hotspots and Wi-Fi phenomenon (which we will discuss in a later chapter). An important market evolution in the cellular sphere – actually quicker and more spectacular than mobile data - has been the development of image-based applications. It was assumed until recently that such applications over radio were incompatible with mass markets and scarce spectrum. But digital image compression has made these last years - and continues to make – impressive strides forward. As Josef Huber[81] puts it :

> « New enhanced coding algorithms, particularly for low to medium bit rates on radio transmission channels with variable delay characteristics, are being developed. What are driving these developments are the limited amount of frequency spectrum available and the consequent requirement to minimize the amount of transmitted data ».

A multiplicity of corresponding standards have been - or are being - produced by various fora and they affect both the existing 2G context and the upcoming 3G context.

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[80] CDMA 2000 is quite developed in the U.S. and expands in a number of countries in the Far East (especially China and Korea). In the U.S., two out of the six nationwide mobile operators, *Verizon Wireless* and *Sprint PCS* are devoted to it ; the improvement in terms of data speeds and performance is expected to result from growing coverage with the *CDMA2000 1xEV-DO* version. Hundreds of Kbps are mostly said to be available to the end-user.

[81] « UMTS and mobile computing » by Alexander Joseph Huber and Josef Franz Huber. Artech House 2002. This book contains fairly detailed information on the multiplicity of compression standards.

(a) For fixed image transmission, JPEG 2000[82] mainly applies. It reduces the information volume to be transmitted to 5% of the original bit-mapping of a color image.
(b) For moving image and real-time video, MPEG-4[83] is most appropriate. It implies bit rates between 5 kbps and 10 Mbps[84]. (One version allows DVD streaming quality with 400-600 kbps bit rates, well within the possibilities of 3G / UMTS systems). MPEG-4 combines one-way and two-way video into a single standard.

In Japan , the market has shown infatuation with camera-phones. The leading cellular operator[85] reported that it sold over three million such pieces during six months, between June and November 2002. Such a number indicates that they are being used primarily over 2G networks[86] and that there is significant potential for the « postcard » application. As the individual concerned subscriber (at the sending end) is unlikely to make very frequent use of this capability, the related spectrum consumption is probably quite low.

Common sense would suggest that there is a large potential for videotelephony ; the fact is that this application never made it on the fixed network anywhere, in spite of developments, demonstrations and marketing efforts which started in the U.S. in the late 1950's[87]. Judging from the number of cell-phone models released in 2002-2003 with videotelephony capability, mobility and portability give a completely different stance to this market. It would seem though that it is too early to judge the quality of the service, say on a 3G WCDMA network[88], when a multiplicity of videotelephony calls are in progress for example within the same building. The limited spectrum available appears to be incompatble with a massive, dense development of this application, in particular if the users want high quality pictures, allowing some movement in front of the cell-phone camera, and the somewhat larger screens now part of the newer models.

THE GLOBETROTTER AND THE OCCASIONAL TRAVELLER

As we implied earlier, many people only rarely leave their home area[89] and they travel abroad even less frequently. But it is when they travel that their need to stay in touch is particularly crucial. Also travel times – say in a car, waiting at an airport or standing in a line – can be easily put to use to communicate.

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[82] JPEG2000 (which stands for *Joint Photography Experts Group*) was developed jointly by ISO and IEC.
[83] MPEG stands for *Moving Picture Experts Group.* MPEG-4 puts the complexity in the encoder, not in the decoder ; an appropriate scheme when downloading video clips or pictures for games for example. And it is the mobile device which largely determines the maximum bit rate, depending on its processing capability, its signal power and its battery consumption.
[84] Video encoding is based on ITU's *H. 263* standard.
[85] DOCOMO
[86] The only true 3G network (i.e. using 3G spectrum) in Japan – FOMA – had throughout 2002 a **much** smaller number of subscribers.
[87] Development of a first rudimentary *Picturephone* was completed at the *Bell Labs* (which then were part of *AT&T*). A more product-like version was demonstrated at the New-York World Fair in 1964 but generated no commercial interest. The major critique was that the apparatus was too cumbersome.
[88] *J-Phone* , a subsidiary of *Vodafone* , introduced in Japan the *V-N701* cell-phone produced by *NEC*. It is able to call « another videotelephony-compatible handset [so that you] can enjoy a natural conversation with video pictures ». It works on J-Phone's W-CDMA 3G network, within the standard UMTS frequency band, using an up to 384 Kbps link. It is equipped with both a front and back camera.
[89] This fact is one of the reasons why, at the origin of cellular, the FCC divided the national territory into many small areas (306 MSA's and 428 RSA's) in each of which two licences were granted.

The traveller typically values his mobile very much, as it stores his frequently called numbers and his messages. It dispenses him from searching public phone booths[90] and availing himself with coins or phone-cards. All this applies even more to the international or intercontinental traveller : different currencies and languages, uneven acceptance of foreign credit cards, a different perception of personal safety and other factors exacerbate the foreigner's communication problems in the absence of « his » functioning mobile phone.[91]

A European who lands at the Boston-Logan airport, for example, and does not have with him a tri-band GSM phone (with an appropriate subscription[92]) will be facing difficulties to make a call, even to Newton, another Boston suburb still within Massachusetts : the public coin phone will request him to insert a certain number of *quarters* before even starting his conversation.

The reader may wonder, at this point, why such trivialities have their place in this report. The following account will, hopefully, convince him of their pertinence. At a high-level conference on spectrum policy held in the U.S. in 2002, the qualified representative of a world leading wireless equipment manufacturer tried to convince the primarily American government (and industry) audience of the avantages for the U.S. to designate 3G spectrum compatible with what had been virtually harmonized worldwide and was already allocated to 3G by Europe and many other countries. The damaging arguments he put forward, under the assumption where the U.S. would allocate frequencies different from those to be used for 3G in the major parts of the world, were as follows :

- Missed economies of scale : mobiles will be more expensive in the U.S.
- Additional R&D : special U.S. models need to be designed which contributes to higher cost ; in addition R&D resources are scarce.
- Lack of variety : a new mobile, a new design or feature will logically be introduced first where the market is the largest. (The U.S. in 2002 constitutes only 20% of the world market for cellular handsets). Consequently, the U.S. customers will not only pay higher prices for their mobiles, but they will also have less choice.

At no point did this qualified industry representative mention ease of international roaming as an advantage of international frequency harmonization ; e.g. between the U.S. and Europe, or between the U.S. and Japan.

As was implied earlier, roaming[93] is of importance to a limited fraction of the subscribers only ; and only a small share of the total calls are international roaming calls[94], especially as seen by operators of larger countries. But because to such users the calls have typically more

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[90] Note that in many developed countries, the number of phone-booths has been significantly reduced over the last years.

[91] There are of course categories of travellers now who see differently : they stay in touch via e-mail wherever they are. To many people though, an e-mail exchange does not replace a conversation ; and we can expect this to be so for quite some time.

[92] A standard GSM subscription generally includes, in Europe, the international roaming capability within Europe. Roaming in the U.S., Australia, China ….etc requires the « world » option to be activated through a simple call to one's operator. (The « world » option is generally a free complement to the base subscription).

[93] In this report we normally use the term *roaming* to mean *international roaming* ; not withstanding the importance, including for the operators' balance-sheets, of intra-U.S. roaming.

[94] In its February 2001 submission to the FCC (Docket No. 00-258), *Siemens* states that « in August 1999, more than 400 million calls were originated by roamers in visited foreign countries ». (These are GSM countries, in view of the context). The figure – which would logically be higher three years later - was made possible owing to « over 20,000 roaming agreements » signed between GSM operators.

value, and because the associated transction costs [95]are significant – and even more so are the final charges – the financial contribution to the operators is by no means negligeable. Note that in many people's view, the level of international roaming charges is in excess of what would be justified, which further acts as a deterrent to roaming.

We believe that the international – mainly intercontinental – roaming potential still remains largely untouched. Consideration of the intercontinental air passenger traffic appears to support that view. According to IATA, the number of passengers on scheduled international flights in 2001 was close to 394 million worldwide. Out of those :

- 14.6 million flew between North America and Europe
- 6.7 million flew between North America and the Far East
- 6.7 million flew between Europe and the Far East.

For these 28 million travellers (some of whom are of course « repeats ») a standard cell-phone bought in the U.S., or in Europe or in Japan will not meet their basic roaming requirements. And the situation is not better for the Japanese travelling to other Far East countries ; and only somewhat better for Americans flying to Central or South America.

A common misconception, furthermore, is that intercontinental travel takes place primarily for business reasons. According to one source[96], in 1993 only 15% of the people flying from the U.S. to Europe were on a business trip. (It is unlikely that this percentage has since increased significantly). In other words, most of the travellers between the U.S. and Europe are occasional travellers : a vast majority of them today certainly own a mobile phone[97] but their device becomes useless once they have crossed the Atlantic. Hence they leave their wares at home.

Offering practical solutions - other than a triband mobile[98] - to the intercontinental roaming maze has become a business in itself. Many specialized companies offer phone rental schemes to the needy traveller, either at home prior to his trip or at the foreign airport of arrival ; it is obvious though that they can never match the convenience of using one own's cell-phone[99] (which is typically becoming smarter and more indispensable, year after year). And taking delivery of a rented phone is one thing ; but it also has to be sent or handed back !

In face of this issue, it must be conceded that some leading phone manufacturers tend to basically include the triband capability in their higher end products ; even if this means some additional cost, this trend goes in the right direction in our view. It seems actually that the term « triband » has acquired attractive value even for those in the marketplace who have no

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[95] Transaction costs are high as multiple operators from diffrent countries are involved.

[96] Mentioned in an article titled « Finally – Roaming relief for the global traveller » in the Sept. / Oct XXXX issue of *Cellular and Mobile International*.

[97] This is a fair assumtion as average mobile penetration in the U.S. is in 2002 well over 50%, and closer to 60-80% in the European countries). – Transatlantic travellers mostly leave their cell-phone at home as they are told that it twill not work anyway.

[98] The triband phone, though, only works in areas covered by GSM 900, GSM 1800 or GSM 1900.

[99] There is a caviat though. A German citizen travelling to the U.S. with his triband GSM mobile, often has the need not only to call home, but also to call people and places in the U.S. ; if he leaves to the American party a message requesting to be called back, he is likely in many cases not to be called back : the U.S. party will find it economically unwise to « call Germany » to reach someone who is manifestly in the country. This problem, related to charging and not related to frequencies, could be solved through temporary number assignments and proper intelligent network functions ; it is unlikely to be addressed in the near future.

idea of what it means[100]. (It is well known that the skills level in the distribution channels is rather low, as the battle on the cellular mass market is much on price).

CHAPTER 3 : PANORAMA OF SPECTRUM HETEROGENEITY IN THE REAL WORLD OF TODAY AND TOMORROW

1. SPECTRUM DOMINANTLY IN USE TODAY[101] THROUGHOUT THE WORLD FOR TERRESTRIAL MOBILE COMMUNICATIONS

Putting aside the case of the European harmonization drive described earlier, most countries have decided « on their own » which frequencies – and often which standard(s) – cellular services should use domestically ; notwithstanding imitating larger neighbours or being influenced – even lobbied – by leading manufacturers, foreign government entities or other bodies.

The 800 MHz band associated with analog AMPS and the 900 MHz band associated with (the first wave of) digital GSM have thus widely served as logical and convenient benchmarks ; followed later by the 1800 and 1900 MHz bands respectively associated with DCS/Europe (now also labeled GSM) and PCS/U.S. (really also *cellular*, though in various digital flavours).

On one hand, the visibility of spectrum decisions remained quite low – and this is still the case today – except the unwinding and outcome of license auctions, highlighted essentially in their economic aspects. On the other hand, two major technology camps emerged (quite unequal in size) : CDMA and GSM. An operator's or a country's decision in favour of one or the other system was usually announced « with a flourish of trumpets » by the concerned camp. Spectrum – its amount or frequency range – seemingly mattered much less, if it mattered at all.

To a large extent, the two camps are respectively embodied on one hand by the *CDMA Development Group* (CDG) – led by *Qualcom*[102] - of which 110 companies[103] are a member (by July 2002) and serve a total of over 50 million subscribers ; and on the other hand the *GSM Association*, which groups close to 600 operators (by November 2002) ; these 600 operators serving over 750 million subscribers, i.e. about three-quarters of the worldwide cellular population. GSM is mainly associated with the 900, 1800 and 1900 MHz bands, whereas CDMA is so far deployed mostly in the 800 and 1900 MHz bands.

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[100] In 2002, the website *cellulartoyz.com* advertized in its *Bell Mobility* section addressing the Canadian market three phones (two from Motorola, one from Audiovox), said for each one to be « 1900/900/900 MHz Triband phones ».

[101] We take year-end 2002 as our reference point

[102] *Qualcom Inc*, originally a California start-up (created in 1985), is now best described as a « maker of microprocessors and software for mobile phones » ; it still holds a number of significant CDMA patents (making its royalty business important) ; but it is by no means alone to do so. CDMA1 and CDMA 2000 are major Qualcom technology developments.

[103] « Including the world's leading manufacturers and operators of digital cellular, personal communications (PCS) and third generation systems based on CDMA technology ». Quote from CDG's comments to the FCC dated July 8, 2002. (ET Docket No. 02-135).

Hence, it is largely correct to say that by year-end 2002, cellular around the world is deployed in four bands : 800, 900, 1800 and 1900 MHz. This applies to the US, to Europe and to many other developed countries, as well as to a number of less developed parts of the world, some of which are on a fantastic demographic, if not economic, growth path : Central / South America is a case in point. In terms of number of subscribers there, the 800 MHz band (identical to the original US cellular band) dominates by far (with AMPS and CDMA). But the GSM 900 and GSM 1800 bands are also in substantial use there, as well as the PCS 1900 band (again identical to the US PCS band).

Even within one South-American country, the situation can be fairly complex ; let us take Brazil. AMPS is largely deployed there, in the 800 MHz band as usual ; and so is TDMA. CDMA is deployed in both the 800 and 1900 MHz bands[104]. Brazilian operators have been licensed on a regional basis – there are 10 regions – which explains their relatively large number (17, but not all mutually independant). *Anatel* , the Brazilian regulator, has three times already announced plans to auction spectrum in the 1800 MHz band, primarily for GSM. Though some GSM commercial launch has taken place mid-2002, it is unclear where the whole matter stands. As stated by *Pyramid Research* in a 2002 report[105] :

> « Lack of clear rules for migration to the 1800 MHz band and worsening economic conditions in Brazil, have forced TDMA operators to reevaluate their network upgrade plans ».

One of the leading operators[106] is well positioned to acquire 1800 MHz spectrum in a number of regions, thus making roaming at a national level easier in the future.

With respect to the four bands in dominant use mentioned above, there are however two « outsiders » worth mentioning : one specifically positioned geographically, the other more spread in a wider part of the world.

Japan, a respected R&D giant for decades, has already in the late eighties developed its own digital technology [107] and started to implement the corresponding network in 1991 under the name *Personal Digital Communications*. PDC enjoyed a phenomenal success[108] but never went beyond th Nipponese islands in spite of its attractive spectral efficiency (when compared to GSM or even CDMA1). Deployment was carried out in the 800 and 1500 MHz bands, thus reinforcing Japan's « cellular isolation » essentially prevailing until DOCOMO's more recent entry into a major 3G world community.

The other outsider is what we could call « NMT/GSM 450 ».The 450 MHz band has been in use for analog cellular since the early eighties, mainly in Scandinavia. But the indigeneous

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[104] Whereas the 800 MHz band is identical to the US's, only a fraction of the US 1900 MHz band applies.
[105] « Communications markets in Brazil » July 2002 by *Pyramid Research LLC*, a consultancy based in in Boston, Mass. focusing on global communications.
[106] *TIM (Telecom Italia Movil)*, the second largest operator in Brazil with only 5 million subscribers by mid-2002, aims at GSM deployment in the 1800 MHz band and is forecast, by Pyramid Research, to dramatically increase its market share in the next years.
[107] Actually in NTT's R&D labs. The mobile communications arm of NTT later separated and became DOCOMO.
[108] According to the *mobilecomms-technology.com* site, by December 1999, PDC accounted for 12% of all digital mobile subscriptions in the world.

NMT-450 system than spread East and still occupies an important place in Eastern and Central Europe, as well as in the Russian Federation. Among the reasons of its success there were a cheaper deployment and the opposition of the military to give up higher frequency bands. Also, such a low frequency has attractive propagation characteristics when the prime goal is wide coverage rather than high traffic capacity.

For example in Sweden, as reported by *TELIA* in 2002, NMT-450 has the widest coverage of all mobile networks in the country, with still over 100,000 subscribers ; they enjoy a roaming capability over the whole Nordic area, Iceland, Russia, Poland, Ukraine, Bulgaria and other countries where NMT-450 also prevails. Adjustments to the swedish network (and to some others, we understand) are being made to bring coverage and link quality with handheld mobiles at par with car-phones i.e. larger antennas.

The use of the 450 MHz band is now so entrenched that it acquired a new life through the so-called *GSM 400* standard, largely recognized by the industry and the standards organizations. And its promoters insist on having *GPRS 400* introduced, followed by a migration path to 3G services in that same band[109]. Mainly because of the economic strengthening of Russia, « 450 MHz Digitalisation » is becoming in 2003 a hot topic.

In addition to the « ex-sovjet » block and Northern Scandinavia, some operators in Africa and in the Far East are also concerned ; and there is substantial interest in China. All this means that the 450 MHz band could, in terms of numbers of subscribers, still become more important than it is today, particularly in a variety of rural and coastal areas in the world.

[109] A different evolutionary path must though be mentioned. In July 2002, *Lucent Technologies* announced an agreement with *Moscow Cellular Communications* (MCC) whereby it will provide its « International Mobile Telecommunications Multi-carrier (IMT-MC) 450 solution ». The stated objective is to « help MCC evolve its analog network to a higher capacity digital network – the first step toward a third generation (3G) network. This is further claimed to maintain national roaming within the Federal Network known as SOTEL. Clearly, the current investments in Russia are within the 450 MHz band.

2. NEW SPECTRUM SPECIFICALLY PLANNED FOR 3G :

BACKGROUND

The next generation of cellular (again, broadly speaking) is by no means a new topic, as it had been expected for many years that public mobile voice communications will evolve towards multi-media capabilities. More precisely and more recently, it is the emergence of the *mobile Internet* concept which was the main driver towards *3G*. As spelled out in a relevant ITU report[110] :

> « Mobile communications and the Internet were the two major demand drivers for telecommunications services in the last decade of the twentieth century. Combine the two – mobile Internet – and you have one of the major drivers of the first decade of the twenty-first century ».

Though the 3G acronym may mean different things to different people, especially if they are located in different parts of the world, it generally implies that the new applications aimed at will require new network architectures, new standards, new infrastructures, new mobile devices and – preferrably, in a market growth perspective - new spectrum.

For simplicity's sake, we will describe how the matter of 3G spectrum was handled, formally, at a worldwide level and then at the European level, before summarizing the more pragmatic US 3G spectrum process which ensued. The chapter will procede with a status overview pertaining to the two countries with a huge wireless potential because of their billion-plus population. And finally the implications of the more recent WI-FI phenomenon will be briefly outlined.

IMT-2000

Work started in a worldwide perspective at ITU level during the late eighties, towards a system – at that time labelled *FLMPTS*[111] - which would accommodate the future communi-cations needs of « nearly everyone », including of the frequent or casual traveller anywhere. Discussions were substantial at the 1992 WARC[112], based on preliminary studies carried out by CCIR. In its conclusions, that conference resolved that « Administrations which implement FLMPTS should :

a. Make the necessary frequencies available for system development
b. Use thoses frequencies when FLMPTS's are implemented
c. Use the relevant international characteristics, as identified by the Recommendations of the CCIR and of the CCITT ».

Specific bands close to 2 GHz were identified for FLMPTS and found, at that same conference, their way into a footnote[113] of the Radio Regulations. Clearly, there was at that

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[110] *Internet for a mobile generation* published by ITU in 2002
[111] *FLMPTS* stands for *Future Land Mobile Public Telecommunications System* which later became *IMT-2000*
[112] *World Administative Radiocommunications Conference* held in Malaga-Torremolinos, Spain. - *WARC's* were from then on just called *WRC's.*
[113] Footnote S5.388 of the Radio Regulations : « The bands 1885-2025 and 2110-2200 MHz are intended for use, on a worldwide basis, by administrations wishing to implement the future public land mobile

time, in spite of the difficulties of the negociations, a strong sense for a worldwide unified concept, with a special focus on easy global roaming for the voice user. Along with the credo of common bands, went the assumption of a common air interface ; so that a new generation of mobile phones could be used anywhere. Beyond this fundamentally terrestrial view, FLMPTS was to include a space segment to achieve the universal coverage aimed at.

It is actually striking that a lot of the overall work at WARC 92 was devoted to space communications services ; be it broadcasting satellites (DAB, HDTV…) or mobile service satellites[114]. And, as reported by an expert participant[115] :

> « ….[the] success of the conference must be qualified, taking into account [that] ….. allocations were not made worldwide for such services the nature of which imply worldwide utilization »

Work on FLMPTS – which became IMT-2000 – went then forward in many ways during the nineties within the ITU framework; including the confirmation by WRC 95 that it was to be deployed primarily around 2 GHz. But the key reference today is rather WRC 2000, which reflects an important change versus the « unified system view » prevailing earlier in the decade. Several evolutions which took place in the meantime were determinant :

- The LEO satellite projects (like *Iridium*, *Teledesic*, or *Globalstar*) lost some of their luster and, at best, began to be seen as « false starts ».
- Terrestrial mobile communications – cellular – on the other hand continued to grow at an unexpected explosive rate, both in the developed and developing world. Hence, it was argued, 3G would need much more spectrum than what had been foreseen around 2 GHz.
- Some countries, it turned out, could not consider freeing the spectrum around 2 GHz which had been initially identified at WARC 92 (the often called *core-bands*[116]).

A qualified American observer writes in 2003 :

> « In order to ensure sufficient spectrum was available for such services, the 1992 WARC created the identification of 230 MHz of spectrum for 3G services on a global basis. However, this identification did not result in the use of this band accross the globe for this service. To the contrary, the United States and several other countries determined that they had other needs in the identified bands so that the identified bands were not allocated domestically to 3G services ». [117]

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telecommunications system (FLMPTS). Such use does not preclude the use of these bands by other services to which the bands are allocated ».

[114] There was a significant and growing interest at that time for non-geostationary satellites (so-called LEO's), a topic which obviously required its place on WARC 92's agenda. As reported by the Wall Street Journal dated February 6, 1992 (hence a week after the start of the 4-week conference) in an article titled *Nations try to clear the Air over rights to Radio Waves* : « Motorola also thinks WARC is vital. The economics of its multibillion Iridium satellite-telephone project teeter upon favourable decisions at the meeting ».

[115] *Report on the Developments at WARC 92* by M. Harbi, member of ITU's IFRB. Presented at the *OECD Seminar on the Economics of Frequency Allocation* held in Paris, April 1992.

[116] In the ITU circles, the label of *core-bands* – not necessarily the notion, we feel ! – has in the meantime *vanished*.

[117] *Spectrum Wars* (page 26) by Jenifer Manner – Artech House 2003 – The author represented an important U.S. telecom's operator at the 2000 WRC in Istanbul.

Thus, the idea of additional 3G bands emerged, though :

> «the European position is that, as far as possible, spectrum for 3G should be contiguous and allocated on a global basis, rather than letting each country use a different part of the waveband[118] ».

A major European industry group[119] studied which « extension bands » could be identified for IMT-2000 in preparation of WRC 2000. Such bands were found in the 2.5-2.7 GHz range as well as in the spectrum used for 2G systems (like GSM). The idea of worldwide harmonization around a pair of contiguous spectrum slices became thus largely obsolete.

So, what did come out of WRC 2000[120] ? The formal conclusions are essentially to be found in a non-transparent « resolution[121] » which we would summarize as follows :

(a) The 230 MHz of spectrum close to 2 GHz already identified in 1992 for IMT-2000 is reconfirmed
(b) Harmonized utilization of spectrum for the terrestrial component of IMT-2000 is stressed
(c) ITU-R is requested to :
    - examine the implications of sharing spectrum between IMT-2000 and other applications or services in the 1.7-1.8 GHz band and in the 2.5-2.7 GHz band[122]
    - develop « harmonized frequency arrangements » for operation of the terrestrial componant of IMT-2000
(d) The countries are requested to consider the evolution of the existing mobile systems using spectrum under 1 GHz towards IMT-2000 in such bands.

In most interpretations of WRC-2000, there are now close to half-a-dozen bands[123] (in the sense of spectrum slices) « designated for IMT-2000 terrestrial use »[124]. In other words, the worldwide efforts through a United Nations Agency to truly harmonize **some** spectrum for a future global mobile system failed, though significant efforts in this direction had started well over a decade earlier. Among the multiple reasons of this failure, we believe that the expectation that the world community had during most of the 1990's, played a key role : LEO

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[118] *Communications Week International* dated February 21 2000. Article page 1 titled : *Fired-up 3G backers set to force WRC spectrum clash*.
[119] The *UMTS FORUM* which has as its members all significant manufacturers and operators more or less involved in UMTS, the European version of IMT-2000.
[120] Held in Istanbul
[121] Resolution 223
[122] Precisely the bands are : 1710-1885 MHz and 2500-2690 MHz
[123] 1885-2025, 2110-2200, 2500-2690, 1710-1885, 806-960, 698-806 MHz
[124] One way in which ITU's IMT-2000 project management presents this (in 2002) is to explicit the « current use of the IMT-2000 spectrum identified at WRC 2000 ».

806-960 MHz	1G + 2G + 3G
1710-1885	2G + 3G
1885-2025	DECT + PHS + 2G + 3G
2110-2200	
2500-2690	

The 400/450 MHz band is not mentioned here though the NMT-450 world depicted earlier is pressing hard to also get on the IMT-2000 bandwagon.

satellite constellations in particular were seen as the ideal approach to solve the global needs that terrestrial cellular could, in some views, not solve ; needs including those of developing countries. As is well known, this is hardly the way things turned out.

Since WRC 2000 and in line with one of its formal requests (mentioned above), work was pursued towards « providing guidance in the selection of frequency arrangements », relating again to the five IMT-2000 bands already alluded to. More precisely, in the interest of reduced equipment development cost and of easier international roaming, a limited number of « frequency arrangements » has been defined, specifying various options as to:

- which part of the allocated spectrum is to be used in a « paired » way (i.e. in FDD mode) and which part is to be used in an « unpaired way » (i.e. in TDD mode)
- in case of « paired » use, which part of the allocated spectrum is for the « uplink » (transmission from mobile to base-station) and which part for the « downlink ».[125]

This work was by year-end 2002 largeley completed[126] and became then a major input into WRC-03. It proposes what we consider to be a disturbing number of « frequency arrangements » : whereas in the relevant 800/900 MHz bands, only two such arrangements are mentioned, ten arrangements are proposed in the relevant bands found in the 1.7-2.2 GHz range. It seems to us that this multiplicity has the potential to further contribute to the heterogeneity of the spectral landscape and therefore to increased difficulties for manufacturers, operators and end-users, especially in an international roaming perspective.

On the other hand, the multiplicity of the IMT-2000 bands being what it is, the work on frequency arrangements aims of course at optimizing the situation, in particular for international roamers ; for instance, between two geographic environments where one of the respective paired bands is common - or largely overlapping – whereas the two other paired bands differ[127].

UMTS

The *Universal Mobile Telecommunications System* concept emerged in Europe in the mid-nineties. It was mainly seen as a way to capitalize on the impressive GSM success – within and beyond Europe – by building on ITU's IMT-2000 work and on specifically driven technological efforts. A high-level European Commission report had already identified in 1995 « mobile and personal communications as a necessary building block of the information society ». Whereas the Internet was not seen at that time as a major piece of the wireless scene, multi-media definitely was (in contrast with GSM, basically a voice communication tool).

Politically, the major step towards UMTS is a December 14, 1998 *Decision of the European Parliament and of the Council on the coordinated introduction of a third generation mobile and wireless communications system (UMTS) in the Community*[128]. It mandates the Member

[125] « Center gap » and « duplex separation » also vary and are specified in the « frequency arrangements ».
[126] Our reference in this respect is the draft dated October 1 2002 of revised *Recommendation ITU-R M. [1036-1]*.
[127] As stated in the same document : « A common base transmit band…..provides the possibility to broadcast to roaming users all information necessary to establish a call ».
[128] Decision 128 / 1999 / EC

States to ensure that UMTS operates in the frequency bands harmonized by CEPT[129], bands which are part of the spectrum identified already in 1992 by ITU's WARC-92 (for *FLMPTS* later renamed *IMT-2000*). Furthermore, the Decision requires National Regulators to ensure that UMTS is organized « pursuant to European standards for UMTS, approved or developed by ETSI » ; and that licences allow transnational roaming within the Community.[130]

A well defined air interface was of course required. It was chosen within ETSI essentially by the operators (with substantial technical support from the manufacturers) ; European carriers but also operators from the Asia-Pacific region who had been admitted in 1997 as *associate members* with full voting rights. Thus, the *W-CDMA* (for *Wideband-CDMA*)[131] standard emerged and became one of the five[132] air-interface standards part of the IMT-2000 framework.

WCDMA is a major technical ingredient of UMTS. Let us quote[133] the VP of the UMTS-FORUM :

> « Actually, the WCDMA development took place in Japan and in Europe. In Japan, NTT DOCOMO started research work in the early 1990's and in Europe development began in 1995 under [European] Commission research programs known as ACTS and FRAMES[134] ».

Spectrum for UMTS has been awarded by national authorities, initially mostly in 2000 and 2001 to operators in Europe : incumbant GSM operators or new entities. Each country determined its own licensing procedure to select the winners among the applicants. These procedures – either auctions or so-called « beauty-contests » – have since been the subject of much controversy because they resulted in a very heterogeneous European landscape in economic terms ; and more importantly because the prices reached by some of the auctions turned out to be – in the judgement of many - unreasonably high. These dysfunctions and related distorsions have been covered by various papers and analyzed by several studies[135]. Hence let us here summarize only: the cost of an individual nationwide license can vary by a factor of 100 from one country to the next[136] ; the over 80 European UMTS licensees have paid a total of more than (the equivalent of) 140 Billion $, a major part of this figure being contributed by the auctions in the UK and in Germany ; and by mid-2003, UMTS deployment in Europe is embryonic.

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[129] Namely 1900-1980, 2010-2025, 2110-2170 MHz (terrestrial) and 1980-2010, 2170-2200 MHz (satellite).

[130] However, within the preamble, the Decision recognizes that the voluntary application of standards remains the default, with specific standards being mandated only when necessary to ensure interoperability and to facilitate international roaming.

[131] The four other IMT-2000 air interface standards are :

- *CDMA2000* a Qualcomm development
- *TD-SCDMA* developed by China, largely with the assistance of Siemens
- *UWC-136* better known as *EDGE*
- *DECT* an older European standard for digital cordless.

[132] We actually see six

[133] Page 71 in *UMTS and Mobile Computing* by Josef Franz Huber and Alexander Josef Huber – Artech House 2002 – Josef Franz Huber is (still in 2003) VP of the UMTS-Forum.

[134] *Advanced Communications Technologies and Services* and *Future Radio Multiple Access Schemes*

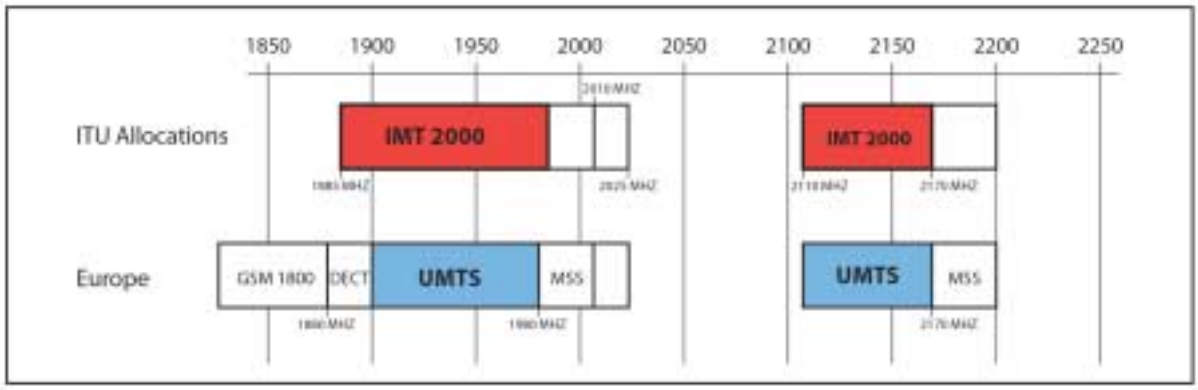
[135] *Comparative Assessment of the Licensing Regimes for 3G Mobile Communications in the European Union and their Impact on the Mobile Communications Sector.* A study carried out by McKinsey and Company for the European Commission, and concluded in June 2002.

[136] As to the price paid per population head (so-called $/pop), it ranges from 20 to 600$, when examining the UMTS auctions carried out in year 2000 according to a May 2001 paper by Elmar Wolfstetter from Humboldt University, Berlin *The Swiss UMTS Spectrum Auction Flop : Bad luck or bad design ?*

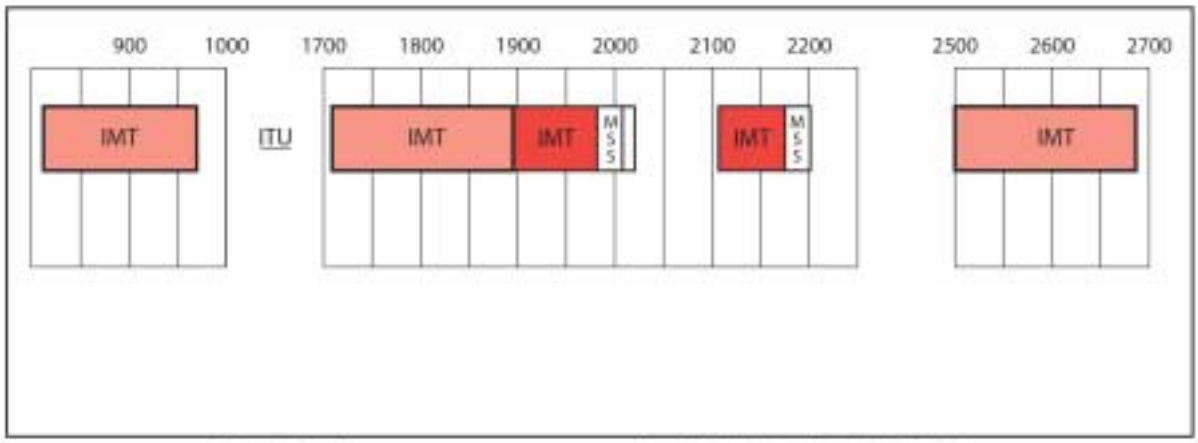
Furthermore, the number of licences awarded varies substantially from one European country to the next [137] : whereas Germany and Austria awarded six licences each, the UK, Italy and the Netherlands awarded five ; a number of countries awarded four and France only three. Obviously, this impacts either the total amount of spectrum allocated to UMTS in a country or the amount made available to each operator.

But again, all these licences share common frequency bands in the vicinity of 1.9 and 2.1 GHz as already mentioned ; thus making international roaming easy (as is the case with GSM) and allowing the development, production and distribution of UMTS products – infrastructure or mobiles – irrespectively of their geographic destination in Europe.

[137] All UMTS licences awarded in Europe are – like with GSM – nationwide.



IMT2000 bands identified at WARC92/WRC95 and UMTS bands.



Complete frequency arrangements for IMT2000 after WRC2000.

Clearly, the timing of UMTS introduction accross Europe – with its up to 2 Mb/s services – is no longer in line in 2003 with the original intentions of the ambituous project nor with the committments associated with the licences (like date-stepped coverage). Respected analysts, even outside Europe, consider though that UMTS will succede in the end because of the huge investments which have been made in it[138]. In addition to relaxation of the key license requirements, two avenues are eagerly discussed with the objective of easing things for the struggling UMTS operators :

(a) Authorizing infrastructure sharing : this means sharing base-station sites, towers, power and possibly other hardware ; it does not mean sharing spectrum. But the fact that colocated operators work in essentially adjacent frequency bands and with common technical specifications should make this reasonably practical. There is of course a fear of reduced competition, especially as infrastructure layout is a major ingredient of an operator's service strategy[139].

(b) Authorizing spectrum or license resale : this could lead to healthy consolidation in countries where the number of UMTS licencees appears to be too high - like Germany or Italy - and where « new entrants » (i.e. not GSM incumbents) view the price paid and the investments required excessive in the present economic environment.

We have so far discussed UMTS « in its cradle », i.e. Europe. Actually its imprint goes much beyond and it has been positioned from the start to justify somewhat the ambituous « universal » qualifer present in its acronym :

(a) As already mentioned, UMTS is a direct outcome of ITU's IMT-2000 work, compatible with bands determined at WARC 92 and still seen by many as IMT-2000's « core-bands ».
(b) ETSI has offered[140] to the Asia-Pacific mobile operators an « associate membership » status with full voting rights. Hence these important and experienced entities became substantial contributors to the UMTS standards like WCDMA.
(c) More specifically, NTT DOCOMO became involved in the development of WCDMA, including some field trials already in 1998.
(d) Five standard development organizations[141] – namely from Europe, the USA, Japan, Korea and later China - agreed to work together on technical specifications for UMTS.[142]
(d) A number of important or less important (non-European) countries went during 2001 or 2002 through 3G licensing in bands identical – or compatible with – the indigeneous UMTS bands. These licences turned out to be for WCDMA but also, in some cases, for CDMA 2000.

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[138] *Why UMTS will not fail.* December 2002 EMAIL Briefing by *The Shosteck Group* based near Washington DC.
[139] The European Commission has expressed itself favourably on this matter already in Spring 2001. It estimated at that time that such sharing could result in 30-40% savings in infrastructure capital costs. Note that network sharing is also becoming a reality in the US, where *CNET News.com* published (on the web) on January 28th 2003 a release titled : « In a cost-cutting move expected to be replicated by most US carriers, Sprint PCS and AT&T Wireless are teaming to build and share cell phone towers, the lifeblood of a cellular phone network ».
[140] In November 1997.
[141] In December 1998, ETSI, ANSI, ARIB, TTA and CWTS formed 3GPP to that effect.
[142] 3GPP is a collaboration agreement established in 1998 which brings together six standards organizations : ETSI, T1, TTA, TTC, ARIB, CCSA.

Here are a few such countries which have, to our best knowledge, concluded their 3G licensing process granting frequencies in bands compatible with the UMTS bands:

* Japan	2 WCDMA licences and 1 CDMA 2000 licence
* South Korea	2 WCDMA licences and 1 CDMA2000 licence
* Australia	6 WCDMA licences
* Malaysia	2 WCDMA licences
* New Zealand	5 WCDMA licences
* Israël	3 WCDMA licences
* Singapoore	3 WCDMA licences
* Hong-Kong	4 WCDMA licences
* Taiwan	4 licences, at least some of which are for WCDMA deployment

It is therefore patent that the UMTS spectrum in the 1.9 and 2.1 GHz bands is largely available around the world for commercial exploitation. By early-2003 though, the only publicly deployed WCDMA network was DOCOMO's in Japan, which had then been commercially opened since one year ; and the number of subscribers was significantly lower than what had been expected.

THE 3G SPECTRUM SAGA IN THE US AND ITS REGIONAL IMPLICATIONS

The term « saga » here refers to a relatively lengthy and contentious sequence of efforts – in the midst of numerous domestic tensions - which have been deployed by the U.S. authorities towards finding spectrum to allocate to so called 3G, or third generation of wireless ; and by mid-2003, this saga is by no means over.

As we will see, the problem is not the result of a lack of attention on behalf of Washington to the 3G spectrum need ; though it could be argued that consciousness of that need developed quite late at the proper levels.

The overall difficult spectrum situation in the U.S. is nothing new and is certainly due, in part at least, to the radiocommunications history of this huge country where broadcasting and many forms of wireless communications developed earlier and deeper than in any other advanced industrial region. Let us quote here a respected analyst of the matter, from an article he wrote in 1992[143] :

> « …..Can the U.S. maintain its world leadership in telecommunications if new products in a key growth area – wireless communications – are denied access to the radio spectrum at home ? This situation is particularly frustrating because the spectrum *shortage* is a manufactured problem : it is a byproduct of the way we manage the spectrum. There are entrenched users and vendors with a vested interest in perpetuating the myth of *spectrum scarcity*. Why should they share something they can get the government to give them for their exclusive use ? »

And further :

> « …Currently there are only three options for obtaining spectrum : (1) allocate spectrum that is reserved or unassigned (2) reallocate spectrum ; or (3) share spectrum with an existing

[143] « Who used up the Radio Spectrum ? » by Ira Brodsky in *Business Communications Review*, January 1992. He was at that time President of *Datacomm Research Company* and had already published several reports on subjects like Wireless Local Area Networks or Portable Computers &Wireless Communications.

> service. The first option is no option at all : there simply isn't any unassigned or reserved spectrum to speak of below 3,000 MHz.
> .....there is some precedent for spectrum reallocation. In 1974, the FCC took away the upper 14 UHF TV channels (channels 69-82) in order to create cellular telephone and specialized mobile radio (SMR). »

A more recent note about the *1996 NTIA Spectrum Chart*[144] says :

> « Because thirty different U.S. radio services are allocated portions of the spectrum in over 450 separate frequency bands, many allocation issues quickly become quite complex ».

In autum 2001, NTIA published in its *NTIA Spectrum Newsletter* a brief analysis[145] titled « The 3G Spectrum Hunt » which proves that at least some people within that Agency understood the situation and its background. We quote :

> «ITU's WARC-92 identified the 1885-2025 MHz and 2110-2200 MHz bands for countries wishing to implement IMT-2000 services. Several countries, including the United States, allocated and licensed portions of the bands identified by WARC-92 for *Personal Communications Services* (PCS) because the success of cellular, as well as the growth of the Internet, stimulated the demand for more spectrum to provide advanced communications applications ».

The fact is that the US delegations at ITU meetings had shown their reticence in face of the IMT-2000 project, a worldwide « standardization » effort towards what was seen as a globally uniform system to fit all needs. This position quite logically reflected the FCC practice[146] and policy to allocate spectrum to broad categories of communications services and not to specific systems or standards. In line with this policy, one may recall that the US government sent a letter to the European Commission in 1998 asking it to support global competition among third generation wireless standards[147].

Early October 2000, President Bill Clinton issued an Executive Memorandum which articulated the need of spectrum for future mobile voice, high speed data and wireless internet access. In particular, it directed the Secretary of Commerce to work cooperatively with the FCC

(1) to develop a plan to select spectrum for 3G
(2) to issue an interim report by November 2000 on the current spectrum uses and reallocation or sharing potential of the bands identified at WRC-2000

The plan was at that time to auction corresponding licenses by September 2002. But the timetable just mentioned became of course less compelling in view of the slower than expected evolution of the marketplace worldwide, particularly in terms of advanced non-voice applications.

A maze of coordinated or less coordinated activities and initiatives followed, towards solving appropriately the problem as phrased in the Executive Memomrandum ; or, more generally,

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[144] « Radio Frequency Spectrum Allocations in the United States / The 1996 NTIA Spectrum Chart ».
A background paper by Norbert Schroeder from NTIA dated July 2000.
[145] The author, Darlene A. Drazenovich, was named next to the title.
[146] Dating back to **after** the introduction of analog cellular with an FCC mandated standard
[147] This letter, dated December 19th, 1998, was signed by the Secretary of State, the Secretary of Commerce, the U.S. Trade Representative and the FCC Chairman.

towards finding any new spectrum for the wireless industry which was asking essentially just that[148]. We will mention a few here.

In January 2001, an Air Force Base[149] carried out a case-study on the impact of accommodating IMT-2000 - in the 1.7-1.8 GHz band - on the Precision Strike Weapon Systems. A IMT-2000 assessment by the DOD with somewhat different assumptions (in the same frequency range) followed in February[150] and in August of the same year the GAO[151] concluded its report with the statement that more analysis was required to support [new] spectrum use decisions for (a specific slice of) that same band.

Similar work was carried out by the FCC regarding the concerned 2.1 GHz band : it established an extremely complex picture involving thousands of licences potentially affected, for a wide variety of services from paging to general aviation.

Clearly, in both of the bands, 1.7-1.8 and 2.1 GHz, the potential for 3G appeared problematic, to the extent where the FCC put focus on the 2.5-2.7 GHz band (also part of the IMT-2000 spectrum identified at WRC-2000) and added formally in September 2001[152] a mobile allocation to it ; though this band is extensively licensed to *Instructional Television Fixed Services* (IFTS) and to *Mulitchannel Multpoint Distribution Services* (MMDS). The FCC made it clear that it will not relocate or otherwise modify these licences, but rather rely on market forces instead of regulatory judgements to determine the best use of these bands[153].

Another part of the spectrum in which there has been a lot of action since early 2000 is the 700 MHz band, spectrum so far essentially devoted to TV broadcasting. As stated in an FCC News Release[154] :

> « The Communications Act of 1934, as amended, requires the Commission to assign spectrum reclaimed from broadcast television using competitive bidding and to auction this spectrum by September 30, 2002. The reclamation of the 700 MHz band is occurring as a result of the

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[148] A September 2001 Bloomberg release states : « Mobile-phone companies say they need more airwaves to meet subscriber needs. Verizon Wireless, the biggest U.S. mobile-phone service provider, has said it may run out of capacity in major markets such as New York and Los Angeles within two years ». Surprisingly, a January 2002 Reuters release is titled « Verizon sees no urgent need for wireless spectrum » and states further : « Verizon Wireless has enough airwave capacity to handle near-term customer growth, and does not need to buy additional spectrum capacity for up to two years ». CTIA, the industry body, has consistently complained about insufficient spectrum.

[149] « Case Study : Impact assessment on Precision Strike Weapon Data Link Systems to Accommodate IMT-2000 ». Prepared by Eglin Air Force Base, Florida, dated January 5 2001.

[150] « Department of Defense Investigation of the Feasibility of Accommodating IMT 2000 within the 1755-1850 Band », February 9 2001.

[151] Report by the General Accounting Office to a Subcommittee of the *Committee on Armed Services, U.S. Senate*, August 2001. (GAO-01-795). The conclusion is clearly spelled out on the front page : « More analysis needed to support spectrum use decisions for the 1755-1850 Mhz band ».

[152] *First Report and Odrer and Memorandum Opinion and Order* adopted in the *New Wireless Services* proceeding on September 24, 2001. Precisely, the mobile allocation was added to the 2500-2690 MHz band.

[153] The FCC had estimated that implementing the sharing or relocation options in that band could take 10 years and cost more than $ 19 billion.

[154] FCC NEWS dated December 12, 2001 : « FCC reallocates and adopts service rules for Television Channels 52-59 »

> planned migration of broadcasters into the *core* broadcast spectrum (currently channels 2-51) that will occur when they convert from analog to digital operations ».

Among the contemplated services to make use of this spectrum are *advanced voice and data communications,* a designation which certainly does not exclude 3G. One FCC Commissioner[155] stated in his opinion :

> « This….balances two important goals : promoting the transition to digital television and establishing a pathway to making [TV] channels……available for new services as Congress instructed us to do. My hope is that this spectrum will someday contribute to bringing more broadband wireless services to rural America ».

The plan for these auctions[156] has been hampered by a major problem, namely the fact that the incumbents do not have to give up the spectrum before 2006, or when the penetration of digital TV reaches 85% if this happens earlier (an unlikely development according to most observers[157]). Because of this protective clause, the wireless industry has largely expressed its opposition to their taking place.[158]

After a lot of battling involving a significant number of members of the House of Representatives in addition to the concerned agencies (FCC and NTIA of course, but also the Secretary of Commerce himself), and subsequent to several announcements of deferral, it appeared by year-end 2002 that the auction of 251 licences in the *lower 700 MHz band* [159] should commence some time in 2003.

Though the future destination of that spectrum in terms of application remains unclear, we observe that there are a significant number of cellular service providing companies in the long list of « qualified bidders » for that 700 MHz spectrum published mid-2002.

Early 2002, the FCC reallocated over half-a dozen small slices[160] in a variety of Government bands, to « benefit consumers by permitting and encouraging the introduction of new and innovative wireless technologies » (which again by no means excludes 3G services).

The pressure to find any new meaningful amount of spectrum for wireless, preferrably in the bands identified by WRC-2000 (for IMT 2000), continued to mount. In April 2002 eight domestic trade associations[161] jointly wrote to President George W. Bush, stating in particular :

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[155] Commissioner Michael J. COPPS

[156] To be precise, there are actually two independent processes affecting respectively the « upper 700 MHz band » (747-806 MHz, or TV channels 60-69) and the « lower 700 MHz band » (698-746 MHz, or TV channels 52-59).

[157] One indication, among others, is NTIA's announcement in September 2002 of its decision to award $36 million of grants to assist 97 public broadcasting stations in their conversion to digital technology ; this in addition to $6 million awarded for the conversion of some special services / items. The total of $42 million will have to be matched by $74 million raised by the recipients.

[158] « Even after the auctions, the broadcasters will have to be paid extortion money to move » said the President of CTIA in the Fall of 2001.

[159] Auction of the *higher 700 MHz band* (746-764 and 776-794 MHz) had also been planned already in 2001. An FCC *fact sheet* detailing that auction plan than indicated : « The spectrum is presently encumbered by approximately 100 existing TV stations, and it may remain so, to some extent, until 12/31/2006 or later. No part of the country is totally unencumbered in this band….. ». Also : « This spectrum offers potential to deploy……. as well as next generation high speed mobile services »

[160] The total of this reallocation amounts to 27 MHz, under the form of 7 slices in the 200, 1300, 1400, 1600 and 2300 MHz bands.

> « In a few years, most new computers, appliances, vending machines, vehicles, offices, factories and homes may have a wireless capability. The American consumer and the American business will be *untethered*. But the current shortfall of commercially available spectrum could slow this advance. Providing additional spectrum for the wireless revolution has the potential to yield more than $500 billion in economic and consumer benefits over the next decade, spur $50 billion or more in capital investment, and create tens of thousands of American jobs.
>
> …….Currently, the NTIA review is examining 120 MHz of internationally harmonized spectrum in the 1710-1770 and 2110-2170 MHz bands.
>
> …….The President's Fiscal Year 2003 (FY03) Budget contains a key recommendation that, if implemented, would bolster this process. We applaud your leadership and urge Congress, the FCC and industry to work with your Administration to deliver 120 MHz of wireless spectrum by 2005……. »

Finally, during Spring 2002, the Secretary of Commerce and the FCC Chairman established a task force « to succeed where others had failed » : the viability of making all or part of the 1710-1770 MHz and 2110-2170 MHz bands available for *advanced mobile wireless (3G) services* was studied. This study concluded mid-2002 that 90 MHz[162] of this spectrum can be allocated for 3G services without disrupting communications systems critical to national security. One should note that the 2.1/1.7 GHz choice was strongly supported by the CDG which stated in its mid-2002 submission to the FCC[163] :

> « Currently, governments internationally and especially throughout the Americas are considering using the 1710-1850 MHz and 2110-2200 MHz bands for additional frequencies for IMT-2000. The use of these bands will advance the potential for international roaming and should therefore be encouraged via U.S. participation in international proceedings……..
>
> The CDG, therefore, urges the Commission and other Federal Government agencies to work towards the identification of the 1710-1770 MHZ / 2110-2170 bands for IMT-2000 in the near future ».

To reach this conclusion, which affects both current government and non-government users, discussions with the concerned spectrum using federal agencies – particularly the DOD (i.e. in the 1.7 GHz band) - had certainly been tense. These entities have imposed severe conditions to its implementation, in terms of relocation scheduling and funding, of specific selected sites protection (meaning exclusion), of particular equipment inventory exhaustion and of possible spectrum sharing in time. It is therefore not clear to us when subject spectrum will be auctioned and become broadly available to future 3G service operators. (The year 2008 has been mentioned early 2003 by some officials).

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[161] The CTIA, the Computer and Communications Industry Association, the Computer Systems Policy Project, the Consumer Electronics Association, the Electronic Industries Alliance, the Information Technology Industry Council, the Telecommunications Industry Association, the U.S. Chamber of Commerce.

[162] « This 90 MHz would come from the 1710-1755 MHz band and a matching 45 MHz from the 2110-2170 MHz band ». *An assessment of the viability of accommodating advanced mobile wireless (3G) systems in the 1710-1770 MHz and 2110-2170 MHz bands*, note published by NTIA on July 22, 2002.

[163] *Comments* (to the FCC) *of the CDMA Development Group in the Matter of the Spectrum Policy Task Force* (ET docket No. 02-135).

A decision the FCC has made since has not clarified the 3G spectrum landscape. In January 2003, the Commission reallocated 30 MHz of spectrum «that can be used to provide a variety of wireless services, including advanced wireless services (AWS), commonly referred to as *Third Generation* or *IMT 2000* [164] ». These 30 MHz[165] come, in our understanding, from earlier MSS (moble satellite services) allocations, a move which sounds logical in view of the gloomy MSS business development during the last decade. Subject reallocated spectrum is close to 2 GHz and a detailed analysis shows that it – quite slightly – contributes to a better match with the basic IMT-2000 (or UMTS) allocation. But in a dissenting view based on a relevant background, one Commissioner questions the wisdom of that decision :

> « I write separately because I believe that the Commission should not abandon a substantial amount of rare globally harmonized satellite spectrum. In today's order the Commission decides to reallocate 10 MHz of spectrum from mobile satellite services (MSS) to advanced wireless services (AWS)……My preference, however, was to choose less problematic frequencies.
>
> The United States led the fight to win globally harmonized MSS spectrum in 1992. Soon thereafter, however, the Commission abandoned the plan to have a worldwide MSS band and allocated 10 MHz to PCS. This reduced by one-third the globally harmonized spectrum available to fledgling MSS operators, although it provided much-needed spectrum to PCS operators. This action engendered significant international disappointment and injured U.S. spectrum planning credibility »

But let us get back to the essentials and try to simplify the overall picture. In terms of committed - or publicly aimed at – 3G spectrum, the world is by mid-2003 rather divided : the *UMTS bands* countries (some of them still refer to the *IMT 2000 core-bands*) with 1.9 and 2.1 GHz frequencies ; and the U.S. with an intent to grant and free 1.7 and 2.1 GHz frequencies. Note that the upper band is common which is an important element of compatibility, especially under the assumption of FDD band-pairing[166], a scheme largely favoured at this stage.

However, many countries – some among the most important ones as we will see - have not made a decision yet, or had not made it public by mid-2002. Particularly prone to be influenced by the U.S.'s choice, for good reasons, are a number of governments of the American continent. NAFTA and the importance of their exchanges and traffics of all kinds with the U.S. could be decision factors for Canada and Mexico. But the same holds true for a number of countries in Central and South-America, which feel economically or socially closer to North-America[167] than to other parts of the world. Actually, 3G constitutes a remote concern for most of them, because they still have a huge 2G – i.e. basic voice - development potential.

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[164] FCC NEWS released dated January 30, 2003 and titled : « FCC reallocates spectrum for new wireless services »

[165] In a *Third Report and Order* the Commision allocated for fixed and mobile wireless services the 1990-2000 MHz, 2020-2025 MHz and 2165-2180 MHz bands

[166] Versus TDD operation in a single band.

[167] Some trade data (released by *Eurostat/Comex*) do actually not confirm this « business proximity ». They indicate that in 1998, Mercosour's exports to the EU exceeded its exports to the U.S. by 45% ; and *Mercosour*'s imports from the EU exceeded those from the U.S. by 12%. Mercosour's members were Brazil, Argentina, Urugay, Paragay, Chili, Bolivia (the two latter countries having only *associate member* status). Trade balances may of course evolve from year to year.

Reinforcing the just mentioned homogeneity trends within the Americas, is the existence of *CITEL*, the telecommunications arm of the *Organization of American States.* CITEL naturally favours commonality of bands with the U.S. and has taken a position similar to the one expressed by CDG (as indicated above).

3. THE ODD CASES OF CHINA[168] AND INDIA

« *Quand la Chine s'éveillera »*[169] : this title drew quite some attention – at least in France - when it came out in 1973 ; the book was written by a high-profile politician after leading a parliamentary mission there. It refers copiously to the economy of course and more specifically to agriculture, industry, energy, railways and other transportation problems ; no word about telecommunications though. It seems that we are now, 30 years later, in the middle of the announced wake-up.

At about the same time, the story goes, a large U.S. based multinational corporation sent one of its executives to India to assess the business potential there. When he came back and reported to the management board, his first words were :

« *India is a land of great future. And it will ever be* »

The statement could still have some truth today, particularly as far as telecommunications services are concerned.

These « one-billion-plus »[170] nations constitute one third of the global population. Though demographic density is high, with extremely compact conurbations and rural pockets, there are void areas in both. The average standards of living are clearly low[171], but China's GNP[172] is reported as being three times India's.

The important Chinese and Indian diasporas abroad are significantly occupied in commercial or other relatively qualified jobs. Familiarity with the english language is good in India and progressing rapidly in China. It is common knowledge by now that China has become in a few years the « world's plant[173] » including for advanced technology products ; whereas India

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[168] We refer here to the *Popular Republic of China*, though the analysis of the Taiwanese situation could also be of interest.

[169] The full title is actually : « *QUAND LA CHINE S'EVEILLERA….. le monde tremblera » (« WHEN CHINA WILL WAKE-UP……the world will tremble »).* By Alain Peyrefitte, published in France by Fayard in 1973. The phrase is attributed to Napoleon who is said to have pronounced it after his reading of « *Voyage in China and in Tartaria »* by Lord Maccartney, first ambassador of the King of England in China.

[170] 1.33 and 1.03 billion respectively (according to data from the *Population Reference Bureau* in Washington, DC).

[171] A low standard of living is not an impediment to significant development of cellular. Africa is a case in point :
it had 31 million cellular subscribers mid-2002 (out of which 11 million in South Africa) for a population of 840 million i.e. 20% lower than India's.

[172] International statistics report for 2001 a GNP of (aproximately) 4600 B$ for China and 1400 B$ for India. These are however *purchasing power parity* adjusted figures.

[173] This plant role goes naturally beyond advanced technology. According to the French paper *Le Monde* dated April 8 2003, China produces 50% of the cameras in the world, 30% of the TV sets and of the air conditioners, 25% of the washing machines, 20% of the refrigerators. 420,000 foreign companies have invested there some 450 Billion $ in the last 20 years.

is rather its « software house ». This confirms that there is technical ability with great potential in both nations and obviously a middle class of significant size.

No doubt, there are huge differences between these two civilization-nations: the « largest democracy in the world » has indeed a strong democratic tradition – and respect for tradition in general - but is no match for the modern dynamics of the « Republic of the People » ; these dynamics resulting in one of the most impressive growth rates observed around the turn of the century[174].

In both countries the telecommunications infrastructure is embryonic because such facilities, until recently, could not be rationally envisaged for the people nor were they seen by the governments as a priority investment at scale. In face of this overwhelming absence of fixed telephone service, wireless has of course a special role to play. The gap in this respect between the two nations is astounding : by year-end 2002, India has 10 million cellular subscribers whereas China has over 200 million. As we will see, the effectiveness of the respective authorities in defining and implementing spectrum licensing policies has certainly been a factor – among others - in this gaping divergence.

Obviously, these two countries represent huge markets, more rapidly in China where the GNP per head has trebled since 1990; but they are also positioned to influence the sector's shape beyond their borders.

CHINA

The MII (*Ministry of Information Industry*) has so far assumed the regulatory role for the telecommunications sector, including spectrum allocation and cellular licensing. In spite of the huge size of the country[175], a nationwide approach has been taken with basically two competing operators : *China Mobile*[176] and *Unicom*[177].

As a starter, in the late eighties, the US analog standard AMPS was adopted and service was developed in the 800 MHz band. The move to digital – namely to GSM in its 900 and 1800 MHz indigenous bands – took place relatively late. Spectrum soon became a limiting factor and prompted interest in an advanced technology, CDMA, and in 3G. Indeed, Unicom was allowed in 2001 to put in place a CDMA[178] network making use of its 800 MHz spectrum[179].

The early interest of China in 3G and its companion spectrum in the 2 GHz range cannot be dissociated from the standards question. Beginning 2003, the Chinese government indicated its intent to hand out several 3G licences by year-end 2003 or early 2004 and also hinted to its

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[174] Under the title « Red-hot growth in the provinces ? » the *International Herald Tribune* dated Feb. 4, 2003 writes : « China's 8 percent economic growth rate was among the fastest in the world ». Then the article explains why the contry's official statistics are not necessarily reliable. There is though a wide concensus that China enjoys one of the highest growth rates among the large countries.

[175] Three times India

[176] The *China Mobile Communications Corporation* is a state owned entity including various subsidiaries. Early 2002 it had about three quarters of all subscribers.

[177] *China Unicom Limited* is incorporated in Hong Kong.

[178] This was actually an arrangement of leasing CDMA network capacity. We understand the CDMA concerned version to be CDMAone (i.e. pre-CDMA2000), with an intent to evolve later to CDMA 1XRTT which allows relatively high data speeds.

[179] Unicom had been assigned both 800 MHz and 900 MHz spectrum. Early 2003 the vast majority of its subscribers were still GSM.

openness to multiple standards : WCDMA, CDMA 2000 and *TD-SCDMA*[180], which are all three part now of the IMT-2000 family of air-interfaces. However, this latter technology was developed by China - with outside assistance[181] - specifically for the Chinese market (which does not mean that the authorities are uninterested to spread it elsewhere) : combining features of both WCDMA and CDMA 2000, it is supposed to suit well all sizes of cells, from rural areas to hot spots and indoor applications in busy city centers. It furthermore allows highly flexible spectrum allocations and offers good efficiency for both asymetric and symmetric data traffic[182]. A distinct motivation of this heavy techno-logy investment was possibly the desire to reduce the royalties[183] charged wherever one of the two other 3G standards is implemented.

By mid-2003 the Chinese 3G spectrum plan had not been formally released and the greedy infrastructure manufacturers from three continents may have to wait until 2004 to see clearly what their opportunity is. Though there are strong indications that subject plan will be compatible with the UMTS bands, there also is mention in ITU documents that the country envisaged to use the – unique – 2300-2400 MHz band for IMT-2000[184]. Four operators are foreseen for the new licences : the two existing mobile operators already mentioned and two existing fixed operators[185]. Though two or three standards may finally be allowed, some observers do not exclude that spectrum allocation will in one way or another favour the operator(s) using the home-grown standard[186] ; no candidacy has been declared for the latter, but the two « old fixed - future mobile » operators are more logically targetted.

Worth mentioning because not fully unrelated to the mobile communications spectrum scene is the Chinese PAS (*Personal Access System*), a derivative from the well known but now defunct Japanese PHS (*Personal Handyphone System*). By year-end 2002 there were over 12 million PAS customers, among which 7 million from 2002 alone, according to the MII ; and another 12 million could be added during 2003. An upcoming conflict has been reported regarding spectrum, as PAS operates in the 1.9 GHz band normally foreseen for 3G. But at the scale of China's ambitions in the mobile sector – both in terms of service and building up a technology industry – it is unlikely that PAS will stand in the way.

Actually we perceive, by mid-2003, a rather confused situation between *Little Smart*, as PAS is increasingly called [187], and another extended WLL solution which has made some inroads into China, namely CDMA 450 deployed in the 450 MHz band ; the issue being how to serve

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[180] For an overall description of this air interface standard see : « TD-SCDMA and W-CDMA make ideal partners for 3G » by Klaus KOHRT from Siemens Mobile, Germany. In *Wireless Europe* issue 17, May 2002, p.22-23.
This article also sheds some light on the technical implications between spectrum allocation and 3G standards.
[181] By the *Chinese Academy of Telecommunications Technology* with assistance essentially from *Siemens*, Germany. But *Philips*, Netherlands and more importantly *Datang*, China are also involved.
[182] The TD-SCDMA technology is for unpaired spectrum allocation, i.e. for TDD (vs FDD) mode.
[183] As far as we are informed, a number of telecommunications manufacturers own pertinent patents in the CDMA field ; but among those, *Qualcomm* from San Diego, California dominates.
[184] Resolution 223 of WRC-2000.
[185] *China Telecommunications Group Corporation* and *China Netcom Corporation Limited.*
[186] A November 1, 2002 *Silicon Strategies* release under the signature of Mike Clendenin from the *EE Times* is titled : « China favors its own 3G standard in spectrum allocation ». We quote :
« ….Another sweetener for companies is the government's decision to allocate an additional 100 MHz block to TD-SCDMA, but that must be shared with other applications that were not made immediately clear ».
[187] *Xiaolingtong* in chinese

the rural areas on one hand and how to let the established cellular operators continue to develop in the cities.

In any case, the size of the market, the competitive advantage of the manufacturing industry[188] and the inflow now of important R&D investments (both normally under the form of international joint ventures) - as well as the geopolitical positioning in the region – could lead China to play a role in the future shape of mobile communications, well beyond its borders.

INDIA

Grasping the misdevelopment of cellular in India, with or without special attention paid to spectrum aspects, is a challenge in itself. The policies liberalizing – or pretending to liberalize – telecommunications started in the early nineties from a very nascent base of that industry. And cellular became entangled in the overall turmoil. A respected economic magazine states :

> « In India, meanwhile, mobile operators found themselves embroiled in a series of legal wrangles with the government. The resulting uncertainty prompted many foreign operators to withdraw from the market altogether in the late 1990's. »[189]

For all practical purposes, cellular was launched by the authorities in 1994 with two metropolitan licences being granted in each of the four major cities[190] ; and during the four following years, 34 licences were further granted in 18 so called *circles*. Basically, India was implementing a « licensing by area » scheme similar to what the FCC had decided in 1981 for the U.S., with a duopoly in each area. Subsequently, though, « third cellular operator licences » and « fourth licences » were also awarded. Conflicts and legal battles (e.g. on interconnection or revenue sharing conditions) with the *DOT* (Department of Telecommunications) which still had a historic operator role, and with *TRAI* (Telecom Regulatory Authority of India) raged endlessly.

The radio frequencies associated with these licences were in the 900 MHz band[191], making India for most of the nine last years a *GSM 900* country ; the « fourth licences » were though in the 1800 MHz band. But the very limited amount of spectrum awarded to each of the four operators competing in each area, contributed to a rather unattractive mobile service provision business. And the Defense establishment has apparently not been willing to better accommodate the needs of the cellular industry.

> « India choose a licensing policy that divided the country into 22 regions…..Bidding in multiple regions was restricted. This aimed to promote competition, but led to a fragmented market with a baffling array of operators, none of which achieved economies of scale. Limited spectrum also hurt service quality »[192].

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[188] In the early years of the 21st century, a high proportion of the mobile phones shipped in the world are, if not built, at least assembled, in China. All major manufacturers have an important presence there, key local groups to work with being *ZTE*, *Legend* and *Huawei*.

[189] « The tortoise and the dragon ». The Economist, January 25-31, 2003. Page 63.

[190] Delhi, Bombay, Calcutta and Madras.

[191] 890-902.5 MHz paired with 935-947.5 MHz.

[192] Same article in The Economist as already referenced. Note that spectrum limitations, especially in dense urban areas, also imply increased infrastructure investments.

Another major obstacle with which the Indian cellular industry has been confronted – and which certainly has confused the marketplace - is the introduction of *WLL (wireless local loop services) with limited mobility*. TRAI recommended in 1999 to the government to allow basic telecom operators and others to offer such services. Whereas the cellular operators had paid hefty license fees, spectrum for WLL was to be awarded free on a first come / first serve basis, which actually generated a rush by a variety of applicants[193]. *COAI* (the Cellular Operators Association of India) opposed the scheme as constituting – rightly so, it seems – unfair competition ; but it was confirmed by the competent tribunal[194] and in December 2002 by the Supreme Court which decided :

(a) that the basic (i.e. fixed line) operators may continue to take subscribers for the « WLL with limited mobility service »
(b) that the telecom tribunal should reconsider the case.

Hence, by early 2003 the scene remains rather unclear.

For subject WLL services, spectrum was found in relatively ample quantity[195] : increasing overall teledensity in the country had become a high priority objective for the government. Whereas the initial plan was to use locally developed technology in a band close to 2 GHz, the final choice of the 800 MHz band led to the selection of a more widely available technology (in fact cellular equipment of the CDMA 1X type)[196]. Some wonder how this choice can lead to low enough prices to generate the very high volume market development required : by year-end 2002, telephone density in India was four (out of hundred) versus a global average of fifteen.

As these WLL licences are increasingly in the hands of strong organizations (particularly the huge *Reliant Group*), one cannot exclude that what is being prepared are a new type of nationwide cellular players, which, though entering the mobile communications market « through the backdoor », can compete effectively with the existing GSM operators ; the latter having themselves strengthened in the meantime through consolidation[197].

As to licensing new spectrum for 3G, there was early 2003 no visible planning activity.

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[193] The majority of such WLL licences were though awarded to two large industrial Indian groups (*Reliance* and *Tatas*).

[194] March 15, 2002 decision of *TDSAT* (Telecom Dispute Settlement and Appellate Tribunal) often referred to as telecom tribunal.

[195] 824-844 MHz and 869-889 MHz ; bands considered attractive for cellular in some other countries.

[196] « DOT's spectrum policy ignores indigeneous technology » : title of an article in *The Economic Times* (of India) dated August 29, 2001. It states : « IIT-Madras, which developed the corDECT system, has asked the DOT to review its spectrum policy ».

[197] Early 2003, there are in India three dominant GSM players known as *Bharti*, *Hutchison* and *Tatas* (actually in a joint venture with AT&T and Birlas).

4. THE « Wi-Fi » PHENOMENON

Truly a surprise entrant on the mobile wireless scene, *W-iFi* (Wireless Fidelity – a strange label indeed[198]) deserved to be named « man of the year » in 2002 if not in 2003. It is difficult now for anyone in the developed world, even the layman, not to be sensitised to the *hotspot* concept : a more or less public area like a hotel lobby, an airport lounge, a sandwich bar, a train station or even a parc where one's portable computer easily logs into the Internet without any physical connection nor cumbersome procedure.

WLANs (wireless local area networks) or *RLANs* (radio LANs as they are frequently called in Europe) were the subject of intensive R&D activity by a number of IT or telecom manufacturers already in the 1980's : the explosion of cable-based LANs in office environments to interconnect the growing number of PC's or other work-stations, gave credence to the idea that being « cableless » would present great advantages in terms of ease of installation and physical deployment flexibility ; nomadic mobility of equipment was not seen at the time as a key factor because portable data-tools like laptops, notebooks and other PDAs were not yet basic instruments of the « white-collar » worker. In any case, the various products WLAN which were released around 1990 met a luke-warm reception – at best - in the marketplace.

This did not discourage corresponding efforts in the standards arenas : whereas IEEE conceived *802.11* for WLANs, ETSI worked on *HIPERLAN*, and *ARIB* started later an effort on *HiSWANa* in Japan.

On the spectrum side, an important background factor is that, for many years, the 2.4 GHz band qualified as a major *ISM* band ; this means that *Industrial, Scientific and Medical* equipment as well as other very low power devices can use such frequencies without license : we enter here the « unlicensed » world in which multiple independent pieces of equipment can work freely, virtually at the same frequency, without in practice interfering with each other, owing to their low transmission power and / or to a smart appropriate protocol. *Spread spectrum* technologies in particular garantee that each receiver will identify well the information intended for it, but only that information.

There had on the other hand, in the U.S., been early efforts on behalf of the computer industry to secure spectrum close to that same band specifically for *Data-PCS*. In 1991, one organization[199] petitioning the FCC said :

> « Before this action, the few radio bands available for wireless computing were overloaded with industrial transmitters or occupied by microwave stations, and thus were unusable without massive relocation costs……. ».

Another key player[200] in the computer industry told the FCC :

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[198] *Wi-Fi* (or *WiFi*) is a brand under which *WECA* (*Wireless Ethernet Compatibility Alliance* which comprises over 50 companies worldwide) promotes the IEEE 802.11 standard. To some, Wi-Fi refers only to 802.11b. We use the term here for the broader hotspot approach in both the 2.4 and 5 GHz bands ; particularly for public access.

[199] Apple Computer Inc.

[200] Microsoft Corporation – This quotation, as well as the previous one, is taken from *Wireless Spectrum Finder* by Bennett Z. Kobb, published by McGraw-Hill in 2001.

> « Data-PCS will operate in an entirely different manner than the technology we view as mobile or portable at present…. Users of notebook and handheld computers might choose to transmit data between themeselves. Ad-hoc work groups might be established as the need arises…….Low-power communicating devices might operate as digital door locks, providing authentication and access to nomadic environments such as automobiles ».

Actually, the unlicensed Data-PCS band[201] has not led to substantial business developments and the term *Data-PCS* is not much heard of these days.

It is the combination of IEEE's standardization effort with the existence of the ISM bands which has allowed WLAN's to come to the forefront in the first years of this century, including on the mobile communications scene ; in fact more for *nomadic* use than for mobile use as such. Let us quote an expert[202] again :

> « The IEEE 802.11 WLAN standard ensures that users can purchase interoperable products from a number of vendors to configure and expand wireless local area computer networks. It was created in 1990 and has had a difficult start : many years passed before agreement was reached on the first version providing 1 or 2 Mbps rates. The standard also included two incompatible approaches, *frequency hopping* and *direct sequence*, which led to incompatible products. Today, IEEE 802.11 is well established, thanks to the ratification of IEEE 802.11b. Its advantages over other WLANs lie in the global ISM band ».

WLANs today have a star-structure : end-user devices transmit to – and receive from – a base-station (tens or hundreds of meters away[203]) often referred to as *access point*. Work has also been carried out though on meshed structures in which any untethered device can radio-link directly with any other one part of the same WLAN, as alluded to earlier.

There are two bands of relevance here : the 2.4 GHz[204] ISM band and the 5 GHz[205] ISM band. Both qualify as ISM bands in all ITU regions and assume now an important role for WLANs.

As to the IEEE 802.11 standard, three versions deserve to be mentioned here (in order of decreasing current importance):

- **802.11b**[206] which works in the 2.4 GHz ISM band and provides speeds up to 11 Mbps. Most of the WLAN activity and deployments in the early years of this decade comply with this standard.
- **802.11a**[207] which works in the 5 GHz ISM band and provides speeds of up to 54 Mbps.
- **802.11g** which also works in the 2.4 GHz ISM band and provides speeds of up to 54 Mbps. This more advanced version was, early 2003, still in a status of formalization.

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[201] The 2390-2400 MHz band. It was to be shared with Amateur Service.
[202] *UMTS and Mobile Computing* already cited.
[203] The higher the radio frequency, the lower the range.
[204] Precisely 2.4-2.4835 GHz
[205] Precisely 5.15-5.35 GHz and 5.725-5.875 GHz.
[206] 802.11b is based on *DSSS* technology (Direct sequence spread spectrum).
[207] 802.11a is based on *OFDM* technology (Orthogonal frequency division multiplex).

ETSI's HIPERLAN[208] and ARIB's HiSWANa standards which aim essentially at the 5 GHz band seem so far not to have found a large place in terms of industrial developments.

The regulatory and technical international picture of the mentioned ISM bands and of unlicensed spectrum is however not simple, in its fine detail. A number of governments have had – and still have – difficulties in making this spectrum available for WLANs (often because it is being used by defense agencies). Hence the exact authorized frequencies are not the same in the various countries e.g. in the U.S., in Japan and in Europe – and there even are differences between member-states of the EU; nor are the regulatory constraints regarding radiated power[209]. It seems that these problems will be gradually solved in the major parts of the world and also that they can be somehow circumvented by the concerned computer, chipset or microprocessor industries ; the nomadic end-user travelling internationally should certainly not be bothered by them.

Furthermore, the « unlicensed » qualification of these bands may be more or less applicable i.e. there may be declarative or other administrative obligations for the WLAN operator ; and even geographic exclusion zones. In some countries, substantial fees applicable in the future to public WLAN operators are not excluded.

Possibly, it is the lukewarm attitude of a number of European countries which has prompted the Brussels Commission, already mid-2002, to press the most reluctant ones to open up[210] ; and later, to formalize Europe's position, namely through a

> « Recommendation[211] that calls upon the Member States to facilitate the use of R-LAN's for accessing public services …….The R-LAN technology will give European citizens ready-access to the knowledge-based society, when in public places, away from their home…. ».

The Commission further recognizes the need to address the related spectrum issues and to harmonize within the European Union the necessary frequency usage parameters and requirements.[212]

Even in the U.S. where the ISM concept was borne and where « unlicensed » has a clear meaning of free access, there were difficult problems in freeing the full 5 GHz ISM band to WLANs ; only recently could NTIA broker a compromise between the incumbent (essentially the DOD) and industry[213]. At the same time, there appeared increasing pressures to extend

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[208] HIPERLAN systems are specified to work within buildings in the 5150-5350 MHz band. Transmission power is limited to 200 mW.

[209] In France for instance, early 2003, the key regulations regarding maximum transmission power (so-called *EIRP*) of WLAN equipment in the 2.4 GHz band require two tables : one applicable in 38 *départements* and the other in the remainder of the country (i.e. 37 *départements*). Also, the levels – 10 mW or 100 Mw – are not the same, e.g. for Paris, in the 2400-2454 Mhz and in the 2454-2483.5 MHz band. These rules as well as the actual possibility to operate depend further on the « in-house » or « outdoors » qualification of the WLAN.

[210] In an article titled « Brussels pushes states over wireless technology », the *Financial Times* dated August 12 2002 states : « The Brussels authorities are pushing France, Greece, Italy, Luxemburg and Spain to allow the technology, which enables users to connect their laptops to the web without wires, in public places…… ».

[211] Recommendation IP/03/418, released on March 20 2003.

[212] Some European countries like France and the UK have difficulties in freeing the 5GHz spectrum (applicable to 802.11a systems) especially for outdoors usage in public places.

[213] « Agreement reached regarding U.S. position on 5 GHz wireless access devices ». NTIA's press release dated Feb. 4th 2003, which contains precise technical conditions pertaining to the use of the relevant bands. This follows negotiations between NTIA, FCC, NASA and the DOD.

the amount of spectrum open to WLANs in the 5 GHz band, the idea being that the shorter propagation in that band can be compensated by a larger amount of spectrum[214].

More generally, the U.S. wants to progress along the lines of a key recommendation of the *FCC Spectrum Policy Task Force* of mid-2002. Let us quote the FCC, in a statement later that year[215] :

> « …..In a Notice of Inquiry approved today, the Commission stated that the current rules for unlicensed transmitters have been a tremendous success. A wide variety of devices have been developed and introduced under those rules for consumer and business use, including cordless phones, home security systems, electronic toys, anti-pilfering and inventory control systems, and computer wireless local area networks. The success of those rules shows that there could be significant benefits to the economy, businesses and consumers in making additional spectrum available for unlicensed transmitters….. »

In a formal personal statement, the FCC Chairman added in the same context :

> « ….Our goal in today's item is to allow for the more efficient and comprehensive use of the spectrum resource while not interfering with existing services. The Commission's Spectrum Policy Task Force Report provided some guideposts to achieving that goal. Among the Task Force's key findings was the obvious success of our current unlicensed spectrum policy model. Indeed, unlicensed devices have become ubiquitous, with estimated sales of over 2 Billion$..... »

In FCC's search for new unlicensed spectrum, some bands below 900 MHz and others above 3 GHz are being exaùined. How relevant this will be specifically to WLAN's or mobility in general, cannot be assessed today.

Starting mainly in years 2000 and 2001, important segments of the industry have involved themselves in Wi-Fi related offerings. On one hand, some operators decide to provide high-speed services through the installation of large numbers of networked hotspots, so that an individual on the move can – with a single subscription – have an easy and efficient access to Internet from anyone of a large number of convenient locations. On the other hand, as the gamut of WiFi products expands[216], some manufacturers announce chipsets and equipment with dual capability : WiFi and cellular[217].

Thus, increasingly, public WLANs are part of the mobile communications scene, even if the services they specifically provide are more of a nomadic than of a mobile nature ; and even though in some organizations, they are part of « fixed » operations and offerings. Indeed, the notion of coverage is competely different from what the end-user typically is accustomed to with cellular ; and WLANs have no forseeable place in truly mobile environments like cars,

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[214] In January 2003, two senators have introduced the *Jumpstart Broadband Act*, a piece of legislation that would urge the FCC to add 255 MHz to the existing unlicensed 5 GHz spetrum.

[215] « *FCC begins inquiry regarding additional spectrum for unlicensed devices* » FCC release dated December 11, 2002.

[216] A key example is *Intel*'s introduction, early 2003, of *Centrino* « …. to realize the benefits of wireless mobility. It is the first architectured **CPU**, **chipset** and **wireless LAN** from Intel designed from the ground up to deliver the benefits of mobility that matter to enterprises….. » as explained on Intel's website.
At the same time, IBM releases dual-band (2.4 GHz and 5 GHz) wireless *ThinkPads*.

[217] « Leaked Motorola plans show possible 802.11 and cellular handset marriage » titles an information service in September 2002. « Handset makers to tee up Wi-Fi phones » titles the Wall Street Journal on February 21 2003. At about the same time, *Sony Ericsson* unveils a GPRS/Wireless Lan PC-Card.

trains or busses.

As one could expect, there have been strong expressions of dissatisfcation on behalf of the cellular industry, in connection with the trend towards unlicensed WI-FI. In an October 2002 letter to key members of the Senate, the President of CTIA[218], for example, wrote :

> « Requiring one commercial entity to pay billions for spectrum when another commercial entity receives its spectrum under the chimera of being « unlicensed »……..We were perplexed and concerned at the suggestion that additional unlicensed spectrum should be given away for free to other commercial entities so that they may offer the same or similar commercial services. This is even more perplexing when one considers that because such spectrum is « unlicensed », there is no way for the government to apply policies deemed to be in the public interest for spectrum users ».

CTIA recalled in this context that the cellular carriers had spent $22 billion buying spectrum at auctions.

Interestingly, it seems that a leading company of the computer industry has played a significant role in the policy move towards unlicensed spectrum[219].

In the U.S., in Europe and in Asia, large powerful operators are investing into Wi-Fi services[220]. Some are basically fixed operators and use the unlicensed path to enter the mobile world ; others, like cellular operators, see Wi-Fi as an extension of their mobile capability. For all, Wi-Fi means access to free spectrum ! The complementarity between Wi-Fi and

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[218] This letter was reproduced – in part – in an October 2002 release of *listserv.media.mit.edu*. It was sent to Senators Ernest Hollings and John McCain, and signed by Thomas WHEELER, who is replaced in November 2003 as President of CTIA by Steve LARGENT, a former U.S. Congressman.

[219] At an October 1 Senate hearing, a Senior VP and CTO of *Microsoft Corp*.testified that one development that would help the overall health of the industry would be more widespread use of Wi-Fi and other wireless technologies : « Policy-makers should more aggressively manage the nation's unlicensed spectrum……..To do this, the industry needs more spectrum for unlicensed use, and the FCC should adopt spectrum etiquettes for the benefits of all Americans ». (The source is the same as for the just mentioned CTIA letter).

[220] In the U.S. for example :

- *T-Mobile*, one of the largest cellular operators, acquired the hotspot operator *Mobilstar* in late 2001. (There are said to be 2200 hotspots in *Starbuck* café's early 2003).
- *AT&T Wireless*, another large cellular operator, gangs up with *Wayport* (said to run 2500 hotspot sites in the hotel and airport circuit).
- Early 2003, *Nextel* develops Wi-Fi plans in cooperation with *Motorola*.

In Europe for example :

- *BT* (British Telecom), essentially a fixed operator, launched Wi-Fi services in November 2001
- *Vodafone*'s German subsidiary announces in November 2002 its agreement with *Lufthansa* to provide Wi-Fi services in the airline's lounges worldwide
- *Orange*, a large cellular operator owned by *France Telecom* and present in a number of countries announces in February 2003 its plan to offer « Wi-Fi mobility solutions that complement GPRS/UMTS services »
- Also early 2003, *Swisscom* readies itself to acquire London based *Megabeam* and Munich based *WLAN AG* which both have hotspot networks. The latter networks will be merged with the hotspot network Swisscom has already set up.

In Asia, a transnational Wi-Fi service structure is being formed. The *WBA* (Wireless Broadband Alliance) plans to integrate 8600 hotspots in five countries. The carriers involved are : *Korea Telecom, China Netcom Communication Group, Maxis Communications* of Malaysia.

cellular is being exploited in various ways, like using cellular base-station sites – which happen to be strategically located - as Wi-Fi access points[221]. A *Nokia* executive says :

> « The Wi-Fi phenomenon is a perfect complement for GPRS and, eventually, W-CDMA. A dual mode device should have the intelligence to sniff out the best signal to use ». [222]

Confirming the above trend, it clearly was the intent of the U.S. authorities to allocate key 5 GHz ISM bands to the **mobile** service and to get this allocation formalized at ITU level[223]. The head of NTIA, testifying before the *Subcommittee on Telecommunications and the Internet* of the House of Representatives[224] stated, while speaking about Unlicensed Operations :

> « We look forward to working with our colleagues …….in countries around the world, to achieve a mobile allocation in the 5150-5350 MHz and 5470-5725 MHz bands that is consistent with protecting the operations of incumbent users ».

The U.S. has essentially achieved this goal at WRC-03 held mid-2003, where a total of 455 MHz were allocated to WLANs and where technical conditions were set for their use[225].

From a spectrum point of view, the virtually worldwide trends described above, in favour of Wi-Fi and of Wi-Fi combined services, confront the regulators, the industry and the community of users with several issues which may not have been fully analyzed :

- The use of unlicensed spectrum, like the 2.4 GHz and 5 GHz ISM[226] bands, assumes that, owing to the low power of the transmitted signals (hence their limited reach), the probability of harmful interference – or of clogging because of too many users, say on a WLAN – is low in practice. The degree of correctness of this assumption does not constitute an issue as such for the user-owner of some ISM equipment configuration. The situation is though different if commercial services are offered to third parties by an operator making use of unlicensed spectrum : what control does he have over the quality of the services he provides ?.[227] This is why some regulators have for a long time limited WLANs to private use e.g. by the company having installed the WLAN on its premises.

- The coexistence of more or less similar mobile applications, some of which use free spectrum and others use spectrum acquired at high cost (typically through auctions) may create

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[221] *Transat Technologies* in the US is developing solutions which use the GSM SIM card to authenticate access onto Wi-Fi networks.

[222] John Ferrari, director of sales and marketing at Nokia, quoted in « A marriage of convenience : where Wi-Fi & Mobile merge ». A release of *Telephonyonline*, a *Primedia* publication.

[223] E.g. at ITU's mid-2003 WRC.

[224] March 25, 2003 testimony of Nancy Victory, Assistant Secretary for Communications and Information (Department of Commerce) before the *Subcommittee on Telecommunications and the Internet* which is part of the Committee on Energy and Commerce (U.S. House of Representatives). This testimony was part of the Hearing on *H.R. 1320, The Commercial Spectrum Enhancement Act.*

[225] In terms of maximum power, indoor versus outdoor use, mitigation measures like DFS.

[226] As Jim Lovette from Apple Computer recalled in this company's submission to IEEE of March 1994, titled « Darwinism and the ISM bands », the ITU defined the use of subject bands in 1982 as follows :

> « Operation of equipment or appliances designed to generate and use locally radio-frequency energy for industrial, scientific, medical, domestic or similar purposes, **excluding applications in the field of telecommunications ».**

[227] The same objection could be invoked about a telephone operator, using for instance the traditional circuit-switched technology : if all subscribers place calls at the same time, the network is jammed. But here the laws of large numbers apply (the so-called Erlang's laws), which is not the case, for instance, with a 802.11b hotspot where only a small number of end-users can efficiently share the 11 Mbps total capacity.

tensions ; not least between powerful market players who no longer feel that they can compete in a fair and balanced way. Many mobile spectrum auctions reached high levels in a « wireless data applications » perspective at a time when the public Wi-Fi concept barely existed. Wi-Fi's spectrum slices are generous compared to cellular[228] ; a single Wi-Fi end-user has potentially access to tens of Mbps whereas the single cellular end-user (say with CDMA 1X or WCDMA current status) has potentially access to hundred of Kbps.

- Wi-Fi could be seen as a new 3G segment. (Often the media now just say « wireless » ; whereas two years ago « wireless » meant wide area cellular, at least in the US). As explained earlier, IMT-2000 encompasses a multiplicity of spectrum bands and a multiplicity of air interface standards ; Wi-Fi as an extension of IMT-2000 would only mean some extra bands and some extra air interfaces. Notwithstanding an important difference though : IMT-2000 implies more or less « carpet-style » coverage, whereas Wi-Fi implies more or less « spotty » coverage[229]. But how important will this difference be in a number of years ? Judging from the recent past, noone can say. It appears that both Wi-Fi operators and 3G operators[230] focus on high density urban areas for their initial key business ; this tempers the usual « complementarity » concensus. For some, the « 4G » vision is the answer.

* Wi-Fi is definitely an extension of the personal computer industry ; an industry, including this extension, controlled de facto to a very high degree by the U.S.[231] . This could lead to tensions at the international trade and regulatory levels. Not that such tensions do not exist in the cellular industry arena ; but in the latter the dominating forces - in terms of standards, IPR's and other protected know-how – appear « geopolitically » more spread.

These projected issues are relevant only if the WI-FI service business succeeds[232] , which many seem to expect[233] : otherwise they would not invest in product developments, hotspot deployments and large-scale alliances currently announced. In any case, there are strong signals that a considerable population of PC or PDA dependent individuals dream about the wide availability of such services, especially if they are free ![234].

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[228] The aggregate spectrum the U.S. plans to push through ITU as « mobile » (supposedly unlicensed) in the 5 GHz range amounts to 455 MHz ; whereas the U.S. plans to free only 90 MHz (supposedly auctioned in 2008) for 3G in the 2 GHz range. This comparison would be out of place if these two frequency ranges would be **extremely** different.

[229] WI-FI equipment including for access points– at least 802.11b – is quite cheap. Hence, extending coverage, for instance with meshed access point topologies, is by no means excluded.

[230] They are identical dual-service companies only to a certain extent.

[231] PC architecture, microprocessors, operating systems, PCMCIA cards, IEEE standards. At the core-chip level for Wi-Fi products, Texas Instruments, Intel, Agere Systems and Intersil are major players ; but so is Philips Semi-conductors. As to the ISM bands, their history is basically American , with the rest of the world largely going along.

[232] In spite of hurdles still to be solved (like security) and of what is sometimes described as a cumbersome value chain : hotspot ownership, network provisioning, authentication&security, billing & roaming, customer ownership.

[233] While others firmly state it will – or should – not.

[234] In the U.S. and in a number of European countries, free WI-FI services exist or are being put in place by cities. *dBusinessNews* (a *Time Warner Cable* partner) reports about the plan of Winston-Salem (North Carolina) along Fourth Street in an April 10 2003 release titled : «Winston-Salem to offer free wireless ». The city's chief information officer is quoted : « Downtown is one of our key priorities and our job is to look at how to use information technology to meet the goals of the city. We see this as an economic development tool…..It will encourage people to come downtown and dine [with a laptop or hand-held device]…….along Fourth Street »

CHAPTER 4 : MORE OR LESS RELATED POLICY TRENDS

Spectrum policy or *spectrum management policy* are by no means new concepts but such phrases appear to have been in little use before the 1990's. The introductive summary of an OECD report « The Economics of Radio Frequency Allocation » dated 1993 states :

> « As the OECD economies have moved towards liberalisation and the introduction of competition in communications markets, the issue of the management of rare resources has come to the fore. Over the last few years, a number of countries have undertaken reviews of their spectrum management policies in order to accommodate new services, often provided on a competitive basis, and to recover or reassign underused portions of the spectrum ».

In December 1998, the European Commission issued a *Green Paper* on *Radio Spectrum Policy* in a wide context of uses (including telecommunications, broadcasting, transport and R&D). Among the objectives and key issues spelled out, let us mention here three :

- Stimulation of technical innovation and support of European competitiveness
- Provision of legal certainty as regards radio spectrum availability and use
- Ensuring coherence between radio spectrum and standardization policies.

This *green paper* was followed over three years later by a *Decision* (so-called *Spectrum Decision*) of the *European Parliament* and *Council*[235], which focuses on the process between the various EU entities and the member-states. It says little on policy as such but stresses :

> « Radio spectrum policy cannot be based only on technical parameters but also needs to take into account economic, political, cultural, health and social considerations ».

The more recent policy trends originated - and continue to originate – primarily in the U.S. and are in line with the overall deregulation wind which has been blowing through the telecom's industry for 35 years.

Little time after he was nominated, the new FCC Chairman in October 2001 gave his views on the U.S. spectrum allocation policy[236]. He saw four main objectives to be pursued :

- A market-oriented policy
- Interference protection
- Aggressive promotion of spectral efficiency
- Reserve and protect spectrum for public safety.

The *FCC Spectrum Policy Task Force*[237] of 2002, after detailed study of the situation, made a number of recommendations going in the same direction. One of these recommendations said :

> « To the extent feasible, more spectrum should be identified for both licensed and unlicensed uses under flexible rules and existing spectrum that is subject to restrictive command-and-control regulation should over time be transitioned to these models »

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[235] *Decision No 676/2002/EC of the European Parliament and of the Council*of March 2002 « on a regulatory framework for radio spectrum policy in the European Community ».
[236] Michael POWELL's press conference of October 23, 2001.
[237] « Spectrum Policy Task Force presents recommendations for spectrum policy reform ». FCC release of November 7, 2002.

The need to revise the way airwaves are managed in the U.S. has since been expressed at high level indeed. In June 2003, the White House issued a memo[238] signed by the President, which launches an *Initiative* aimed at defining a *Spectrum Policy for the 21st Century*. Though the high level Task Force thus created is likely, in our reading, to put emphasis on the needs and assets of the Federal Government as well as on homeland security, the intended scope is quite wide. A number of important wireless application areas are mentioned (with the exception of broadcasting). Objectives[239] and means of the Initiative are well spelled out ; but nothing is said about market-oriented mechanisms or flexibility ; nor does it make reference to the international dimension. As the Task Force is due to report only before June 2004, it is too early to foresee if its outcome will, in any way, affect the policy directions referred to above and more specifically the mobile communications sector.

Flexibility in spectrum management can be achieved essentially through two broad means : non-traditional technical solutions to avoid harmful interference on one hand ; and trading of spectrum rights on the other hand. The benefits are double : better usage of spectrum and less workload for the spectrum regulator.

Multiple uses of the same frequencies are possible through various mechanisms. One is *cofrequency-sharing* which implies the imposition of technical and operational requirements ; it was implemented successfully by the FCC at the time of the PCS auctions in the 1.9 GHz band, because this band was already occupied by some 4500 point-to-point microwave links[240]. There are also technologies of the DFS (dynamic frequency selection) type, which may involve activity sensing of specific sub-bands to allow sharing a given band. More generally, the 2002 FCC Spectrum Policy Task Force recommended in its conclusions to give greater consideration to the *Time* factor to permit more dynamic allocation and assignment of spectrum usage rights.

The topic of *spectrum trading* or its variants (*secondary markets*[241] or *subleasing*[242]) has drawn substantial attention these last years both in the U.S. [243] and in Europe. Actually, the first country having introduced secondary spectrum markets is New Zealand, already in 1989, as part of a broad telecom deregulatory scheme[244]. Trading « exposes the user to the

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[238] *Presidential Memo on Spectrum Policy : Memorandum for the Heads of Exective Departments and Agencies* issued on June 5 2003.

[239] (a) Foster economic growth (b) Ensure national and homeland security (c) Maintain U.S. global leadership in communications technology development and services (d) Satisfy other vital U.S. needs in areas such as public safety, scientific research, Federal transportation infrastructure and law enforcement.

[240] Cofrequency-sharing and the special PCS case is explained in detail in « Spectrum Wars » by Jennifer Manner, published in 2003 by Artech House.

[241] A legal and regulatory analysis of secondary markets may be found in « Spectrum Wars » just mentioned. Also a letter dated March 7 2002 from the head of NTIA to the FCC Chairman, spells out the conditions to make secondary markets a success. (« In the matter of promoting efficient use of spectrum through elimination of barriers to the development of secondary markets » - Docket N°. 00-230).

[242] *Reuter* has announced on June 10, 2003, that the American company *IDT Corporation* is creating a unit to lease airwaves. The FCC approval to do so was given one month earlier. Subject spectrum could be used to « fill-in dead zones in cellular phone networks ». We see some difficulty there, because the « fill-in » normally requires homogenous, compatible spectrum.

[243] A study by the FCC's *Office of Plans and Policy*, released on November 15, 2002 is titled « A proposal for a rapid transition to market allocation of spectrum ». In fact the study proposes « a two-sided spectrum auction [mechanism] ……[so that) reallocated bands could be quickly and efficiently restructured ».

[244] An overview of what has taken place in New Zealand in this respect can be found in « Spectrum Wars ».

opportunity cost of the spectrum [245]». At the center of the matter is the question of ownership : is granted spectrum an asset, like real estate for instance, or is it just a right to use in conjunction with a license with its attached conditions and for a limited time ?

In the long drawn-out and high- profile *Nextwave* case, the U.S. Supreme Court finally gave a direction[246] : it ruled that the licences that the company had acquired (at a very high cost) through auctions in 1996, remain its property, though it had gone bankrupt and had not paid all its dues. Thus Nextwave repossesses the disputed spectrum and can sell it to other companies ; this is actually occurring in 2003, with an explicite FCC approval however[247].

On the European side, allowing spectrum trading became a hot topic mainly in 2002. A report on the Sevilla EU Summit, in June, mentions :

> « The Commission has proposed that the 3G licensing conditions should be changed and that member states could sanction operators to share infrastructure and allow them to trade spectrum »[248].

One of the pressure points was the UMTS situation, in which some mergers of licencees appeared opportune, but were handicapped by the obligation of one of the merged entities to hand back its licence to the authorities. An extensive Europe-wide study has since been launched to evaluate the related implications, with the intent of producing an appropriate *Directive*.

Note that, also in 2002, UK's *Radiocommunications Agency* has conducted an inquiry on spectrum trading. One of the key contributors[249] interestingly pointed out under the 3G heading that :

> « Although spectrum trading may be beneficial, the timing of its introduction needs to be carefully considered. In particular for the mobile sector, there is the danger that regulatory and market uncertainty could result in inappropriate values being paid for spectrum, destabilizing the industry and users ».

In our view and in the very context of this report focusing on worldwide mobility, actual consolidation of cellular bands is very difficult to achieve through spectrum trading, especially in the U.S. ; unless an increasingly fragmented service is deemed acceptable ; or unless flexible « multi-banding » is technically achievable.

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[245] Already mentioned « Review of Radio Spectrum Management » by Martin Cave – For UK's Department of Trade and Industry – March 2002.

[246] « Supreme Court sides with Nextwave » - Washington Post, January 27 2003 – On the ruling of that same day.

[247] Several sources indicate, mid-2003, the intent of two U.S. mobile operators to buy spectrum from Next-wave ; namely *Cingular* and *Verizon Wireless*. The latter's CEO stated : « We are always looking to strengthen our spectrum position ». – *LA Business Journal* of July 30, 2003 and *Detroit Technology News* of September 10, 2003.

[248] « European Commission may allow infrastructure sharing and spectrum trading » - June 24, 2002, release of Internet letter *3G.Newsroom.com*.

[249] Comments dated October 4, 2002, to the *RA Agency* by *INTELLECT*, the trade body for the UK based information technology, telecommunications and electronics industry - (This trade body has 1,000 members employing a total of over 1.1 Million people).

CHAPTER 5 : THE IMPACT OF THE GROWING MULTI-BAND ENVIRONMENTS

From the previous chapters it results clearly that the number of frequency bands being used for public (terrestrial) mobile communications is on the rise. Let us recall the main reasons why this is so :

- Bands which were allocated to cellular in the early days are still valid for cellular. As this application literally exploded in an unexpected way over at least two decades, it needed more and more spectrum : hence one has rarely taken spectrum away. A case in point is the 800 MHz band allocated in the US to cellular by the FCC in 1970 : it still is of great importance today (actually throughout the Americas). And so is the 450 MHz band in Russia, in Eastern Europe and even in China.

- The authorities had to allocate additional spectrum where they could find it, not necessarily contiguous to existing cellular bands. For example, the expansion of GSM 900 took place in the 1800 MHz band ; and in North America the expansion into digital took place primarily in the 1900 band. (These higher frequencies are besides more suitable for dense urban environments). In the U.S., pressure for more cellular spectrum – virtually in any reasonable frequency range - has been continuous ; and a variety of bands allocated to « advanced wireless services » could well be used for cellular type services.

- International coordination towards some globally common mobile bands worked poorly in practice. When the U.S. choose the 1900 MHz band for PCS, little importance was attached to harmonization with, for instance, Europe or Japan ; the air interface standards in these geographic areas being different anyway. As to 3G / IMT-2000, by the time the U.S. took the matter seriously it was too late for Washington to envisage making available the bands which had been defined at WRC 92.

- Various (still terrestrial) wireless approaches were introduced over the years to satisfy some particular mobility needs ; unless these approaches prove, at some stage, clearly unsuccessful or can be phased out, the associated spectrum is blocked for a long time. *DECT* (Digital European Cordless Telecommunications System) is a good example : it was supposed to meet a vast array of requirements but DECT phones are sold today mainly for use in homes or small offices. The (fairly narrow) DECT band[250] is naturally frozen – at least in Europe – making agreements on new allocations in the critical 2 GHz range more difficult.

* Similarly, special classes of operators were introduced early in the picture, like *SMR's* in the U.S., and they were awarded specific bands. Their services, particularly those of the leading one, *Nextel* , have gradually become for the end-user equivalent to public cellular. Nextel makes use of its nationwide band to compete with *cellular* and *PCS* operators, in American regulatory parlance. It is faced with the same strategic issues : coverage, international roaming, adding WI-FI services….etc.

* To rapidly provide access to some telephone service in very poor areas of the world,

[250] 1880-1900 MHz

wireless with limited mobility has been introduced in countries like India and China, along with appropriate spectrum allocations. But in the marketplace this variant is not easy to distinguish from plain cellular and its enhancement to include (at least regional) roaming is more than likely.

* Finally, the multiplicity of mobile bands is jumping ahead further with the high promise emergence of public WLANs and the rush towards free spectrum by a number of leading established cellular operators, as well as some established fixed operators or other entities. It has become clear in the earlier part of 2003 that such spectrum will be considerably expanded, at least in the U.S. ; and it has indeed acquired formal « mobile » international status at the mid-2003 WRC.

In addition to these genuine mobility factors, mobile devices more and more often have features requiring still other radiocommunication channels. Inter-device proximity communication (like between a PDA and a PC nearby to update some files or between a cellphone and its headset) using *bluetooth*[251] , or positioning via GPS, require separate channels which canot be ignored when addressing the multi-band requirement of a portable wireless device.

IMPACT ON MANUFACTURERS

The infrastructure equipment and mobile phone industries[252] have followed two seemingly contradictory trends :

a. On one hand, they have turned global, much more global of course than the traditional telecom's manufacturers of the sixties or seventies. Their home turf is less and less significant for the big names. Very high levels of outsourcing (mainly in the 1990's) and a shift towards production in Asia have further contributed to this globalization. The PC/IT industry is the model to follow.
b. On the other hand, they keep and even develop the capability to adapt to local and regional conditions : this sounds like an obviousness for any industry. Except that local and regional conditions of mobile markets differ not just in terms of fashion, taste, habits, climate, environmental regulations, basic energy costs and mains voltage, as they would for cars or refrigerators.

[251] *Bluetooth* has been conceived originally to allow exchange of information between devices not further apart than a couple of meters ; thus it allows typically to separate the ear-and-mouthpiece from the cell-phone as such. It is however considered by some as a WLAN technology competing with IEEE 802.11. Formally an ETSI standard, it works in the 2.4 – 2.4835 GHz ISM band.

[252] The infrastructure equipment industry and the mobile phone industry are different, but overlap largely : Motorola is strong on both sides and so are, to a lesser extent, Siemens and Alcatel. Nokia, also present on both sides, is extremely strong in phones. Nortel is on the network side only. Ericsson, strong in infrastructure equipment, has been over the years *in* and *out* of the handset business ; that business is now handled by a joint venture with Sony labeled *SonyEricsson*. Some manufacturers, active in phones only, like Samsung and Panasonic have a strong worldwide presence. And there are a number of smaller phone manufacturers with a national or regional presence only ; we believe that their quantitative significance in global terms is low.

The local and regional markets are here still dependent on unescapable technical specifics : standards[253] and radio frequencies, a couple even more closely tied than common sense would lead to expect[254]. In the few countries having the capability of independent technological policy and decision making, the standard and the frequency were joint conscious choices :

- AMPS and the 800 MHz band in the US
- GSM and the 900 and (later) 1800 MHz bands in Europe
- PDC and the 1500 MHz band in Japan.

Things then opened up in terms of standards in the U.S. But introducing such flexibility is much easier than for frequencies ; though this could change in some future, spectrum still is the solid immutable ground – in a real estate sense - on which facilities can be built, modified and rebuilt.

The vast majority of countries make decisions copying what was done elsewhere i.e. choosing a proven or otherwise reliable « standard – frequency » couple. This is clearly the way GSM spread beyond Europe with its 900 and 1800 MHz bands, except in the Americas ; and it explains why the 800 and 1900 MHz bands largely dominate in Central and South America. Manufacturers – their proposals and their wares – certainly play a role in such decisions ; but we see international relations (not excluding political lobbying) and regional coherence as the dominant influences.

The fact is that the high level of R&D costs and the way products are technically structured, reinforce the « standard-spectrum » couple. Reengineering for 800 MHz dozens of GSM models conceived for 900 and 1800 MHz is a costly venture[255] ! Rengineering a W-CDMA 1.9 / 2.1 GHz base-station to work in the 1.7 / 1.9 GHz bands is a big development! [256] Similarly, in our observation, one finds few (if any) CDMA deployments in these GSM bands ; hence few (if any) CDMA handsets working in the GSM bands.

An additional consideration is that there is virtually no true free market for handsets at the end-user level (as is the case for PC's or Apple compatible computers). The phones are largely bought and sold through operators[257] who subsidize them in conjunction with service contracts ; sometimes they are badged with the operator's name, the brand then no longer appearing. All this further shapes the geographic polarization of the markets. As to the diversity of the models which is huge – in physical and functional characteristics – it has been exploding, relegating the frequencies at which a cellphone works to a « barely worth mentioning » point in a long list of features.

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[253] Mainly but not only air interface standards. GSM for instance includes internal network interfaces and important functions embodied in the *SIM* (subscriber identity module) card.

[254] The air interface standard defines the protocol, the way the signals are transmitted, received and interpreted. Once that complex protocol is defined and exercised by programmed microprocessors, it would seem for example that whether a 1800 or a 1900 MHz frequency is used affects only separate physical components like filters, capacitors, oscillators, antennas….

[255] This is why introducing *GSM 800* into the U.S. and into other countries of the Americas is not an easy matter. There was in 2003 an open controversy within the U.S. industry as to how soon GSM 800 terminals will actually be available in quantity and in what variety.

[256] Statement made at GSM 2003 in Cannes, France (February 2003) by a development manager in charge of UMTS base stations, with one of the large European manufacturers.

[257] Or through distributor networks they control. It is this consideration which has led *DELL* to abandon, in the Fall of 2003, its earlier announced plans to get into the smart phones business.

For a number of years now, the vast majority of the phones sold have been dual-band ; in simplified terms: 900 and 1800 MHz bands in the non-American GSM world ; 800 and 1900 MHz bands on the American continent. In view of the way they see their business, the manufacturers have been slower – or are still lukewarm – towards coming out with multi-band products (meaning beyond standard dual-band). In the US, it seems that the business made with multi-band phones is tiny; we will come back to this assertion. Whereas in Europe, the quantity of tri-band phones (GSM 900,1800,1900[258]) is by no means negligeable ; they are sold typically to customers who want to be able to use them while traveling to the US ; but also more broadly as high-end models basically incorporating the tri-band capability. Going tri-band has become a simplification strategy for some upper level brands.

Tri-band phones are known by the dealers to be substantially more expensive. But it is difficult to assess this difference somewhat precisely because of the variable featuring mentioned.

For the 3G bands – which are mid-2003 a significantly implemented reality only in Japan and in some European countries – the industry, again, did not behave uniformly. The sets offered by DOCOMO are 1.9 / 2.1 GHz compatible and thus work only on FOMA, a WCDMA network which has already a good coverage[259]. As the UMTS deployments in Europe are still quite spotty, GSM back-up is a necessity ; the few UMTS handsets introduced so far acommodate therefore four bands : the two just mentioned plus the traditional GSM 900 / 1800 bands (and this UMTS / GSM duality is planned to remain so for quite some time).
A more delicate question is their usability in the U.S : we understand that the first models did not have the GSM 1900 capability and therefore are useless there[260] ; whereas those models to come on the market in the latter part of 2003 are claimed to have this capability i.e. already five mobile bands[261]. Not mentioning the adaptation of, say WCDMA, to the U.S. specific 3G band (1.7 GHz), band which is, it must be said, unlikely to be deployed before 2008.

The reader by now certainly has a feel for the fragmentation of the cellular industry in terms of markets, technologies, equipment, products and « phasing » (e.g. the still present analog heritage, 2G, 2.5G, 3G….and 4G being increasingly talked about ; mid-2003, a manufacturer has even introduced the notion of 2.75 G !) ; this fragmentation results from a variety of factors among which regulation, spectrum management and spectrum history are probably key. Notwithstanding, though, the high level of concentration affecting that industry : half-a-dozen household names[262] - operating virtually worldwide - presumably control over 90% of the design and production of cellular gear. Particularly striking is Nokia's 37-40% market-share of the over 400 million mobile phones produced annually. To stay ahead of competition, but also to adapt to that fragmented environment, Nokia has eight highly specialized divisions – like *CDMA Technologies* – each with its R&D capability, a central R&D force generating the common socle.

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[258] And quad-band GSM phones (adding the U.S. 800 MHz band) are around the corner

[259] Logically, Japan had little reason to further invest into PDC, a standard – with a unique band combination - it had sold nowhere.

[260] By mid-2003, the only operator having deployed UMTS networks in Europe is « 3 », a company part of the *Hutchison Whampoa* Hong-Kong based conglomerate. Only two phones were available, both from NEC. They do not have the GSM 1900 back-up capability.

[261] These first UMTS models are from Siemens, SonyEricsson and Motorola.

[262] As already referred to : Motorola, Ericsson, Nokia, Siemens, Alcatel, Samsung, Matsushita (i.e. Panasonic)….

The cellular manufacturing industry has made it clear publicly that it is in favour of harmonized spectrum (and naturally to a lesser extent, in favour of harmonized standards). A heterogeneous technical environment is a generator of duplication and higher costs ; it is said to impact potential economies of scale. A major worldwide cell-phone manufacturer has argued publicly in the earlier part of 2002, that if the U.S. selects, for 3G, bands different from the « core bands » chosen by the major part of the world, customers in the U.S. will have access to less product choice, at a higher cost and with delay.

On the other hand, one cannot exclude that a fragmented environment can be in favour of the industry, giving it some additional dimension to play with, reducing in fact competition on pure cost-price terms. If just one standard and just one frequency band would prevail in the world, the disposable phone[263] would probably have made it!

But public mobile terrestrial communications can no longer be equated with « cellular » and the like. The described emergence of WI-FI with its own generous bands has acquired formal worldwide ITU status ; it represents in our view a new « game in town » for the cellular industry. WI-FI is a creation of the PC world[264], which will not prevent it from englobing « pocket » devices like PDA's and basic voice services with smart phones very soon. Granted, important activity was already taking place in convergence areas between cell-phone and PC : operating systems[265], application platforms, image handling and compression, browsers and other software tools for easier Internet access……But on WI-FI, the PC world has logically the high hand, as it has on cable-based LANs (like Ethernet) ; all the more that the cellular manufacturers are busy adding more mundane functions and features to the mobile phones, to oppose the falling price trend ; and enhancing their wares to enable cellular operators to expand the applications they offer in order to increase ARPU. There still is a long way to a broad 3G success and to a decent ROI on the corresponding R&D investments ; not mentioning a decent ROI for operators who made astronomic investments in licences : they will restart substantially ordering equipment to renew or expand their infrastructures once they see proper margins !

Consequently we consider WI-FI to be a true challenge, certainly for the operators as we will discuss, but also for the manufactures. What is at stake is the medium-term corpus of the wireless data opportunity : what paths, what bands will it go ? The widely spelled-out position is that WI-FI on one hand and cellular on the other, in its 2.5G (like GPRS) or 3G versions, are complementary ; but the proof that either one is a good business has not been made. This being said, a significant number of cellular equipment manufacturers have, in the latter part of 2002 or early 2003, announced products (or intentions in view of) physically combining WI-WI and cellular capabilities[266].

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[263] Incorporating xxx hours of calling time

[264] IEEE 802, PC assemblers, Intel and Microsoft essentially.

[265] In terms of operating systems : whereas all major handset manufacturers bet on *Symbian*, Microsft has already announced in 1999 that it will involve itself in smart phones and, for this purpose, scale down its ubiquitous *Windows.*

[266] *FierceWireless,* an Internet information service focusing on WLANs, stated in a release dated Feb. 23rd 2003 : « Handset makers tee up with WI-FI phones : Manufacturers are developing mobile phones that will operate on both WI-FI and traditional cell networks. Motorola plans to introduce a WI-FI capable cell phone by the end of 2004. Nokia….Ericsson and Qualcomm are looking into the WI-FI phone market, but have given no further details ». This news is said to have its source in the *Wall Street Journal.* Similar plans of NEXTEL have also been rumored.

The integrated circuit manufacturers play of course an important role for the mobile phone industry : both the heavyweights[267] and a large number of smaller less known firms are deeply involved. They strive at high level integration of the circuitry, including multi-band, in order to reduce weight, size, power requirement ; and also cost, providing the volumes are high. Dual-band chips (e.g. GSM 900/1800) have been around for some time, but are shrinking further[268] ; quad-band chips are announced (e.g. GSM 800/900/1800/1900). Special efforts will go towards GSM / WCDMA integration, i.e. two quite different protocoles in four bands, within a single tiny module[269] ; but the volumes seem not to be there yet to justify such investments.

As to the WLAN chipsets, they have become a significant business : « Both Intel and Microsoft want to see WLAN included in all new laptops sold, and all indications are that soon it will be » says an April 2003 report[270]. But what is meant with « imbedding » WI-FI into cellphones is still unclear to us; hype and desired strategic positioning probably play their role here. Those active in this area mention power consumption as a major difficulty. Corresponding tri-band - e.g. in the U.S. : 800, 1900 and 2400 MHz – is not too big a technical issue ; but going further into multi-banding (as would be required for roaming to Europe or accommodating additional new cellular bands in the U.S. or the 5 GHz WI-FI band) implies more advanced hence remote technologies, among which software radio is often mentioned. Here are two public statements on this matter by recognized experts :

- Question : « How can a software radio cover a wide frequency range without having a tuned circuit for each frequency band ? »
  Answer by Joe Mitola: « Micromechanical systems (MEMS) can be used to create software reconfigurable capacitors. A little motor pushes teeth together or apart to vary the capacitance ».[271]

- Clark Nguyen : « Radio-frequency (RF) filters still hog a lot of space on the phones' circuit boards. These quartz and ceramic filters grab a specific frequency for your phone calls while blocking all others. They can vary in size, but often measure 2 by 2 centimeters ; and you need several to receive and transmit…….[The filters can be shrunk by using MEMS technology]……It's the IC revolution for mechanical stuff »[272].

Reliable, robust, low-cost MEMS are probably not around the corner.

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[267] It is known that *TI* (Texas Instruments) provides a large share of the *DSP's* (digital signal processors) at the heart of digital mobile phones. For *Intel* and *AMD* (Advanced Micro Devices) cellphones are also an important market segment.

[268] Early 2003, *Skyworks* announced a 13 x 13 mm module, incorporating virtually all GSM/GPRS functions for the two bands. Both silicon and AsGaas technologies are used.

[269] *Baskerville*'s *mobile devices* newsletter dated Sept. 4 2002 states in an article tiled « Operators realism focuses attention on chip and handset vendors » : « ….While Nokia has worked to integrate dual-mode into a single chipset, U.S.-based startup *Zyray Wireless* has chosen a two-chip path ……»

[270] Quoted from an April 4th, 2003 release of *Europemedia*'s World Archive. This release also provides data on number of WLAN chipset sales : 20 Million in 2002, 33 Million expected in 2003, and 94 Million in 2007. These are volumes no longer negligeable compared to worldwide mobile phone sales !

[271] « SDR defines fourth generation » article in *Wireless Europe* magazine, April 2003.

[272] « What's needed for teensy-weensy cell phones » in *Business Week* magazine, dated November 5, 2001. Clark Nguyen is with the University of Michigan.

What could be seen as a contradictory perception, is the announcement early 2002 by an experienced well established company:

> « RF Solutions Inc. today announced it is developing a multi-band, multi-standard RF chipset to support 802.11a, -b and –g for both cellphones and WLANs »[273]
> The company invokes « its flexible transceiver architecture ».

Not to be ignored when aiming at multi-band devices in the portable and « pocket » class, are antenna requirements. Antennas represent an industry sector in itself. They are more and more physically integrated in the device ; they may have to additionally accommodate GPS and bluetooth, which use separate bands not intrinsically part of the mobile world. Suitable antennas with multi-band capabilities are the subject of extensive R&D, often by smaller less known companies. As one of them[274] states :

> « In cellular telecoms the key interest is in combining diversity. More than one radio signal comes in at once and the challenge for phone makers is how to process the signals. Handsets will soon operate at five cellular bands (GSM-800, 900, 1800 and 1900, and round 2.1 GHz for 3G), as well as bluetooth and GPS. I envision one antenna for all the cellular frequencies, with additional antennas for bluetooth and GPS ».

In summary, the increasing multi-band environments mean technical and strategic challenges for various segments of the mobile communications manufacturing industry, as well as added costs. But they also mean diversification in terms of players and an additional track of convergence between the IC, IT, telecommunications and other sectors of the ICT world, like video and broadcasting.

IMPACT ON OPERATORS

As mentioned earlier, in countries of significant size, cellular traffic is to a very large degree local, then regional and somewhat national ; in relative quantitative terms, the international traffic is marginal. This pattern is not fundamentally different for telephone traffic via fixed lines ; but particularly on some – even key – international routes, wireless can really be the poor relation in the overall communication picture[275].

The international traffic – or rather the need to communicate when travelling abroad – has though drawn the cellular operators' attention early on. Whereas international roaming[276] between GSM systems is a basic functional ingredient of their common architecture, heterogeneous roaming – i.e. between systems of quite different types, like between AMPS

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[273] Reported by *ElectronicNews*, an internet information service.

[274] Colin Ribton, systems integration manager at *Antenova*, a UK-based company, quoted in an article titled : « Multiple frequencies call for innovation in antenna design » part of the October 2002 issue of *Wireless Europe* magazine.

[275] *News.com* reported on March 17, 2003 on an *IDC* study which established that : « International calls by U.S. dialers, both landline and cellular, amounted to a $9 billion revenue generation in 2002. The lion's share of the revenue went to landline phone companies… ».

[276] From an operator's point of view, allowing international roaming means allowing his subscriber to place and receive calls when he is abroad and to charge him for such calls on his standard bill. The operator will then cede back to the foreign operator(s) involved a fraction of the generated revenue.

and GSM[277] - has been the subject of « solution searching to a difficult problem » already in the early or mid-nineties.

Even between GSM operators, roaming requires formal agreements (and some minor software and administrative provisions). Interestingly, the GSM Association did not play a role in the establishment of such agreements for voice ; they were negociated and implemented bilaterally like random marriages. In April 2002 though, the GSM Association reported that it was taking things in hand to more quickly allow international GPRS roaming : it recognized that data services should be usable within the international GSM world as easily as voice services ; and therefore the organization became proactive at the level of the corresponding specifications and implementation tools.

Let us through a few more recent examples illustrate further the interest cellular operators have shown in international roaming.

a. Mid 2002, *AT&T Wireless* announced[278] a tidal wave of deals with foreign operators, to allow two-way roaming : it had signed agreements with 41 operators in 35 countries. As the company's CTO said a few months later : « Two years ago, international was not in our business plan…..The tangle of technology and services made it too difficult »[279]. What he referred to, is mainly the fact that the 41 operators are all GSM operators working in the 900 and/or 1800 MHz bands ; whereas AT&T Wireless was migrating its network to GSM indeed, but in the 1900 MHz band. Not only had this operator achieved by then decent GSM coverage in the U.S., but triband phones had become widely available.

b. Even an operator like *Bouygues Telecom* - present only in France where he is the smallest of the three – indicated by year-end 2001 that he had signed roaming agreements with 340 foreign operators in 140 countries[280].

c. The *Global Passport International Service* for CDMA users expands, in April 2002, to Japan –China roaming, after having alreaday been available between the U.S., Canada, Korea, Australia, New-Zealand, and Hong-Kong .

d. Interstandard roaming is also addressed e.g. by the *Global Roaming Forum*. Already early 2001, roaming had been achieved between a European GSM operator and a Korean CDMA operator[281] ; the

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[277] « FINALLY – Roaming relief for the global traveler ». Article published in the Sept. / Oct. 1995 issue of *Cellular &Moblile International*. The focus of the article is on a solution being implemented (by *GTE Telecommunications Services*) for AMPS subscribers travelling to European countries with GSM coverage or vice-versa.

[278] *AT&T Wireless* announcement of August 6, 2002 as reported by *Infoworld*, an Internet based information service.

[279] Rod Nelson at *CTIA Wireless 2003* as reported by *News.com* on March 17. AT&T Wireless claimed at this accasion that it had signed more international roaming agreements than any of its competitors.

[280] This appears in a submission by *Bouygues Telecom* to ART, the French telecom's regulatory body.

[281] *Bouygues Telecom* from France and *KTF* (Korea Telecom Freetel).

roaming subscriber needing though two different phones.

e. *Nextel* has made provisions in 2002 to allow its customers to use, with a single number :
   - IDEN phones in the U.S.
   - GSM phones in a number of countries abroad[282].

   It furthermore, in 2003, made available to « frequent business travellers » a dual-mode phone[283].

f. In January 2003, *Lucent* and *T-Mobile* launched a pilot project (in the U.S.) towards allowing roaming between 3G cellular and WI-FI WLANs.

g. In April 2003, five leading Asian mobile operators teamed up to form the *Asian Mobility Alliance*[284].

When queried, cellular operators do not present their interest in international roaming as motivated by the directly resulting business. Beyond their executives' common sense, it is the image on the marketplace and the competitive edge factor which are more often invoked. Irrespectively of possible technical incompatibilities (bands and/or standards), administration of international roaming obviously implies costs and particularly transaction costs, as several operators may be involved in a single call. The absorption of these costs, in reasonable business terms, is in our view hampered by a « chicken and egg » problem : the charges are very high and the relevant traffic is very low. The matter of these high charges is complex and not in the scope of this study[285] ; but it cannot be ignored because it heavily pollutes the examination of any other factor which may impede the development of international wireless traffic.

Whereas there is a strong likelihood that the mentioned charging problems will be made up for in the short or medium term, the spectral landscape – the basic status of the bands – is much more immutable : the cellular operators each have specific bands available in specific regions and this pattern changes very slowly, ifever; the transactions and mergers taking place from time to time between them, particularly in the U.S., affect more the business-geography, the coverage and the competitive graph than the amount or nature of the frequencies available. There are though current policy trends which start introducing some flexibilty on this front and which we will mention later.

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[282] When travelling abroad, the subscriber takes his SIM card out of the IDEN phone and puts it into the GSM phone.

[283] The *i2000 plus* is designed to enjoy *Nextel's Worldwide Service* in over 90 countries. We assume that it is a triband device acommodating, in addition to Nextel's specific 800 MHz band, GSM 900 and GSM 1800.

[284] These operators are from Malaysia, the Philippines, Australia, Singapoore and Hong-Kong.

[285] The problem of the high charges for international wireless calls is addressed by several bodies, among which the *European Commission* and *INTUG* (International Telecom's Users Group) ; the latter is dominated by large multinational corporations. In a letter to the FCC dated Apil 18, 2002, INTUG focuses on the exorbitant amounts charged to U.S. parties calling, from a fixed line, cellular subscribers based abroad. Referring to a study by *Arbinet*, calling a cellular subscriber in the Netherlands is about 13 times more costly then calling a fixed line subscriber there (for the same duration) ; this factor is 9 for Germany, 8 for Australia, close to 5 for Japan. INTUG has shown that normal competitive mechanisms do not exist in this context to press the prices down.

In this context of stability of the 2G spectrum, the fact that GSM is being deployed in (part of) the Americas, and particularly in the U.S., in bands different from those used elsewhere is a « pain in the neck » for the European operators and it will continue to be so for a long time. They have improved over the last years in the way they communicate on this with their customers (and with the distribution channels). But they still seem to stand firm on the inappropriate principle that « the subscriber should not have to bother with technicalities like coverage, frequencies and standards » meaning that he should really not understand anything; indeed, as each cell-phone model has a different man-machine interface, as the exploding panoply of services requires familiarity with numerous additional procedures and as charging (hence the bill) is not easy to understand[286], that subscriber has enough to deal with! Typically, the European operator's website will have a unique page dedicated to the « American Continent which uses special standards » with a link to the long list of triband phone models[287] and another link to a cell-phone hiring company[288].

Several operators in the Far East have started early, on the steps of DOCOMO[289], to deploy networks in the new 3G bands [290](not to be confused with migration to so-called « 3G » services within the existing 2G bands, as takes place in the U.S.). Market success has been uneven but overall honorable, showing evidence for the image application markets, whether fixed « postcard », or moving « video ». In Europe, by mid-2003, 3G i.e. UMTS network openings were still sporadic though imminent in a number of countries. Whereas the new available 3G spectrum constitutes a great relief, WCDMA deployment is expensive and some operators are considering an interim step known as EDGE, providing the end-user with data rates better than GPRS and still in the existing GSM bands.

For such 3G networks, in Europe and to some extent in the Far East, GSM back-up is the rule ; the applicable phones hence provide extensive worldwide roaming capability in addition to the 3G services where there is 3G coverage. We have earlier described more specifically the question of the GSM 1900 back-up. Clearly, the band heterogeneity effect gets amplified with the new generation : probably not a significant business impact for the operators, but at least a potential embarrassment if the – high-end by nature – UMTS phones could not work in America.

We have in another section addressed the « WI-FI » phenomenon, which has really emerged on the developed world's markets only recently, say in 2002 and 2003. Broadly speaking, we are talking here about spotty high speed wireless internet access via WLANs working in the 2.4 and 5 GHz bands. Their « mobile » dimension – formalized at WRC 2003 – leads us to examine whether for the established operators this is an opportunity or a threat.

Whereas one could, in theory, have envisaged a frontal opposition between the cellular business most often based on expensive and exclusive licensing on one hand, and this more PC driven, unconstrained emerging WLAN industry exploiting free unlicensed spectrum, this

[286] With new charging « formulas » often proposed.
[287] In May 2003, Orange lists 26 models of GSM triband phones, from seven manufacturers.
[288] The European operator's « American Continent » webpage may mention frequency bands, but typically calls GSM 1900 a « different standard ». It may also refer to *iDEN / Nextel* and its specific 800 MHz band.
[289] In Japan, *Docomo* opened its *FOMA* network and services in October 2001 ; *J-Phone* followed in December 2002. In Korea, *LG, SK Telekom and KTF* have opened 3G services ; but it is unclear if that is within the bands they were granted in their 3G licences.
[290] As indicated earlier, this is in FDD mode, within the basic 1.9 and 2.1 GHz UMTS bands.

is not what is really occurring, as we see it mid-2003. The cellular world takes a pragmatic view and undertakes a lot of action to occupy this new terrain rather than opposing it. Through its fairly long experience in mobile, it holds several winning cards to confront the newcomers :

(a) Making a sound business with « mobile » WLAN access assumes a large number of hotspots physically and logically interconnected, the type of network cellular knows how to conceive, build and operate.

(b) Business justified hotspots are at busy places where cellular base-stations are likely to be already installed, with a useful high-speed link to a backbone.

(c) Roaming, authentication (e.g. with phone SIM cards) and billing for WI-FI can directly draw on the cellular operator's experience.

(d) Mobile populations employed by the corporate world have been targeted and served by cellular operators for years ; they are expected to constitute the most profitable segment of the WI-FI business. And spectrum-wise, there is better worldwide alignment than with cellular.

In the eyes of most of the the cellular industry, hotspots are « complementary » to the more advanced services offered today and to the 3G services to come. Some real world observations support this view :

1. *Ericsson*, the leader in cellular infrastructure equipment and solutions, is helping its naturally favoured class of customers, the mobile operators, to position themselves in the mobile WLAN business. It has designed a *Mobile Operator WLAN System* for which it won contracts at least in China, in Japan and in Denmark. Ericsson does not exclude though, providing such systems to fixed operators who want to venture into this mobile high-speed access busines.

2. The three French cellular operators are each planning a WI-FI deployment in many cities around the country[291]. (A total of 6000 hotspots should be in place by 2007). Their originality is to allow inter-operator roaming so that a subscriber to operator A can use a hotspot from operator B or C, if he happens to be at a place where A has no coverge. This arrangement will probably discourage other sizable entities from seriously entering this business in France.

As an industry executive says : « It will never be the size of our 2G or 3G operations, but it is a training ground for customers who will ask for wide-area data services »[292]. We see though a flaw in this logic applied to the European cellular operators : investing substantially in WLANs, now that 3G has already suffered so much delay and will still require more investments, can only be viewed as a stopgap solution justified by the lack of real 3G readiness, in terms of technology, products, services or market maturity. This logic would better apply to the U.S., where there will be no 3G spectrum granted before several years.

[291] One of them in cooperation with a Swiss WI-FI operator.
[292] Per Dordlof, from Ericsson, according to a Yahoo ! June 12 2003 release titled : « Ericsson sees WLAN boosting demand for cell phones ».

Furthermore, for the operators providing over time coherent cellular / WI-FI solutions in the above mentioned spirit, will be difficult with the number of bands involved (not mentioning the multiplicity of standards). Here again, the increasing number of mobile bands, will generate inconveniencies, particularly for the occasional intercontinental traveller, as well as for the globetrotter. A totally integrated voice/data, really mobile solution, taking advantage of the above, may be far away.

CONCLUSION

The previous chapters widely support, in our view, the following conclusions :

1. The number of frequency bands used around the world for mobile communications is on the increase. This increase takes place not just globally, but also within the major geographic areas leading the way : the U.S., Europe, key countries in the Far-East, Latin America, and probably Russia.

2. There are four major reasons to the increase in the number of mobile bands :

    a. Old bands – like the original analog cellular bands – will remain largely used for mobile communications systems.

    b. The growth in cellular traffic procedes in many countries, generating pressures for additional capacity which, in practice, means more spectrum ; this is particularly so in the U.S. As virtually all spectrum is allocated, extra bands are found – with difficulty – only in ranges not contiguous with the current bands.

    c. For the next generation of cellular, so-called 3G, new bands have been identified and then recommended, largely through a lengthy ITU driven process. But no worldwide agreement could be reached on a minimal scheme (like a common pair of bands for operation in FDD mode). Thus an array of new and old cellular bands qualify now formally as *3G bands*.

    d. A powerful PC-based nomadic communications concept emerged years after 3G was conceived : WLANs deployed in traditionally unlicensed bands at hotspots, logically interconnected, thus enabling public WI-FI. These bands are increasingly seen as *mobile bands.*

3. With the increase in the number of bands – not mentioning the various air interface standards (often called *technologies*) which will use them – the mobile communications scene is becoming more complex for all stakeholders, but mainly for the end-user : in his home country when he subscribes to and uses services ; and even more so when he travels to other countries or continents. His vision of a small, reasonably expensive cellphone on which he

can virtually anywhere place and receive calls – providing suitable administrative provisions are in place – will remain a dream.

4. Bands and air-interface standards are not independent. A government which, as a policy, wants to be *technology neutral*, still has the responsibility of specifying the bands which will be granted (through auctions or whatever other procedure) to mobile operators. In fact, by selecting bands this government is likely, consciously or unconsciously, to favour some standard (e.g. NA-TDMA, GSM) or exclude some others (e.g. CDMA). Technological neutrality is best achieved through harmonized bands ; otherwise the advocates of technology A will fight for band (a) and the advocates of technology B for band (b)[293] : and this battle takes place at the government or national regulatory agency level ; in practice mostly in the restaurants nearby ! If technology competition is the goal[294], it is clearly better to leave the choice of the technology to the operators instead of the regulator.

As the world has not agreed on a minimal set of « core bands » for 3G, this problem of « false technological neutrality » will prevail for many years, in face of the multiple standards encompassed by IMT-2000 ; among which CDMA2000 and WCDMA in their priviledged bands.

5. The total span of bands used, to be used or considered for terrestrial mobile communications is not huge : they are located approximately between 400 MHz and 6 GHz. Granted, frequencies behave differently if they are in different ranges of this span, especially in terms of propagation. However, the actual selection, by the regulators, of the bands for various systems in various countries results essentially from the accidents of history, and much less from true technical considerations ; and each operator positions himself in geographic, operational and marketing terms by using the spectrum he has. As to the WI-FI bands (2.4 and 5 GHz), they are not far off the 3G bands (ranging from 1.7 to 2.6 GHz) ; what makes them different is regulation : being normally unlicensed, they are unprotected and only low-power, hence low-reach signals may be transmitted in them.

Could this artificial, regulatory borderline between on one hand cellular, including 3G (licensed often at high cost) and on the other hand public WI-FI (unlicensed[295], essentially free of charge) become vulnerable some day ?

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[293] It is wrong to assume that, for example, GSM 1900 is a different *technology* from GSM 1800. This is just the GSM technology deployed in two different bands which are, in technological terms, quite equivalent. On the other hand, converting dozens of mobile models designed for GSM 1800 to GSM 1900 is a costly proposition.

[294] A goal probably not shared by the majority of nations, as far as public mobile communications are concerned.

[295] J.Manner in her book « Spectrum Wars » already mentioned, makes a detailed comparaison between licensed and unlicensed spectrum usage. We do not see though, how the factors mentioned, could allow to establish a government policy for mobile communications in this respect : what is really at stake is low power signals with very short reach hence spotty coverage and many base stations, against high power signals with much wider reach.

6. At a global scale, for the first decade of the 21st century and probably beyond, the most harmonized piece of mobile spectrum …consists of the ISM bands, now qualifying as mobile ! Their harmonization seems to us to be again more accidental than resulting from a planned, coordinated, multilateral ITU process.

460 million cellphones are expected to be sold in 2003 (and the volumes achieved in 2001 and 2002 are only slightly lower). Beyond this number, though driven essentially by voice, it is the vast combinatorial variety of incorporated features and functions which is most striking. And beyond these features and functions – expanding that universe again – there are even more services offered by the operator networks to which the cellphone owners subscribe ; such services being increasingly offered in conjunction with third parties like information providers. To access these features, functions and services inherent to his *personal* device, the subscriber makes use of appropriate instructions and procedures.

All this is often heavily affected, when roaming abroad leads to being connected to another operator's network. It would have been proper, in the user's view, that he would not have to worry in addition about frequency bands ! Even if only a small fraction of the cellular subscribers population is concerned – 1.1 billion year-end 2002, 1.8 billion expected by 2007[296] - some common worlwide « core-bands » would have meant convenience for at least millions of suscribers and would have avoided many more missed calls. In our belief, it will become increasingly apparent during this decade, that the world telecommunications community has – in total silence - failed to meet a simple objective which was clearly on ITU's table and well understood by all its members already some fifteen years ago !

With the concentration and international consolidation taking place in the cellular service industry[297], the « seamless roaming » requirement will receive more and more attention. ; e.g. by organizations like Vodafone or Orange, both present in many countries ; or by *AMI*, an association of operators in the Far East[298]. As mentioned earlier, large U.S. operators have been closing many international roaming agreements[299], mainly in the GSM sphere. The fact is that, concerning the frequency and standard aspects, the corresponding marketing announcements are often non-informative and even misleading.

It appears to us that commercial solutions to extensive multi-band requirements (2G + 3G+ WI-FI + Bluetooth + GPS ; across continents) rely on rather advanced technologies (like software radio and MEMS) and are therefore years away. Architectures separating multi-band RF circuitry from the circuitry executing the air interface standard would help ; and so would frequency-agile and standard-agile base-stations (unlikely to be justified in many places, considering the low proportion of international roamers). Efforts towards multi-band

[296] Figures out of Ericsson's annual report for 2002.
[297] « The 20 largest operators now serve 75% of the subscribers » says Ericsson in its annual report for 2002.
[298] The *Asian Mobility Initiative*, created in April 2003, associates operators from Australia, the Philippines, Singapoore, Malaysia and Hong Kong.
[299] According to NewsCom dated March 17, 2003, AT&T close « a slew of new agreements with wireless carriers in about 100 different countries ». Nextel is making efforts in the same direction, though it has its own frequency band and standard, both different from GSM's.

technologies should therefore be redoubled, not only by the concerned industry sectors but also within academia and publicly funded research.

ACRONYMS

ACTS	*Advanced Communications Technologies and Services* A European Commission driven research project
AMPS	*Advanced Mobile Phone System* The original U.S. (analog) cellular standard defined by the FCC
ANFR	*Agence Nationale des Fréquences* French authority in charge of spectrum management
ARIB	Japanese *Association of Radio Industries and Businesses*
ART	*Autorité de Régulation des Télécommunications* French regulatory body in charge of telecommunications
ARPU	*Average Revenue Per User* A business measurement commonly used in the cellular industry (per user meaning per end-user or per subscriber)
CCSA	*Canadian Communications Standards Association*
CDG	*CDMA Development Group* Industry association consisting of cellular operators and manufacturers exploiting the CDMA technology – Led by Qualcomm
CDMA	*Code Division Multiple Access* A technology (to share access to spectrum) based on *spread spectrum* technology and largely developed in the U.S. by Qualcomm – Has led to a leading family of cellular (and WLL) standards
CEPT	*Conférence Européenne des Postes et Télécommunications* Organization of over 44 European states to coordinate telecommunications and postal matters
CITEL	*Inter-American Telecommunications Commission* An entity of the OAS (*Organization of the American States*)
CTIA	*Cellular Telecommunications Industry Association* (renamed *Cellular Telecommunications and Internet Association*) - Consists essentially of the U.S. cellular operators and manufacturers
DAB	*Digital Audio Broadcasting*

D-AMPS	*Digital AMPS* Evolution of the analog AMPS standard
DCS	*Digital Communications System* Now largely obsolete designation of GSM 1800 i.e. GSM in the 1800 MHz band
DECT	*Digital European Cordless Telephone* An ETSI standard for short-haul radiotelephony (and Data transmission) with specific spectrum allocation in Europe
DFS	*Dynamic Frequency Selection* A technique to improve spectrum sharing e.g. in the WLAN context
DTI	*Department of Trade and Industry* in the UK Responsible for spectrum auctions
DVB	*Digital Video Broadcasting*
EDGE	*Enhanced Data Rates for GSM Evolution* An alternative to GPRS, allowing much higher data rates
ETSI	*European Telecommunications Standards Institute*
ERO	*European Radiocommunications Office*
EU	*European Union*
FRAMES	*Future Radio Multiple Access Schemes* A European Commission driven research project
FCC	*Federal Communications Commission* in the U.S.
FDD	*Frequency Division Duplexing* A basic way of transmitting information in both directions
GSM	*Global System for Mobiles* A (digital) cellular standard of European origin
GHz	*Gigahertz* i.e. a measurement of radiofrequency (1 GHz = 1000 MHz)
GPRS	*General Packet Radio Service* A GSM enhancement aiming at faster transmission of data
GAO	*General Accounting Office* in the U.S.

HIPERLAN	*High Performance Radio Local Access Network* An ETSI standard
HDTV	*High Definition Television*
HSCSD	*High Speed Circuit-Switched Data* Refers to GSM's capability to offer quasi-transparent bit-transport pipes
IC industry	*Integrated Circuits* i.e. advanced components industry
iDEN	*Integrated Digital Enhancement Network* The radio technology used primarily by Nextel
IEEE	*Institute of Electrical and Electronic Engineers* A U.S. based association particularly active in producing standards
IMT-2000	*International Mobile Telecommunications* for the years after 2000 – A third generation ITU driven project including frequency bands and standards
ISM	*Industrial, Scientific and Medical* Refers to specific bands dedicated to such applications
IT or ICT	*Information Technology* or *Information and Communications Technologies*
JPEG	*Joint Photography Experts Group* JPEG 2000 designates a compression standard for fixed color images
LEO	*Low Earth Orbit* In the present context, refers to communications satellite constellations
MMDS	*Multichannel Multipoint Dostribution System* Orginally used for pay-TV applications, it also provides two-way high bandwidth communications for stationary use
MPEG	*Moving Picture Experts Group* A family of compression standards
MEMS	*Microelectromechanical Systems* More or less a domain of the nanotechnologies
MSA	*Metropolitan Statistical Areas* A division of geographic territories used in the U.S. for the original granting of cellular licences and

	spectrum
MMS	*Multi-media Messaging Service* A capability part of UMTS and other 3G systems
NTIA	*National Telecommunications and Information Agency* Reports to the U.S. Department of Commerce and, among other missions, advises the President.
NMT	*Nordic Mobile Telephone* – An analog cellular standard
NTT	*Nippon Telegraph and Telephone Corporation* Ex-Japanese PTT
NA-TDMA	*North American TDMA* A digital cellular standard
OCDE	*Organization for Economic Cooperation and Development*
OFCOM	UK's *Office of Communications* Recently established structure to regulate communications As such, will replace Oftel and RA
OFTEL	*Office of Telecommunications* British reguling authority in charge of telecommunications
PDA	*Personal Digital Assistant*
PCS	*Personal Communications Services* Refers essentially to the second (and digital) generation of cellular in the U.S., in a new spectrum band
PAS	*Personal Access System* Chinese version of PHS
PHS	*Personal Handyphone System* A simplified, low function version of cellular voice, with small coverage areas, conceived by Japan and very developed there – Now becoming obsolete
PDC	*Personal Digital Cellular* A Japanese cellular standard
PTS	*Post och Telestyrelsen* Swedish authority in charge of telecommiunications regulation and spectrum management

PTT	*Post, Telegraph and Telephone* Refers to government entities which were traditionally, In many countries, running telecommunications (on a monopoly basis) and managing spectrum
RR's	ITU's *Radio Regulations*
RA	UK's *Radiocommunications Agency*
RACE	*Research and Development in Advanced Communications for Europe* An EU driven project
RSA	*Rural Statistical Area* A division of geographic territories used in the U.S. to originally grant cellular licences and spectrum
RLAN	*Radio Local Area Network*
SDR	*Software Defined Radio* A technology providing flexibility at the transmitting or receiving end
SIM	*Subscriber Identity Module* Originally introduced by GSM, the SIM card stores the information specific to the subscriber – Technically it is a chip-card or smart-card
SMR	*Specialized Mobile Radio* SMR operators represent in the U.S. regulatory terminology a special category, separate from cellular or PCS, originally aiming at specific business sectors
SMS	*Short Message Service* Originally a GSM capability – But the designation is now also used in other cellular contexts
TACS	*Total Access Communications System* An analog cellular standard based on AMPS, originally implemented in the UK
TDD	*Time Division Multiplexing* A way of transmitting information in both directions in a single band or channel
TDMA	*Time Division Multiple Access* A technology to share access to spectrum and used in a a Variety of cellular standards

TD-SCDMA	*Time-Division Synchronous CDMA* A 3G standard developed by China with European (and other) industry assistance
TIA	U.S. *Telecommunications Industry Association*
UMTS	*Universal Mobile Telecommunications System* An ETSI driven 3G standard
UTRA	*Universal Terrestrial Radio Access* A set of air-interface specifications belonging to UMTS
UWC	*Universal Wireless Communications* UWC-136 is a variation of GSM/EDGE
WAP	*Wireless Application Protocol* A GSM Internet access capability via GPRS
W-CDMA (or WCDMA)	*Wideband CDMA* Major air-interface standard underlying UMTS
Wi-Fi (or WI-FI)	*Wireless Fidelity* A common designation of a hotspot architecture implementing one of the IEEE 802.11 standards
WLAN	*Wireless Local Area Network* Alternate designation of *RLAN*
WLL	*Wireless Local Loop* Fixed radio access for telephony or data
WRC (or WARC)	*World Radiocommunications Conference* or *World Administrative Radiocommunications Conference* Meetings organized by ITU every three or four years in order to revise or enhance the RR's
1G, 2G, 3G, 4G	*First, Second, Third or Fourth Generation* of cellular or, more broadly, of mobile communications
3GPP	*Third-Generation Partnership Project* A collaboration agreement between several telecommunications standardization bodies

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