Wireless Networks for the Developing World: The Regulation and Use of License-Exempt Radio Bands in Africa

by

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Abstract

As radio technologies and public policies evolve, an increasing amount of spectrum is being set aside for transmission use without a license. These license-exempt, or "unlicensed" bands, include 2.4 GHz and 5 GHz in the USA and much of Europe. I argue that this unlicensed spectrum, and low-cost wireless technologies that operate in these bands, is of particular value in the developing world, where it has the potential to substantially impact accessibility and availability of information and telecommunication services. In the context of numerous institutional and structural obstacles to entry license-exempt regulation potentially provides a friendly environment for entrepreneurship, reducing barriers to entry and the risk of regulatory capture.

In order to assess this opportunity in the context of Africa, I have surveyed every country in the continent on their regulations and use of the 2.4 and 5 GHz bands. Responses, from differing country informants though mostly from the regulators themselves, were received from 47 of the 54 countries of Africa, which accounts for 95% of the continent's population.

The responses show that there is significant diversity and heterogeneity in the regulation of these bands across Africa. Not only do licensing requirements and specific conditions change widely from country to country, but so do power, range and services restrictions, as well as certification requirements. In addition, regulation is still not in place in some countries, and is changing in others. Enforcement is low, adding to overall uncertainty.

Lack of clarity in regulation and enforcement creates confusion and may discourage smaller players from entering the market. For bigger players interested in taking advantage of economies of scale and implementing common strategies across borders, the heterogeneous regulatory environment will also act as a deterrent and a barrier to entry.

Despite this heterogeneity, these bands are being used in most African countries, not only for "hotspot" style or other localized coverage in urban areas, but also for longer area coverage. A significant 37% of the countries that responded are using wireless technologies operating in these bands for providing backhaul network connectivity in rural areas. In unlicensed bands regulation tends to place a burden on the transmitter though, e.g. through power restrictions, in particular where competition in the market is low.

In view of the continent's weak teledensity and lack of alternative infrastructure, establishing a more certain and uniform regulatory framework and promoting an appropriate business climate across Africa may be instrumental in encouraging private investment and connectivity through technology in these bands. The ITU may have a key role to play, both by issuing clearer guidelines for the regulation of license-exempt bands, and by serving as a convening forum for countries to establish common regulatory strategies. While a fair balance is needed in regulation, this thesis argues that governments should err on the side of laxity in order to lower barriers to entry and counterbalance current overregulation of these bands.

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List of Acronyms

3G	– 3^{rd} generation [cellular system]
ADPCM	– Adaptive Differential Pulse Code Modulation
AP	– Access Point
AT&T	– American Telephone and Telegraph
BDT	– Bureau Development Telecommunications
BS	– Base Station
BWA	– Broadband Wireless Access
CCK	– Complimentary Code Keying
CEPT	– European Conference of Postal and Telecommunications
COUHES	– Committee On the Use of Humans as Experimental Subjects
CSMA	– Carrier Sensing Multiple Access
CSMA/CA	– CSMA/ Collision Avoidance
CSMA/CD	– CSMA/ Collision Detection
DAI	– Digital Access Index
DARPA	– Defense Advanced Research Projects Agency
DBS	– Direct Broadcasting Satellites
DCF	– Distributed Coordination Function
DCS	– Dynamic Channel Selection
DECT	– Digital Enhanced Cordless Telecommunications
DFS	– Dynamic Frequency Selection
DS	– Direct Sequence
DSSS	– Direct Sequence Spread Spectrum
EAP	– Extensible Authentication Protocol
EIRP	– Effective Isotropic Radiated Power
ETSI	– European Telecommunications Standards Institute
ERC	– European Radiocommunications Committee
FCC	– Federal Communications Commission
FH	– Frequency Hoping
FIPS	– Federal Information Processing Standards
GDP	– Gross Domestic Product
GHz	– Giga Hertz
GIS	– Geographical Information Systems
GITR	– Global Information Technology Report
GMSK	– Gaussian Minimum Shift Keying
HIPERLAN	– High Performance Radio Local Area Network
ICT	– Information and Communications Technology
IEEE	– Institute of Electrical and Electronics Engineers
IETF	– Internet Engineering Task Force
IMT-2000	– International Mobile Telecommunications-2000
IP	– Internet Protocol
IR	– InfraRed
ISM	– Industrial, Scientific and Medical
ISP	– Internet Service Provider
ITU	– International Telecommunications Union
ITU-D	– ITU's Development Sector
LAN	– Local Area Network
LgD	– Long Distance

MAC – Medium Access Control
MAN – Metropolitan Area Networks
MANET – Mobile Ad-hoc NETworks
Mbps – Megabits per second
MHz – Mega Hertz
MIT – Massachusetts Institute of Technology
MNC – MultiNational Corporation
MoWLAN – Mobile over WLAN
MT – Mobile Terminal
NoI – Notice of Inquiry
NPRM – Notice of Proposed Rule Making
OFDM – Orthogonal Frequency Division Multiplexing
OFDMA – Orthogonal Frequency Division Multiple Access
PAN – Personal Area Networks
PCS – Personal Communications Services
PDA – Personal Digital Assistant
PHY – Physical Layer
POTS – Plain Old Telephone Service
PTT – Public Telecommunications Operator
QoS – Quality of Service
RA – UK Radiocommunications Agency
RLAN – Radio Local Area Network
RF – Radio Frequency
SIP – Session Initiated Protocol
SPTF – Spectrum Policy Task Force
TPC – Transmit Power Control
UK – United Kingdom
UMTS – Universal Mobile Telecommunications Services
UN – United Nations
U-NII – Unlicensed National Information Infrastructure
URL – Uniform Resource Locator
USA or US – United States of America
USD – United States Dollars
UWB – Ultra Wide Band
VoIP – Voice over IP
WARC – World Administrative Radio Conference
WAS – Wireless Access Systems
W-CLECs – Wireless Competitive Local Exchange Carriers
WECA – Wireless Ethernet Compatibility Alliance
WEP – Wireless Equivalent Privacy
WiFi – Wireless Fidelity
WiMAX – Worldwide Interoperability for Microwave Access Forum
Wireless HUMAN – Wireless High speed Unlicensed Metropolitan Area Network
WiSIP – WiFi Session Initiated Protocol
W-ISPs – Wireless Internet Service Providers
WLAN – Wireless Local Area Network
WMAN – Wireless Metropolitan Area Network
WRC – World Radio Conference
WSIS – World Summit on the Information Society
WTO – World Trade Organization

1. Introduction

This chapter starts by introducing the topic of this thesis, and summarizing its main findings. It then explains the motivation for this work, by briefly running through recent trends in license-exempt bands regulation, the need for sustainability and the role of entrepreneurship and community involvement in the developing world. It further discusses the institutional context in which firms operate and the importance of Information and Communications Technologies (ICTs) for development. The chapter then lays down the context for this work by discussing some background areas: spectrum management and regulation, telecommunications policy and sector reforms and universal service issues. The chapter finishes by laying out the structure for the rest of the thesis.

1.1 Summary

Spectrum Management is an area that has been under growing attention and debate in the last few years. Traditionally spectrum management has been largely based in a somewhat static approach, with allocations determined by the International Telecommunications Union (ITU), and national governments and telecommunication regulators responsible for spectrum assignment, monitoring and enforcement (Nunno 2002). In general, spectrum has been attributed on an exclusive basis, through a licensing regime. More recently several countries are shifting towards different models, introducing market-based management approaches such as auctions, spectrum pricing or trading, and exploring decentralized structures or de-regulatory solutions, such as the use of unlicensed bands[1], band managers or general authorizations (Cave 2002).

In parallel, the changing nature of technology has brought improvements in interference management techniques: the so-called ‘smart’ and ‘polite’ technologies, with more ‘adaptable’ devices (Gast 2002), having the potential to change in a significant manner the co-existence of different technologies in the frequency and spatial domains. These technical changes necessarily pose questions as to the appropriateness of the current regulatory models - adopted to deal with yesterday’s technology – when dealing with more ‘intelligent’ devices. In particular, these changes in technology are bringing about new spectrum management models, with growing use of license-exempt bands, and in particular the use of WLAN technologies.

[1] In this thesis I use interchangeably the term ‘Unlicensed’ and ‘License-exempt’ bands.

This thesis looks at these new trends in regulation and technology from the perspective of the developing world. Unlicensed spectrum and low-cost radio technologies that operate in these bands can be of particular value in that context, where they have the potential to substantially impact accessibility and availability of information and telecommunication services. In particular, decentralized bottom-up solutions, simple enough to be maintained and expanded by locals with limited technology experience, can be more appropriate to the financial and political reality of these countries. In the context of numerous institutional and structural obstacles to entry - as is the case in the developing world - license-exempt regulation potentially provides a friendly environment for entrepreneurship, reducing barriers to entry and the risk of regulatory capture.

This thesis contributes to this area by studying the general outlook of the regulation and use of unlicensed bands, specifically the bands 2.4 and 5GHz, in Africa. Since very little information is available on what is happening in Africa in this area, this thesis collects data by means of a survey distributed to all African countries and reports its results. Furthermore, it also studies whether there is any correlation between the regulation in these bands and general country indicators of competitiveness for the Information and Communication Technologies (ICT) sector.

Responses, from differing country informants though mostly from the regulators themselves, were received from 47 of the 54 countries of Africa, which accounts for 95% of the continent's population. The responses, show that there is significant diversity and heterogeneity in the regulation of these bands across Africa. Results point to general uncertainty and confusion associated with the regulatory regimes of the 2.4 and 5GHz bands across Africa. Lack of clarity in regulation and enforcement may discourage smaller players, who do not have the time or the resources to deal these, to enter the market. In addition to the confusion inside the country, there is also significant heterogeneity among countries. For bigger players interested in taking advantage of economies of scale, implementing common strategies across borders, the heterogeneous regulatory environment will also act as a deterrent and a barrier to entry.

Despite this heterogeneity, these bands are being used in most African countries. The main users are ISPs, followed by Telecom operators. There are reports of the advantages of using these bands, such as low cost of existing infrastructure, and reduced fees and barriers to entry. I find that the most common use of these bands is for "hotspot" style or other localized coverage in urban areas. Nonetheless, a significant 37% of the countries that responded are using wireless technologies operating in these bands for providing backhaul network connectivity in rural areas.

In unlicensed bands regulation tends to place a burden on the transmitter tough, e.g. through power restrictions. Laxer licensing regimes place, on average, more restrictive conditions on power and range. Information about licensing will not, on its own, properly characterize the possible uses of these bands, i.e.: the fact that a band is unlicensed does not necessarily mean that access or use are easier, since regulation can be accompanied by specific restrictions for use.

I further find that GDP per capita and teledensity do not correlate strongly with the type of licensing regime in place. I do find, however, that generally countries that have lower competition in their local and long distance markets impose more restrictions on use, in particular on power and range. Restrictions may be being used to control market power and keep barriers to entry high.

In view of the continent's weak teledensity and lack of alternative infrastructure, establishing a more certain and uniform regulatory framework and promoting an appropriate business climate across Africa may be instrumental in encouraging private investment and connectivity through technology in these bands. This thesis discusses how the ITU may have a key role to play in this matter. Additionally, governments should strive to establish an appropriate business climate by lowering barriers to entry, ensuring certainty, and when possible providing access to capital. This could be done for example by implementing targeted, flexible and accessible Universal Service Funding Policies applicable to alternative technologies, such as the ones operating in license-exempt bands.

The appropriate balance between barriers to entry and the well functioning of the bands should set the level of restrictions to impose, bearing in mind that, currently, there is a tendency to over regulate and keep barriers to entry high. Considering that spectrum is a renewable resource, the purpose of the regulation should not be to eliminate all interference, but to maximize output. For Africa, with its weak teledensity position, a higher use of the bands - in particular in rural areas - may translate into significant differential advantages, by going from no service to 'some' service. In addition, due to low usage of telecommunication services, congestion of the bands is less likely. This thesis argues that this justifies erring on the side of laxity, when defining regulation for these bands.

1.2 Motivation

The motivation for this thesis lies in the interception of different areas: the use of license-exempt bands, the need for sustainability, the role of entrepreneurship, and the institutional context in the developing world. The next sections discuss these areas and the relevance of the ultimate goal of enabling ICT access in Africa.

1.2.1 The use of license-exempt bands

This section discusses some of the technical, commercial and regulatory issues linked to license-exempt regulation. It further looks at the recent uptake in devices operated in these bands, and its relevance for the developing world - although there are some initial reports of projects using wireless technology operating in these bands, little information is known as to its regulation and use in that context.

Regulation of spectrum management and licensing procedures came about by necessity. In the US, and until the 1930's anyone possessing radio equipment could broadcast its signal over the air. Experience showed that reliable communications were not assured, since interference resulted any time several transmitters operated in near proximity. Sales and usage of radio systems lowered considerably (Carter et al. 2003). The solution found was to specify different frequency bands, and attribute responsibility for band allocation to a regulator or national governing authority[2].

There are nevertheless certain technologies and situations in which license-exempt spectrum can be used. That is the case, for example, when emissions are limited in range (e.g., microwave ovens). Or when appropriate techniques are used - embedded interference management techniques (some devices can now detect other users, wait before they transmit or use power control) or spread spectrum transmission. These enable coexistence of several users in the same band in the same place, without necessarily causing insurmountable interference. Chapter 2 contains a more detailed description of these types of technologies.

Technically, spectrum usage is potentially optimized by the use of unlicensed spectrum. By not restricting spectrum usage to a single 'owner', it makes use, in the space dimension, of 'idle' locations, or in the time dimension, of the periods where other transmitters are silent. There are nevertheless limits to the number of users in a band, and there is also some degradation of the quality of service associated with shared use. For that reason the authorization for use of unlicensed bands is sometimes accompanied by some limitations in transmitted power and/or in transmission environment (e.g. limitation to indoor

[2] In the US that regulator is the Federal Communications Committee (FCC).

environments only)[3]. All in all unlicensed bands are increasingly popular, and are experiencing unprecedented growth (Carter et al. 2003).

Commercially, this type of regulation facilitates market-entry and gives incentives for localized, entrepreneurship-type solutions to develop. If operation is on an 'interference sufferance basis'[4], users of unlicensed devices to not have to go through the hassle or the delays of applying for a license (causing shorter development cycles), and generally (although not necessarily) spectrum use is free of charge, bringing down deployment costs. These bands have proven to be attractive, having spawned a variety of new applications. The recent explosion of WiFi hotspots in coffee shops and private homes is a good illustration of such success.

From a regulatory standpoint not requiring operators to obtain a license removes barriers to entry and reduces the risk of regulatory capture. Indeed, governments and regulators sometimes favor the incumbent operators and their interests, either explicitly or implicitly. There is some risk, for example, that licensing processes suffer delays, or that licenses are denied to smaller players (see Section 1.2.3 for more details). Not requiring a license eases the burden on operators and protects smaller firms shielding them from the incumbent's interests. This comes, however, at the cost of lower guarantees for quality of service, and a reduced support for dispute resolution, since in general regulators are not required to control or ensure any quality of service requirements for unlicensed spectrum.

Today, millions of unlicensed devices are already in operation, driven by rapid advances in technology, entrepreneurship, and policy liberalization. The demand for unlicensed bands is growing in some countries, and some regulators have recognized that need. In the US the FCC's Spectrum Policy Task Force, formed in June 2002, recognized that 'unlicensed devices have gained a foothold as an important use for spectrum', and that additional unlicensed spectrum seems to be needed (Carter et al. 2003). Also in the UK, the recent Spectrum Management Review conducted by Professor Martin Cave recognized the need for additional unlicensed spectrum (Cave 2002).

Meanwhile, and in the context of the developing world, the low costs, widespread availability and ease of installation make these technologies extremely attractive. There are various advocates for the use of WLAN-type technologies - and in particular the 2.4GHz band - in the developing world context, and there

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[3] i.e., there are no guarantees and no protection from interference. In the US these limitations are defined in Part 15 regulations.

[4] I.e., there are no guarantees, from the regulator, of non-interference, or of quality of service.

are several small companies and projects deploying network projects, mostly at a local scale. Some examples of projects, companies and communities working in this area can be found in Table 1.1.

Table 1.1 – Some examples of projects companies and communities using WLAN-type technologies in the developing world

Type	Name	Country	URL
Pilots/Projects	ITU Pilot Projects: Wireless IP for Rural Connectivity	Uganda, Brazil, Yemen, Bulgaria, Sri Lanka	http://www.itu.int/ITU-D/fg7/
	SARI	India	http://edevelopment.media.mit.edu/SARI/
	BushMail	Africa	http://www.bushmail.co.za/index.php
	Chini Tu	Kenya	http://openict.net/projects/chini-tu/wiki/view/AxKit/DefaultPage
	Wireless Roadshows	Various	http://www.informal.org.uk/wirelessroadshow/
Companies	First Mile Solutions/DakNet	Various	http://www.daknet.net/
	Locust World community and mesh network projects	Various	http://www.locustworld.com/, http://www.muniwireless.com/archives/000201.html
Online community/resources	Africa WiFi	-	http://wifi.tu5ex.org/index.php
	Wire.less.dk	-	http://wire.less.dk/?en.0.0
	Open ICT.net/Wireless Long Haul	-	http://openict.net/projects/wireless-longhaul/wiki/view/AxKit/DefaultPage

These projects use mostly technology operating in the 2.4GHz band – and sometimes also in the 5GHz bands. Although there are other frequency bands allocated as ‘unlicensed spectrum’, this thesis concentrates on the 2.4 and 5GHz bands, because these are the most widely used. More precisely, this thesis concentrates in the following bands:

- 2.4 – 2.4835 GHz
- 5.15 - 5.35 GHz; 5.47 - 5.725 GHz and 5.725 - 5.875 GHz

The regulation in these bands varies widely from country to country. Countries have some leeway in defining the regulations to apply in their respective countries, and different solutions have been adopted. More details are given in Section 1.3.2. In addition, some of the technology used in these bands is relatively new, and regulation and use are changing.

Despite the potential of these technologies, there is very limited information about the regulation of these bands around the world. Little is known for example - and in particular in Africa - about which countries require a license for operation, or under which conditions and limitations (use, range, etc) is unlicensed use allowed. There is no information either about the use of the bands – are they being used, or do they largely remain idle?

In 2003 the ITU introduced a new question about the policy for licensing WLAN in its annual survey to regulators[5] The information asked is however very general and responses are limited and incomplete, in particular in the context of Africa[6]. The US State Department has also recently collected information about the use of WLAN. The information is however confidential (Lamb 2003).

In addition, literature in this field is limited, in particular documentation on recommendations and guidelines for regulation for the specific context of the developing world. The New America Foundation has recently published some material about spectrum and unlicensed use, but the content is directed mostly at the US (Snider 2003, Snider et al. 2004). The Global Internet Policy Initiative (GIPI) has issued a short document describing policies in four countries around the world (GIPI 2002). Recently (in June 2003) the Wireless Opportunity Initiative, jointly with the UN ICT task Force has organized a conference on this topic - The Wireless Opportunity for Developing countries (W2i et al. 2003). Michael Best has also recently written about the subject (Best 2003).

All in all, this seems to be an area full of potential, where very little has yet been done.

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[5] In the 2003 the ITU has asked regulators: 'Is there a policy for licensing Wireless LAN (e.g. WiFi 802.11)? If Yes, explain', from World Telecommunication Regulatory Database.

[6] ITU World Telecommunication Regulatory database, based on responses to 2003 regulatory survey, obtained from Nancy Sundberg, ITU.

1.2.2 Sustainability and Entrepreneurship

One of the motivations for looking at wireless technologies and unlicensed spectrum regulation is that the low-cost technologies that operate in these bands can potentially enable sustainable connectivity solutions. Indeed, one of the main challenges in ensuring global connectivity is intimately related to sustainability. Philanthropy may have a role to play, but only market based initiatives can ensure sustainability and continuity; subsidized programs that do not have a business strategy in place run the risk of disappearing with the end of the subsidy (Nettesheim et al. 2002). The problem is especially acute in rural areas.

The World Bank distinguishes between a 'market efficiency gap', and an 'access gap' (World Bank 2002b). The market efficiency gap refers to 'the difference between the current level of service penetration and the level achievable in a liberalized market, under a stable regulatory environment'. These reforms are discussed in Section 1.3.3. The access gap is arguably harder to close, and denotes those situations where 'a gap between urban and rural areas continues to exist even under efficient market conditions, since a proportion of the population (relatively large in developing countries), cannot afford the market prices at which the service is offered'[7].

Even in developed countries rural areas are often covered through cross-subsidization (i.e., using revenues from more profitable locations, such as urban areas). In the developing world context, because of recurrent market and political failures - low availability of capital, and low access and representation for low-income communities (Best et al. 2002) – providing access is even more difficult. To complicate issues the marginal cost per line is much higher where subscriber lines need to be widely spread-out, such as in much of sub-Saharan Africa, or where communities are fairly remote (World Bank 1997)[8].

Closing the access gap is therefore, in great part, an issue of:

i) finding technological solutions with lower prices, and

ii) finding the sustainable business models appropriate for the developing world context (World Bank 1997)[9].

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[7] This is intimately linked with poverty – i.e., people not having the money to pay for the services, or, equivalently, to situations where price is below cost.

[8] In some countries costs are also high because of import substitution. Import substitution is a trade and economic policy based on the premise that a developing country should attempt to substitute products which it imports (mostly finished goods) with locally produced substitutes. This usually involved high tariff barriers to protect local industries and hence import substitution policies. Often, it has the practical effect of suppressing competition in the market, and therefore raising costs and prices (Wikipedia website).

[9] In parallel, solutions proposed today for rural areas are principally community solutions, as opposed to individual access solutions.

It has been suggested that it will be difficult to solve the connectivity problem solely through the expensive and centralized solutions proposed by existing telecommunications companies. Wired networks are suited mostly for deployment in large-scale centralized networks. The entire network must be planned in advance, and built in a top-down fashion, which is highly capital intensive. Instead one can think of using lower-cost, decentralized wireless technologies, more appropriate to the financial and political reality of these countries – such as the ones deployable on the license-exempt bands.

Sustainability in telecommunication projects can potentially be achieved through large companies and even multinational corporations (MNCs). Alternatively, and especially if this simpler type of technologies is used, sustainability can also potentially be achieved by using small entrepreneurial models. Indeed, technology in these bands is simple enough to be maintained and expanded by locals with limited technology experience. 'Setting up a few central wireless stations could allow companies to purchase their own wireless equipment, and effectively own their part of the infrastructure as well as client-equipment […] ensuring maintenance of the system' (ICT4dev 2004).

Entrepreneurship and grassroots bottom-up approaches to development are becoming more important in this context (Krag 2003, Prahalad et al. 2002, Prahalad et al. 2002b), and some entrepreneurs have expressed their views that technology entrepreneurship can be the driving force for economic change in their country (Parker 2002). Literature also refers to entrepreneurs as those who drive forward technological and economic innovation (Moore 2002).

From a social and political standpoint the existence of smaller players can also be seen as a vehicle for the democratization of technology. Indeed these players, closer to the community, have a better feel of what it needs, and can help it provide that for itself. This comes along the same lines as municipal broadband projects, where a community decides to organize and provide itself the broadband service. Apart from having a potential impact on the access to the telecommunications infrastructure, this also redistributes and helps disperse power within the country, allowing small entrepreneurs to sell the service and potentially earn a living (Qadir 2003).

The idea of a bottom up economy for the telecommunications market, taken one step further, brings the possibility of a different kind of networks.

As Michael Best suggests:

> "One basic approach looks something like this: small entrepreneurs provide Internet and voice services within their own communities by purchasing inexpensive basic radio equipment and transmitting on unlicensed frequencies. Collections of these local operators, collaborating (and interconnecting) with larger Internet and basic service operators, begin to weave together a patchwork of universal access where little or no telecommunications services existed before. This access patchwork would be cheap, robust, and extremely responsive to innovation.
> […]
>
> Each mini-telecommunications operator could provide services within its local community just by purchasing the basic radio equipment and transmitting on these unlicensed frequencies. The model is inexpensive, responsive to local needs and realities, can grow organically and is fully scalable. In addition, most of these technologies enable broadband access. As the number of local providers increases, so does the overall capacity of the network. Each new operator increases the number of pathways between any two points.
>
> Nicholas Negroponte of the Massachusetts Institute of Technology calls this the "lily pad and the frog" effect. Each local entrepreneur builds a lily pad of wireless network connectivity. Other entrepreneurs in surrounding communities are doing the same thing. Eventually, the "lily pads" of network connectivity grow closer and closer, and some even overlap. Sooner or later, the "pond" is going to be completely covered by connectivity. Telecommunications users--the frogs--will then jump from network to network. This "lily pad" model is made increasingly possible by ongoing research into mesh networks, in which equipment may be simultaneously an end-user terminal and a router for data traveling to other subscribers, creating a fluid, decentralized and constantly evolving network." (Best 2003 p.107; p.112).

It should be noted, however, that the use of entrepreneurial and smaller scale models is not limited to rural connectivity, and can also be used in urban areas. In this context entrepreneurs can enhance access by provide alternative infrastructure.

In order for sustainable solutions to flourish in this area the right investment and institutional climate need to be present. With this respect, it is important to establish an attractive and welcoming environment for investment – be it for larger or smaller players. Removing barriers to entry, facilitating business set up, and providing access to capital can maximize the chances of success and enhanced connectivity.

In parallel, establishing the right regulatory environment is also essential. In particular, the use of unlicensed bands can be particularly appropriate for small entrepreneurs. Indeed, applying for a license can be costly and time consuming, and small players may lack the status and the resources to smoothly navigate through the process[10]. Apart from the practical difficulties in the process of obtaining a license, and when compared to larger more established players, small entrepreneurs may stand a lower chance of earning a license.

[10] Smaller players may fro example lack the sufficient legal expertise, or the financial guarantees to apply for a license.

1.2.3 Institutions and the developing world context

This thesis argues that unlicensed regulation may be well adapted and present an opportunity in the institutional context of the developing world, by lowering barriers to entry and shielding new entrants from regulatory capture. Indeed, there are many difficulties associated with running a business in emergent markets. The low availability of capital or the lack of trained human resources is one of them, but not less important are the difficulties of dealing with the local environment and local partners and, in addition, dealing with regulation and government agencies - for example when applying for a license. In some cases entrepreneurs need a lot of perseverance, and sometimes luck (Maddy 2000).

Companies often encounter inefficiency, corruption, and in the case of regulation, capture. As Iqbal Quadir, thr founder of GraemenPhone puts it: 'The bottle neck is at the top of the bottle'(Qadir 2002). 'Setting up GraemenPhone, in particular, took nearly 5 years. In many countries it takes months to incorporate a new company and years to get a cellular license. Government bureaucracies resist entrepreneurial activities that may redistribute power, and vested interests protect private and public monopolies and quasi monopolies. There are systemic obstacles and barriers to entry' (Qadir 2003).

It follows that some of the most difficult barriers to overcome are not technological, cultural, or even inherently economic, but rather have to do with a lack of government policies (both national and trans-national) (Moore 2002). Often countries are impoverished in the first place because their governments have historically been unable to adopt beneficial policies.

Indeed, there are examples of technological developments that have only been successful because of the lack of government participation. Such is the case of the development of the internet, which was, to start with a non-regulated technology. Iqbal Qadir interprets the internet growth in this light:

> 'The speed of proliferation caught governments by surprise and they had no laws in place to stop private initiatives. In most countries they found their initial footholds due to unprepared regulatory environments, although they were later regulated. […] Ignorance led them to underestimate the potential impact of ICTs and they let these technologies slip out of their hands. This is exemplified by the fact that fixed telephone services are monopolies in 121 countries of 184 (67 percent) and Internet services are monopolistic in only 13 countries out of 97 (13 percent)' (Qadir 2002, p.82).

Another example is the case of cellular technology - which potential was not at first understood - or the case of the Indian technology sector, of which some experts say it has developed as rapidly and as broadly as it has because the Indian government did not have a minister in charge of it (Parker 2002).

In fact, entrepreneurs may represent a threat to existing governments, and as James Moore puts it ‘developing countries are not usually open fields waiting for planting’ (Moore 2003). According to him longstanding economic ecosystems are in place, with members of the government often linked to natural resources or foreign aid. They often perceive that their positions in society depend to a great extent on the continuation of these links.

The telecom sector in particular is often the major monopoly business in many developing countries, contributing with high sums to the state budget. In many developing countries telecommunication operators are either state owned or only partially privatized (Noll, 1999).

Digital entrepreneurs can be a direct threat to telecom companies, because of their technological and organizational capacity to work around bigger companies – be they monopolies, or established companies (in the case of liberalized markets). When rule of law is weak, however, licenses are sometimes withheld, or interconnection with the monopoly telecommunication company disrupted[11]. James Moore gives an example in Ghana, where ‘under the prior regime, a business leader was jailed and had his equipment destroyed, ostensibly because of immigration violations but—it is widely believed—because he provided too much potential competition to a rival better connected to the government’ (Moore 2003).

1.2.4 ICT’s relevance for Development

This section addresses the question of whether we should care about bringing connectivity to the developing world. There is in some circles great optimism about the impact of ICT in economic development. On the other hand some (including leaders in the high-tech industry (NYTimes 2000)), argue that in the context of Africa, where extreme poverty reigns, there are other more urgent priorities such as food, health care, water, sanitation or education. It is needless to say that hunger and disease are bigger problems than internet access, but strategies have to be diverse and to act in different fields.

[11] It should be noted that interconnection is also a problem in other developed countries, such as the US or the UK.

There is also skepticism on the efficiency of ICT projects around the world to enhance development. It is much easier to measure the usage of computers in telecenters or the utilization of community phones than to determine the impact of ICT on development and wealth. A lot has been written about this issue (Jensen et al. 2003, Blattman et al. 2002, Hanna 2003, UNDP 2001, Eggleston et al. 2002, Moore 2002). Policymakers in developing countries, facing the difficult challenge of setting priorities and finding the right balance in allocating often extremely scarce resources, need information on the contribution and cost-effectiveness of different strategies to development.

Currently there is neither a solid theoretical basis nor convincing empirical evidence to support huge optimism (Eggleston et al. 2002). There is, however, indication that ICTs have helped in a number of circumstances. Internet and digital communication technologies offer new means of addressing critical issues facing developing countries. From the user point of view, it gives him 'the ability to communicate with relatives or call a doctor but, much more critically, gives the capacity to coordinate development activities, pursue scientific study, conduct business, operate markets, and participate more fully in the international community'(Pitroda 2003). Non-governmental organizations in Africa are using the internet in the fight against AIDS, to improve government transparency, and as a means of leveling the economic playing field for small and medium-sized enterprises (Tactical website). ICT can also help in education (Hawkins 2002) and in making markets work more effectively, by ensuring information circulates (Eggleston et al. 2002). In general, ICT is one of the building blocks for what some call 'business ecosystems'[12].

All in all, perhaps one of the strongest arguments for the importance of ICT is the demand of basic communication services (Blattman 2002), and the willingness to pay for these services. In rural India, for example, it is estimated that 5-6% of GDP per capita is spent on communications related services. In addition, and according to a recent report on a ICT project in Tamil Nadu, each 1% increase in per-capita income has resulted in a 1.4% increase in communications related expenditures among rural households' (Pentland 2002).

In the context of growing digital divides between the developed and the developing world, discussing and finding appropriate strategies and policies may be instrumental in generating more efficient and effective communications systems, and achieve a higher penetration of telecommunication services. Indeed, although no technology-centric approach can on its own solve problems like those often discussed under terms like 'digital divide', universal service', or 'rural connectivity', fair distribution of connectivity and access to communication are without a doubt an important precondition for development.

[12] The idea is that like individual plants or animals individual businesses cannot thrive alone – they must develop in clusters or economic ecosystems. See (Moore 2003).

1.3 Background

This section provides a brief description and a summary of the related work in some relevant areas to the problem at hand. This description helps set the scene for the analysis that follows.

1.3.1 Spectrum Management

The management of spectrum has undergone significant changes in recent years, introducing more market based mechanisms and shifting, in some areas, to a more deregulated approach, of which the use of license-exempt regulation is an example. The appropriate models for spectrum management have been the subject of heated debates. This section gives some background in this respect.

Electromagnetic radiation has been defined as ‘a form of oscillating electrical and magnetic energy capable of traversing space without benefit of physical interconnection’, and the rate of oscillation is its frequency. Of the whole range of frequencies which together constitute the electromagnetic spectrum, only the portion going from 10KHz to 3,000GHz is classified as the radio spectrum (Harvey 1971). The radio spectrum is a natural resource and it is limited. In addition electromagnetic interference is such that if two users transmit in the same place, at the same time, in the same frequency, and with sufficient power, they will interfere with each other[13].

In the US, and until the 1930’s anyone possessing radio equipment could broadcast its signal over the air. Experience showed that reliable communications were not assured, since interference resulted any time several transmitters operated in near proximity. This market failure caused the sector to go into crisis (Carter et al. 2003). Given the scarce nature of spectrum, and a growing number of users, governments and international organizations such as the ITU[14] have taken in their hands the responsibility to manage spectrum, in order to ensure its best utilization.

Spectrum has been divided into different bands (ensuring enough separation and guard bands), and allocated to different services (so as to control e.g. the type of power and modulation). The ITU’s Radiocommunication Sector (ITU-R) maintains a Table of Frequency Allocations which identifies spectrum bands for about 40 categories of wireless services with the goal of avoiding interference among

[13] This is true in particular for narrow band traditional technologies.
[14] Spectrum management cannot be performed on a national basis only, since coordination is needed at borders and in the bands used for high range communications, e.g. satellite communications. In addition, global coordination of spectrum allocation ensures the same bands are used for the same services in different locations, which facilitates economies of scale for equipment.

those services (Nunno 2002). Once the broad categories are established, each country may allocate spectrum for various services within its own borders in compliance with ITU's Table of Frequency Allocations. National regulators are also in charge of assigning spectrum to particular users, for example through the use of licenses[15].

Spectrum allocation at international level is a heavy and bureaucratic process, partly due to the organizational structure of the ITU and the need for coordination and agreement at national, regional, and international level. The ITU – a specialized branch of the United Nations – is the oldest intergovernmental/multilateral regime in the world (Drake 2000) and works mostly on a consensus base (ITU RR website). This means decisions are often the possible compromise between different positions, and do not always reflect a consistent set of policies. Despite following a national sovereignty principle, (which means that states retain absolute sovereign control over their telecommunications systems and ultimately have the responsibility to define national regulations), the ITU Radio Regulations have the force of a treaty obligation between nations[16].

Spectrum is generally considered to be a scarce resource, and therefore limited in supply. The fact that very few market mechanisms are embedded in the allocation and assignment process can however explain some of the inefficiencies in the use of spectrum. For example, there are bands allocated for applications that are hardly used. Users of obsolete technologies generally have little incentive to give the spectrum back for re-allocation. Martin Cave and others have argued that more market mechanisms should be introduced in spectrum management, to ensure that it is used efficiently, and by who values it the most[17] (Cave 2002). Some mechanisms are already in place around the world, and the tendency is to have an increasingly market-based management. Examples of market based mechanisms include licensing fees, the use of auctions, spectrum pricing, and also the introduction of trading rights (Bauer 2002, Hazlett 1998, Kwerel et al. 2002)[18].

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[15] A specific example may be helpful: In 2000 the ITU has identified some bands (1885-2025 MHz and 2110-2200MHz) as the initial bands for IMT-2000 deployment. IMT-2000 is a family of standards for 3rd generation (3G) cellular systems. Europeans have chosen UMTS as the particular standard to be used in these bands. Individual countries have further attributed licenses assigned spectrum to particular operators, such as Vodafone, or T-Mobile, for example, in the UK.

[16] Apart from the Radio Regulations the ITU also issues recommendations and reports, technical studies, etc.

[17] One may argue that there may be some societal or military uses for which the states should give sufficient resources, but Cave defends that the system needs to include that explicitly (e.g. by government paying the fees), in such a way that the incentive structure for efficiency is maintained.

[18] In the US, for example, the Federal Communication Commission (FCC) has, since 1994, managed to transfer several billion USD annually to the federal government by auctioning licences to operate wireless networks for Personal Communications Services (PCS) and Direct Broadcasting Satellites (DBS) (Arnbak 1997).

In parallel, technology has evolved and enabled more advanced interference management techniques: from the so-called 'smart' and 'polite' technologies (mechanisms embedded, for example, in WLAN standards) to more radical technologies such as Ultra Wide Band (UWB)[19] These technologies enable ways of controlling interference, even when there are several users using the same frequency in the same place. Because of these evolutions, and the need to decentralize spectrum management, there are an increasing number of advocates for deregulation of spectrum management (Cave 2002) and the extablishment of license-exempt bands. Both in the UK and in the US regulators have decided to allocate more spectrum for unlicensed use.

On a yet more radical note there is also a movement – the Open Spectrum Movement – which advocates that spectrum should be treated as a 'commons' as opposed to the property rights model in place today – i.e., that there is no need for licenses at all. According to this movement "although the current shortage of radio spectrum is usually attributed to the scarcity of spectrum, it is due to the inefficiency of legacy radio technologies and old systems of spectrum management" (Ikeda 2003, Benkler 2002, David Reed webpage). It further argues that 'market-oriented' allocation of exclusive rights to spectrum, is harmful because the spectrum is not a property, and that new packet radio technologies enable efficient communications by sharing a wide band without licenses.

Given all of the above perspectives, spectrum management systems have been the subject of heated debates. Just recently, in 2002 the FCC has undergone a substantial review, under the auspice of the Spectrum Policy Task Force (SPTF) (FCC 2002b). Some have characterized the Task Force final report as a 'sweeping overhaul of spectrum management that would overturn 90-year assumptions about scarcity and interference issues' (Lynch 2002). The Task Force report proposes a mix of tradable spectrum rights and a commons-based approach. The commons approach is not, however, as radical as the one advocated by the Open Spectrum group, and it generally refers to the use of unlicensed bands or to concept of having, under certain conditions, licensed and unlicensed users sharing some of the same bands[20].

1.3.2 Regulation of 2.4 and 5GHz bands

This thesis studies the use and regulation of license-exempt bands, and in particular it concentrates on the following bands:

- 2.4 – 2.4835 GHz
- 5.15 - 5.35 GHz; 5.47 - 5.725 GHz and 5.725 - 5.875 GHz

[19] For more information see (UWB WG website).
[20] This concept is known as the 'interference temperature concept' For more information see (FCC 2003).

This section reviews the regulation of these bands by the ITU, the US and Europe. The applicable regulation changes from country to country, and is in some instances not clear.

The bands 2.4-2.5 GHz and 5.725-5.875 GHz have been designated by the ITU for industrial, scientific and medical (ISM) applications. This is done to assist with containing interference to radio communications from ISM devices (Atheros 2003).

ISM devices are non-radio communications devices that use radiofrequency energy for such purposes as heating, drying or welding. The most common ISM device in the 2.4 GHz band is the domestic microwave oven. Some of this energy will leak out of the device - in effect, it is an unintended radiator of radiofrequency energy - and could cause interference to radio communications. ISM-designated bands are also allocated for various radio communication services, on the basis that radio equipment operating in these bands must accept any harmful interference caused by ISM applications.

This international regulatory approach to supporting ISM applications has led indirectly to the widespread use of ISM-designated bands for non-critical short-range communications, and new types of short-range applications continue to appear in such bands. Outside these bands, ie, for most of the radio spectrum, regulatory regimes arguably place much more stringent requirements on unintended radiators.

In the past, most of the 5 GHz band has been used on a primary basis by radio determination and the earth exploration satellite and space research services; and on a secondary basis, by radiolocation as well as the amateur and amateur-satellite services. Recent technological developments made successful sharing possible between the existing allocated services and Wireless Access Systems (WAS) [21] These developments have prompted the allocation, in the recent World Radio Conference (WRC) 2003, of the 5.15-5.35 and 5.47-5.725 GHz bands for mobile service use for the implementation of wireless access systems (WAS), including radio local area networks[22].

These bands are regulated in many different ways in various countries.

[21] Spectrum sharing between the radars and WAS at 5 GHz can be accomplished by employing dynamic frequency selection (DFS). For more information on DFS see Chapter 2.

[22] For more information on conditions of use see ITU Recommendation R M.1450, which defines the needed characteristics for broadband radio local area networks (RLANs). See also (ITU 2003) and http://www.itu.int/ITU-R/study-groups/was/itu/.

In the US, section 15.247 of the FCC Rules and Regulations deals with license –exempt use within the 2400-2483.5 MHz, and 5725-5850 MHz bands[23], which are regulated on a no-interference, no-protection basis: indeed, the 2400-2500 MHz and 5725-5875 MHz bands are designated in the US for Industrial, Scientific and Medical (ISM) applications. Radio communications services operating in these bands must accept harmful interference from these applications.

The FCC has additionally provided access for Unlicensed National Information Infrastructure (U-NII) devices to operate in the bands 5150-5250 MHz, 5250-5350 MHz and 5725-5825 MHz. Once again, these devices can use this bands 'at their own risk' – i.e., there are no guarantees of protection from intereference. The use of these bands is unlicensed, and non-exclusive (i.e., several users can use the bands at the same time). Section 15.407 of the FCC Rules and Regulations sets out the general technical requirements for U-NII devices[24].

In Europe, the European Conference of Postal and Telecommunications (CEPT) administrations make recommendations to the European Union member states regarding spectrum management issues. CEPT/ERC Recommendation Rec 70-03 (ERC 2003) describes the spectrum management arrangements for 'Short Range Devices' relating to allocated frequency bands, maximum power levels, channel spacing and duty cycle. For short range devices, individual licenses for users are not normally required. However, for particular applications individual licenses may be required in some countries. The recommendation points to a number of standards.

The body coordinating telecommunications standards for the countries of Europe is the European Telecommunications Standards Institute (ETSI). ETSI recommends equipment standards and frequency band arrangements. It is, however, up to individual countries to implement the frequency band licensing arrangements and adopt the standards developed by ETSI as each sees fit. This means that while ETSI material represents a consensus of a European-wide view it does not necessarily represent the arrangements found in individual countries.

[23] It used to requires frequency hopping and direct sequence spread spectrum modulation. In a Second Report and Order of the FCC adopted 16 May 2002, the FCC made some significant changes to section 15.247. It modified the existing rules to allow the use of non-spread spectrum devices under this section, and removed a number of existing conditions on the use of both frequency hopping and direct sequence spread spectrum devices. The changes appear to be a necessary precursor to the support of devices using OFDM modulation. Regulations accessible at http://www.access.gpo.gov/nara/cfr/waisidx_00/47cfr15_00.html.

[24] The FCC rules do not stipulate any modulation schemes, channeling arrangements, operating protocols or any other specifications for co-existence or interoperation between U-NII devices.

The band 2400-2500 MHz is also designated for ISM applications across Europe. CEPT/ERC Recommendation Rec 70-03 makes recommendations for the characteristics of the low power spread spectrum devices operating in the 2.4 GHz band. It further includes arrangements for WLAN devices in the band 5150-5350 MHz and 5470-5725 MHz.[25] The same recommendation includes arrangements for the band 5725-5825 MHz[26].

Specifically for the 2.4 GHz Band the radiated power limits stipulated in the ERC recommendation are significantly lower than the limits set down in FCC 15.247. The use of these bands in Europe is therefore more restrictive than what it is in the US.

1.3.3 Telecommunications Policy, market structure and sector reforms

Section 1.2.3 has discussed the institutional context in the developing world, and how it can potentially serve as an obstacle and source of difficulties for telecommunications operators, in particular to new entrants. This thesis finds that there is some burden placed on regulation in the particular instances where competition in the market is low. These factors are intimately related to the forces at play in the telecommunications industry and its history in terms of market structure and sector reforms.

Historically the Telecommunication Industry has been organized as a monopoly. This has been justified by i) large fixed costs, and the argument that a single enterprise would be able to provide services at lower cost that two or more companies (i.e. the natural monopoly argument); ii) network externalities justifying the organization of the telecommunications sector on a national basis; iii) the necessity of cross-subsidies to finance telecommunications access in, e.g. rural or low user density areas; iv) strategic or security concerns determining the sector should be reserved to particular enterprise often controlled by the state. In the presence of a monopoly, government control was needed to keep the volume, quality and price of services at a welfare maximizing level, as well as to promote efficiency and innovation – since monopolies have reduced incentives to do this.

However, monopolistic arrangements proved disappointing. Problems included low efficiency, high prices and regulatory capture (i.e. non-independent regulators), especially in state-owned companies - the government often lacked technical skills and dependence on short term political considerations was detrimental. Arguments for a natural monopoly also proved to be weak (Geradin et al. 2003).

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[25] Devices should conform to the standard EN 300 836 for High Performance Radio Local Area Network (HIPERLAN) type 1 devices. IEEE 802.11a devices are not directly supported under this standard. More information on these standards can be found in Appendix II.

[26] These arrangements support use by Road Transport and Traffic Telematics devices conforming with the standard EN 300 674 and Non Specific use devices.

In many countries the Telecommunication Industry has now been privatized and liberalized. Increasingly, internal and external forces are pushing governments away from direct control of the telecommunications industry towards market-based mechanisms (Beardsley et al. 2002). Additionally the removal of monopoly rights is now also required in the framework of the World Trade Organization (WTO) and the Reference Paper on Telecommunications (Bronckers et al. 1997, Fredebeul-Krein et al. 1999).

Literature shows that reforms and introduction of competition in the Telecommunication markets have significant impact on performance (Geradin et al. 2003, Pitroda 1993). In particular, countries that have reformed the telecommunications sector have achieved a significantly higher Internet penetration than their economic peers. This still holds even after adjusting for GDP (McKinsey 2002).

In many countries, however, liberalizing the markets and ensuring a level playing field has proven to be a significant challenge, and existing monopolies or their legacy still represent a significant barrier to entry. Sector reform typically entails significant changes in ownership, cost levels, and prices of multiple services, and is a difficult task. Regard needs to be taken for the interests of the different stakeholders. The understanding of the key trade-offs explicitly and in advance of reforms, and of the obstacles that will necessarily be faced through the process are key (Mc Kinsey 2002).

Even in a liberalized context, regulation is still needed. In fact, the market structure has to be modified to promote and maintain competition (e.g. removing artificial barriers to entry), and the incumbent will still control price and quality in segments such as the local loop. It is necessary to severe the links between the incumbent and political and regulatory authorities, ensure a level playing field, and that new entrants can obtain access to incumbent's network (through interconnection or other). Additionally, regulation may be needed to ensure non discriminatory access to scarce resources such as spectrum. Indeed for example in a licensed environment, incumbents may have significant advantages in the process of obtaining a license.

Reforms are particularly needed in developing countries where, traditionally, Telecommunication companies used to serve elites (Noll 1999). Some of the monopoly companies in these countries continue to maintain prices high to exploit those elites. Revenues from Telecommunications companies are often seen as a source of taxes or revenues to be used in other parts of the government, and were operated 'as a large cash cow'[27]. Additionally, companies were especially inefficient and with high numbers of employees. Levels of corruption are also high.

[27] Fiscal and monetary reforms in developing countries can sometime complicate reform of the Telecommunication sector. Nationalized telecom firms are the source of substantial net cash flows for the government, especially if not properly maintained and expanded. Reformers are likely to seek ways to make the fiscal impact of

1.3.4 Universal Service

Universal Service is a concept that refers to the objective of providing telecommunications access universally – i.e., to everybody. Some governments have explicit funds to achieve this objective. Unlicensed bands can potentially be used for provision of rural connectivity and Universal Service. If appropriate policies and are in place, these funding mechanisms can be used for the deployment of this type of technologies.

It was AT&T president Theodore Vail that probably first used the term in 1907 to refer to 'the company's goal of achieving an integrated centrally-controlled telephone network' (Riordan 2002) but this term has gained a different meaning today, and it generally refers to the challenge of extending the network in such a manner that the entire population is served. According to the World Bank the term Universal Service is a term 'traditionally used in the industrialized world to refer to the policy objective of providing telephone service to all households, regardless of their location and income level' (World Bank 1997).

One of the arguments for universal service is that access telecommunications is a basic human right. The moral basis of this claim is that the telephone is now a necessity rather than a luxury and that therefore all should have access to it (Sawhney 1994). A lot has been written about the history, goals and appropriate levels for Universal Service (i.e., what should constitute an 'essential services package'? What is the right level required?) (Crandall et al. 2000, Gillett 2000, Garnham 1997, Compaine et al. 2001, Youtie et al. 2002).

Nicholas Garnham, for example, believes the debate on universal service is largely based on myth and a dangerous misunderstanding of history and argues that the concept of universal service 'was dreamt up by Theodore Vail as part of a deal with the state and federal governments to maintain AT&T's monopoly, […] and it was always more rhetoric than reality'. He argues AT&T never provided geographical universality of access and that the growth of telephone penetration rates followed a normal demand driven curve. He notes European PTTs have not even resorted to the rhetoric of universal service, and in general the provision of telephony lagged behind demand (Garnham 1997).

For the purpose of this section I am mostly interested in the different funding mechanisms utilized, since cost is the biggest obstacle to connectivity (Sawhney 1994). In the presence of monopolies, Universal

telecommunications reform positive to offset the short-term cash flow loss from the state owned enterprise (preserving monopoly while improving efficiency maximizes fiscal benefit for the government) (Noll, 1999).

Service was funded through cross-subsidization between different services or users – i.e., to enable an enterprise to compensate for losses incurred because of some activities or users (such as rural telephony or local service) with the excess profits gained with some other activities or users (such as urban telephony or international services) (Geradin et al. 2003). Indeed, there is an implicit transfer from business to residential; long distance to local; urban to rural (CSTB 2002). In developing countries, where funds are limited, funding of Universal Service through cross-subsidization can be problematic.

Monopolies, normally owned by the state, were asked to implement Universal Service as a social service. Once markets open to competition, however, the cross-subsidization is incompatible with the regime of open competition (Geradin et al. 2003)[28]. In some cases governments have imposed a universal service obligation requiring the incumbent telecommunications operator to provide service to all parts of the country at a uniform price. New entrants without such an obligation have a strong incentive to focus on low-cost, `profitable' customers, in a phenomenon known as 'cream-skimming' (Cave 2003).

An alternative model implies the separation of the collection and allocation of Universal Service Funds. Collection can be made through general taxation or by placing a levy on all operators, proportional to their turnover.[29]. These funds would then be used to provide Universal Service. In some cases it would still be the incumbent providing the service. Although the incumbent may indeed be placed in a better position to provide the service, this does not necessarily have to be the case. In addition, a significant problem remains of determining the subsidy that should be attributed to provide service[30]. To solve both of these hurdles, in some countries the process has been opened to competition by awarding Universal Service funds through a competitive auction (Weller 1999, Milgrom 1996)[31].

In Chile, since 1994, a system of competitive bidding has been used to allocate the public subsidies made available to improve telecommunications access in poor and rural areas. Besides the fact it introduces competition for the market (thereby lowering the amount of subsidies needed to provide universal service), the system has other attractive features. For example, rural concessions have been granted to several distinct operators, thereby allowing some degree of benchmarking across regions. The licenses are not

[28] In the UK, even after the privatization and liberalization of the telecom markets, OFTEL, the regulator, decided that US obligations should be provided by the incumbents without any compensation, considering that the costs were in great part compensated by the commercial advantages of BT. See (Geradin et al 2003, p.192-193).
[29] There is some debate about different manners in which to calculate the level of contributions by different operators . See (FCC 2002).
[30] Alternatively the level of the subsidy can be fixed, and companies would bid on the level and quality of the service.
[31] Auctions have the additional advantages of revealing the buyer's valuations and expedite the process.

exclusive in order to leave the door open to the introduction of some degree of competition not only for, but also in, the market (Kerf et al. 2003). Operators remain largely free to choose the technology and project design which proves most effective. This fund has been very successful, and it has reduced the proportion of Chile's population living in places without access to basic voice communication from 15% in 1994 to 1% in 2002 (World Bank 2002). Similar positive experiences have been observed in Peru and Guatemala (World Bank 2002b).

These schemes greatly improve the efficiency of allocation and utilization of funds. An inherent problem, nevertheless, is that they still require availability of capital to constitute the funds, which in developing countries is lacking. After liberalization Bolivia implemented an alternative scheme that addresses this difficulty: no-fee licenses were offered in exchange for commitments to rural service and education (Best et al. 2002).

Exploring such flexible schemes for the financing of telecommunication project may prove particularly useful and relevant in the context of bottom-up entrepreneurial deployments in the developing world. If these players have the potential to be more efficient and effective in the provision of services to rural areas, it is essential to shift the patterns of access to capital to meet their needs.

1.4 This Thesis' structure

This document is organized in six chapters. Chapter 1 – the current chapter - introduces the question and does a brief literature review of related work in relevant areas. Chapter 2 describes some aspects of the technology deployed in the 2.4 and 5GHz bands. The survey and methodologies followed are described in Chapter 3, while Chapter 4 describes and analyzes its results. Chapter 5 explains the policy implications of the results and issues recommendations, and Chapter 6 summarizes the work and concludes.

2. Wireless smart technology: current solutions for 2.4 and 5GHz bands

This chapter describes some aspects of the technologies deployed in the 2.4 and 5GHz bands. One should point out the advantage of wireless systems over wired ones. Indeed, digging up sidewalks or installing towers and wiring is costly. The recent the success and fast growing cellular industry in the developing world, is partly explained by just that.

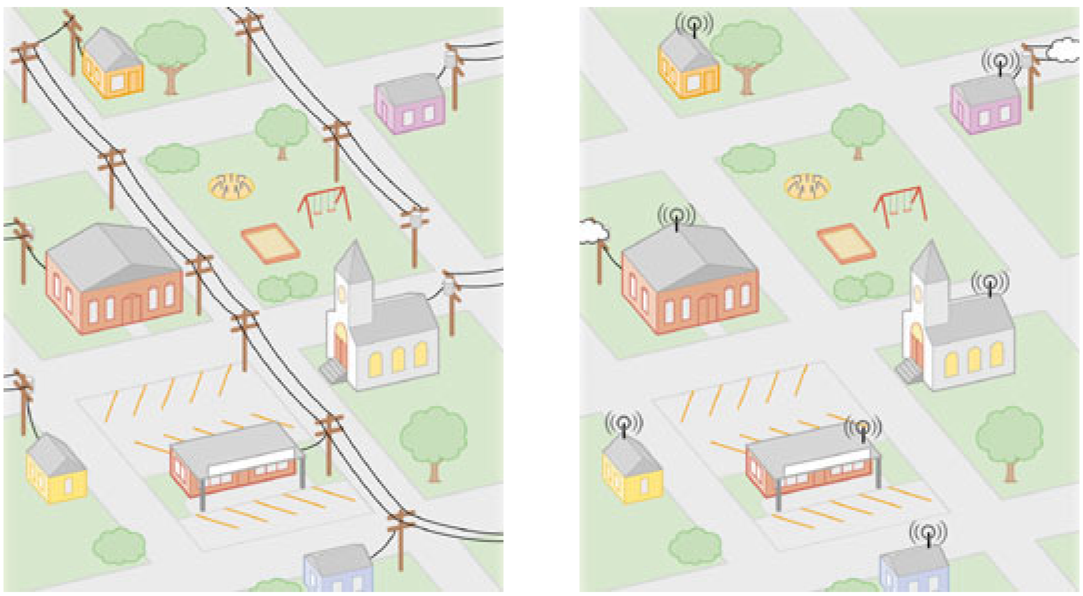

Figure 2.1 – Wired vs. Wireless Networks
Source: (Community Wireless website)

However, the wired vs wireless distinction is only a first categorization. Wireless technologies are in turn further characterized by different architectures, standards and interference management techniques. These are the subject of this chapter.

Section 1 looks at the system's architecture. It talks about the different connectivity segments and possible configuration combinations, and also addresses different topologies for the local network. Section 2 considers specific technology solutions. It does a brief comparison of the different standards that operate in the 2.4 and 5GHz bands, and finishes with some notes on the end user devices and applications supported.

2.1 Architecture

2.1.1 Different segments

For a telecommunications network to work, connectivity needs to be ensured at different levels. Connectivity is needed at the local level, connecting households and user devices to the information network - what is sometimes called the local loop, but also at regional, national and international levels.

Telecommunication networks follow a particular architecture, which is briefly described in this section. The different elements of the network need to be present for meaningful connectivity. I.e., the existence of a standalone local loop can be of use for neighbors to communicate amongst themselves, but its usefulness is limited in the absence of a transport network and connection to the backbone.

In this context, it is important to look at the different segments of the network, and understand how they fit together. Figure 2.2, taken from Michael Best (Best 2003), describes these, schematically. This figure illustrates the use of wireless technology in different segments of the network: wireless backhaul, Wireless Metropolitan Area Network (WMAN) and Wireless Local Area Network (WLAN) deployments. These segments are differentiated by the distances they bridge, and also by the different point-to-point or point-to-multipoint distribution configurations.

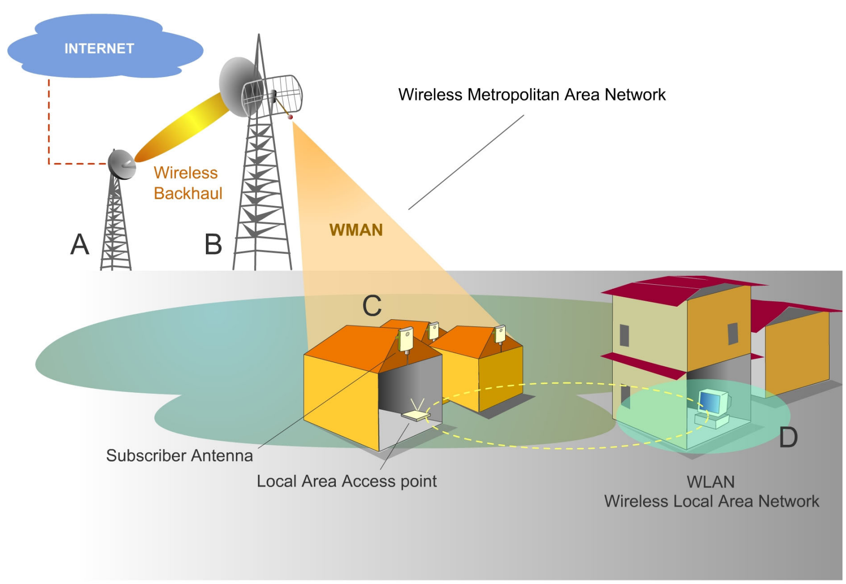

Figure 2.2 – Different segments in connectivity
Source: (Best 2003)

In this figure several elements are depicted:

- A: Radio tower connected to the internet through a wired connection
- B: Intermediate radio tower
- C: Building with base station/access point
- D: End-user equipment, e.g. personal computer.

A detailed description can be found in Michael Best's original publication. A shortened version is presented here. The objective of this network is to connect the end-user equipment (D) to A, where a wired internet connection is available. This is, in this example achieved through the use of several segments and technologies. To start with a point-to-point connection is used between radio towers A and B, with only one antenna (i.e. one receiver/transmitter) in both extremities. The purpose of this connection is typically to transmit over long distances (in the order of tens of kms). Several of these links can be used, one after the other: in this way the signal will be transmitted, in 'hops', to a potentially remote location. This is normally referred to as wireless backhaul.

The connection from B to C is a point-to-multipoint connection. This means that radio tower B is now radiating to and receiving from several stations of type C – i.e., several buildings with base stations, or access points. This is normally called a Wireless Metropolitan Area Network (WMAN).

The access point in C will then radiate the signal to end-user equipment in its closer proximity (e.g. inside the same building). This is what is normally called a Wireless Local Area Network (WLAN)

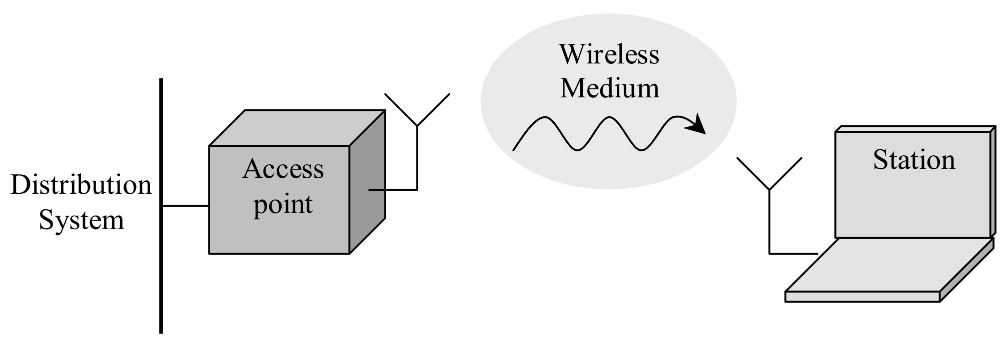

Figure 2.3 – The WLAN segment
Source: After (Gast 2002)

It should be re-iterated that this configuration describes a situation where all segments are being deployed through wireless technology, but that need not be the case. Indeed, some of these segments can potentially be served by other means such as fiber, cable or wired networks. Indeed, the 802.11 standard does not specify any particular technology for the distribution system (see Figure 2.3). For example, in a typical urban environment 'hotspot'[32] in the US, the WLAN connection (i.e. the access point in the building, C) is directly linked to the wired infrastructure, normally a T1 connection[33] - or whatever medium is delivering broadband to the particular 'hotspot' location (coffee shop, airport lounge, etc).

In the context of developing countries, and when thinking about designing networks to extend connectivity, one or several of these links may already be present, depending on the penetration of wired networks. One can expect that access to Telecommunications Infrastructure will be easier in urban rather than in rural environments.

Consequently, connectivity to rural areas will have to be established over longer distances, and longer chains will typically be needed. I.e.: in an urban environment it is more likely to find wireless WLAN-type deployments only. In rural environments, and in the absence of alternative infrastructure, one must necessarily think of the higher end segments as well (i.e. connection to the backbone), as these are likely absent. A more complete solution over longer distances will be needed.

Once again, this transmission can be accomplished through different technologies. Since in general wired infrastructures (such as fiber or cable) involve high costs, wireless solutions are often preferred. The use of satellite technology, for example, and in particular the use of VSAT links are a popular solution[34]. In this chapter I will talk about alternative technologies to achieve higher segments connectivity, deployable in the 2.4 and 5GHz band.

Different segments need technologies with different characteristics. As communications go from A to B to C to D the beams become less directive, and more prone to interference. The power profile also changes. Several wireless standards have been developed to serve different needs, and operate in different bands. Some of these are described in Appendix II.

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[32] A hotspot is generally speaking a WLAN deployment that is open to the public, sometimes against payment of a fee.
[33] T1 connections go up to 1.5Mbps (Young, 2003).
[34] For some information on communication options for remote areas – general overview of e.g. VSAT, HF, WiFi, etc, see http://www.maflink.org/sat/sattutorial.htm. One interesting configuration is the combination of WiFi and VSAT or other "broadband" satellite. Instead of using a VSAT connection for each user or business, one an think of a VSAT served hub, which would then use WiFi to further distribute the network reaching other villages, or simply other users inside the same village/location. Since Wifi is cheaper than VSAT, this would bring down costs.

2.1.2 Topologies for last mile

Last section has mentioned possible configurations through combinations of technical solutions in different segments. In the last mile segment (i.e. the WLAN segment) there are also different possible topologies.

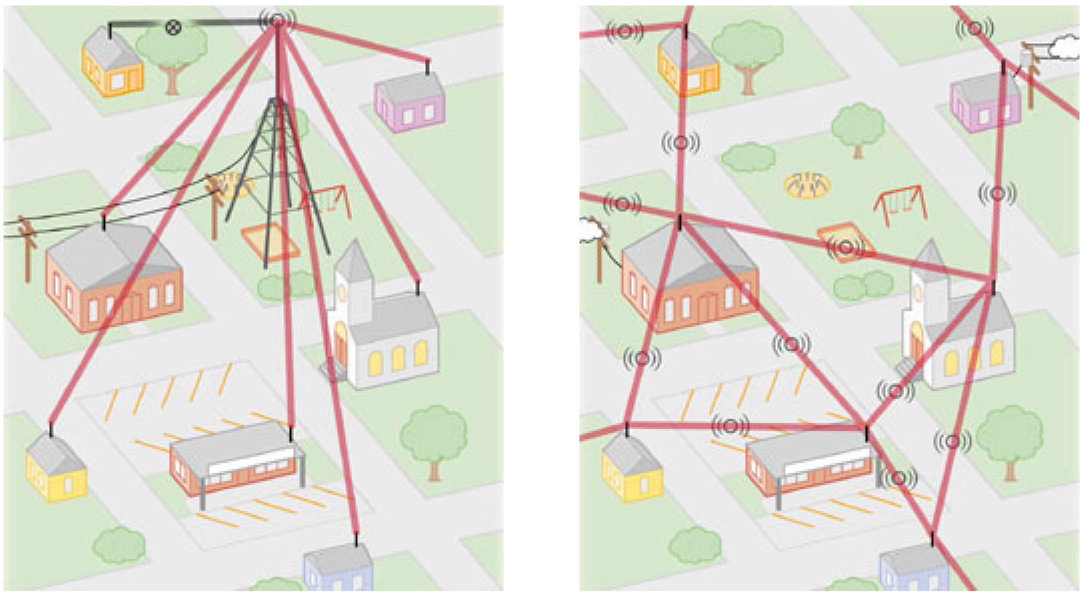

Figure 2.4 – Hub & Spoke vs. Mesh Networks: Different architectures for the last mile
Source: (Community Wireless website)

One main distinction, illustrated in Figure 2.4, is the Hub and Spoke versus the Mesh Network approach. This first solution represents a somewhat hierarchic approach, with a central hub or transmission tower, from which all other communications depart. In the Mesh Network configuration communications are more decentralized, and have the advantage of being easily expandable, bypassing obstacles through adaptive behavior, and potentially needing lower power. In order to properly function, however, this configuration requires some minimum density of nodes which, in early stages of deployment, in particular in developing countries, will not likely be present. This type of networks will be explained in more detail in the following subsection.

The fact that 802.11 does not specify any particular technology to connect the several access points to form a large coverage area gives the system significant flexibility (See Figure 2.5).

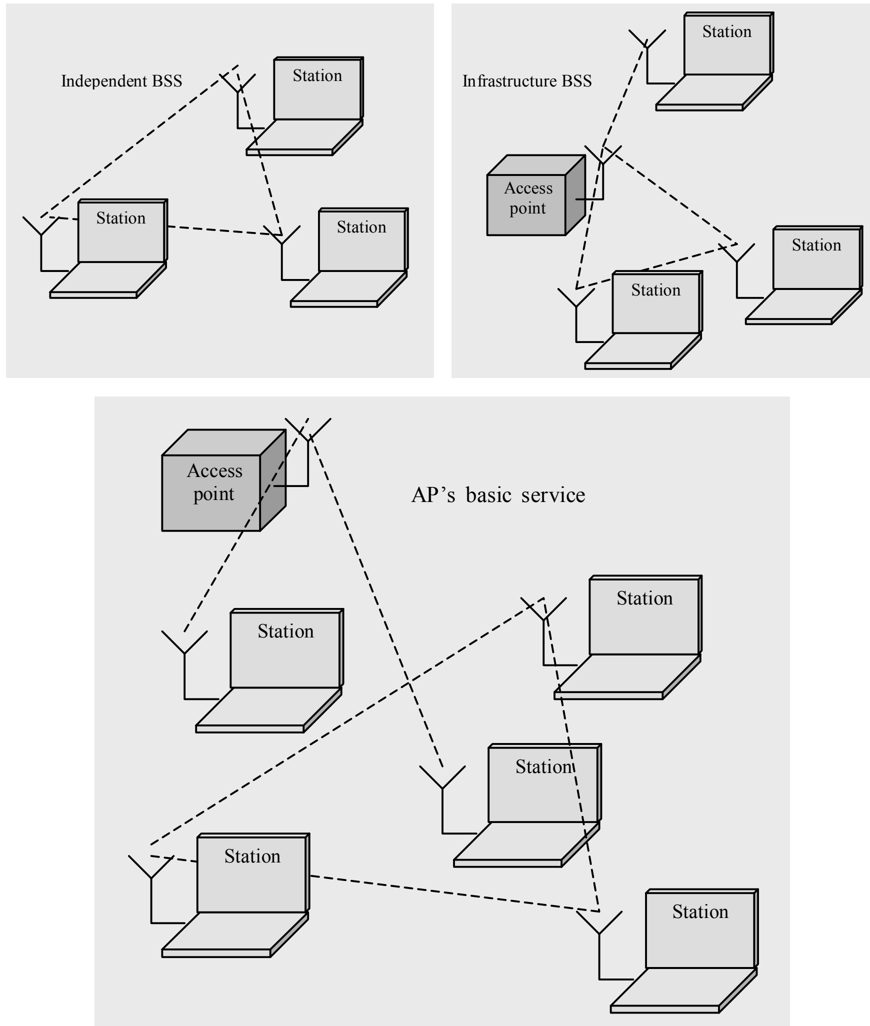

Figure 2.5 – Possible topologies for the distribution system
Source: After (Gast 2003)

2.1.3 Mesh, ad-hoc and viral networks

This section describes what are normally called mesh, ad-hoc, or viral networks. Some of the advocates of license-exempt bands believe that these type of networks can be of particular value in the context of the developing world. The concept of mesh, ad-hoc and viral networks are explained below, along with some reflections on the applicability of these concepts in the context of this thesis.

These types of networks are not synonyms, but rather related concepts. They all gravitate around the notion of incremental or decentralized networks, needing no central backbone, infrastructure, or organization in order to work, but scaling up by using 'neighbors' as resources for communication. Similarly to what happened in the IT world, these types of networks represent a shift in architecture, moving communications intelligence from the core of a network to the periphery, in this case to the user nodes (Lipman et at 2003). This represents a shift in the technical architecture but also in the current paradigm of the Telecommunications Industry. Today, both the technology and regulatory environment reinforce centralized control and vertical integration. Distributed and bottom-up networks would therefore dramatically change this landscape by using unlicensed devices, and intelligent, personalized nodes and permit easy entry, free growth, and low-cost innovation (VCP website).

Mesh Networks

A mesh network can be defined as follows (Krag 2004):

> "A mesh network is a network that employs one of two connection arrangements, full mesh topology or partial mesh topology. In the full mesh topology, each node is connected directly to each of the others. In the partial mesh topology, nodes are connected to only some, not all, of the other nodes."

In recent years, the term "mesh" is often used as a synonym for "ad hoc" or "mobile" network. According to the definition above, however, a mesh network does not necessarily evolve or change over time – a mesh network is not necessarily dynamic.

In the absence of a central hub to redistribute the data, mesh networking transforms all nodes into routers, with information hopping across nodes to get to its final destination, forming a spontaneous, temporary communications cooperative (Jardin 2003).

Ad-hoc networks

According to Rappaport et al. (2002):

> "An ad hoc network (also known as a packet radio network) is the cooperative engagement of a collection of mobile nodes that allows the devices to establish ubiquitous communications without the aid of a central infrastructure. The links of the network are dynamic in the sense that they are likely to break and change as the nodes move about the network".

Work on ad-hoc networking has started in the 60's, with the ALOHA protocol (Abramsson 1970) – supporting distributed channel access in a single-hop network. In 1973, DARPA began the development of a multi-hop packet radio network protocol (Jubin et al. 1987). If historically ad-hoc networks have been used in situations where decentralized network architectures are an operative advantage or even a necessity (such as in battlefields or in a disaster site), with the emergence of wireless devices and Personal Area Networks (PANs) the role of ad-hoc networking will likely grow.

Some standards already include ad-hoc operation. Such is the case (as is explained in Appendix II) of HIPERLAN/2, which allows adjacent terminals to communicate with each other. The IEEE 802.11 ad hoc mode, the 802.16 mobile ad-hoc networks (MANET), or the 802.15 PANs are other examples (Rappaport et al. 2002).

The idea of a "mobile mesh network", in which it is assumed that (at least some of) the nodes of the network are mobile units that change position over time, is a powerful possibility. Even in stationary networks, however, it is useful to adapt dynamically to, for example, new nodes joining the network (dynamically updating and optimizing the mesh connections), or to situations of propagation blockage, or congested connections, etc. This is illustrated in Figure 2.6.

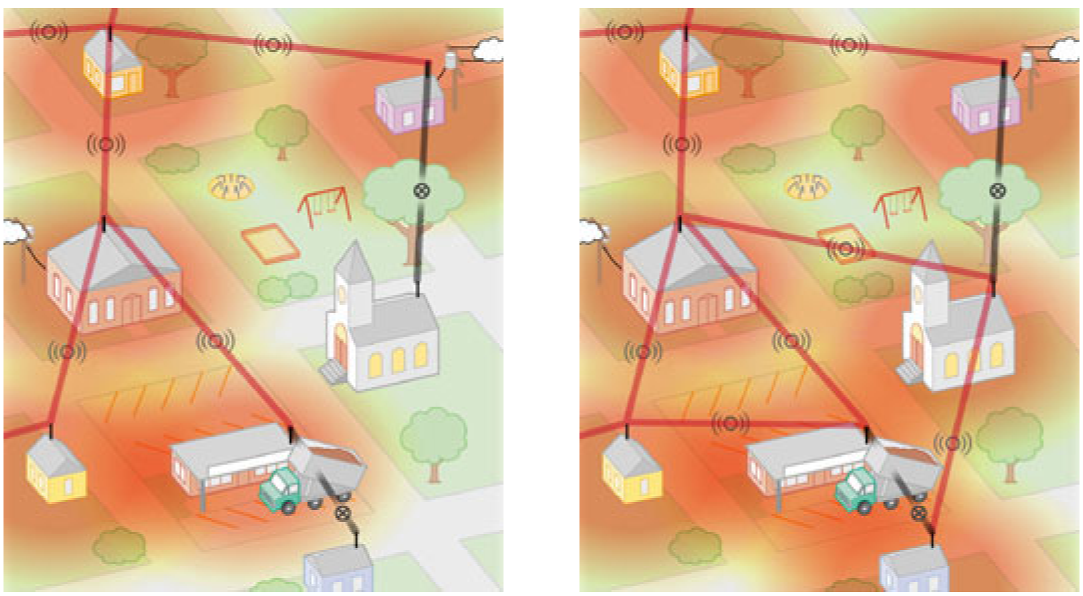

Figure 2.6 – Static vs. Dynamic mesh networks
Source: (Community Wireless website)

The operation of ad-hoc networks poses a number of challenges, which Rappaport describes (Rappaport 2002):

- The need to design and optimize security and routing functions for distributed scenarios (e.g. designing approaches to minimize updates of routing table). Overhead must be minimized while ensuring the proper functioning of the network.
- Latency may be an issue in multihop networks, as well as fluctuating link capacity
- Acceptable tradeoffs are needed between network connectivity (coverage), delay requirements, network capacity, and the power budget.

Viral networks

The concept of viral networks adds an additional 'bottom up' and 'entrepreneurial' layer to the previously described cooperative networks. The idea, according to Andrew Lippman, from MIT's Media Lab is that "communications can become something you do rather than something you buy" (Lippman et al. 2003). Communications become a bottom-up phenomenon, with users building their own nodes and where "the whole is woven together into a mesh by loose agreements" (Negroponte 2002). This model brings several advantages in situations where there is limited capital available for the development of a central network.

The term viral refers to the fact that adoption can be incremental, gaining momentum as it scales. Unlike viral environments some systems require a critical mass of adoption for benefits to be experienced (Lippman et al. 2003). In a viral environment performance increases with the number of nodes. Typically, adding handsets means interference goes up and quality of service goes down. In this topology, more nodes equals better service.

Current status and applicability in the context of this thesis

Although these are powerful concepts, these types of networks are still starting to emerge. There is some technology available and applied research in the field (Bletsas 2004), but several challenges remain: e.g. in the areas of security, efficient billing, and dynamic and efficient routing algorithms. It may be too early to see this having a significant impact in the communications landscape.

These types of networks are the enablers of Nicholas Negroponte's model of "the lily pad and the frog" already alluded to in Section 1.1.2 (Negroponte 2002). Given the status of technology and of connectivity in Africa it may not be realistic to think that mesh networks will be able to close connectivity holes only by promoting collaborative agreements between ad-hoc viral nodes.

Given the incremental nature of these networks, however, it is possible to think that initial wireless access nodes can serve as the stepping stone for the build up of such networks in the future. For the time being, it is important to work with available and accessible technology.

Having said this, mesh networks do present a number of advantages, for example when used in conjunction with 802.11 equipment. These are described by Tomas Krag et al. in a recent article (Krag et al. 2004), and are described below[35]:

- **Price:** Since each mesh node runs both as a client and as a repeater, there is an opportunity to save on the number of radios needed
- **Ease and simplicity:** By using a box with pre-installed wireless mesh software, and standard wireless protocols such as 802.11b/g, it is often enough to drop the box into the network, or at least setup is simplified
- **Organization and business models:** given the decentralized ownership model, each participant is responsible for maintaining its own hardware, simplifying the financial and community aspects of the system.
- **Network robustness:** mesh topology and ad-hoc routing technology offer greater stability and robustness to changing conditions or failure at single nodes
- **Power:** In mesh network arrangements power consumption is reduced – with the possible exception of the nodes that maintain an up-link to the Internet – and can therefore be built with low power requirements. They can be deployed as completely autonomous units with solar, wind, or hydro power.
- **Reality fit:** The probability that users see one or more neighboring users is larger than the probability of seeing one of the central points of a traditional topology network, given difficult terrain conditions (in urban or rural environments)

2.2 Standards and end-user devices

This section considers specific technology solutions: both on the network side (by comparing the different standards that operate in the 2.4 and 5GHz bands) and on the end-user side.

2.2.1 Notes on wireless standards

The definition and use of license-exempt bands has been made possible by the evolution of technology. Receivers have evolved, generally, from ‘dumb’ to ‘smart’ devices, capable of coping with interference in a more dynamic, responsive and intelligent way. This evolution enables the coexistence of users in the same frequency bands, while avoiding unsurmountable interference.

[35] For a description of the 802.11 standards see Appendix II.

Indeed, the classic approach to radio communications is to confine an information-carrying signal to a narrow frequency band and transmit at a reasonably high power. There is naturally, some noise present in the frequency band. Transmitting a signal in the face of noise basically consists of ensuring that the power of the transmitted signal is much greater than the noise (Gast 2002). With these higher power levels, however, only a limited number of devices can use the available spectrum because nearby devices operating on the same frequency alternately amplify and cancel nearby transmissions (Carter et al. 2003). It follows that in the traditional model a legal authority, such as a regulator, imposes rules on how the RF spectrum is used. In general, licenses are issued to guarantee the exclusive use of a particular set of frequencies. Licenses can restrict the frequencies and transmission power used, as well as the area over which radio signals can be transmitted. When licensed signals are interfered with, the license holder can demand that a regulatory authority step in and resolve the problem, usually by shutting down the source of interference.

Unlicensed bands differ in a fundamental way from this traditional spectrum management model. Spectrum use is not exclusive, and the regulator generally does not hold any responsibility in managing interference or resolving interference disputes. Generally, unlicensed devices have to obey to certain limitations (e.g. on transmitted power or on modulation), but no technology solution is generally prescribed.

As Michael Gast puts it, “Unlicensed" does not necessarily mean "plays well with others” (Gast 2002). These bands, which have seen a significant deal of activity in recent years, have only been made possible by the evolution and emergence of technological solutions that enable coexistence of devices without prohibitive interference. Some of those techniques are described in Appendix I.

It should be noted that as the number of users grows and the number of networks in close proximity increases, the capability to deal with “stressed networks” becomes increasingly important.

In parallel with the evolution of interference management techniques, a wide variety of wireless standards that are suitable for use in unlicensed spectrum bands[36] has been developed over the years.

[36] Indeed, cellular phone technology such as GSM or PCS is also wireless, but the frequency use and modulation are such that spectrum use needs to be coordinated to avoid interference and ensure the system’s well functioning.

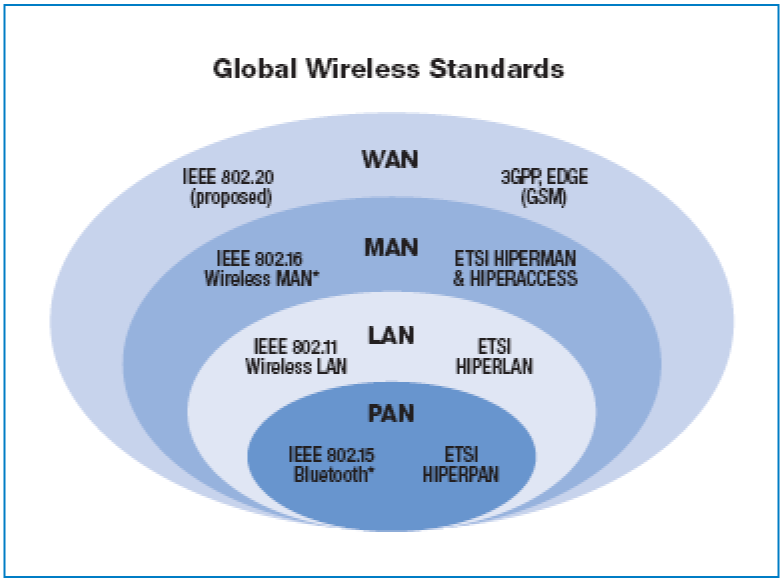

Figure 2.7 – Example of Wireless standards for the different segments
Source: (Intel 2003)

Indeed, there is currently a wide variety of standards – approved and in existence, being finalized, or under preparation. Examples are the 802.11b, 802.11a, 802.11h, 802.11g, HiperLan and HiperLan/2 standards. As is illustrated in Figure 2.7 different standards are used to serve different network segments (see Section 2.1.1). Appendix II provides a brief overview of the basic characteristics of some of these standards, as well as of their emergence and major differences.

This variety of standards is exacerbated by the fact that countries have different regulation concerning the use of spectrum, and therefore pose different requirements upon equipment and transmission characteristics (Courtney 2002). The 802.11a, for example, is not accepted in Europe. The standard 802.11h was developed in order to comply with European regulations.

These standards differ in many ways: bit rate, range, spectrum used, price of equipment, etc. Table 2.1 shows a summary of the different standards mentioned in Appendix II, and of their basic characteristics[37].

[37] The information from this table comes from several sources: Best 2003, Gast 2002, personal contacts with Bob Heile, from the IEEE 802.15 standardization group, and Michail Bletsas, from Media Lab, and online resources.

Table 2.1 – Different wireless standards and some basic characteristics

Standard	Application (pt-to-pt; Pt-to-multipt)	Frequency Band	Bandwidth **Throughput (link rate)**	Availability today	Max Range	Modulat.	MAC	Comments
802.11	WLAN	- FHopper (54 hops sec -DS 2.4GHz - Infra Red	1 Mbps (FH and DS), 2 Mbps	No, replaced by newer versions	-	FSK - FH QPSK - DS	CSMA	First standard (1997). Featured both frequency hopping and direct-sequence modulation techniques.
802.11b	WLAN, Pt to multipt & Pt to pt	2.4GHz	5.5 Mbps (11 Mbps)	Since 1999 Widespread, popular, inexpensive	Typ. 75m, 1km possible (Pt-to-multipt) 20Km poss. (pt-to-pt)	QPSK	CSMA	Most common 802.11 equipment. Reduced data rates at long range, relatively inefficient spectrum use
802.11g	WLAN	2.4GHz	22- 54 Mbps	Available	-	OFDM w/ opt. CCK	CSMA	Evolution of 802.11b, same band. Faster standard in the 2.4GHz
802.11a	WLAN	5GHz	6 - 54 Mbps	Available	30m (Pt-to-multipt)	OFDM	CSMA	1999, but products released late 2000. Still more expensive than 11b. Not accepted in Europe (see 802.11h)
802.11h				See 802.11a				Same as 802.11a, but with MAC enhancements. Includes DFS and TPC to operate in Europe
802.16	WIMAN (WiMax)	10-66 GHz (licensed)	70 Mbps	Yes, but still emergent	Typical 7km 30-50Km possible	Depends on data type & error rates	TDMA	Local metropolitan data system. Good range, good speed, but still emerging
802.16a	WIMAN (WiMax)	2-11 GHz (licensed)	70 Mbps	Should be available in the next year	See above	See above	TDMA	Point-to-multpoint Fixed broadband wireless access WLAN backhaul, both for hot spots and home networking
802.16b	WIMAN (WiMax)	5-6 GHz (unlicensed)		Should be available in the next year	See above	See above	TDMA and OFDMA	Includes Mesh mode
HIPERLAN/1		5GHz	11-20 Mbps	Limited availability		GMSK	-	Limited availability, lacks vendor support
HIPERLAN/2		5.15-5.30 GHz	up to 54 Mbps	Very limited availability		OFDM		Has own DFS Better QoS than 802.11a Very rigid, expensive to build
Canopy	Pt-to-pt, pt-to-multipt	2.4 and 5GHz	up to 14Mbps (pt-to-multipt) or 6Mbps (pt-to-pt)	Yes	15km 55km Pt to pt	-	-	Proprietary standard, relatively expensive
corDECT	Point-to-multipoint	1880 - 1935 MHz	32 Kbps ADPCM & Internet at 35/70 Kbps	Yes	10-25km Pt-to-multipt	-	-	Specifically designed for Universal Access

It is difficult to report information on range, since it depends on configurations, and regulations, antenna gains, propagation characteristics, etc. The values in the table are indicative only. In general, 802.11 standards are meant for more localized use (although longer ranges are possible) and 802.16 standards are more applicable for transmission over longer distances, over tens of kilometers.

It is also difficult to get quality and reliable information on prices, but the available numbers indicate that these are, in general, low cost technologies, when compared to alternative technological solutions. Some indicative values are provided below. 802.11 products are shipping with prices of less than USD 75-100 per node (WiFi Alliance website). Some 802.16 or equivalent products are already on the market, and prices range from USD 300 to USD 5000 per node. These costs can result in values that are significantly lower than the ones. According to Michael Best:

> 'Here is the punch line: initial trials have demonstrated that networks for voice and high-bandwidth data can be deployed over hundreds of kilometers, at costs currently under USD 50,000. Put another way, at per-subscriber costs approaching USD 300[38] (and continuing to drop), communities in relatively rural and dispersed areas can receive voice and data connectivity. Compare this to standard fiber and copper technologies deployed in many urban areas. There, network backbone costs can range from USD 20,000 to USD 40,000 per kilometer and, as a rule-of-thumb, per-subscriber costs hover at about USD 1000.' (Best 2003, p. 110)

The choice of technology to use will necessarily depend on the context and applications needed. The most well established and widely deployed standard is 802.11b. As mentioned in Chapter 1 there is a wide variety of projects deploying WLAN and 802.11b solutions in developing countries. Indeed, community networks have been particularly successful in out-of-the way places where traditional wireline approaches where not feasible. Several factors play for the adoption of 802.11 standards in the developing countries context (ICT4DEV 2004):

- **Price**: because it is mass produced equipment is relatively cheap. Being relatively simple and fairly ubiquitous, it is simples to get replacements, and repairs.
- **Availability**: since equipment is widely available, tested and with proven successes adoption is realistic. Other standards exist which are still in development or testing phase.
- **Open Standards and flexibility**: Open standards, with effective interoperability between vendors prevents vendor lock-in, which in the developing country can be a significant problem.

[38] Note that costs such as installation, grounding, transportation, etc. can vary considerably from location to location and influence these numbers.

Looking specifically at the frequency bands in which these standards operate, we see that there are several wireless standards and equipment operating in both the 2.4 and 5GHz bands:

Table 2.2 – Standards and equipment operating in the 2.4 and 5GHz bands

Band	2.4GHz	5GHz
Standards	802.11, 802.11b and 802.11g, Canopy (also used by Bluetooth and microwave ovens)	802.11a, 802.11h, 802.16b, Hiperlan1, Hiperlan 2, Canopy

Below, I describe some of the factos which may influence the choice of using one of these bands over the other:

- **Attenuation**: Multipath fading[39] and attenuation from obstacles becomes more severe with higher frequencies. In particular, higher frequency signals are disturbed by smaller obstacles. In addition, the Free Space Loss[40] (the attenuation experienced by a signal when propagating over space), grows with frequency, for a dipole antenna. In some circumstances, however, one may think of using a different type of antenna, with different characteristics. Having said this, the range depends on many factors. One estimation (Gast 2002) indicates, for example, that the radius of 802.11a access points would be 20-25% shorter than the 802.11b ones.
- **Congestion and related interference**: As mentioned above, one of the reasons for the development of 802.11a was the fact that the 2.4GHz band is becoming crowded. Because the 5GHz band is much larger than the 2.4GHz band and is not already occupied by microwave ovens and other devices, there should be fewer problems with interference.
- **Availability and state of the art:** in general, the choice of using the 2.4 or 5GHz will depend largely on the availability of devices. At present, 2.4GHz devices are more widespread and are therefore more common.
- **Regulatory framework:** A last factor is related with the state of regulation for the two bands. In many countries, and since availability of 2.4GHz equipment is higher, legislation applicable to that band was finalized and applied before 5GHz relevant regulation. In the UK, for example,

[39] A type of fading caused by signals taking different paths from the transmitter to the receiver and, consequently, interfering with each other (Ksys website).
[40] Free Space Loss is given by the expression: FSL(dB) = 32.45 + 20Log10F(MHz) + 20Log10D(km), where ‘F’ is the frequency and ‘D’ is the distance from the transmitter to the receiver.

consultations about regulation in these two bands were issued in 2002. However, the go-ahead for unlicensed use was given to the 2.4GHz first. At the time (June 2002) the justification was that further compatibility and interference tests were needed in the 5GHz band.

In terms of bandwidth the widely adopted 802.11b standard operates at bit rates of up to 11Mbps. The higher bit rates achieved by 802.11a (providing 54 Mbps) in the 5-GHz band, which could give this standard some advantage, are now being matched by 802.11g, in the 2.4 GHz bands.

Moving on, with the development and availability of 802.16 products (the so-called WiMAX products), and as wider area solutions are sought, this family of standards is likely to become increasingly popular.

2.2.2 Notes on end-user devices and applications

WLAN-type technology is generally associated with internet and data applications. Typically, at least in the developed world, end-user equipments are battery-operated laptops or handheld computers. This needs not be the case.

In the context of the developing world, some may argue against the appropriateness of this type of technologies because cost is relatively high and availability of such devices is limited. Wireless network interface cards to be used in a personal computer can now be purchased for less than USD 50. The cost of the computer is, however, significantly higher. In addition, there seems to be more demand for voice than for data services.

Some of these standards, however, specifically support voice as well as data communications - corDECT is one such example (see Appendix II). Bhutan Telecom, for example, has implemented a pilot projects using 802.11b technologies to provide rural voice services[41].

As Voice over IP (VoIP) technology is improved, WLANs can offer wireless service that support voice and integrate phone-like features with Internet access (Rappaport 2002). There remain some issues with QoS, capacity and reliability of the backbone. Indeed, the data packets belonging to a voice conversation cannot arrive ‘late’ – otherwise the conversations break up.

[41] For a more detailed description of the project see (Best 2003).

Figure 2.8 – WiFi phones: Vocera's Badge, PulverInnovations' WiSIP and IPBand's WiFiPhone
Sources: Extracted from (Vocera website, PulverInnovations website, WiFi Phone website)

Nevertheless, and while VoIP use in developing countries is already a reality[42], VoIP over WLAN is taking off. On the standards side there is some ongoing work on QoS enhancements, for example for voice applications (Forbes 2003b). Kineto's Mobile over Wireless LAN (MoWLAN) network solution enables mobile operators to leverage VoIP and WLANs in homes, offices and hot spots to deliver mobile voice and data services indoors (Daily Wireless 2003, Kineto website). WiFi phones already exist and are becoming available now. Figure 2.8 shows some examples. Prices range from roughly USD 150 to 300, but this is likely to come down (Forbes 2003, Vocera website, PulverInnovations website, WiFi Phone website)[43]. In the US there are several companies starting to offer the service (CNET News 2004, Wireless weblog 2004, Unstrung 2004). These solutions follow different configurations and are applicable to distinct environments[44], but show the increased availability of this type of technology.

[42] For numerous reports on VoIP and its use across the world see for (Cook 2003).
[43] For some of these technologies, apart from buying the handset itself, users also need to pay for a license, which can be substantially more expensive.
[44] Vocera, for example, advocates this solution predominantly for office environments, hospitals, etc.

3. Survey on the use of unlicensed spectrum

In the first two chapters I have laid down the context and explained the technology that can be used in unlicensed bands, and specifically in the 2.4 and 5GHz bands. As has already been mentioned some of the technology deployed in these bands is relatively new, and regulation and use are changing. Very limited information is available about the regulation of these bands around the world, and specifically in Africa. As mentioned in Chapter 1, in 2003 the ITU introduced a new question about the policy for licensing WLAN in its annual survey to regulators[45], but the results are very general and incomplete. Also the US State Department has recently collected information about the use of WLAN, but the information is confidential (Lamb 2003).

Part of this thesis' contribution is to study the general outlook of the regulation and use of unlicensed bands, specifically the 2.4 and 5GHz bands, in Africa. In order to do this a survey has been conducted in all African countries to collect information of the reality in the terrain. This data will subsequently be studied both by using descriptive statistics and by performing a cross section country analysis, and calculating correlation between the information obtained in this survey and country telecom and governance indicators (see Chapter 4).

This chapter describes the methodology followed in conducting this survey. It defines its focus and scope, the distribution, follow up, and collection of results, and it further describes the attained level of response.

3.1 Focus and scope

The survey collects information on the regulation and use of the above mentioned bands in all fifty four countries in Africa[46]. Indeed, countries have put in place different regulation, and experiences of use are also different. The survey focuses on collecting information in three main areas:

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[45] In the 2003 the ITU has asked regulators: 'Is there a policy for licensing Wireless LAN (e.g. WiFi 802.11)? If Yes, explain', from ITU World Telecommunication Regulatory database, based on responses to 2003 regulatory survey, obtained from Nancy Sundberg, ITU.

[46] For a complete list of all African countries please see Appendix III. Special note on Western Sahara: Morocco virtually annexed the northern two-thirds of Western Sahara (formerly Spanish Sahara) in 1976, and the rest of the territory in 1979, following Mauritania's withdrawal. Western Sahara is currently under *de facto* control of Morocco (CIA World Factbook website). For the purpose of this thesis it is accounted for as a different country. However, and after checking with the Moroccan regulator, the Moroccan survey results are still applicable to this territory too. The same applies for the indicators used in Chapter 4.

Part A looks at spectrum licensing rules and enforcement in the so-called unlicensed bands, specifically in the 2.4 and 5GHz Bands[47]. Some countries have assigned this spectrum on an unlicensed basis, while others require a license for operation. In addition, certain conditions for unlicensed use may apply, such as the need for a registration with the regulator, the observance of maximum power limits, or the restriction to certain propagation environments (e.g. indoors) or applications (e.g. voice vs data). Enforcement and responsibility of dispute resolution are also important information, since in some countries, despite the fact that it is illegal to transmit without a license, the bands are still being used, and the government or regulator do not enforce the established rules. This section of the survey further covers the certification of equipment, as well as the current existence of revocation of licenses.

Part B covers the background to the regulations, in particular the motivation and rationale behind current regulation, and their origin. It further covers the existence of additional unlicensed bands, as well as potential plans for future changes in the regulatory system.

Part C looks into the implementation and experiences of use. While in some African countries these bands are being used, in others, due to the regulation in place, lack of equipment availability, or lack of demand, they are largely empty. This part of the survey collects information on the experiences of use in these bands (who are the providers, who are the users, which are the main applications, and in which context – i.e. localized coverage, rural deployment, etc). It also looks into the perceived success of the strategies in place, as well as the main difficulties or obstacles found. In terms of implementation, it covers issues such as equipment deployed, commercial products, and capacity of regulators (or enforcers in general) to police regulation. As has been alluded to in Chapter 1 (see Section 1.3.4) Universal Service Funds can potentially be used to deploy wireless networks, in particular in rural environments, if the appropriate policies are in place. The survey asks whether Universal Service policies in place allow this, and whether these funds are being used to deploy such networks.

The specific text of the survey can be found in Appendix IV.

When designing the survey I tried to use multiple choice questions as much as possible, since these are easier to answer, and also to code. On the other hand 'open text' questions capture more detail, additional information, particular stories, etc. The survey uses a mixture of both.

[47] More precisely the bands: i) 2.4GHz Band (2400 - 2483.5 MHz), and ii) 5GHz Band (5.15 - 5.35 GHz; 5.47 - 5.725 GHz and/or 5.725 - 5.875 GHz).

3.2 Target respondents

The survey was distributed to all fifty four countries in Africa[48]. Within each country, three types of respondents have been targeted:

- **Regulators** - since these have the most up to date information on regulation, spectrum allocation and assignment
- **Other national organizations linked to the telecommunications sector and operators** – these were contacted in cases where no contact for a regulator was found, or to use as a backup in case regulator did not respond
- **Alternative 'non-official' (but reliable) sources such as, e.g. ISPs operating in the country** – used, when possible, to attest for the practical implementation of the government policies on a practical basis.

Contacts for the first two have been extracted from the ITU contact database, from the ITU website (ITU website). Additional contacts have also been obtained from the list of participants in the fourth annual Global Symposium for Regulators that was promoted by the ITU's Telecommunication Development Bureau (BDT) just before the World Summit on the Information Society (WSIS), in December 2003 (ITU 2003b).

Contacts for alternative sources have been obtained through informal contacts with individuals and associations working in the field of Telecom and internet connectivity in Africa. In particular, Mike Jensen, from the African Internet Infrastructure Information[49] and Russel Southwood, from Balancing Act Africa[50]

A total of approximately two hundred and sixty contacts have been collected, for all countries, including all three contact categories. The survey has been sent out to all of those.

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[48] See footnote 46 on Western Sahara, page 57.
[49] See http://www3.wn.apc.org/africa/.
[50] See http://www.balancingact-africa.com/.

3.3 Survey Format

The survey was primarily distributed by e-mail[51].

To account for the different languages spoken across Africa, the survey and accompanying information have been distributed in English, but also translated by the author into French and Portuguese – according to the official language of each country. These three languages cover the range of official languages spoken in all countries. The survey and accompanying e-mails in these three languages can be found in Appendix IV.

In order to account for low bandwidth as well as for the potential use of different software packages in some countries, the survey has been sent in both Microsoft Word (*.doc), and plain text file (*.txt) formats. Respondents were urged to use the most convenient format for them.

Appropriate measures have been taken to ensure informed consent and voluntariness. As can be seen in Appendix IV, a disclaimer has been added in the header of the survey form, to ensure respondents understood their rights and the context of their participation in this study. In addition, anonymity is also guaranteed for those who so prefer and indicate[52].

3.4 Distribution and follow up

The survey has been distributed and responses collected between January and April 2004. As mentioned before the survey has been distributed primarily via e-mail. Ideally the survey form would be filled in by the respondents and sent back via e-mail. A response was requested after approximately one to two weeks after the sending date.

A total of around two hundred and sixty e-mails have been sent to all countries. Many of the e-mail addresses were no longer valid, and were sent back. Others have bounced in firewalls, or have not been delivered due to servers being down, or to the user account being over quota.

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[51] More on distribution below.

[52] In compliance with Federal regulations (CFR 1994) and MIT policies, the survey has been conducted according to the guidelines provided by the Committee On the Use of Humans as Experimental Subjects (COUHES) at MIT, in order to observe all ethical and legal guidelines for conducting studies involving human subjects (COUHES website). In view of its low risk and minimal adverse impact this survey has been granted exempt status by COUHES on the 10th December 2003.

In cases where no e-mail address was available, or when the e-mails addresses were not valid and there was no other contact for the country in question, respondents have been contacted via telephone or by fax.

A first reminder was sent, where needed, approximately 15-20 days after the first contact. A second reminder was sent around 30 days after the first contact. Where possible (i.e., where phone numbers were available) this second contact was done by phone.

All telephone contacts were conducted by the author in English, French and Portuguese – according to the official language of each country.

As was to be expected in a continent with such strong communications deficiencies as Africa, the distribution of the survey, as well as the collection of results has encountered a number of difficulties. Common problems were servers that had been down for several weeks, continued failures in power supply, or the fact that e-mail was not checked regularly. For that reason the telephone contacts were invaluable in ensuring a higher response level.

In the cases were internet access has proven to be deficient telephone and fax were used to send and receive the data. One response has also been sent back by regular mail.

3.5 Response rate

From the approximate two hundred and sixty e-mails contacts collected (on average, just less than 5 e-mails per country) around 20% were no longer valid, or could not be reached. Around 35% have replied. This includes all answers: either just acknowledging receipt and indicating a more appropriate contact point, or responding to the survey itself. Around 20% of the persons contacted have actually replied to the survey.

Response lag times, (i.e., the time between the first e-mail was sent to the time when the survey response was received) varied, as can be seen in Figure 3.1.

In general, the people contacted were very helpful and cooperative. This study would have not been possible without the participation of all people involved. The names and institutions that have responded to the e-mails and to the survey can be consulted in Appendix V (except those who have chosen to remain anonymous).

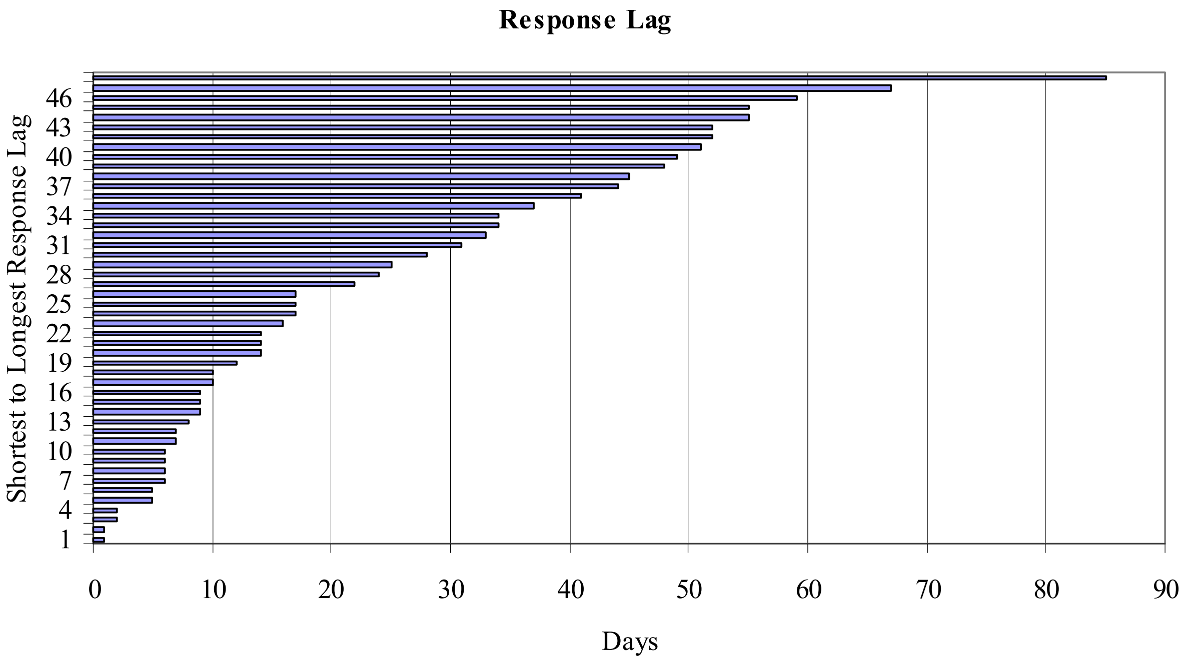

Figure 3.1 – Distribution of response lag, for all countries (time between 1st e-mail and response[53])

Out of the 54 African countries, survey responses are available for 47 countries – including Zimbabwe, for which only partial information is available. This corresponds to around 87% of countries[54], which exceeded expectations. Considering, in particular, the technical and institutional difficulties that characterize these countries, this is a very good response. In addition, if we calculate the corresponding percentages in terms of population, in order to consider the different country size, we get a response rate covering 97% of the population.

[53] In some countries the first person contacted was not the appropriate one, and the survey was forwarded to someone else. This 'Response lag' does not take that into account. It just accounts for the lag between the day the first e-mail was sent to the day when the response was eventually received, even if form someone else. For some countries there is more than one response. Both are included above.

[54] Including Zimbabwe, for which only partial information is available.

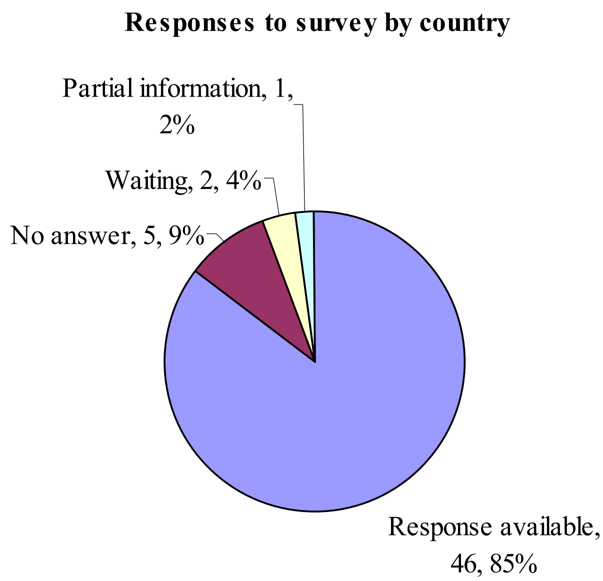

Figure 3.2 – Responses to survey by country

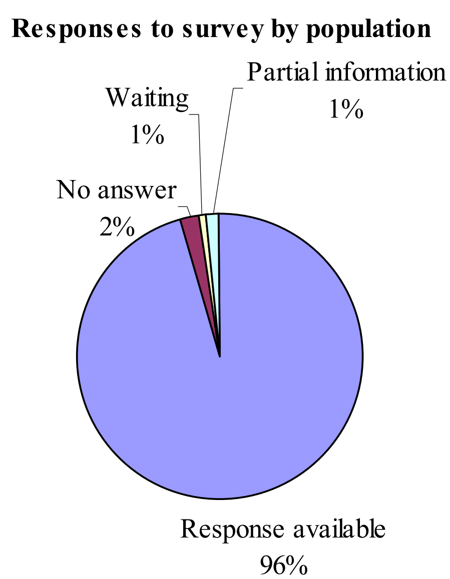

Figure 3.3 – Responses to survey by population

Figure 3.4 shows a map of the responses available. No responses are available for the following countries: Djibouti, Equatorial Guinea, Guinea-Bissau, Lybia, Republic of the Congo (COG), Sierra Leone and Swaziland.

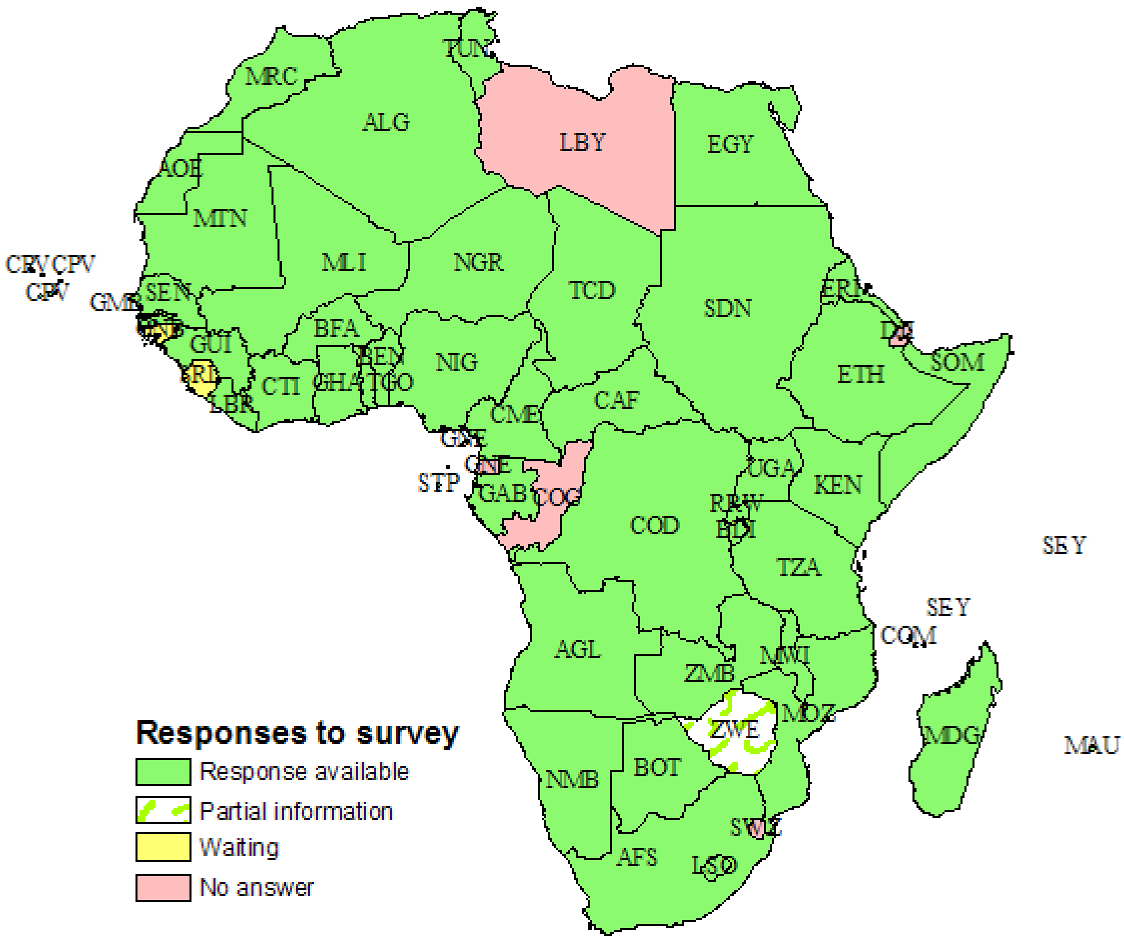

Figure 3.4 – Responses to the survey - country codes can be found in Appendix III (ITU code)

Most responses were obtained from regulators. As has been mentioned in Section 3.2 I have also contacted alternative 'non-official' sources. In many cases, however, these people have forwarded the e-mail and survey to the regulator, due to the survey's regulatory focus.

The responses collected are the responsibility of the respondents. Some care has been taken when selecting sources of information. The accuracy of the information cannot however be guaranteed.

The responses obtained have been translated into English, and are analyzed in the next chapter. A preliminary comment is that for the ‘open text’ questions responses are somewhat weak, and not much detail is provided - typically answers are very short. This may be explained by the additional effort required to respond to that type of questions (as opposed to the multiple choice ones) and by the fact that the survey is relatively long.

4. Analysis of the survey's results

This Chapter reports the main results of the survey described in Chapter 3. Most of the survey raw data can be found in Appendix VI. This chapter will present and analyze the most relevant results. It will start by characterizing the different licensing regimes in place in the different countries, including a discussion of certification and enforcement. It will then look at the use that is made of these bands, and discuss some difficulties in its use and regulation.

The quality of the information in this Chapter is purely dependent on the survey results. Inconsistencies in the data are possible, and are of the respondents and not the author's responsibility. Since countries in Africa can be so heterogeneous, and data is necessarily incomplete, care should be taken when drawing generalizing conclusions from the data, or trying to extend them to other settings. Despite this caveats, the data gathered is informative and suggests suitable recommendations for the enhancement of connectivity in the continent.

4.1 Regulatory regimes and diversity

This section describes the main elements of the regulatory regimes in African countries for the 2.4 and 5GHz bands. As Table VI.1 and Table VI.2 in Appendix VI illustrate, these regimes are significantly diverse in terms of *a priori* requirements for transmitters to obtain a license. In addition, there is significant diversity in restrictions applied to aspects such as transmit power and range, particular licensing conditions, equipment certification requirements, and enforcement regimes. In addition to diversity, there is significant uncertainty: in many countries regulation is changing, or is not clearly defined.

Diversity and lack of enforcement point to the general uncertainty and confusion associated with the regulatory regimes of the 2.4 and 5GHz bands across Africa. In addition, there is significant heterogeneity among countries.

4.1.1 Licensing regimes across Africa

International regulation of the 2.4 and 5GHz bands, and in particular the recommended/proposed licensing regimes have been discussed in Chapter 1. As mentioned, individual countries are largely free to regulate as they wish. The survey finds that as a consequence, the regulatory regime in the different countries is very diverse.

In general, in licensed regimes the regulator has to authorize the use of the bands, and it formally does so by issuing a license. In unlicensed bands the users are granted a general authorization to operate in the bands, provided they follow certain guidelines for power, range, etc.

Figure 4.1 below shows the regulation adopted by African countries for the 2.4GHz Band. This map shows the distribution of licensed and unlicensed regulation[55]. Countries represented in white are countries for which no data is available.

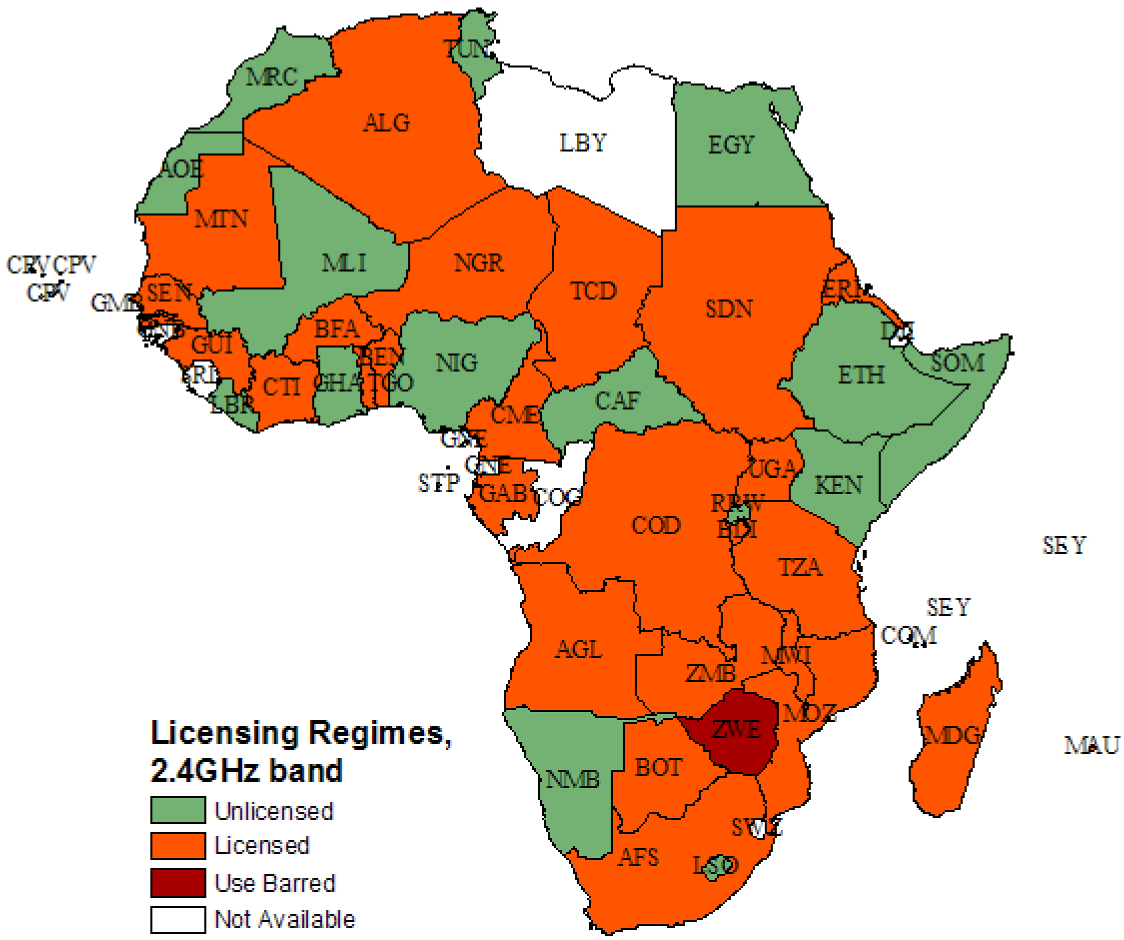

Figure 4.1 – Map of licensing regimes – simple categories for the 2.4GHz Band

[55] Categories and regulation are defined in different ways in all the countries. (See below for a more detailed categorization.) Being so the representation in the Figures is necessarily a simplification. In some countries, like in South Africa or Mauritius, unlicensed use is allowed indoors, while a license is required for less restricted communications. In those cases regulation is shown for the more restrictive conditions of use in terms of licensing (and less restrictive in terms of power, range, etc). See Appendix VI for more information.

Figure 4.1 shows that a mix of regulation is used. The majority of countries, however, require a license for operation in this band. There is an additional category used for the case of Zimbabwe where, since the beginning of 2004, the regulator has banned the use of these bands. The 2.4GHz band had been uncontrolled and used extensively for data links to ISPs and within commercial organizations. According to the information gathered, as from the end of January 2004 ISPs can no longer operate within this band.

Table 4.1 – Countries with different regulations for 2.4 and 5GHz Bands

Country	2.4GHz Band	5GHz Band
Uganda	Licensed	Regulation currently being prepared
Egypt	Unlicensed	Licensed
Tunisia	Unlicensed	Licensed
Nigeria	Unlicensed	Licensed

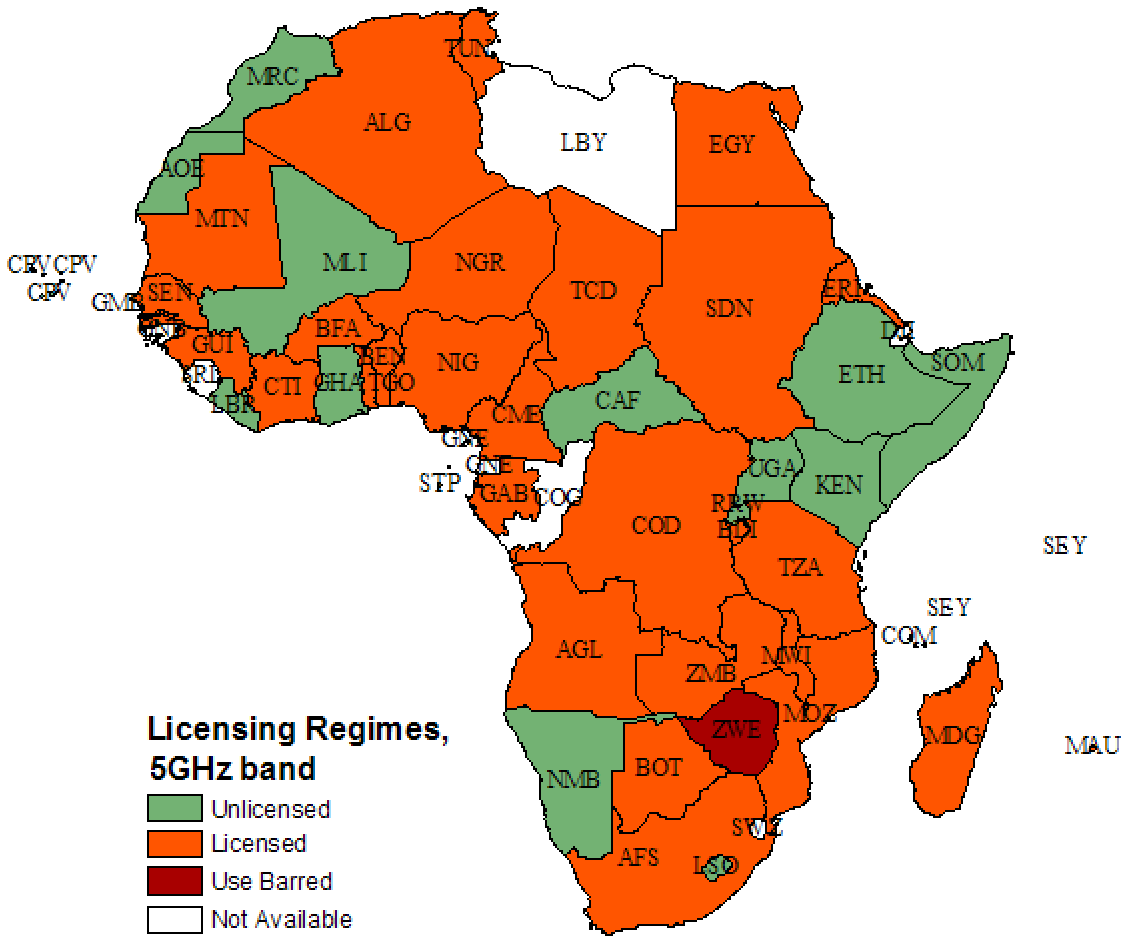

Figure 4.2 – Map of licensing regimes – simple categories for the 5GHz Band

Fewer responses are available for the 5GHz band. In general this band has been allocated more recently, with decisions as recent as the last World Radio Conference (WRC) 2003. Less information – and also less equipment - is available for it, and some countries are currently preparing regulation for this band (e.g. Uganda). Differences between the regulation in the 2.4 and 5GHz bands can be seen in Table 4.1, which shows, along with Figure 4.2, that there are fewer countries offering the 5GHz band as unlicensed (e.g Egypt, Tunisia, Nigeria, who have defined 2.4 as unlicensed, require a license for 5GHz).

Figure 4.3 and Figure 4.4 below show percentage information, at country level. For the 2.4 GHz Band a license is required in 54% of the countries, i.e. 29 countries. For the 5GHz Band the same is true for 57%, which corresponds to 31 countries.

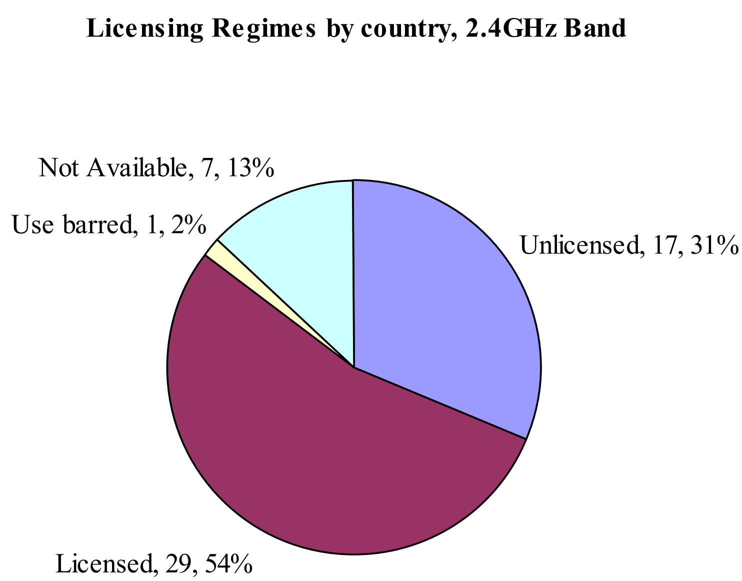

Figure 4.3 – Licensing regimes, 2.4GHz Band – % of countries

The Licensed/Unlicensed categories used above include a lot of different situations. Indeed, in some countries no license is required because there simply is no regulator – as in the case of Somalia or Liberia – or because there is no regulation in place, as is the case of Mali, where the regulator is currently being set up.

Licensing Regimes by country, 5GHz Band

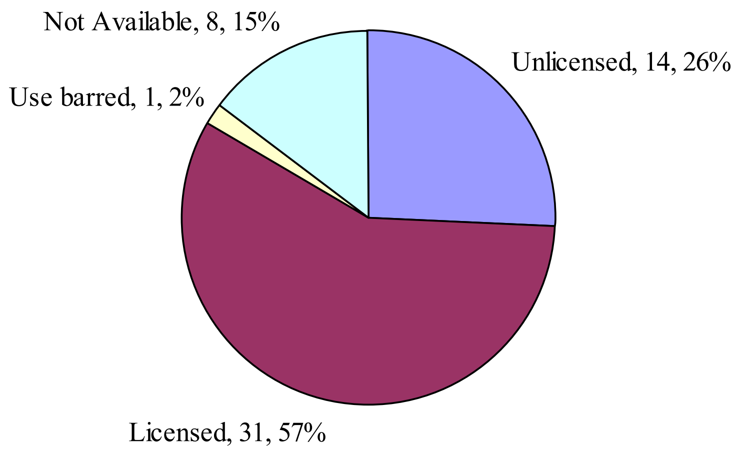

Figure 4.4 –Licensing regimes, 5GHz Band – % of countries

The Licensed/Unlicensed categories can be broken up further. As mentioned above, in general, in licensed regimes the regulator authorizes the use of the bands by issuing a license. This is normally accompanied by the payment of a license fee. In some cases this authorization is granted automatically (i.e., in practice it is a tax), while in others there is a formal approval process. Even when licenses are granted automatically, there are cases where some minimum conditions apply. In Botswana, for example, in order to apply for a license, the operators have to be registered in the country, and present a business plan. In unlicensed bands (where users are granted a general authorization) the regulator may require the users to register. This is generally a simple process (just requiring an address, or so). Payment of a fee is generally not required, but there are some exceptions – Kenya is one of them.

These four situations - i) Unlicensed; ii) Unlicensed with registration required; iii) Licensed but automatic on payment of fee and iv) Licensed not automatic - constitute progressively more restrictive licensing categories, and are used to further categorize the licensing regimes in place[56]. Figure 4.5 and Figure 4.6 show the licensing regimes broken down according to these distinctions.

[56] The distinction between the 'Unlicensed regime with registration' and the 'Licensed automatic regime' is mostly the issuance, for the latter, of a formal license and authorization, and often a more cumbersome process, implying the payment of a fee. However, e.g. in Kenya, which is under the 'Unlicensed regime with registration' the payment of a fee is still required.

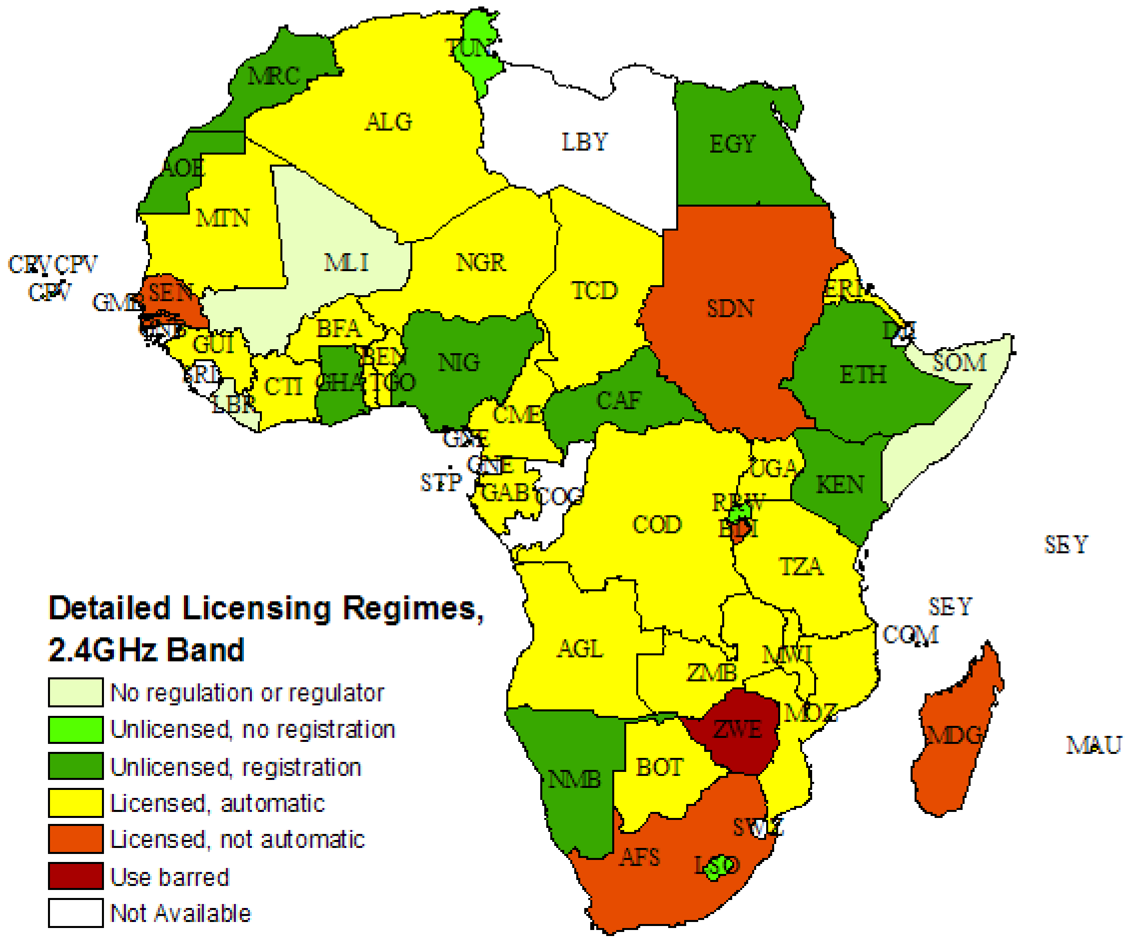

Figure 4.5 –Map of licensing regimes– detailed categories for the 2.4GHz Band

Figure 4.7 and Figure 4.8 show the percentage of countries using the different regulation. It can be seen that most regulators allow unlicensed use, but require a registration. Exceptions for the 2.4GHz band are Rwanda, Lesotho and Tunisia. It is significant that unlicensed bands, as are normally thought of in the United States (i.e., no license or registration required), only exist in Africa in these three countries (which represents 6% of the countries) for the 2.4 GHz Band, and 2 countries for the 5GHz Band (i.e. 4% of the countries). These are extremely low values. As for licensed use, license attribution is mostly automatic on payment of a fee[57].

[57] As mentioned above for the case of Botswana, some minimum conditions may still apply.

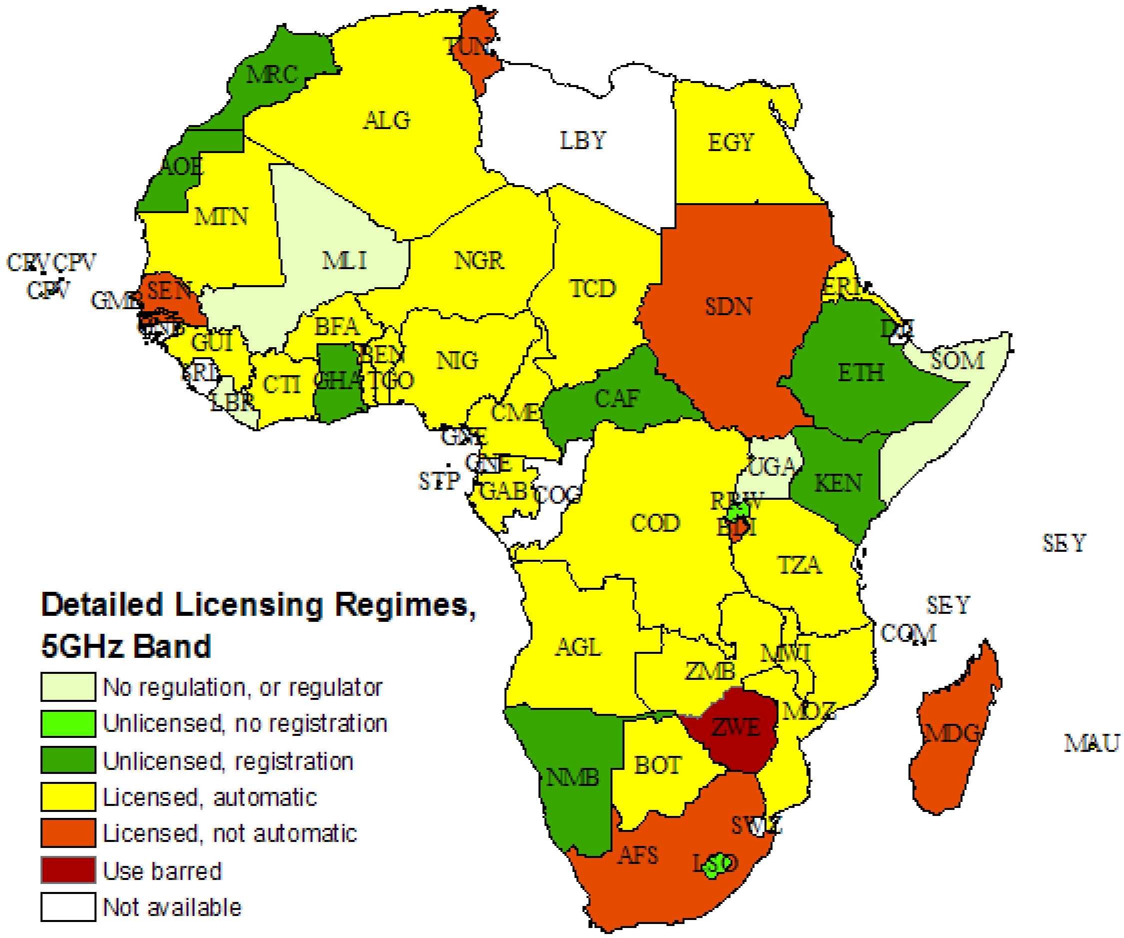

Figure 4.6 – Map of licensing regimes– detailed categories for the 5GHz Band

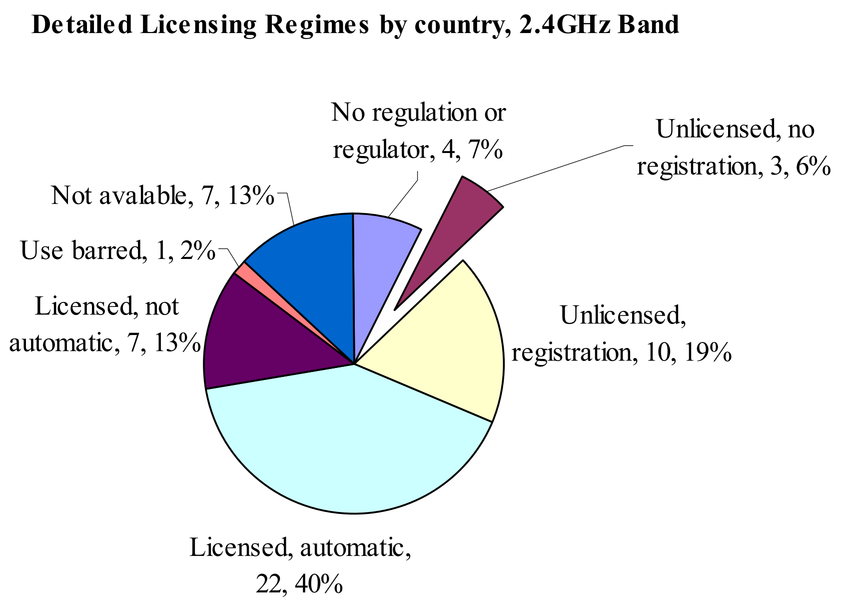

Figure 4.7 – Licensing regimes, 2.4GHz Band, detailed categories – % of countries

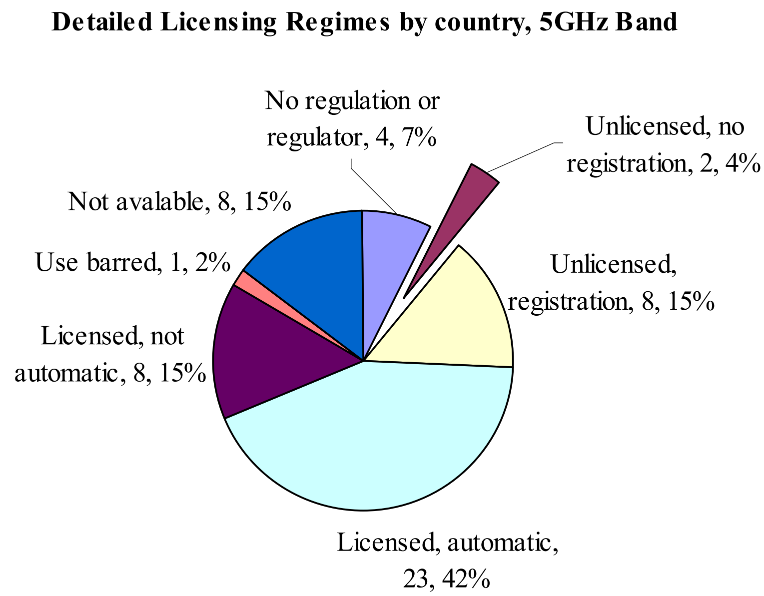

Figure 4.8 – Licensing regimes, 5GHz Band, detailed categories – % of countries

Equivalent results, broken by population, can be found in Appendix VII.

4.1.2 Non standard configurations and heterogeneity

There is extreme diversity in the regulation in place. Indeed, in addition to the licensing regime shown above countries place all sort of restrictions. There are often requirements of equipment certification, as well as restrictions on the maximum power and range, and on services (e.g. only data and no voice allowed) etc. In addition, some countries impose special regimes, such as setting different conditions for incumbents, requiring companies to register in the country, etc. Complete details for some of these differences can be found in Appendix VI. Selected illustrative examples are listed here:

- In Eritrea, the monopoly operator can use the 2.4 and 5GHz bands freely, while companies like ISPs have to pay a fee.
- In Botswana, despite the fact that license attribution is said to be automatic, some minimum conditions apply: in order to receive a license ISP operators are required to be a registered company in Botswana and also have to prove their financial sustainability by providing their business plan.

- In Namibia the bands are unlicensed, but ‘any use beyond the boundaries of one’s property, it's illegal’[58].
- South Africa and Mauritius have a tiered regime, having different licensing requirements or fees for different transmitter ranges. In South Africa, specifically, use is unlicensed in more restrictive range conditions (within single premises, or indoors) while it is licensed beyond those limits (i.e., between premises or outdoors).
- In Mozambique the use of the 2.4 GHz band is not allowed for commercial purposes.

Regulation in the 2.4 and especially in the 5GHz band is relatively recent. In some countries (e.g. Mali, Somalia, Liberia) regulation is not clearly defined, and several countries are implementing new regulation, or changing the existing regulation. Such are the cases of, for example, Guinea, Egypt, Nigeria, or Uganda.

It is not possible to code some of these conditions and characteristics when reporting the quantitative results for the survey. Qualitatively, however, these results point to a situation of significant heterogeneity of licensing regimes in place across African countries.

4.1.3 Certification

Some countries require equipment certification. Certification generally consists of a series of tests to ensure the equipment complies with certain specifications, for example in terms of out-of-band emission, etc. Both the FCC in the US (FCC ID website) and the European Union (EU website) certify devices in this manner. In some other countries certification can be simply mandating the devices to be used to be certified by the FCC, the EU, or other. In the US, certification is used in unlicensed bands[59] can be seen as a counterbalance to licensing.

The survey enquired about whether the different regulators certify equipment to operate in the 2.4 and 5GHz bands. The results can be seen in Figure 4.9 and Figure 4.10, respectively. At least half of the countries certify equipment for both bands, and certification is higher for the 2.4 GHz Band, which is an expected result, since equipment in this band is more ‘mature’.

[58] Contact with ISP in Namibia.
[59] According to Part 15 regulation.

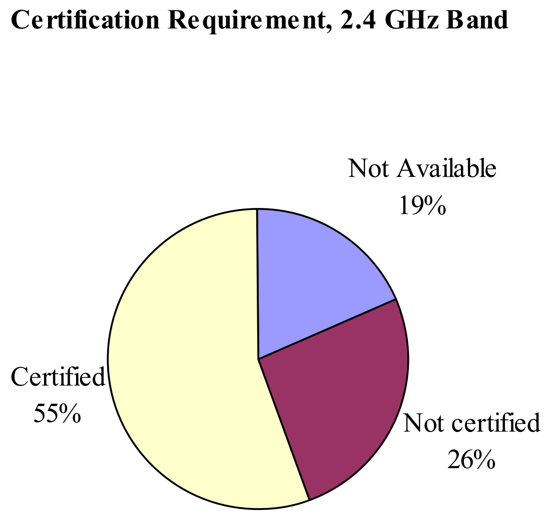

Figure 4.9 – Certification for 2.4GHz Band

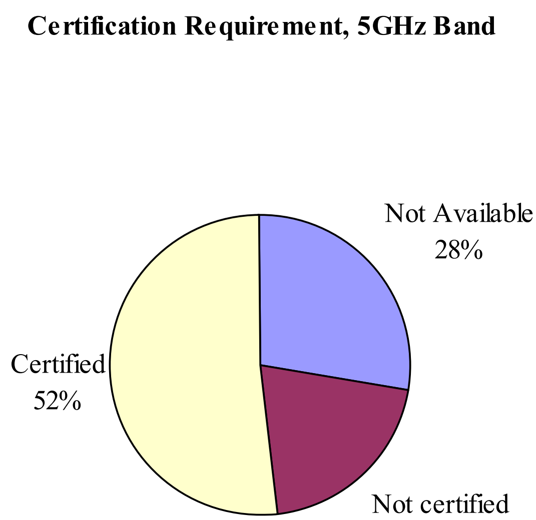

Figure 4.10 – Certification for 5GHz Band

Figure 4.11 and Figure 4.12 show information on certification by licensing categories. We may be in the presence of two combined effects. On one hand laxer licensing regimes can sometimes be the consequence of regulators that 'wash their hands' from ensuring well functioning bands. This may explain why certification requirements are not strong for the less restrictive licensing regimes. In the opposite direction, and since these bands are normally regulated on a 'best-effort' or 'no QoS guarantee' basis, regulators may choose to certify the equipment to operate in these bands to have some control over interference. This may explain the strong certification requirements for the countries with an 'Unlicensed/Registration' regime[60].

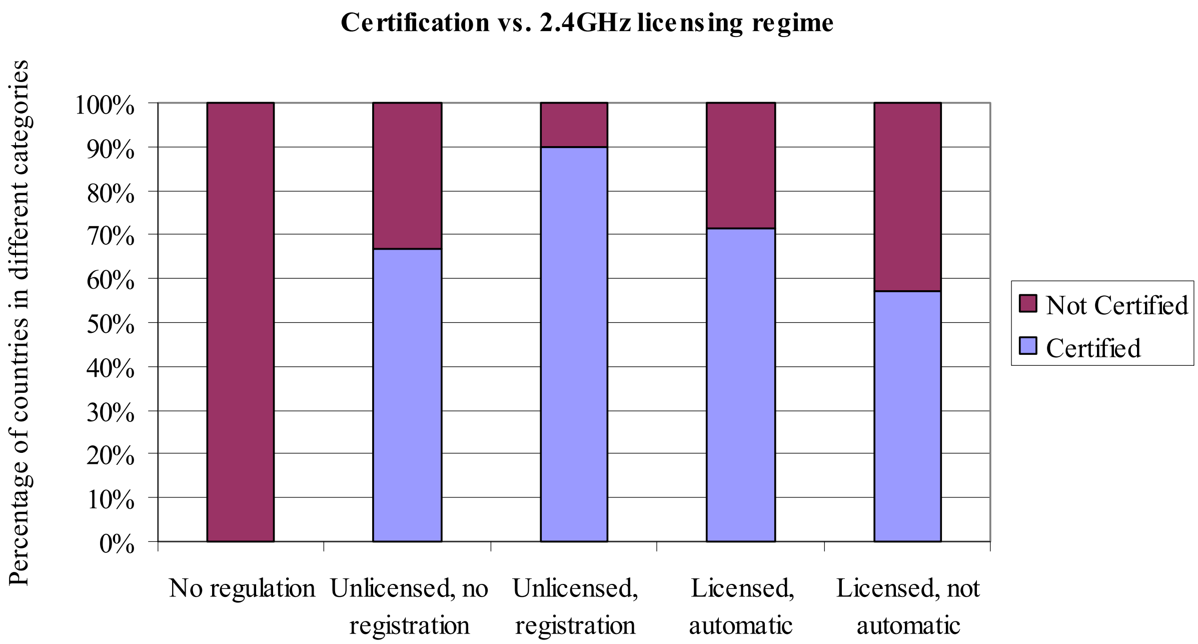

Figure 4.11 – Certification vs licensing regime for 2.4GHz Band

[60] For significance analysis see Appendix VIII. Not all the difference in proportions are significant. For unlicensed bands in particular results are weak because of small sample size.

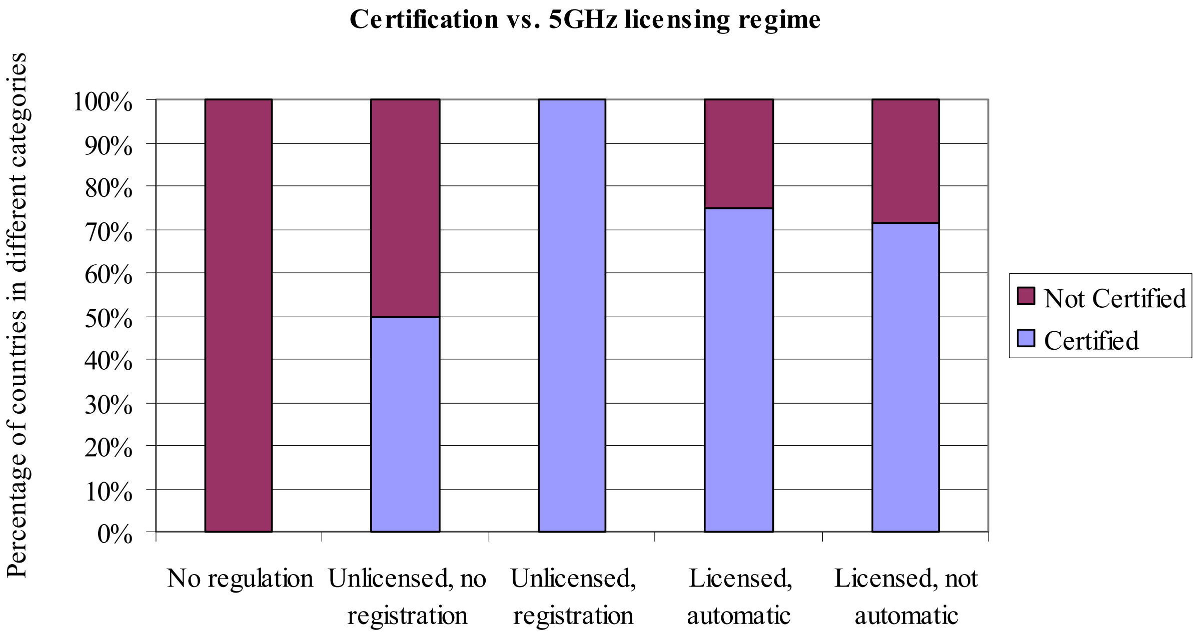

Figure 4.12 – Certification vs licensing regime for 5GHz Band[61]

4.1.4 Enforcement

Enforcement of these rules is limited. The survey asked the regulators if the regulations in the 2.4 and 5GHz bands were strictly enforced. It further asked whether regulators had the capacity (technical or other) to enforce regulations. Some of the responses affirmed that regulations were strictly enforced. Nevertheless, some of these regulators did not have the capacity to do it. Figure 4.13 shows the corresponding results.

Even though 50% of the countries contacted say the regulations are strictly enforced, only 20% says it has the capacity to do so. Most of the responses come from regulators, who have some incentive to inflate this numbers (since it is their responsibility to enforce the rules) but also some incentive to deflate them (since they may want to apply for funds to get additional equipment). As a consequence there is a fair amount of uncertainty with regard to actual enforcement. In any case, the figures suggest low enforcement.

[61] Idem.

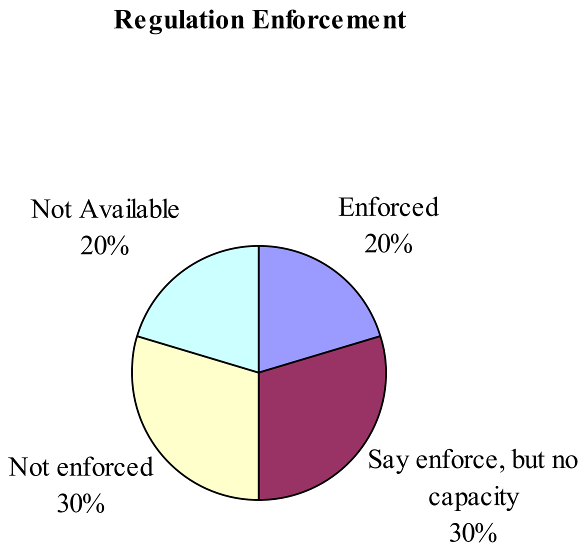

Figure 4.13 – Enforcement – percentage of countries

Crossing enforcement data with licensing information, and for the 2.4 GHz band (see also Figure 4.23, p.92), results show that enforcement is minimum for the unlicensed unregistered regulation. As argued then, this may indicate that these regulators in practice may choose unlicensed regulation to 'wash their hands' from any responsibility to monitor or resolve any conflicts that may arise. For the remaining categories the more regulated the use, the less enforcement is exercised – the regulator may consider that, by restricting the licensing *a priori*, it can relax enforcement *ex ante*.

From the information collected, it seems to be the case that in many countries there are significant levels of 'illegal transmitters', or transmitters going above the maximum allowable power levels - examples are Gabon, Senegal, Namibia, Cameroon, Angola and Uganda. This may happen because operators know regulation is not or cannot be enforced. Botswana has advanced an alternative explanation: the fact regulation varies from country to country may lead to misinformation. I.e., since these bands are unlicensed in some countries, people may believe they are also unlicensed in the countries where, in fact, they are not.

The lack of enforcement has in practice been a problem in some countries, where bands are said to be saturated because users exceed the allowable power levels. According to the survey, this is the case in Cameroon, Angola and Uganda.

Several regulators have mentioned that they are in the process of acquiring appropriate monitoring equipment to reduce the abuses in their respective countries. Examples are Angola, Botswana, Cameroon, Gabon, Malawi and Senegal.

4.2 The use of the 2.4 and 5GHz bands

Despite the diversity described above, these bands are being used in most African countries. The main users are ISPs, followed by Telecom operators. There are reports of the advantages of using these bands, such as low cost of existing infrastructure, and reduced fees and barriers to entry. The difficulties or limitations associated with use will be explained in the following section.

We find that the most common use of these bands is for “hotspot” style or other localized coverage in urban areas. Nonetheless, a significant 37% of the countries that responded to the survey are using wireless technologies operating in these bands for providing backhaul network connectivity in rural areas (see Figure 4.17). We also find that there are relatively more countries deploying wider area coverage networks in licensed environments than in unlicensed ones. A possible explanation will be presented in the following section.

4.2.1 Experiences of use and users

Some of the technology used in the 2.4 and 5GHz bands is relatively recent. Given generally the low penetration and low use of technology in Africa, and given the fact that some technology takes time to reach the continent, it could be expected that these bands would have a moderate to low use.

Responses to the survey show, however, that these bands are being used in most African countries.

Figure 4.14 shows a usage map of the bands. Only in Central African Republic and in Ethiopia are these bands not being used. Some countries have indicated explicitly that only the 2.4 GHz band is currently being used. That is also indicated in the Figure[62].

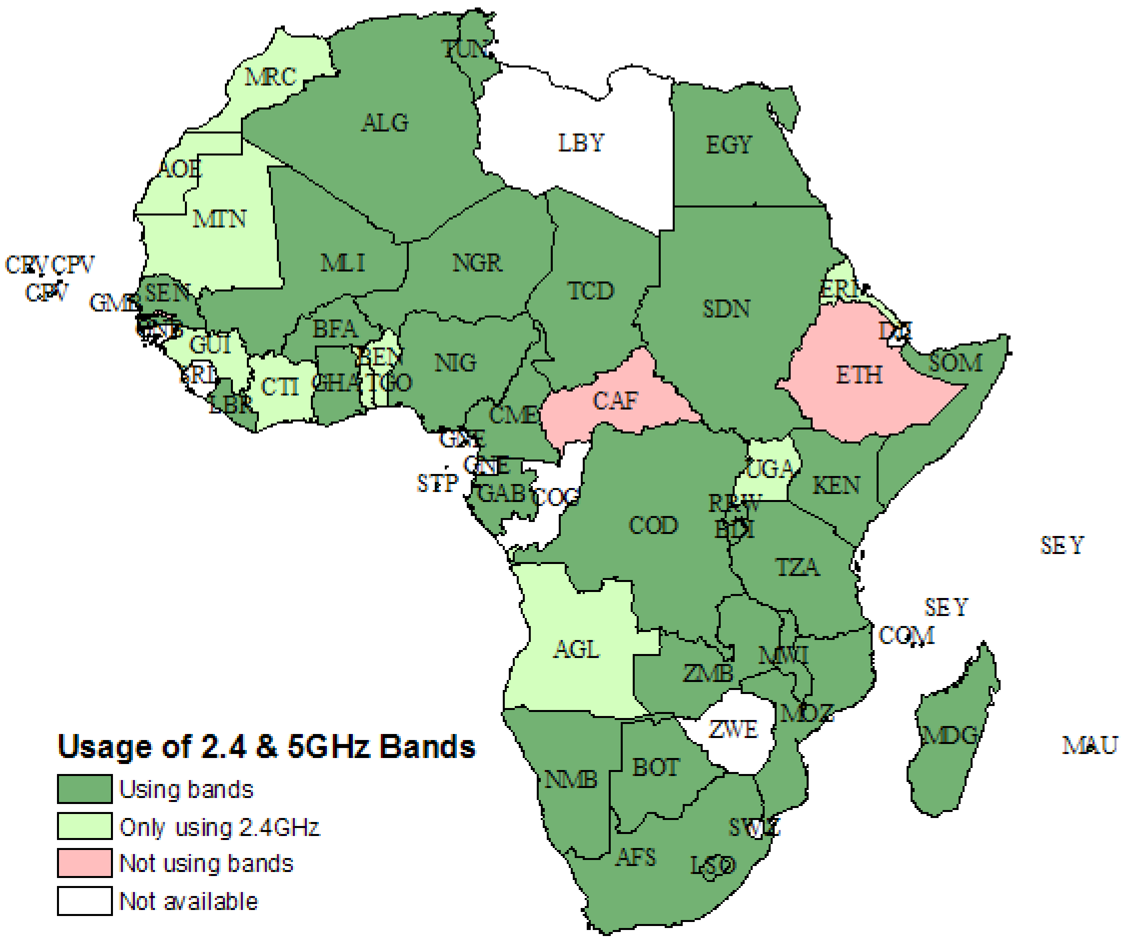

Figure 4.14 – Usage map of 2.4 and 5GHz Bands

The ubiquitous use of the 2.4 and 5GHz bands seems to indicate that they may hold an opportunity for the countries in Africa. Unfortunately the data gathered does not allow us to take any conclusions as to the intensity of use of the bands – i.e, we only know whether or not the bands are being used in a particular

[62] Countries categorized as 'Using the bands' are not necessarily using both the 2.4 and 5GHz – they have simply not been specific on which bands are being used.

country, but do not know whether use is widespread, in-depth or sporadic. It does show, however, that a significant majority of African countries are indeed using the bands, which is, arguably, an unexpected result.

Low cost equipment, accessibility, and being an opportunity to build an alternative to the incumbent operator may explain the ubiquitous use of the bands. In addition, deregulation of the bands and reduced fees may further lower barriers to entry. In Kenya, for example, the survey reports that:

> "Even though, these users must apply for a permit from the commission for the sake of our database and inventories, the fee […] is minimal US$132. This factor has attracted a great deal of operators into these bands unlike before when they used to be charged approximately US$800[63]".

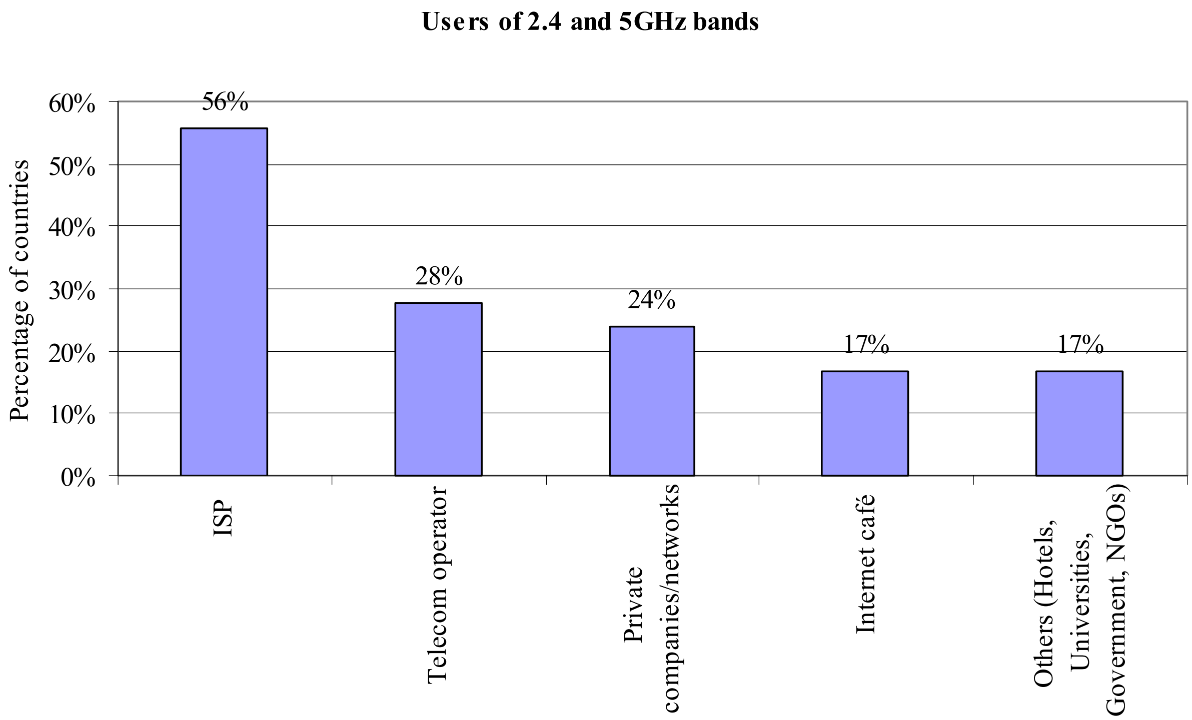

Figure 4.15 – Main users of 2.4 and 5GHz Bands[64]

Figure 4.15 shows that the main users of the bands are ISPs. More than half of the countries have indicated them as one of the users. Telecom operators come as the second most important users, followed by private companies/networks – several companies use e.g. the 2.4 GHz band to provide connectivity between their buildings or sites.

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[63] Response to survey from Kenya.
[64] Countries can choose more than one type of user.

These bands can serve as a viable alternative to leased lines: in Cape Verde the government itself uses the 2.4GHz band to connect the different ministries and government sites, because the leased lines are too expensive. Also in the Seychelles the 2.4GHz band is said to compete effectively with leased lines. Senegal has mentioned that the lack of reliable infrastructure has led operators to develop wireless solutions to offer quality service to their costumers.

One of the motivations for this thesis was to study the opportunity for entrepreneurship in the context of the 2.4 and 5GHz bands. The fact that ISPs, who are generally small scale, are the most common user, gives us an indication that the 2.4 and 5GHz bands are indeed an opportunity for entrepreneurship. Whether this opportunity is enhanced by unlicensed regulation is a question for further research. I.e., in this section we are looking at the main users irrespectively of the licensing regime. Unfortunately, we do not have sufficient information to see under which regime are smaller players preferentially operating.

4.2.2 Localized coverage vs Backhaul connectivity in rural areas

In the US the most visible use of wireless technologies in the 2.4 and 5GHz is through hotspots, set up in urban centers in coffee shops, hotel lobbies, airports, etc.
Figure 4.16 shows that in Africa only 26% of countries indicate the existence of hotspots accepting payment.

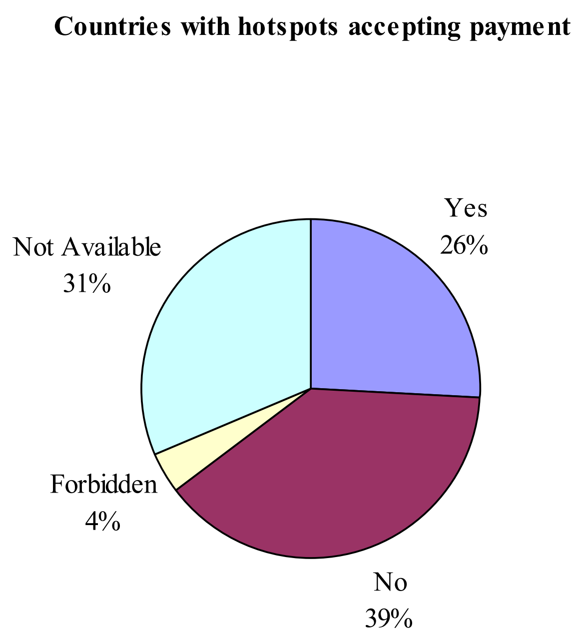

Figure 4.16 – Hotspots accepting payment of a fee

Figure 4.17 characterizes the main types of use for both bands. We find that the most common use of these bands is for "hotspot" style or other localized coverage in urban areas. This is not surprising given that the most widespread equipment is "WiFi" radios comporting to the IEEE 802.11b standard, designed primarily for use in hotspots.

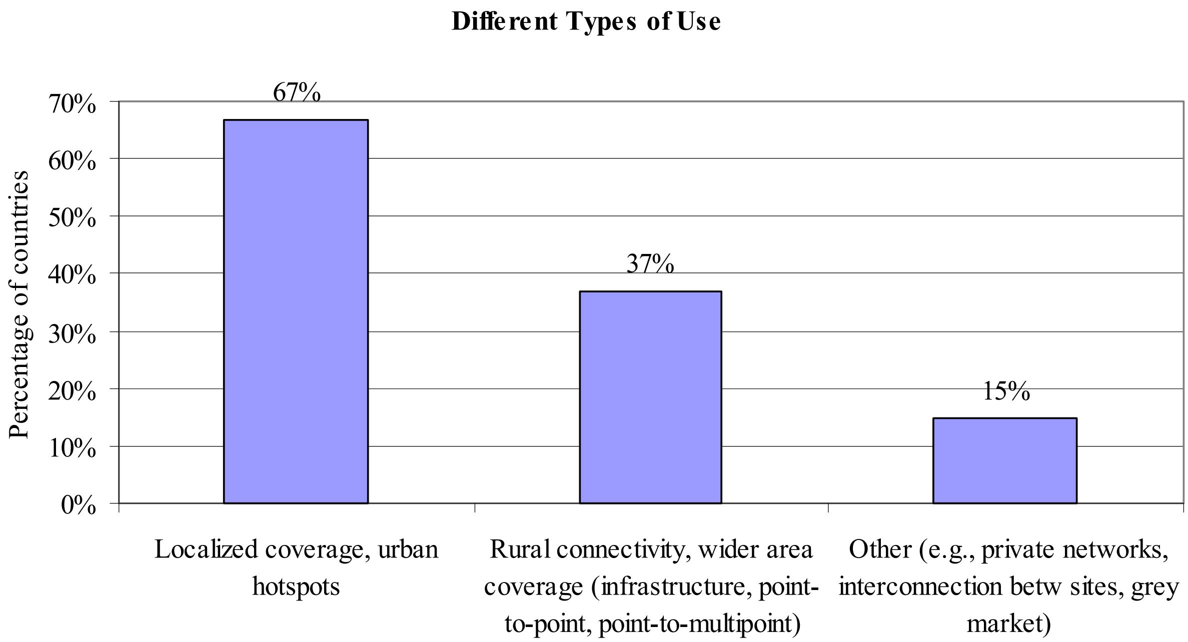

Figure 4.17 – Main types of use for 2.4 and 5GHz Bands[65]

Nonetheless, a significant 37% of the countries that responded are using wireless technologies operating in these bands for providing backhaul network connectivity in rural areas– this may point to a particular need that can be filled through the use of these technologies.

Unfortunately, the granularity of the data is not enough to determine who is using the bands for which purpose. I.e, we cannot know whether it is ISP or other operators who are using the bands for localized vs. wider area coverage.

[65] Countries can choose more than one type of use.

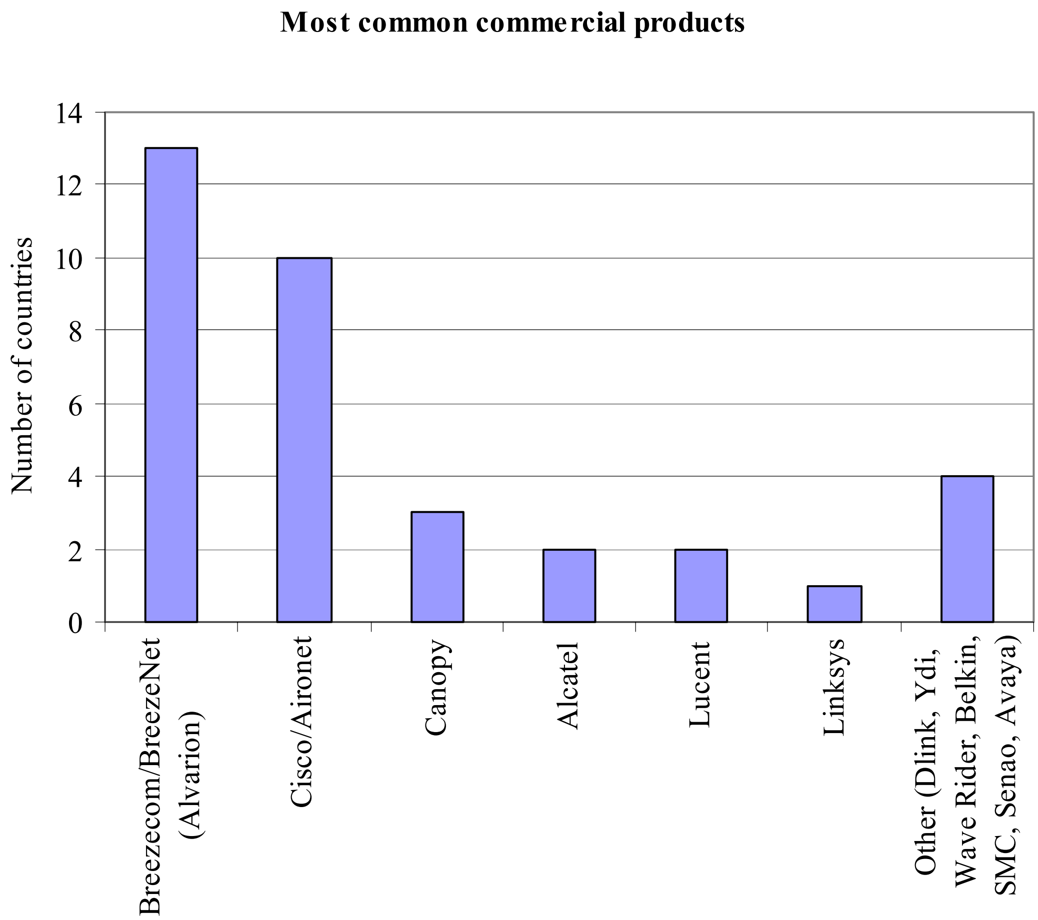

Figure 4.18 – Most common commercial products

When asked whether the protocols used were opened or closed most countries mentioned open protocols, in particular the 802.x family of standards. Figure 4.18 shows the most common commercial products. Breezenet, from Alvarion (previously Breezecom), is the most commonly mentioned product, followed closely by Cisco (Aironet) equipment. Breezenet is an open standard solution for point-to-point and point-to-multipoint links (Alvarion website). The Aironet/Cisco is a WLAN 802.11x product. The relatively high number of countries purchasing BreezeNet equipment emphasizes the importance of backhaul connectivity.

The idea behind this thesis is that the use of wireless technology in the 2.4 and 5GHz bands can represent an opportunity to enhance connectivity in Africa. Regulation serves different purposes[66]. Nevertheless, because the possibility to provide rural connectivity represents an important opportunity for Africa, where

[66] For survey information on what are the main objectives for the regulation currently in place see Appendix VII.

a big percentage of rural population remains isolated from most telecommunications equipment, it is important to look at the licensing regimes that favor this type of coverage and ensure that there are no unnecessary or excessive barriers to entry and use in the longer-range market.

The data from the survey does not directly give us information about the effect of regulation on the use of the bands. It does not tell us directly whether certain types of regulation are too strict – whether, for example, there is more use in unlicensed bands. It is also not possible to know whether certain regulation is favoring a particular type of user. This is because, again we do not have info about the intensity of use, nor can we directly cross user and licensing information. We can, however, compare the types of use that are present in a country with the corresponding licensing regime. In order to do that we have broken down the information concerning the type of use into Licensed and Unlicensed regulation – see Figure 4.19.

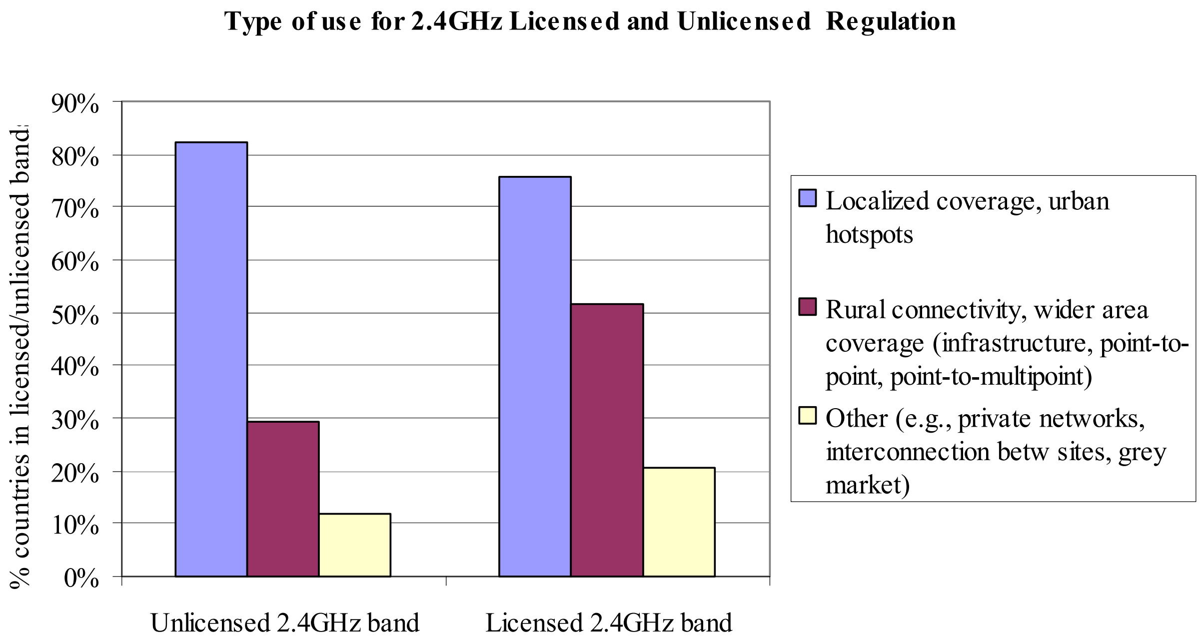

Figure 4.19 – Main types of use crossed with 2.4GHz Band regulation[67]

To start with it should be noted that there is a possible bias in the data, since regulators are less likely to be aware of the type of use for unlicensed bands – which they do not control.

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[67] Note 1 - This graph is constructed crossing usage information (which is for both the 2.4 and 5GHz band) and licensing information – for the 2.4GHz Band only. Since the 2.4GHz band is the one with most widespread use, this should not introduce a big distortion.
Note 2 - These are percentages of different numbers, so the fact that the percentage goes down does NOT necessarily mean that there are less countries providing that service.

With that in mind, we can proceed to analyze Figure 4.19. We find that there are relatively more countries deploying wider area coverage networks in licensed environments than in unlicensed ones.

Possible explanations are suggested below:

1. It happens that the users who prefer unlicensed bands, or for whom it is easier to get a license, happen to use the bands for specific uses, for example:
   - ISPs, the main users of the bands, prefer unlicensed bands, or tend to be barred from licensed ones because of barriers to entry, and they happen to use bands predominantly for localized coverage. In general, it could be argued that smaller companies or entrepreneurs may be more effective at a local level, whereas rural connectivity requires an additional degree of coordination and organization[68].
   - Telecom operators, who face less barriers in obtaining a license, are using these bands to provide rural coverage in their 'normal operations'. In Somalia, for example, Somali Telecom is using these bands for microwave links/point-to-point connections. I.e., it is not that unlicensed or entrepreneurs are not appropriate for rural connectivity. It is that those who do not face barriers to entry and can therefore easily obtain a license are taking advantage of the low cost and convenience of technology to deliver rural service[69].
2. The providers of rural connectivity prefer a licensed environment:
   - A more protected and certain licensed environment may be more appropriate for this type of infrastructure, which implies higher implementation and coordination costs.
   - It can happen that there is too much interference in unlicensed bands, and that therefore rural connectivity solutions are in practice not possible. This is not likely, as there is little infrastructure in Africa in the first place, and therefore the risk of interference is lower.
3. A third possibility is that the use of unlicensed bands use is so restrictive (in terms of power, range, etc) that the bands cannot be used for wider area coverage.

We do not have sufficient information to confirm the first two points, since we would need to know which users provide which type of services. The second hypothesis asks for caution, in particular in ensuring some certainty and stability in the business environment.

[68] I.e., it may be that the real barrier is not the licensing regime, but rather the fact the rural/wider area coverage requires a different type of organizational structure.

[69] Somalia is a different case, since there is no regulation, and therefore no need for a license.

Section 4.3.1 looks further into the third possibility by analyzing data from the survey and find that indeed, laxer licensing regimes place, on average, more restrictive conditions on power and range. This may explain why, when compared to licensed environments, wider area networks in unlicensed environments are limited.

4.3 Difficulties in use and regulation

This section is dedicated to potential problems associated with the use and regulation of these bands. I will look at how regulation can constitute a barrier to entry and use, and later look at interference problems and practical considerations linked to equipment.

We find that there are relatively more countries deploying wider area coverage networks in licensed environments than in unlicensed ones. This may suggest that more certain licensed environments are more appropriate for wider area networks. An alternative explanation, supported by the data gathered, is that countries allowing some license-exempt use usually have more stringent restrictions on this very use, for instance maximum power outputs, range of use, and so forth. Information about licensing will not, on its own, properly characterize the possible uses of these bands.

In addition we find that GDP per capita and teledensity do not correlate strongly with the type of licensing regime in place. Data suggests, however, that the use of the 2.4 and 5GHz bands is less restricted in African countries that enjoy a higher degree of competition in the telecommunications market, and potentially a lower degree of regulatory capture. Restrictions may in some instances be being used to control market power and keep barriers to entry high.

4.3.1 Licensing versus associated restrictions

Section 4.1.1 has described the licensing regimes in place across Africa, specifying the licensed/unlicensed use of the bands, as well as additional requirements such as the need to register, or to pay a fee. In addition, to licensing requirements regulation can be accompanied by specific restrictions, e.g. on power or range, and therefore the fact that a band is unlicensed does not necessarily mean that access or use are easier. One of the responses to the survey, for example, describes the situation where use is unlicensed, but "if one intends to use either band beyond the boundaries of one's property, it's illegal"[70]. It is therefore important to understand which kind of restrictions are defined to accompany regulations, since licensing information only will not properly or fully characterize the possible uses of these bands.

Restrictions can be applied in many different ways. By limiting the power, or circumscribing the allowed range – by limiting it to indoors, or to the bounds of a particular property, etc. These two are obviously related, since the power will determine the range and vice-versa. Further restrictions can be applied on the type of services to be used, by for example, barring voice services. In some countries regulators choose to protect the incumbent and existing operators by not allowing voice services, for example barring VoIP. In addition, in certain countries only certified equipment can be used. An indirect form of restriction is the type of enforcement in place, i.e., rules can be very restrictive, but if no enforcement is in place, it is equivalent to say that the conditions of use are relaxed. As should be evident from the above, crossing the licensing regimes with the restrictions will result in a wide variety of regulatory combinations with varying degree of 'restrictiveness'.

The country level information available from the survey is sometimes reported in different ways, making it difficult to catalogue restrictions precisely. It is however possible and useful to study the 'restrictiveness' trend between unlicensed and licensed bands. Are unlicensed bands, in general, more or less restrictive than licensed bands? In order to answer this question I have defined preliminary indexes for different types of restrictions – see Table 4.2. The higher the index the more restrictive a country is for a certain parameter – for example power, range, etc – e.g. a power index of 4 denotes the most restrictive regulation, in relative terms, for allowed emission power.

Table 4.2 – Definition of restriction class criteria

Index	Eirp (W)	Range	Services	Enforcement	Certification
0	Not limited	Not limited	No regulation	No regulation	
1	>=4	Outdoors long range (>1km)	Voice and data both allowed	Not enforced	Not certified
2	[1, 4[	Outdoors, short range	Not specified for voice	Enforced but no capacity	certified
3	[0.1, 1[	Indoors only	Only data allowed	Enforced	
4	<0.1				

70 Contact with ISP in Namibia

The groupings defined above are constructed and do not intend to represent in any way a particular distribution[71]. The objective is purely to allow for comparison – within the same category (power, range, etc) of the levels of restrictions in different countries. It does not make sense to compare indexes from different categories, since there is no magnitude relation or normalization. Despite the different propagation behavior for the 2.4 and 5GHz band the same indexes are used for both the bands.

The data from the survey was used to calculate average values of 'restrictiveness' associated with the different licensing regimes. More information on the type of restrictions imposed can be found in Appendix VI. Figure 4.20 shows the trend of 'restrictiveness' across licensing types, for the 2.4 GHz Band. From the graph we can see a trend, in particular for power and range, for a more restrictive environment in more relaxed licensing regimes.

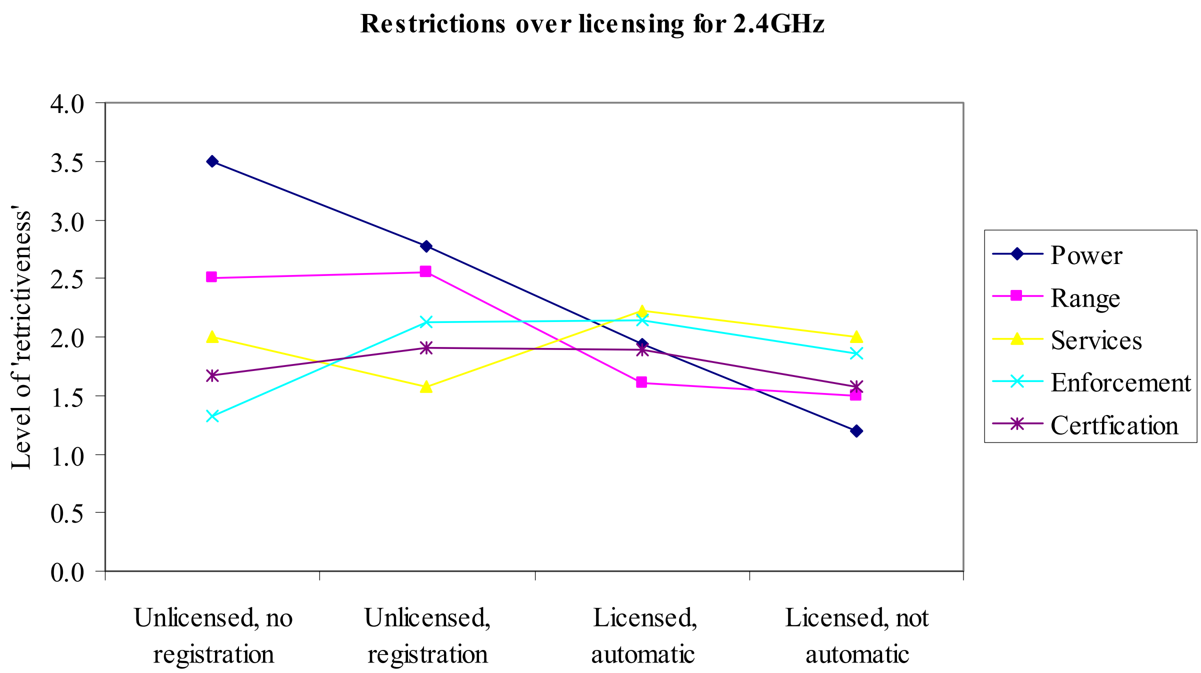

Figure 4.20 – Restrictions over licensing for 2.4GHz Bands

Figure 4.21, shows the results, for power, showing the associated standard errors. Significance analysis has also been performed, and additional information is available in Appendix VIII. A similar analysis is done for range - see Figure 4.22, below.

[71] I.e., when deciding on the categories the objective was not to have the same number of countries in each group, or any similar criteria.

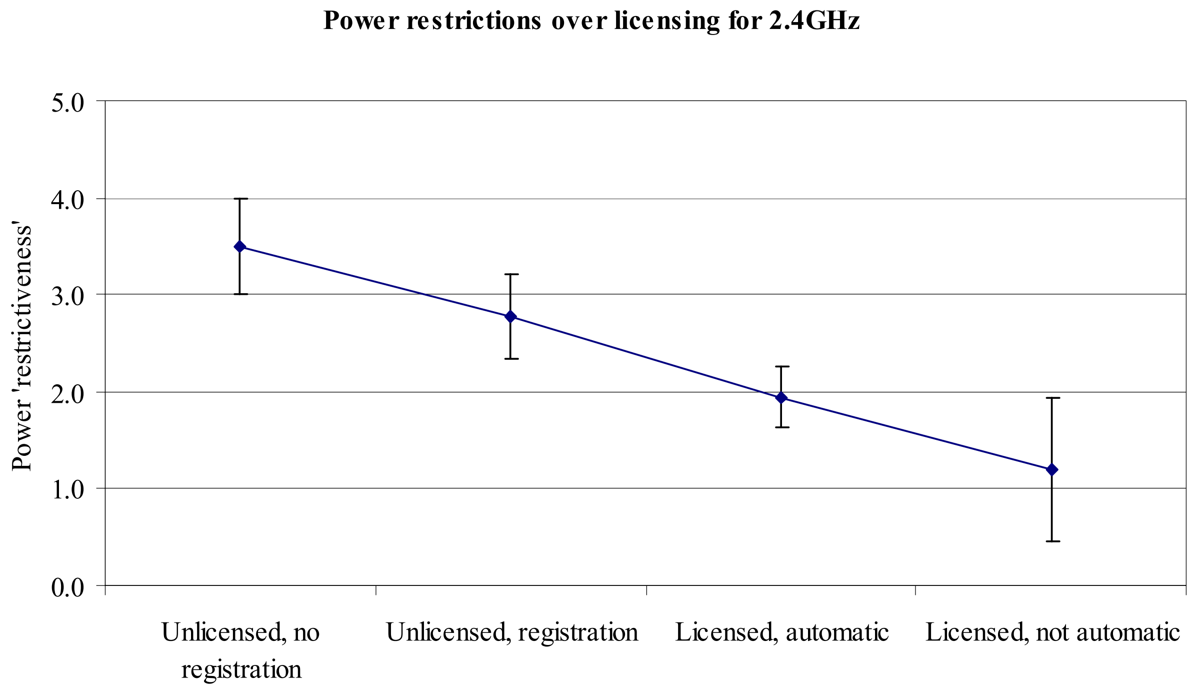

Figure 4.21 – Power restrictions over licensing for 2.4GHz Bands

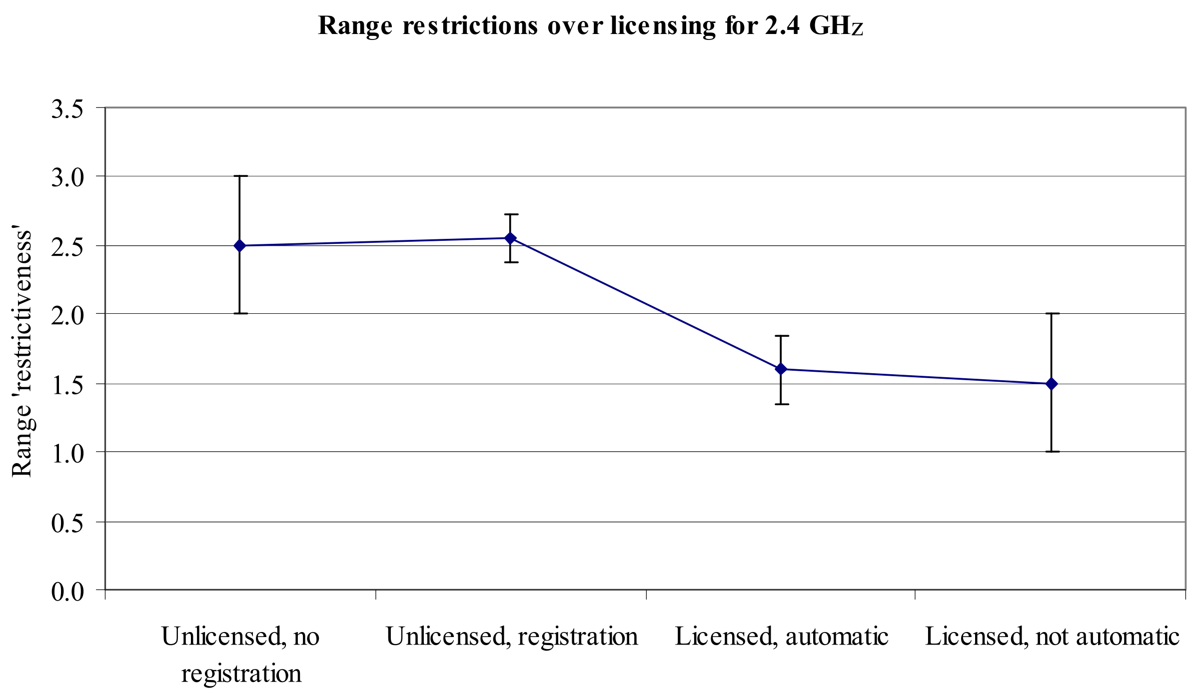

Figure 4.22 – Range restrictions over licensing for 2.4GHz Bands

It is significant that, even when accounting for differences in available data points for each category and standard errors, the trend still holds[72]. I.e., more relaxed licensing regimes have, on average, more restrictive conditions places on power and range. This is an important result, since it suggests that the African countries that use unlicensed regulation tend to place a burden on the conditions for use. It further indicates that should unlicensed bands be perceived as less successful, the reason could simply be the fact that the associated restrictions are higher.

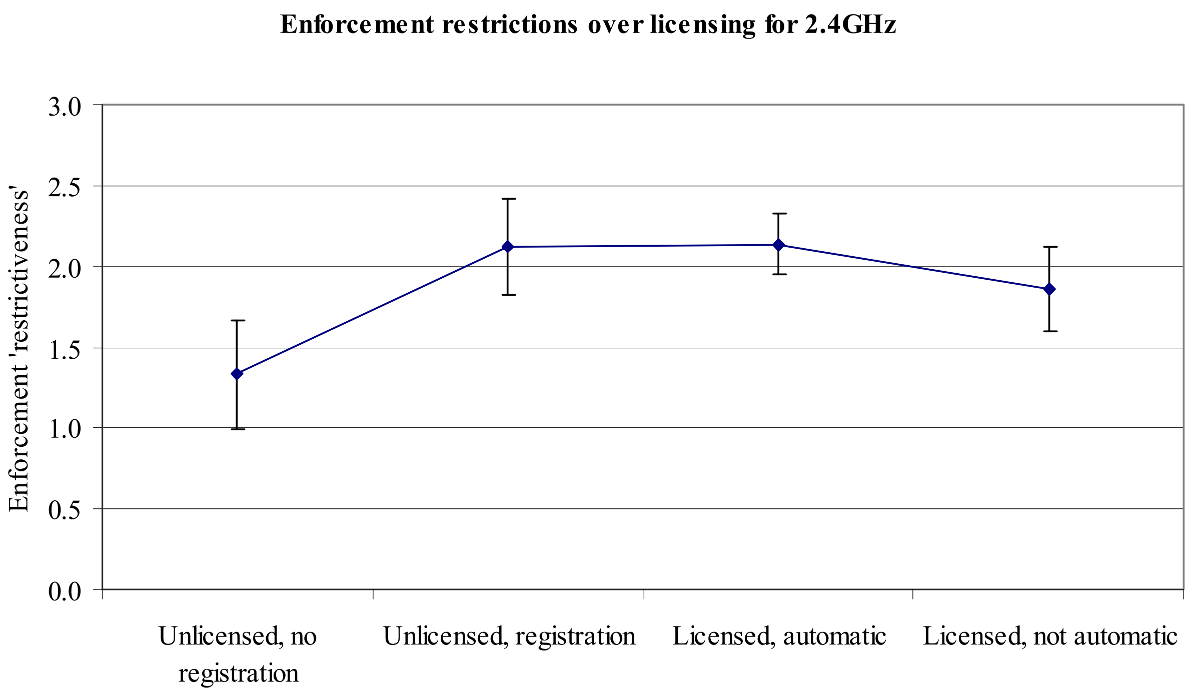

Figure 4.23 – Enforcement restrictions over licensing for 2.4GHz Bands

Results for enforcement are show that enforcement is minimum for the unlicensed unregistered regulation. This may indicate that these regulators in practice may choose unlicensed regulation to 'wash their hands' from any responsibility to monitor or resolve any conflicts that may arise. For the remaining categories the differences (service and certification) are not significant – see Appendix VIII.

[72] I have performed a regression analysis to study the significance of these results.

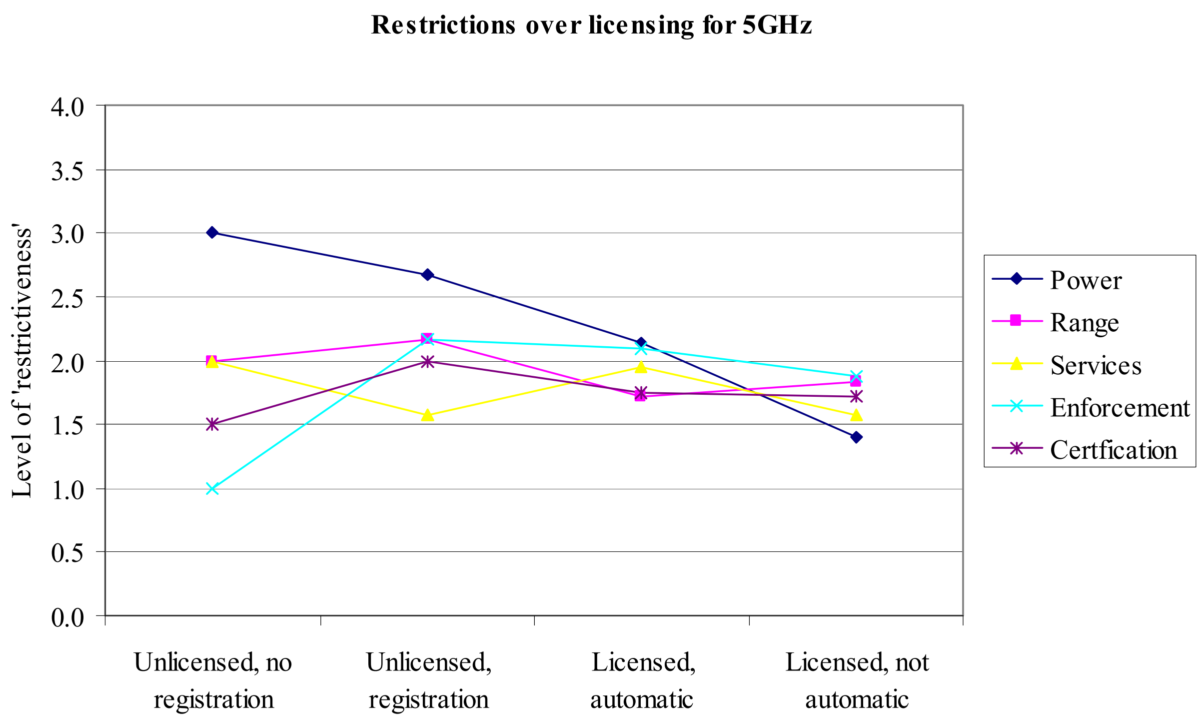

Figure 4.24 – Restrictions over licensing for 5GHz Bands

Figure 4.24 shows the same analysis for the 5GHz Band. The 5GHz band is less restrictive in terms of power than the 2.4 GHz band, which matches the differing propagation characteristics for these frequencies. Comments for this band are similar in what respects power restrictions, although results are less significant (see Figure 4.25). Dependence on other restriction types is not significant (see Appendix VIII for more information).

Going one step further, I have crossed the usage information with the usage restrictions, to see whether wider area coverage usage corresponds to the situations where there are fewer restrictions. Although the data shows such trend, the result is not statistically significant, and is thus not conclusive[73]. It is possible that it is still early to see the effects of licensing restrictions on usage, since the technology is rather recent. In addition, the data for this particular topic is rather incomplete.

[73] More details can be found in Appendix VIII.

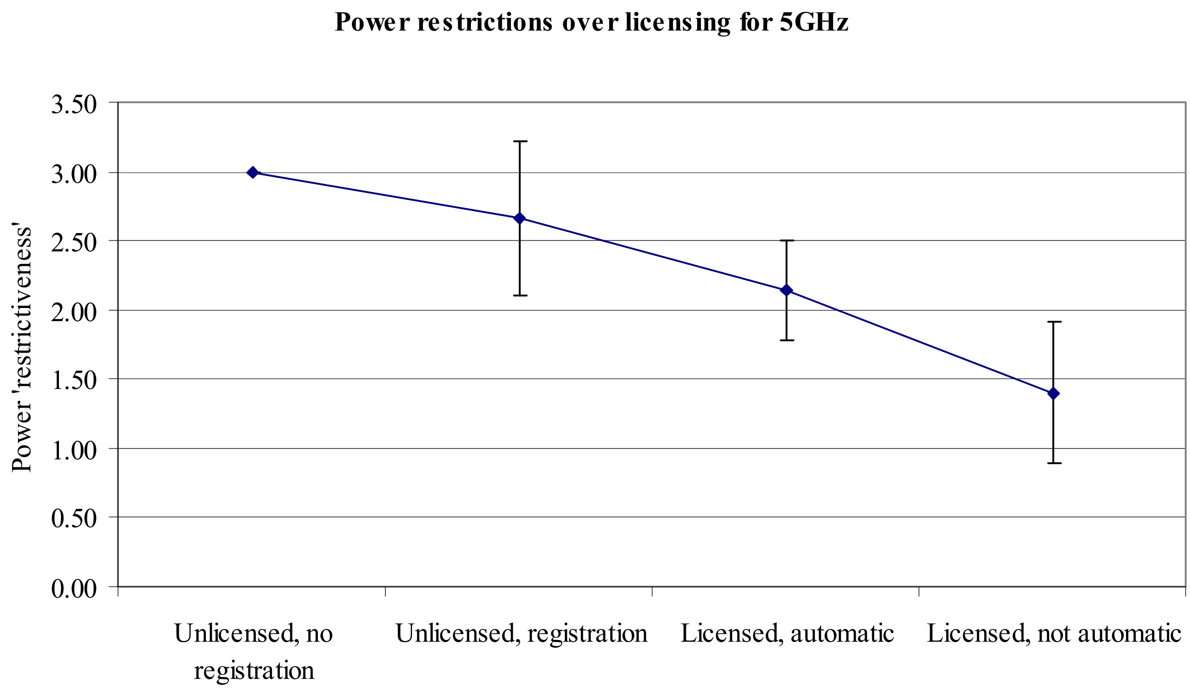

Figure 4.25 – Power restrictions over licensing for 5GHz Bands
Note: no error bar can be calculated for the 'Unlicensed, no registration' category, because there is only one data point

The results in this section show that restrictions are higher for laxer licensing regimes. Information about licensing will not, on its own, properly characterize the possible uses of these bands, i.e.: the fact that a band is unlicensed does not necessarily mean that access or use are easier, since regulation can be accompanied by specific restrictions for use. Choosing the right level of restrictions may be instrumental in enabling some applications, while providing a certain level of protection. The results suggest that the restrictions in place in some regimes may be excessive, and should be loosened.

4.3.2 Restrictions as barriers to entry

This section presents the result of a cross correlation analysis between the licensing and restrictions data from the survey and general and ICT macro indicators for each country.

Table 4.3 shows the survey variables that were used for the cross correlation analysis, along with the coding.

Table 4.3 – Dependent variables, from survey, and respective coding keys

Dependent Variables	Coding Key
Licensing categories for the 2.4 and 5GHz Band	0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic
Power (EIRP) restrictions for the 2.4 and 5 GHz Band	0: not limited; 1: >=4; 2: [1,4[; 3: [0.1,1[; 4: <0.1 – in Watts
Range restrictions for 2.4 and 5 GHz Band	0: not limited; 1: Outdoors long range (>1km); 2: Outdoors short range; 3: Indoors only

These variables were crossed against several indicators, collected from different sources. Table 4.4 shows details of the indicators used, which include ICT general indicators (e.g. teledensity, Digital Access Index, etc), ICT competition indexes (level of competition in the local and domestic long distance markets), GDP per capita, and country level general governance indicators (e.g. control of corruption, regulatory quality and transparency).

This cross correlation analysis is not meant to show any causality between the indicators and the survey results. In any case these are very early results of licensing, and it would be difficult to see such causality results in the data. The objective is rather to characterize the different country's contexts, and observe whether some of the survey results fit well into the landscape characterized by the other indicators. No explicit regression is therefore used. Spearman correlation between the variables and the indicators is used to perform the analysis[74].

[74] Spearman correlation is used, instead of the more common Pearson correlation, which can only be used with continuous variables. As can be seen in the table, a lot of the variables and indicators are only ordinal.

Table 4.4 – Macro Indicators for the country and ICT sector: coding key and sources

Type of indicator	Indicator	Meaning	Coding Key/interpretation	Source
General ICT indicators	Teledensity 02	Total teledensity (fixed + cellular subscribers)/population	Not coded	Obtained from ITU[75]
	Internet Hosts 02 per capita	Internet hosts/population	Not coded	Computed from ITU (both internet hosts & population)[76]
	DAI	Digital Access index	Constructed w/ knowledge, affordability, infrastructure & quality factors	Downloaded from ITU[77]
	Internat'l internet bandwidth per 100 inhabitants		Not coded	Downloaded from ITU[78]
	Internet tariff as a percentage of GNI	Internet access price as percentage of per capita income	Not coded	Downloaded from ITU[79]
ICT competition indexes	Local Competition	Competition in the local market	1: Monopoly; 2: Duopoly; 3: Partial competition; 4: Full competition	Obtained from ITU[80]
	Domestic LgD Competition	Competition in the domestic long distance market	1: Monopoly; 2: Duopoly; 3: Partial competition; 4: Full competition	Obtained from ITU[81]
GDP per capita	GDP per capita	Gross Domestic Product per capita (GDP/Population)	Not coded	Computed from ITU (GDP & population)[82]
General governance indicators	Control of Corruption		From -2.5 (less control) to +2.5 (more control)	World Bank[83]
	Regulatory Quality		From -2.5 (less quality to +2.5 (more quality)	World Bank[84]
	Transparency		From -2.5 (less transparency) to +2.5 (more transparency)	World Bank[85]

[75] From World Telecommunications Indicators Database 2002, obtained from ITU, through Ms. Esperanza Magpantay. Available series list can be accessed at http://www.itu.int/ITU-D/ict/publications/world/material/series.pdf.
[76] See supra note.
[77] Data available at (ITU DAI website).
[78] See supra note.
[79] See supra note.
[80] Regulatory Information obtained from (ITU Regulatory website) and from Ms. Nancy Sundberg.
[81] See supra note.
[82] See supra note 75.
[83] World Bank 2002c.
[84] See supra note.
[85] See supra note.

Table 4.5 illustrates the most significant result of this analysis: countries that have lower competition in their local and long distance markets impose more restrictions on use, on both power and range[86]. This result is significant at the 95% confidence level, and for some cases also for a 99% confidence level. While this type of analysis cannot prove a causal relationship between these two factors, it suggests that the use of unlicensed spectrum is less restricted in African countries that enjoy a higher degree of competition in the telecommunications market, and potentially a lower degree of regulatory capture. In countries where competition is low, restrictions are likely to be set at an excessive level, and should be loosened.

Table 4.5 – Spearman Correlation (Rs) between survey variables and ICT Competition indexes[87]

	Local Competition				Domestic LgD Competition			
Indicators	**n**	**Rs coefficient**	**p**	**Significant 95%?**	**n**	**Rs coefficient**	**p**	**Significant 95%?**
Licensing Categories for 2.4GHz Band	43	0.15	0.34	No	41	0.21	0.19	No
Licensing Categories for 5GHz Band	41	0.09	0.46	No	39	0.17	0.31	No
EIRP Restrictions for 2.4GHz Band	**34**	**-0.58**	**0.0004**	**YES**	**33**	**-0.58**	**0.0004**	**YES**
EIRP Restrictions for 5 GHz Band	**26**	**-0.42**	**0.03**	**YES**	**25**	**-0.52**	**0.008**	**YES**
Range Restrictions for 2.4GHz Band	**37**	**-0.41**	**0.012**	**YES**	**36**	**-0.43**	**0.009**	**YES**
Range Restrictions for 5 GHz Band	**31**	**-0.40**	**0.03**	**YES**	**30**	**-0.42**	**0.02**	**YES**

Appendix IX shows that general ICT indicators do not correlate strongly with the licensing regimes in place, nor with the power and range restrictions imposed on the use of these bands. Indeed, most of the correlation are not significant, and in some cases are not consistent across bands.

The survey variables do not correlate strongly with GDP per capita either, nor with the general governance indicators. The governance indicators, produced by the World Bank, are not specific for the ICT sector. We have done a preliminary correlation analysis between these indicators and some of the specific ICT indicators, and did not always get meaningful results – for example, regulatory quality correlates positively with teledensity, but negatively with the number of players in the local market. This suggests that these general governance indicators may not be sufficiently informative for the ICT sector.

[86] The same is true for the International Long Distance market. Most of the other correlations did not yield a significant result, as shown in Appendix IX.

[87] In the table, *n* denotes the size of the sample; *Rs* is the Spearman Correlation coefficient; *p* is the probability associated with the confidence interval. The last column shows whether there is correlation, at a 95% confidence level.

We have additionally studied the correlation between the sources of revenues for regulators and the licensing regime in place: i.e., we tried to find whether regulators who get more revenue from licenses are on average more likely to ask for a license fee. The data for this, supplied by the ITU (ITU regulatory website), is however very sketchy, and results were inconclusive.

4.3.3 Interference

Apart from usage data it is important to understand whether there are interference problems in these bands. The survey reported that the lack of enforcement has in practice been a problem in some countries, where bands are saturated because users exceed the allowable power levels. This was the case in Cameroon, Angola and Uganda, for example[88].

Figure 4.26 shows that in the presence of a laxer licensing regime, interference problems seem to be lower than for more restrictive licensing regimes. This result is interesting because it is the opposite of what we would expect. There are two possible explanations. The first is that since restrictions (e.g. power and range) are higher for unlicensed, less interference problems arise. The second explanation is that this is a measurement error: it is possible that more stringent regulators want to justify their choices by saying that saying that there is interference, and that therefore a stricter licensing regime is needed.

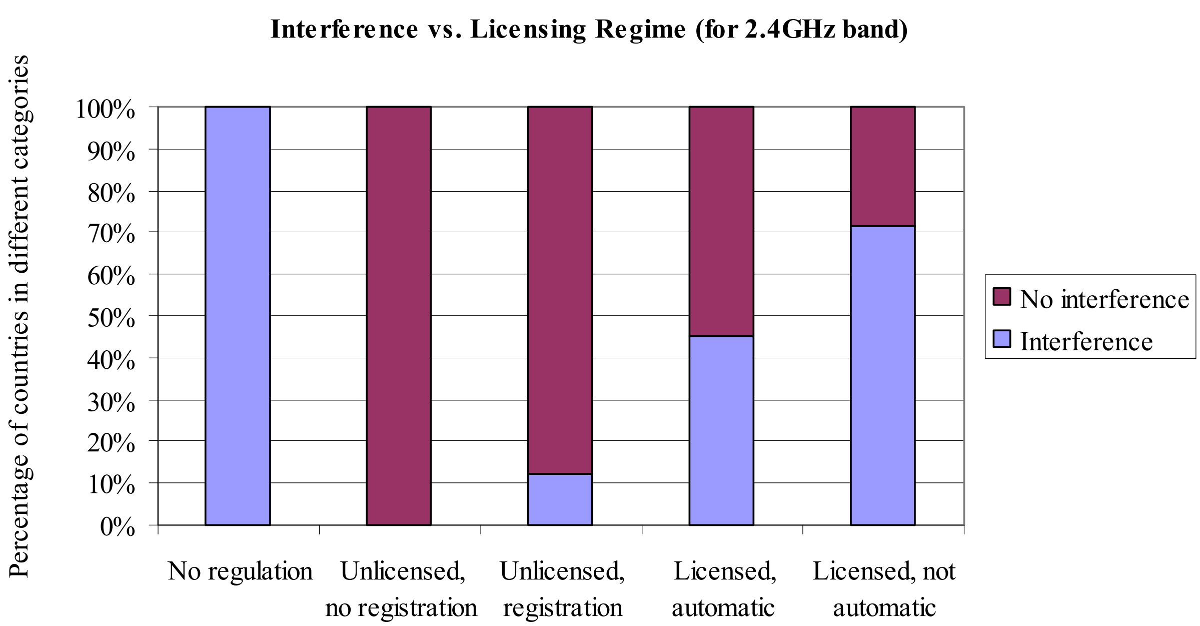

Figure 4.26 – Interference for 2.4GHz Band, by licensing type[89]

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[88] In Cote d'Ivoire the band is said to be saturated, but not necessarily because of interference.
[89] For significance analysis see Appendix VIII.

Figure 4.27 shows the cross between interference and certification information. Although the data conforms to the expected result (i.e. more equipment certification leads to fewer interference problems) the difference is not significant. There may be, however, a measurement error for interference, as discussed above.

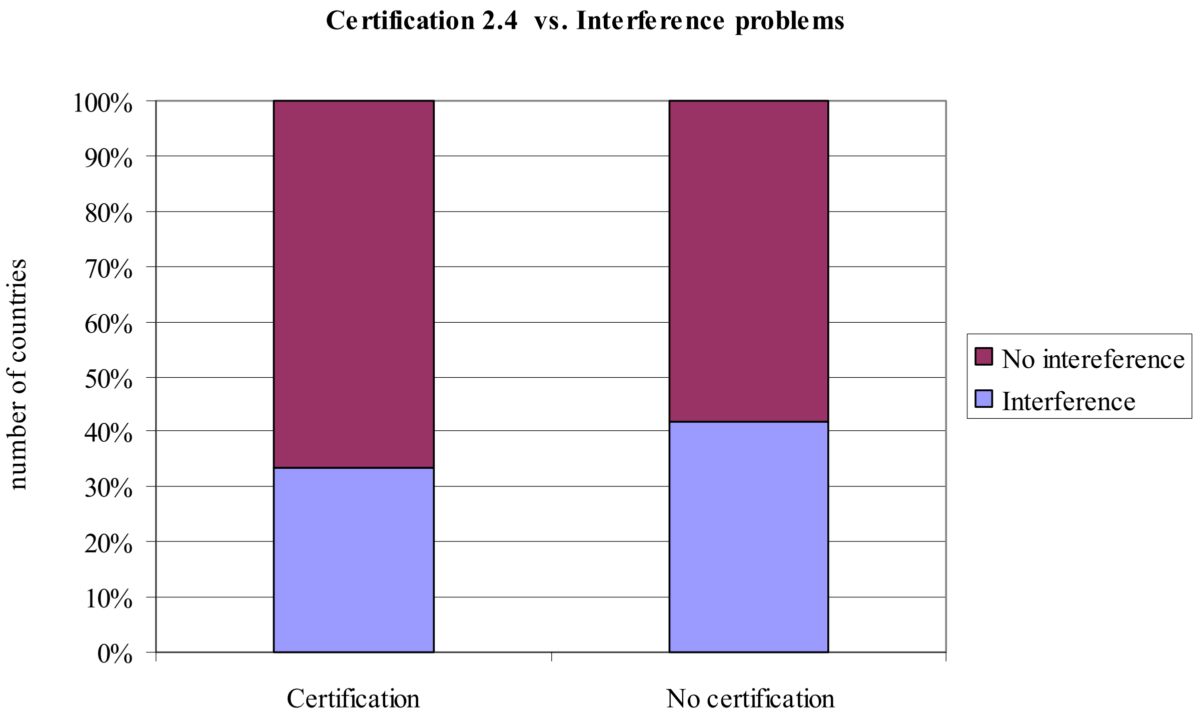

Figure 4.27 – Certification vs Interference

4.3.4 Price and availability of equipment

The problems faced with relation to both end-user equipment and networks equipment are similar. By order of importance: availability and price (see Figure 4.28 and Figure 4.29). However, it should be said that these are problems, in Africa, not just for these but also most other technologies.

When compared to other telecommunications equipment the technology used in these bands is generally low cost, and costs will tend to further go down with growing adoption and time (Best 2003). Burkina Faso has mentioned that price is high partly due to the yet low number of customers using these bands. Indeed, price is a function of the demand. As the use spreads, price should consequently come down.

Other problems were also mentioned, such as the shortage of electricity, the difficulty to make repairs, or the danger of lightning storms. More countries have mentioned problems for end-user equipment than for network equipment.

Problems mentioned for end-user equipment

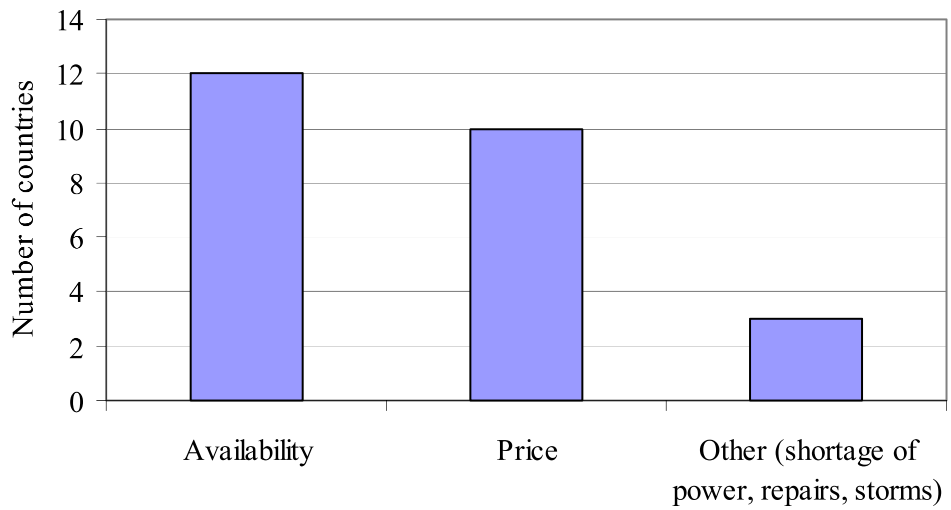

Figure 4.28 – Main issues with end-user equipment[90]

Problems mentioned for network equipment

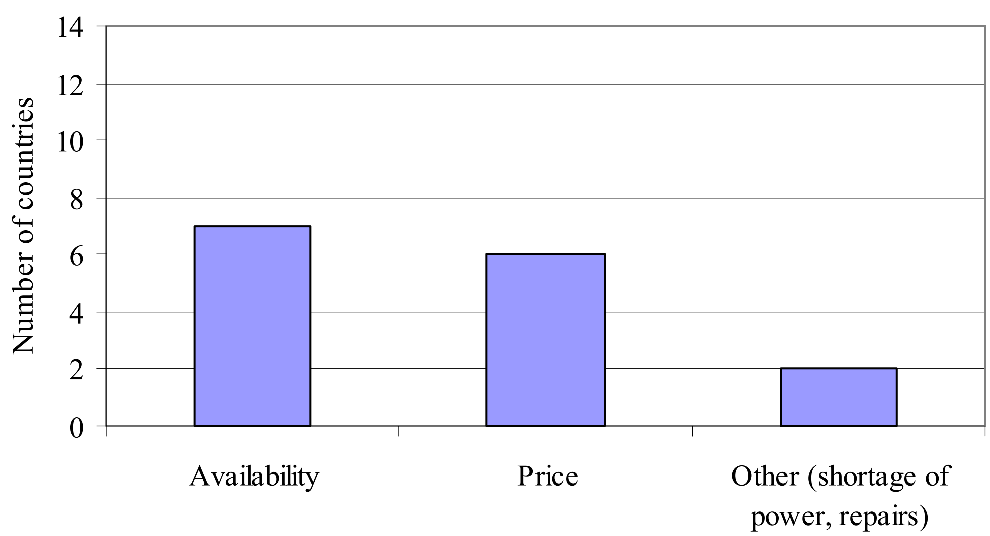

Figure 4.29 – Main issues with network equipment

[90] Countries can choose more than one type of problem.

5. Implications and Recommendations

In the last chapter I have presented the main results from the survey. This Chapter begins by characterizing the different stakeholders positions and describing some of the political and market failures associated with each of the players. It then discusses some of the policy implications and recommendations based on the results.

I will consider the major challenges brought to light by the survey results, namely regulatory uncertainty and significant heterogeneity across countries: these may introduce barriers to entry, and significantly discourage small and bigger players from entering the market. The ITU, other international organizations and governments may have a key role to play by promoting policies and taking measures that ensure the right business environment is in place.

While full resolution of the ongoing debate about appropriate regulatory models for unlicensed bands is beyond the scope of this thesis, this chapter characterizes the trade-offs that need to be weighted in when designing regulation. Based on the survey results, which showed an unexpected level of restrictiveness around regulation of these bands, and other arguments based on the nature of the spectrum resource, this chapter recommends that African policies should 'err on the side of laxity' more than they currently do. The chapter concludes with some remarks on the possible models for common use resource management and its applicability in Africa.

5.1 Stakeholder analysis

Describing the different stakeholders' interests and stances is important to understand the regulatory outcomes, as well as its organizational implications. When designing meaningful strategies or proposing recommendation, simply relying on technology or on its economic potential is not enough. We need to understand the organizational and regulatory implications to the different players.

In this section I will speak briefly about the different stakeholders, namely: regulators, incumbent telecommunication companies, smaller entrepreneurial type companies, bigger new entrant companies, manufacturers, the ITU and the general public.

5.1.1 Regulators

The objective of regulators should generally be to administer a country's resources and enact regulation that best serves its interests. These objectives are not always easy to accomplish, nor is it straightforward to determine which the best policies to follow are.

There are, however, several political and market failures in the process. First of all, there is the political problem of regulatory capture (Geradin et al. 2003). Traditionally, regulators have dealt primarily with the incumbent telecommunications operator. This means that privileged relationships may have been set up – in some countries, in particular for state owned operators, the companies themselves, or else a common 'owner' ministry, exercise some of the regulatory powers. For some regulators, the incumbents contribute a significant part of their revenues. There is additionally problem with asymmetry of information because, for historical reasons, the regulator typically knows best the operations of the incumbent, and is not so familiar with alternative ways of doing things. When compared to small entrepreneurial firms, the regulators may have a less dynamic and more conservative way of operating. All of these factors create a regulatory and policy bias favorable to the incumbent.

Some of the regulators contacted for the survey have explicitly indicated the protection of incumbent's profits as one of the rationales for regulating (see Appendix VII for more information). Indeed, especially in countries that are yet to privatize their telecommunication sectors, it is in the government's interest to protect their profits – either because the incumbents' profits will flow to the government budget, or because the revenues from a possible privatization will be higher if earnings are inflated[91].

In addition, since regulators generally have the responsibility to manage spectrum – allocating and monitoring it, ensuring quality of service and resolving potential conflicts – it is possible that they will have the tendency to be over protective over the spectrum resources, and have incentives to set high restrictions, as to protect spectrum and avoid disputes it would have to solve. Because revenues from licenses are sometimes part of the regulators' budget, there is also a bias towards licensed regimes, to enable the collection of fees. This may explain the fact that a significant percentage of the countries require a license for the 2.4 and 5GHz bands, but licenses are automatic on payment of a fee – i.e., licenses should more properly thought of as a tax.

Lastly, enforcing regulations requires time and resources. As the survey results show many of the contacted regulators do not have the technical and/or human capacity for enforcement.

[91] Even when the telecommunications sector is not privatized governments can charge considerable taxes on earnings.

5.1.2 Incumbent telecommunication companies

Generally telecommunications companies want to shield themselves from competition, taking advantage of their often substantial market power. For that reason, they typically are advocates for the imposition of higher restrictions – even if these also affect themselves, since they can use alternative technology networks. Incumbents typically also defend restrictions on services. The advent of Voice over IP (VoIP) in particular has worried operators, who fear the risk of losing significant part of their revenues to other entrants. There is some reason for being concerned, since incumbents need to have the revenue to support and maintain their infrastructure, which is also the countries' infrastructure. Operators are also worried about losing the voice revenues because pricing structures are not always aligned, and data services may suffer, as a consequence.

When talking about extending connectivity to rural regions the use of these bands is not necessarily eating into these incumbents profits, who are often unable or willing to cover disadvantaged areas. Incumbents are likely to be more worried about competition in urban areas. In addition, however, the incumbents themselves can use the bands, if they find that they provide advantages with respect to the more established technologies.

For historical and political reasons incumbents often enjoy implicit or explicit preferential treatment in the market. An example is given in the survey: In Eritrea, incumbents do not need to a license to operate, nor need they pay the associated fee, unlike all other entrants. Additionally, incumbents' experience in telecommunications systems deployment and operations gives them a number of advantages: privileged access to suppliers, an existing relationship with clients, organizational structures already in place to deal with customer service, billing, etc. Since they often own most of the backbone infrastructure, it is also easy to engage in discriminatory behavior, by delaying or denying interconnection to their network and consequently placing others in a difficult situation.

Lastly, if a license is required, incumbents will generally be in a financial and political privileged position to obtain one, and generally do not have to worry about staying outside of the game. Indeed, they are likely to lobby against market opening, but are generally interested to play in the market if a specific segment opens to competition.

5.1.3 Small entrepreneurial type companies

In view of their size and entrepreneurial nature, new small entrants' resources are limited. They generally have lower access to capital and a small workforce, and therefore do not have the time or the resources to, for example, apply for a license, or wait a long time for a regulatory decision.

They also have limited time to deal with the regulator or to lobby for particular regulation and often do not have the required influence to achieve favorable results. It is a good example of Mancur Olson's collective action dilemma (Olson 1982), where there are a number of small players, whose collective action is difficult because the interests that it represents are disperse, whereas the ones from bigger players (such as the incumbent) are concentrated.

Generally, small entrepreneurs want as little hassle as possible, and do not want to solve complicated coordination problems. They are generally therefore in favor of a deregulatory environment and low barriers to entry– and in particular of unlicensed spectrum regulation.

It can be argued that prior to the regulation of spectrum, addressed by this thesis, other obstacles lay in the way of entrepreneurs. Examples are access to the backbone network and access to capital. ISPs are likely in a privileged position in these other fields, since they already have experience and expertise in dealing with these issues.

Low restrictions on power, services, and range enhance small firms opportunity to reach more people and have higher revenues. Nevertheless, it is in their interest to have well functioning bands and, consequently have some restrictions (if not disproportionate), in as much as they ensure a minimum quality standard and a healthy use of the bands. The fact that in Africa there is close to no legacy technology also facilitates their entry.

As mentioned before small entrepreneurs can represent a significant opportunity in the context of developing countries, by giving a different dynamism to the market, and encouraging innovation. Micro and small enterprises are placed in a privileged position to provide locally tailored value-added services more adapted to the community needs. From a social capital perspective entrepreneurs can be more than small telecom firms, by enabling the democratization of technology, with people and communities being able to provide for themselves what they think is important. Being close to the community they will also have the incentive to utilize scarce resources effectively.

Companies and individuals in the more developed world may have much to offer in the form of alliances with smaller entrepreneurs in developing countries – by enhancing innovation opportunities and helping with technology and business transfer of knowledge. Some examples are already in place. See for example the DigitalDividend.org (www.digitaldividend.org), or BusyInternet (www.busyinternet.com) initiatives (Moore 2002).

As a last note, these players have the potential to become bigger players, with time, should they become successful.

5.1.4 Larger new entrant companies

Examples of larger new entrant companies are foreign telecommunication operators who want to enter into new markets. Some of what has been said for small entrepreneurial firms still stands for these type of companies: They will still be in a weak position, when negotiating with the incumbent, they too do not yet own a network and may encounter problems of denied interconnection, and they also want low barriers to entry (at least for themselves) and well functioning bands.

They have, however, access to more resources (time, money, expertise), and can for that reason exert pressure on regulators. In the particular case where the new entrants are foreign based firms, they bring with them technical know-how and expertise, as well foreign capital that the governments will eventually be interested in attracting (unless, for example, it does not compensate for the loss of profits for the state-owned incumbent).

They typically want to enter the market in order to compete with the incumbent and gain market share. For that reason, once barriers are low enough for them to enter, they are likely to prefer to limit the number of entrants, and may therefore favor a licensed environment. This would also give them a more stable and certain environment, as well as guarantees for quality of service.

Since they typically will want to operate in different locations inside the country (both in order to use it as a backbone to carry traffic between cities or, if that proves to be financially attractive, to reach and serve rural villages), they will be looking for solutions for wider area coverage, in addition to the localized ones. It is possible, however, that they concentrate primarily in more protected and established bands and technology types, since these guarantee a better quality of service.

5.1.5 Equipment vendors

Despite the low availability of capital in Africa, the continent is a huge unexplored market. Vendors such as Nokia, Cisco or Ericsson have all the interest in developing and manufacturing technical solutions to connectivity if they know there will be a significantly big market to absorb them.

Since there is no legacy equipment, finding innovative new solutions is easier in this context. These players need, however, some guarantee that there will be a big enough customer base to ensure scale advantages and that they will be able to penetrate the markets in order to sell their equipment. Consequently, manufacturers are looking for the appropriate business climate, and would like to see uniform and aligned regulatory frameworks across countries – inside Africa, but also with the rest of the world.

5.1.6 ITU

The ITU is traditionally a source of information and advice for developing countries. In addition its development, the ITU-D (ITU-D website), serves as a convening forum for the telecommunication regulators of developing countries, organizing several workshops, training for regulators, etc. It is, therefore, in a privileged solution to influence the policies and regulatory choices of developing countries.

The results of the survey that is indeed the case. Figure 5.1 shows that most countries – just under 60% responded that they have based their regulations on the ITU recommendations. The ITU can have a significant influence on the regulatory choices that developing countries make. The ITU recommendations on these bands regulation is however rather vague.

The ITU is, however, and as mentioned in Chapter 1, a somewhat slow-moving institution. It has in recent years been painted as overly conservative, and often dominated by developing countries governments (Drake 2000), with little foresight as to the opportunities ahead.

In the face of the fast development of breakthrough technologies, it may not have the sufficient dynamism to react fast enough. Currently, and because of being slow, new technological solutions have happened through occasional joint ventures between operators and manufacturers, and have been developed by more dynamic forums such as the Internet Engineering Task Force (IETF)[92].

[92] Examples are the SIP (Session Initiated Protocol) or Diameter protocols, as well as the packet protocols for VoIP.

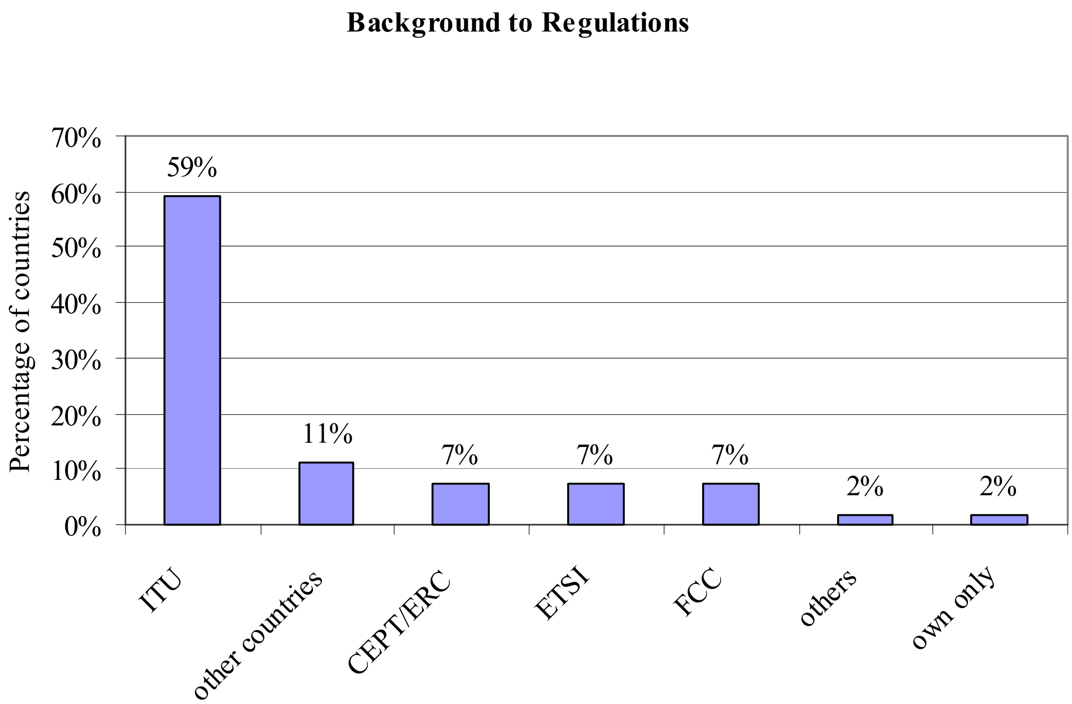

Figure 5.1 – Background to regulations[93]

5.1.7 General public

It is the general public who benefits from the quality, accessibility and availability of telecommunication services. The public will therefore be in favor of all policies that directly affect all of these, for example lowering prices, extending coverage, etc. The public does not necessarily have a big influence or interest in the regulatory decisions that are taken, but focuses more on the outcome, which directly affects it.

5.2 Policy recommendations

In this section I consider the major challenges brought to light by the survey results, and issue policy recommendations for the regulation of the 2.4 and 5GHz bands.

Addressing uncertainty and heterogeneity is key. The ITU may have a role to play by issuing firmer recommendations and serving as a convening forum for African countries to develop common strategies. Ensuring a stable business environment and revising Universal Service Policies to be more inclusive may also have a significant impact on the establishment of new service providers in Africa.

[93] Countries can choose several sources.

While explicitly discussing the best regulatory models for unlicensed spectrum goes beyond the scope of this thesis, I discuss some of the current thinking here, in as much as it illuminates the options and discussions in the specific context of this thesis. The objective of regulation should be to maximize output and the greater good for a country – regulation will therefore necessarily be the result of trade-off considerations between certainty, accessibility, quality, innovation, etc. I argue that, when striking that balance, regulators should, in this context, 'err on the side of laxity' – more than what they currently do, for these reasons:

- spectrum is a renewable resource
- Africa could be the continent with the most to gain from additional access to infrastructure
- Bands are likely to be less congested in Africa
- It could counterbalance the bias for overregulation due to regulatory capture

The following sections explain these arguments in more detail.

5.2.1 Reduce Uncertainty and Heterogeneity

Policy Recommendation 1 - In view of the continent's weak teledensity and lack of alternative infrastructure, establishing a more certain and uniform regulatory framework across Africa would promote private investment and connectivity through technology in these bands.

The regulatory scenario described in Section 4.1 speaks to the general uncertainty and confusion associated with the regulatory regimes of the 2.4 and 5GHz bands across Africa. These regimes are uncertain within each country, with low enforcement, and relatively complicated, with diverse associated restrictions. There are, in addition, other uncertainty sources. Some examples are provided below:

- In its response to the survey, the Democratic Republic of Congo (where licensing is said to be automatic on payment of a fee), has said that it is difficult to obtain a license, since 'there are many taxes to pay' and there is no specific policy in terms of Telecom[94]. Congo further mentions that 'there have been conflicts between the Telecom and the Media Ministry about regulation and licenses'.
- In Benin, according to the survey, service restrictions are defined case by case.
- There are reports that in Mozambique the regulator tried to block use of the 2.4GHz saying it was illegal, but later on it was found that there were in fact no regulations for this area of the communications services (W2i et al. 2003).

[94] There is, in Congo, Full competition in most Telecommunications sector, according to the ITU.

This uncertainty creates higher barriers to entry, especially for small entrepreneurs who do not have the time or the resources to deal with all of these. As a consequence, it may discourage smaller players to enter the market. Bigger players have more resources to deal with the regulator. Nevertheless from an investor's point of view, risky environments, with uncertain and changing regulation, are to be avoided.

There is also significant heterogeneity among countries. In its response, Botswana gives as a possible explanation for 'illegal, or out of limits transmitters' the fact that this heterogeneity may lead to confusion as to what is or is not allowed. Once again, for bigger players interested in taking advantage of economies of scale and implementing common strategies across borders, the heterogeneous regulatory environment will also act as a deterrent and barrier to entry. As mentioned before, there can be much to gain from partnerships with foreign firms. Operators may facilitate knowledge and technology transfer, and equipment vendors may be in a position to design equipment adapted to the countries' realities needs.

5.2.2 A key role for the ITU

Policy Recommendation 2 - The ITU could have a key role to play, both by taking a firmer position and issuing clearer guidelines for the regulation of license-exempt bands, and by serving as a convening forum for countries to establish common regulatory strategies.

International organizations may have a key role to play in achieving this common platform. It has been mentioned earlier in this chapter that the ITU has considerable influence in the developing world's regulator's choices. Indeed, the results from the survey show that African countries tend to give significant importance to the ITU, with 59% of the countries basing their regulation on its recommendations or Radio Regulations.

The ITU currently does not have a clear policy or recommendation on the preferred regulatory regime for these bands. Figure 5.2 shows the background to the regulations by licensing type. It is significant that countries which have said they based their regulation on the ITU have implemented a wide variety of regulatory policies. This indicates some confusion on the actual ITU recommendations[95].

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[95] It may also be that countries want to have a justification for the regulatory choices they have made themselves, and find in the ITU a credible organization in which to 'look for shelter'.

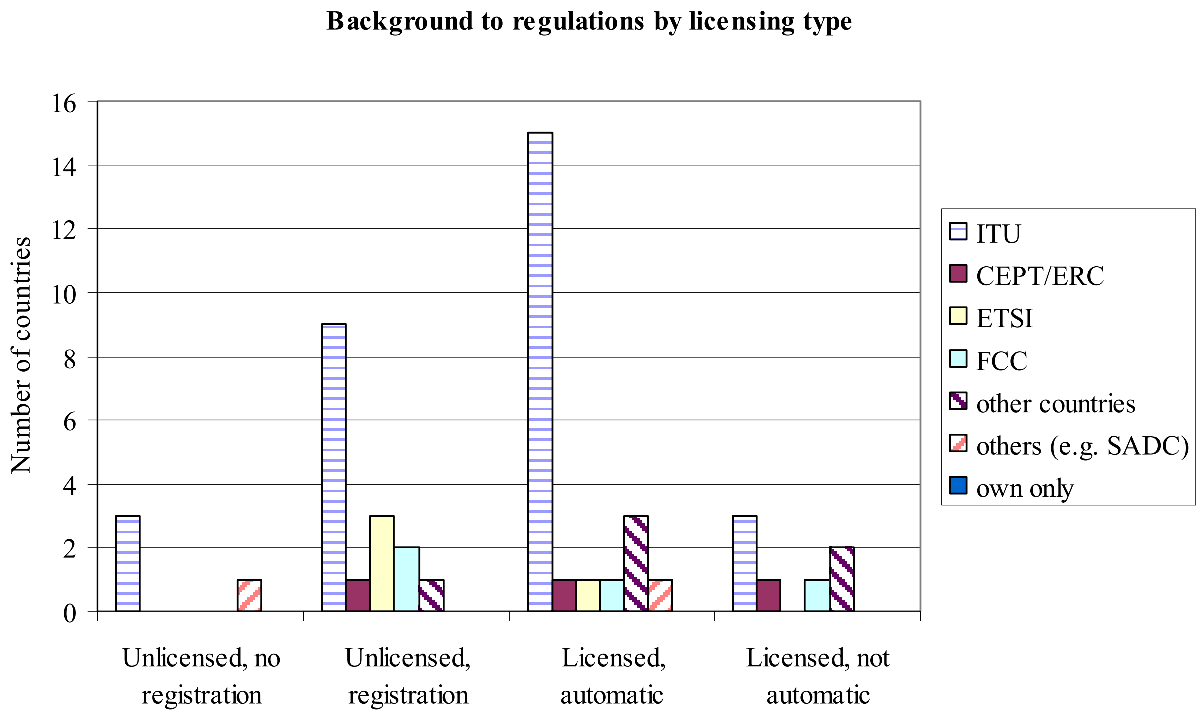

Figure 5.2 – Background to regulations by licensing type

It follows that the ITU could have significant impact by providing clearer guidelines for the regulation of license-exempt bands. In addition, it may be an appropriate forum for African countries to discuss possible changes in regulation, and coordinate on common strategies.

5.2.3 Establish an appropriate business environment

Policy Recommendation 3 - Governments should strive to establish an appropriate business climate: lower barriers to entry, ensure certainty, and when possible provide access to capital.

This thesis has concentrated on the regulation of the 2.4 and 5GHz bands and its effect on the provision of telecommunication services, in particular through entrepreneurship and small-scale businesses in Africa. It should be clear that spectrum regulation is only one of the obstacles that entrepreneurs - or for that matter larger players - face in this context.

In the context of regulation, interconnection and fair access to the backbone are also likely to be issues. The government or the regulator should strive to isolate themselves from the incumbents and avoid protectionism. This will likely bring the greater good for the country in the longer run.

In addition, economic viability is another factor to take into account, in particular in rural areas. New entrants must also be provided with the appropriate conditions to establish and maintain a business, for example: access to credit, an attractive climate for investment and risk, etc. Entrepreneurship in particular may not yet be part of the culture of some developing countries, and therefore it may be appropriate to develop entrepreneurial skills in these emerging markets by promoting education and training programs in this area (Moore 2002).

5.2.4 Revise Universal Service Policies for use in these bands

Policy Recommendation 4 – Countries should review Universal Service Funding Policies in light of their applicability to new market entrants and alternative technologies such as the ones operating in license-exempt bands. Targeted, flexible and accessible Universal Service Funds should be implemented.

Unlicensed bands can potentially be used for provision of rural connectivity and Universal Service. Given the identified potential for this technology and its low cost, allowing the use of Universal Service funds for wireless projects in these bands may represent a cost effective utilization of the subsidies.

If appropriate Universal Service policies are in place, the corresponding funding mechanisms can be used for the deployment of these type of technologies. This is especially true if the specific Universal Service policies in place allow for competitive, targeted and efficient subsidies[96]. An example is the attribution of funds/subsidies is done through competitive targeted bidding (i.e., firms bid for the subsidy, on a project-by-project basis, and the most competitive wins). This would allow smaller players to apply for the funds, should they be competitive enough.

Figure 5.3 shows that from the countries who replied to the survey at least 47% have Universal Service Policies in place. In practice, from the surveyed countries, only three responses mentioned that Universal Service Funds have been used to deploy equipment in the 2.4 and 5GHz bands (see Figure 5.4) – Kenya, Madagascar, and Rwanda.

[96] See Section 1.3.4 for more information.

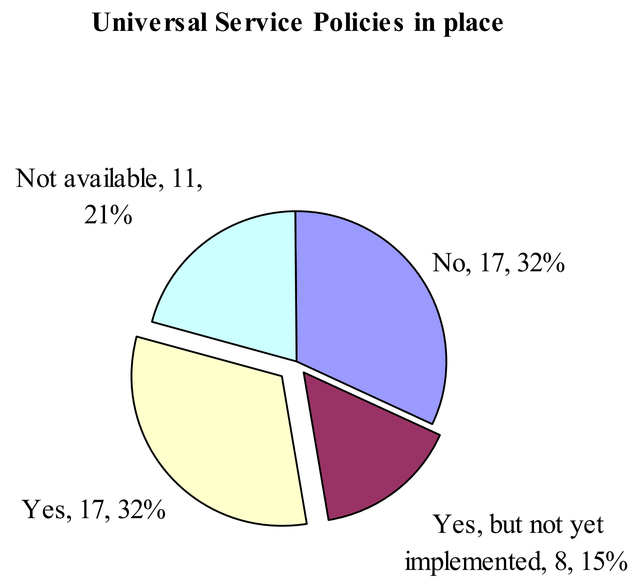

Figure 5.3 – Universal Service Policies in place

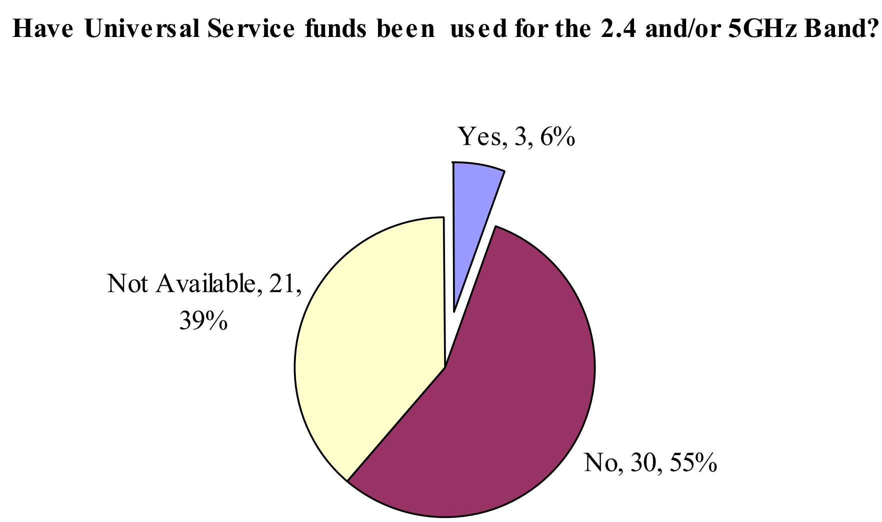

Figure 5.4 – Universal Service Funds used in these bands

Possible reasons for this disparity are:

- Only incumbent or large operators have access to the funds, and they are not interested in these type of solutions. Universal Service Providers are very often the incumbent operators, i.e. often only the incumbent can make use of the Universal Service subsidy to provide service (Wellenius 1997). This is partly because the incumbent owns most of the infrastructure, and is therefore in a privileged position to provide access solutions. The incumbent is, however, very inefficient, and it would be beneficial to open the Universal service market to competition
- Specific technology is mandated for use of the subsidies, not necessarily including 2.4 and 5GHz bands technology. It may be that the subsidies can only be used for more reliable technology, as opposed to the best-effort characteristic of the WLAN-type technologies. In the context of low connectivity in Africa, regulators should consider alternative technologies, in particular is they represent a cheaper and cost effective solution.
- Another explanation may simply be that it is difficult to apply and receive subsidies – in line with the institutional barriers and inefficiencies - or that nobody has yet thought about applying for the funds to use it with this type of technologies.

Targeted, efficient and flexible universal service funds can serve as a tool to extend connectivity, for countries that explicitly and proactively want to enhance internet penetration. Governments should strive to have consistent policies in place to enable improved connectivity in their countries. Rwanda (one of the countries using the subsidies in these bands), for example, is purposely working to extend internet connectivity:

> "The connectivity is one of the major issues as far as Internet development in Rwanda is concerned. Right now four private ISP's are operating and we expect the connectivity to be extended to remote areas in the near future as the government is looking to provide support for schools, public institutions and the community"[97]

5.2.5 Fair balance needed in regulations

Policy Recommendation 5 - A fair balance needs to be found when defining the regulatory regime to be applied in these bands. Indeed, several parameters need to be defined: i) Licensing, ii) Restrictions on power and range, iii) restrictions on services, iv) requirements for certification, iv) level of enforcement. The appropriate balance between barriers to entry and the well functioning of the bands should set the level of restrictions to impose, bearing in mind that, currently, there is a tendency to over regulate and keep barriers to entry high.

[97] From response to survey, Rwanda.

The challenge of managing interference in unlicensed bands is brought about by the fact that everybody can use the spectrum and that, in the absence of power limitations, if the different users all transmit at maximum power there will be an unmanageable level of interference for all. If all keep the power down, everything will work fine. There are, however, strong incentives to free ride, since if all users control their power, a singular user could pump up its own power, gaining from it, and still keep interference at a manageable level. This brings us to a typical 'tragedy of the commons' situation, where users all have a strong incentive to 'pollute' the bands. This is, in game theory terms, a pareto-inferior outcome, or also a prisoner's dilemma situation, where the players do not have an incentive to move to a more favorable outcome. One of the challenges of the 'commons' regime – i.e., of allowing several users to co-use the bands and manage it as a common resource - is to establish an appropriate level of restrictions, so that users do not get trapped in the 'tragedy'.

In parallel, the regulation to adopt depends largely on the main policy objectives the regulator or the government wants to achieve. I have mentioned before that given the low penetration of telecommunication services, one of the main objectives should be to enhance connectivity. Still, the type of regulation will be different whether the main objective is to ensure connectivity locally, or to use the technology available in these bands as means of providing a backbone/wider area coverage, and reaching rural communities.

Indeed, some countries may already have an infrastructure in place for the point-to-point segment of the communications service, in which case the regulatory objective may be to encourage and enable localized coverage. Or it may be that the countries main deficiency is that there are large portions of the populations that are still isolated and far from any telecommunications infrastructure, in which case it will be most important to provide a connection to those regions. Once an objective is defined, one can choose the set of regulations that is believed to best serve those purposes. This thesis started by making the distinction between licensed and unlicensed bands.

In that respect, the survey results mention advantages and disadvantages of both regimes. Tanzania mentions that licensing gives control on usage of the bands, hence achieving a good quality of the network; Uganda defends that licensing ensures more discipline in use of the bands; Malawi responded that licensing has good effects in the band, but that it may limit the number of users. On the unlicensed regimes side Kenya points out the lower cost of entry for unlicensed regimes, and other countries speak to the advantages of increased accessibility to the bands.

However, Section 4.3.1 hints at the fact that licensing may not be the most relevant category. There are, indeed a number of regulatory choices or levers: i) licensing categories, ii) restrictions on power and range, iii) restriction on services, iv) certification requirements, v) level of enforcement, etc.

Regulators need to find the appropriate level of restrictions. Determining a level that is "not too high, not too low, but just right" (Margie 2003) may prove a difficult task, because of the need to take into account a number of trade-offs. Table 5.1 illustrates this point, and shows advantages and disadvantages of regulatory choices associated with these different levers.

Table 5.1 – Trade-offs to consider when defining regulation and setting restriction levels

Type of restriction	Advantages	Disadvantages
Unlicensed bands	- Lower barriers to entry, promoting competition in the market - Avoid regulatory capture, in particular in concentrated markets	- Potential less certain regulatory environment - More difficult to manage interference - Less revenue for the government, and less resources to finance the monitoring of the bands
Low power & range restrictions[98]	- Enables wider area coverage, increasing population covered - Higher competition in the long distance market - Encourage innovation and experimentation	- Levels of interference can rise - Bands may become congested and unusable
Certification required	- Ensures quality and reduces interference	- Discourages innovation and experimentation
Services restricted (e.g. no voice allowed)	- Good for incumbent and traditional telecom companies (can have monopoly over voice)	- Bad for users, there will be less competition in the market for those services
Strict Enforcement	- If regulations are set at an appropriate level, enforcement is good, since it will control interference and punish offenders, ensuring the well functioning of the bands	- Can be a form of capture if restrictions are set too high

[98] Note: if restrictions are high, if there is no enforcement, the situation is equivalent to not having restrictions at all.

The optimal choice between these trade-offs will necessarily depend – but also be influenced - by a number of circumstances. Examples are: i) concentration in the market, ii) level of regulatory capture, iii) level of penetration of telecommunications services, iv) country GDP and access to resources, etc.

Sections 4.3.1 and 4.3.2 show that there is some tendency to over regulate and keep barriers to entry high. In particular, higher restrictions to use are negatively correlated with the level of competition in the Telecommunications market. This should be considered when establishing the right balance.

While we want to protect the well functioning of the bands, we do not want to set overly restrictive conditions, since, e.g. if the maximum allowable power is too low, we will be restricting use which would have still been acceptable. Indeed, first of all, we do not want to unduly block band usage. In addition, one of the advantages of unlicensed bands is that they constitute an excellent ground for experimentation and for innovation. Setting limitations in too strict a way would harm that possibility. In a recent article Anthony et al., argue that:

> "Policymakers general lack of understanding into their capacity to define the market for innovation has created somewhat of a paradox. This paradox exists in heavily regulated industries such as telecommunications where decades of policies directed at creating economic welfare have fostered environments that have actually stifled the most dynamic type of innovation, disruption. […] if government officials understand what causes innovation, policies might not be so restrictive. […] disruptive technologies are powerful Schumpeterian forces capable of dramatically altering a competitive landscape while creating enormous economic and consumer welfare" (Anthony et al. 2002, p.1).

While technology and band usage is new, monitoring the bands and tuning regulation is important. Doing this is however costly, and there may not be the appropriate resources to do this in Africa.

One can think of parallel structures and solutions to regulation that would either give flexibility to the system, or give an incentive for users to do 'the right thing' – this is important in a context where there is little enforcement of the rules. Two variations are provided below:

- **Tiered licensing regime**: one could imagine a regime that would be unlicensed for low power localized coverage, licensed for point-to-multipoint type use, and licensed and certified for point-to-point and long range connection. This would reduce barriers to entry for the more localized market, while still guaranteeing some control of interference
- **Tiered certification regime**: in this variation several configurations would be made possible for the different tiers of service. Regulators could determine, for example, that for longer range service and a certain amplifier, only a directional antenna (vs. an omnidirectional antenna) could be used, etc. This could make the rules and restrictions easier to enforce.

There are some disadvantages associated with these types of regimes:

- The first is that if it is already difficult to establish the right value/level for restrictions for a more general regime, establishing a tiered structure can be even more difficult.
- The second is that defining configurations and setting all these rules may actually hurt innovation. Restraining a system to particular configurations and implicitly picking specific technologies/architectures will necessarily hurt experimentation by blocking all other possible configurations, even the ones that have not been thought of before.

5.2.6 Regulation should 'err on the side of laxity'

Policy Recommendation 6 - This thesis argues that governments should err on the side of laxity in these bands, in order to lower barriers to entry and counterbalance the current overregulation of these bands. Indeed, taking into account that spectrum is a renewable resource, the purpose of the regulation should not be to eliminate all interference, but to maximize output. For Africa, with its weak teledensity position, a higher use of the bands - in particular in rural areas - may translate into significant differential advantages, by going from no service to 'some' service. In addition, due to low usage of telecommunication services, congestion of the bands is less likely.

Given the continent's telecommunication deficiencies, enhancing connectivity should be a main driver for Telecommunications policy. There are strong arguments for rejecting a strict and inflexible regulatory system, which keep barriers to entry high and translate into the current overregulation of these bands. These arguments are summarized below.

Ostrom notes that spectrum, unlike fish or forest resources, is an instantly renewable resource: overuse has little impact over time once the overuse ends. The problem is one of crowding, rather than degrading the characteristics of the system itself. Ostrom says that:

> "… systems of instantly renewable resources are by definition forgiving, in that they instantly reward changes in user behavior. Because there is little danger of overshooting and collapse, there may be more willingness on the part of the responsible for governing such systems to experiment with novel approaches to their management, because the costs of institutional mistakes are small. On the other hand, since the consequences of poorly designed and enforced institutions are reversible, there is less incentive to take any serious action with respect to governance of such resources"(Ostrom 2003, p.16).

This points to reduced risk and some ‘tranquility’ in the face of regulatory mistakes and of laxity in the management of these renewable resources, since we do not run the risk of irreversibly depleting spectrum resources

In addition, the objective of regulation should not necessarily be to minimize interference, but to maximize output. As Margie puts it:

> “…all property rights interfere with the ability of people to use resources. What has to be insured is that the gain from interference more than offsets the harm it produces. There is no reason to suppose that the optimum situation is one in which there is no interference” (Margie 2003).

Indeed, some interference may be acceptable, if the overall regime brings other benefits to society. The challenge is to determine what should be the permissible interference, looking at it both from the perspective of the individual spectrum user but also of the overall good to society.

Both the US and European countries have struggled to find the right balance[99]. This is a difficult task, in particular if we bear in mind that the limits in these bands are not necessarily set with a specific technology in mind.

In the US the FCC has recognized that is some circumstances – for example in the case of UWB (a new standard for which there was only incomplete information and multiple possible uses) ‘the Commission shied away from setting a permissible level of interference anywhere near the harmful interference level’, having acted instead ‘with "an abundance of caution," and set "conservative" rules that "may be overprotective” (Margie 2003). In this case, recognizing that it does not have an adequate and consistent standard for setting permissible interference, the FCC has initiated a Notice of Inquiry (NOI) in order to establish a better standard.

If the US and Europe struggle to find and apply the appropriate regime, it should come as no surprise that this is even more difficult to do so in the context of Africa, where there are less resources and expertise. Nevertheless it could be argued that in this field, Africa should lead.

[99] This assumes that enforcement is present. In the context of Africa, as has been seen, this is not so clear. Enforcement is low, and so just establishing the right restrictions does not necessarily solve the interference problem, if users do not abide by the rules.

In a continent where the levels of connectivity are so low, and where in some instances there is no alternative infrastructure, people would have the most to gain by allowing more players in the market. Indeed, this could mean going from ‘no service’ to ‘some service’. In addition, these bands are arguably less crowded in Africa, and therefore the probability of interference is reduced.

Finally there is, as explained above, a bias towards overregulation, caused by historical reasons and capture. Explicitly adopting relatively laxer regulation could counterbalance this bias.

For all of the above, when regulating this spectrum, regulators should ‘err on the side of laxity’. Leaning towards laxity – always in relative terms – should not be equivalent to denying responsibility over spectrum oversight. Washing hands of the responsibility to monitor and/or appropriately regulate the spectrum may put in danger the confidence of investors and potential users of the bands.

The lack of enforcement has, in Africa, opened the opportunity for users to take advantage of these bands across the continent – as has been seen through the information collected in the survey. This opportunity will be lost if the restrictions are set too high (e.g. by requiring a license, or by setting maximum allowed power levels too low). Once the appropriate regulations and restrictions are in place, however, enforcement is essential to guarantee the willingness to invest.

5.3 Considerations on institutional structures for managing the commons

This chapter finishes with some considerations, applicable beyond the African context, on models for managing common resources, in this case spectrum ‘pools’.

As explained by Coase, when there is an interferer and an interferee, if the rules in place do not solve the problem, the parties can enter into private transactions, which will result in an efficient amount of interference – meaning a level of interference that maximizes the combined values of the parties' use of the band in question (Coase 1959). This may become more difficult if the number of users in the band grows too much – i.e, if the transaction costs grow higher.

The tragedy of the commons situation brings with it a sense of hopelessness. Ostrom, who has studied in depth property rights regimes and commons models, believes that this is not necessarily true. He argues that this notion can be dangerous, since ‘the constraints that are assumed to be fixed for the purpose of analysis are taken on faith as being fixed in empirical settings, unless external authorities change them’

(Ostrom 1990). He further believes that not all users of natural resources are similarly incapable of changing their constraints and that as long as individuals are viewed as prisoners, policy prescriptions will address this metaphor. He talks about the need to establish processes so that the capabilities to change the constraining rules of the game are enhanced, and speaks to the need of a collective action theory.

Finding the appropriate set of rules and managing them over time presents a number of challenges and it is important to look at the process through which these rules are chosen, and the institutional design that best guarantees this. Institutions can behave in a command-and-control fashion, or in a more participatory way.

The ability of common pool resource appropriators to communicate, devise rules for appropriating the resource, and penalize rule-breaching behavior is considered to be an essential element of successful institutions for common-pool resource management. Ostrom, who has studied commons resource management at length, discusses a set of general principles that increase performance of an institutional design (Ostrom 2003). Table 5.2 shows Ostrom's list of desirable general principles, along with some comments on the perceived situation and difficulties in Africa.

Table 5.2 – Desirable general principles and the situation in Africa

Source for 1st column: (Ostrom 2003, p.22)

Characteristic	Status
Rules are designed and managed by resource users	In general resources are managed by the regulator
Compliance with rules is easy to monitor	A big percentage of African countries does not have the appropriate equipment to monitor bands
Rules are enforceable	Rules are enforceable, but because hard to monitor and poor governance/institutions, not enforced
Sanctions are graduated	Some interference should be tolerated…?
Adjudication is available at low cost	Need for negotiation structures, etc
Monitors and other officials are accountable to users	Capture and lack of expertise, together with a tradition for command and control can be a major obstacle
Institutions to regulate a given common-pool resource may need to be devised at multiple levels	-
Procedures exist for revising rules	This requires an active and well functioning regulatory system. Also requires time and resources, which may be absent

The table above suggests that the main obstacles to an efficient spectrum management regime may be governance and market concentration. In general, strong institutions are needed, as well as an external functioning legal environment, elements that are often missing in Africa. Some flexibility to change and tune the rules is also key in finding the appropriate level of control. Too much flexibility can however hurt investment, since investors like certainty and a stable regulatory environment.

In addition, users who trust each other are more likely to restrain their use of the common pool resource and comply with agreed-upon limits of resource use. Smaller players must be given enough strength and bargaining power, or else their participation in such a system could be impaired. Additional research is needed to find appropriate and concrete management models that fit these criteria in the context of Africa.

The table assumes that there are already common pools of resources – i.e., that there is already spectrum allocated for unlicensed use. This may not be the case. For unlicensed spectrum regulation to move forward there must be active plans to win broad-based support from different players since, as has been suggested in Section 5.1 there will likely be opposition to the establishment of such bands. The incumbent, large new entrant firms, and even the regulators themselves are likely to be against it. If the power of incumbents is underestimated the use of unlicensed bands may remain limited.

6. Summary and Conclusions

This thesis has studied the regulation and use of the 2.4 and 5GHz bands in Africa. Chapter 1 has explained the motivation for this study and has explained the context in which it is set. Unlicensed spectrum – in particular the 2.4 and 5GHz bands[100] – and the low-cost radio technologies that operate in these bands can be of particular value, since they can potentially impact accessibility and availability of information and telecommunication services. In the context of numerous institutional and structural obstacles to entry - as is the case in the developing world - license-exempt regulation potentially provides a friendly environment for entrepreneurship, reducing barriers to entry and the risk of regulatory capture.

Chapter 2 has looked at the technologies deployable in these bands. For a telecommunications network to work, connectivity needs to be ensured at different levels: at the local level, connecting households and user devices to the information network - what is sometimes called the local loop, but also at regional, national and international levels[101]. There is wireless technology and standards available for use in the 2.4 and 5GHz bands at different levels. For example, the widely used 802.11b standard is typically a localized solution, while 802.16 is meant for Metropolitan Area Networks applications. Not all segments of the telecommunications network need to be deployed through wireless technology. Indeed, some of these segments can potentially be served by other means such as satellite, fiber, cable or wired networks.

This thesis contributes to this area by studying the general outlook of the regulation and use of the bands 2.4 and 5GHz, in Africa. It does so by means of a survey distributed throughout the continent. This survey and its distribution are described in Chapter 3. Responses to the survey were collected between January and April 2004 and cover forty seven out of the total fifty four countries in Africa. This corresponds to around 87% of countries, covering 97% of the African population. Most of the responses are from the regulators of these countries.

The main findings and the recommendations following from the analysis of the results are described below. Further research areas are also identified for future work.

[100] These bands are regulated as unlicensed bands in several countries, including the US, and parts of Europe. This thesis looks, more specifically, into the following sub-bands:

- 2.4 – 2.4835 GHz
- 5.15 - 5.35 GHz; 5.47 - 5.725 GHz and 5.725 - 5.875 GHz.

[101] See Chapter 2 for more details.

6.1 Summary of main findings

This chapter describes the main findings of the survey and the analysis of its results.

6.1.1 Licensing regimes are diverse and uncertain

The survey finds that the regulatory regimes in the different countries are very diverse, as is explained in Section 4.1. Even when unlicensed use is explicitly defined, in some countries regulators require users to register with the regulator. In the case of licensed use some countries attribute the license automatically on payment of a fee, whereas in some other countries the license attribution process is not automatic. More than 50% of the countries require a license to operate in these bands. The numbers are slightly higher for the 5GHz band. It can be seen that most regulators allowing unlicensed use require a registration. Exceptions, for the 2.4GHz band, are Rwanda, Lesotho and Tunisia. It is significant that unlicensed bands, as they are normally thought of in the US, only exist in three African countries (which represents 6% of the countries) for the 2.4 GHz Band, and in two countries for the 5GHz Band (i.e. 4% of the countries). As for licensed use, license attribution is mostly automatic on payment of a fee

In addition to licensing, however, regulation is characterized by a wide array of variations. For example, there are differences in terms of the restriction imposed on the maximum power and range, and on services (e.g. only data and no voice allowed). Some countries require equipment certification, and some others establish more complex tiered licensing regimes (e.g. having unlicensed use indoors, licensed outdoors, etc).

In parallel countries place all sort of restrictions, such as setting different conditions for incumbents, requiring companies to register in the country or present a business plan, etc. In many countries regulation is changing, or is not clearly defined.

Enforcement of these rules is limited. Indeed, even though 50% of the countries contacted say the regulations are strictly enforced, only 20% says it has the capacity to do so. Given that most of the responses come from regulators, these numbers are likely to be even lower. From the information collected, it seems to be the case that in many countries there are significant levels of 'illegal transmitters', or transmitters going above the maximum allowable power levels - examples are the Gabon, Senegal, Namibia, Cameroon, Angola and Uganda. Several regulators have mentioned that they are in the process of acquiring appropriate monitoring equipment.

This scenario points to the general uncertainty and confusion associated with the regulatory regimes of the 2.4 and 5GHz bands across Africa. These regimes are uncertain within each country, and relatively complicated, with diverse associated restrictions. This uncertainty creates higher barriers to entry, especially for small entrepreneurs who do not have the time or the resources to deal with all of these. As a consequence, it may discourage smaller players to enter the market. Bigger players have more resources to deal with the regulator. Nevertheless from an investor's point of view, risky environments, with uncertain and changing regulation, are to be avoided.

In addition to the confusion inside the country, there is also significant heterogeneity among countries. In its response, Botswana gives as a possible explanation for 'illegal, or out of limits transmitters' the fact that this heterogeneity may lead to confusion as to what is or is not allowed. For bigger players interested in taking advantage of economies of scale and implementing common strategies across borders, the heterogeneous regulatory environment will also act as a deterrent and barrier to entry.

6.1.2 Ubiquity of use

Despite this heterogeneity, these bands are being used in most African countries. This is discussed in Section 4.2. The main users are ISPs, followed by Telecom operators. There are reports of the advantages of using these bands, such as low cost of existing infrastructure, and reduced fees and barriers to entry. We find that the most common use of these bands is for "hotspot" style or other localized coverage in urban areas. This is not surprising given that the most widespread equipment is "WiFi" radios comporting to the IEEE 802.11b standard, designed primarily for use in hotspots. Nonetheless, a significant 37% of the countries that responded are using wireless technologies operating in these bands for providing backhaul network connectivity in rural areas– this may point to a particular need that can be filled through the use of these technologies.

6.1.3 Limits imposed by regulation and difficulties in use

When studying the interrelationship between the types of use and the licensing regimes in place, we find that there are relatively more countries deploying wider area coverage networks in licensed environments than in unlicensed ones (see Figure 4.19, Section 4.3.1). This may suggest that more certain licensed environments, potentially operated by bigger market players are more appropriate for wider area networks, which may require a greater degree of coordination. An alternative explanation, supported by the data gathered, is that countries allowing some license-exempt use usually have more stringent restrictions on this very use, for instance maximum power outputs, range of use, and so forth. More generally, laxer licensing regimes place, on average, more restrictive conditions on power and range, as is discussed in Sections 0. This may explain why, when compared to licensed environments, wider area networks in unlicensed environments are limited. It is therefore important to understand which kind of restrictions is defined to accompany regulations. Information about licensing will not, on its own, properly characterize the possible uses of these bands, i.e.: the fact that a band is unlicensed does not necessarily mean that access or use are easier, since regulation can be accompanied by specific restrictions for use.

In Section 4.3.2 we have also studied the correlation between regulation in these bands and general indicators for the nation and ICT sector. We find that GDP per capita and teledensity do not correlate strongly with the type of licensing regime in place. We do find, however, that generally countries that have lower competition in their local and long distance markets impose more restrictions on use, in particular on power and range. This seems to suggest that the use of unlicensed spectrum is less restricted in African countries that enjoy a higher degree of competition in the telecommunications market, and potentially a lower degree of regulatory capture. In other countries restrictions may be being used to control market power and keep barriers to entry high. The effectiveness of entrepreneurship-type solutions may therefore be limited in countries where the degree of competition is low.

The problems faced with relation to both end-user equipment and networks equipment are similar. By order of importance: availability and price. Other problems were also mentioned, such as the shortage of electricity, the difficulty to make repairs, or the danger of lightening storms. More countries have mentioned problems for end-user equipment than for network equipment. It should be noted that price is a function of the demand. If the use of this technology spreads, price should consequently come down.

Unlicensed bands can potentially be used for provision of rural connectivity and Universal Service. If appropriate Universal Service policies are in place, the corresponding funding mechanisms can be used for the deployment of this type of technologies. From the countries who replied to the survey at least 47% have Universal Service Policies in place, but from those, 15% have not yet implemented the policies. In practice, from the surveyed countries, only three (Kenya, Madagascar, and Rwanda) mentioned that Universal Service Funds have been used to deploy equipment in the 2.4 and 5GHz bands (see Figure 5.3 and Figure 5.4). Reasons for this disparity may be that only bigger or incumbent operators have access to the funds, or that specific technology is mandated for use of the subsidies, not necessarily including 2.4 and 5GHz bands technology. Targeted, efficient and flexible universal service funds can serve as a tool to extend connectivity, for countries that explicitly and proactively want to enhance ICT penetration.

6.2 Recommendations

The policy recommendations are discussed in Chapter 5. From the above, it follows that:

Policy Recommendation 1 - In view of the continent's weak teledensity and lack of alternative infrastructure, establishing a more certain and uniform regulatory framework across Africa would promote private investment and connectivity through technology in these bands.

Policy Recommendation 2 - The ITU could have a key role to play, both by taking a firmer position and issuing clearer guidelines for the regulation of license-exempt bands, and by serving as a convening forum for countries to establish common regulatory strategies.

Policy Recommendation 3 - Governments should strive to establish an appropriate business climate: lower barriers to entry, ensure certainty, and when possible provide access to capital.

Policy Recommendation 4 – Countries should review Universal Service Funding Policies in light of their applicability to new market entrants and alternative technologies such as the ones operating in license-exempt bands. Targeted, flexible and accessible Universal Service Funds should be implemented.

Policy Recommendation 5 - A fair balance needs to be found when defining the regulatory regime to be applied in these bands. Indeed, several parameters need to be defined: i) Licensing, ii) Restrictions on power and range, iii) restrictions on services, iv) requirements for certification, iv) level of enforcement. The appropriate balance between barriers to entry and the well functioning of the bands should set the level of restrictions to impose, bearing in mind that, currently, there is a tendency to over regulate and keep barriers to entry high.

Policy Recommendation 6 - This thesis argues that governments should err on the side of laxity in these bands, in order to lower barriers to entry and counterbalance the current overregulation of these bands Indeed, taking into account that spectrum is a renewable resource, the purpose of the regulation should not be to eliminate all interference, but to maximize output. For Africa, with its weak teledensity position, a higher use of the bands - in particular in rural areas - may translate into significant differential advantages, by going from no service to 'some' service. In addition, due to low usage of telecommunication services, congestion of the bands is less likely.

6.3 Further research

The work of this thesis is a contribution to the study of the use of unlicensed bands and spectrum management models in developing countries. Further research is needed, however, to understand the specific opportunities for the use of wireless technology and license-exempt bands in Africa, as well as to identify and characterize in more detail the appropriate policies to implement.

Specifically, some of the areas that could be further developed are indicated below:

- Gather more information on the use of bands, specifically about the extent of use (i.e., is use of the bands widespread, or only occasional?) and about the interrelationship of users and type of use (e.g.., who is doing rural coverage?). This can be done, to start with, by talking to equipment suppliers and operators, in order to get more 'on-the ground' information.
- Once additional information is available, study the effect of regulation on the use of the bands, i.e., study whether certain types of regulation are too strict or whether, for example, there is more use in unlicensed bands. Also analyze whether certain regulation is favoring a particular type of user.
- Develop case studies to look at closer level. Several categories can be established in terms of income, teledensity, regulation (licensing, Universal Service Policies in place) and use (using information from the previous point). Case studies can then be developed on representative countries of clusters of categories.
- Look for reasons why spectrum policies differ in different countries. Study how different factors, (e.g. income, percentage of people in rual vs urban areas, geography, etc) influence the regulatory choices of these countries.
- Using information from the case studies to be developed, further work is needed on the appropriate balance to strike between lowering barriers to entry and ensuring the well functioning of the bands. This work can lead to more specific recommendations to improve the regulatory environment
- Enabling a budding business environment, conducive to investment and output, can be instrumental in ensuring a brighter prospect for the connectivity scenario in Africa. Further research should also focus on finding the appropriate models for business development, such as access to capital, structures for trust, etc. Differentiated conditions are likely to be needed for larger companies and for small entrepreneurs or community based initiatives.

- The management of unlicensed spectrum can further be developed by studying innovative and decentralized models for management of common use resources, in contrast with a top-down command-and-control spectrum management approach.

6.4 Final remark

Ensuring accessibility to ICT infrastructure can, in my view, be of extreme importance for the developing world countries, and specifically for Africa. I believe it is our responsibility to invest the necessary resources to find innovative, creative and effective solutions to improve connectivity. No technology-centric approach can on its own solve problems of fair distribution of connectivity and access to communication. This thesis finds that the current regulatory status may be biased towards overregulation. Taking the institutional and business environment into account is essential if we want to find workable solutions - adapted to these countries' contexts. Erring on the side of laxity may enable some connectivity growth in Africa. There is a long road ahead, but hopefully a combination of initiatives can in the medium to long run have an impact and change the connectivity landscape in the continent.

Appendix I - Interference management techniques

This Appendix describes some of the interference management techniques that have, in recent years, enabled the increasing use of license-exempt bands, by making possible the coexistence of users in the same frequency band without insurmountable interference. Some of the technologies described below are fairly well known, and extensively utilized, while some others are being developed now[102].

Carrier Sensing Multiple Access (CSMA)

In 802.11b network the access to the channel by multiple transmitters is coordinated by the MAC protocol, which is the well-known, Carrier Sensing Multiple Access (CSMA) protocol with collision avoidance feature. That is, a transmitter can start its transmission only if it senses that the channel is currently idle, and will backoff when sensing channel busy. As a result, even if two closely located access points are allocated in the same frequency channel, much of the mutual interference can still be avoided by the CSMA protocol, and the available bandwidth are implicitly shared between the two cells. Using these technique comes at the expense of increased delay and degraded network throughput (Leung 2004)[103].

Dynamic Frequency Selection (DFS), Dynamic Channel Selection (DCS)

DFS/DCS are protocols in which the system will continually sample the channels for interference, in real time, and will try to select a vacant channel or else the most optimal. . If the channel is degraded communication will be moved to another channel. This helps both neighboring and interfering installations. One likely application of dynamic channel selection is selecting lower-powered channels for short-range indoor situations while transparently switching to a higher-power channel when longer ranges are required. This method is being made compulsory, in Europe, for the operation of 802.11a in the 5GHz band (Gast).

[102] While Carrier Sensing Multiple Access (CSMA) is implemented in the MAC (Multiple Access Control) layer, all the others are implemented in the PHY (Physical) layer. For additional information on OSI layers see (Tannenbaum 1988).

[103] The 802.11 MAC supports in addition the Point Coordination Function (PCF) and the Distributed Coordination Function (DCF). The PCF provides contention-free access, while the DCF uses the carrier sense multiple access with collision avoidance (CSMA/CA) mechanism for contention based access. These protocols ensure that a "fair" access to the medium (Gast 2002).

Transmit Power Control (TPC)

Transmit power control is a commonly used method that enables dense network deployments by allowing administrators to control the area that an access point services by tuning the power to achieve the desired size. This feature makes the access point and end-user equipment negotiate the lowest acceptable power to maintain a link. This means that they use low power when possible and only maximum power when necessary. Apart from reducing interference, this is more energy efficient for the battery and also increases capacity, since the system will be able to support more users (UNINETT website).

Orthogonal Frequency Division Multiplexing (OFDM)

OFDM is a modulation scheme that offers several access and signal processing benefits not available in other modulation schemes, allowing wireless networks pack high spectral efficiency into relatively small spectrum bandwidths (Rappaport 2002). OFDM chops a large frequency channel into a number of subchannels, which are then used in parallel for higher throughput. The frequencies of the transmitted carriers are arranged in a precise mathematical relationship such that the sidebands of the individual carriers overlap and the signals are received without adjacent channel interference (Carter et al. 2003).

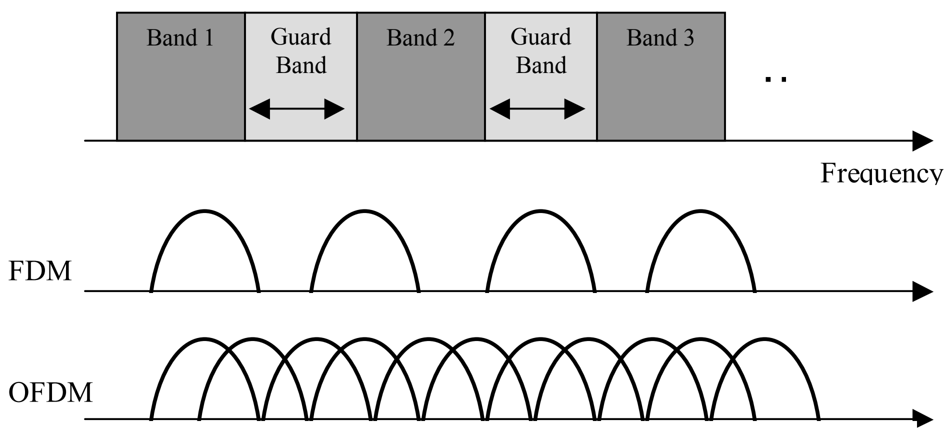

Figure I.1 – Traditional FDM (on top) vs. Orthogonal FDM (below)

Source: After (Gast 2002)

According to Rappaport OFDM technology possesses a number of unique features (Rappapport 2002):

- Robustness against multipath fading and intersymbol interference
- Efficient use of the available radio frequency (RF) spectrum
- robustness against narrowband interference
- OFDM does not require contiguous bandwidth for operation
- Enables single-frequency networks, which is particularly attractive for broadcasting applications

Both the 802.11a and 802.11g protocols incorporate OFDM in order to achieve data rates more than twice those of wireless computer networks using the 802.11b protocol.

Spread Spectrum

Spread-spectrum technologies greatly facilitate the deployment of unlicensed bands. In some cases, its use is a requirement imposed by the regulatory authorities (Best 2003); in other cases, it can be the only practical way to meet regulatory requirements.

As mentioned before traditional radio communications focus on cramming as much signal as possible into as narrow a band as possible. Spread spectrum works by diffusing signal power over a large range of frequencies (Gast 2002). Spreading the transmission over a wide band makes transmissions look like noise to a traditional narrowband receiver.

This does not mean that spread spectrum is a "magic bullet" that eliminates interference problems. Spread-spectrum devices can interfere with other communications systems, as well as with each other; and traditional narrow-spectrum RF devices can interfere with spread spectrum. As more RF devices (spread spectrum or otherwise) occupy a particular area, the noise level will go up, the signal-to-noise ratio decrease, and the range over which you can reliably communicate will drop.

There are several types of spread spectrum techniques. Below, a brief explanation of Direct Sequence Spread Spectrum (DS SS) and Frequency Hoping (FH).

Direct Sequence Spread Spectrum (DS or DSSS)

Direct sequence spread spectrum is the most widely used type of spread spectrum system. It is a digital modulation technique achieved by modulating a narrow band radio frequency carrier with a high speed spreading code sequence. Since the spreading code spreads the narrow band signal over a wider band of spectrum, the power level at any given frequency is very low, minimizing interference. Conversely, interference from a narrow band waveform has a limited effect on a spread spectrum signal (Carter et al. 2003).

Frequency Hoping (FH)

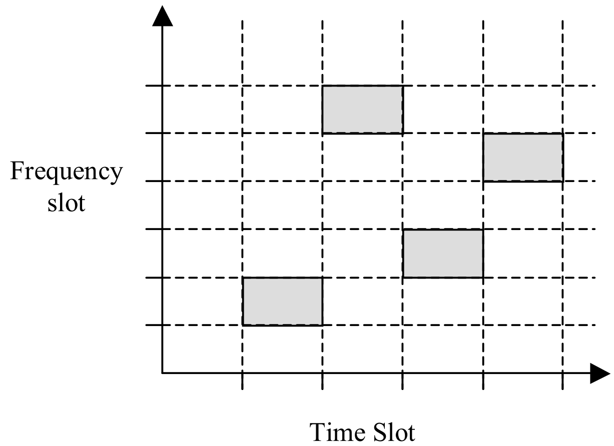

Figure I.2 – Frequency Hoping: the basic principle

Source: After (Gast 2002)

Frequency hopping spread spectrum is a form of signal spreading in which the frequency of the transmitted signal "hops" from channel to channel in a random pattern, transmitting a short burst at each subchannel. As the amount of time the signal is using any single channel is very short, even if a particular channel is interfered, interference is minimized since the channel is only in service for a very short period before the transmitter hops to a different channel (Carter et al. 2003).

While Frequency Hopping systems are the cheapest to make (precise timing is needed, but no sophisticated signal processing is required), Direct Sequence systems require more sophisticated signal processing, which translates into more specialized hardware and higher electrical power consumption. Direct-sequence techniques also allow a higher data rate than frequency hopping systems.

Ultra Wide Band (UWB)

Ultra Wide Band (UWB) is an emerging technology that has just been approved approved by the FCC for a number of communications and sensing applications. Its principle of operation can be seen in Figure I.3: UWB relies on the fabrication of ultra-short baseband pulses that have enormous bandwidths, on the order of several GHz. Unlike conventional wireless systems that upconvert baseband signals to radio frequency (RF) carriers, UWB can be used at baseband and can be thought of as a baseband transmission scheme that happens to propagate at RF frequencies (Rappaport 2002).

UWB is similar to spread spectrum in that the signal is spread across such a wide bandwidth that the power falling across any given ordinary communication channel is low. This makes it possible for UWB device to operate on spectrum occupied by existing services without causing interference, and thus promoting spectrum efficiency (Carter et al. 2003).

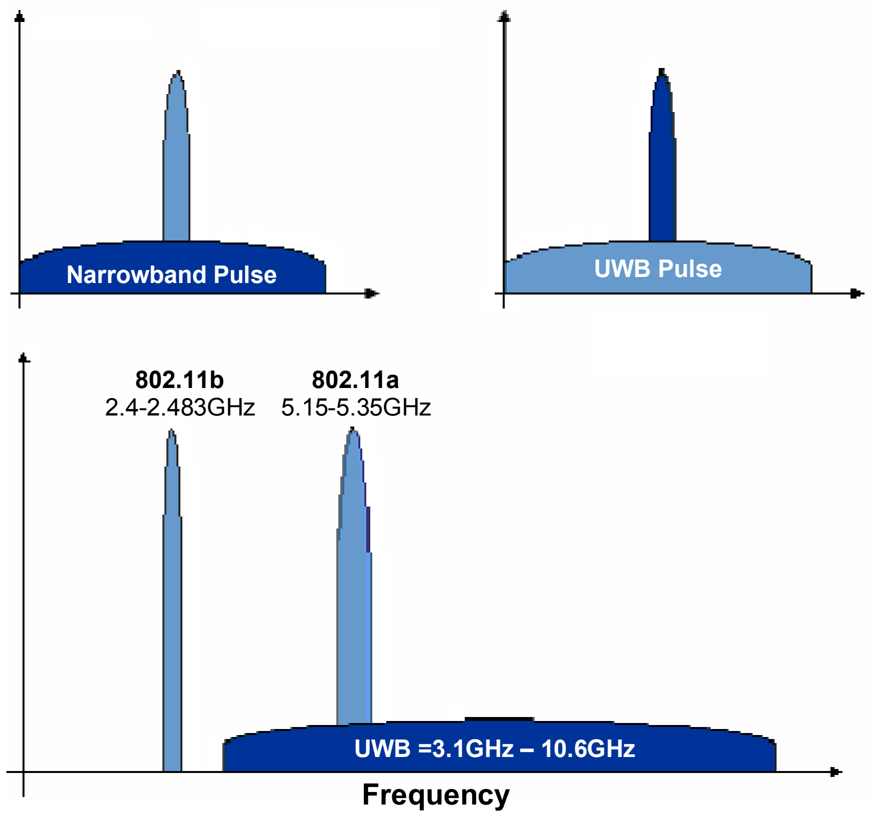

Figure I.3 – Ultrawideband: principles and initial spectrum allocation

Source: (Freedhoff 2001)

UWB is a short distance wireless technology and has been demonstrated to provide reliable data rates exceeding 100 Mb/s within buildings, with extremely low power spectral densities (Rappaport 2002).

In addition to their potential for communications systems, UWB technology can also support the operation of new low power radar products that can provide precise measurement of distances or detection of objects underground or behind walls or other structures.

Appendix II - Overview of some wireless standards

There is currently a wide variety of standards – approved and in existence, being finalized, or under preparation. This Appendix described the most relevant ones. These standards implement some of the interference management techniques described in Appendix I.

Many of these standards belong to the 802.xx family. The first meeting of the IEEE[104] Project 802[105] (a project of the Computer Society "Local Network Standards Committee") was held in 1980. At the time the objective was to develop a LAN standard, with speeds from 1 to 20 Mbps. The access method was similar to that for Ethernet, as well as the bus topology (IEEE 2002).

802.11

The first standards based on 802.11 were initially released in 1997. 802.11, which operated in the 2.4 GHz band, included an infrared (IR) layer that was never widely deployed, as well as two spread-spectrum radio layers: frequency hopping (FH) and direct sequence (DS)[106]. Initial 802.11 products were limited to 2 Mbps.

802.11 adapts Ethernet-style networking to radio links. It uses a carrier sense multiple access (CSMA) scheme to control access to the transmission medium. However, collisions waste valuable transmission capacity, so rather than the collision detection (CSMA/CD) employed by Ethernet, 802.11 uses collision avoidance (CSMA/CA) (Gast 2002). Since the development of the initial 802.11 product the standards have been evolving to include different Medium Access Control (MAC) mechanisms, Physical Layer (PHY) characteristics, and enhanced security features, as well as higher data rates and Metropolitan Area Networks (MANs) capabilities.

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[104] The IEEE – Institute of Electrical and Electronics Engineers is a non-profit, technical professional association. The IEEE is a main coordinator and producer of standards (it has nearly 900 active standards and 700 under development). In addition it produces a wide variety of publications, and organizes majors conferences in areas ranging from computer engineering, biomedical technology and telecommunications, to electric power, aerospace and consumer electronics, among others. For more info see www.ieee.org.

[105] 802 was just the next project number in the sequence being issued by the IEEE for standards projects.

[106] Some concepts linked to Medium Access Control (MAC) mechanisms are explained in section 2.3. For additional information see (Gast 2002, IEEE 1997).

802.11b

The most well established and widely deployed standard is 802.11b[107], a specification which was ratified in 1999. After a slow start, 802.11b kit has had significant success, and therefore this Appendix will look at it in some detail. Client devices and access points based on 802.11b transmit data at maximum throughput of 11Mbit/s, although some tests indicate lower usual rates (of about 5.5Mbitps) (Courtney 2002).

802.11b equipment transmits and receives in the 2.4GHz band. This band is also used by short-range Bluetooth[108] and DECT wireless devices, as well as microwave ovens. Enterprises that have deployed significant amounts of WLAN and Bluetooth hardware in the same office so far report minimal problems. Nevertheless, interference can be an issue when devices are situated in close proximity. Connections can be blocked in worst case scenarios.

802.11b goes by a variety of names. Some people call it wireless Ethernet, in parallel with the traditional wired Ethernet (802.3). More recently, the Wireless Ethernet Compatibility Alliance (WECA) has been pushing its Wi-Fi ("wireless fidelity") certification program, which includes a variety of wireless technologies. Any 802.11 vendor can have its products tested for interoperability[109], and it receives a Wi-Fi mark. This certification has apparently helped the growth of 802.11b.

The use of 802.11b has experienced significant growth: in the year 2000, WLAN sales worldwide climbed above the critical billion-dollar level and the market continued to grow at a high pace during the first half of 2001, despite general industry slowdown (HIPERLAN2 website). This technology is being used around the world mainly to deploy ‘hotspots’ in coffee shops, airports lounges, university campuses, etc. 802.11b has now been included as standard equipment in many laptop computers and hand-held devices. Most 802.11 hardware vendors also support Linux.

[107] For specifications see (IEEE 1999).
[108] Bluetooth is a wireless technology that eliminates wires and cables between both stationary and mobile devices, enabling the wireless connection of personal devices in Personal Area Networks (PANs). Examples are wireless headphones, communication between PDAs and computers, etc. Bluetooth has been adopted by many industry sectors (e.g. telecom, computer and home entertainment industry, automotive). For more information see www.bluetooth.com.
[109] For newer products based on the 802.11a standard, WECA will allow use of the Wi-Fi5 mark. The "5" reflects the fact that 802.11a products use a different frequency band of around 5 GHz.

Security has been and still is an issue with 802.11b. Wired Equivalent Privacy (WEP) was initially marketed as the security solution for wireless LANs, but several design flaws were found. Other solutions now include the Extensible Authentication Protocol (EAP) (Gast 2002).

With the growth in 802.11b use other issues emerge. The first is congestion: when there are relatively few networks and users, the networks were rarely subjected to severe stresses. With usage growing, congestion and quality of service increasingly becomes a problem. In addition, while it was a new technology, users were forgiving when they failed - wireless connectivity was a privilege, not a right. Users are now becoming increasingly exigent. This may not necessarily be a problem in the developing world context, where the density of users is likely to be lower. Growing use and unrestricted use of power can, however, present the same problems.

While 802.11b is primarily a WLAN context technology, it has actually been engineered to be used in point-to-point (backhaul) and point-to-multipoint (WMAN) configurations. There are, however, more appropriate 802.x standards for this type of configuration, and these will be discussed below.

802.11a

Growing use of this technology brings some fear of congestion, which according to some (Courtney 2002) was the reason why IEEE developed another standard: the 802.11a., also in 1999 (IEEE 1999). This standard operates in the 5GHz band. Because the 5GHz band is much larger than the ISM band and isn't already occupied by microwave ovens and other devices, there should be fewer problems with interference.

802.11a increases the maximum data rate to 54Mbit/s [110] and uses orthogonal frequency division multiplexing (OFDM) [111]. 802.11a uses the same MAC layer as 802.11b, and some vendors are announcing that their access points can be upgraded to 802.11a by purchasing a new card and installing new firmware[112].

802.11a products are already available in the US but have faced regulatory approval problems in other countries. Both the European Telecommunications Standards Institute (ETSI) and the UK Radiocommunications Agency (RA) have in the past objected to 802.11a's use of certain parts of the 5.15 to 5.35GHz waveband, because of the risk of interference for military and government communications.

[110] According to Courtney, proprietary compression methods make 108Mbit/s bandwidth possible (Courtney 2002).
[111] See Appendix I for more information.
[112] Despite the potentially simple software upgrade to the 802.11a, in many cases bit rates are limited by the Ethernet port capacity - in some cases 10-Mbps or less.

802.11h

To address these concerns, the IEEE has developed a revised version of the 802.11a standard that includes new features to avoid interference (Kowalenko 2003): transmit power control (TPC) and dynamic frequency selection (DFS), sometimes called dynamic channel selection (DCS). The purpose of these functions is to minimize the possibility of interference by reducing power output and detecting the clearest transmission channels[113].

802.11g

Building on the success of 802.11b, a new standard has been developed that extends data rates up to at least 22Mbps, but with the possibility to go up to 54Mbps (Kraemer 2001). This standard - 802.11g is a 2.4-GHz standard, like 11b, but it uses the OFDM modulation technique of 11a. The upgrade path from 11b to 11g might be easier than that from 11b to 11a; because both standards use the same frequency band. 802.11g also promises to be less expensive than 11a. However, this standard does not address the 2.4 GHz band congestion problem (Courtney 2002).

HiperLan (or HiperLan1)

Hiperlan (also called HiperLan1) is an ETSI standard that supports data rates of 11-20 Mbps, and operates in the 5GHz band. An interesting characteristic is that it may provide coverage beyond the radio range limitation of a single node via multihop relaying (HIPERLAN1 website). Partly due to the existence of other standards (e.g. the 802.11a) supporting higher data rates, HiperLan suffers from a lack of vendor backing and a far smaller user base than 802.11b (Courtney 2002).

HiperLan2

The upgraded version of HiperLan, HiperLan2, also developed by ETSI is more attractive, and could pose a threat to the predicted dominance of 802.11a. HiperLan2 provides the same 54Mbit/s maximum data transfer rates and transmits in the same 5GHz waveband. Although the physical layer is virtually the same as for 802.11a, however, HiperLan2 has its own DFS[114] scheme built in, and it offers better quality of

[113] See Appendix I for more information.
[114] Dynamic Frequency Selection (DFS). See Appendix I for details.

service (QoS)[115], making it more acceptable to regulators in Europe. Despite the fact that it appears to have lost the support of all the major vendors except Ericsson and Nokia, it may surface as the technology of choice for carriers and mobile operators wanting to integrate their mobile cellular networks with public-access WLANs and hotspots, since it offers interoperability with 3G[116].

This standard includes two modes of operation: in the "network mode", also called "centralized mode", Mobile Terminals (MT) communicate with an Access Point (AP); in the "peer-to-peer mode", also called "direct mode" MTs communicate directly, without recourse to the AP (HIPERLAN2 website).

802.16

Whereas the standards described above are mainly WLAN standards, 802.16 is a standard for fixed point-to-multipoint or point-to point broadband wireless access systems, i.e., it is mostly a WMAN, or wireless backhaul standard[117]. 802.16 can provide aggregate rates of up to 70 Mbps. This standard includes a particular physical layer specification broadly applicable to systems operating between 10 and 66 GHz.

The variants 802.16a operates in the 2-11 GHz band (licensed use). 802.16b, also called WirelessHUMAN™ (Wireless High-Speed Unlicensed Metropolitan Area Network) is intended for operation under license exempt regulation in the 5-6 GHz band (IEEE 2001, IEEE 2001b, IEEE 802.16 website). Enhancements to the 802.16 standard include OFDM support. 802.16b further includes a Mesh Mode option, enabling subscriber to subscriber communications (Newlans 2003).

Rappaport considers that 'several promising wireless competitive local exchange carriers (W-CLECs) and wireless Internet Service Providers (W-ISPs)' failed because they were ahead of their time, but that 'these may someday stage a comeback with the IEEE 802.16 wireless Metropolitan Area Network standard' (Rappaport 2002). The 802.16 standard is being promoted by WiMAX (the Worldwide Interoperability for Microwave Access Forum) (WiMAX website).

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[115] For an in-depth description of HiperLAN2 see (H2GF 2001)

[116] Indeed, close links have been maintained between HiperLan2 and 3GPP, the European standard body for 3G.

[117] While the WLAN provides high data rates and mobility to several end-users, the WMAN provides fixed broadband wireless access to the WLAN or WMAN base station. See (IEEE 802.16 website) and also (Engels et al 2003).

Proprietary standards

In addition to these standards there are other proprietary ones. Michael Best[118] mentions a few in the publication already referred to. Two standards are described here as they are interesting solutions to longer range deployments.

One such standard is the Motorola's Canopy system, which includes a point-to-point and a point-to-multipoint solution. Initially using the 5GHz spectrum, it is also now available in the 2.4GHz band (Motorola Canopy website). The Canopy point-to-multi-point system offers data rates of up to 6 Mbps (aggregate data rates[119]) and the point-to-point system delivers 14 Mbps (aggregate data rates) to network end users. In terms of range a single point-to-multipoint system can cover a range of up to 15 kilometers, while a point-to-point system can deliver up to 55 kilometers.

The second, corDECT, is a standard that has been developed in the Indian Institute of Technology, Madras (corDECT website). It is a solution for point-to-multipoint connection, with a specified range of 10 kilometers, although relay stations can be used to extend this range up to 25kms. In practice, according to Michael Best (Best 2003) higher ranges (of up to 40kms) have been achieved. The system enables simultaneous voice and data connectivity, delivering voice using 32 Kbps ADPCM (Adaptive Differential Pulse Code Modulation), and Internet at 35/70 Kbps. The system operates below 2GHz (the DECT band is between 1880 - 1935 MHz).

Additional standards

There are other standards in this area, apart from the ones indicated above: the standard 802.20, for example, is a broadband mobile solution, but it is still not available. The family of standards 802.15 is intended mainly for PAN (Personal Area Networks) applications, more particularly Bluetooth type applications, multimedia centric wireless networks, and monitoring and control applications. These standards are however not directly or significantly relevant for this thesis.

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[118] Michael Best mentions several ones (Best 2003). Two of those are referred here. Additional ones include, e.g., The D-Link AirPlus DWL-900AP+, based on 802.11 but getting up to 22Mbps - see http://www.dlink.com/products/?model=DWL-900AP%2b.

[119] The term aggregate means that these bandwidth is shared by all users.

Appendix III - List of countries with respective codes

Table III.1 – List of countries with respective codes

	COUNTRIES	ITU CODE[120]	FIPS_10-4[121]
1	Algeria (People's Democratic Republic of)	ALG	AG
2	Angola (Republic of)	AGL	AO
3	Benin (Republic of)	BEN	BN
4	Botswana (Republic of)	BOT	BC
5	Burkina Faso	BFA	UV
6	Burundi (Republic of)	BDI	BY
7	Cameroon (Republic of)	CME	CM
8	Cape Verde (Republic of)	CPV	CV
9	Central African Republic	CAF	CT
10	Chad (Republic of)	TCD	CD
11	Comoros (Union of the)	COM	CN
12	Congo (Republic of the)	COG	CF
13	Côte d'Ivoire (Republic of)	CTI	IV
14	Democratic Republic of the Congo	COD	CG
15	Djibouti (Republic of)	DJI	DJ
16	Egypt (Arab Republic of)	EGY	EG
17	Equatorial Guinea (Republic of)	GNE	EK
18	Eritrea	ERI	ER
19	Ethiopia (Federal Democratic Republic of)	ETH	ET
20	Gabonese Republic (Gabon)	GAB	GB
21	Gambia (Republic of the)	GMB	GA
22	Ghana	GHA	GH
23	Guinea (Republic of)	GUI	GV
24	Guinea-Bissau (Republic of)	GNB	PU
25	Kenya (Republic of)	KEN	KE
26	Lesotho (Kingdom of)	LSO	LT
27	Liberia (Republic of)	LBR	LI
28	Libya (Socialist People's Libyan Arab Jamahiriya)	LBY	LY
29	Madagascar (Republic of)	MDG	MA
30	Malawi	MWI	MI
31	Mali (Republic of)	MLI	ML
32	Mauritania (Islamic Republic of)	MTN	MR
33	Mauritius (Republic of)	MAU	MP
34	Morocco (Kingdom of)	MRC	MO
35	Mozambique (Republic of)	MOZ	MZ
36	Namibia (Republic of)	NMB	WA
37	Niger (Republic of the)	NGR	NG
38	Nigeria (Federal Republic of)	NIG	NI
39	Rwandese Republic	RRW	RW
40	Sao Tome and Principe (Democratic Republic of)	STP	TP

[120] For ITU codes see http://itu.idxc.org/. These codes are used to index the data tables to maps.
[121] For Federal Information Processing Standards (FIPS) Codes, go to http://earth-info.nima.mil/gns/html/fips10-4.html, or http://www.netscout.net/oneworld/countrycodes.htm.

41	Senegal (Republic of)	SEN	SG
42	Seychelles (Republic of)	SEY	SE
43	Sierra Leone	SRL	SL
44	Somali Democratic Republic	SOM	SO
45	South Africa (Republic of)	AFS	SF
46	Sudan (Republic of the)	SDN	SU
47	Swaziland (Kingdom of)	SWZ	WZ
48	Tanzania (United Republic of)	TZA	TZ
49	Togolese Republic	TGO	TO
50	Tunisia	TUN	TS
51	Uganda (Republic of)	UGA	UG
52	Western Sahara[122]	AOE	WI
53	Zambia (Republic of)	ZMB	ZA
54	Zimbabwe (Republic of)	ZWE	ZI

[122] See Footnote 46, page 57, for note on Western Sahara.

Appendix IV - Survey and e-mail in English, French and Portuguese

Subject: MIT Research: Request for information on spectrum usage in [*name of country*]

Dear Mr/Ms. [*xxxx*]

I am a graduate student at the Massachusetts Institute of Technology, and I obtained your contact information through [*the ITU/other*].

I am currently performing a study on the status and use of the 2.4 and 5 GHz radio bands. More precisely, I am interested in the following bands:

- 2400 - 2483.5 MHz
- 5.15 - 5.35 GHz; 5.47 - 5.725 GHz and 5.725 - 5.875 GHz

These bands are often referred to as "Unlicensed bands". In the United States this spectrum includes the ISM (Industrial, Scientific and Medical) and U-NII (Unlicensed National Information Infrastructure) bands. Currently these bands are used for a variety of short-range low-power devices, including Bluetooth, WLAN, and microwave ovens.

This study will focus on the regulation and use of these bands in countries throughout Africa. By understanding the general outlook for these bands, we aim to identify opportunities and issue recommendations for regulation.

I am particularly interested in the current practices in [*name of country*] and your assistance with this survey will be critical to its success. Could you please answer the list of attached questions in the context of [*name of country*]? Your help will be acknowledged in my final report at MIT, unless you prefer to remain anonymous.

I have attached the survey in two formats: Microsoft Word (Survey_Spectrum_en.doc) and plain text (Survey_Spectrum_en.txt). Please use the format that is most convenient for you, and send me the completed form via e-mail.

Ideally, I would like to have your response by [*date*]. Please let me know if this is possible.

This survey is only possible with your help and participation – I thank you very much in advance. I would also be happy to share with you some of the results, when they become available. If this would be of interest to you, please let me know.

I am looking forward to your reply.

My very best regards,

Isabel Neto

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Survey on Regulation and Use of Spectrum in the 2.4 and 5 GHz Bands

For more information, please contact:
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Disclaimer: Your participation in this study is completely voluntary and you are free to decline to answer any or all of the questions. The data collected will be analyzed and some of the results will be made public. Confidentiality and/or anonymity will be assured, if so required.

If you prefer to remain anonymous please check this box ☐

Please answer the following questions about the regulation and use of these frequency bands:

- **The 2.4 GHz band (2400 - 2483.5 MHz)**
- **The 5 GHz bands (5.15 - 5.35 GHz; 5.47 - 5.725 GHz and/or 5.725 - 5.875 GHz)**

The use of these bands varies across countries. In many countries they are often referred to as "Unlicensed bands". In the United States, this spectrum includes the ISM (Industrial, Scientific and Medical) and U-NII (Unlicensed National Information Infrastructure) bands. Currently these bands are used for a variety of short-range low-power devices, including Bluetooth, WLAN, and microwave ovens.

Part A – Regulation in place for specific bands

A.1 – Regulation for the 2.4 GHz band

1. a. Is a license required for operating radio transmitter devices in this band?

   ☐ Yes (go to 1.b) ☐ No (go to 1.c)

   b. If you replied YES to 1.a please provide details

   - License to operate required ☐ Yes ☐ No
   - License for use of spectrum required ☐ Yes ☐ No
     - Is spectrum licensed on an exclusive basis? ☐ Yes ☐ No
   - License automatically granted on payment of a fee ☐ Yes ☐ No
   - Have any licenses been issued? ☐ Yes ☐ No
   - Have any licenses been revoked? ☐ Yes ☐ No

   c. If you replied NO to 1.a

   - Is registration without a license required? ☐ Yes ☐ No

2. Does the regulator certify radio transmitter devices manufactured to transmit in this band?

   ☐ Yes ☐ No

3. What is the maximum emitted power in this band? Watts

4. What are, if any, the restrictions placed on:
- distance of propagation vs power level (maximum kilometers for given power level), maximum field strength (millivolt per meter) or EIRP?
- place of transmission (*e.g.,* indoor versus outdoor use)?

5. Are there restrictions on the type of services used? Are voice and data both allowed?

6. When were these regulations put into place? If there has been a recent change in regulation, how has it impacted the use of these bands?

7. a. Are these regulations strictly enforced? ☐ Yes ☐ No
b. Who is the enforcing officer (which government department/agency)? Who is responsible for dispute resolution?

8. Please supply a reference to the text of the relevant regulations for this band

A.2. – Regulation for the 5 GHz bands

9. a. Is a license required for operating radio transmitter devices in this band?
☐ Yes (go to 9.b) ☐ No (go to 9.c)
b. If you replied YES to 9.a please provide details
   - License to operate required ☐ Yes ☐ No
   - License for use of spectrum required ☐ Yes ☐ No
     - Is spectrum licensed on an exclusive basis? ☐ Yes ☐ No
   - License automatically granted on payment of a fee ☐ Yes ☐ No
   - Have any licenses been issued? ☐ Yes ☐ No
   - Have any licenses been revoked? ☐ Yes ☐ No

c. If you replied NO to 9.a
   - Is registration without a license required? ☐ Yes ☐ No

10. Does the regulator certify radio transmission devices manufactured to transmit in this band?
☐ Yes ☐ No

11. What is the maximum emitted power in this band? Watts

12. What are, if any, the restrictions placed on:
- distance of propagation vs power level (maximum kilometers for given power level), maximum field strength (millivolt per meter) or EIRP?
- place of transmission(*e.g.,* indoor versus outdoor use)?

13. Are there restrictions on the type of services used? Are voice and data both allowed?

14. When were these regulations put into place? If there has been a recent change in regulation, how has it impacted the use of these bands?

15. a. Are these regulations strictly enforced? ☐ Yes ☐ No
b. Who is the enforcing officer (which government department/agency)? Who is responsible for dispute resolution?

16. Please supply a reference to the text of the relevant regulations for this band

Part B – Background to the regulations

17. What is the principle rationale for these regulations (*e.g.,* controlling quality of service, managing interference, protecting profits of existing operators, ensuring ease of use, etc.)?

18. How is the regulation affecting the use of these bands (*e.g.,* in terms of use, quality, sustainability, etc.)?

19. Who authored the regulations (which government department)? Were the regulations based on ITU standards or another country's regulations?

20. Are there bands, other than these, where no license is required to transmit?

21. Are there plans in the future to change the regulations or their implementation?

Part C - Implementation and experiences of use

22. Are these bands being used?

23. Who are the main users in these bands? (*e.g.,* coffee shops, existing telecom operators, ISP's, municipalities, etc.)

24. In which context are services being offered?
- ☐ Localized coverage, urban hotspots
- ☐ Rural connectivity, wider area coverage (infrastructure, point to point)
- ☐ Other

25. Are there providers of end-user "hot-spot" services with associated fees? Where are these hot-spots and are they accessible to most people?

26 a. What protocols are being used in these bands and are they mainly open (*e.g.,* 802.11) or closed/proprietary protocols (*e.g.,* Motorola Canopy)?

b. What are the most popular commercial products?

27. Are there any issues with end-user equipment (price, availability, etc.)?

28. Are there any issues with equipment on the network side (price, availability, etc.)?

29. Are there significant issues with in-band and out-of-band interference to other services?

30. Does the regulator have the technical capacity to detect illegal transmitters? (*e.g.,* does it have the appropriate radio detection equipment, etc.)

31. Are there any provisions to support service providers via a Universal Service Fund?

32. Have these funds been used for the deployment of radio equipment in these bands?

☐ Yes ☐ No

33. Is there anything else you would like to add?

Thank you very much for your participation.

Subject: Recherche à l'MIT: Demande d'information sur utilisation de spectre frequentielle au [*name of country*]

Cher Monsieur, chère Madame [*xxxx*]

Je suis chercheur au Massachusetts Institute of Technology, et j'ai obtenu votre contact par [*the ITU/other*].

Je réalise actuellement une étude sur la réglementation et l'utilisation des bandes radio 2.4 et 5 GHz. Je m'intéresse en particulier aux bandes suivantes:

- 2400 - 2483.5 MHz
- 5.15 - 5.35 GHz; 5.47 - 5.725 GHz et 5.725 - 5.875 GHz

Ces bandes sont souvent appelées "Bandes sans licence/Unlicensed". Aux États-Unis ce spectre inclus la bande ISM (Industrial, Scientific and Medical) et U-NII (Unlicensed National Information Infrastructure). À présent ces bandes sont utilisées pour plusieurs applications de courte portée et faible puissance, par exemple Bluetooth, WLAN et les fours micro-ondes.

Cette étude va se concentrer sur la réglementation et l'utilisation de ces bandes dans des pays africains. En comprenant l'état général de ces bandes notre objectif est d'identifier les opportunités et ainsi produire des recommandations de réglementation ou autres.

Je suis particulièrement intéressée par l'expérience du [*name of country*] et votre assistance sera déterminante dans le succès de cette étude. Je voudrais vous demander de répondre à l'enquête que je joins dans le contexte du [*name of country*]. Votre aide sera reconnue dans mon rapport final à l'MIT, sauf si vous préférez l'anonymat. Si vous croyez qu'il y a d'autres personnes plus adéquates pour répondre à cette enquête, pourriez-vous m'envoyer leur contact email?

Je joins l'enquête dans deux formats: Microsoft Word (Survey_Spectrum_fr.doc) et un simple fichier de texte (Survey_Spectrum_fr.txt). Je vous prie d'utiliser et remplir le fichier qui vous convient le plus, et de m'envoyer votre réponse par email.

Idéalement je souhaiterais une réponse avant le [*date*]. Est-ce que vous croyez que c'est possible?

Cette enquête sera possible uniquement avec votre aide. D'avance, je vous remercie pour votre participation. Lorsque les résultats de cette recherche seront disponibles, je pourrais vous les adresser. Si vous êtes intéressé, n'hésitez pas à me contacter

En attendant votre contacte et votre réponse, [*Monsieur, Madame*], je vous prie de bien vouloir recevoir l'expression de mes salutations les plus distinguées,

Isabel Neto

Technology and Policy Program
Massachusetts Institute of Technology
77 Massachusetts Avenue; E40-371
Cambridge, MA 02139
Tel: (857) 222-0484
e-mail: ineto@mit.edu

Enquête sur la réglementation et l'utilisation des bandes de fréquences 2.4 et 5 GHz

Pour d'autres informations, vous pouvez contacter:
Isabel Neto
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USA
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e-mail: ineto@mit.edu

Avertissement: Votre participation dans cette étude est totalement volontaire et vous êtes libre de ne pas répondre à une ou plusieurs des questions. L'information collectée sera analysée et certains résultats seront rendus publics. Confidentialité et/ou anonymat seront garantis, si nécessaire.

Si vous préférez rester anonyme, cochez cette case: ☐

Répondez aux questions suivantes sur la réglementation et l'utilisation des bandes de fréquences suivantes:

- **La bande 2.4 GHz (2400 - 2483.5 MHz)**
- **La bande 5 GHz (5.15 - 5.35 GHz; 5.47 - 5.725 GHz et/ou 5.725 - 5.875 GHz)**

L'utilisation de ces bandes varie dans différents pays. Dans plusieurs pays, ces bandes sont souvent appelées "Bandes sans licence/Unlicensed". Aux États-Unis ce spectre inclut la bande ISM (Industrial, Scientific and Medical) et U-NII (Unlicensed National Information Infrastructure). Actuellement, ces bandes sont utilisées dans plusieurs applications de courte portée et faible puissance, par exemple le système Bluetooth, les réseaux WLAN et les fours à micro-ondes.

<u>Part A – Réglementation en place dans des bandes spécifiques</u>

A.1 – Réglementation pour la bande 2.4 GHz

1. a. Est-ce qu'il est nécessaire de détenir une licence pour émettre des émissions radio dans ces bandes?
   ☐ Oui (poursuivre avec 1.b) ☐ Non (poursuivre avec 1.c)

   b. Si vous avez répondu OUI dans 1.a, spécifiez:
   - o Licence pour émettre/opérer nécessaire ☐ Oui ☐ Non
   - o Licence pour utiliser le spectre nécessaire ☐ Oui ☐ Non
     - ▪ Est-ce que le spectre est accordé de façon exclusive ☐ Oui ☐ Non
   - o Licence automatiquement attribuée contre paiement d'une taxe ☐ Oui ☐ Non
   - o Y a-t-il des licences déjà attribuées? ☐ Oui ☐ Non
   - o Y a-t-il des licences déjà révoquées? ☐ Oui ☐ Non

   c. Si vous avez répondu NON dans 1.a:
   - o Est-ce qu'un enregistrement est nécessaire, même s'il n'y a pas de licence?
     ☐ Oui ☐ Non

2. Est-ce que le régulateur certifie l'équipement radio produit pour émettre dans cette bande?
☐ Oui ☐ Non

3. Quelle est la limite maximale de puissance d'émission dans cette bande? Watts

4. Quelles sont les restrictions imposées:
- Sur la distance de propagation vs. niveau de puissance (limite de kilomètres pour une limite de puissance donnée), intensité de champ maximum (millivolt par mètre) ou EIRP?
- Lieu d'émission (par exemple, intérieures ou extérieures)?

5. Est-ce qu'il y a des restrictions dans le type de services utilisés? Est-ce que la voix et les données sont toutes les deux permises?

6. Quand est-ce que cette réglementation a été mise en place? S'il y a eu des changements de réglementation récemment, comment est-ce qu'ils ont affecté l'utilisation?

7. a. Est-ce que la réglementation est fiscalisée avec rigueur? ☐ Oui ☐ Non
b. Qui est le responsable pour la fiscalisation de ces bandes? (quel département du gouvernement)? Qui est responsable pour la résolution de conflits?

8. Pourriez-vous indiquer la référence du texte de la réglementation pertinente pour cette bande?

A.2. – Régulation pour la bande 5 GHz

9. a. Est-ce qu'il est nécessaire de détenir une licence pour émettre des émissions radio dans ces bandes?
☐ Oui (poursuivre avec 9.b) ☐ Non (poursuivre avec 9.c)

b. Si vous avez répondu OUI dans 9.a, spécifiez:
- o Licence pour émettre/opérer nécessaire ☐ Oui ☐ Non
- o Licence pour utiliser le spectre nécessaire ☐ Oui ☐ Non
  - ▪ Est-ce que le spectre est accordé de façon exclusive ☐ Oui ☐ Non
- o Licence automatiquement attribuée contre paiement d'une taxe ☐ Oui ☐ Non
- o Y a-t-il des licences déjà attribuées? ☐ Oui ☐ Non
- o Y a-t-il des licences déjà révoquées? ☐ Oui ☐ Non

c. Si vous avez répondu NON dans 9.a:
- o Est-ce qu'un enregistrement est nécessaire, même s'il n'y a pas de licence?
☐ Oui ☐ Non

10. Est-ce que le régulateur certifie l'équipement radio produit pour émettre dans cette bande?
☐ Oui ☐ Non

11. Quelle est la limite maximale de puissance d'émission dans cette bande? Watts

12. Quelles sont les restrictions imposées:
- Sur la distance de propagation vs. niveau de puissance (limite de kilomètres pour une limite de puissance donnée), intensité de champ maximum (millivolt par mètre) ou EIRP?
- Lieu d'émission (par exemple, intérieures ou extérieures)?

13. Est-ce qu'il y a des restrictions dans le type de services utilisés? Est-ce que la voix et les données sont toutes les deux permises?

14. Quand est-ce que cette réglementation a été mise en place? S'il y a eu des changements de réglementation récemment, comment est-ce qu'ils ont affecté l'utilisation?

15. a. Est-ce que la réglementation est fiscalisée avec rigueur? ☐ Oui ☐ Non

b. Qui est le responsable pour la fiscalisation de ces bandes? (quel département du gouvernement)? Qui est responsable pour la résolution de conflits?

16. Pourriez-vous indiquer la référence du texte de la réglementation pertinente pour cette bande?

Part B – Contexte de la réglementation

17. Quelle est la justification de la réglementation de ces bandes (par exemple: contrôle la qualité de service, gestion des interférences, protection des profits des opérateurs existant, assurance de la facilité d'utilisation ou d'accès, etc.)?

18. Comment est-ce que la réglementation affecte l'utilisation de ces bandes (par exemple: en fonction de l'utilisation, de la qualité, de la viabilité, etc.)?

19. Qui est l'auteur des réglementations (quel département du gouvernement)? Est-ce que les réglementations sont basées sur des standards de UIT ou sur les modèles de réglementations présents dans d'autres pays?

20. Est-ce qu'il y a des bandes - exception faite de celles-ci - pour les quelles il n'y a pas besoin d'une licence d'émission?

21. Est-ce qu'il est prévu dans l'avenir de changer la réglementation ou son implémentation?

Part C - Implémentation et expériences d'utilisation

22. Est-ce que ces bandes sont effectivement utilisées?

23. Qui sont les utilisateurs principaux de ces bandes? (Par exemple, Cafés Internet, opérateurs telecom, ISP's (Internet Service Providers), municipalités, etc.)

24. Dans quel contexte est-ce que ces services sont offerts?
- ☐ Couverture localisée, 'hotspots' urbains
- ☐ Connection rurale, couverture de régions plus grandes (infrastructure, point à point)
- ☐ Autres. Spécifiez:

25. Est-ce qu'il y a des fournisseurs de services de "hot-spot" contre payement? Où sont les hot-spots et est-ce qu'ils sont accessibles à la majorité de la population?

26 a. Quels sont les protocoles utilisés dans ces bandes? Est-ce qu'ils sont surtout ouverts (par exemple, 802.11) ou fermés/'proprietary' (par exemple, Motorola Canopy)?

b. Quels sont les produits commerciaux les plus répandus?

27. Est-ce qu'il y a des problèmes ou des difficultés avec l'équipement terminal – i.e., du côté de l'utilisateur – par exemple prix, disponibilité, etc.?

28. Est-ce qu'il y a des problèmes ou des difficultés avec l'équipement du réseau – i.e., du côté de l'opérateur – par exemple prix, disponibilité, etc.?

29. Est-ce qu'il y a des problèmes significatifs d'interférence, dans ou en dehors de la bande, avec d'autres services?

30. Est-ce que le régulateur a la capacité de détecter les émissions illégales? (par exemple, est-ce qu'il a un équipement de détection de radio approprié, etc.)

31. Est-ce qu'il y a des mesures pour supporter l'opérateur ou le fournisseur de services en utilisant un fond de Service Universel?

32. Est-ce que ces fonds ont été utilisés pour déployer l'équipement radio dans ces bandes?

☐ Oui ☐ Non

33. Souhaiteriez-vous ajouter une remarque ou un commentaire?

Merci beaucoup pour votre assistance.

Subject: Investigação no MIT: Pedido de informação sobre uso de espectro em [*name of country*]

Exmo Senhor [*xxxx*]

Sou uma investigadora do Massachusetts Institute of Technology, e obtive o seu contacto através de [*the ITU/other*].

Estou presentemente a conduzir um estudo sobre a regulamentação e uso das bandas rádio 2.4 e 5 GHz. Mais precisamente, estou interessada nas bandas seguintes:

- 2400 - 2483.5 MHz, e
- 5.15 - 5.35 GHz; 5.47 - 5.725 GHz e 5.725 - 5.875 GHz.

Estas bandas são por vezes chamadas “Bandas sem licença/Unlicensed”. Nos Estados Unidos este espectro inclui as bandas de ISM (Industrial, Scientific and Medical) e U-NII (Unlicensed National Information Infrastructure). De momento, estas bandas são usadas por vários equipamentos de curto alcance e baixa potência, incluindo Bluetooth, WLAN, e fornos microondas.

Este estudo vai focar-se na regulamentação e uso destas bandas em países africanos. Ao definir o estado geral destas bandas, o nosso objectivo é identificar oportunidades e propor recomendações para regulamentação.

Estou particularmente interessada nas práticas correntes em [*name of country*], e a sua colaboração será determinante no sucesso deste estudo. Gostaria assim de lhe pedir que respondesse à lista de perguntas que junto no ficheiro anexo no contexto de [*name of country*]. A sua ajuda será reconhecida no meu relatório final no MIT, excepto se preferir o anonimato.

Junto em anexo o inquérito em dois formatos: Microsoft Word (Survey_Spectrum_pt.doc) e um ficheiro simples de texto (Survey_Spectrum_pt.txt). Gostaria de lhe pedir que utilizasse o formato que lhe é mais conveniente, e que mo enviasse devidamente preenchido por e-mail.

Gostaria de ter uma resposta até [*date*]. Acha isso possível?

Este inquérito apenas será possível com a sua ajuda e participação – e desde já lhe agradeço muito. Também gostaria de partilhar consigo os resultados deste inquérito, quando disponíveis, caso isso seja do seu interesse. Se for o caso, não hesite em contactar-me.

Esperando o seu contacto e a sua resposta, despeço-me, com os melhores cumprimentos,

Isabel Neto

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Massachusetts Institute of Technology
77 Massachusetts Avenue; E40-371
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Inquérito sobre Regulamentação e Uso de Espectro nas Bandas 2.4 e 5 GHz

Para mais informações, por favor contactar: Isabel Neto
Technology and Policy Program,
Massachusetts Institute of Technology
77 Massachusetts Avenue; E40-371
Cambridge, MA 02139
USA
Tel: +1 (857) 222-0484
e-mail: ineto@mit.edu

Nota: A sua participação neste estudo é completamente voluntária e é livre de recusar responder a uma ou mais perguntas. A informação adquirida será analizada e alguns dos resultados serão publicados. Confidencialidade e/ou anonimidade serão garantidas, se solicitado.

Se preferir manter-se anónimo por favor assinale com uma cruz ☐

Por favor responda às seguintes perguntas acerca da regulamentação e uso das seguintes bandas de frequência:

- **A banda dos 2.4 GHz (2400 - 2483.5 MHz), e**
- **As bandas dos 5 GHz (5.15 - 5.35 GHz; 5.47 - 5.725 GHz e/ou 5.725 - 5.875 GHz).**

O uso destas bandas varia de país para país. Em muitos países, estas bandas são por vezes denominadas como "Bandas sem licença/unlicensed". Nos Estados Unidos, este espectro inclui as bandas ISM (Industrial, Scientific and Medical) e U-NII (Unlicensed National Information Infrastructure). De momento, estas bandas são usadas por vários equipamentos de curto alcance e baixa potência, incluindo Bluetooth, WLAN, e fornos microondas.

<u>Parte A – Regulamentação relativa a bandas específicas</u>

A.1 – Regulamentação na banda 2.4 GHz

1. a. É necessária uma licença para operar equipamentos transmissores nesta banda?
☐ Sim (siga para 1.b) ☐ Não (siga para 1.c)
b. Se respondeu SIM na pergunta 1.a, por favor especifique
   - É necessária licença para operar ☐ Sim ☐ Não
   - É necessária licença para usar o espectro ☐ Sim ☐ Não
     - O espectro é licenciado de modo exclusivo (i.e., cada banda para um só operador)? ☐ Sim ☐ Não
   - Licença automaticamente atribuída mediante o pagamento de uma taxa ☐ Sim ☐ Não
   - Já foram atribuídas licenças nesta banda? ☐ Sim ☐ Não
   - Já foram revogadas licenças nesta banda? ☐ Sim ☐ Não

c. Se respondeu NÃO em 1.a
   - É necessário registo, apesar de não ser necessária licenca? ☐ Sim ☐ Não

2. O regulador certifica o equipamento de transmissão rádio fabricado para transmitir nesta banda?
☐ Sim ☐ Não

3. Qual é o limite máximo de potência para esta banda? Watts

4. Quais são as restrições impostas:
- Na distância de propagação vs nível de potência transmitida (Limite máximo de kilometros para um dado nível de potência), limite máximo do nível de campo eléctrico (millivolt por metro) ou EIRP?
- No local de transmissão (*e.g.,* ambientes interiores vs. ambientes exteriores)?

5. Há restrições no tipo de serviços a serem utilizados? Voz e Data são ambos permitidos?

6. Quando é que estas regulamentações foram implementadas? Se houve uma mudança recente na regulamentação, como é que as mudanças afectaram o uso destas bandas?

7. a. Esta regulamentação é fiscalizada com rigor? ☐ Sim ☐ Não
b. Quem é que fiscaliza esta banda (que agência ou departamento do governo)? Quem é responsável pela resolução de conflitos?

8. Por favor, forneça uma referência para o texto de regulamentação relevantes para esta banda

A.2. – Regulamentação na banda 5 GHz

9. a. É necessária uma licença para operar equipamentos transmissores nesta banda?
☐ Sim (siga para 9.b) ☐ Não (siga para 9.c)
b. Se respondeu SIM na pergunta 9.a, por favor especifique
   - É necessária licença para operar ☐ Sim ☐ Não
   - É necessária licença para usar o espectro ☐ Sim ☐ Não
     - O espectro é licenciado de modo exclusivo (i.e., cada banda para um só operador)? ☐ Sim ☐ Não
   - Licença automaticamente atribuída mediante o pagamento de uma taxa ☐ Sim ☐ Não
   - Já foram atribuídas licenças nesta banda? ☐ Sim ☐ Não
   - Já foram revogadas licenças nesta banda? ☐ Sim ☐ Não

c. Se respondeu NÃO em 9.a
   - É necessário registo, apesar de não ser necessária licenca? ☐ Sim ☐ Não

10. O regulador certifica o equipamento de transmissão rádio fabricado para transmitir nesta banda?
☐ Sim ☐ Não

11. Qual é o limite máximo de potência para esta banda? Watts

12. Quais são as restrições impostas:
- Na distância de propagação vs nível de potência transmitida (Limite máximo de kilometros para um dado nível de potência), limite máximo do nível de campo eléctrico (millivolt por metro) ou EIRP?
- No local de transmissão (*e.g.,* ambientes interiores vs. ambientes exteriores)?

13. Há restrições no tipo de serviços a serem utilizados? Voz e Data são ambos permitidos?

14. Quando é que estas regulamentações foram implementadas? Se houve uma mudança recente na regulamentação, como é que as mudanças afectaram o uso destas bandas?

15. a. Esta regulamentação é fiscalizada com rigor? ☐ Sim ☐ Não

b. Quem é que fiscaliza esta banda (que agência ou departamento do governo)? Quem é responsável pela resolução de conflitos?

16. Por favor, forneça uma referência para o texto de regulamentação relevantes para esta banda

Part B – Contexto da regulamentação

17. Qual é a justificação para a regulamentação nestas bandas? (*por ex.,* controlar a qualidade do serviço, gerir interferência, proteger os lucros dos operadores existentes, assegurar facilidade de uso ou de acesso, etc)?

18. Como é que a regulamentação está a afectar o uso destas bandas (*e.g.,* em termos de uso, qualidade, sustentabilidade, etc.)?

19. Quem é o autor das regulamentações (que departamento do governo)? As regulamentações definidas e adoptadas foram baseadas em standards da UIT ou em regulamentação de outros países?

20. Para além destas bandas (2.4 e 5GHz) há outras bandas para as quais não seja necessário uma licença para transmitir?

21. Há planos para, no futuro, mudar a regulamentação ou a sua implementação?

Part C – Implementação e experiências de uso

22. As bandas acima referidas estão efectivamente a ser usadas?

23. Quem são os principais utilisadores destas bandas? (por ex. Internet café, operadores de telecomunicações já existentes, ISP's, municípios, etc.)

24. Em que contexto é que os serviços estão a ser oferecidos?

☐ Cobertura localizada, *hotspots* urbanos

☐ Conectividade rural, cobertura de áreas mais alargada (infraestrutura, ponto-a-ponto)

☐ Outro. Qual:

25. Há fornecedores de serviços em "hot-spot", mediante o pagamento de tarifas? Onde são estes hotspots? São acessíveis para a maioria das pessoas?

26 a. Que protocolos estão a ser utilizados nestas bandas? São predominantemente abertos (por ex. 802.11) ou fechados ('proprietary') (*e.g.,* Motorola Canopy)?

b. Quais são os productos comerciais mais populares?

27. Há alguns problemas ou dificuldades com o equipamento terminal - i.e., de utilizador – por ex. preço, disponibilidade, etc.?

28. Há alguns problemas ou dificuldades com o equipamento do lado da rede – i.e., do lado do operador, provisão de serviço – por ex. preço, disponibilidade, etc?

29. Há problemas significativos relacionados com interferência, dentro ou fora da banda, com outros serviços?

30. O regulador tem a capacidade técnica para detector transmissores ilegais? (i.e., tem o equipamento de detecção de rádio apropriado, etc?)

31. Há medidas para suportar operadores ou fornecedores de serviços através de um fundo de Serviço Universal?

32. Esses fundos já foram usados para construir e/ou operar equipamento rádio nestas bandas?

☐ Sim ☐ Não

33. Tem mais alguma coisa a acrescentar?

Muito obrigado pela sua participação.

Appendix V - List of people successfully contacted in the different countries

Table V.1 – List of people successfully contacted in the different countries

Country Name	ITU Country Code	Contact Name	Position/company	Nature of contact
Algeria (People's Democratic Republic of)	ALG	M. HAKIMI Mohamed Tahar	Directeur et Chargé du Secrétariat Permanent du Réseau Arabe de Régulateurs Autorité de Régulation de la Poste et des Télécommunications (ARPT)	Survey Response
Angola (Republic of)	AGL	Sr. Domingos Pedro Antonio, Deputy Director General	Idem, INACOM	Survey Response
Angola (Republic of)	AGL	Silvio Almada	ISP	Contact only
Benin (Republic of)	BEN	M. Sabi Soumanou Sanni, Directeur général	Office des postes et des télécommunications (OPT)	Forwarded survey
Benin (Republic of)	BEN	Cyrille F. ASSOGBA	Office des postes et des télécommunications (OPT)	Survey Response
Botswana (Republic of)	BOT	Arindam Bose		Contact only
Botswana (Republic of)	BOT	Dr. MOTHIBI John	Botswana Telecommunications Authority (BTA), Board Member	Forwarded survey
Botswana (Republic of)	BOT	Mr Kepaletswe	Botswana Telecommunications Authority (BTA), Board Member	Survey Response
Burkina Faso	BFA	M. Arnaud Boisset	CFAO Technologies ; Conseiller du Commerce Exterieur de la France	Survey Response
Burkina Faso	BFA	M. Sibiri Ouattaba, Directeur de la Régulation	Autorité Nationale de Régulation des Télécommunications (ARTEL)	Contact only
Burkina Faso	BFA	Mr. WEMA Dieudonné	Directeur des Télécommunications mobiles, ONATEL	Contact only
Burundi (Republic of)	BDI	S.E. M. Séverin Ndikumugongo, Ministre des Transports, Postes et Télécommunications, M. Vital Ndayarinze, Chef de Cabinet du Ministre	Ministère des Transports, Postes et Télécommunications	Forwarded survey
Burundi (Republic of)	BDI	Col. Nestor Misigaro, Directeur général, M. Néhémie Nzisabara, Directeur technique	Agence de Régulation et de Contrôle des télécommunications (ARCT)	Survey Response
Burundi (Republic of)	BDI	M. Mathias Mandevu, Directeur technique	Office national des télécommunications (ONATEL)	Forwarded survey
Cameroon (Republic of)	CME	Jean-Claude TCHOULACK	PTO	Survey Response
Cape Verde (Republic of)	CPV	Mr. David Gomes, Director Geral	Direcção Geral das Comunicações	Survey Response
Central African Republic	CAF	Patrice Henganami	PTO	Survey Response
Chad (Republic of)	TCD	M. André Tonon Nadjiounoum, Directeur des Télécommunications	Ministère des Postes et Télécommunications	Survey Response
Chad (Republic of)	TCD	Tarous Ndoumambe		Forwarded survey

Table V.1 – List of people successfully contacted in the different countries (cont.)

Country Name	ITU Country Code	Contact Name	Position/company	Nature of contact
Comoros (Union of the)	COM	M. Mahamoud Abiamri, Directeur des télécommunications	Société Nationale des Postes et Télécommunications (SNPT)	Forwarded survey
Comoros (Union of the)	COM	M. Nouroudini Ahmed	Société Nationale des Postes et Télécommunications (SNPT)	Survey Response
Côte d'Ivoire (Republic of)	CTI	M. Jean-Baptiste Yao Kouakou, Secrétaire général	Agence des Télécommunications de Côte d'Ivoire (ATCI)	Forwarded survey
Côte d'Ivoire (Republic of)	CTI	M. Patrick Ghansah Serges	Agence des Télécommunications de Côte d'Ivoire (ATCI)	Forwarded survey
Côte d'Ivoire (Republic of)	CTI	M. Bini Kouame	Agence des Télécommunications de Côte d'Ivoire (ATCI)	Survey Response
Côte d'Ivoire (Republic of)	CTI	M. M'POUE Apete Sylvestre	Agence des Télécommunications de Côte d'Ivoire (ATCI)	Forwarded survey
Democratic Republic of the Congo	COD	M. Ntumba Badiganga	Consultant (ISP?)	Survey Response
Democratic Republic of the Congo	COD	Aubin Kashoba Kalasa, with assistance from M. Bertin Mantobo, from Réglementation et Politique des Télécommunications du Ministère des PTT	Afrinet, ISPAssoc-DRC	Survey Response
Egypt (Arab Republic of)	EGY	Eng. Amr M. AbdelKader Hashem, Manager, Communications Policy Unit	Ministry of Communications and Information Technology	Forwarded survey
Egypt (Arab Republic of)	EGY	Ismail Elghetany	Ministry of Communications and Information Technology	Survey Response
Egypt (Arab Republic of)	EGY	Ms Ghada Howaidy, International Relations Manager	Ministry of Communications and Information Technology	Forwarded survey
Equatorial Guinea (Republic of)	GNE	Mr Daniel Dauchat, (ITU contact person)	Guinea Ecuatorial de Telecomunicaciones, Sociedad Anónima(GETESA)	Forwarded survey
Equatorial Guinea (Republic of)	GNE	Isidoro Eyi	Representant pour les Telecommunications	Forwarded survey
Eritrea	ERI	M. ZERAI TEKLEHAIMANOT Mogos,Communications Department	Ministry of Transport and Communications	Survey Response
Ethiopia (Federal Democratic Republic of)	ETH	Mr. Mulat Agumas, Head of Licensing and Frequency Management Department; Mr. Messay Bekele, Head of Licensing Division	Ethiopian Telecommunications Agency (ETA)	Forwarded survey

Table V.1 – List of people successfully contacted in the different countries (cont.)

Country Name	ITU Country Code	Contact Name	Position/company	Nature of contact
Ethiopia (Federal Democratic Republic of)	ETH	*Anonymous respondent*		Survey Response
Ethiopia (Federal Democratic Republic of)	ETH	Mr Brahima Sanou, Head, ITU Regional Office for Africa	ITU Regional Office for Africa (Ethiopia)	Forwarded survey
Ethiopia (Federal Democratic Republic of)	ETH	Assef Bahta	ECA	Forwarded survey
Gabonese Republic	GAB	M. LICHAMBANY Armand Clotaire	Secrétaire général, Agence de Régulation des Télécommunications (ARTEL)	Forwarded survey
Gabonese Republic	GAB	Monsieur Bernard Limbondzi	Agence de Régulation des Télécommunications (ARTEL)	Survey Response
Gambia (Republic of the)	GMB	Jorn Grotnes	ISP	Contact only
Gambia (Republic of the)	GMB	Dr. JALLOW Saidou S.	Permanent Secretary Department of State for Communications, Information and Technology	Survey Response
Ghana	GHA	Mr Kwaku Ofosu-Adarkwa, Acting Chief Director (Permanent Secretary)	Ministry of Communications and Technology	Forwarded survey
Ghana	GHA	Mr Issah Yahaya	Ministry of Communications and Technology	Survey Response
Ghana	GHA	Ing. Dickson Oduro-Nyaning, Chief Network Officer	Ghana Telecommunications Company Limited (Ghana Telecom)	Forwarded survey
Ghana	GHA	Bernard Forson	National Communications Agency	Survey Response
Guinea (Republic of)	GUI	Aboubacar KOUROUMA	ISP	Survey Response
Guinea-Bissau (Republic of)	GNB	Dr Anésimo A. Silva Cardoso, Président de l'Institut	Instituto das Comunicações da Guiné-Bissau (ICGB)	Forwarded survey
Guinea-Bissau (Republic of)		Nelson Barros.	Instituto das Comunicações da Guiné-Bissau (ICGB)	Contacted and Waiting Survey Response
Guinea-Bissau (Republic of)	GNB	Abdulai Sila	PTO	Forwarded survey
Kenya (Republic of)	KEN	Mr Wilson Chepkwony, Head, Frequency Spectrum Management	Communications Commission of Kenya	Forwarded survey
Kenya (Republic of)	KEN	Miss Rachel Alwala, International Liaison	Communications Commission of Kenya	Forwarded survey
Kenya (Republic of)	KEN	Mrs Clare Ruto, Company Secretary/Manager Regulatory Affairs	Kencell Communications Limited	Forwarded survey
Kenya (Republic of)	KEN	Isabelle Kandagor	CCK	Survey Response
Kenya (Republic of)	KEN	Mr. OBAM Daniel	Communications Radio Technology Expert, Ministry of Transport and Communications	Contact only
Lesotho (Kingdom of)	LSO	Mr Tennyson Saoana, Manager, Frequency Manag. & Monitoring	Lesotho Telecommunications Authority	Forwarded survey

Table V.1 – List of people successfully contacted in the different countries (cont.)

Country Name	**ITU Country Code**	**Contact Name**	**Position/company**	**Nature of contact**
Lesotho (Kingdom of)	LSO	Mr. POSHOLI Monehela	Lesotho Telecommunications Authority	Forwarded survey
Lesotho (Kingdom of)	LSO	Mr. Rankobane Mathule	Manager - Technology & Standards Lesotho Telecommunications Authority	Survey Response
Lesotho (Kingdom of)	LSO	Mr. MANGOAELA Percy	Lesotho Telecommunications Authority, Chairman of the board	Contact only
Liberia (Republic of)	LBR	Mr. Egales Beda	Telecommunications Expert, worked in Liberia for 3 years, specially in the field of VSAT, point-to-point, point-to-multi-point connections	Survey Response
Madagascar (Republic of)	MDG	Roland Ramamonjisoa		Survey Response
Malawi	MWI	Mr Shadrek J. Ulemu, Deputy Director-General	Malawi Communications Regulatory Authority (MACRA)	Survey Response
Malawi	MWI	Bessie Saidie	ISP	Forwarded survey
Mali (Republic of)	MLI	M Cheick Sidi Mohamed Nimaga, Président Directeur Général	Société des Télécommunications du Mali (SOTELMA)	Forwarded survey
Mali (Republic of)	MLI	Denis Bilodeau	USAID	Survey Response
Mauritania (Islamic Republic of)	MTN	M. Sidi Abdallah Ould D. Kerkoub, Directeur général	Autorité de Régulation	Forwarded survey
Mauritania (Islamic Republic of)	MTN	M Mohamed Vadel Ould Tabou	Autorité de Régulation	Survey Response
Mauritius (Republic of)	MAU	Mrs Premila Aubeelack, Permanent Secretary	Ministry of Information Technology & Telecommunications	Forwarded survey
Mauritius (Republic of)	MAU	Reshad Joomun	PTO ISP	Forwarded survey
Mauritius (Republic of)	MAU	Dr M.K. Oolun	(Director of Licensing) at the Information and Communication Technologies Authority.	Survey Response
Morocco (Kingdom of)	MRC	M. Hassan Lebbadi, Directeur a.i. des Etudes et Planification	Département de la Poste, des Télécommunications et des Technologies de l'Information	Forwarded survey
Morocco (Kingdom of)	MRC	M. Az El Arabe Hassibi, Chef de la Division Gestion du spectre de fréquences	Agence Nationale de Réglementation des Télécommunications (ANRT)	Survey Response
Morocco (Kingdom of)	MRC	Mme BENLEMLIH Hamida	Chef Division Veille Technologique, Agence Nationale de Réglementation des Télécommunications (ANRT)	Forwarded survey
Mozambique (Republic of)	MOZ	Sr. João Jorge, National Director	Instituto Nacional das Comunicações de Moçambique (INCM)	Contact only
Mozambique (Republic of)	MOZ	Jamo Macanze	MAAC Secretariate	Survey Response

Table V.1 – List of people successfully contacted in the different countries (cont.)

Country Name	ITU Country Code	Contact Name	Position/company	Nature of contact
Namibia (Republic of)	NMB	Ms Esther Kaapanda, Deputy Director of Communication	Ministry of Works, Transport and Communication	Forwarded survey
Namibia (Republic of)	NMB	Mr. Jan H. Kruger, Head of Secretariat	Namibian Communications Commission - NCC	Forwarded survey
Namibia (Republic of)	NMB	Mr. Barthos	Namibian Communications Commission - NCC	Survey Response
Namibia (Republic of)	NMB	Joris Komen	Schoolnet	Survey Response
Niger (Republic of the)	NGR	*Anonymous respondent*		Survey Response
Niger (Republic of the)	NGR	Mr Sadou Soloke	PTO ISP	Forwarded survey
Nigeria (Federal Republic of)	NIG	Mr G. O. Asiegbu, Permanent Secretary	Ministry of Communications	Forwarded survey
Nigeria (Federal Republic of)	NIG	Ms. Esther Ggonda	Ministry of Communications	Contact only
Nigeria (Federal Republic of)	NIG	Eng. Ernest C.A. Ndukwe, Chief Executive Officer	Nigerian Communications Commission (NCC)	Forwarded survey
Nigeria (Federal Republic of)	NIG	Eng. Bello and Bola Ibrahim	Nigerian Communications Commission (NCC)	Survey Response
Nigeria (Federal Republic of)	NIG	Ms. EMAKPORE Lolia	Head Corporate Planning & Research, Nigerian Communications Commission (NCC)	Forwarded survey
Rwandese Republic	RRW	Albert Nsengiyumva	Director National University of Rwanda Computing Center	Survey Response
Rwandese Republic	RRW	Antoine Bigirimana and Ragne Marie Ristvedt	E-ICT Integrated Training Center	Forwarded survey
Sao Tome and Principe (Democratic Republic of)	STP	M. Fernando J. Paquete da Costa, Assessor da Administração	Companhia Santomense de Telecomunicações (CST)	Survey Response
Senegal (Republic of)	SEN	Mme Aïssatou Dieng Diop, Directeur des Opérations internationales	Société Nationale des Télécommunications du Sénégal (SONATEL)	Forwarded survey
Senegal (Republic of)	SEN	M Birame Ndoye	Agence de Régulation des télécommunications Gestion de Fréquences	Forwarded survey
Senegal (Republic of)	SEN	*Anonymous respondent*		Survey Response
Seychelles (Republic of)	SEY	Ms. L. Palani	Ministry of Economic Planning – Telecom Division	Survey Response
Sierra Leone	SRL	Mr Alfa Sesay, Managing Director, SIERRATEL	Sierra Leone Telecommunications Company (SIERRATEL)	Contacted and Waiting Survey Response
Somali Democratic Republic	SOM	Ms Eileen McKeough	Somali Telecom Group	Survey Response
South Africa (Republic of)	AFS	Mr Pakamile K. Pongwana, Deputy Director General	Department of Communications	Forwarded survey

Table V.1 – List of people successfully contacted in the different countries (cont.)

Country Name	ITU Country Code	Contact Name	Position/company	Nature of contact
South Africa (Republic of)	AFS	Mr Talaat Laham, Chairman & Chief Executive Officer	Cell-C (Pty) Ltd.	Forwarded survey
South Africa (Republic of)	AFS	*Anonymous respondent*		Survey Response
South Africa (Republic of)	AFS	Mike Jensen	Africa Internet Infrastructure Information	Survey Response
Sudan (Republic of the)	SDN	Terri Beckham	ISP?	Forwarded survey
Sudan (Republic of the)	SDN	Mr. Jalal	National Telecom Corporation (regulator)	Survey Response
Tanzania (United Republic of)	TZA	Peter Ulanga	Tanzania Communications Commission	Contact only
Tanzania (United Republic of)	TZA	Mr. KAMULIKA Masegese	Information Technology Officer, National ICT Coordination Office	Forwarded survey
Tanzania (United Republic of)	TZA	*Anonymous respondent*		Survey Response
Tanzania (United Republic of)	TZA	Andrew Kisaka	Regulator	Survey Response
Togolese Republic	TGO	M. Balakiyém Telou, Directeur des Etudes, de l'Ingénierie et du Marketing	Centre régional de Maintenance des Télécommunications de Lomé (CMTL S.A.)	Forwarded survey
Togolese Republic	TGO	Germain BOYODI Directeur technique; Mr. Gabsim, Ingénieur chargé de la gestion des fréquences	Autorité de Réglementation des Secteurs de Postes et de Télécommunications	Survey Response
Tunisia	TUN	M. Ali Ghodbani, Directeur Général	Centre d'Etudes et de Recherches des Télécommunications (CERT)	Forwarded survey
Tunisia	TUN	Mr. SOUAÏ Sadok	Directeur du réseau de contrôle, Agence Nationale des Fréquences	Forwarded survey
Tunisia	TUN	Ms. Lilia Soussi	Agence Nationale des Fréquences	Survey Response
Uganda (Republic of)	UGA	Mr. MWESIGWA Patrick	Uganda Communication Commission, Technical Manager	Survey Response
Zambia (Republic of)	ZMB	Mr. MULUSA Nicholas	Acting Assistant Controller, The Communications Authority	Forwarded survey
Zambia (Republic of)	ZMB	Mr. Kephas Masiye	Head of our Radio Frequency Management department ,The Communications Authority	Survey Response
Zambia (Republic of)	ZMB	Mr. KAKUBO Lotty	Senior Licensing Officer, The Communications Authority	Contact only
Zambia (Republic of)	ZMB	Richard Mwanza	Comms Authority of Zambia	Contact only
Zimbabwe (Republic of)	ZWE	Dr Cuthbert Chidoori, Director-General	Postal and Telecommunications Regulatory Authority (POTRAZ)	Forwarded survey
Zimbabwe (Republic of)	ZWE	Mr Reward Kangai, Managing Director	NetOne Cellular (Private) Limited	Forwarded survey

Table V.1 – List of people successfully contacted in the different countries (cont.)

Country Name	ITU Country Code	Contact Name	Position/company	Nature of contact
Zimbabwe (Republic of)	ZWE	Mr Marcelino Tayob, Senior Advisor for Eastern and Southern Africa	ITU Area Office (Zimbabwe)	Forwarded survey and Partial Survey Response
Zimbabwe (Republic of)	ZWE	Gideon Magoda	POTRAZ	Contacted and Waiting Survey Response
Zimbabwe (Republic of)	ZWE	Mr. Jim Holland	ZISPA (Zimbabwe Internet Service Providers Association)	Partial Survey Response

Appendix VI - Detailed responses to part of the survey

This Appendix contains several tables with the raw data from the survey. The information is organized in these tables as follows:

- Table VI.1 – Licensing information (Part A) for 2.4GHz[123]
- Table VI.2 – Licensing information (Part A), for 5GHz
- Table VI.3 – Background to regulation (Part B)
- Table VI.4 – Experiences of use (Part C1)
- Table VI.5 – Equipment, products, Universal Service (Part C2)
- Table VI.6 – Other information (Part C3)

This contains the responses to most of the survey questions. Some of the answers were slightly edited or coded for better reading.

[123] This table also includes information on the capacity of the regulator to enforce rules, for both 2.4 and 5GHz bands

Table VI.1 – Licensing information (Part A) for 2.4GHz (cont)

Table VI.1 – Licensing information (Part A) for 2.4GHz

Country	Lic. Reg [124]	Excl. use	Certif.	Power Restr. [W]	Range Restric.	Services restric.	Enfor-cement	Capacity to enforce (both bands)
Algeria	3	No	Yes	10µ	Indoors	Data services only allowed in the band		Currently acquiring monitoring equipment
Angola	3	No	No	100m	Restrictions included in CEPT T7R 10-01	Both voice and data allowed	No	Some capacity
Benin	3	No	Yes		Indoors	case by case	Yes	Not really, a survey every so often enables some control
Botswana	3	No	Yes	200 m	Indoor and Outdoor Coverage	Data services only allowed in the band	Yes	BTA is in the process of acquiring the Spectrum Monitoring system to detect illegal transmitters.
Burkina Faso	3	No	No	[no limit]	None	Nothing is defined	No	No
Burundi	4	No	Yes		Indoors	Data services only allowed in the band	No	Yes
Cameroon	3	Yes	Yes		The distance is important - generally the emission power is not a blocking factor as long as it doesn't disturb other users in the band. Some use it for indoors, and some for outdoors.	The restrictions are generally on the service. For a commercial network (network open to public) an operator license is needed. For data transmission only if is a 'declaration regime'	Yes	Not for now, but the equipment has been ordered and will soon be delivered
Cape Verde	2		Yes	Minimum	Minimum power	Under study		
Central African Republic	2		Yes		Indoors		No	No
Chad	3	No	Yes	0.04	Indoors	Only internet data allowed	Yes	Yes
Chad	3	No	Yes	0.04	Indoors	Only internet data allowed	Yes	Yes
Comoros	3	No	Yes	0,01 ISM, no limit for others	Indoor or outdoor	No restrictions. Both voice and data allowed. Band following ITU ***RR de l'UIT,1998***	Yes	[No] Yes, for emissions between 9 KHz et 2 GHz in the capital city. The only equipment available works in that band only, and is fixed, in the office

[124] 0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic

Table VI.1 – Licensing information (Part A) for 2.4GHz (cont)

Country	Lic. Reg [125]	Excl. use	Certif.	Power Restr. [W]	Range Restric.	Services restric.	Enfor-cement	Capacity to enforce (both bands)
Congo	NA	NA	NA	NA	NA	NA	NA	NA
Côte d'Ivoire	3	No	Yes	0.1	Have to comply to place of emission, power limits, coverage area	If public network only data allowed. Otherwise all allowed	Yes	Yes. Equipment is limited in the band, but there is equipment to measure intermodulation and spectrum analyzers
Democratic Republic of the Congo	3	No	No	[no limit]	No power limit, can be used indoor or outdoor. Restrictions: need to respect the Security and National Defense networks. Cannot emit in such a way as to interfere with other networks/services	No. Mostly data is transmitted, but VoIP is allowed, and so is videoconference (Multimedia)	No	No, often there are abuses without detection
Djibouti	NA	NA	NA	NA	NA	NA	NA	NA
Egypt	2		Yes	100 mw (eirp)	Indoor only is permitted and outdoor has to get temporary license with restriction to EIRP 100mW. This may change in near future	No	Yes	Yes
Equatorial Guinea	NA	NA	NA	NA	NA	NA	NA	NA
Eritrea	3	No	Yes		Only monopoly can use. Have banned private ISP use for data	Voice only allowed for the monopoly, only data for ISPs	Yes	Yes, but not properly functioning
Ethiopia	2		No	0.1	Indoor			
Gabonese Republic	3	No	Yes	10		Both voice and data allowed	Yes	Yes
Gambia	4		No	[no limit]	No restriction	Only data allowed	No	No (lack of technical staff & equipment)
Ghana	2		Yes	Not specif.	N/A	Both voice and data allowed.	Yes	Yes
Guinea	3	No	No		No restrictions	No explicit restriction on the type of service to be used. However, a license is needed for phone to phone VoIP	No	No
Guinea-Bissau	NA	NA	NA	NA	NA	NA	NA	NA

[125] 0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic

Table VI.1 – Licensing information (Part A) for 2.4GHz (cont)

Country	Lic. Reg [126]	Excl. use	Certif.	Power Restr. [W]	Range Restric.	Services restric.	Enfor-cement	Capacity to enforce (both bands)
Kenya	2		Yes	0.2	[See attachment]	Both voice and data allowed	Yes	Yes
Lesotho	1		Yes	10m	10mW at 200m max; WLAN restricted to own premises both indoor & outdoor (new regulations being promulgated)	Only data allowed	No	Not at present. Radio monitoring equipment will only be in place before year end
Liberia	0		No	NA	Not available	No	No	No
Libya	NA	NA	NA	NA	NA	NA	NA	NA
Madagascar	4	No	Yes			Licenses are attributed through a bidding process. These are licenses for data, but so far there has been an implicit agreement that this also includes voice.	Yes	No, they do not yet have the appropriate equipment
Malawi	3	No	No	4	0.1, no restriction	No voice allowed	No	Not yet
Mali	0		No		There is currently no regulatory policy on the use of this band.	Not yet present		No, it does not even have a spectrum analyzer
Mauritania	3	Yes			This frequency band should be used in accordance to the recommendation CEPT/ERC/REC 70-03 (i.e., power limits, field strength and ranges). Currently this band is used by the incumbent operator to distribute its telephone network in the suburbs of the capital. It is also used by other users for data transmission.	No restrictions		Yes, we have 2 fixed centers for control of frequencies <3GHz and 2 mobile stations which cover spectrum <26 GHz
Mauritius	3	No	Yes	10	License fee is exempted for coverage less than 1 Km, power less than 20 dBm, and indoor applications	No	Yes	Yes

[126] 0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic

Table VI.1 – Licensing information (Part A) for 2.4GHz (cont)

Country	Lic. Reg [127]	Excl. use	Certif.	Power Restr. [W]	Range Restric.	Services restric.	Enfor-cement	Capacity to enforce (both bands)
Morocco	2		Yes	0.01	i) The maximum EIRP is 10 mWatts. ii) Free use is limited to the interior of a building or of a single property iii) Outdoor use is currently explored under an authorization regime for independent private network. These authorizations have been attributed by ANRT iv) All radio installation must be previously agreed upon by ANRT	The decision ANRT/DG/N°07/03, which sets conditions for free utilization of the radio install. in several bands, establishes, that free installations can only be established essentially for non-voice, at low range. Voice is not explicitly authorized, nor explicitly forbidden		ANRT has control equipment orientated mainly towards outdoor use & higher powers. The use if such equipment for the 2.4 and 5.2 GHz control could be done, but some adaptations would have to be done to do so
Mozambique	3	No	Yes	0.1	Indoors or condominiums	Only data allowed	No establish procedure or departm. respons. for enforcem.	No
Namibia	2		Yes	1	ERC Recommendation 70-03 applies	No	Yes	We have appropriate radio detection equipment
Niger	3	Yes	No	[Not defin.]	No restriction, for the time being	Only data allowed	Yes	Not for the time being
Nigeria	2		Yes	1	200m, 30dbm indoor and outdoor	Yes	No	Yes, spectrum
Rwanda	1		No	NA	NA	Yes both allowed	No	No
Sao Tome and Principe	0							
Senegal	4	No	Yes	0.01 SSFH, freq. hopp., 0.1 SSDS	Maximum range 100m for SSFH and 200m for SSDS. Use is restricted to indoors or inside same property (indoor). It is only under these restrictions that the ISM bands can be used freely. (See REGIME DES INSTALLATIONS LIBRES defined in Law 2001-15. However, the use of these equipments in outdoor or outside the EIRP …	Both voice and data allowed	Yes	Equipment is being acquired

[127] 0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic

Table VI.1 – Licensing information (Part A) for 2.4GHz (cont)

Country	Lic. Reg [128]	Excl. use	Certif.	Power Restr. [W]	Range Restric.	Services restric.	Enfor-cement	Capacity to enforce (both bands)
Senegal (cont.)					… indicated is regulated under an authorization regime and their establish. is regulated in framework of independent private networks			
Seychelles	4	No	No	FCC stand. [47CFR15.247]	refer to FCC standards [47CFR15.247]	Both voice and data allowed	Yes	No
Sierra Leone	NA	NA	NA	NA	NA	NA	NA	NA
Somali Democratic Republic	0		No		No restrictions	None		n/a
South Africa	4[129]	No	No	[Not defin.]	None, only that the signal not be used to cross premises	Only as per above, which also means that the band cannot be used to connect to the PSTN	Yes	No
Sudan	4	No	Yes	4		Both data & voice allowed	Yes	Yes
Swaziland	NA	NA	NA	NA	NA	NA	NA	NA
Tanzania	3		Yes	0.1	Restriction imposed only for allowable maxim. power	Restriction is only for ISP Where only data is allowed	Yes	Yes, mobile monitoring unit
Togolese Republic	3	No	Yes	[Not defin.]	for outdoors, range around 15Kms	Only data is allowed	Yes	No, but ART&P is in the process of buying equipment
Tunisia	1		Yes	0.01	100 m, 10 mW ; integrated antennas		Yes	Currently purchasing equipment
Uganda	3	No	Yes	1		Only data allowed	Yes	Yes
Western Sahara[130]					(See Morocco)			(See Morocco)
Zambia	3	No	Yes	1	The peak spectri density should not be greater than 17dBm in any 1 MHz band. No restrictions on the placing of transmitters.	Currently only data is allowed. In the processing of reviewing use of voice.	Yes	Yes
Zimbabwe	5							

[128] 0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic
[129] Licensed outdoors
[130] See Footnote 46, page 57, for note on Western Sahara.

Table VI.2 – Licensing information (Part A), for 5GHz

Country	Lic. Reg[131]	Excl. use	Certif	Power Restr. [W]	Range Restric.	Services restric.	Enforce-ment
Algeria	3	No	Yes	10µ	Indoors	Only data transmission allowed	
Angola	3	No	Yes	200m	Restrictions included in UIT-R M.1450	Both voice and data allowed	Yes
Benin	3	No	Yes		Indoors		
Botswana	3	No	Yes	5150 - 5250 MHz: 200m 5470 - 5725 MHz - 1W; 5725 - 5850 MHz - 25mw	5150 - 5350 MHz- Indoor ; 5470 - 5725 MHz - Indoor and Outdoor; 5725 - 5850 MHz - Indoor and Outdoor	Only data transmission allowed	Yes
Burkina Faso	3		No				
Burundi	4	No	Yes			Both voice and data allowed	No
Cameroon	3	Yes	Yes		The request should specify the place and level (power) of emission. Generally the distance and the service are important factors. For internet use think no authorization needed, but not sure	Restrictions on voice: one has to be licensed operator or have an authorization; Data transmission is subject to 'authorization or declaration' regime	Yes
Cape Verde	2		Yes	Minimum	Minimum EIRP	Yes	Yes
Central African Republic	2		Yes		Indoors	No	No
Chad	3	No	Yes	0.04	Indoors	No restrictions, voice and data both allowed	Yes
Comoros	3	No	Yes	0.01 for ISM, no limit for others	Indoor or outdoor	No restrictions. Both voice and data allowed. Band following ITU ***RR de l'UIT,1998***	Yes
Congo	NA	NA	NA	NA	NA	NA	NA
Côte d'Ivoire	3	No	Yes	Power depends on coverage area	Band just been opened for local loop and point-to-multipoint; All conditions to be defined in preparation – This band was only authorized in the last WRC	Until a change in regulation only data is allowed for commercial services. For private networks both voice and data area allowed	Yes
Democratic Republic of the Congo	3	No	No		No power limit, can be used indoor or outdoor. Restrictions: need to respect the Security and National Defense networks. CanNot emit in such a way as to interfere with other networks/services	No restrictions. Both voice and data allowed. Band following ITU ***RR de l'UIT,1998***	No
Djibouti	NA	NA	NA	NA	NA	NA	NA
Egypt	3		Yes	200mw -1mW (depends on sub band)	EIRP	No	Yes

[131] 0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic

Table VI.2 – Licensing information (Part A), for 5GHz (cont.)

Country	Lic. Reg[132]	Excl. use	Certif	Power Restr. [W]	Range Restric.	Services restric.	Enforce-ment
Equatorial Guinea	NA	NA	NA	NA	NA	NA	NA
Eritrea	3	No	Yes		Only monopoly, have banned private use ISPs can use for data (Same regulation as for 2.4GHz, but still no users)	Voice only allowed for the monopoly, only data for ISPs	Yes
Ethiopia	2		No	0.1	indoor		
Gabonese Republic	3	Yes	Yes	From 5-10		Both voice and data allowed	Yes
Gambia	4	No	No	No restriction	No restriction	Only data allowed	No
Ghana	2		Yes	N/A	No limitations placed on range, maximum field strength and place of transmission depend on technology used.	No restrictions on type of services used. Both voice and data are allowed	Yes
Guinea	3	No	No		No restrictions	No explicit restriction on type of service to be used. However, a license is needed for phone to phone VoIP	No
Guinea-Bissau	NA	NA	NA	NA	NA	NA	NA
Kenya	2		Yes	0.2	For primary users there are none. The limiting factor will be the maximum output power.	None for ISM operators. both voice and data allowed	Yes
Lesotho	1		Yes	100m	Both indoor & outdoor	Only data allowed	No
Liberia	0		No	NA	NA	NA	No
Libya	NA	NA	NA	NA	NA	NA	NA
Madagascar	4	No	Yes			Licenses are attributed through bidding process. These are licenses for data, but so far there has been an implicit agreement that this also includes voice.	Yes
Malawi	3	No	No	4	0.1 watts, No restrictions	No voice allowed	No
Mali	0		No		None at present	None at present	
Mauritania	3	No			According to National Frequency Table these frequencies are shared between the civil and military use, with the exception of the 5850Mhz-5950Mhz band, which is only civil. The use of these bands must follow recommendations ERC/DEC92-02 and ERC/REC 70-03 No restrictions on place of emission	Currently these bands are programmed to be used for the following services: Radiolocation, amateur radio, uplink satellite, secondary mobile use, ISM and fixed (5850-5925) Mhz. Voice and data are both allowed	Yes

[132] 0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic

Table VI.2 – Licensing information (Part A), for 5GHz (cont.)

Country	Lic. Reg[133]	Excl. use	Certif	Power Restr. [W]	Range Restric.	Services restric.	Enforce-ment
Mauritius	3	No	Yes	5	License fee is exempted for coverage less than 1 Km, power less than 20 dBm, and indoor applications	No	Yes
Morocco	2		Yes	0.2	i) The band currently authorized for free use is only the 5150-5250 MHz.ii) the maximum EIRP is 200 milliWatts. iii) Free use is limited to the interior of a building or of a single property iv) All radio installation must be previously agreed upon by ANRT	According to the decision, this band is intended for applications of RLAN type - defined as a public network for radio data transmission, established and explored at the interior of a single building or property. As a consequence, voice is not currently authorized in this band.	
Mozambique	3	No	Yes		outdoors	Only data is allowed	No procedu. or departm. respon-sible for enforce.
Namibia	2		Yes	0.1	ERC Recommendation 70-03 applies	No	Yes
Niger	3	Yes	No	Not yet defined	No restriction	No limitation	Yes
Nigeria	3	No	Yes	1	200m, 30dbm Indoor and outdoor	Both voice and data allowed	No
Rwanda	1		No	NA	NA	No	No
Sao Tome and Principe	0						
Senegal	4		Yes	For 5150-5350MHz band 100mW EIRP and for 5470-5725 band maximum power 1W EIRP	Maximum range of 200m inside building/same property. Use restricted to indoors or inside same property (indoor). It is only under these restrictions that the ISM bands can be used freely. (see Regime des Installations Libres in Law 2001-15). However, the use of these equipments in outdoor or outside the framework of independent private netwks…	Both data and voice are allowed	Yes

133 0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic

Table VI.2 – Licensing information (Part A), for 5GHz (cont.)

Country	Lic. Reg[134]	Excl. use	Certif	Power Restr. [W]	Range Restric.	Services restric.	Enforce-ment
Senegal (cont.)					… EIRP indicated is regulated under an authorization regime and their establishment is regulated in the		
Seychelles	4	No	No	In accordance with FCC standard [47CFR15.401-407]	Refer to FCC standard [47CFR15.401-407]	No restrictions, both voice and data are allowed	Yes
Sierra Leone	NA	NA	NA	NA	NA	NA	NA
Somali Democratic Republic	0		No		None	None	No
South Africa	4		Yes	EIRP for Indoor use : 200mWatt Outdoor use: 1Watt.	5150 - 5350 - Hiperlan indoor use only. 5470 - 5725 MHz - Hiperlan indoor and outdoor use. 5725 - 5875 MHz - ISM observe CISPR 11 and its amendments		Yes
Sudan	4	No	Yes	4		Both &data allowed	Yes
Swaziland	NA	NA	NA	NA	NA	NA	NA
Tanzania	3			0.1	Same as for 2.4GHz		Yes
Togolese Republic	3	No	Yes	Not defined	For outdoors, range around 15Kms	only data allowed	Yes
Tunisia	4	No		0.01			
Uganda	NA						
Western Sahara[135]				(See Morocco)		(See Morocco)	
Zambia	3	No		1	The peak spectri density should Not be greater than 17dBm in any 1 MHz band. No restrictions on the placing of transmitters.	Currently only data is allowed. However we are in the processing of reviewing use of voice.	Yes
Zimbabwe	5						

[134] 0: No regulator or regulation; 1:Unlicensed no registration; 2:Unlicensed, registration; 3:Licensed automatic; 4:Licensed not automatic
[135] See Footnote 46, page 57, for note on Western Sahara.

Table VI.3 – Background to regulation (Part B)

Country	Rationale for licensing	How is regulation affecting bands?	Who authored reg? Regulation based on	Other bands unlicensed?	Plans to change regulation or implement.?
Algeria	Protecting profits of existing operators		Ministére de la Poste et des Téchnologies de l'Infomation et de la Communication	All bands require a license	It is possible
Angola	Mainly to avoid interference with other services using the same band	Under study	INACOM, UIT, CEPT and other countries	All bands require a license	No
Benin	NA	NA	NA	NA	NA
Botswana	Managing the Interference and protecting consumers	Normally the band is used by ISPs. ISP licensed operators are required to be a registered company in Botswana and also have to prove the financial sustainability by providing the business plan	Botswana Telecommunications Authority, based on the ITU Radio Regulations	No	No
Burkina Faso	Taxes (revenues)	NA	ARTEL	No	
Burundi	Quality control, interference management, protection of existing operator, assurance of ease of access	Depending on use, quality, viability, coverage (?)	Agence de Regulation et du Controle des Telecoms, based on ITU	No	Yes
Cameroon	Management of interference, type of service (?)	Use, quality of transmission	ART (Agence de regulation des Télécommunications), who is the government's enforcer	No	No answer
Cape Verde	Management of interference		under discussion	Not yet defined	Yes
Central African Republic	Under preparation	Under preparation	Agence de regulation (ART), based on ITU standards		
Chad					
Comoros	Management of interference, protection of existing operators profits, assurance of ease of access and use	The regulation does not affect the use of these bands	MEDIPTTI ,based on ITU standards	Yes	It is planned to change de regulations
Congo	NA	NA	NA	NA	NA
Côte d'Ivoire	Quality of service control, spectrum use optimization, interference management, ensure fair access to spectrum and to those requiring protection for existing operators	The regulation allows for an optimized use of these bands, while proving protection against interference and jamming	The ATCI, which is a state company, is technically responsible for the regulation. It is based on ITU standards, while also looking at what is done in other countries	Current regulation imposes license for netwk establishment & explorat.; spectrum attribution letter (certain spectrum parts) & authoriza. letter for 2.4GHz band	Yes, changes are currently being prepared

Table VI.3 – Background to regulation (Part B) (cont)

Country	Rationale for licensing	How is regulation affecting bands?	Who authored reg? Regulation based on	Other bands unlicensed?	Plans to change regulation or implement.?
Democratic Republic of the Congo	Mainly: protect operator, users, and state interests	Mainly the services offered, bands used and profits achieved	Ministère des PTT, based on a mix of regulatory models	No	Yes
Djibouti	NA	NA	NA	NA	NA
Egypt	Protecting profits of existing operators, ensuring ease of use		NTRA. Mainly ITU and ETSI	some bands are used for SDR and it complies with ETSI	Any regulation can be changed
Equatorial Guinea	NA	NA	NA	NA	NA
Eritrea	Protect competition, security			No	
Ethiopia	Managing interference and protecting profits of existing operator		Ethiopian Telecom. Agency authored it. It is based partly on ITU's and partly on aNother country's regulations	No	
Gabonese Republic			ITU standard	None	
Gambia	Controlling quality of service managing interference, ensuring level playing field for all operators	These bands are yet to be used	DOSCIT regulations are based on benchmarking	No	It may change w/ establish. of Public Utilities Regulatory Agency (PURA)
Ghana	The rationale for these regulations are to control quality of service, managing interference, protecting profits of existing operators, ensuring ease of use, promoting investment, and ensuring Universal Access.	Positive	NCA authored the regulations based on ITU standards	No, there are no bands other than these where no license is required	Not now
Guinea	Frequency manag. to avoid interference & guarantee better quality of service and enforcement to augment de revenue from licenses for the Telecom sector in Guinea		Based on ITU standards and the Moroccan and Senegalese regulatory models. The future regulation is being drafted by the Direction Nationale des Postes et Télécommunications.	No	Yes, it should evolve

Table VI.3 – Background to regulation (Part B) (cont)

Country	Rationale for licensing	How is regulation affecting bands?	Who authored reg? Regulation based on	Other bands unlicensed?	Plans to change regulation or implement.?
Guinea-Bissau	NA	NA	NA	NA	NA
Kenya	Control quality of service and to protect ISM operators	Even though operators are attracted to this band there are issues regarding quality of service that have been an issue for secondary users and have reflected then into other bands. Sustainability may be achieved by ISM operators who may not necessarily be so many nor be ISM service providers	The Government of Kenya based on ITU standards	ISM bands only do Not require a license to transmit.	Such plans would depend on the prevailing demands for + spectrum within and or without these bands.
Lesotho	Controlling quality of service and ensuring ease of use	Lesotho is an emerging market hence cannot say for certain at the moment	The regulations based on ITU standards and SADC protocols for localized adaptation		New regulat. are being promulgated
Liberia	Not available	No regulation/ each operator in these bands is responsible for any problem on his radio link	Minister of Post and Telecommunications. here is a representative of ITU who is also consultant of Liberia telecommunications Corp	No	Yes
Libya	NA	NA	NA	NA	NA
Madagascar	Spectrum management and quality of service control		Regulation is the responsibility of Independent regulatory Authority (OMERT), that has referred to ITU standards	The CB (Citizen band), that are object of pre-authorization by OMERT	This regulation should change soon, to allow for more flexibility in the use of the ISM bands
Malawi	Controlling quality of service and managing interference	Regulation has good effects at the band, however, it limits the number of users as they are Not protected	The Authority, basing on ITU standards	No	Yes
Mali	The CRT in Mali still has no policies for these bands. Created in 2001, it still has not become operational. USAID is prepared to provide technical and legal support, and training.	It's the "wild west" in Mali, in that anyone can use either of these bands with no control, monitoring, or other oversight.	The regulations will be drafted by the CRT and approved by the Ministry of Communications and New Information Technologies.		Regulations to be drafted by the CRT

Table VI.3 – Background to regulation (Part B) (cont)

Country	Rationale for licensing	How is regulation affecting bands?	Who authored reg? Regulation based on	Other bands unlicensed?	Plans to change regulation or implement.?
Mauritania	Protect operators against interference and jamming	The attribution of these bands is in accordance with the international allocations of spectrum (RR) and also with the international agreements at regional and sub-regional level	It is the Regulatory Authority in charge of the Telecom sector. It is based on ITU standards	No	
Mauritius	Mainly interference management and promoting access to ICTs, while ensuring that No sort of garbage band is created in the country	In fact more and more indoor applications are picking up on this band (i.e. promoting ICT) but at the same time we have ensured that the outdoor applications are properly handled so as Not to affect other existing services near the ISM bands. e.g fixed links on those bands need to be properly monitored to ensure interference free communication with for e.g band C satellite comm systems	The Ministry Of IT and Telecoms, based on ITU recommendations to the extent possible, while taking into consideration the local realities such as the opportunity costs that are to be borne by allowing widespread use of the unlicensed band which has been modeled on a 'public park' concept.	Yes, some other ISM bands for low power radio devices	Yes, to be in line with best international practice. Regulation is oriented towards int'l recomm. & practices to the extent it is possible
Morocco	Ease of use and access, promotion of generalized access to telecom service, lightening of spectrum management regulation authority, since No allocations and assignments, Nor problem resolution is needed, international tendency for liberalization of these bands	Since these bands are under a free usage regime ANRT doe Not affect anything. However, the choice of bands to be used under a free regime is a responsibility of ANRT who decides according to i) the occupation of the bands ii) the international tendencies in terms of usage and band management iii) the requests received from potential users or industry or the suppliers for some bands	Because of the Law n°24-96 ("Telecommunications Act"), the Agence Nationale de Réglementation des Télécommunications is responsible to establish the categories of radio installations which can be freely used as well as the conditions for use. In terms of choice of bands the Radio Regulations and the relevant ITU recommendations are used. In terms of equipment technical specifications, the ANRT also uses, when justified, the international Norms, e.g. those from the ETSI or the FCC. Certain technical specifications…	See annex 1 of the ANRT/DG/N°07/03 decision, 25 dec 2003	If it is needed, namely to add new bands

Table VI.3 – Background to regulation (Part B) (cont)

Country	Rationale for licensing	How is regulation affecting bands?	Who authored reg? Regulation based on	Other bands unlicensed?	Plans to change regulation or implement.?
Morocco (cont.)			…adopted by ANRT and published on its website make reference to ETSI or FCC Norms. In terms of legal aspects, a comparison and the follow up of the regulatory tendencies is conducted, allowing (taking into account the national regulatory landscape) to take that into account when justified		
Mozambique	Quality control, manage interference, ensure easy of use and access	Under study	The government, through INCM. Regulations based on the ITU and on other countries	No	Yes
Namibia	Controlling quality of service and managing interference; *From alternative source: protecting state-owned telecom operator*	Permit is issued *From alternative source: prevents competition*	ITU standards and ERC recommendations, Ministry of Information & Broadcasting	Yes, all ISM bands	No
Niger	Alignment with international regulation	No problem for the time being	Regulation based on ITU standards	No	Not yet
Nigeria	Managing interference, Quality of service	No assessment yet	NCC, partially base on ITU standard	No	Yes
Rwandese Republic	controlling quality of service and ease of use	Not really much involved in this matter as it is still young	The regulator is autoNomous connected to the Ministry of Infrastructure and is based on ITU standards	No	No
Sao Tome and Principe					
Senegal	Interference management, favor diversification for data transmission, which is a big challenge in the ICT sector, provide ease of use to broadband networks	Depends on applications and services	The ART authored the regulations according to the national context and de different requests for these bands. ART has inspired itself also and for most cases in the…	The license (authorization) is Not necessary except in the cases for indoor use and under the power and range limits specified above. In all other…	The regulation may evolve, it is not fixed

Table VI.3 – Background to regulation (Part B) (cont)

Country	Rationale for licensing	How is regulation affecting bands?	Who authored reg? Regulation based on	Other bands unlicensed?	Plans to change regulation or implement.?
Senegal (cont.)			regulation of CEOT countries, namely the R&TTE directive and the ERC 70-03 recommendation	…cases it requires that the equipment is previously agreed/certified	
Seychelles	To ensure optimal use of the radio frequency spectrum	The bands provide national coverage for WLAN/BFWA(Wireless Internet Access). Competes effectively with leased lines	Telecom division. The policy is based on the FCC standards	No	At present none
Sierra Leone	NA	NA	NA	NA	NA
Somali Democratic Republic					
South Africa	Maintaining the license provisions of the licensed telecom operators	They are not used extensively, so regulations have not affected them.	The national regulator (ICASA)	No	No
Sudan			National Telecom Corporation, Both ITU and others.	All bands should be licensed	
Swaziland	NA	NA	NA	NA	NA
Tanzania	Managing interference	Give control on usage of the band as stipulated by ITU Hence good quality of the network	ITU	No	No
Togolese Republic	Interference management, protecting profits of existing operators, ensuring ease of use or access	Depending on the user	ITU standard	No	No
Tunisia	Interference management, ease of use	Depending on the usage	Ministère des Technologies de la Communication et du Transport; ITU plus specificities of the Tunisian context	No	Yes, currently being developed
Uganda	Managing interference	Regulations is ensuring more discipline in use of the bands	Uganda Communications Commission . Based on ITU Standards	None	Not immediately

Table VI.3 – Background to regulation (Part B) (cont)

Country	Rationale for licensing	How is regulation affecting bands?	Who authored reg? Regulation based on	Other bands unlicensed?	Plans to change regulation or implement.?
Western Sahara[136]		(See Morocco)		(See Morocco)	
Zambia	Ensuring ease of usage and protecting interference potential	There is greater usage of these bands	ETSI AND FCC Standards including reference to ITU Recs	In Zambia all frequency bands usage are required to have a license	There plans to deregulate some bands as license free. (also plans for providing Broadband Wireless in 3.4Ghz Band.
Zimbabwe					

[136] See Footnote 46, page 57, for note on Western Sahara.

Table VI.4 – Experiences of use (Part C1)

Country	Bands used?	Main users	Lo-cal use	Rural, wider area netwk use	Other use	Hotspot against payment?
Algeria	Yes	Telecom operators		Yes		Ongoing trials by telecom operat.
Angola	Only the 2.4 Ghz band	ISP's, Internet café	Yes	Yes (point-to-point)		
Benin	Only the 2.4 Ghz band	2.4GHZ used by OPTBENIN		Connection between towns		
Botswana	Yes	ISP's	Yes	Yes		
Burkina Faso	Yes	ISP and private companies	Yes	Yes		Yes, we provide the service
Burundi	Yes	ISP	Yes			
Cameroon	Yes	ISP, Private companies, telecom operators	Yes		Intranet, private networks with interconnection between sites	Yes, in the bigger cities, and generally in big urban agglomerations
Cape Verde	Only the 2.4 Ghz band	Private networks, future ISPs, Internet, etc	Yes	Yes		Not yet
Central African Republic	No					No
Chad	Yes	ISPs: SAO-NET , SY-NET, SOGITEL (ISP), CMAR	Yes			
Comoros	Yes	Telecom operators	Yes	Yes		No
Congo	NA	NA	NA	NA	NA	NA
Côte d'Ivoire	2.4 GHz band is currently saturated in the capital city. The 5GHz band has just been open, and 1st requests currently under examination	Telecom operators, ISP, Cyber cafés and independent private networks	Yes	Yes		For now, there are no hotspot operators
Democratic Republic of the Congo	Yes	ISP, Telecom operators, Independent networks	Yes	Yes	Interconnection between company sites	Not yet
Djibouti	NA	NA	NA	NA	NA	NA
Egypt	Yes	ISP's, existing operators	Yes		Yes	Not yet
Equatorial Guinea	NA	NA	NA	NA	NA	NA

Table VI.4 – Experiences of use (Part C1) (cont)

Country	Bands used?	Main users	Lo-cal use	Rural, wider area netwk use	Other use	Hotspot against payment?
Eritrea	4 ISP and monopoly, but only 2.4	business and residence, mostly in cities where there is infrastructure	Yes			ISPs charge. Dial up charge from operator very expensive
Ethiopia						
Gabonese Republic	Yes	operators	Yes	Yes		Bidding taking place now
Gambia	No			Yes		Yes, they are located in urban areas and they are accessible to most people in those areas
Ghana	Yes, these bands are being used except the first two of the 5GHz band	Existing telecommunications operators and ISPs.	Yes	Yes	infrastructure point to multi point	No
Guinea	Yes, only the 2.4GHz	ISP's, Cafés Internet, NGOs, the American Embassy	Yes	Yes		No
Guinea-Bissau	NA	NA	NA	NA	NA	NA
Kenya	Yes	Some existing telecom operators and ISP's have point to point links used to transport data.	Yes	Yes, in urban areas		No. But we have Wireless Access Point-to-point links in urban areas which are short hops/Radii for WLL
Lesotho	Yes	Government ministries & private use for WLAN networks	Yes	Yes		Lesotho is an emerging market (moreover new regulations are being promulgated for hot-spots and other services
Liberia	Yes	ISPs, private companies, NGOs	Yes			
Libya	NA	NA	NA	NA	NA	NA
Madagascar	Yes	Universities, Private operators, cybercafes, the public, after having bought a connection with a supplier (who must have a license)	Yes (cyb erca fe)		Connection between buildings	No
Malawi	Yes	ISPs		Yes		No
Mali	Yes, mostly the 2.4 GHz band	The 2.4 band is being used by ISPs to connect their larger clients, by gov't ministries, by the University of Bamako, etc.	Yes			No
Mauritania	The 2.4 GHz is used by operators. 5GHz not used for now	Telecom operators and interconnection of hospitals and other private networks for data transmission		Yes	Point-to-point and point-to-multi point for the 2.4GHz band.	No

Table VI.4 – Experiences of use (Part C1) (cont)

Country	Bands used?	Main users	Lo-cal use	Rural, wider area netwk use	Other use	Hotspot against payment?
Mauritius	Yes	ISPs	Yes			There are no fees. Such facilities are opened to the public
Morocco	The 2,4 GHz band is effectively being used. The 5GHz band not yet, and no equipment has yet been approved for this band. For the other bands in annex 1, they are almost entirely used with the exception of the 446 MHz band, which has just been added to the 25 Dec 2003 decision	For the RLAN type bands (currently 2,4 GHz) : One operator, certain hotels. For the other bands in annex 1 usages are diversified			Localized coverage for indoor use	Currently, and since the ANRT/DG/N°08/03 decision establishing the usage conditions for the public access points to the RLAN ("Hot-spot") is recent (it has been published on the 25 Dec2003), no hotspot supplier has yet been declared to ANRT. Hotspot installation has been submitted (in addition to the dispositions of the ANRT/DG/N°07/03 decision, 25 Dec 2003) to the obligation of deposing (with the ANRT) a declaration by the supplier of RLAN Internet services. The acceptance receipt given by ANRT is the authorization for installation and exploitation of RLAN public access points. However, and before the publication of this decision, free tests have been conducted in hotels, conference halls
Mozambique	Yes	Telecom operators and ISPs	Yes	Yes		
Namibia	Yes	Private operators(Virtual private networks. From alternative source: telecom Namibia, schoolnet Namibia, one illegal ISP	Yes		From alternative source: commercial (illegal) alternative to Telecom Namibia	It is not allowed
Niger	Yes	Telecom operators and private services, such as banks	Yes	Yes		No
Nigeria	Yes	ISPs	Yes			
Rwandese Republic	Very much used by ISP's	ISP's to connect big subscribers and cyber cafes	Yes			Wireless is still used mainly in big cities [Yes?]

Table VI.4 – Experiences of use (Part C1) (cont)

Country	Bands used?	Main users	Lo-cal use	Rural, wider area netwk use	Other use	Hotspot against payment?
Sao Tome and Principe						
Senegal	Yes	Coffee shops, existing telecom operators, ISP's, municipalities. In addition companies in sectors such as banking, commercial businesses, travel agencies, maritime and aeronautic transportation, etc	Yes		WLAN, Broadband Wireless Access, WLL	Yes
Seychelles	Yes	ISPs	Yes			Yes, Hotspots are also run by ISPs. There is one at the airport today (no additional fees)
Sierra Leone	NA	NA	NA	NA	NA	NA
Somali Democratic Republic	Yes	Telecom operators using 2.5 and 5 GHz for microwave links	Yes	Yes		No
South Africa	Yes	Cybercafes, malls, ISPs	Yes		Grey market connections by enthusiasts and some ISPs	Yes, in malls, cybercafes etc and Yes if 'most' people can get to a mall, then they would be accessible to 'most' people
Sudan	Yes	ISP's & OTHERS	Yes	Yes	Yes	INSOME URBAN AREAS
Swaziland	NA	NA	NA	NA	NA	NA
Tanzania	Yes	ISPs		Yes		
Togolese Republic	Yes, the 2.4 GHz	Cafés Internet, ISP	Yes			No
Tunisia	Yes	Mainly trial applications	Yes			No
Uganda	Yes. 2.4 GHz	ISPs	Yes			No
Western Sahara[137]		(See Morocco)			(See Morocco)	
Zambia	Yes	ISP's	Yes			
Zimbabwe		[ISPs]				

[137] See Footnote 46, page 57, for note on Western Sahara.

Table VI.5 – Equipment, products, Universal Service (Part C2)

Country	Protocols open/closed	Commercial products	Main problems ntwk equip	Main problems end-user equip	Interference?	Provisions Service providers through USFunds?	Have funds been used?
Algeria	Open	Not yet commercialized (being trialed out)	No problems	No problems if they have been certified	No problems	No	No
Angola					Serious interference	Yes	No
Benin							
Botswana	Normally is 802.11 equipment supplied by Breezecom, Cisco	Breezecom and Cisco	None	None	Unknown	No	No
Burkina Faso	802.11		Weak purchasing power, few customers, so high price	No	No	No	
Burundi		Café internet			No	Not yet	
Cameroon		Data, internet, voice, video, etc.	Yes, but this is resolved by the terminal rental agreements. There are still the environmental risks, due to climate or storms	No	Yes, since some bands are saturated and certain users do not respect their coverage zone, or are using high bandwidth transmitters	There is a Universal Service fund to support de operators who invest in rural areas. This represents around 1.5% of de operators profits	No
Cape Verde		CISCO	Yes	This equipment is not yet commercialized, since there is no local dealer	Not yet, but perhaps in the future, depending on usage level	There will be soon	No
Central African Republic						No	
Chad					No	The provisions exist, but are not yet in place	No

Table VI.5 – Equipment, products, Universal Service (Part C2) (cont)

Country	Protocols open/closed	Commercial products	Main problems ntwk equip	Main problems end-user equip	Interference?	Provisions Service providers through USFunds?	Have funds been used?
Comoros	Closed	-	Yes, the equipment has to be imported from abroad. The commercialization of such product is not common		No, such problems risk to emerge on the FM band (87,5 - 108 MHz) if the regulator doesn't react	No	No
Congo	NA	NA	NA	NA	NA	NA	NA
Côte d'Ivoire	TCP/IP, X25 with TDMA or CDMA access mode	Broadband internet connection	For the local loop, the prices are so high that only companies and Cyber-café can currently use ISP services. Individual users have to use Dial up	No	Not respecting the maximum power limits or intermodulation interference are the source of jamming and interference with other services	A Universal Service Fund exist under another format for telecom development	No
Democratic Republic of the Congo	Yes, mainly 802.11.(b,a & g)	- Cisco Systems, Breezecom (Alvarion), Linksys, Dlink	Yes, high prices, often unavailable	Yes, high prices, often unavailable	yes, a lot of radio interference, in which respects to voice	No, but is defined in the framework of Telecom law in RDC.	No
Djibouti	NA	NA	NA	NA	NA	NA	NA
Egypt	802.11b /802.11g/802.11a	Cisco -3M-symbol and others	Not yet	Not yet	No protection against interfere. & must not cause interference for licensed services in these bands	Not yet	No
Equatorial Guinea	NA	NA	NA	NA	NA	NA	NA
Eritrea					There have been and users have been advised to adjust their antennas	Not yet implemented included in 1998	
Ethiopia							
Gabonese Republic	Open				No	Under development	No

Table VI.5 – Equipment, products, Universal Service (Part C2) (cont)

Country	Protocols open/closed	Commercial products	Main problems ntwk equip	Main problems end-user equip	Interference?	Provisions Service providers through USFunds?	Have funds been used?
Gambia			Price and availabilty		None reported yet	No such funds so far	
Ghana	Open protocols (eg 802.11)	BreezeCom and Cisco products	The issues with end-user equipment are with price and availability	Same issues with regards to the price and availability	No	Yes (telecom operators)	No
Guinea	Open	Alvarion Breezecom, Aironet cisco	Price, availability and repairs	Price, availability and repairs	Sometimes interference between alvarion operators	No	No
Guinea-Bissau	NA	NA	NA	NA	NA	NA	NA
Kenya	Open	Data networks operations	The equipment is readily available	They may be relatively cheap depending on their capacity	No	Yes we have a universal service fund, achieved by universal service obligation vested on other operators, to enable penetration and service provision in the rural areas	Yes
Lesotho	802.11x and hiperlan - mainly open standards		No	No	No	No	
Liberia		Alvarion, YDi, Cisco	Availabilty of the service with ISPs	Availability		No	No
Libya	NA	NA	NA	NA	NA	NA	NA
Madagascar	Mostly 802.11, specially BreezeCom	BreezeCom and Alcatel	Mainly the price that is outside the public 'possibilities'	Mainly price	Not that we know of. Some performance problems have been flagged	The US Fund exists and is mainly used by the regulator to ensure coverage on rural areas	Yes
Malawi		Breezecom			No	Not yet	No
Mali	802.11b	Internet Explorer and Outlook Express			Yes, since many ISPs use omni-directional antennas	No	

Table VI.5 – Equipment, products, Universal Service (Part C2) (cont)

Country	Protocols open/closed	Commercial products	Main problems ntwk equip	Main problems end-user equip	Interference?	Provisions Service providers through USFunds?	Have funds been used?
Mauritania	Open				No	There is an agency for UService and the law establishes an Universal Service Fund which is fed by operators' contributions through payment of annual fees	
Mauritius	IEEE 802.11/16	Cisco, Breezecom	Not to our knowledge	No	No	This is currently being worked out, and there is some serious thought in that direction	
Morocco	802.11 equipment has been agreed by ANRT		The decision regarding "hot-spot" establishment has just been published (25 Dec 2003). It is too soon to see the eventual problems	The decision regarding "hot-spot" establishment has just been published (25 Dec 2003). It is too soon to see the eventual problems	The decision regarding hotspots establishment has just been published (25 Dec 2003). It is too soon to see eventual problems. However on the 2.4 GHz use, ANRT has never been informed of interf. problems. That doesn't prove they don't exist	The licensed operators contribute annually for the Uservice framework. Their contribution represents currently around 4% of their profits (chiffres d'affaires), after tax	No
Mozambique	ISPs use 802.11	Motorola, Alcatel			Yes	Yes	No
Namibia	Open	Open, Alvarion + BreezeNet + WaveRider	Price: expensive, not locally available	Price	No	No	No
Niger			No idea about implementation problems	No major problem	No complaints so far	Yes	No
Nigeria	IEE802.11	Breezecom	Yes	Yes	Yes	No, being planned	No

Table VI.5 – Equipment, products, Universal Service (Part C2) (cont)

Country	Protocols open/closed	Commercial products	Main problems ntwk equip	Main problems end-user equip	Interference?	Provisions Service providers through USFunds?	Have funds been used?
Rwandese Republic	802.11	Aironet Cisco Wireless Lucent	Availability since the equip. is imported from US or Europe or South Africa, also, technical issues like lightening storm and shortage of electricity	Lightening storm and shortage of power are the major issues	No	Yes , Universal funds to extend services to remote areas has been applied recently by the new regulator	Yes
Sao Tome and Principe							
Senegal	802.11	Alvarion, SMT, Breezenet	Often quality may suffer from reliability, namely in the case of fluctuating propagation. However, the devices may not always be available since their introduction must have a previous authorization from ART	(see previous column)	Not with other services, but within the same service. The direction of the links may cross	The fund should be implemented, but is still not in place. Once in place, nothing will be excluded to promote universal service	No
Seychelles	Both protocols are being used. 802.11 for 2.4GHz and Canopy for 5.7 GHz Band		Both price and availability are a major concern		No	No	No
Sierra Leone	NA	NA	NA	NA	NA	NA	NA
Somali Democratic Republic	No regulator, so any protocol can be used	None			Yes, because different phone companies sometimes use microwave in the same frequencies, which creates interfer. This occurs since there is no regul. or coordination	No	No

Table VI.5 – Equipment, products, Universal Service (Part C2) (cont)

Country	Protocols open/closed	Commercial products	Main problems ntwk equip	Main problems end-user equip	Interference?	Provisions Service providers through USFunds?	Have funds been used?
South Africa	Mainly 802.11a/b	Belkin, SMC, Senao, Avaya, Cisco, 3Com	Not that I know of	Not sure	Not that I know of	Not in this area	No
Sudan					Yes		
Swaziland	NA	NA	NA	NA	NA	NA	NA
Tanzania		Alvion	At the moment no		No	Yes	No
Togolese Republic	Proprietary		Availability and price	Availability and price	Yes	Yes, but only in the framework of Universal Service	No
Tunisia	802.11		Prices going down, availability going up	No	No	Yes	No
Uganda	802.11	Breeze com and Lucent Technologies	None	None	A lot of interference due to some users using external amplifiers to boost their signals so as to achieve longer coverage which violates the regulations	Yes for rural and remote areas	No
Western Sahara[138]		(See Morocco)			(See Morocco)		
Zambia	802.11	BreezeCom, Breeze Acees so far but Motorola Canopy just approved	No info on the pricing available	No info from service providers	None so far	CAZ has set aside some Rural Telecomms Development Fund (RTDF) and is working out modalities of disbursing the same	No
Zimbabwe	NA	NA	NA	NA	NA	NA	NA

[138] See Footnote 46, page 57, for note on Western Sahara.

Table VI.6 – Other information (Part C3)

Country	Other information (from survey, e-mails, or personal contacts)
Algeria	The reforms in the telecom sector are relatively recent. The regulator is less than 3 years old. At the end of the year all telecom markets will be open for competition, if there are no delays.
Angola	The 2.4GHz band was adopted for licensing of technologies which use spread spectrum. The band is very congested due to the massive use by some service providers, especially internet (ISPs), using it without respecting the technical conditions imposed in the licensing acts. The monitoring and enforcement is in this moment still weak, but in the near future this situation may be significantly changed: Angola is in the process of acquiring, installing and starting operation of a monitoring center.
Benin	-
Botswana	The bands are being used extensively to provide the data service. The main problem is that some of the users do not observe the specified transmitter power limits and they end up polluting the band unnecessary deteriorating the quality of service of other operators. There is a strong possibility that some people are operating without the license. More especially that the ISM band is not licensed in other countries so people just operate assuming that is not licensed in Botswana also.
Burkina Faso	-
Burundi	-
Cameroon	Recommend to look at the site www.minpostel.gov.cm, under 'decret e textes' The 2.4 Band is totally saturated at present. Several operators share it. CAMTEL has point-to-point links which use the 5GHz Band, I would be surprised if it is also used by other operators. Generally the lack of reliable infrastructure have brought emergent operators to develop wireless solutions to offer quality to the client. Obtaining a license is compulsory, but some operators do not bother with that formality and deploy equipment in a illegal way. The widespread fraud will soon be over, since the regulator will soon receive equipment for controlling the spectrum utilization – it will then easily find fraud
Cape Verde	For a country with our 'orography' - very hilly terrain the wireless technology will always be welcome. On the other hand, due to the high prices of the public telecommunications operator for leased lines this technology solves and will solve the problem of many operators. We still don't have WLAN operators, but there is a state entity who has a computer network that links all ministries and government buildings. Initially dedicated circuits between distant buildings were used. But due to the high prices for the public operator they have chosen to implement this through wireless technology using CISCO technology in the 2.4GHz Band. We are hoping to soon have operators using this technology. Our policy is to accept the use but at the same time also control it, since we are a small country with a terrain that is sensitive to interference
Central African Republic	-
Chad	-
Comoros	-
Congo	NA
Côte d'Ivoire	The telecom sector is such that at present the implementation of the regulation poses some problems. But soon, with a new regulation, certainly all aspects of telecommunications will be considered - the technology changes fast, and regulation is often 'late'
Democratic Republic of the Congo	The license is not easy to obtain and there is no policy on terms of Telecom. There are many taxes to pay. There have been conflicts between the Telecom and the Media Ministry about regulation and licenses. Often there is no equipment for enforcement and no expertise available.
Djibouti	NA
Egypt	In this time our telecommunication regulatory authority is in the way to issue the regulations concerning the bands 2.4GHZ and 5 GHZ so complete answer for your study is not available
Equatorial Guinea	NA
Eritrea	There are 4 ISPs. They pay an annual fee, different regime for monopoly
Ethiopia	-

Table VI.6 – Other information (Part C3) (cont)

Country	Other information (from survey, e-mails, or personal contacts)
Gabonese Republic	For the 2.4 and 5GHz bands there are operators/persons who use the bands without a license. For the moment, we have just setup a frequency control center which is starting to control and detect the ‘breachers’. But I can assure you that there are many people using these bands without an authorization.
Gambia	
Ghana	The Regulatory Sector is undergoing major capacity building to be able to enforce the technical regulations; With the 5 GHz band the National Communications Authority has only the last band as unlicensed .ie. (5.725 - 5.875GHz)
Guinea	For the moment there is no explicit regulation in this domain. This regulation is being discussed in the national assembly
Guinea-Bissau	NA
Kenya	See attached document. A permit may only be required for operators coming in as non ISM operators (secondary users) but ISM operators do not need any. Even though, these users must apply for a permit from the commission for the sake of our database and inventories. the fee as in the attachment herewith is minimal US$132. This factor has attracted a great deal of operators into these bands unlike before when they used to be charged approximately US$800. To control quality of service the commission does not automatically grant licenses/permits to secondary users.
Lesotho	i) Being technologically neutral - the LTA (regulator) advocates for use of open standards as much as possible.; ii) New regulations for WLAN & MANs are in the process of being promulgated.
Liberia	In Liberia all the telecommunications installations need to be fully checked and registered. The country has been affected by 13 years of war and there is no regulation for the unlicensed bands
Libya	NA
Madagascar	The response to this survey has been based on personal judgment and can include mistakes. Please contact omert@dts.mg for more information (see also www.omert.mg). The regulatory and legal framework is currently being revised by an international specialist. It is possible that in the near future there will be big changes, but we do not yet know which ones.
Malawi	It is possible that there are some unlicensed operators utilizing the ISM Bands. We acknowledge this deficiency in our inability to monitor these operations but as already indicated very shortly we will have all the necessary tools in place.
Mali	The entire regulatory and policy environment in Mali concerning the use of 2.4 and other bands (even FM radio) is still very nascent and chaotic. The CRT has only recently found office space and hired appropriate staff, and has yet to issue any regulatory policies and rulings. The CRT has four primary responsibilities: (1) IT sector regulation (conflict resolution, assignment of frequencies, establishment of fee and tariff structures); (2) monitoring of the use of spectrum; (3) consumer rights and protection (consumer satisfaction, provider conformance, etc.); and (4) development and promotion of the IT sector. It is staffed with four engineers, one lawyer, and various administrative support staff. It consists of five departments: the General Directorate, and Admin/Finance, Legal, Economic/Competition and Technical departments. Planned for 2004 are the creation of a regulatory work group, mandated with drafting policies on the use of radio spectrum. In summary, the CRT has only recently become operational, but so far has not played any significant role in the regulatory and policy environment.
Mauritania	
Mauritius	Mauritius is very opened to best international practice in terms regulation. However, the regulator is very prudent in implementing regulations that have proven to work elsewhere as the context is different locally. In this respect, to the extent possible and where appropriate we do adopt and homologate new standard and regulatory reforms when they become applicable elsewhere. The concept of the unlicensed band is one of the many
Morocco	
Mozambique	The use of the 2.4 GHz band is only allowed for research purposes, etc. Commercial use is not allowed. The licensing is done by INCM, Mozambique’s regulator.
Namibia	No License is required for any ISM-band, but a permit under ITU or CEPT condition and the draft regulation conditions. *From alternative source: Unlicensed, but any use beyond the boundaries of one’s property, it's illegal*

Table VI.6 – Other information (Part C3) (cont)

Country	Other information (from survey, e-mails, or personal contacts)
Niger	I cannot say that there is no one using these bands illegally - everything is possible, but in any case using these bands requires an authorization
Nigeria	
Rwandese Republic	The connectivity is one of the major issue as far as Internet development in Rwanda is concerned. Right now 4 private ISP's are operating and we expect the connectivity to be extended to remote areas in the near future as the government is looking to provide support for schools, public institutions and the community
Sao Tome and Principe	
Senegal	There are companies operating illegally in these bands, but ART is in the process of tracking them down and reflecting in the ways to make them stop the emissions.
Seychelles	
Sierra Leone	NA
Somali Democratic Republic	[NB: there is no government in Somalia, so no regulator either]
South Africa	It is the regulation of telecom service provision that affects the use of these bands, not anything specific to regulation of ISM bands. There are definitely telecommunication service providers such as wireless internet service providers that use the band without the required license. There are also point-to-point links used by various entities in this band without the required license. Mostly action is only taken in response to a specific complaint of interference and illegal use by the incumbent fixed line operator
Sudan	Now these bands are governed under the mainframe of Telecom Law 2001 & the relative by ACts 2002; www.ntc.org.sd; Licensing these bands separately is under study.
Swaziland	NA
Tanzania	Control on ISM band is only focused to ISPs for management of frequency interference
Togolese Republic	
Tunisia	New text, currently being prepared, accounts for radio low power low range devices, the introduction of new ISM equipment, and the extension to the 5GHz band, the actualization of the National Frequency plan, and the expansion of new ISM bands. Additionnel références: : Code des Télécommunications : Loi 1-2001 du 15 janvier 2001, Arrêtés du ministre des technologies de la communication du 11 février 2002, relating to : a). National Frequency plan b) radio low power low range equipment c) amount to be paid for frequency attribution
Uganda	Please note that we haven't started using the 5GHz band YET but we are preparing the guidelines to open it up in line with the recommendations adopted by WRC 03
Western Sahara[139]	(See Morocco)
Zambia	
Zimbabwe	Until last year the 2.4 GHz ISM band was uncontrolled and used extensively for data links to ISPs and within commercial organizations. However last year all operators of such links were ordered to stop using them. As of the end of January this year no ISPs are supposed to be operating within this band. As can be expected, this edict has caused extreme inconvenience and expense. Basically in Zimbabwe it is not possible to use the ISM bands. ISP are using it but have to migrate (during 2003) to licensed bands. There was a meeting with the regulator and those who are still operating with the objective to discuss ways of minimizing the impact on users. The regulator has refused to extend the deadlines.

[139] See Footnote 46, page 57, for note on Western Sahara.

Appendix VII - Additional Graphs

Detailed licensing categories, by population

When representing the same information, but weighted by population, Unlicensed Bands are only experienced by 2% of the population for the 2.4GHz Bands, and by 1% for the 5GHz Bands[140]. The results in the pie charts for population change significantly because of Nigeria. Nigeria, with a population of around 120 million, is the country with the highest population in Africa, (he second largest being Ethiopia or Egypt, with only 67 million people) and adopts a different policy for the 2.4GHz and 5GHz bands (unlicensed and licensed, respectively).

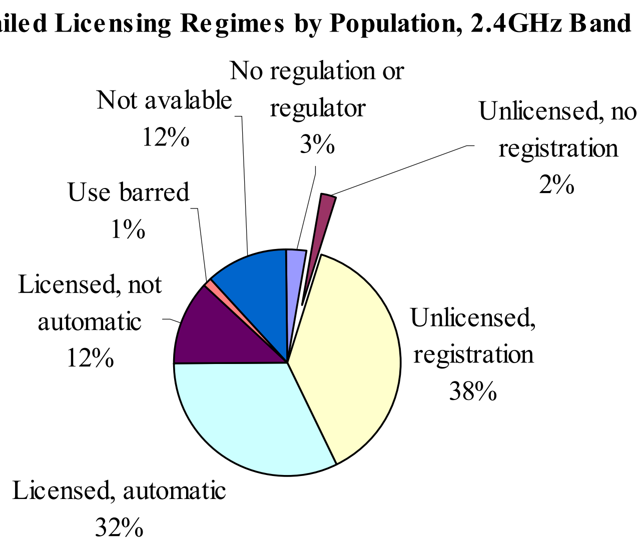

Figure VII.1 – Licensing regimes, 2.4GHz Band, detailed categories – % of population

[140] Population data source: ITU, data for 2002. For Western Sahara data from CIA World Fact Book, 2003.

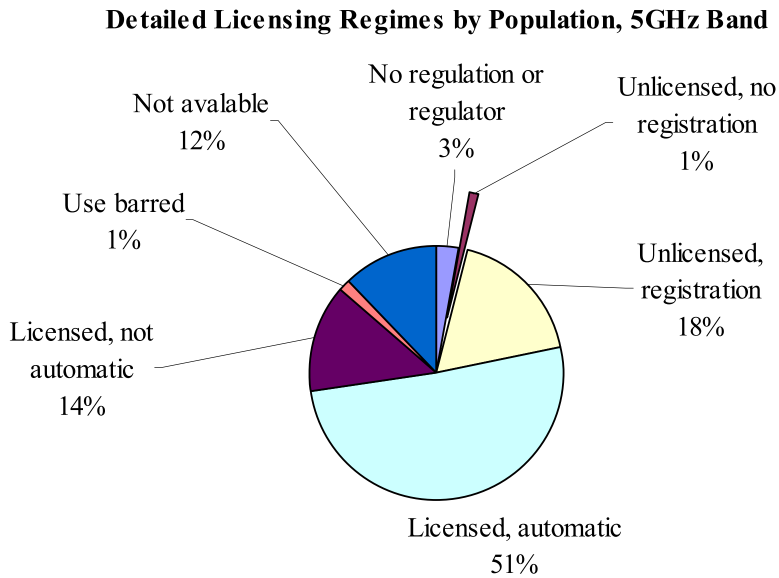

Figure VII.2 – Licensing regimes, 5GHz Band, detailed categories – % of population

Exclusive use of spectrum

As can be seen in Figure VII.3 and Figure VII.4, from the countries that require a license to operate, only a small fraction assigns the spectrum on an exclusive basis. Further analyzing the results, and paradoxically, it can be found that the regulators that mandate exclusive use of spectrum do so under the automatic licensing regime. This is difficult to interpret; one possibility is that there is a limited number of licenses and that they are attributed automatically, on a first-come first-served basis.

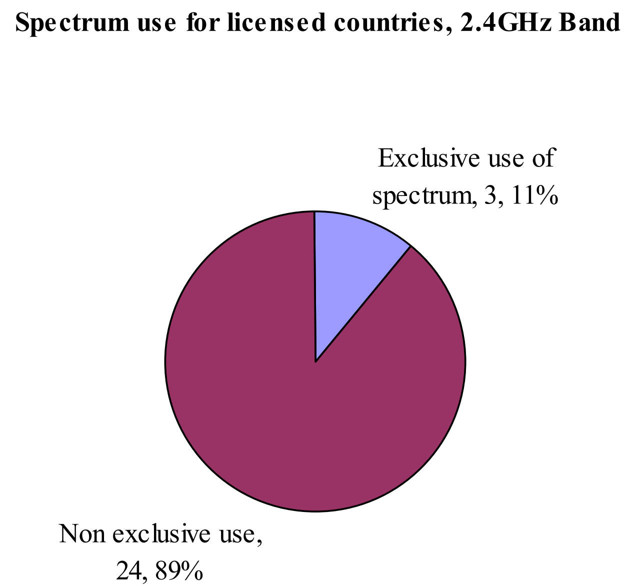

Figure VII.3 – Exclusive use of spectrum for 2.4GHz

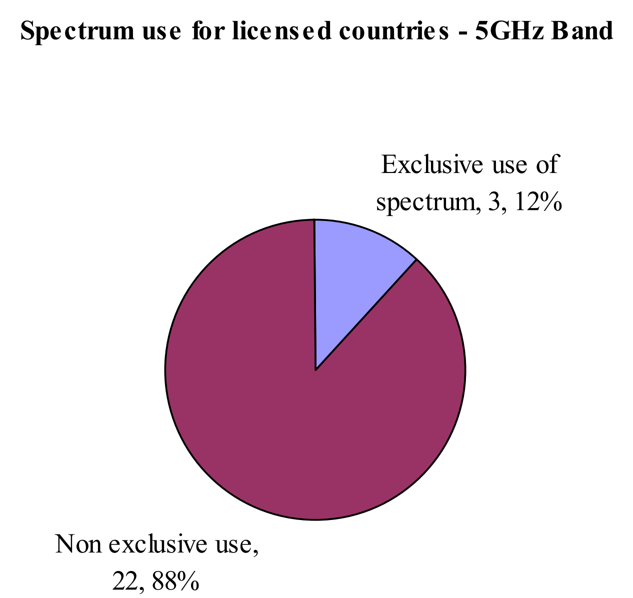

Figure VII.4 – Exclusive use of spectrum for 5GHz

Background to the regulations

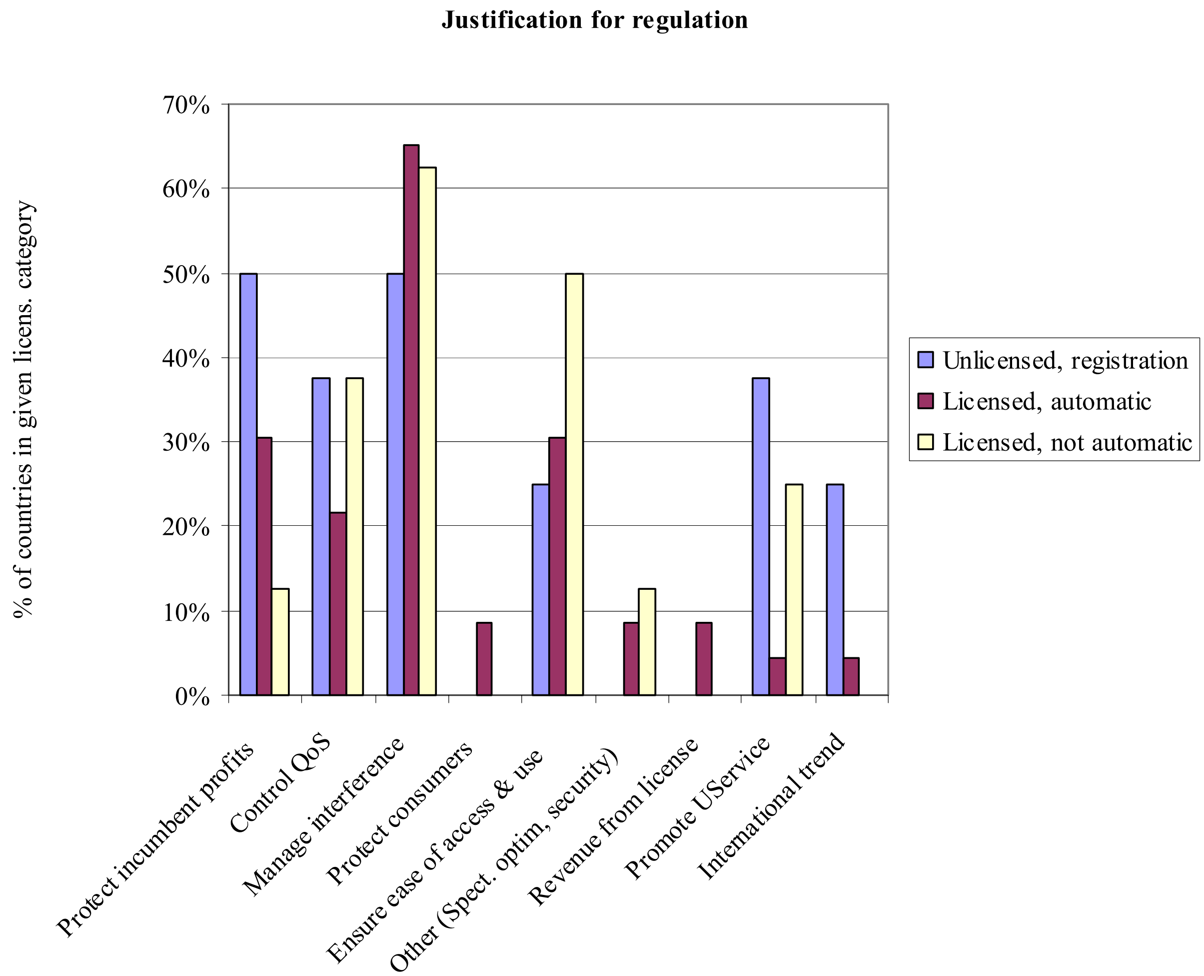

Figure VII.5 – Rationale for regulation, by licensing type[141]

Figure VII.5 shows the different rationales invoked for the regulation adopted. The justifications that were more commonly used were interference management, controlling QoS, ensuring ease of access and protect profits of existing operators.

When looking at the relative importance of the justifications per licensing regime the results do not always make sense. For example, the reason 'protection of existing operators' should be higher for more regulated options, like the non-automatic licensing. The data shows, however, that this reason is used more often for unlicensed regimes. The same happens to 'ensuring ease of access'.

[141] The most stringent regulation (btw 2.4 and 5GHz was used to categorize this). Too few data points were available for 'unlicensed no registration', and that is why this regulation is not represented in the graph.

This may be explainable with the way the question was asked. Respondents were not comparing types of regulation and giving reasons to go for one over the other, but rather just finding justifications to use a certain type of regulation, without any baseline or normalizing scenario. E.g. respondents may have chosen ‘protecting profit of existing operators’ when requiring registration – as opposed to the situation where no registration is required – even if this would protect existing operators less than if licensing was required.

Appendix VIII - Statistics analysis for Section 4.3.1

This Appendix contains additional information about the analysis in Section 4.3.1.

Table VIII.1 shows the mean of 'restriction' indexes, per restriction category, for the different licensing regimes. These are the values used to draw Figure 4.20 and other figures in that section, and in this Appendix. These average indexes are a measure of the 'restrictiveness' with which regulation in these bands is defined. Once again these are just indicative numbers, and do not represent any 'physical' or 'real' number. E.g., the fact that the power index for unlicensed is 3.5, does not place the average power used in any category in Table 4.2. It purely serves the purpose of comparing, in relative terms, groups of countries with different restriction levels.

Table VIII.1 – Averages for restrictions per licensing type

	2.4 GHz					5GHz				
Licensing type	**Power**	**Range**	**Services**	**Enforcement**	**Certification**	**Power**	**Range**	**Services**	**Enforcement**	**Certification**
Total	**1.97**	**1.73**	**1.98**	**1.88**	**1.67**	**2.00**	**1.73**	**1.71**	**1.84**	**1.72**
Unlicensed, no registration	3.50	2.50	2.00	1.33	1.67	3.00	2.00	2.00	1.00	1.50
Unlicensed, registration	2.78	2.56	1.57	2.13	1.90	2.67	2.17	1.57	2.17	2.00
Licensed, automatic	1.94	1.60	2.23	2.14	1.89	2.14	1.72	1.95	2.09	1.75
Licensed, not automatic	1.20	1.50	2.00	1.86	1.57	1.40	1.83	1.57	1.88	1.71

These averages are calculated using a different number of data points for different categories (there are different countries in each licensing regime group, and there is not 'restriction' information for all countries). Figure VIII.2 shows the number of data points used to calculate the different means – these will determine the standard errors for the different values. These numbers are accounted for and used in the error bars that can be seen in the figures.

Table VIII.2 – Number of points used to calculate averages in previous table

	2.4 GHz					5GHz				
Licensing type	**Power**	**Range**	**Services**	**Enforcement**	**Certification**	**Power**	**Range**	**Services**	**Enforcement**	**Certification**
total	**37**	**40**	**41**	**43**	**44**	**28**	**33**	**38**	**43**	**39**
Unlicensed, no registration	2	2	2	3	3	1	1	2	2	2
Unlicensed, registration	9	9	7	8	10	6	6	7	6	7
Licensed, automatic	18	20	22	22	19	14	18	20	22	20
Licensed, not automatic	5	6	7	7	7	5	6	7	9	8

Note: In order to perform a more accurate test, and apart from analyzing the standard errors, I have further conducted regressions, using dummy variables for the different licensing regimes. The results were similar, and are available on request.

Restrictions vs. Licensing Regime for 2.4 GHz Band

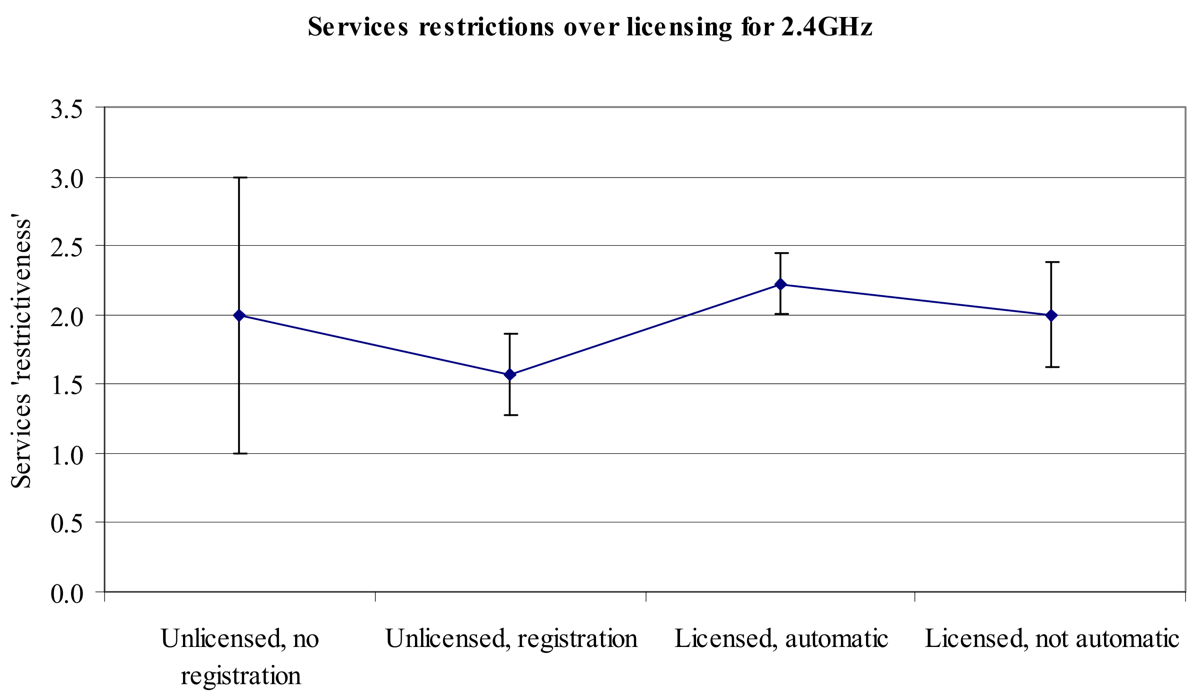

Figure VIII.1 – Significance analysis – Services restrictions vs. Licensing, 2.4GHz

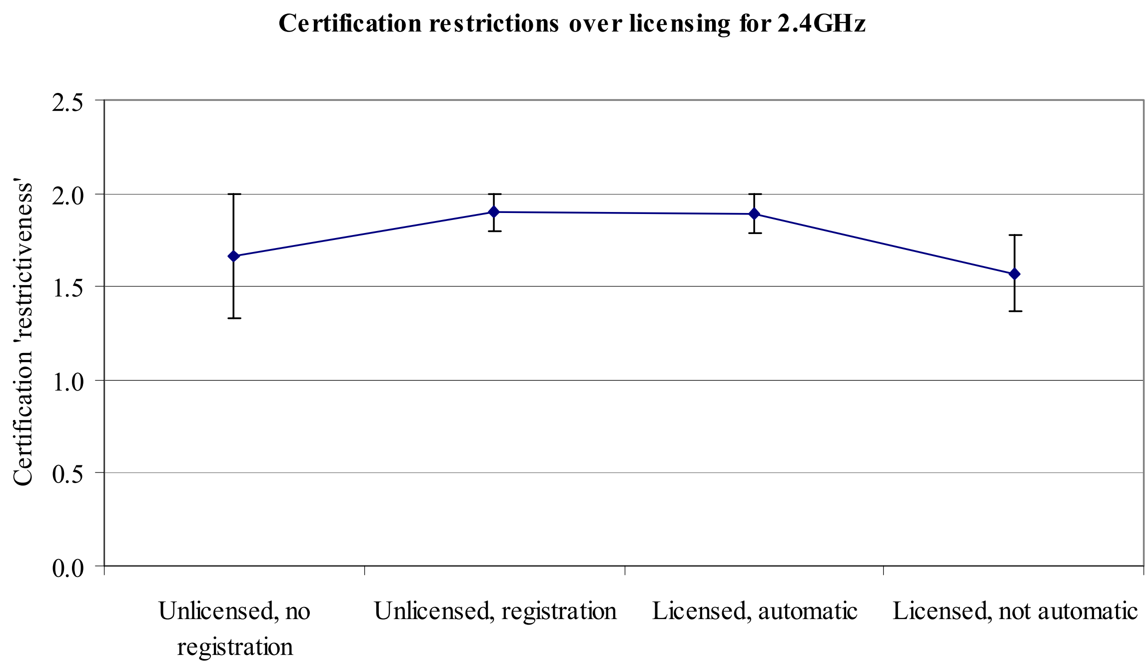

Figure VIII.2 – Significance analysis – Certification restrictions vs. Licensing, 2.4GHz

Restrictions vs. Licensing Regime for 5 GHz Band

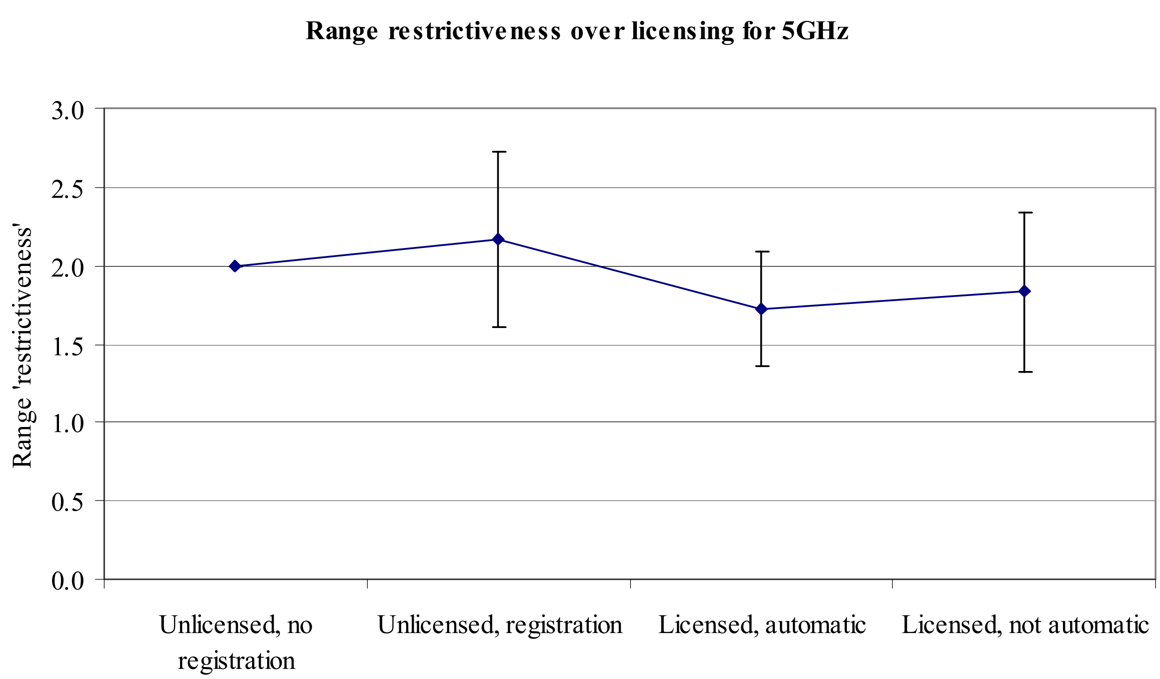

Figure VIII.3 – Range restrictions over licensing for 5GHz Bands

Note: no error bar can be calculated for the 'Unlicensed, no registration' category, because there is only one data point

Enforcement over licensing regimes for 5GHz

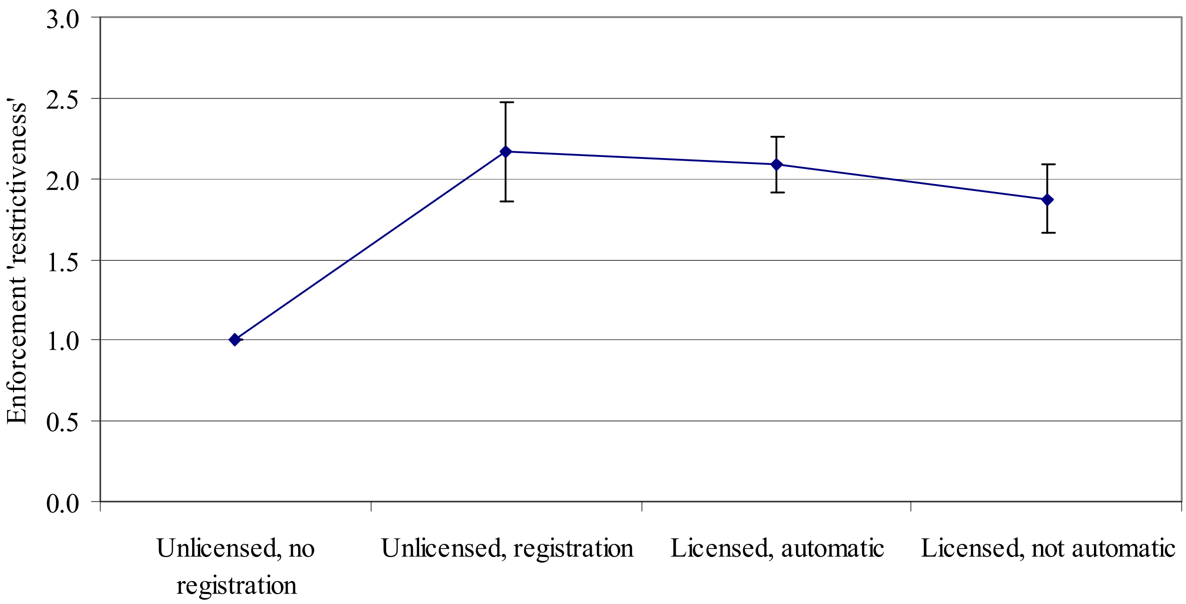

Figure VIII.4 – Enforcement restrictions over licensing for 5GHz Bands

Services restrictions over licensing regimes for 5GHz

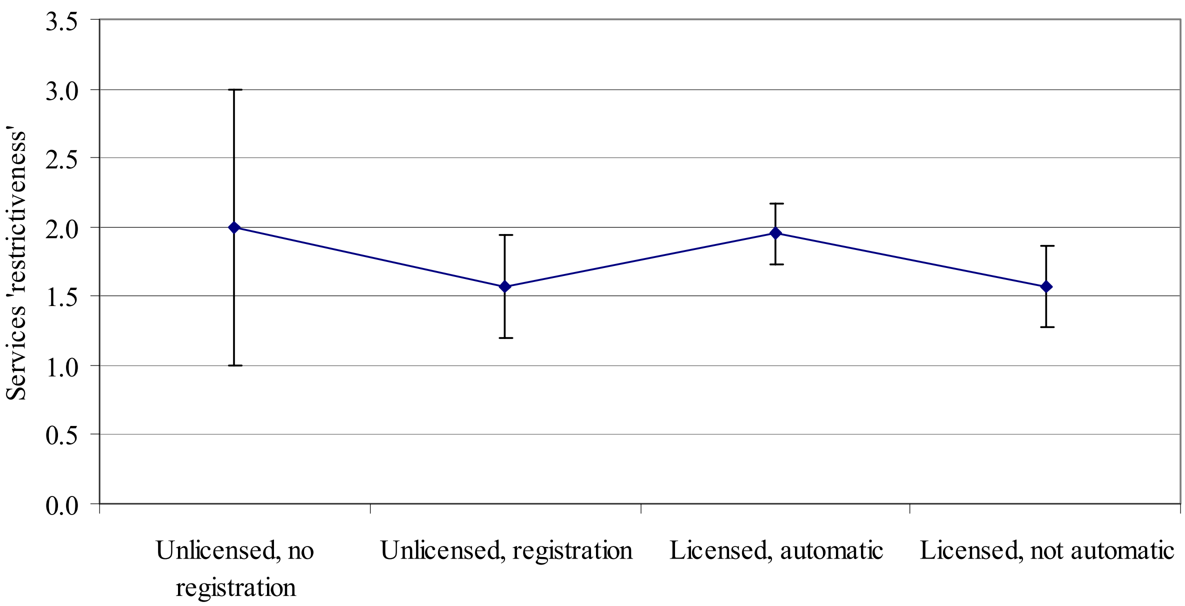

Figure VIII.5 – Significance analysis – Services restrictions vs. Licensing, 5GHz

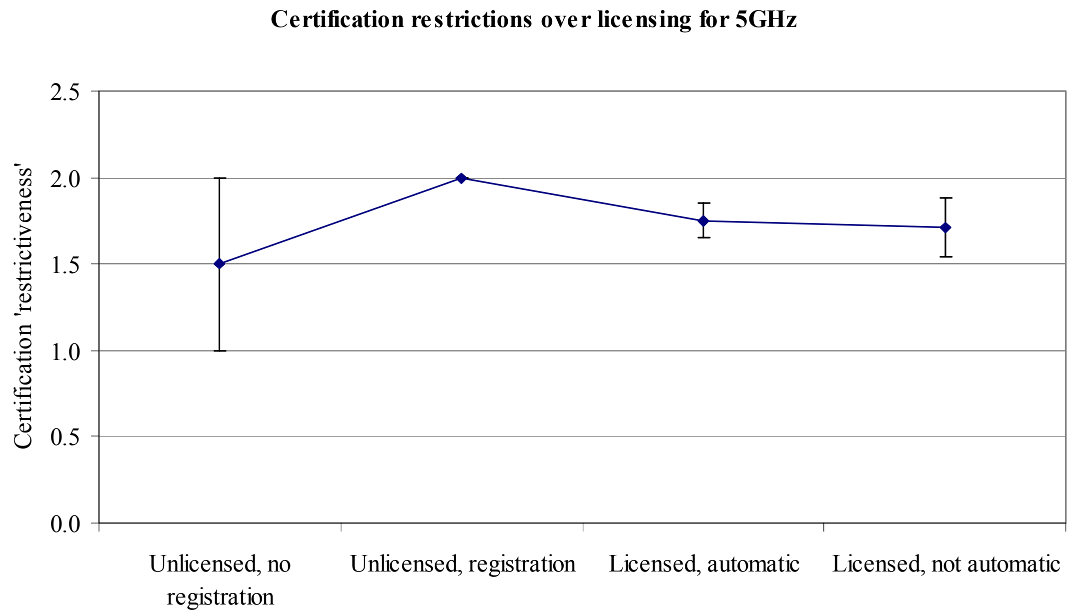

Figure VIII.6 – Significance analysis – Certification restrictions vs. Licensing, 5GHz

Restrictions vs Type of use for 2.4GHz Band

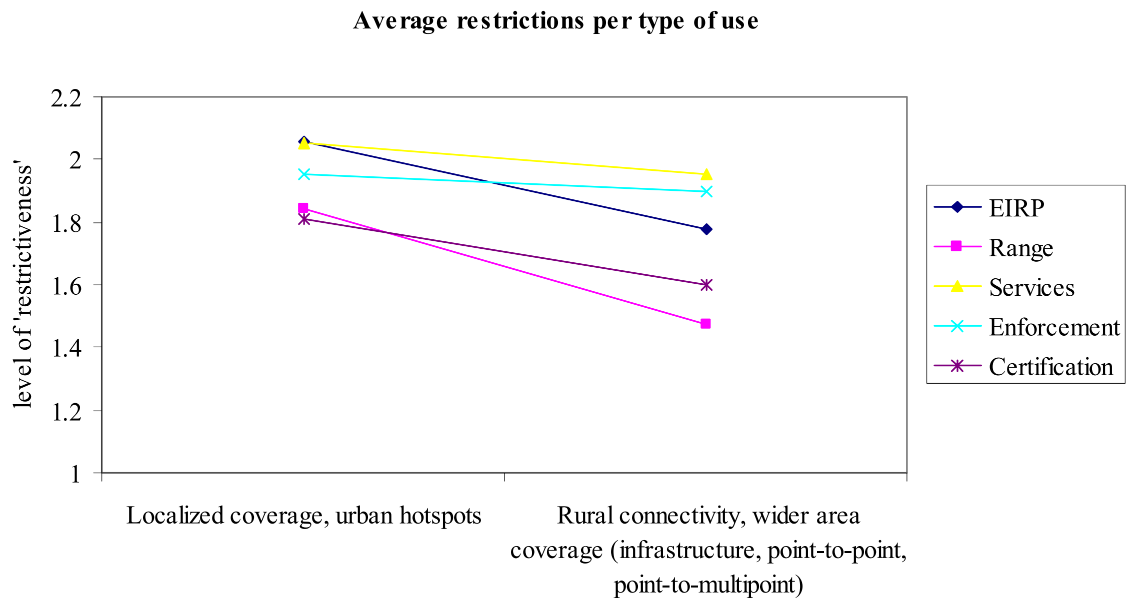

Figure VIII.7 – Restrictions vs. type of use for 2.4GHz Bands[142]

Analyzing the results, I find that none of these differences are significant.

[142] To construct this graph I have crossed restriction information with the most expansive use in a particular country. I.e., a country where both localized and rural connectivity are provided, was used in the rural connectivity only category. This assumes that where you can do rural coverage you will also be able to do localized coverage. Categorizing countries in this way will give more significant results.

Appendix IX - Statistics analysis for Section 4.3.2

General ICT indicators

Table IX.1 – Spearman Correlation (Rs) between survey variables and general ICT indicators[143]

	Teledensity 02				Internet Hosts 02 per capita				DAI				International internet bandwidth per 100 inhabitants				Internet tariff as a percentage of GNI			
Indicators	**n**	**Rs coef**	**p**	**Signif 95%?**	**n**	**Rs coef**	**p**	**Signif 95%?**	**n**	**Rs coef**	**p**	**Signif 95%?**	**n**	**Rs coef**	**p**	**Signif 95%?**	**n**	**Rs coef**	**p**	**Signif 95%?**
Licensing Categories for 2.4GHz Band	43	0.12	0.45	No	44	0.25	0.11	No	43	-0.07	0.64	No	43	-0.02	0.91	No	43	0.05	0.73	No
Licensing Categories for 5GHz Band	41	0.19	0.24	No	42	0.24	0.12	No	41	0.05	0.77	No	41	0.09	0.60	No	41	-0.05	0.77	No
EIRP Restrictions for 2.4GHz Band	33	0.25	0.16	No	34	0.17	0.34	No	33	0.19	0.28	No	33	0.22	0.21	No	33	-0.34	0.054	No
EIRP Restrictions for 5 GHz Band	26	0.30	0.13	No	26	0.21	0.30	No	26	0.34	0.09	No	26	0.25	0.22	No	26	-0.37	0.06	No
Range Restrictions for 2.4GHz Band	36	0.02	0.89	No	37	0.05	0.75	No	36	0.01	0.96	No	36	0.01	0.95	No	36	-0.08	0.66	No
Range Restrictions for 5 GHz Band	31	0.38	0.04	YES	31	0.29	0.11	No	31	0.38	0.03	YES	31	0.37	0.04	YES	31	-0.41	0.02	YES

Note: For the specific case of Range restrictions for 5GHz band we find other statistically significant correlations.

[143] In the table, *n* denotes the size of the sample; *Rs* is the Spearman Correlation coefficient; *p* is the probability associated with the confidence interval. The last column shows whether there is correlation, at a 95% confidence level.

GDP per capita

Table IX.2 – Spearman Correlation (Rs) between survey variables and GDP per capita[144]

Indicators	GDP per capita			
	n	Rs coefficient	p	Significant 95%?
Licensing Categories for 2.4GHz Band	36	0.06	0.71	No
Licensing Categories for 5GHz Band	34	0.19	0.28	No
EIRP Restrictions for 2.4GHz Band	29	0.12	0.53	No
EIRP Restrictions for 5 GHz Band	22	0.11	0.64	No
Range Restrictions for 2.4GHz Band	31	-0.14	0.45	No
Range Restrictions for 5 GHz Band	27	0.37	0.06	No

General governance indicators

Table IX.3 – Spearman Correlation (Rs) between survey variables and general governance indicators[145]

Indicators	Control of corruption				Regulatory Quality				Transparency			
	n	Rs coef	p	Signif. 95%?	n	Rs coef	p	Signif. 95%?	n	Rs coef	p	Signif. 95%?
Licensing Categories for 2.4GHz Band	44	0.08	0.60	No	44	0	0.99	44	43	-0.11	0.48	No
Licensing Categories for 5GHz Band	42	0.15	0.33	No	42	0.10	0.53	No	41	-0.12	0.44	No
EIRP Restrictions for 2.4GHz Band	34	0.35	0.044	YES	34	0.27	0.12	No	34	0.16	0.36	No
EIRP Restrictions for 5 GHz Band	26	0.20	0.32	No	26	0.19	0.35	No	26	0.06	0.76	No
Range Restrictions for 2.4GHz Band	37	0.28	0.10	No	37	0.19	0.25	No	37	0.24	0.15	No
Range Restrictions for 5 GHz Band	31	0.38	0.03	YES	31	0.34	0.06	No	31	0.06	0.75	No

[144] See supra note for interpretation of *n*, *Rs*, and *p* values.
[145] Idem.

References

Abramsson, N. 1970. "*The ALOHA System -- Another Alternative for Computer Communications*," Proc. AFIPS Conf., vol. 37, 1970, pp. 695–702

Alvarion Website. Retrieved May 4th, 2004 from http://www.alvarion.com/RunTime/HomePage.asp?brze=1 and http://www.alvarion.com/RunTime/Products_2010.asp?tNodeParam=16

Anthony, S.; Roth, E. and Christensen, C. 2002. "*The Policymaker's Dilemma: The impact of Government Intervention on Innovation in the Telecommunications Industry"*, Retrieved May, 4th, 2004 from http://www.innosight.com/template.php?page=research#PolicymakersDilemma.pdf

Arnbak, J. 1997. "*Managing the Radio Spectrum in the New Environment*", in Melody, William (ed.) "*Telecom Reform – Principles, Policies and Regulatory Practices*", Chapter 11; Den Private Ingeniørfond, Technical University of Denmark, 1997, retrieved January 10th, 2004 from http://www.cti.dtu.dk/publications/reports/telecomreform.pdf

Atheros 2003 "*Worldwide regulatory progress for WLAN*", White paper, Retrieved April 20th,2004 from, http://www.atheros.com/pt/Atheros_Regulatory_whitepaper.pdf

Bauer, J.2002. "*A Comparative Analysis of Spectrum Management Regimes*", TPRC, Retrieved 20th April from http://intel.si.umich.edu/tprc/papers/2002/85/SpectrumManagement.pdf

Beardsley, S.; von Morgenstern, I.B.; Enriquez, L. and Kipping, C. 2002. "*Telecommunications Sector Reform— A Prerequisite for Networked Readiness*". McKinsey & Company, Inc, Chapter 11, GITR 2002. Retrieved January 25th, 2004 from http://cyber.law.harvard.edu/itg/libpubs/gitrr2002_ch11.pdf

Benkler, Y. 2002 "*Some Economics of Wireless Communications*", Harvard Journal of Law and Technology, Volume 16, No 1, Fall 2002, Retrieved March 10th, 2004 from http://jolt.law.harvard.edu/articles/pdf/v16/16HarvJLTech025.pdf

Best, M. 2003 "*The Wireless revolution and Universal Access*", Chapter 7, Trends in Telecommunications Reform 2003, published by the ITU

Best, M. Maclay, C. 2002. "*Community Internet Access in Rural Areas: Solving the Economic Sustainability Puzzle*" Chapter 8, GITR, Retrieved January 10th, 2004 from http://www.cid.harvard.edu/cr/pdf/gitrr2002_ch08.pdf

Blattman, C. ; Jensen, R. and Roman, R. 2002. "*Assessing the Need and Potential of Community Networking for Developing Countries: A Case Study from India*". Retrieved January 10th, 2004 from http://edevelopment.media.mit.edu/SARI/papers/CommunityNetworking.pdf

Bletsas, A.; Lippman A. 2004. "*Efficient Collaborative (Viral) Communication in OFDM Based WLANs*", Retrieved March 15th, 2004 from http://web.media.mit.edu/~aggelos/papers/bletsas_isart03.pdf, retrieved in 2004

Bronkers, M. and Larouche, P. 1997 "*Telecommunications Services and the World Trade Organization*", 31 Journal of World Trade 5 (pp. 5-45)

Carter, R.; Lahjouji, A. and McNeil, N. 2003. "*Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues*". FCC Working Paper #39, May 2003, Retrieved January 25th 2004 from http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-234741A1.pdf

Cave, M. 2002 "*Radio spectrum management review; an independent review for the DTI and HM treasury*". Retrieved November 2003 from http://www.spectrumreview.radio.gov.uk/

Cave, M. 2002b "*Independent Spectrum Review*", Presentation on 'Spectrum and Services beyond 3G – First Annual workshop on Spectrum Allocation and Assignment Policy', Retrieved June 2003 from http://www.calit2.net/events/2002/Spectrum/presentations/

Cave, M. 2003 "*Economic Aspects of the New Regulatory Regime for Electronic Communication Services*", Warwick Business School Discussion Paper. Retrieved April 15th from http://users.wbs.warwick.ac.uk/cms_attachment_handler.cfm?f=f00db97b-6048-4a0a-972c-255780b37ebf&t=economic_aspects.pdf.pdf

CIA World Factbook website. Retrieved December 2003 from http://www.cia.gov/cia/publications/factbook/geos/wi.html, Retrieved May 2004

CNET News. 2004, "*Vonage to offer portable WiFi phones*". Retrieved April 20th from http://news.com.com/2100-7351-5181617.html

Coase, R. 1958. "*The Federal Communications Commission*", 2 J.L. & ECON. 1

Code of Federal Regulations (CFR), "*Protection of Human Subjects*" (45 CFR 46), October 1994, Department of Health and Human Services, Retrieved December 3rd, 2003 from http://www.med.umich.edu/irbmed/FederalDocuments/hhs/HHS45CFR46.html

Community Wireless website. Retrieved April 24th, 2004 from www.freepress.net/wifi

Compaine, B. and Weinraub,M. 2001. "*Universal Access to Online Services: An Examination of the Issue*". In Benjamin M. Compaine ed., "*The Digital Divide: Facing a Crisis or Creating a Myth?*" MIT Press, 2001. pp. 147-177;

Computer Science and Telecommunications Board (CSTB), National Research Council, 2002. "*Broadband: Bringing Home the Bits*". pp. 194-215. Retrieved June 2003 from http://books.nap.edu/books/0309082730/html/194.html

Cook, G. 2003. "*The COOK report on Internet*", Volume XII, No 1-3, April – June 2003, Retrieved 30th March from http://www.cookreport.com/index.shtml

CorDECT website. Retrieved February 12th, 2004 from http://www.tenet.res.in/cordect/cordect.html

COUHES website. Retrieved October 25th, 2003 from http://web.mit.edu/committees/couhes/, Courtney, M. 2002. "*Confusion hinders WLAN adoption*", Network IT Week, Retrieved January 5th, 2004 from http://www.networkitweek.co.uk/Analysis/1132886

Crandall, R. and Waverman, L. 2000. "*Who Pays for Universal Service? When Telephone Subsidies Become Transparent*". Brookings Institution Press. Retrieved June 2003 from http://brookings.nap.edu/books/0815716117/html/;

Daily Wireless. 2003 "*Kineto WiFi Phone*". Retrieved April 17th, 2004 from http://dailywireless.org/modules.php?name=News&file=article&sid=1457

David Reed webpage. Retrieved March 2004 from http://www.reed.com/dprframeweb/dprframe.asp?section=paper&fn=openspec.html

Drake, W. 2000. "*The Rise and Decline of the International Telecommunications Regime*" in Christopher T. Marsden,, ed., "*Regulating the Global Information Society*", Routledge, London

Eggleston et al. 2002."*Information and Communication Technologies, Markets, and Economic Development*", Karen Eggleston, Robert Jensen and Richard Zeckhauser, GITR 2002. Retrieved March 14th from http://www.ksg.harvard.edu/cid/cidbiotech/events/jensen2.pdf

Engelsm M., Coenen, P. and Hoymann, C. 2003. "*Congestion control mechanism for interworking between WLAN and WMAN*", Call for contribution IEEE 802.16d-03/45. Retrieved April 20th, 2004 from www.ieee802.org/16/tgd/contrib/C80216d-03_54.pdf

ERC, 2004. "*Status of ERC Recommendation 70-03*". Retrieved April 15th, 2004 from http://www.ero.dk/doc98/official/pdf/rec7003e.pdf

European Union, "*CE marking*". Retrieved March 13th, 2004 from http://europa.eu.int/comm/enterprise/newapproach/legislation/guide/document/chap07.pdf

Federal Communications Commission (FCC) ID website. Retrieved May 4th, 2004 from http://www.fcc.gov/oet/fccid/

Federal Communications Commission (FCC). 2002. "*Further Notice of Proposed Rulemaking and Report and Order*". FCC 02-43. Retrieved April 14th 2004 from http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-02-43A1.pdf for complete report.

Federal Communications Commission (FCC). 2002b. "*Spectrum Policy Task Force Report*". Retrieved April 13th from http://www.fcc.gov/sptf/.http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228542A1.pdf, November 2002, FCC

Federal Communications Commission (FCC). 2003. "*Notice of Enquiry and Notice of Proposed Rulemaking – Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed operation in Certain Fixed, Mobile and Satellite Frequency Bands"*. ET Docket No. 03-237. Retrieved April 14th 2004 from http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-03-289A1.pdf

Forbes 2003. “Talking in the free world”, Retrieved April 23rd, 2004 from http://www.forbes.com/2003/09/25/cx_dl_0925tentech.html

Forbes 2003b. “*The Near Future Of Wi-Fi*”, Retrieved April 23rd, 2004 from http://www.forbes.com/2003/04/15/cx_ah_0415tentech.html

Fredebeul-Krein, M. and Freytag, A. 1999. “*The Case for a More Binding WTO Agreement on Regulatory Principles in Telecommunications Markets*”. 23 Telecommunications Policy 625

Freedhoff, M. 2001. Presentation on “*UWB Technology*”, Time Domain.

Garnham, N. 1997. “*Universal Service*”, in Melody, William (ed.) “*Telecom Reform – Principles, Policies and Regulatory Practices*”, Chapter 16; Den Private Ingeniørfond, Technical University of Denmark, 1997, Retrieved Febraury 31th, 2004 from http://www.cti.dtu.dk/publications/reports/telecomreform.pdf

Gast, M. 2002 “*802.11 Wireless Networks – The definitive Guide*” O’Reilly

Geradin, D. and Kerf, M. “*Controlling Market Power in Telecommunications: Striking the Right Balance Between Antitrust and Sector-Specific Rules and Institutions*”, Oxford University Press, 2003

Gillett, S. 2000. "*Universal Service: Defining the Policy Goal in the Age of the Internet*”. The Information Society 16(2). Retrieved January 30th from http://itc.mit.edu/itel/docs/MISC/Gillett_Universal.html;

GIPI. 2002. “*Regulatory Treatment of 802.11b Services*” Retrieved October 30th , 2004 from http://www.internetpolicy.net/practices/80211b.pdf.

Hanna, N. 2003. “*Why National Strategies are Needed for ICT-enabled Development*”,Retrieved January 2004 from http://www.developmentgateway.org/download/222192/Why_National_Strategies.doc

Harvey, L. 1971.”*The invisible resource, Use and Regulation of the Radio Spectrum*”, The John Hopkins Press

Hawkins, R. 2002. “*Ten Lessons for ICT and Education in the Developing World*”. GITR 2002, Retrieved January 3rd, 2004 from http://www.cid.harvard.edu/cr/pdf/gitrr2002_ch04.pdf

Hazlett, T. 1998. “*Assigning Property Rights to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years?*”, The Journal of Law and Economics, Volume 41, Number 2, Part 2, October 1998; Retrieved January 25th, 2004 from http://www.manhattan-institute.org/hazlett/rahazl3.pdf

HIPERLAN1 website, Technical Overview, Retrieved March 2004 from http://portal.etsi.org/bran/kta/Hiperlan/hiperlan1tech.asp, retrieved may 2004

HIPERLAN2 website. “*Why HIPERLAN 2?*”. Retrieved May 4th, 2004 from http://www.hiperlan2.com/WhyHiperlan2.asp, and http://www.hiperlan2.com/

HIperlLAN2 global forum (H2GF). 2001. "*HiperLAN2 - The Broadband Radio Transmission Technology Operating in the 5 GHz Frequency Band*" White Paper. 2001

ICT4DEV website. Retrieved January 15th, 2004 from http://ict4dev.org/wiki/index.php/QuestionsWireless

IEEE 802.11, 1997. "*Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification*"

IEEE 802.11b. 1999. "*Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification: High-Speed Physical Layer Extension in the 2.4 GHz Band*"

IEEE 802.16 website. "*The IEEE 802.16 Working Group on Broadband Wireless Access Standard*". Retrieved March 2004 from http://grouper.ieee.org/groups/802/16/ and http://wirelessman.org/

IEEE. 2001. "*New IEEE WirelessHUMAN™ Project Developing Standards for Fixed Wireless Access in License-Exempt Bands*" Retrieved March 7th, 2004 from http://standards.ieee.org/announcements/wirelesshuman.html

IEEE. 2001b. "*The 802.16 WirelessMAN MAC: ™ It's Done, but What Is It? - creating the IEEE 802.16 WirelessMAN™ Standard for Wireless Metropolitan Area Networks*". Retrieved March 4th, 2004 from http://ieee802.org/16/docs/01/80216-01_58r1.pdf

IEEE. 2002. "*Overview and Guide to the IEEE 802 LMSC*" Retrieved March 4th, 2004 from www.ieee802.org/802%20overview.pdf

Ikeda, N. 2003. "*Spectrum Buyouts: A Mechanism to Open Spectrum*", revised December 2003, Retrieved February 2004 from http://www.rieti.go.jp/jp/publications/summary/02030001.html.

Intel. 2003. "Broadband Wireless Access for everyone", p.2, Retrieved March 2004 from http://www.intel.com/ebusiness/pdf/wireless/intel/80216_wimax.pdf, 2003

ITU DAI website, Digital Access Index webpage. Retrieved January 2004 from http://www.itu.int/ITU-D/ict/dai/

ITU Radio Regulations (RR) website "ITU overview, Radio Regulations Board" - Retrieved March 2004 from http://www.itu.int/aboutitu/overview/rrb.html

ITU Regulatory website. Country and regulatory profiles. Retrieved January 2004 from http://www.itu.int/ITU-D/treg/profiles/guide.asp?lang=en

ITU website. ITU global directory. Retrieved November 2003 from http://www.itu.int/cgi-bin/htsh/mm/scripts/mm.list?_search=ITUstates&_languageid=1

ITU. 2002. "*List of data for World Telecommunications Indicators Database*". Retrieved January 2004 from http://www.itu.int/ITU-D/ict/publications/world/material/series.pdf

ITU. 2003. "*Resolution 229 [COM5/16] WRC03*". Retrieved March 2003 from http://www.itu.int/ITU-R/study-groups/rsg8/rwp8a/seminars/new-tech/Documents/229.doc

ITU. 2003b. “*List of participants for the 4th Global Symposium for Regulators, 8-9 December 2003*”. Retrieved December 2003 from http://www.itu.int/ITU-D/treg/Events/Seminars/2003/GSR/Documents/Participants-Final.pdf

ITU-D website, retrieved March 2004 from http://www.itu.int/ITU-D/

Jardin, X. 2003. “*Beyond Wi-Fi*”. Wired. Retrieved March 2004 from http://www.wired.com/wired/archive/11.05/unwired/futurewifi.html

Jensen, R.; Zeckhauser, R. 2003. ‘*The Digital Provide: What Information Technology Can Do For the World’s Desperately Poor*’. Retrieved March 2004 from http://www.ksg.harvard.edu/cid/cidbiotech/events/jensen1.pdf

Jubin, J. and Tornow, J. 1987. "*The DARPA Packet Radio Network Protocol*" Proc. IEEE, vol. 75, Jan. 1987, pp. 21–32

Kerf, M.; Neto, I, Geradin, D. 2003 “*Anti-trust vs Sector Specific Tools in Telecom: The Impact on the Competitiveness of Liberalized Telecommunications Markets*”, Viewpoint Note, World Bank, Aug 03 - awaiting publication

Kineto website. Retrieved March 2004 from http://www.kinetowireless.com/products/index.html

Kowalenko, K. 2003 “*Wireless Standards' Popularity Warrants a New Regulatory Advisory Group*” The Institute

Kraemer, B. 2001. “*OFDM WLAN Standards & Regulatory Issues*”, Intersil, Retrieved March 2004 from www.ofdm-forum.com/ library/WLAN%20Standards%20and%20Regulatory%20Issues%20-%20Bruce%20Kraemer%20-%20Sec.pdf April 2001

Krag, T, Büettrich, S. 2004. “*Wireless Mesh Networking*”,Retrieved January 2004 from http://www.oreillynet.com/pub/a/wireless/2004/01/22/wirelessmesh.html

Krag, T. 2003. “*Wireless Networks as a Low-Cost, Decentralized Alternative for the Developing World*”. Retrieved February 2004 from informal & wire.less.dk

Ksys website. Retrieved 4th May 2004 from http://www.ksys.info/wlan_glossary.htm

Kwerel, E.; Williams, J. 2002. “*A proposal for a rapid transition to market allocation of spectrum*”, Published by the FCC, Retrieved November 2003 from http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228552A1.pdf

Lamb, R. 2003, US State Department, e-mail, December 2003

Leung, K.; Byoung-Jo K. 2004. “*Frequency Assignment for Multi-Cell IEEE 802.11 Wireless Networks*”,Retrieved March 2004 from http://www.research.att.com/areas/MobileNetworkResearch/Perf_Enhance_Tech/Radio_Resource_Management/KLeungJKimWLANChannelAssign.pdf, retrieved March 2004

Lippman, A.; Reed, D. 2003. "*Viral Communications*", Media Laboratory Research DRAFT paper. Retrieved March 2004 from http://web.media.mit.edu/~lip/Papers/Viral.pdf

Lynch, G. 2002. "*COMMENTARY: The FCC proposes a spectrum revolution*". America's Network Weekly, Retrieved April 2004 from http://www.americasnetwork.com/38781.html

Maddy, M. 2000. "*Dream Deferred: The story of a High-Tech Entrepreneur in a Low-Tech World*". Harvard Business Review, May-June 2000 May/Jun2000, Vol. 78 Issue 3, p56, 10p, 3c

Margie, P. .2003. "*Can You Hear Me Now? Getting Better Reception from the FCC's Spectrum Policy*". 2003 STAN. TECH. L. REV. 5, Retrieved April 2004 from http://stlr.stanford.edu/STLR/Articles/03_STLR_5 index.htm, retrieved May 2004

Meshnetworks website, Retrieved January 2004 form http://www.meshnetworks.com/

Milgrom, P. 1996. "*Procuring Universal Service: Putting Auction Theory to Work*", Lecture at the Royal Swedish Academy of Sciences, 9 December 1996.

Moore, J. 2002. "*Digital Entrepreneurship and Innovation: A Framework for Policy, Legal and Regulatory Action*", Prepared for the joint meeting of the United Nations ICT Task Force, G-8 Group of Nations DOT Force, and World Economic Forum Global Digital Divide Initiative, Retrieved March 2004 from http://cyber.law.harvard.edu/openeconomies/actionframework.htm

Moore, J. 2003. "*Digital Business Ecosystems in Developing Countries*". Retrieved February 2004 from http://cyber.law.harvard.edu/bold/devel03/modules/Moore.pdf

Motorola Canopy Website, Retrieved April 20th, 2004 from http://motorola.canopywireless.com and http://motorola.canopywireless.com/press/021604.php, retrieved May 2004

Negroponte, N. 2002 "*Being Wireless*". Wired. Retrieved April 2004 from http://www.wired.com/wired/archive/10.10/wireless.html

Nettesheim, C. and Manget J. 2002. "*Options on the Future: The Role of Business in Closing the Digital Divide*", published by Boston Consulting Group. Retrieved March 10th, 2004 from http://www.bcg.com/publications/files/Options_Future_Digital_Divide_Rpt_Jan02.pdf

Newlans 2003. "*802 Tutorial - Use of Millimeter Waves for Broadband WLANs*' Retrieved April 14th, 1004 from http://www.ieee802.org/802_tutorials/nov03/IEEE%20Presentation-mmwave.ppt

Noll, R. 1999. "*Telecommunications Reform in Developing Countries*", AEIBrookings Joint Center for Regulatory Studies, Working paper 99-10, Retrieved on October 2003 from www.aei.brookings.org/publications/working/working_99_10.pdf

Norris, P. 2001. "*Digital divide: civic engagement, information poverty, and the Internet worldwide*". Cambridge University Press, 2001. Chapter 1, Retrieved November 2003 from http://ksghome.harvard.edu/~.pnorris.shorenstein.ksg/book1.htm

Nunno, R. 2002. "*Review of Spectrum management practices*",. Published by the FCC. Retrieved March 2004 from http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-229047A1.pdf

NYTimes, 2000. "*Bill Gates Turns Skeptical on Digital Solution's Scope*", Retrieved January 2004 from http://www.nytimes.com/2000/11/03/technology/03GATE.html?ex=1074920400&en=99f99b531be9341a &ei=5070)

Olson, M. 1982. "*The Rise and Decline of Nations*", Chapter 2, "The logic", Yale University Press

Ostrom, E. 1990. "*Governing the commons: The evolution of institutions for collective action*". Cambridge University Press, 1990

Ostrom, E.; Dolsak, N. eds, 2003 "*The commons in the new millennium*", MIT Press.

Parker, J. 2002. "*The Lotus files: the emergence of technology entrepreneurship in China and India*", The Fletcher Forum of World Affairs, Summer/Fall 2002, pp.119-134, Retrieved April 2004 from http://changshagroup.com/resources/The%20Lotus%20Files%20Report%20Spring%202002.pdf

Pentland, A.; Fletcher, R. Hasson, A. 2002. "*A Road to Universal Broadband Connectivity*". Retrieved January 2004 from http://cba.media.mit.edu/publications/articles/02.00.pentland.pap.pdf

Pitroda, S. 1993."*Development, Democracy and the Village Telephone*". Harvard Business Review, November-December 1993 Nov/Dec93, Vol. 71 Issue 6, p66

Prahalad, C.K. and Hammond, A 2002. "*Serving the World's poor, profitably*". Harvard Business Review, September 2002, Vol. 80 Issue 9, p48

Prahalad, C.K. and Hammond, A. 2002b "*What Works: Serving The Poor, Profitably: A Private Sector Strategy for Global Digital Opportunity*", Published by the Markle Foundation & World Resources Institute. Retrieved December 2003 from http://pdf.wri.org/whatworks_serving_profitably.pdf. and http://www.si.umich.edu/ICOS/hammond.pdf

Pulver Innovations website, WiSIP phone specifications. Retrieved May 4th, 2004 from http://www.pulverinnovations.com/wisip.html,

Qadir, I. 2002. "*The bottleneck is at the top of the bottle*". The Fletcher Forum of World Affairs, Summer/Fall 2002, pp.69-89. Retrieved October 2003 from http://fletcher.tufts.edu/forum/Summer%202002/quadir.pdf

Qadir, I. 2003. "*Bottom Up economics: conversation with Iqbal Quadir*", Harvard Business Review, August 2003

Rappaport, T. 2002. "*Wireless Communications: Past Events and a Future Perspective*", IEEE Communications Magazine, May 2002.

Riordan, M. 2002. "*Universal Residential Telephone Service*". In Martin E. Cave, Sumit K. Majumdar and Ingo Vogelsang, eds., "*Handbook of Telecommunications Economics*", Volume 1: Structure, Regulation and Competition. North-Holland, 2002, pp. 424-473. retrieved October 2003 from http://www.columbia.edu/~mhr21/US-aug-29.pdf

Sawhney, H. 1994. "*Universal Service: Prosaic Motives and Great Ideals*". Journal of Broadcasting and Electronic Media 38 (4), pp. 375-95. Retrieved January 2004 from http://www.benton.org/publibrary/policy/uniserv/Conference/sawhney.html

Snider, J.H. 2003. "*The citizen's guide to the airwaves*" New America Foundation, Washington DC, 2003;

Snider, J.H.; Holmes, N. 2004 "*The cartoon guide to Federal Spectrum Policy*". New America Foundation

Tactical Technology Collective website, Retrieved March 2004 from http://www.tacticaltech.org/?q=node/view/22

Tannenbaum, A. "*Computer Networks*". Prentice Hall, Englewood Cliffs, NJ, 1988.

UltraWideBand (UWB) Working group website. Retrieved January 2004 from http://www.uwb.org/

UNDP. 2001. "*Information Communications Technology for Development*", Evaluation Office - No. 5 September 2001, Retrieved January 2004 from http://www.internetpolicy.net/practices/essentials5-web.pdf

UNINETT website– Retrieved May 2004 from http://www.uninett.no/wlan/radio.html

Unstrung. 2004. "*Net2Phone Plans WiFi VOIP*". Retrieved April 24th, 2004 from http://www.unstrung.com/document.asp?doc_id=51483

Viral Communications Program (VCP) website. Retrieved January 2004 from http://web.media.mit.edu/~lip/Viral_Entry.html

Vocera website. Retrieved April 15th, 2004 from http://www.vocera.com/products/products.shtm

Wellenius, B. 1997. "*Extending Telecommunications Service to Rural Areas --the Chilean Experience*", World Bank Viewpoint Note No. 105.

Weller, D. 1999. "*Auctions for universal service obligations*". Telecommunications Policy 23 (1999) 645-674 Pre-pub version retrieved January 2004 from http://faculty-gsb.stanford.edu/wilson/archive/E542/classfiles/gte_colr_auctions.pdf;

WiFi Alliance website, Retrieved April 13th, 2004 from http://www.wi-fi.org

WiFi phone website, Retrieved April 15th, 2004 from http://www.wifiphone.org/products.html

Wikipedia website, Retrieved May 4th, 2004 from http://en.wikipedia.org/wiki/Import_substitution

WiMAX Forum Website, Retrieved May 4th, 2004 from http://www.wimaxforum.org/home

Wireless Internet Institute (W2i), the UN ICT Task Force, and infoDev Program of the World Bank (eds.). 2003. "*The Wireless Internet Opportunity for Developing Countries*"

Wireless weblog. 2004. "*First Commercial WiFi Phone Service Set to Debut*", Retrieved April 15th, 2004 from http://wireless.weblogsinc.com/entry/4182211555576411/

World Bank. 1997. "*Options for Rural Telecommunications Development*", Rogati Kayani, Andrew Dymond, World Bank Technical Paper No. 359; IBDR/The World Bank, Washington DC

World Bank. 2002. "*Closing the Gap in Access to Rural Communications – Chile 1995 – 2002*", Bjorn Wellenius, World Bank Discussion Paper No. 430; IBDR/The World Bank, Washington DC. Retrieved January 2004 from http://www.infodev.org/library/working.htm

World Bank. 2002b. "*Telecommunication and Information Services for the Poor – Towards a strategy for Universal Access*". Juan Navas Sabater, Andrew Dymond, Niina Juntunen, World Bank Discussion Paper No. 432; IBDR/The World Bank, Washington DC

World Bank. 2002c. World Development Indicators 2002 Online. Retrieved January 2004 from http://www.worldbank.org/data/dataquery.html

World Telecommunication Development Conference (WTDC). 1998. "*WorldTel – A Global Telecommunication Development Partner*". ITU – Telecommunications Development Bureau, Valetta

World Telecommunication Development Conference (WTDC). 2002. "*The new missing link: The Digital Divide*". Retrieved December 2003 from http://www.itu.int/ITU-D/conferences/wtdc/2002/brochure/missing_link.html.

World Telecommunication Development Conference (WTDC). 2002b. "*Istanbul Declaration*". Retrieved December 2003 from http://www.itu.int/ITU-D/conferences/wtdc/2002/declaration.html

Youtie, J., Shapira, P. and Laudeman, G. 2002. "*Transitioning to a Knowledge Economy: The LaGrange Internet TV Initiative.*" Presented at the 30th Research Conference on Communication, Information and Internet Policy. Retrieved March 2004 from http://intel.si.umich.edu/tprc/papers/2002/100/LGIAI-TPRC-2002.pdf

Young, M. T-Mobile USA, Personal conversation, November 2003