Universidade de Aveiro Departamento de Eletrónica, Telecomunicações e Informática
2014

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Partilha de Infraestruturas de Telecomunicações em Moçambique

Telecommunications Infrastructure sharing in Mozambique

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia Eletrónica e de Telecomunicações, realizada sob a orientação científica do Professor Doutor Anibal Manuel de Oliveira Duarte, Professor Catedrático do Departamento de Eletrónica, Telecomunicações e Informática da Universidade de Aveiro.

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Palavras-chave

Operador Neutro, Partilha de Infraestruturas, Redes Móveis, Mercados Emergentes

Resumo

O mercado das telecomunicações móveis enfrenta desafios crescentes em todo o mundo, especialmente nos mercados emergentes do continente Africano. O aumento do investimento privado em diferentes sectores, associado à necessidade de fornecer respostas rápidas, sustentáveis e eficientes do ponto de vista económico-financeiro tornou-se premente não só para o desejado crescimento destes mercados, mas também para o seu continuado desenvolvimento.

O mercado das telecomunicações móveis em Moçambique, país sobre o qual nos focamos neste estudo, apresenta desafios específicos no que respeita à cobertura de comunicações móveis nas áreas mais remotas e rurais. Num dos países mais pobres do mundo, onde a rede móvel prevalece sobre a rede fixa, e sendo importante continuar a atrair investimento neste sector, não descurando as áreas menos atrativas do ponto de vista financeiro, importa estudar e explorar os diferentes modelos tecnológicos que podem ser implementados.

Esta dissertação identifica os principais constrangimentos que levam ao reduzido investimento na cobertura móvel nas áreas menos apetecíveis para investidores em Moçambique, estudando a aplicabilidade e sustentabilidade do conceito de Operador Neutro associado à partilha de infraestruturas como uma das soluções a adotar.

Pretende-se que este trabalho contribua para o desenvolvimento da área das telecomunicações móveis neste mercado emergente e que esta proposta possa ser aperfeiçoada de modo a contribuir para outros objetivos de crescimento e desenvolvimento de Moçambique.

Keywords

Neutral Operator, Infrastructure Sharing, Mobile Networks, Emerging Markets

Abstract

The mobile telecommunications market faces growing challenges throughout the world, especially in the emerging markets on the African continent. The increase of private investment in different areas combined with the need to provide swift, sustainable and efficient answers from an economic and financial perspective has become urgent not only for the desired growth of these markets, but also for their continued development.

The market of mobile telecommunications in Mozambique, the country chosen for our study, presents specific challenges in the network coverage in remote and rural areas. In one of the poorest countries in the world, where mobile communications prevail over fixed-network connections, and considering the importance of continuing to attract investment in this sector, without neglecting the least attractive regions from a financial perspective, it is important to study and explore the different technological models which can be implemented.

This dissertation identifies the main investment constraints behind the reduced mobile coverage in the least attractive regions in Mozambique and studies the applicability and sustainability of implementing the concept of Neutral Operator associated with infrastructure sharing as one of the solutions to be adopted.

It is our purpose that this study may contribute to the development of the mobile telecommunications market in this emerging market and that the Neutral Operator Model may be adapted and improved as needed in order to meet other growth and development objectives for Mozambique.

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List of Abbreviations

2G	Second Generation of Mobile Telecommunications Technology
3G	Third Generation of Mobile Telecommunications Technology
4G	Fourth Generation of Mobile Telecommunications Technology
ATM	Asynchronous Transfer Mode
Avg	Average
BSC	Base Station Controller
BSS	Business Support System or Base Station System
BTS	Base Transceiver Station
CAPEX	Capital expenditure
CN	Core Network
CP	Costumer Premises
DCS	Digital Cellular System
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HLR	Home Location Register
IPTV	Internet Protocol for TeleVision
IS	Infrastructure Sharing
ITU	International Telecommunication Union
IWF	Interworking Function
ME	Mobile Equipment
MNO	Mobile Network Operator
MS	Mobile Station
MSC	Mobile services Switching Centre
MVNO	Mobile Virtual Network Operator
NO	Neutral Operator
NOM	Neutral Operator Model
NSS	Network Switching System
OMS	Operations and Maintenance System
OPEX	Operational Expenditure
PLMN	Public Land Mobile Network
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RAN	Radio Access Network
RF	Radio Frequency
RNC	Radio Network Controller
ROI	Return On Investment

R&D	Research & Development
SIM	Subscriber Identity Module
SMS	Short Message Service
TRAU	Transcoding Rate and Adaptation Unit
TRX	Transceiver
VLR	Visitor Location Register
WSIS	World Summit on the Information Society
WLAN	Wireless Local Area Network

List of Symbols

B	Interface between an MSC and a VLR
C	Interface between an HLR and an MSC
D	Interface between an HLR and a VLR
E	Interface between an MSC and an MSC, or between an MSC and an MGW
F	Interface between an MSC and an EIR
Gr	Interface between an SGSN and an HLR
Gs	Interface between an SGSN and an MSC
Gx	Interface between an S-GW and an UTRAN
Iu-CS	Interface between an RNC and an MGW
Iu-PS	Interface between an RNC and an SGSN
Iub	Interface between an RNC and a NodeB
Iur	Interface between RNCs
km	Kilometre
LTE-Uu	Interface between an eNodeB and an MS
m	Meters
min	Minutes
s	Seconds
Um	Interface between a BTS and an MS
Uu	Interface between a NodeB and an MS

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1. Introduction

This study addresses the current challenges in the telecommunications sector in Mozambique and, more specifically, the lack of telecom coverage in remote and rural areas of the country, the constraints which have made the expansion of services for operators a financial risk and the possible solutions research and development in the telecom sector can provide.

The motivation behind our study lies in combining the needs and lacks in the telecom sector in an emerging market such as Mozambique with the social dimension which any investment project needs to cater for in such economies.

Telecommunications have developed at a speed which would have seemed impossible not very long ago, bringing about a number of possibilities that can creatively be adapted to the specificities of different markets and economies, where a number of factors other than the financial one need to be considered.

In this study we explore the potential of Infrastructure Sharing as a possible solution for the Mozambican mobile telecommunications market, along with the relatively recent concept of Neutral Operator (NO). Our choices are based not only on the technological and financial dimensions, but also on the social and cultural variables which result from our direct observation of common problems in mobile telecommunication coverage in remote and rural areas in African emerging markets throughout the years of 2006 to 2013. Cost effectiveness will therefore be combined with the social variable, but always safeguarding the quality of the services provided and their ability to grow and accommodate future technological development in the sector. While specifically addressing the issue of improving territorial and demographic mobile telecommunication coverage, this study also attempted to design a solution which can accommodate general growth and development goals defined by the Mozambican government and by the World Summit on the Information Society (WSIS).

Our knowledge of the reality of the country, the sustainability of the model, the reduced or null investment from a commercial operator perspective and of other variables which will be discussed in detail in the following sections of this dissertation encourages us to believe that Mozambique meets the necessary requirements to successfully start implementing and exploring the model we will present.

For methodological purposes, our findings have been divided into five sections:

1) *Introduction* – where a general overview of the Mozambican reality with regards to demography, the current status of the mobile telecommunications activity and, finally, the legal framework which regulates the market is given;

2) *Infrastructure sharing* – where different possibilities of sharing are listed and described;

3) *Business Models* – section dedicated to the definition and discussion of the different business models;

4) *Case study* – this section focuses on the type of infrastructure sharing considered more appropriate for the Mozambican market and the manner in which such a sharing solution can be made operational by a state and/or private entity and, finally

5) *Conclusions and Final Considerations*.

1.1. Framework

A brief description of Mozambique today is required in order to contextualize our work and the proposals which will be made throughout the following sections.

1.1.1 An overview of Mozambique

Mozambique, together with other Portuguese speaking countries, has always remained under the attention of different business sectors in Portugal due to different historical ties. In the light of the current financial and economic situation in Portugal (and in Europe), Mozambique has gained a significant importance in the exporting of goods and services, while also becoming a market of interest for foreign investment. This country has witnessed a very significant immigration over the more recent years and investment has increased, especially after the findings and potential commercial exploration of natural resources such as gas, petrol and coal. The country is considered to be one of the better performing economies in Sub-Saharan Africa due to its post-conflict transition and its efforts to maintain political and economic stability after the 16 year civil war which ended in 1992.

Agriculture is the sector which employs over 80% of the population, although the country's main industries are: aluminium, natural gas, shrimp, cashew nut, wood and electricity (Mozambique has the ability to produce over 16,000 megawatts), exporting essentially to South Africa, Zimbabwe and Malawi. The extraction of natural gas and other mineral resources have been strong factors of attraction for foreign investment, which in turn has motivated the development of basic infrastructures (roads, bridges, telecommunications, and water supply) through the joint efforts of the government and private sector, slowly allowing once inaccessible areas to become closer to the rest of the country.

These facts have put Mozambique on the list of interesting emerging markets with an estimated growth of 7.1% in 2010 and an expected 13.3% in 2014. Growth is happening; however, 69% of the population continues to live below the poverty line, keeping the country among the twenty poorest in the world. Development is therefore not happening alongside growth. Development is therefore one of the points taken into consideration within the scope of this study.

For the purpose of our work, it is important to be aware of the geography and demography of Mozambique, as both factors play an important role in the implementation of any telecom project.

The map below illustrates the extension of Mozambique and the different neighbouring border countries which might, in the long term, come to benefit from the solutions Mozambique needs to develop in order to pursue its path of growth and development.

Figure 1 – Map of Mozambique

Mozambique has a coast line of 2.300 km and approximately 801 537 km^2 and is the 34th biggest country in the world with roughly 20 million inhabitants [1], distributed throughout 10 provinces, as illustrated in Table 1. More recent numbers point to a population of approximately 24 million, although official registers are dated from 2007. We would not consider the increase of 4 million people surprising in the light of the growth in private investment in the country, with special reference to the northern regions of Tete and Nampula.

Province	Population
Niassa	1.055.482
Cabo Delgado	1.683.681
Nampula	3.861.347
Zambézia	3.880.184
Tete	1.593.258
Manica	1.400.415
Sofala	1.715.557
Inhambane	1.444.282
Gaza	1.362.174
Maputo	2.370.415
	20.366.795

Table 1 – Distribution of the Mozambican population per Province (official numbers from 2007)

This brief demographic explanation is relevant to the purpose of our study as we shall see in further sections, because it provides a clearer view of the importance of continuing to develop basic infrastructures in Mozambique not only because of financial motivations, but also because of the social dimension which also needs to be addressed.

In the specific case of the telecommunications market, the demands are growing significantly. And the demand is not just on innovative services; there is a need to cater for the populations and communities in the more remote and rural areas. The lack of coverage in these more discriminated areas can reach areas of up to 150km or more in some cases, compromising the much desired universal access defined by the Mozambican government.

In subsection 1.1.2, an overview of the current telecommunications scenario in Mozambique is given.

1.1.2 The status of mobile telecommunications in Mozambique

Mozambique currently has three mobile operators which started their operations as early as 1997, growing in 2003 and 2011. One of the operators is a branch of the state held telecom company which provides fixed-line telecommunication throughout the country. These three operators have approached the market in very different manners, generating a level of competition which is reflected in tariffs and coverage.

According to the *Instituto Nacional das Comunicações de Moçambique* (INCM), in the end of 2013 there were 4.150 Base Stations (commonly known as sites) in the country, with the most relevant growth being registered as of 2010, although the third operator only started market penetration in

2012. The appearance of the third operator brought a new level of competitiveness to the mobile telecom market, having built 2000 sites between 2010 and 2013, contrasting significantly with the 2150 built by the two incumbent operators between 1997 and 2013 (see Table 2).

Operator	No. of Base Stations
A	1200
B	950
C	2000
	4150

Table 2 – Distribution of sites per operator in the end of 2013

The intense competition over the last four years clearly illustrates the added value Mozambicans ascribe to mobile telecommunication services. As stated by Audience Scapes – The Intermedia Knowledge Center "(…) Mozambique already has comparable if not lower costs for mobile services than many of its southern African neighbours. The lowering of mobile use costs has largely been the result of heavy competition between the country's two service providers (…)" [3], with the additional pressure brought about by the third operator.

According to the ITU World Telecommunication/ICT Indicators Database, in 2007 there were approximately 25 users per 100 inhabitants. Prepaid and credit sharing services, bonuses and free minutes make mobile telecom services a highly valued commodity among Mozambicans, which has led to the appearance of several foreign companies willing to invest in the sector. However, with the need to provide services in regions further north of the country's capital where the return on investment is highly questioned, potential new operators are easily discouraged, as pointed out by Meddour, D. et al:

*This [*high level of investment vs high costs to recover investment*] often makes mobile services less affordable and may discourage operators to innovate and migrate to new technologies in emerging markets. It may also cause licensed mobile network operators (MNO) to obstruct the entry of new operators in the market and additionally, it may be too costly for new entrant operators to rollout mobile networks in rural and less populated areas, resulting in exclusion of a part of the population or certain regions from access to mobile telecommunication services.*

Today, not only has the number of users grown together with the demand for different services, but the non-profitable distances which need to be covered in between the bigger population agglomerations in order to grant all citizens with access to telecommunication services has become pressing.

These new challenges combined with the changes which need to take place to improve coverage are a fertile ground for cost efficient and highly competitive solutions. In our work we will focus on the potential of infrastructure sharing (which will be discussed in greater detail in Section 2) because despite the rapid deployment of sites by the three operators, it is not sufficient to focus exclusively on the improvement of coverage as the high costs involved will soon jeopardize the sustainability of the operations, compromising the quality of the services the legal framework for the sector defends and aims at safeguarding.

Operators have therefore come to a stage where they need to find answers and the government itself needs to pursue the commitment to make telecommunications accessible to the entire population.

The main issues for these entities can therefore be summed up as follows:

1. The uneven distribution of sites per user/area – This particular situation is visible to the naked eye when travelling along the N1 from North to South in Mozambique. There are significant extensions of road where three sites can be seen, side by side, while in over a distance of 150 km, not one site exists.
2. The lack of coverage in “shadow zones” usually perceived as less profitable areas by operators leaves a vast part of the population without access to telecommunication services – a consequence of a very low Return on Investment (ROI) per operator.
3. The possibility of reducing infrastructure expansion costs while safeguarding profitability for operators.

Another important aspect when addressing possible solutions is

4. The applicability of solutions such as infrastructure sharing within the legal framework and regulations for the telecom sector in Mozambique.

Point 4 is particularly relevant to this study because any cost and time efficient solution presupposes the compliance with the existing regulation and supervision of a market in which competitiveness has to be guaranteed, while leaving room for continued improvement over time. This leads us to address the issue of regulation in the Mozambican telecom sector in Section 1.1.3.

1.1.3 Regulation of the Mozambican Telecommunications Market

Innovation and development lead to new dynamics and new ways of providing existing services and/or implementing new services. Therefore, our study would appear incomplete if we did not touch on the topic of regulations, regulating agencies, policies, regulatory requirements among other legal guidelines. Without appropriate regulations, the adoption of new solutions can be compromised.

In the case of telecommunications, rigorous regulation has been developed and implemented in different parts of the world, in this way assisting in the increase of competition among operators and creating frameworks that encourage the adoption of sharing solutions, promotes the adoption and development of new technologies and, consequently, works towards the reduction of infrastructure expansion costs. Regulatory guidelines are therefore crucial aspect to the telecommunications activity in any country, playing a vital role in the way in which the business grows, how private investment is attracted and also on the possibility of implementing and sustaining solutions such as the Neutral Operator Model proposed in this study.

The discussion around the need to make telecommunication regulations and policies more muscular, efficient and innovation friendly is not new with regard to the African market. Several African and international entities have strived to open up this discussion in order to create awareness of the importance of having the appropriate legal framework in place, but also the necessary entities to certify that operators and other parties comply with the law. Mozambique is not an exception. With a clear understanding of the role of telecommunications in an economy, legal requirements have been developed in order to support the development of this sector.

The Mozambican telecommunications market is regulated by decree-law 8/2004, dated July 21 which defines the guidelines for the public and private telecommunications sector. This decree-law outlines the requirements for private investment, encourages technological innovation and improvement of the quality of telecommunication services provided, and highlights the importance of guaranteeing coverage of these services across the country, without comprising the quality of the services provided. Clauses 35, 44 and 45 define the benefits of general infrastructure sharing in from the perspective of cost reduction and coverage. Passive infrastructure sharing is dealt with in greater detail in decree-law 62/2010, dated December 27. This decree-law also defines the roles and responsibilities of the National Institute for Communications in Mozambique (*Instituto Nacional das Comunicações de Moçambique* – INCM), the current Regulatory Agent for Telecommunications in Mozambique. Decree-law 8/2004 is the result of part of the INCM's endeavours to consolidate the regulation of a growingly competitive telecom market.

Both decree-laws highlight the following goals when dealing with infrastructure sharing in general and passive infrastructure in particular:

- reduce the duplication of investments in passive telecommunication infrastructures and other network resources;
- protect areas where the implementation of passive infrastructures and other network resources generate environmental and public concerns;

- the benefits for the users in terms of costs, quality and availability of the services provided.

From the perspective of this study, the fact that the existing legislation already contemplates infrastructure sharing is highly positive together with the existence of a Regulatory Authority such as the INCM.

The INCM, created by decree-law 22/92, dated September 10, is a state dependent entity supervised by the Ministry of Transports and Communication with administrative, financial and patrimonial autonomy. In 2001, the INCM was appointed Regulatory Authority responsible for the supervision of the Postal and Telecommunication services in Mozambique and also as the entity which assists the government in the designing of policies and regulations for the postal and telecommunications sectors in addition to regulating, supervising and representing these sectors.

In the case of the technical specifications for telecommunications, the INCM is responsible for:

- Planning, controlling and managing the radio spectrum and orbital positions;
- Standardizing, approving and homologation of telecommunication materials and equipments and defining the conditions for their connection to the network, according to the legislation in force;
- Design and manage the numbering and distribution of operators in an objective, transparent and non-discriminatory manner;
- Coordinate the use of the radio-electric frequency at a regional and international level.

The INCM has a number of other functions, but those abovementioned indicate the essential role that this entity will have in the implementation of a Neutral Operator Model (NOM) solution in Mozambique.

The hierarchical nature of the relationship between governments and regulatory agencies is one of the aspects that the African Economic Outlook (AEO) focuses on when referring to the importance of developing more muscled telecom regulatory agencies in general, and in Africa in particular. Accountable regulatory agencies are essential to attract private investment to the telecommunications market which has registered a significant growth in the continent over the last few years: “While private investment [in telecommunications] in Africa has progressively risen from USD 5.4 billion in 2000 to USD 13.5 billion in 2007, some experts say this could have been higher with more appropriate regulatory frameworks.” [4]

We hope that this study, will be an added-value in the designing of solutions for some of the telecom challenges identified and to the further discussion of the proven advantages of the Neutral Operator Model.

1.2 Purpose

The purpose of this work is to study the constraints of the current mobile telecommunications market in Mozambique with regard to the coverage of remote and rural areas and discuss some preliminary views and possibilities of implementing a sustainable model in the country.

The motivation behind the discussion of Infrastructure Sharing and of a Neutral Operator for the Mozambican mobile telecom sector is based on the following assumptions and ideas:

a) Infrastructure sharing and a neutral operator could contribute towards the improvement of territorial and demographic (mobile) telecommunications coverage;
b) the neutral operator would be either a state entity or a private entity operating under a concession contract with the state (incumbent);
c) the design approach to this neutral operator explores, among other possibilities, the option of resorting to a form of infrastructure sharing which can be further optimized in the future, providing a solution which is sustainable over time.

As discussed in detail in the sections that follow, the concepts of infrastructure sharing and the role of a Neutral Operator gain a different dimension in a growingly competitive sector. High expectations have been created about the technological solutions made available by different entities and emerging markets are in need of cost efficient and sustainable solutions that contribute to making these economies attractive to private investors and which are aligned with the growth and development strategies and policies for each country.

2. Infrastructure Sharing

The concept of infrastructure sharing has already been discussed in the previous section, however here we will go into greater detail in order to make the choices in our case study (Cf. Section 4) clearer.

Infrastructure sharing has become the common cost effective solution for many countries to stay onboard the intense technological development in the area of telecommunications throughout the most recent years. It has also allowed operators to expand and broaden their scope of performance by offering new services to users with greater quality. Different forms of sharing can be developed for different purposes which illustrates the flexibility and dynamics which characterize the way in which telecommunication R&D is evolving and also the trends in communication needs throughout the world.

The potential behind infrastructure sharing is tremendous which is why different forms of sharing will possibly develop in the near future in order to cater for specific problems of specific markets. Meddedour, D. et al also draw our attention to the growing complexity which will naturally characterize network sharing development:

Network sharing can be characterized into four main dimensions, firstly based on the business model, which describes the parties involved and the contractual relationship between the parties; the geographic model, describing each operator's physical footprint; the technology model, describing the technical approach used for sharing (…); and the process model determining the services to be shared. Thus, the technological approaches chosen for infrastructure sharing is strongly linked to the business model, the geographic consideration and the process model, and the choice of a certain approach will limit the degree of freedom for reasonable choices of the other dimensions.[3]

By consolidating sharing practices, the concept of NO gains greater sustainability in its role as a facilitator and becomes more capable of accommodating the different requirements in each remote or rural area where mobile communication coverage needs to be improved.

These four abovementioned dimensions – business model, geographic model, technology model and process model – clearly demonstrate that sharing is a complex process which requires adequate regulatory guidelines and a legal context which allows for good practices.

Infrastructure sharing and the implementation of an NO are not exempt of challenges and require significant coordination and cooperation between the parties involved, especially with the growing levels of complexity in telecom solutions. Operators and other entities will need to develop the necessary mechanisms to overcome the constraints they may feel at the levels of deployment and operation of networks which might impact on the competitive side of the business. In our case study, we identify some of the technical issues which might pose a problem to operators according to the different levels of sharing chosen to cover the more isolated and remote areas of the country. We are however motivated to believe that despite these constraints, the benefits surpass the disadvantages and will allow for a significant impact on the development of mobile services in Mozambique.

The following Figures show the basic elements for the construction of a mobile telecommunications site. The constituents are typically as follows:

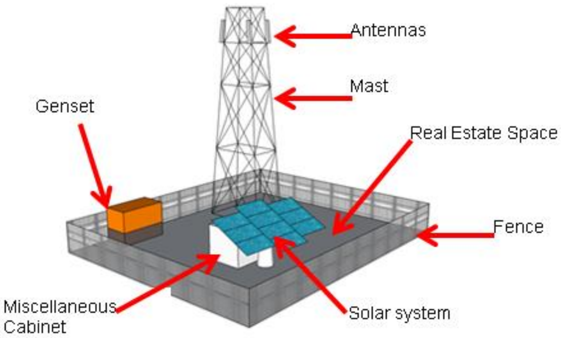

Figure 2 – Site Constitution (Source : author)

As we will see throughout this section, these are the typical physical resources which can be shared within the context of a Technology Model as exemplified in Figure 3.

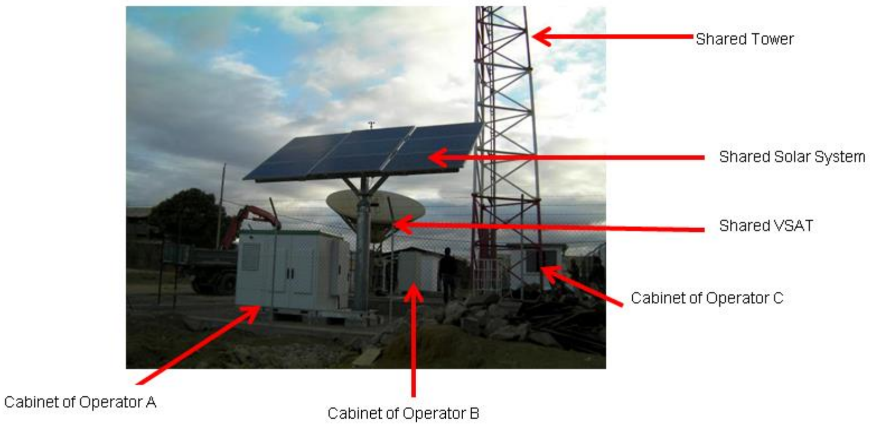

Figure 3 – Shared Site (Source: author)

In terms of a technology model we can resort to different types of sharing:

a) Passive Sharing
b) Active Sharing

2.1 Passive Sharing

Passive sharing refers to the sharing of space in passive infrastructure, such as building premises, sites and masts. Passive sharing is typically a moderate form of network sharing, where there are still separate networks that simply share physical space.

2.1.1 Site Sharing

Site Sharing consists of one single area (tower, fence, halls, etc) that is used by different operators. In such cases, operators share the same physical space but install their own masts, antennas and cabinets.

In the case of site sharing, operators reach an agreement for the sharing of the infrastructure available (e.g. site area, buildings, towers and masts) which allows them to provide their services in highly populated areas which usually have severe limitations on space availability. This solution is also appropriate for situations in which operators need to work underground and in remote areas with high operational costs (transmission and power).

This is the most common form of sharing, despite the possible trust issues which might arise between incumbents operators and new players on the market. Some operators resist to site sharing allegedly because they do not want to lose the flexibility of their network. Loss of network flexibility in this context means that operators are forced to request authorization to the other operators, for example, to physically intervene on their equipment or to access the site within a sharing environment.

This is where regulatory enforcement must exist in order to safeguard the rights of each operator and also the quality of the services provided to users.

In the figure below, the solid line around the equipment and masts represents the fenced-off compound that the operators will either own or lease. Within this compound, each operator usually installs their own infrastructure separately from that of other operators. However, they may decide to share support equipment, including shelters, power supply and air conditioning.

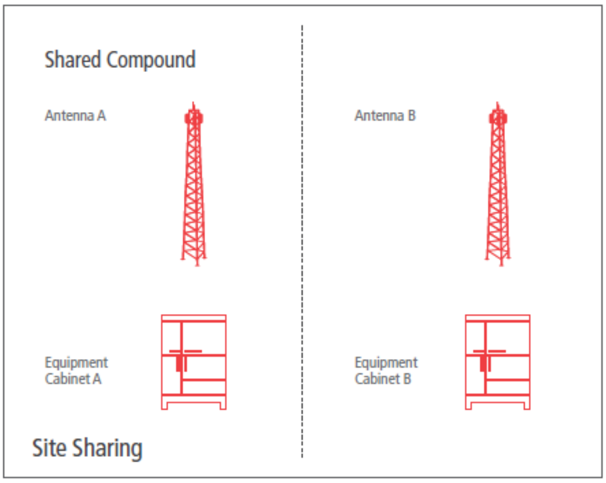

Figure 4 – Site Sharing (Source:[6])

2.1.2 Mast Sharing

Mast Sharing consists in using the same pole to install a certain number of antennas which belong to different operators. This is a common practice for Roof Top Solutions which traditionally accommodate a significant number of antennas belonging to different operators, in this way providing a more aesthetic and environmentally friendly solution.

Mast or tower sharing is a step up from operators simply co-locating their sites and involves sharing the same mast, antenna frame or rooftop. Below, in Figure 5, we can see an example of mast sharing in the Mafalala neighbourhood in Maputo where the solution certainly contributes towards a more pleasant visual environment.

Figure 5 – Roof Top Solution (Mafalala neighborhood) (Source: author)

Figure 6 below shows a single fenced-off compound where operators can install their own infrastructure, ranging from antennas to base transceiver station (BTS) cabinets. Despite the installation of single-owned equipment, this equipment shares a common infrastructure such as a physical mast or similar structure which may need to be adapted and reinforced to support the additional equipment.

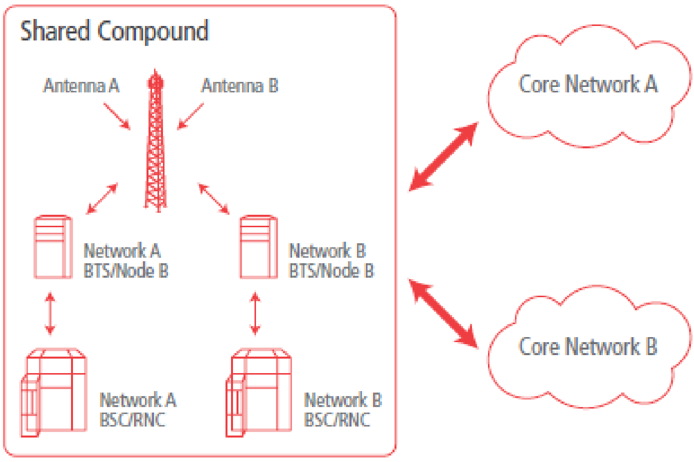

Figure 6 – Mast Sharing (Source:[6])

This solution encourages sharing and cooperation, while guaranteeing that each operator service remains separate from other that of other service providers.

2.2 Active Sharing

Active Sharing is a more intensive type of sharing, where operators share elements of the active layer of a mobile network, such as antennas, radio nodes, node controllers, backhaul and backbone transmission, as well as elements of the core network.

2.2.1 Core Network Sharing

Core Network Sharing is another option within the area of infrastructure sharing. Core Network Sharing is understood within the scope of this work as the sharing of fibre.

Figure 7 – Installation of buried fibre infrastructure (Source:[9])

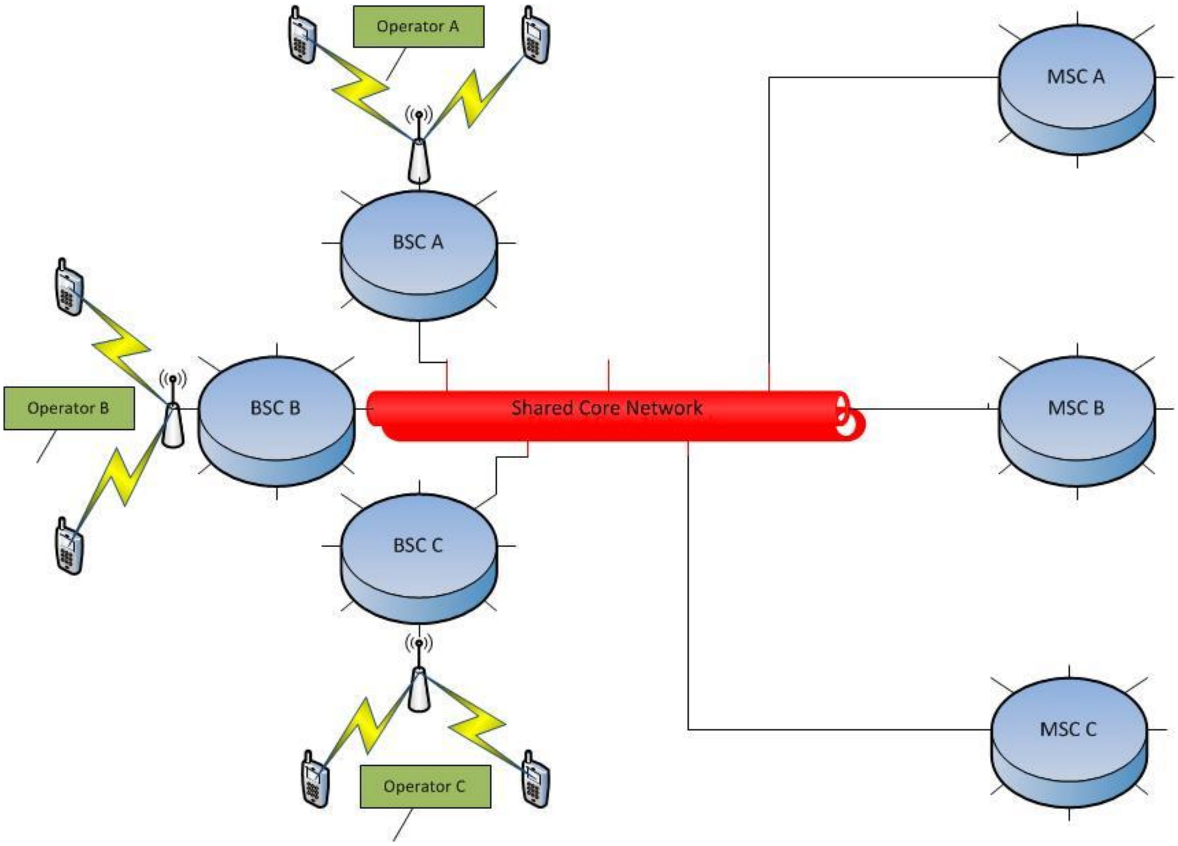

Figure 8 – Core Network Sharing (Source: author)

In the cases when an operator has spare capacity on its core network, sharing the infrastructure with another operator is an option that can be particularly interesting to new operators seeking to enter the market and who do not intend to build their own core network or have other sorts of limitations. The most common form of sharing this type of infrastructure without generating issues among competitors is through dark fibre agreements in which the operator shares the spare fibre in its network.

Usually, the new operator has its own access network, but when there is a need to connect two clusters and the distance is considerable, sharing fibre with an existing operator is a very attractive, time and cost effective solution.

2.2.2 RAN Sharing

RAN Sharing consists in share the equipment itself. Sharing RAN equipment is common when there are space constraints for the installation of telecom solutions or when the percentage of traffic does not justify the investment in one piece of equipment per operator. This is frequent in shopping centres and similar locations.

RAN sharing is the most comprehensive form of access network sharing as it involves the sharing of all access network equipment, including the antenna, mast and backhaul equipment. Each of the RAN access networks is incorporated into a single network, which is then split into separate networks at the point of connection to the core.

The figure below illustrates how RAN sharing might work between two partner networks. In such situations, both operators share all the access network elements up to the point where they connect with the core network. At this point of connection, each operator divides its user traffic on its own core network ring to be processed by its own core network elements and infrastructure. The way in which each party operates this process will depend on the location where the sharing takes place.

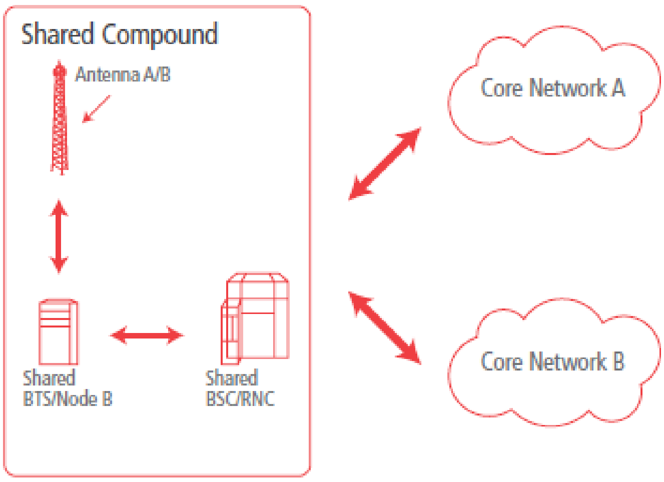

Figure 9 – RAN Sharing (Source:[6])

By briefly presenting the different and most common forms of sharing, we hope to have contributed to a clearer understanding of the different options an operator can resort to in order to overcome coverage problems in remote areas.

Each form of sharing unveils potential problems which call for regulatory agents capable of guaranteeing that the more beneficial aspects of sharing are guaranteed. Time has shown that operators, states and users have much to gain with the development of similar solutions but we are aware that each of the potential problems gains a different dimension according to the country solutions are implemented in, existing legal and regulatory guidelines and the willingness to adopt models that contribute towards the growth and development of the telecom market.

3. Business Models

There are several possible Business Models which can be applied to the telecommunications market in order to answer specific demands. The model chosen for each situation should take into account the characteristics of the country, economy, political and social context, and also the population's willingness and ability to purchase the services to be provided. In this chapter, we choose to discuss two possible business models which could be applied to the Mozambican context.

3.1 Mobile Virtual Network Operator (MVNO)

The concept of Mobile Virtual Network Operator (MVNO) is, like its name suggests, a virtual entity that provides public mobile telecommunications services without being the owner of the mobile frequencies or access network. The MVNO operates by selling minutes previously purchased from an infrastructure owner (for example, a mobile network operator).
MVNOs can resort to different forms of operating their business, but they do require an extensive rolled out mobile network which, in the case of Mozambique, could be a problem precisely because we are searching for a cost efficient solution to cover extensive remote and rural regions. However, the interesting part of this model is that it can be the motivation behind a Neutral Operator Model (NOM) which can greatly benefit from the perspective of providing services to MVNOs who need to expand services in order to continue to be active and competitive agents on the market.

Despite the possibly slower consolidation of this reality because the country has its own specific requirements and characteristics, presenting a new and more cost efficient solution for operators to expand into what were previously high risk areas will certainly boost competition in a positive manner.

MVNOs can also play an active part in solving technological/infrastructure limitations such as lack of capacity on networks, lack of financial resistance to high risk investments, bringing more services and more affordable tariffs to the Mozambican market, a market which recognises the added-value of mobile telephone services.

Our intention in presenting the MVNO model is its interest as a complement to the Neutral Operator Model discussed next.

3.2 Neutral Operator

The concept of Neutral Operator (NO) is still a relatively recent notion which appeared around 2000 when the idea of Infrastructure Sharing started to become a more consolidated reality. Although infrastructure sharing has become a common reality for the solution of a number of the growing challenges in the telecommunications market, the concept of NO has taken a little longer to be implemented, especially in the context of the emerging markets because it needs to take into account more than just the technological and/or practical side of the solution. An NO becomes an active agent in the economies where it is implemented.

Considering the complexity of the concept of NO, this section will be dedicated to its definition and discussion.

Infrastructure sharing, a very important dimension of the Neutral Operator Model, has been successfully implemented in a number of countries, with special reference to emerging markets such as India and Africa. In order to gain a clearer understanding of this concept, Neutral Operator should be understood in the context of this work as an operator which supplies services (traffic transport/capacity/network) for other Telecommunication commercial operators. Additionally, and as defined by Infante, J et al (s.d.) [5]:

The Neutral Operator basically allows to share investments, promoting competition in the different business sectors such as services (access to Internet, to audiovisual contents, to corporative intranets, etc. offered by the service providers) and access networks (collect and transport user traffic from different coverage areas to the points of presence of the Neutral Operator).

Apparently simplistic in its definition, the concept of the Neutral Operator Model goes hand in hand with the concept of infrastructure sharing because this new active agent occupies a mediating position within the telecommunications sector by generating a new dynamics between the government, operators, investors and the users. The Neutral Operator Model can also become the engine and opportunity for new services to be developed, for improved quality of services and for better investment opportunities.

The neutral operator model is based upon a separation of network infrastructure and service provision. It envisions the deployment of a new form of network operator, the Neutral Operator, which acts as a coordinator between the lastmile access providers and the service providers. Furthermore, it is the Neutral Operator who manages the network infrastructure, either deployed by itself or rented to some infrastructure provider.[5]

The NO therefore becomes more than a technological solution for telecommunication problems; this entity is actively engaged in developing a sustainable and profitable form of overcoming the mobile telecommunications constraints which we focus on in this study: the improvement of the territorial and demographic mobile telecommunications coverage in remote and rural areas.

By presenting other operators with the possibility of sharing infrastructures according to the many options available (cf. Section 2 – Infrastructure Sharing) the NO is capable of accommodating different solutions, for different requirements in a significantly more competitive manner. The following Figures 10, 11 and 12 illustrate the basic architecture of an NO and invite us to hypothesize about the different possibilities of infrastructure sharing according to different situations we might encounter in Mozambique.

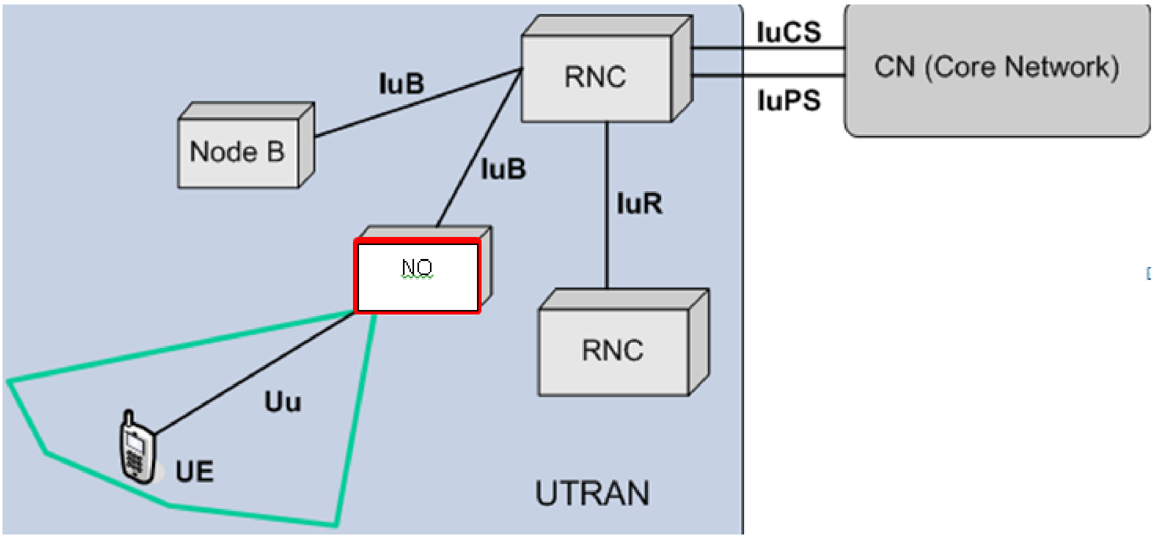

Figure 10 – Basic architecture of an NO (Source:[5])

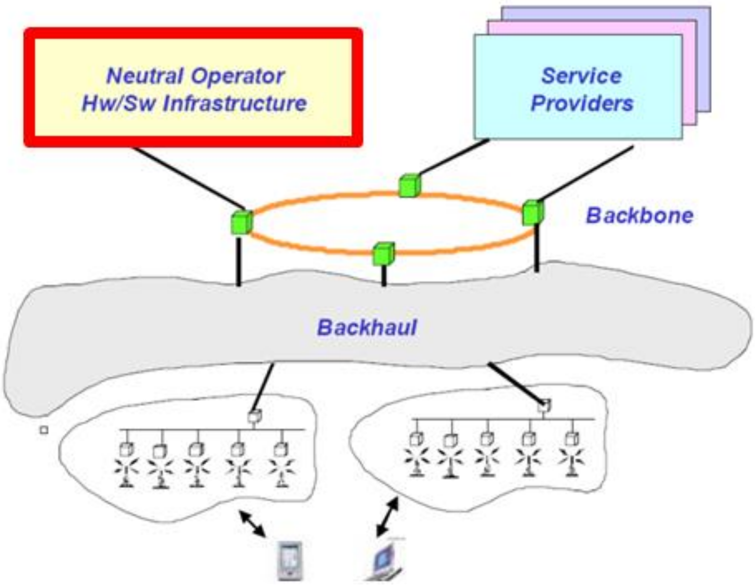

Figure11 – Basic architecture of an NO (Source:[5])

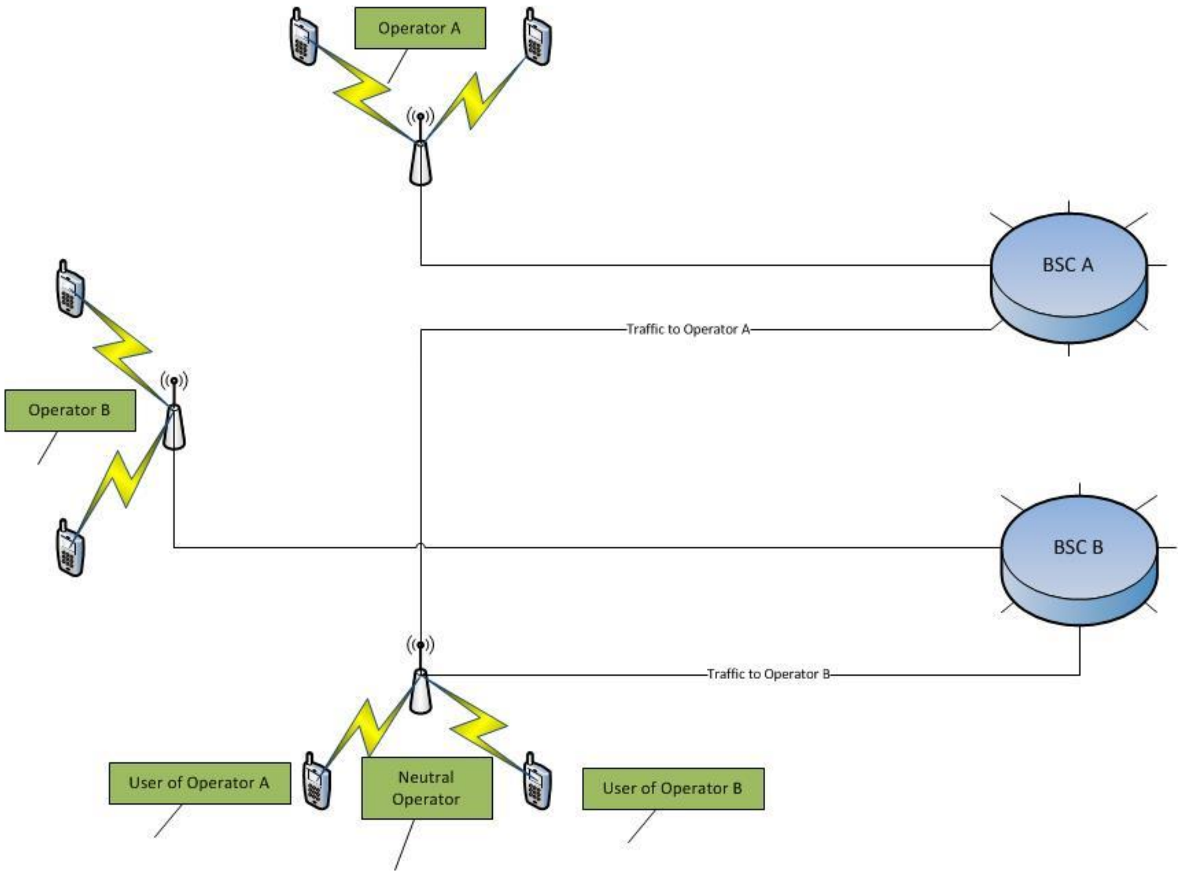

Figure 12 – Basic architecture of an NO (Source: author)

The NO typically invests in the infrastructure, namely building the base station in more remote areas where other operators are usually unwilling to invest and charges operators with traffic, transport and capacity, as illustrated in Figures 10, 11 and 12. These figures also exemplify the neutral presence that the NO aims at upholding because although it presupposes a business model, an NO does not compete with the operators; instead, it creates the necessary conditions for those operators to penetrate an area until then perceived as less attractive from an investment perspective. In this case, the initially unappealing area becomes an opportunity for the incumbents and new operators to continue to provide services, without the nearly prohibitive investment usually required to cover such territorial extensions and the depressed Return on Investment (ROI).

In order to cater for the needs of its potentially different clients, the NO can explore different forms of sharing that may vary from physical resources to transmission links and even to the sharing of areas of coverage. The NO may also need to meet a set of requirements defined by Regulatory Agents who can require specific bandwidth capacity; sharing agreements might have to be previously defined along with other provisions. The role of facilitator brings a more complex dimension to the concept of NO because its implementation and operation needs to safeguard a non-discriminatory approach to the development of sharing protocols and services, while complying with legal requirements and regulations in order to fulfil the role it was designed for.
In Section 2, we've dealed with the concept of infrastructure sharing in detail, but in the meantime it is worth considering the four model proposal that Meddour, D. et al present and which the NO will need to explore along with other variables when being designed:

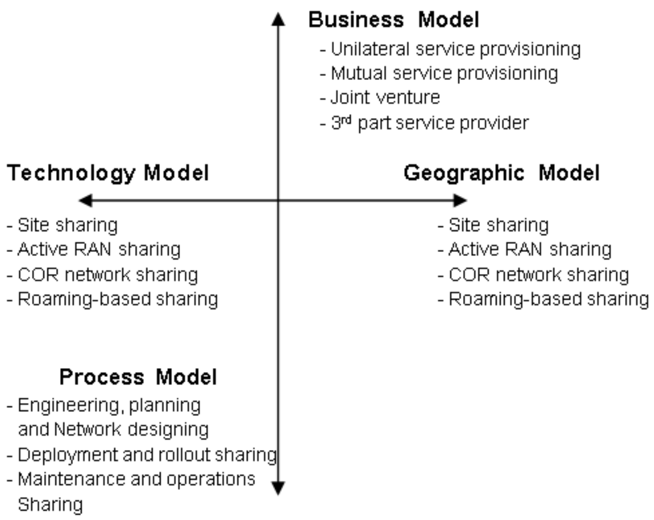

Figure 13 – Four options for infrastructure sharing (Source:[3])

By separating network infrastructure and service provision, the NO opens up a new world of possibilities not only to operators who would otherwise not invest in the infrastructure, but also to the growth of technological solutions which can assist in the development of countries such as Mozambique. The separation of these two areas brings benefits to both parties, as stated by Infante J. et al, namely “inherent roaming facilities, decreased network costs, higher area coverage, increase in the potential customer base, etc. But this advantages can only be realized if the neutral operator itself can come up with a business model that ensures its sustainability.” [5][5]

The concept of NO is theoretically interesting and seems to provide limitless advantages in cost reduction, more efficient and sustainable expansion of services, the possibility of developing new services for users without the additional investment in non-profitable areas, meeting international goals of coverage and access to telecommunication services. However, some concerns related to operator autonomy, for example, sometimes surface along with the concern about the practicalities of dealing with a common infrastructure for different purposes. Despite these concerns, the pressure currently put on operators to provide more at lower prices encourages the parties to negotiate a number of solutions that allow them to continue in the telecom run.

4. Case Study

4.1 Contextualization

Mozambique was the country of our choice for our case study for reasons already presented but which we choose to revisit:

a) personal experience in the country in the deployment of mobile telecom solutions
b) relevant constraints to territorial and demographic mobile telecommunications coverage
c) the need to continue to attract private investment to one of the poorest countries in the world
d) the possibility of implementing the Neutral Operator Model which would contribute to a rapid and cost efficient solution to provide isolated areas of the country with access to mobile telecom services

In a country with a population of approximately 24 million inhabitants, unofficial sources allow us to state that the number of mobile telecom services users is of approximately 10 million people (Table 3). In a country where official statistics tell us that the number of mobile phone users is nearly twice the number of people with access to electricity, we cannot help but think that the implementation and development of sharing solutions could be a significant engine in the growth and development of this country.

Operator	Users
A	4.000.000
B	3.500.000
C	2.000.000
	9.500.000

Table 3 – Distribution of users per operator * Estimate of the author

The three operators currently providing services in Mozambique since 1997, 2003 and 2012 have an approximate distribution of subscribers as presented in Table 3. The need to find new solutions for mobile telecommunication problems has only more recently become an issue among operators as these expand their services further north. In this process, companies are confronted with cost of expanding services into remote and rural areas where the timespan for the Return On Investment (ROI) can be quite daunting and a risk for some companies considering the apparently nonprofitable extension of territory to be covered, where users might not only not be willing to pay for the high investment made, but also not be capable of supporting the costs of tariffs which might be defined for these services. At a time when fast profit and payback period are a goal in themselves, we are confronted with the reality of the challenge from an investment point of view and, on the other hand, with the Government guidelines and regulatory policies which point towards the need to ensure the appropriate coverage of the country. However, and despite the natural resistance to high risk investment for some companies, the time has come in which the growth that Mozambique is experiencing over more recent years is forcing both government and operators to reconsider a number of variables, especially in the field of telecommunications services.

This more recent dilema of guaranteeing coverage in areas which are currently deprived of telecom solutions was the motivation behind our study and behind the choice of the Neutral Operator Model as a solution because we believe that despite the different netwok sharing options available, the NOM not only allows for quicker answers to pressing problems, but also because it is an opportunity for the Government to become an active stakeholder in the process of implementing and meeting the objectives it has designed and defined for the expansion of telecommunciation services. Citizens who are currently deprived of all the opportunities access to telecom services provide can be given the chance to not only improve their lives at an individual level, but also as a community. In this way, the added value of sharing infrastrutures via an NOM is the direct contribution to making one of the twentiest poorest countries in the world develop alongside the growth it is experiencing.

With these challenges in mind, our case study focuses on the following:

a) identification of the constraints to investment in remote areas
b) design and proposal of an Neutral Operator Model for Mozambique
c) identification of possible constraints/solutions to the implementation of the NOM

4.2 Current mobile telecommunication architecture

Before identifying the constraints mentioned in a) it is important to take into account the current network architecture adopted by the three operators. Given that the three operators generally have their sites in the same areas, the architecture is as follows:

- Sites in the main cities of Mozambique
- BSCs in the capital of each district, except in Maputo which has more than one
- Major differences can be found in their Core and Access network as illustrated below **(Table 4)**

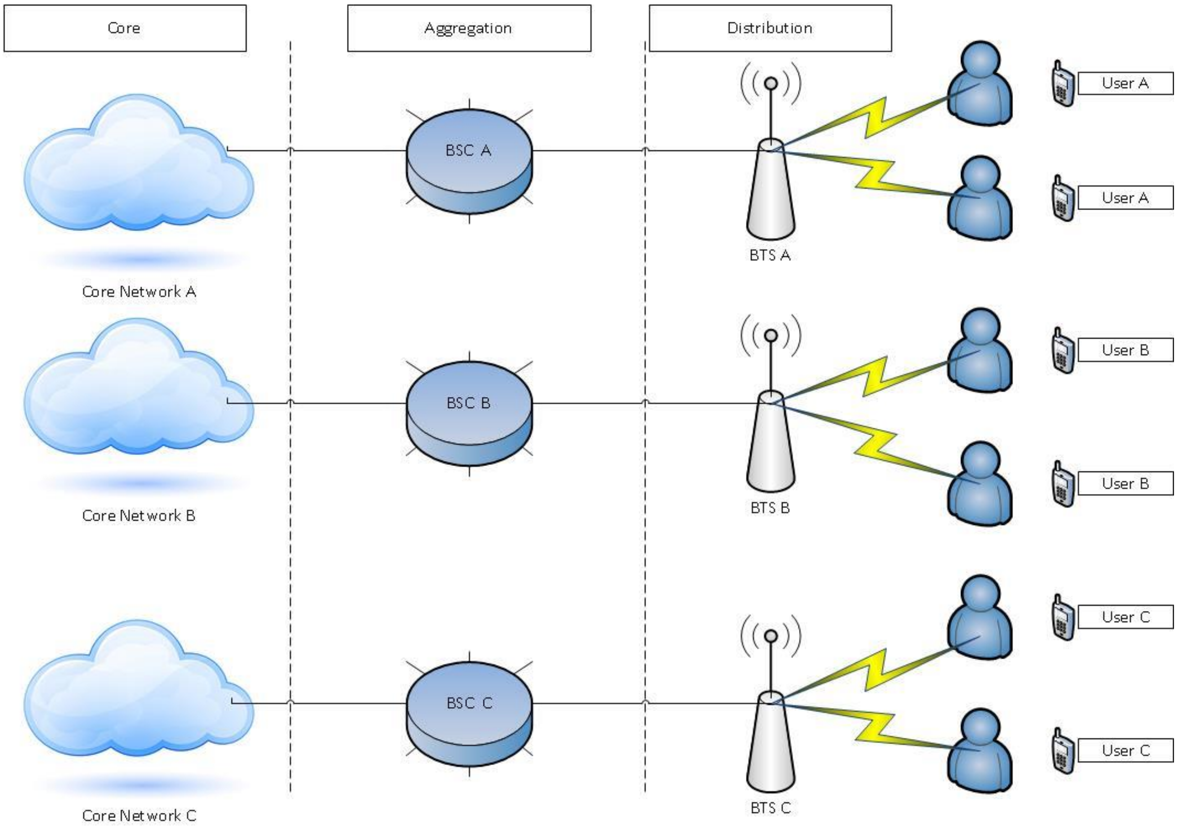

Figure 14 – Typology of Mozambican Mobile Network (Source: author)

Figure 15 – Typology of Mozambican Mobile Network (Source: author)

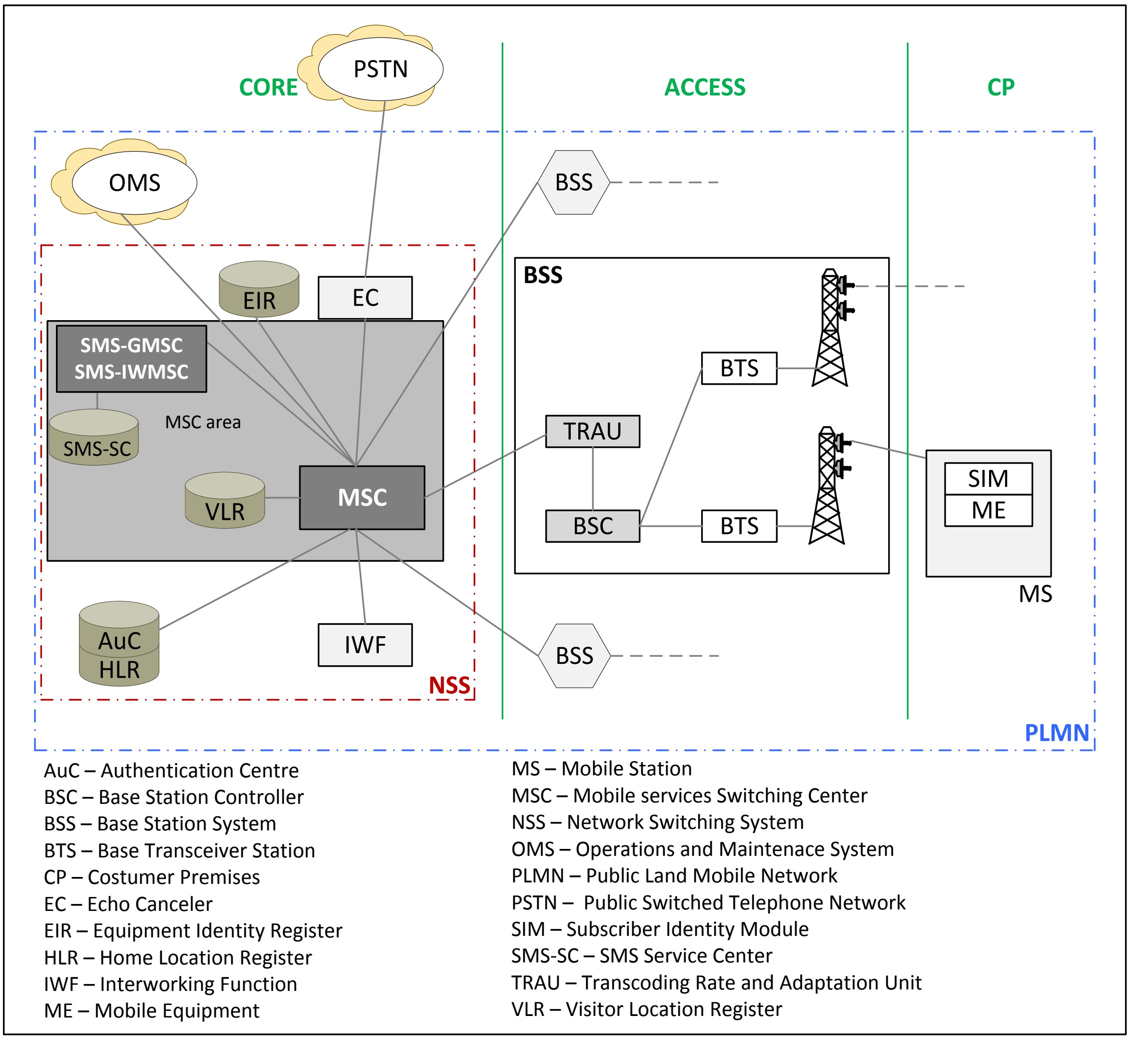

Figure 16 – Typical Typology of a Mobile Network (Source:[17])

Operator	Access	Core
A	80% MicroWave ; 20% Fibre	60% MicroWave ; 40% Fibre
B	60% MicroWave ; 40% Fibre	30% MicroWave ; 70% Fibre
C	15% MicroWave ; 85% Fibre	100% Fibre

Table 4 - Types of Access and Core Network per operator * Unofficial sources

As we can see, and from the perspective of the NOM infrastructure sharing approach, despite the differences in the types of core network and and types of access between operators, these are not obstacles to the sharing of physical infrastructures. Although there are naturally other factors to be taken into account, but at a first glance, there are no physical infrastructure incompatibilities. Unfortunately, this conclusion is not as simple as it seems, which is why section 4.3 is dedicated to a more detailed discussion of the constraints to development in rural and remote areas of Mozambique.

4.3 Constraints to investment in remote areas

As we have briefly mentioned in previous sections, a company or other entity's decision to invest in a project is based on a number of factors such as CAPEX, OPEX, ROI among financial indicators. The decision making process and feasibility studies therefore take into account the obstacles and constraints which will bring more or less risks to an investment. We know that different entities have different forms of analysing the feasibility of a project and that the greater or lesser financial risk is also determined by the investing party's financial capacity and the guidelines and mandates that it is driven by. This is also more the case when looking at investment projects in emerging markets where the period and risk of payback are substantially different to those we might find in developed and consolidated markets. In the cases of emerging markets, investment can be perceived as much more than the financial ROI and many investors include objectives such as community development as part of their investment plan. This is usually the case of financial entities that are more capable of supporting risks, and who are willing to wait longer for their payback than the traditional banking system and traditional company approaches to investment. Investment in emerging markets is therefore a topic in itself which we will not be going into detail about, but which is worth mentioning when discussing investment possibilities in our case study.
Among the many challenges any investment is confronted with in Mozambique, there are immediate and objective factors that impact of any analysis of investment in telecom infrastructures:

- A country with a 2.300 km coast line and approximately 801 537 km^2
- Small cities
- Population with very low economic income
- Inexistence of basic infrastructures throughout the country (roads, electricity, water, etc.)

In the case of the telecom sector, these four factors we chose to list (and which are not the only difficulties to be encountered) have a very significant impact on the costs any entity would need to support in order to implement a project. Logistic costs increase very significantly, costs of services come close to prohibitive, payback periods seem to limitless and on the whole the risk and constraints easily outweigh the profits which all companies seek to achieve within the shortest period of time.
However, government objectives remain unaccomplished and operators would like to go the extra mile but are faced with economic and financial dampeners. It is for this reason that we believe that the NOM can provide a speedy and effective solution for a problem which needs to be addressed

now. The requirements for the implementation of the NOM are already roughly available and capable of being discussed and refined in order to become a reality, namely:

- Government motivation
- Legal framework in favour of infrastructure sharing
- Regulatory agency and policies which allow the NOM to be implemented
- An existing government budget dedicated to the deployment and implementation of sites via the INCM
- Three operators who need to cater for growing telecom demands

The figure of the INCM is of vital importance to our perception of the NOM for Mozambique because this entity embodies the Government's priorities in the field of telecommunications and because it already has a system which allows the appropriate partners to be selected whenever the budget is to be invested. Some of the factors taken into account are:

- National coverage plan
- Number of communities served
- Technical solution
- Universal service

This criteria aims at reducing telecommunication exclusion of populations that are located in more remote areas. However, it is also a clear sign that the INCM has the ability to become an active stakeholder in the creation of the NOM not only due to its budget which can reduce the investment risk for other parties, but also because what could initially be perceived as an investment with no return can in fact become a generator of income for the Government which will have more generous payback periods and will have a business model that generates income for future investments in the telecom area. It is also highly beneficial for the government to be a stakeholder in a project such as the NOM because it will be able to take proactive measures to ensure that the combat against telecommunication and information exclusion is being ensured, telecom expansion can be designed to accompany other social concerns and third party stakeholders in the NOM comply with policy and regulatory guidelines. The benefits of bringing together private and state entities in traditionally high income projects like telecom projects makes this type of investment go beyond the usual, and sometimes limited in scope, financial study.

We believe that a NOM for Mozambique will necessarily require a state partner considering the invaluable contribution that such an entity will bring to the deployment and implementation of the project, in addition to providing the opportunity to develop legislation which takes into account the social importance of information and telecommunication.

4.4 The Neutral Operator for Mozambique

Previous sections of this work discussed the multiple options available from a sharing perspective and we also discussed the complexity behind the concept of NO.

We will now bring these two concepts together in the designing of what we believe could be an applicable Neutral Operator Model to improve territorial and demographic coverage in remote areas of the country.

In order to make the architecture of the NOM clearer, the figure below illustrates the architecture of such an NO solution and also demonstrates that operators can become exclusive service consumers of shared infrastructures, paying exclusively for what they use expanding their own services into more remote and rural or peripheral areas.

The NO will need to meet certain technological requirements in order to offer a sharing service and that will include:

1. Build a site in a remote area (Rural Zone)
2. Connect that site to the other operators using a shared network

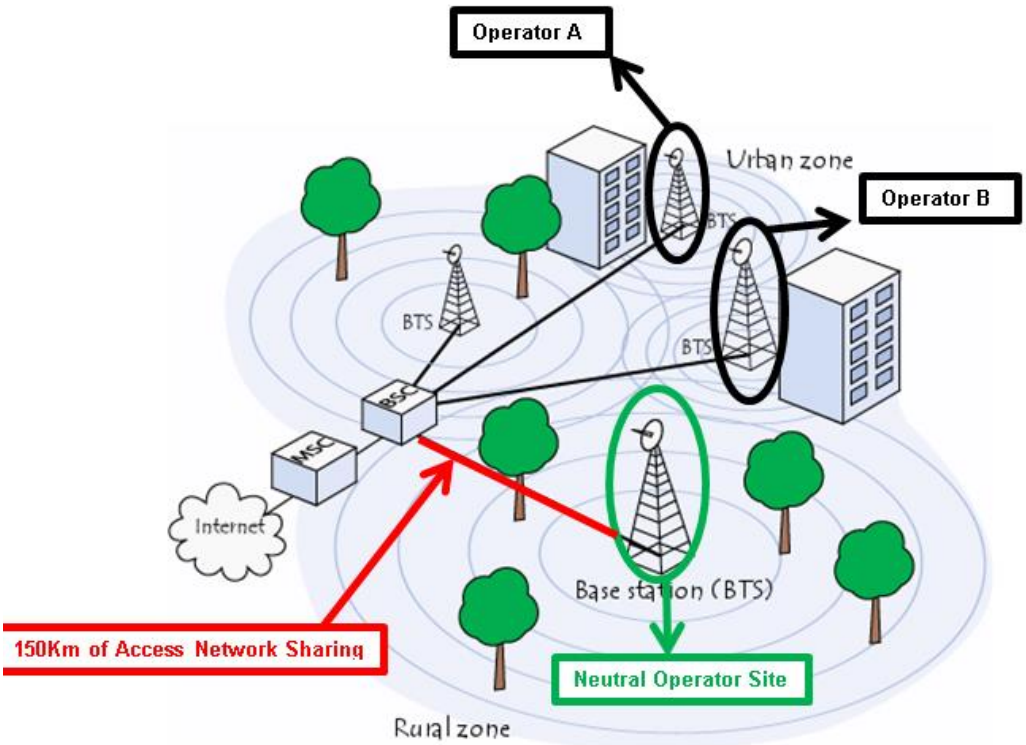

Figure 17– Proposal of a Neutral Operator for Mozambique (Source:author)

Any business model requires limits and criteria to become operational and the NOM is not an exception because it does not aim at being a nonprofitable investment. Therefore, and for the purpose of creating a starting point for discussion, we would propose the following criteria for the NO in Mozambique:

1. Minimum of 2000 users per village where site is to be installed
2. Guaranteed income which allows each user to spend an average $10/month on telecommunications
3. The nearest point of interconnection with other operators is at a distance of over 150Km

After guaranteeing that the selected area meets the above listed requirements, the NOM could become a reality through the agreement between parties about the following:

1. The new site is built by a private company who rents the traffic to the operators
2. The connection from the site to nearest interconection point with other operators belongs to a partnership between the private company and the Government

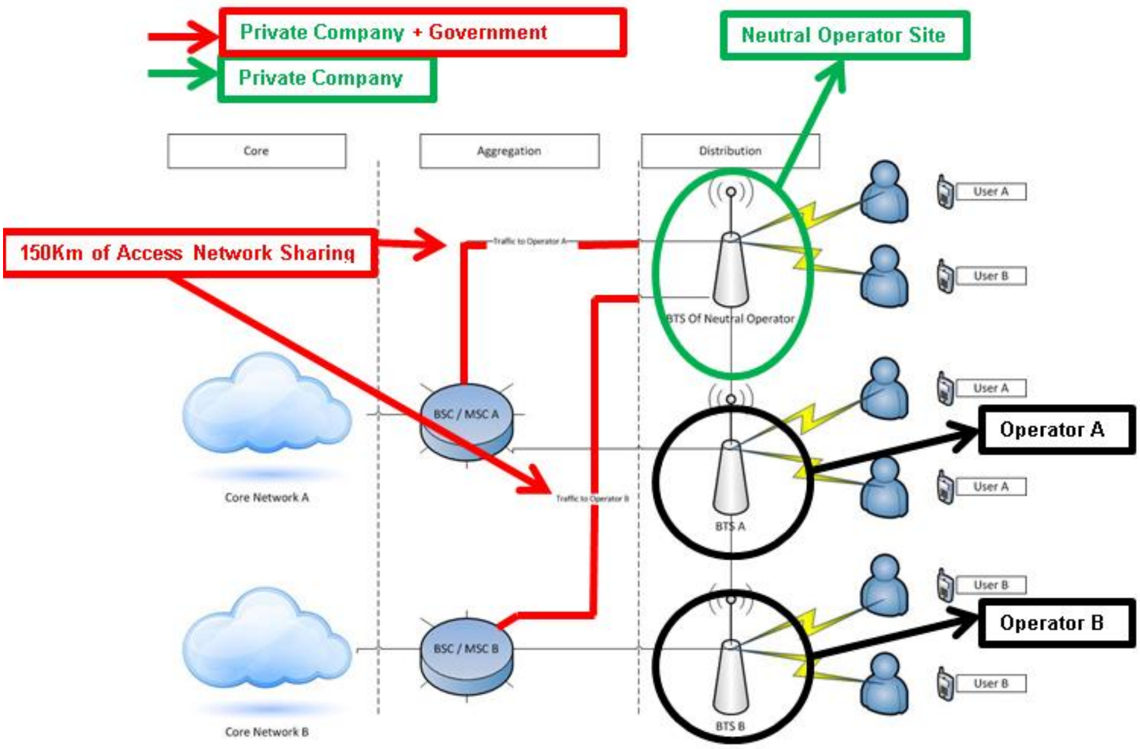

Figure 18 – Proposal of a Neutral Operator for Mozambique (Source:author)

The contractual specificities and the benefits for each party have been discussed in previous sections and are an equally important dimension of the success of the implementation of the NOM. In addition to the advantages already mentioned above for the NOM in Mozambique, and which is based on the identification of the high costs associated to the deployment of mobile telecom infrastructures in remote areas (see section 4.6), we believe that the NO based on Access Network Sharing is an alternative for coverage in remote areas, given the inexistence of commercial operators in a 150Km radius, which lead to the inexistence of towers, antennas or other infrastructures to be shared.

Another advantage of the NOM is the simplicity with which operators can envision the expansion of their services into remote areas, without the risks of investments required without this solution.

The figure below shows a more detailed description of the internal organization of the NO, where we can clearly see each operator's equipment.

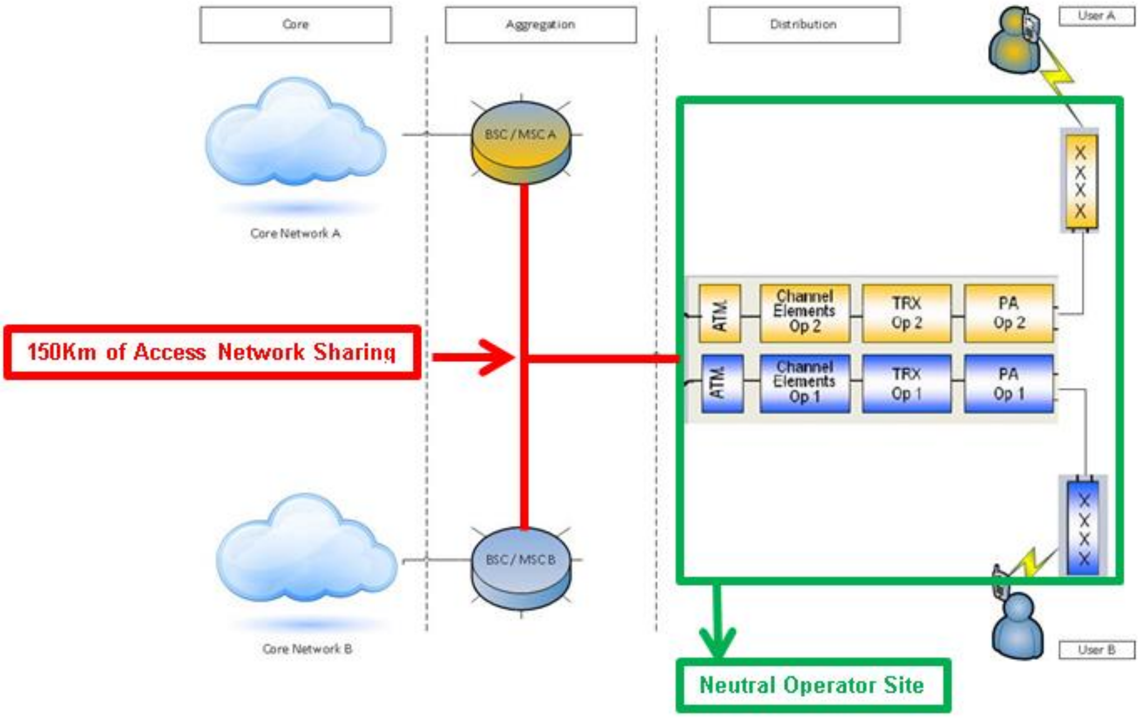

Figure 19 – Proposal of a Neutral Operator for Mozambique (Source:author)

Legend:

PA – Power Amplifier

TRX – Transceiver

Chanel Elements – Data processor for different services

ATM – Transmission Switch

After understanding how the physical sharing of an infrastructure takes place, it is relevant to understand how the telephone call is processed within an NO context.

Figure 20 shows us each of the steps a telephone call made in a remote area by an operator 2 user follows within the context of a Neutral Operator Model:

1. **User 2 makes a phone call to another user**
2. **The signal generated by it's celphone is received by the antenna 2 installed on the site of the NO**
3. **This signal is then treated by all the components of the operator 2 as if there was not other operator sharing the site**
4. **The NO deliver to the shared Acess Network the traffic generated by the User 2**
5. **This traffic is delivered to the nearest BSC of the operator 2 by the shared Acess Netwowrk**
6. **From the BSC, the traffic is forwarded to the Core Network (where is the MSC) by the Backbone of operator 2**

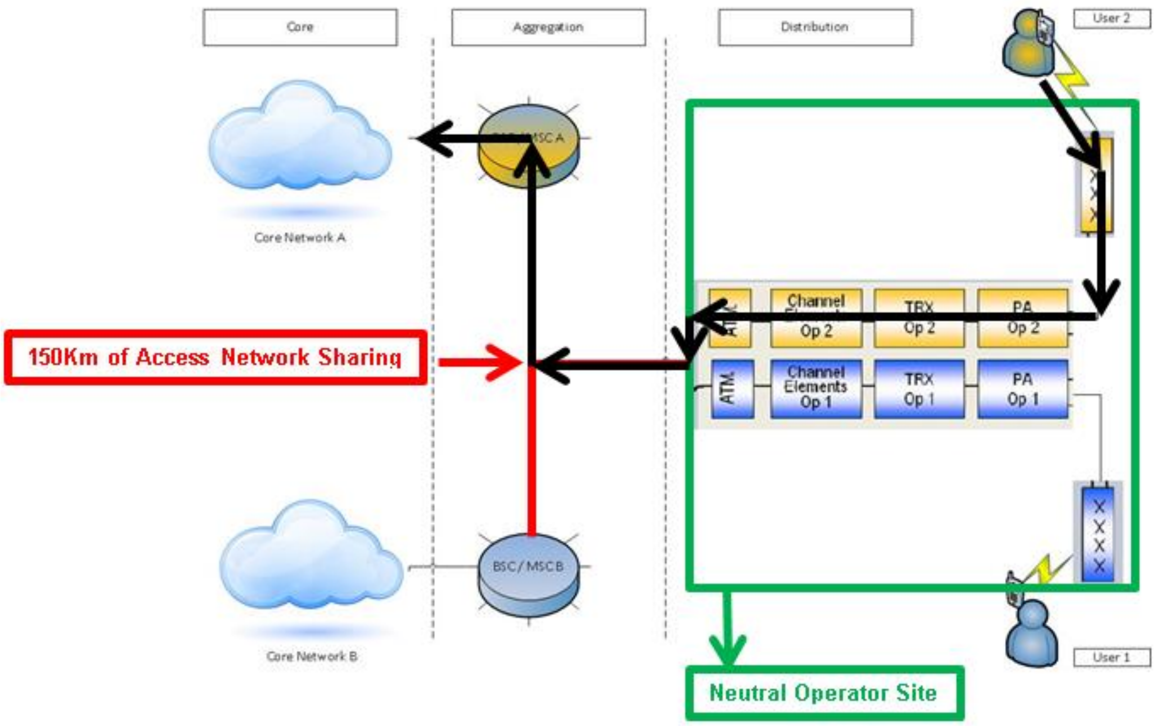

Figure 20 – Establishment of a phone call (Source:author)

As we can see, the fact that it is possible to identify exactly where sharing takes place, contracts between parties can safeguard individual interests within a common structure, while creating the necessary conditions for all parties to participate in a global solution that benefits service providers and users.

Table 5 in turn shows the shared parts of the telephone call and those which are operator dependent:

	Neutral Operator	Access Sharing	Operator
User 2 makes a phone call to another user	x		
Reception of the signal by the antenna	x		
Signal treatment	x		
Traffic generated delivered from site to BSC		x	
Traffic generated delivered from BSC to Core Network			x

Table 5 – Shared parts and the operator ones in a phone call

The description of the process once again encourages us to believe that Mozambique already has the necessary conditions to embark on a project of this nature - unlike other poor countries in Africa - without having to activate mechanisms that in themselves could make this solution dependent on private investment and/or too ambitious to become practical and operation within a short period of time.

Like any model, the NOM faces constraints which we have listed throughout the previous sections, such as:

- Insufficient and/or inexistent legal frameworks for infrastructure sharing
- Motivation of different parties to become involved in a sharing project
- Difficulties in firming protocols between private companies and the government
- Lack of attractive conditions for potential investors
- Operator concerns with the safeguard of their individual differentiating characteristics

However, in the case of Mozambique, and as described above, the necessary requirements for a project like this to be implemented already exist. It is important to work in advance with the regulating entities and establish partnerships between them in order to facilitate work with the operators and create new laws which include the NOM in existing legislation.

4.5 Financial Analysis

4.5.1 Financial Definitions

Before starting our financial study,it is important to provide some definitions to assist us through section 4 of this work. The following materials are based on [20]:

CAPital EXpenditures (CAPEX)

All costs associated to the acquisition, construction or extensions of fixed assets are considered CAPEX. A company's fixed assets is the set of assets held by the company, which do not have the purpose of being sold or rented, and which are essential to the normal operation of the company. Fixed assets are usually divided into two groups: tangible fixed assets and intangible fixed assets.
Tangible fixed assets are the set of tangible assets defined above. These assets are subject to depreciation during the economic period of a project.
Examples of tangible fixed assets are buildings, vehicles, network equipment, among others.
On the other hand, the intangible fixed assets are the set of intangible assets such as licenses, patents and other acquired rights which are fundamental to the operation of a company. These assets are subject to depreciation when they have a limited period of time.
The correct quantification of CAPEX is essential when launching new services and/or improving or expanding existing services.

OPerational EXpenditures (OPEX)

Unlike CAPEX, OPerational EXpenditures (OPEX) does not aim increasing company assets, in i.e., to increase the assets which can generate future income for the company. OPEX includes all the necessary costs for the normal operation of an entity.
OPEX costs can include maintenance of equipments, periodic licenses with a period inferior to one year, marketing, client networking, service management, financial operations, among others.
The increase of competition between companies and products, combined with the need to obtain immediate profit, leads to the growing importance of OPEX in the field of economic analysis. Recently, a number of companies have chosen not to acquire infrastructures and to prefer service consumption exclusively. An example of this option are the business models based on cloud and grid computing solutions with the purpose of providing services in these areas.

Cash-Flow

Cash Flow, also known as treasury movements, is the movement of money registered by the entity promoting the project, during a certain period of time.

The cash flow includes the profits (cash inflows) and operational costs (cash outflow) over a certain time span, i.e., if we add the gross income to the amortizations, we obtain the gross cash flow of the investment.

However, the taxes on income and value of capital costs which might have taken place in the same period of time also impact on the result.

Usually, the cash flow of an investment project is calculated on an annual basis, during the years in which the project is operational.

The cash flow resulting from an investment is rarely invariable during the lifetime of an equipment or product. Usually, the first cash flow is negative due to the significant investment made at the beginning of the project and profits are relatively low.

Associated to the concept of cash flow is the concept of cash balance which is the cumulative sum of all cash flows up to a specific time. The cash balance is also calculated annually.

A common method used in the feasibility study of an investment project is the analysis of cash flows which is in turn confronted with different technological alternatives.

The use of the incremental approach in these cases is quite common, i.e., only the costs directly related to the project being assessed are considered. The general costs - the way in which a project can contribute to cover general company costs - are not usually taken into account in these studies.

Net Present Value (NPV)

The Net Present Value (NPV) is considered the main criteria in the decision to implement a project as it includes the total amount of funds required for the implementation of the project.

Before calculating the NPV of a project, it is necessary to:

- Determine the discount rate
- Determine the capital invested

Each annual Cash Flow CF_p is multiplied by the corresponding rate $(1+T_A)^{-p}$, where T_A is the discount rate and p corresponds to the year of the investment project, which has a duration of 5 years on this case study. The sum of all the discounted cash flows is therefore the sum, in the present or during the reference period, of all the future costs and profits, i.e., the net present value, as illustrated in equation [20]:

$$NPV = \sum_{p=0}^{T} CF_p \cdot (1 + T_A)^{-p} = \sum_{p=0}^{T} \frac{CF_p}{(1 + T_A)^p}$$

Equation 1 - Formula for the calculation of NPV [20]

Usually, the normal arithmetical amortizations are not considered when calculating the NPV.

Internal Rate of Return (IRR)

In some cases, it is possible that not all data concerning financing rates is available; in other cases, when faced with several investment projects, different levels of values or of duration may occur, generating a greater difficulty in choosing one of the projects if there is no differentiating indicator.
This indicator includes the discount rate in which the sum of all the costs is equal to the sum of all the profits, i.e., the discount rate makes the NPV negligible.
This rate can, for example, be compared with the interest discount rate of the project itself, in order to determine the profitability of the project and its ability cover the capital invested.
When justifying the decision with the IRR, it is common to choose the project in which the IRR indicator value is higher to the discount rate. However, it is not always easy to obtain the most relevant IRR value for the project.

Payback Period

The Payback Period indicator is the time span, usually accounted for in years, since the initial period until the moment when the cash balance becomes positive.
The first cash flow is usually negative due to the very significant financing effort to install the necessary infra-structure made by the entity promoting the project.
Afterwards, although the cash flows are no longer negative, the values are relatively low up to the point in which the accumulated balance supersedes the effect of the initial cash flow.
The calculation of the Payback Period is based on the cumulative sum of the cash flows until these are close to 0, removing the respective year.

However, the use of this indicator is not a widespread practice, despite its relatively simple calculation. The reason for this is the fact that the Payback Period does not reflect the behaviour of the project after its implementation.

4.5.2 CAPEX Calculations

Considering the impact of CAPEX on the investment decision, and with regard to our case study, Graph 1 clearly shows how the CAPEX for materials is a major problem for operators that would like to go into remote and rural areas in an emerging market like Mozambique.

We can see that 37% of the CAPEX is related to materials and 31% to power challenges. If we look at the specificities of the Mozambican reality previously described, the implementation of an NO becomes even more relevant considering the benefits operators would have in not having to support the above mentioned 68% of costs which easily outweigh the more immediate profit which is necessary to encourage investment in remote and rural areas.

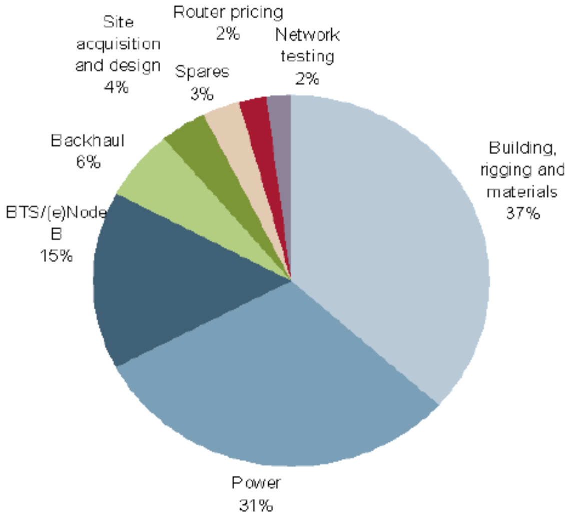

Chart 1 – CAPEX in emerging markets (Source:[3])

From our experience and based on the findings of our study, the NO is a very convenient and highly attractive alternative for Mozambique as the CAPEX is inexistent for the operators because the NO supports the heavy investment and the users, in this case the operators, only support the costs of traffic which will in turn be supported by the client user, in this way reducing the risk of the expansion of services. With this very significant risk reduction, telecom services will more rapidly be made accessible to the now discriminated parts of the population.

We can refine our analysis even more by revisiting the basic architecture of an NO in Figure 21.

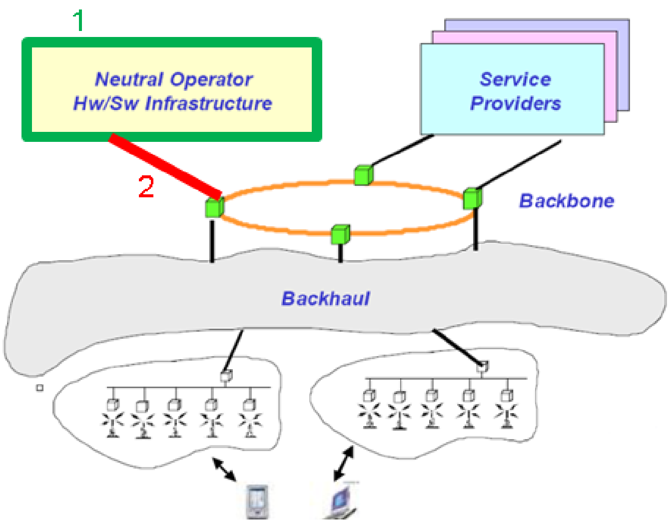

Figure 21 – Basic architecture of an NO (Source:[5])

Figure 21 allows us to immediately separate this architecture into identifiable two parts for financial calculation purposes:

1. The construction of a site in a remote area
2. The connection of the site to the other operators using a shared network

By separating the NO into these two parts, it is possible to calculate an approximate budget for each of the investments which would need to be made.

1. The NO site is made up of the following:

- One 100m tower in a 10x10m site with a fence
- One outdoor cabinet with a solar system
- 24 batteries
- One solar panel/genset/on grid controller
- One Genset
- All the antennas, cables, BTS and wiring

The tower is 100m tall in order to cover the largest area possible around the site. The choice of a 10x10m site is a footprint requirement for this type of tower. The equipment cabinet with a solar panel system and a controller included reduces OPEX costs. During the day, the sun charges the batteries using the solar panel and the site operates on batteries until charge capacity limit is reached. After that, the NO can use the on grid power of the electrical network, or the genset, or can also activate the option of only making the site operational on sunny days.

Figure 22 – Site in Espungabera-Mozambique (Source: author)

Figure 22 is an image of a site in Espungabera – Mozambique, which has all the elements required to be able to provide NO services.

Table 6 takes us further in the cost analysis of the CAPEX involved in an NO solution:

Identification of cost elements - Infrastructure of the NO				
Cost elements	**QTY**	**Unit**	**P. Unit**	**P. Total**
Site with 100m tower	*1*	*un*	*$130.000,00*	*$130.000,00*
Tower	1	un		
Fence	1	un		
Outdoor Cabinet with solar panel	1	un		
Bateries	24	un		
Solar panel/genset/on grid controller	1	un		
Genset	1	Un		
Passive and Active equipment (BTS S333, Antennas, etc)	*1*	*un*	*$30.000,00*	*$30.000,00*
TRX	*1*	*un*	*$3.000,00*	
				$160.000,00

Table 6 – Identification of cost elements – Infrastructure of the NO

2. Connection of the infrastructure to the Backbone of each operator

Table 7 provides the costs involved in the second part of the NO investment and which is related to the connection of the infrastructure to the backbone of each operator

Identification of cost elements - Connection of the infrastructure to the Backbone of each operator				
Cost elements	**QTY**	**Unit**	**P. Unit**	**P. Total**
Optical Fiber passed and tested	*1*	*Km*	*$7.000,00*	*$7.000,00*

Table 7 – Identification of cost elements – Connection of the infrastructure to the Backbone of each operator

Depending on the distance between the site and the nearest back bone, it is possible to identify the costs of implementing an NO site in a remote area.

If we consider installing a site at a distance of 150 km far from the nearest back bone, costs would come to approximately the following:

	Cost elements			QTY	Unit	P. Unit	P. Total
Core							
Aggregation	*Optical Fiber passed and tested*			*150*	*Km*	*$7.000,00*	*$1.050.000,00*
Distribution	*Site with 100m tower*			*1*	*un*	*$130.000,00*	*$130.000,00*
	Passive and Active equipment (BTS, Antennas, etc)			*1*	*un*	*$30.000,00*	*$30.000,00*
							$1.210.000,00

Table 8 – Case Study Elements

The Optical fibre has a very relevant weight on this case study. As we can see form the estimates presented, optical fibre has a weight of 1.050.000/1.210.000, which corresponds to 87% of the total cost.

Now, we are going to consider our client distribution and growth over a period of 5 years.
Chart 2 illustrates the patterns which reflect the adoption of a varied set of technologies and products throughout the twentieth century, identified by M.O. Duarte [19]

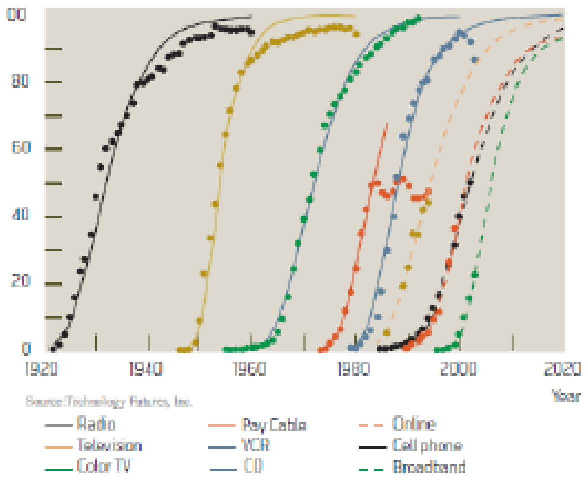

Chart 2 - Adoption patterns for a set of varied Technologies and products throughout the 20th century [18]

The observation of this figure allows us to identify a pattern of temporal development similar to an ***S***. This type of curve – frequently referred to as a *logistic curve* and which belongs to the family of curves which geometry defines as sigmoids – can be empirically understood in the following manner:

- The adoption of a new product can be explained as depending fundamentally on the effects listed below:
  - An *innovation* effect: something new which attracts the attention of the user appears and makes him want to use the product.

- An *imitation* effect: even if the appearance of a new product did not capture the attention of the user, the fact that others have started to use the product leads the user to want to have the same experience

- Any one of these processes takes some time to develop and while they do develop, both the number of users who can be 'contaminated' (imitation effect) and the impact of using the product (innovation effect) rapidly grow. This tendency will start to slow down at the point when the number of users who can potentially be 'contaminated' starts to decrease and when the 'contamination' process starts becoming more difficult and eventually becomes null when all the users that can potentially be 'contaminated'.

There are several mathematic models which represent possible scenarios for market penetration of a certain product, service, technology, etc. The model based on logistic curves has been used extensively in the past to deal with telecommunications technologies and services [19] and will be adopted in this work to model the growth of new users in the Mozambican telecommunications market.

$$Growth = starting\ Levell + \frac{Saturation\ Level - Starting\ Level}{1 + Alfa.\, e^{t.Beta}}$$

t is *time* expressed in years

Equation 2 – Growth equation [19], [20]

Based on the factors of this equation, we can create three different types of scenario:

a) Worst case scenario
b) Normal case scenario
c) Best case scenario

Table 9 presents the (empirically) chosen values of Alfa and Beta parameters for each type of scenario.

Worst Case Scenario	
Starting Level	10%
Saturation Level	70%
Alfa	5000,00
Beta	-1,50
Normal Case Scenario	
Starting Level	10%
Saturation Level	70%
Alfa	2000,00
Beta	-1,50
Best Case Scenario	
Starting Level	10%
Saturation Level	70%
Alfa	900,00
Beta	-1,50

Table 9 – Parameters for three different scenarios

Over the study period of 5 years we will get the following growth distribution:

Worst Case Scenario					
Years	1	2	3	4	5
Growth		10,24%	11,06%	14,48%	25,93%
Nº of users	2000	2205	2449	2803	3530
Normal Case Scenario					
Years	1	2	3	4	5
Growth		10,60%	12,58%	20,07%	38,49%
Nº of users	2000	2212	2490	2990	4141
Best Case Scenario					
Years	1	2	3	4	5
Growth		11,31%	15,46%	28,57%	50,06%
Nº of users	2000	2226	2570	3305	4959

Table 10 – Growth for three different scenarios

These scenarios are illustrated in the following chart:

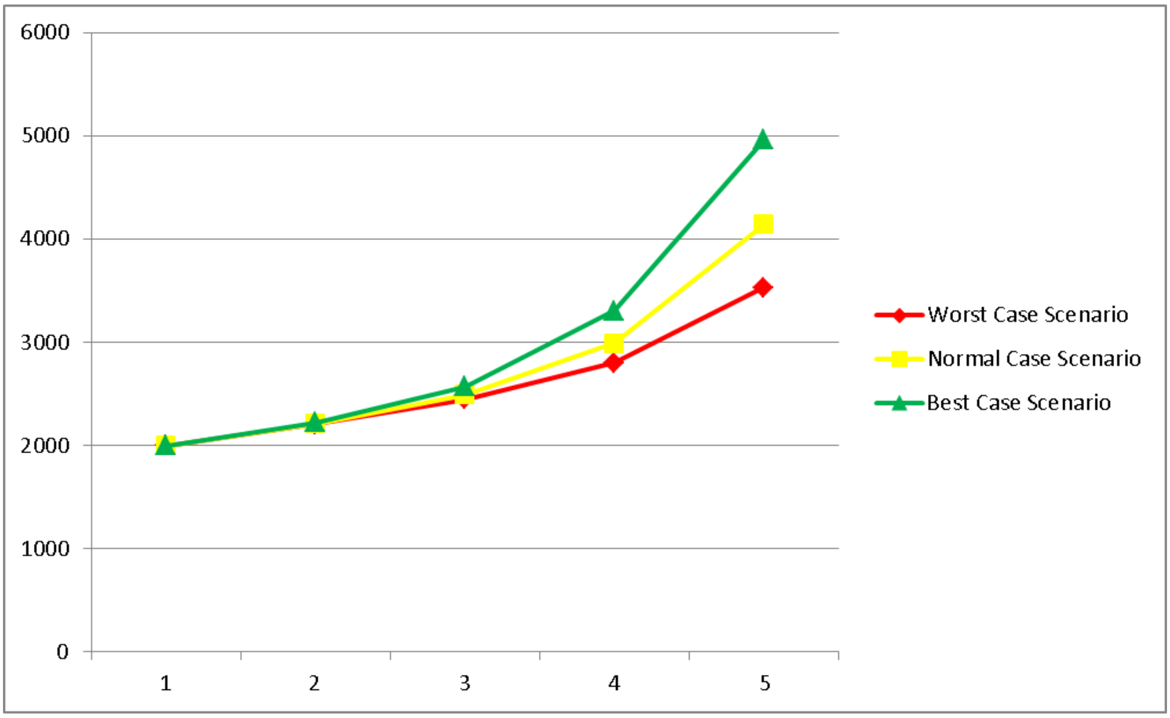

Chart 3 - Adoption patterns for the considered scenarios (5 year study period)

Previous chart corresponds to just the first 5 years of a longer period with a behaviour as depicted in the following chart:

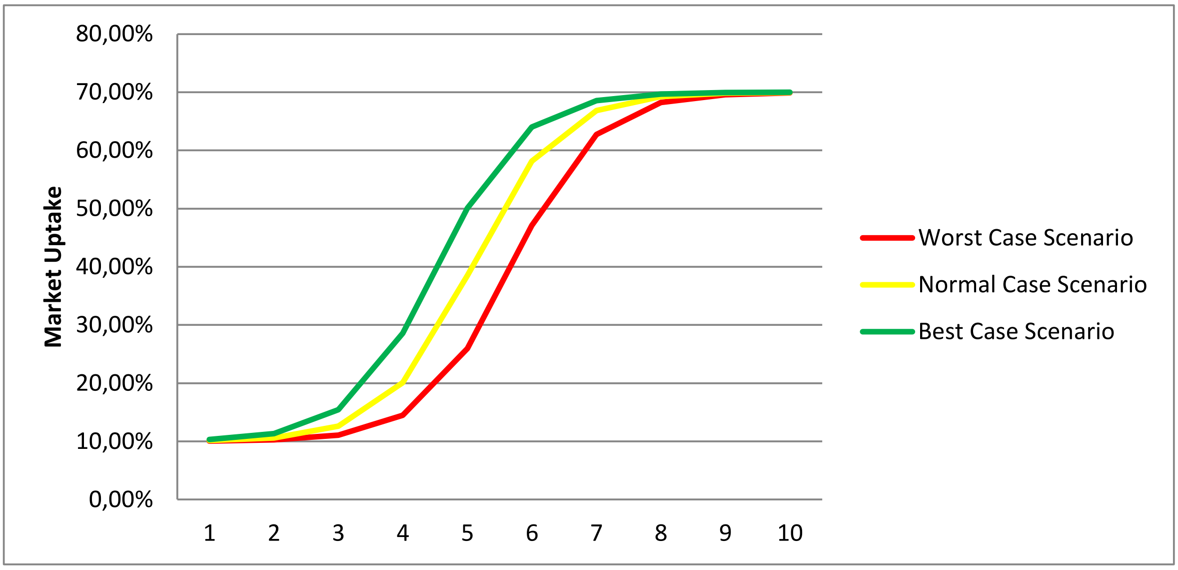

Chart 4 - Adoption patterns in the long run

A 5 year can seem questionable when considering the payback period of a project, even more so when the project is in the technology area, which is one of the reasons why having the government as a stakeholder becomes of major importance in the context of emerging markets. It is impossible to foresee the requirements for telecom technology over the next 5 years, but experience has shown the integration potential of new technology on pre-existing structures. In the case of poor countries, and considering the importance of the social dimension of any investment project, we believe that for the purpose of the analysis of the applicability of this model and being aware of the Mozambican reality, that a 5 year project is feasible.

With our growth calculations ready, we need to understand the impact and influence of this growth on the network elements in order to finish calculating our CAPEX.
In order to do so, we need to calculate the BTS configuration and estimate the maximum number of simultaneous users for this site.

1. Considering that at the Busy Hour (BH - time of the day with more traffic) each user requires 60s of conversation (λ), then this corresponds to (3600s) μ for an hour

   A[Erlang] = λ / μ => 60/3600=0.017Erl=17mErl

2. Considering that there is a 1% Probability of blocking (P_b), the Erlang B formula calculates the blocking probability of a buffer-less loss system, where a request that is not immediately attended is aborted, so that there is no queuing of requests. Blocking occurs when a new request arrives at a time where all lines are busy.
   The formula provides the Grade of Service (GoS) which is the probability P_b that a new call arriving to the resources group is rejected because all lines are busy:

   F(*E*, *m*) where *E* is the total traffic offered in Erlang, offering *m* identical parallel lines

$$P_b = F(E,m) = \frac{\frac{E^m}{m!}}{\sum_{n=0}^{m} \frac{E^n}{n!}}$$

Equation 3 - Erlang B equation

   where:

   m is the number of identical parallel resources (telephone lines)
   E = λh is the normalized ingress load (offered traffic stated in Erlang).

   For example, considering m=2 and E=3 we will have:

$$\frac{\frac{3^2}{2!}}{\sum_{n=0}^{2}\frac{3^n}{n!}} = \frac{\frac{9}{2}}{\frac{3^0}{0!}+\frac{3^1}{1!}+\frac{3^2}{2!}} = \frac{4,5}{1+3+4,5} = \frac{4,5}{8,5} = 0,52\%$$

3. Considering that the 2000 users are uniformly distributed by each one of the 3 sectors, it means that one sector has to support 2.000/3=666 users

4. This lead us to 666 users * 17mErl/user= 11,1Erl per sector

Using a normal Erlang B table for:

- Traffic=11,1Erl
- Blocking rate (GoS)=1%

N	1%	1.20%	1.50%	2%	3%	5%	7%	10%	15%	20%	30%	40%	50%
1	0.01	0.01	0.02	0.02	0.03	0.05	0.1	0.11	0.18	0.25	0.43	0.67	1
2	0.15	0.17	0.19	0.22	0.28	0.38	0.5	0.6	0.8	1	1.45	2	2.73
3	0.46	0.49	0.54	0.6	0.72	0.9	1.1	1.27	1.6	1.93	2.63	3.48	4.59
4	0.87	0.92	0.99	1.09	1.26	1.52	1.8	2.05	2.5	2.95	3.89	5.02	6.5
5	1.36	1.43	1.52	1.66	1.88	2.22	2.5	2.88	3.45	4.01	5.19	6.6	8.44
6	1.91	2	2.11	2.28	2.54	2.96	3.3	3.76	4.44	5.11	6.51	8.19	10.4
7	2.5	2.6	2.74	2.94	3.25	3.74	4.1	4.67	5.46	6.23	7.86	9.8	12.4
8	3.13	3.25	3.4	3.63	3.99	4.54	5	5.6	6.5	7.37	9.21	11.4	14.3
9	3.78	3.92	4.09	4.34	4.75	5.37	5.9	6.55	7.55	8.52	10.6	13	16.3
10	4.46	4.61	4.81	5.08	5.53	6.22	6.8	7.51	8.62	9.68	12	14.7	18.3
11	5.16	5.32	5.54	5.84	6.33	7.08	7.7	8.49	9.69	10.9	13.3	16.3	20.3
12	5.88	6.05	6.29	6.61	7.14	7.95	8.6	9.47	10.8	12	14.7	18	22.2
13	6.61	6.8	7.05	7.4	7.97	8.83	9.5	10.5	11.9	13.2	16.1	19.6	24.2
14	7.35	7.56	7.82	8.2	8.8	9.73	10.5	11.5	13	14.4	17.5	21.2	26.2
15	8.11	8.33	8.61	9.01	9.65	10.6	11.4	12.5	14.1	15.6	18.9	22.9	28.2
16	8.88	9.11	9.41	9.83	10.5	11.5	12.4	13.5	15.2	16.8	20.3	24.5	30.2
17	9.65	9.89	10.2	10.7	11.4	12.5	13.4	14.5	16.3	18	21.7	26.2	32.2
18	10.4	10.7	11	11.5	12.2	13.4	14.3	15.5	17.4	19.2	23.1	27.8	34.2
19	11.2	11.5	11.8	12.3	13.1	14.3	15.3	16.6	18.5	20.4	24.5	29.5	36.2
20	12	12.3	12.7	13.2	14.0	15.2	16.3	17.6	19.6	21.6	25.9	31.2	38.2
21	12.8	13.1	13.5	14	14.9	16.2	17.3	18.7	20.8	22.8	27.3	32.8	40.2
22	13.7	14	14.3	14.9	15.8	17.1	18.2	19.7	21.9	24.1	28.7	34.5	42.1
23	14.5	14.8	15.2	15.8	16.7	18.1	19.2	20.7	23	25.3	30.1	36.1	44.1

Table 11 – FR Channels Calculation

Based on this Erlang B table, 19 channels will be needed. Each TRX has 8 Channels, so we will need 3 TRX/sector, which in turn requires a S333 configuration.

The Erlang B tool allows us to confirm that for 17mErl/subscriber for an S333 configuration we can reach 2.629 users simultaneously, which is more than the initial consideration of 2.000.

Capacity Calculation - Full Rate		
Subscriber behaviour (mE/Sub)	17 mE/sub	

Site Configuration	Erlang / Site	Subscriber / Site
O1	2,93	173
O2	8,20	482
O3	14,90	876
O4	21,93	1290
O5	28,25	1662
O6	35,60	2094
O7	43,06	2533
O8	49,64	2920
O9	57,22	3366
O10	64,86	3815
O11	72,53	4267
O12	80,24	4720

Site Configuration	Erlang / Site	Subscriber / Site
S111	8,80	518
S222	24,60	1447
S333	44,69	2629
S444	65,79	3870
S555	84,76	4986
S666	106,81	6283
S777	129,17	7598
S888	148,92	8760
S999	171,67	10098
S101010	194,57	11445
S111111	217,59	12800
S121212	240,72	14160

Site Configuration	Erlang / Site	Subscriber / Site
B11	5,87	345
B22	16,40	965

Table 12 – Capacity Calculation

This data requires an S333 configuration which was the one initially considered for the CAPEX calculation of the BTS, allowing the growth to 2.629 users. For more than 2.629 users and up to 3.870 users, an S444 configuration should be preferred and so on. These options represent a $3.000 investment per TRX, which comes to a total $9.000 investment.

Considering the previous table and our user growth formula, we will have different site configurations according to the number of subscribers. This is illustrated in table 13:

Worst Case Scenario					
Years	1	2	3	4	5
Growth		10,24%	11,06%	14,48%	25,93%
Nº of users	2000	2205	2449	2803	3530
BTS Config.	333	333	333	444	444

Normal Case Scenario					
Years	1	2	3	4	5
Growth		10,60%	12,58%	20,07%	38,49%
Nº of users	2000	2212	2490	2990	4141
BTS Config.	333	333	333	444	555

Best Case Scenario					
Years	1	2	3	4	5
Growth		11,31%	15,46%	28,57%	50,06%
Nº of users	2000	2226	2570	3305	4959
BTS Config.	333	333	333	444	555

Table 13 – Capacity Scenarios

The final CAPEX table will then come to the following:

Worst Case Scenario					
Years	**1**	**2**	**3**	**4**	**5**
CAPEX	$1.210.000,00			$9.000,00	

Normal Case Scenario					
Years	**1**	**2**	**3**	**4**	**5**
CAPEX	$1.210.000,00			$9.000,00	$9.000,00

Best Case Scenario					
Years	**1**	**2**	**3**	**4**	**5**
CAPEX	$1.210.000,00			$9.000,00	$9.000,00

Table 14 – CAPEX Scenarios

4.5.3 OPEX Calculations

For the purposes of OPEX calculations, we considered that site maintenance and the fibre access network are provided by the same company:

	OPEX			QTY	Unit	P. Unit	P. Total
Core							
Aggregation	*Fiber Maintenance*			*12*	*Month*	*$3.000,00*	*$36.000,00*
Distribution	*Site Maintenance*			*12*	*Month*	*$1.000,00*	*$12.000,00*
							$48.000,00

Table 15 – OPEX Calculations

We also considered that there is no significant difference between the maintenance costs of an S333 site or of an S666 site. Even if we talk about an S777 which implicates a new BTS, these values are not very different.

We also considered that each user has a weight of $1 on the OPEX , so the final table is as follows for each of the three different scenarios:

Worst Case Scenario					
Years	**1**	**2**	**3**	**4**	**5**
OPEX	$50.000	$50.205	$50.449	$50.803	$51.530

Normal Case Scenario					
Years	**1**	**2**	**3**	**4**	**5**
OPEX	$50.000	$50.212	$50.490	$50.990	$52.141

Best Case Scenario					
Years	**1**	**2**	**3**	**4**	**5**
OPEX	$50.000	$50.226	$50.570	$51.305	$52.959

Table 16 – OPEX Scenarios

4.5.4 Revenue Calculations

For the purpose of revenue calculations, we took into consideration the fact that the Fibre Access Network would be rented to the government in order to connect schools, hospitals, communities and private companies to the Internet and TV Broadcast along the 150Km of the access network (discussed in further detail in section 5). Therefore, for a typical typology of 2000 users, and an average of $10/user spent on telecommunications, the following values can be considered:

	Revenue elements			QTY	Unit	P. Unit	P. Total
Core							
Aggregation	*Dark Fiber Renting*			*1*	*year*	*$70.000,00*	*$70.000,00*
Distribution	*Trafic generated by the 2.000 operators users*			*12*	*Month*	*$20.000,00*	*$240.000,00*
							$310.000,00

Table 17 – Revenue Calculations

Considering the growth of the number of users along the years, numbers will be as follows:

Worst Case Scenario					
Years	**1**	**2**	**3**	**4**	**5**
Revenues	$310.000	$334.576	$363.841	$406.389	$493.629
Normal Case Scenario					
Years	**1**	**2**	**3**	**4**	**5**
Revenues	$310.000	$335.432	$368.834	$428.814	$566.914
Best Case Scenario					
Years	**1**	**2**	**3**	**4**	**5**
Revenues	$310.000	$337.144	$378.432	$466.553	$665.066

Table 18 – Revenue Scenarios

4.5.5 Economic Results

Worst Case Scenario					
Years	1	2	3	4	5
CAPEX	-$1.210.000,00	$0,00	$0,00	-$9.000,00	$0,00
OPEX	-$50.000,00	-$50.204,80	-$50.448,68	-$50.803,24	-$51.530,24
Revenues	$310.000,00	$334.576,15	$363.841,19	$406.388,50	$493.629,08
Anual Net Cash Flow	-$950.000,00	$284.371,35	$313.392,51	$346.585,27	$442.098,83
Cash Flow	-$950.000,00	-$665.628,65	-$352.236,14	-$5.650,88	$436.447,96
Annual Interest Rate	5,00%				
NPV (VAL)	$255.424,08				
IRR (TIR)	15,72%				
Payback Time (years)	4				
Normal Case Scenario					
Years	1	2	3	4	5
CAPEX	-$1.210.000,00	$0,00	$0,00	-$9.000,00	-$9.000,00
OPEX	-$50.000,00	-$50.211,93	-$50.490,29	-$50.990,12	-$52.140,95
Revenues	$310.000,00	$335.431,78	$368.834,25	$428.814,27	$566.913,79
Anual Net Cash Flow	-$950.000,00	$285.219,85	$318.343,97	$368.824,15	$505.772,84
Cash Flow	-$950.000,00	-$664.780,15	-$346.436,18	$22.387,96	$528.160,80
Annual Interest Rate	5,00%				
NPV (VAL)	$328.657,19				
IRR (TIR)	18,28%				
Payback Time (years)	3				
Best Case Scenario					
Years	1	2	3	4	5
CAPEX	-$1.210.000,00	$0,00	$0,00	-$9.000,00	-$9.000,00
OPEX	-$50.000,00	-$50.226,20	-$50.570,27	-$51.304,61	-$52.958,88
Revenues	$310.000,00	$337.143,53	$378.431,87	$466.553,35	$665.065,57
Anual Net Cash Flow	-$950.000,00	$286.917,33	$327.861,61	$406.248,74	$603.106,69
Cash Flow	-$950.000,00	-$663.082,67	-$335.221,06	$71.027,68	$674.134,37
Annual Interest Rate	5,00%				
NPV (VAL)	$445.471,47				
IRR (TIR)	22,07%				
Payback Time (years)	3				

Table 19 – Five Year Cash Flow

At a first glance, the implementation of the NO could be more profitable if the investment were made in Europe. The IRRs are high – varying between 15% in the worst case scenario and 22% for the best case scenario – and so is the NPV. This would apparently encourage investment in such projects, without a great sense of risk. However, in a country like Mozambique, the interest rates that commercial banks offer stand at around 14%; an investment of approximately $1.200.000.00 could reach rates of 18%. This means that with a fixed deposit in a commercial bank, relevant interest rates could be negotiated, without investment risk.

The chart below demonstrates that any of the scenarios presented reaches breakeven point before a period of 4 years, which could also be perceived as a highly encouraging factor.

One cannot, however, forget that Mozambique, like other countries in Africa, is highly exposed to natural catastrophes (strong rains, floods, hurricanes, etc.) which cannot be accounted for in this study and which would have a very strong impact on the CAPEX and OPEX, and in this way change the current beauty of the numbers.

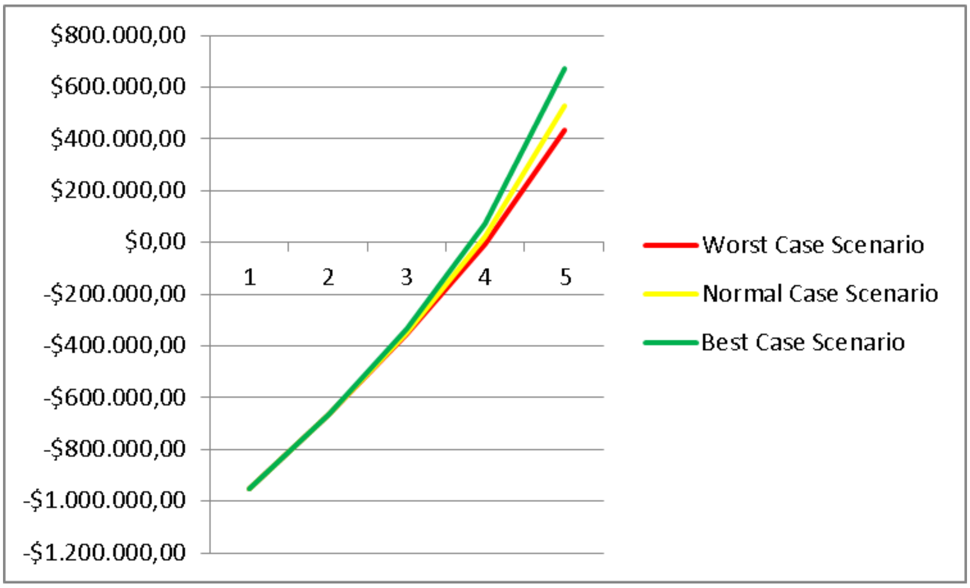

Chart 5 – Five Year Cash Flow

4.5.6 An Alternative Scenario

Whenever a new product, service, technology, etc., enters a market, there are always a number of possible scenarios which can be considered; there are even situations in which the market reaction exceeds expectations (positively or negatively).

However, for methodological purposes, we need to create limits and we have therefore created an additional scenario.

In this alternative scenario, we consider that the population reacts massively to the presence of communication solutions in remote and rural areas.

Considering that the 'contamination' effect happens and the number of users increases and, simultaneously, each user starts speaking for longer periods of time during the Busy Hour (BH), this will impact on the distribution for the three scenarios presented previously and results will then be as follow:

	Seconds of conv	Erlangs/user		
Worst Case Scenario	60	0,017		
Nº of users	2000	2500	3000	3500
Erlangs/sector	11,11	13,89	16,67	19,44
BTS Config.	333	333	444	444
	Seconds of conv	Erlangs/user		
Normal Case Scenario	90	0,025		
Nº of users	2000	2500	3000	3500
Erlangs/sector	16,67	20,83	25,00	29,17
BTS Config.	444	444	555	666
	Seconds of conv	Erlangs/user		
Best Case Scenario	120	0,033		
Nº of users	2000	2500	3000	3500
Erlangs/sector	22,22	27,78	33,33	38,89
BTS Config.	555	555	666	777

Table 20 – Evolution on Erlangs Vs Users

The graph below provides a clearer understanding of this effect:

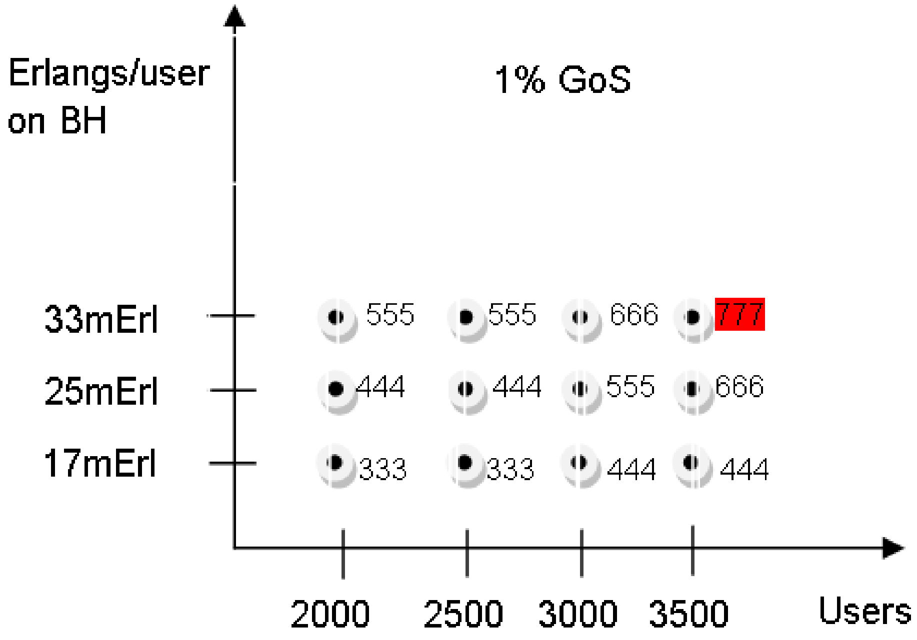

Chart 6 – Evolution on Erlangs Vs Users

As we can see, in the worst case scenario we would have an S777 configuration which would lead us to introduce a second BTS, considering that a normal BTS only reaches the maximum configuration of S666.

The initial study was carried out considering only one BTS and one site 2G with GPRS for financial reasons. However, should the number of users reach the values presented above, it would be necessary to carry out an analysis in order to better identify the origins of the traffic and then evaluate a different TRX distribution from the one initially proposed. It might also be necessary to install one or two additional sites in the proximities to improve coverage and efficiency and/or 3G and 4G.

This scenario would require a greater CAPEX as more sites would need to be constructed, but instead of using optical fiber, in such a case mini links could be the option, in this way reducing CAPEX. Secondary sites could have different structures to those presented here as they would be capacity sites and not coverage sites, hence the CAPEX reduction.

The same site could also incorporate different technologies (GSM and DCS) with traffic control software, in this manner also reducing CAPEX.

5. Conclusions and Final Considerations

This study addressed three main objectives which were defined considering the Mozambican reality, the challenges the country is currently facing at the level of telecommunications and the possibilities which research in the telecom sector have made available in order to overcome the very relevant issues which emerging markets, such as Mozambique, are faced with today.

Throughout these four sections, the most common challenges to the growth and expansion of telecom services were pointed out and discussed, with special reference to the Mozambican reality. Our knowledge of the country and of the telecom area encouraged us to pursue possible solutions which would not only contribute to overcoming telecom discrimination, but which also include a social dimension, i.e., an investment which would envision not only growth, but also development of the society in which it was implemented. For this reason, we selected what we believe would be the most interesting form of infrastructure sharing at this stage for the country. Considering the nature of this investment, we consider that continuous adjustments would be made in order to refine the model, the nature of the relationship between contracting parties, the type of benefits that operators could look forward to and the type of performance the state could expect from the operators in order to guarantee compliance with agreements and also with government policies in the area of social and technological development. Our proposal of a NOM should therefore be seen in a holistic manner.

In the attempt to avoid falling into a general discussion about telecom challenges in emerging markets, with special reference to the African reality which we are familiar with, in this study we set out to find a specific answer for a specific problem. The problem at the basis of our work was clearly identified: lack of telecommunications coverage in rural and remote areas of Mozambique which leads to the demographic discrimination of populations and communities that are scattered out over a very extensive and vast territory. With the fast and very significant development of the telecom sector over recent years, we analysed different possible answers to this problem, bearing in mind that the solution proposed should allow for immediate implementation and operation. The business models selected also took into account the specificities of the country in which the solution would be implemented. Based on these variables, we argued in favour of the potential of infrastructure sharing and of implementing a Neutral Operator Model.

When proposing the NOM for Mozambique, and when justifying the very important role we believe an NO and respective infrastructure sharing can play, we presented a financial approach to this investment which could benefit from a more detailed discussion with state entities and other potential investment partners.

Considering the technical benefits of choosing a neutral operator as a form of covering the more remote and rural areas, we argued in favour of a neutral operator that would include a state entity or a concession contract with a private entity operating under a concession contract with the state (incumbent). Here we highlighted the importance of analysing the feasibility of this project beyond the traditional financial denominators considering the fact that the context of implementation is that of an emerging market and that, ideally, all investment should also address a social dimension and encourage development and not only growth..

When arguing in favour of an investment in an emerging market, we believe that there is a social dimension that cannot be overlooked and which becomes a very relevant variable when we analyse the short, medium and long-term advantages for the client, i.e., the populations and the economy in general. The risk involved in any investment can be perceived in different ways by different entities with investment capabilities: a bank will have a lower tolerance to risk than an investment fund focused on investing in a specific area, in poor countries, accepting a risk that goes beyond that which an entity like a bank is capable of supporting. We therefore proposed that the investment in the NOM be approached in an ‘out of the box’ manner and as a possible area of interest for financial partners which might not be banks in order to go beyond the mere investment in telecom solutions and aiming at broader developmental goals that include access to the information society, investment in health and education, investment in basic infrastructure, encouragement of investment in remote and rural areas. From such a perspective, more than only contributing to the development of telecommunications, a project such as this one is undoubtedly an investment that focuses on more global goals.

Another finding which resulted from this study and which substantiates our opinion that an investment of this nature require social awareness is the fact that the payback period, or return on investment, will be far from attractive for the more common investor profile during the first 5 years. Our study revealed that the NPV would only be $255.424,08 and the IRR (TIR) 15,72%. The interest rates for more traditional investments in Mozambique can easily reach 14% (a deposit in a bank, for example) but if we talk about $1.000.000,00 investment can go to 17% or 18%, but the benefits for the populations and communities over this period of time would be significant. The access network sharing proposed could be used to:

- connect schools, hospitals, public entities and private companies to the Internet;
- encourage the development of different forms of reaching remote populations in areas which are fundamental to their development and the development of the country – e-platforms could be more easily implemented, current limitations created by distance and lack of communication could motivate different entities to expand their services in the health and business sectors;
- use fibre to implement IPTV and then Broadcast using the tower site

- current mobile telecom services will become accessible to populations, which immediately increases the motivation to broaden services which are available in more populated areas (banking services, pre-paid credit services for mobile communication and electricity services, among others)
- envisioning the advantages of infrastructure sharing could be the starting point for other businesses and entities to share this approach to reach more remote areas in order to benefit all parties involved and simultaneously local communities

We have repeatedly insisted on the importance of understanding investment in emerging markets in more than an exclusively financial manner, although we are aware that investments are made in order to generate profit. However, there are already many different entities operating in Africa who are capable of supporting the risk involved in such investments. The cultural variables must therefore be included in the feasibility study in order to better adapt the technological solution to the Mozambican reality. This is also the reason we advocate the involvement of a state entity such as INCM that is not only familiar with government guidelines, but is also capable of guaranteeing that stakeholders are obliged to take into account local needs and expectations.

This study has opened up additional topics which we think would be interesting areas of study in the future, such as:

- a more detailed study of the financial and social implications and benefits of partnerships between the state and private sector
- understanding what projects are currently being implemented in Mozambique that require the existence of a more extensive mobile telecommunications network
- study of the existing legal framework for Mozambique and its adequacy to the integration of future technological solutions such as the one proposed in this work.

It is our hope to have contributed to a discussion for telecom solutions for Mozambique, a country we believe has the conditions to start improving

References

[1] Workgroup reflexion infoDev from ITU: http://www.ictregulationtoolkit.org/en/Section.3192.htm , accessed on 07-07-2014.

[2] Louay Abou Chanab, Bahjat El-Darwiche, Ghassan Hasbani and Mohamad Mourad, "Telecom Infrastructure Sharing- Regulatory Enablers and Economic Benefits", 2007, http://www.strategyand.pwc.com/media/file/Telecom_Infrastructure_Sharing_Regulatory_Enablers_and_Economic_Benefits_FINAL.pdf
accessed on 17-07-2014

[3] On the Role of Infrastructure sharing for Mobile Network Operators in Emerging Markets http://arxiv.org/ftp/arxiv/papers/1211/1211.7113.pdf, accessed on 04-04-2014.

[4] The Policy, Legal and Regulatory Lessons http://www.africaneconomicoutlook.org/en/theme/ict-africa/the-policy-legal-regulatory-lessons/», accessed on 01-06- 2014.

[5] Wi-Fi Neutral Operator: Promoting cooperation for network and service growth http://109.69.9.58/wp-content/uploads/2011/10/ITSInfanteOliverMacianv2.pdf accessed on 05-04-2013.

[6] Mobile Infrastructure Sharing http://www.gsma.com/publicpolicy/wp-content/uploads/2012/09/Mobile-Infrastructure-sharing.pdf accessed on 04-04-2013.

[7] Measuring Information Society http://www.itu.int/en/ITUD/Statistics/Documents/publications/mis2013/MIS2013_without_Annex_4.pdf accessed on 05-04-2013.

[8] "Regulamento de Partilha de Infra-estruturas Passivas de Telecomunicações em Moçambique" Decree-law 62/2010, dated December 27

[9] ITU Asia Pacific Centres of Excellence Training Course OnInfrastructure Sharing http://www.itu.int/ITU-D/asp/CMS/ASP-CoE/2010/InfraSharing/S1.pdf accessed on 10-06-2013

[10] Crucial economics for mobile data backhaul http://smallcells.com/SenzaFili_BackhaulTCO.pdf accessed on 01-06- 2014.

[11] Infrastructure sharing in practice: sharing mobile networks http://www.itu.int/ITU-D/asp/CMS/ASP-CoE/2010/InfraSharing/S12.pdf accessed on 04-04-2013.

[12] Economics of Shared Infrastructure Access http://stakeholders.ofcom.org.uk/binaries/consultations/wla/annexes/csmg.pdf accessed on 27-10-2012.

[13] Mobile Sharing http://www.itu.int/ITU-D/treg/bestpractices.html accessed on 10-10-2010.

[14] Telecom Infrastructure Sharing
http://www.booz.com/media/file/Telecom_Infrastructure_Sharing_Regulatory_Enablers_and_Economic_Benefits_FINAL.pdf

[15] Telecom Regulatory authority of India- RecommendationsTelecommunications on Infrastructure Policy
http://www.trai.gov.in/WriteReadData/Recommendation/Documents/Rec_Infrastructurel.pdf accessed on 04-04-2013.

[16] Mobile Sharing
http://www.itu.int/ITUD/treg/Events/Seminars/GSR/GSR08/discussion_papers/Camila_session4.pdf accessed on 04-04-2013.

[17] J. U. Sverzut, Redes GSM, GPRS, EDGE e UMTS, 1st ed. São Paulo, SP: Editora Érica, 2005

[18] Lawrence K. Vanston and Ray L. Hodges, “Technology forecasting for telecommunications”, Telektronikk, Abril de 2004

[19] M.O. Duarte, “Modelos de previsão: adopção e abandono de tecnologias e produtos; evolução do preço de um produto em função do seu grau de maturidade”, Setembro 2011

[20] M.O.Duarte, “Techno-Economic Analysis in Telecommunications”, Study Notes, Universidade de Aveiro, 2013