ICT-777137

5G-RANGE

5G-RANGE: Remote Area Access Network for the 5th Generation

Research and Innovation Action

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Deliverable D7.2 - Exploitation, communication, dissemination and standardization – Part II

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Abstract

This deliverable describes (i) The Total Addressable Market (TAM) of unconnected population in Brazil, based on the methodology presented in the previous deliverable (7.1); (ii) The translation of this TAM to financial terms with a Business Case Model; (iv) The regulatory aspects being addressed by Brazilian Agency of Telecommunication (ANATEL); (v) The exploitation, communication and dissemination of the project results; (vi) Standardization activities proposal for the project.

Target audience

The primary target audience has been deemed as confidential.

Impressum

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Work Package leaders:	Carlos Sallé, TID (EU), Maria Valéria Marquezini, EDB (BR)
Project Co-ordinators:	Marcelo Bagnulo, UC3M (EU), Priscila Solis, UnB (BR)
Technical Managers:	Peter Neuhaus, TUD (EU), Luciano Mendes, Inatel (BR)

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Executive Summary

Work Package 7 has two main objectives: i) measure the opportunity of connecting the unconnected for Brazil and defining new alternative scalable business models to deploy networks in ultra-low density areas, and ii) strengthen the impact of the 5G-RANGE project through specific exploitation-oriented activities, communication and dissemination of project information and project results and contributions to standards. This deliverable makes the sizing of the Total Addressable Market (TAM) for the rural unconnected people in Brazil and its translation into financial terms, as well as presents dissemination activities and standardization plans of the 5G-RANGE Project.

Using the data-based methodology to estimate the amount and distribution of unconnected population in a given country presented in previous document (deliverable D.7.1, [1]), the TAM in Brazil has been estimated. The results show that around 14 million unconnected people for a given Mobile Network Operator (MNO), most of which are Greenfield (meaning there is no 2G in that given area) and a small amount is Overlay (meaning that there is 2G in that area). Also, there is a total of around 34.000 settlements where the 14 million people live (roughly 450 people per settlement). According to the adopted methodology, around 23.000 4G sites should be deployed to cover the whole opportunity. However, there is an uneven distribution of the opportunity: less than 37% of the sites concentrate more than 75% of the opportunity.

In terms of network deployment, two main use cases where 5G-RANGE technology could be used were selected:

1) Use Case 1 – Direct Connectivity: Full deployment of 5G-RANGE as Radio Access Network (RAN) technology and only as RAN technology;
2) Use Case 2 – Backhaul Connectivity: Full deployment of 5G-RANGE as Backhaul technology and only as Backhaul technology.

The real implementation may be a hybrid of both, for it can be deployed as RAN technology in some places and as Backhaul in others. However, since there are no objective criteria to decide for one or the other, they are analyzed separately. Simulation numbers show 5G-RANGE could attack 11 million out of the 14.7 million with direct connectivity. Doing this would require deploying almost 700 5G-RANGE sites (with several sectors each). For Backhaul deployment, the population around the selected 5G-RANGE sites is very similar (11 million people). However, in this case, only around 6 million can be connected because of the limitations of 4G sectors per 5G-RANGE site. This opportunity would require deploying roughly 700 5G-RANGE sites and around 6.000 LTE sites. The presented lower TAM does not imply lower number of connected people since penetration of standard vs non-standard service will play a big role.

Based on the TAM, the translation into financial impact (what is usually referred to as the Business Case of an opportunity) can be done. It means modelling how deploying 5G-RANGE would work: costs incurred, revenues generated, etc. Once all the inputs and hypotheses have been introduced into the model and it has been properly tuned, it is analyzed the Profit and Loss (P&L) of that business, which gives information about its financial impact. Results show a fair split of the value generated by this opportunity between the Rural Mobile Infrastructure Operator (RMIO) and the MNO in both use cases and two considered scenarios (Optimistic and Realistic). Also, as could be expected, although Use Case 1 (Direct Connectivity) and Use Case 2 (Backhaul Connectivity) have similar Paybacks, Use Case 2 is more capital intensive than Use Case 1.

Since 5G-RANGE technology is originally proposed to operate in TV White Space (TVWS) unlicensed spectrum, it is extremely impacted by TVWS regulation. Due to early stage of development in some regions, TVWS regulations around the world are not harmonized yet. It is therefore important to understand the differences of the different regulations and the rationale behind them so that better White-Space Devices (WSDs) can be designed to tackle the needs of various regions and applications. Specifically, in the case of Brazil the WSD regulation is in progress with no fixed decisions yet.

Regarding the WSD Regulatory Impact Analysis, two main aspects are being addressed by National Telecommunications Agency of Brazil (ANATEL):

1) Spectrum allocation and licensing regime: the purpose is to promote the expansion of the telecommunications services that make use of radio frequencies, without harmful interference on the existing systems. A problem that has been identified is the fact that there is currently no possibility of using WSD systems for the expansion of telecommunications services mainly in rural areas, given the lack of normative forecast, which has been limiting the most efficient use of the spectrum;
2) Device and geolocation database administration: the goal is to create conditions for the development and implementation of geolocation databases to be used by WSD. The problem to be solved is the development of a method that ensures the protection of the systems that operate in the VHF and UHF bands, in case of the implementation of WSD technology.

Other requirements that are being considered by ANATEL in the WSD regulation are:

- Establish a population criterium to select the municipalities that the use of WSD would be allowed;
- Consider WSD as a short-range device, in order to have a license free regime;
- Consider the use of geolocation database together with spectral sensing methods to identify the available radiofrequency blocks in a given locality;
- Provide that technical criteria will be created by means of technical requirements (e.g., specific technical requirements of the geolocation database, maximum power, spurious and out-of-band emissions limit).

5G-RANGE project is following the TVWS regulatory actions being conducted by ANATEL and working on opportunities to influence the rules definition to be adopted in Brazil.

Regarding the second project objective to strengthen the impact of the 5G-RANGE project through specific exploitation-oriented activities, we have produced 34 dissemination contributions over the last 12 months, varying from conference attendance, journal papers, standardization activities, speaker panels, webinars, workshops, press releases and presentations, to name a few.

In terms of standardization, during this deliverable, the work has been focused on identifying 5G-RANGE opportunities in 3GPP standardization body. 5G-RANGE introduces new services, that could include long-range, remote area broadband access network services, resulting new marketplace, or new business model. Considering the new RAN architecture, there is the inclusion of cognitive function in the 5G NR system. In this way, the consortium identified three subjects can be considered prominent for approach in the standardization process strategy: (1) Long-range, remote area broadband access, (2) Unlicensed access and (3) New services and architecture involving RAN. In addition, we have submitted a contribution describing the receiver driven less than best effort mechanism defined by 5GRANGE to the Internet Congestion Control Research Group (ICCRG) at the Internet Research Task Force (IRTF). The proposed draft was presented in two ICCRG meeting and in the last meeting it was decided to accept the draft as working group item, the first but most critical step toward turning the document into an RFC.

The next deliverable for Work Package 7 is going to be an extension of the current document which aims to conclude all ongoing activities, consolidating all results on exploitation, communication, dissemination and standardization during the project cycle.

List of Authors

André Mendes Cavalcante (Ericsson - EDB)

Carlos Sallé Moreno (TID)

Jorge Seki (CPqD)

Maria Valéria Marquezini (Ericsson - EDB)

Nathália Figueiredo (CPqD)

Marcelo Bagnulo (UC3M)

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Definitions and abbreviations

3GPP	Third Generation Partnership Project
5G	5th generation wireless systems
ANATEL	National Telecommunications Agency of Brazil
ARPU	Average Revenue per User
B2B	Business-to-Business
BR	Brazil
CAPEX	Capital Expenditure
CPE	Customer-Premises Equipment
EBIT	Earnings Before Interest and Taxes
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
ECC	Electronic Communications Committee
FCC	Federal Communications Commission
FCF	Free Cash Flow
Hz	Hertz
IMT-2020	International Mobile Telecommunication system - 2020
Inatel	National Institute of Telecommunications
IoT	Internet of Things
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LAA	Licensed Assisted Access
LTE	Long Term Evolution
MAC	Medium Access Control
MBB	Mobile Broadband
MIMO	Multiple-Input and Multiple-Output
mMIMO	massive MIMO
mMTC	massive MTC
MNO	Mobile Network Operator
MTC	Machine Type Communications
NPV	Net Present Value
NR	New Radio
NW	Network
O&M	Operations & Maintenance
Ofcom	Office of Communications (UK regulator for telecommunication/postal)
OOB	Out-of-Band
OOBE	OOB Emission
OPEX	Operational expense
OTT	Over The Top
P&L	Profit and Loss
PHY	Physical layer
PoC	Proof of Concept
QoS	Quality of Service
RMIO	Rural Mobile Infrastructure Operator
TAM	Total Addressable Market
Telco	Telecommunications company
TVWS	TV Whitespace
UE	User Equipment
UHF	Ultra-High Frequency
VHF	Very-High Frequency
WS	White Space
WSD	White Space Device

1 Introduction

Work Package 7's goal is to measure the opportunity of connecting the unconnected in Brazil and defining new alternative scalable business models applicable in Brazil and potentially in other countries across Latin America and Europe, leveraging local communities and entrepreneurs that would fast and profitably deploy networks in ultra-low density areas whilst having high capillarity for network operations and commercialization. This starts by identifying all the show-stoppers on a systematic way and design the business mechanisms that create the right incentives to foster a massive adoption by local entrepreneurs.

A second objective of the work package is to strengthen the impact of the 5G-RANGE project through specific exploitation-oriented activities, communication and dissemination of project information and project results and contributions to standards.

As such the specific objectives of this Work Package are the following:

- Identify the main show stoppers, including a regulatory analysis, to implement alternative business models in low density unconnected areas
- Define a business model for connecting the unconnected, including a deep study of the processes, activities, investments, costs and expected revenues, using Brazil as an illustrative example
- Create a business case for each of the stakeholders in a scenario of traditional deployment (radio access network owned by incumbent) and in alternative model (Rural Operator owns the RAN);
- Communication of project information including achievements, results, events and other related information via websites, press releases and other media coverage.
- Dissemination of project results via scientific publications, white papers and demonstrations of the 5G-RANGE prototypes;
- Organization of events and workshops to increase the visibility of the project results;
- Promotion of the project results in targeted standardization bodies;
- Foster and promote commercial exploitation of the project output and its assets.

The analysis for all sections is applicable to any unconnected area worldwide (many covered by European operators), although all the detailed analysis has been focused on Brazil due to the relevance in terms of untapped opportunity and the wide casuistic found due to its extension and diverse and challenging geography.

Due to the gradual build-up defined to the deliverables of this Work Package, where each future Milestone looks to add to previous work done on an incremental manner until the final deliverable in Month 30, this deliverable is an extension of the previous document (deliverable D.7.1, [1]), aiming to expand in various areas, in particular: (1) the alternative business models explored and the outputs of the data analysis to measure the rural unconnected opportunity in Brazil, (2) the regulation aspects for White-Spaces (WSs) unlicensed spectrum usage that are being considered by National Telecommunications Agency of Brazil (ANATEL), (3) the dissemination activities developed by the project in its second year, and finally, (5) introduces the standardization activities, focused on the related 3GPP technical documents related to long range coverage and in the IETF/IRTF regarding the contributions in receiver driven congestion control.

2 Business Case

In this Work Package's previous deliverable (D.7.1), we introduced a data-based methodology to estimate the amount and distribution of unconnected population in a given country. This methodology leverages data with information around demography (where do people live?), coverage (where is there 2G, 3G and/or 4G service?) and infrastructure (how far away is a given settlement from the nearest point of presence?) to estimate the best way to tackle the deployment of new connectivity where required. In the following paragraphs we will show the results of this methodology applied to Brazil.

Once all the data has been gathered, cleaned, validated and integrated, we are ready to estimate the business impact of the solution proposed by the 5G-RANGE consortium. Moreover, thanks to the figure of the Rural Mobile Infrastructure Operator (RMIO), we can model this impact assuming the deployments happened under this business model. The goal of this section is to present:

i. The results drawn by the methodology in terms of Total Addressable Market (TAM) for a Mobile Network Operator (MNO) and an ecosystem of RMIOs;
ii. Where the solution should be deployed to cover the unconnected opportunity in Brazil for an MNO with the help of one/several RMIOs;
iii. What is the financial result of deploying this solution with this business model.

Throughout this whole section, we will assume the role of an MNO that intends to tackle its unconnected opportunity with the help of the RMIO figure.

2.1 Total Addressable Market

2.1.1 Overall results for Brazil

In order to estimate the Total Addressable Market (TAM), the methodology explained in Work Package (Report D.7.1) [1] is used. As a reminder, this methodology generates insights after gathering data about:

i. Population in Brazil
ii. Infrastructure of the MNO (and other players if available)
iii. Coverage (2G, 3G and 4G) of the MNO

Once this data has been integrated, the methodology generates the needed insights around the opportunity. For this exercise, where we take the role of an MNO, the numbers drawn by the methodology are shown below. It is important to highlight that, although this is a more robust bottom-up methodology, the results have been validated with different classical top-down methodologies for TAM estimation.

From the numbers shown in Table 1, the TAM in Brazil is around 14 million unconnected people for a given MNO, most of which are Greenfield (meaning there is no 2G in that given area) and a small amount is Overlay (meaning that there is 2G in that area). We can also see from the numbers that there is a total of around 34.000 settlements where the 14 million people live (roughly 450 people per settlement), which shows some of the scattering problems mentioned in [1]. Also, according to the methodology, around 23.000 4G sites should be deployed to cover the whole opportunity. Figure 1 shows the TAM distribution map in Brazil according to Table 1.

Table 1 - Total addressable market for rural areas in Brazil.

	Population	# Settlements	# 4G sites
Greenfield	14.605.359	33.799	23.034
Overlay	130.838	332	87
Total	**14.736.197**	**34.131**	**23.121**

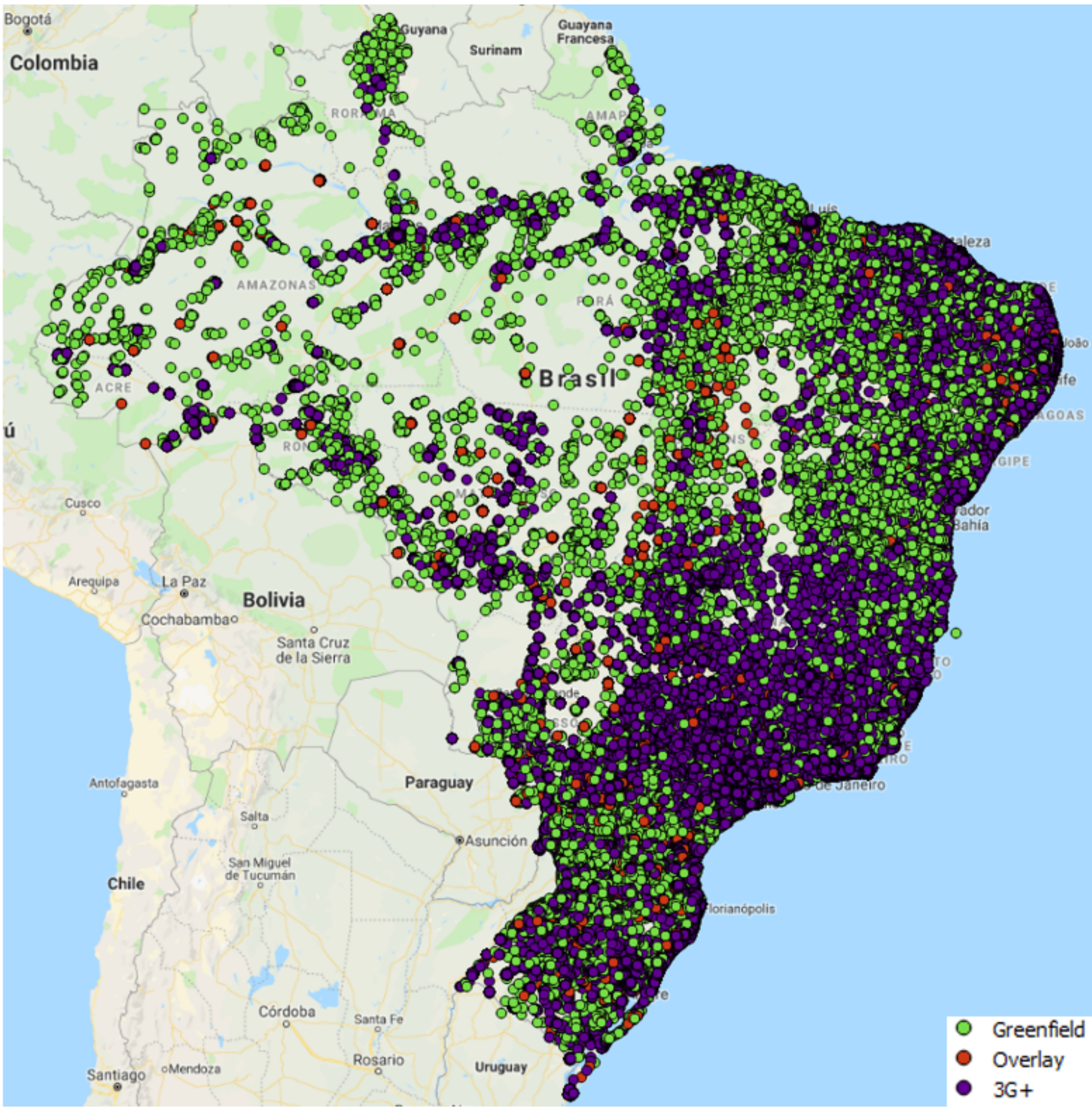

Figure 1 - Distribution map of TAM in Brazil.

Table 2, Figure 2 and Figure 3 show more detail around the distribution of the opportunity. As we can see, there is an uneven distribution of the opportunity: less than 37% of the sites concentrate more than 75% of the opportunity.

Table 2 - Distribution of the opportunity in Brazil.

Site population	# Sites	Population	% sites	% population
> 10000	67	968.369	0,3%	6,6%
5000-10000	217	1.471.491	1,2%	16,6%
1000-5000	2688	4.874.018	12,9%	49,6%
500-1000	5573	3.823.691	37,0%	75,6%
100-500	12025	3.471.851	89,0%	99,1%
0-100	2551	126.777	100,0%	100,0%

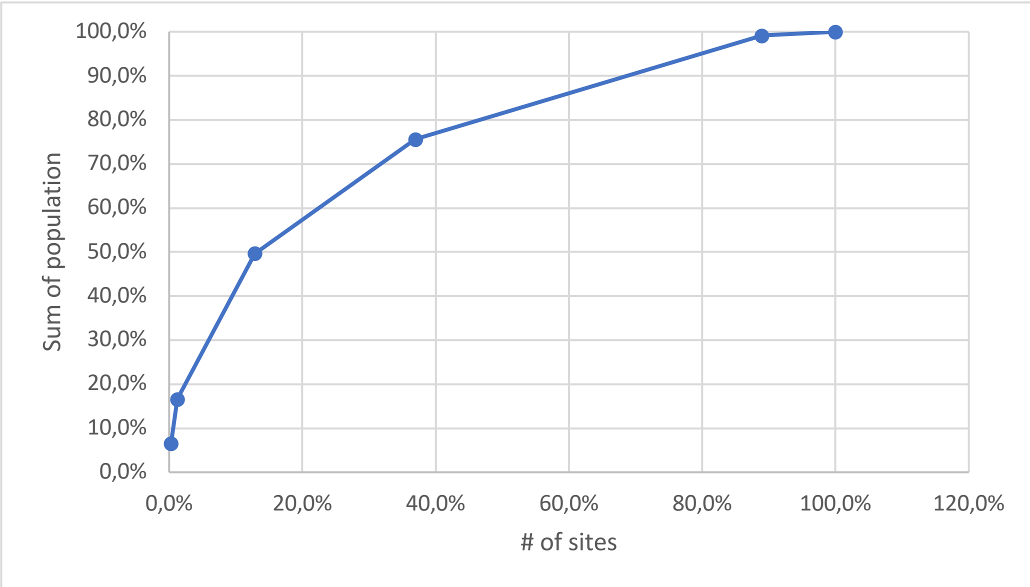

Figure 2 - Cumulative distribution function (CDF) of TAM.

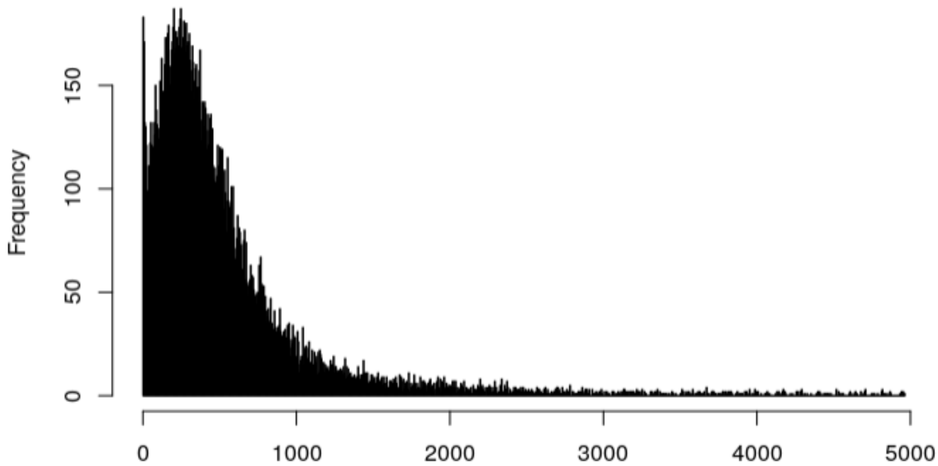

Figure 3 - Size of cluster distribution: X-axis – population served by a site, Y-axis – Frequency of occurrences of X.

Now that the TAM is sized, we can simulate how to tackle it with 5G-RANGE's solution.

2.1.2 Deployment of 5G-RANGE

2.1.2.1 Use cases considered and structure

In this project, there are four core use cases identified where 5G-RANGE technology could be used:

i. **Direct connectivity (voice & data)** – users purchase devices compatible with 5G-RANGE and they connect directly to the solution. In this case, the technology would be used as RAN.
ii. **Backhaul connectivity** – the technology would provide backhaul to standard 4G sites. Users would use standard LTE devices to connect to voice & data services
iii. **e-Health** – the connectivity provided enables e-Health products and services
iv. **Smart Farming** – the connectivity provided enables Smart Farming products and services

There is a big difference between use cases (i) and (ii) with respect to use cases (iii) and (iv). The first two impact the very way that connectivity is provided, while the latter are Over-The-Top (OTT) services, agnostic to how connectivity is provided. In short, as long as there is connectivity, both OTT use cases will happen. On the other hand, use case (i) and use case (ii) differ on how to use the technology and using one implies not using the other.

To account for this, we have structured this section in two different lines:

3) Full deployment of 5G-RANGE as RAN technology and only as RAN technology
4) Full deployment of 5G-RANGE as Backhaul technology and only as Backhaul technology

In the first line, we will be analyzing use cases (i), (iii) and (iv), while in the second line we will analyze use cases (ii), (iii) and (iv). The real implementation may be a hybrid of both, for it can be deployed as RAN technology in some places and as Backhaul in others. However, since we have no objective criteria to decide for one or the other, we will analyze them separately.

2.1.2.2 Direct Connectivity

This use case assumes that 5G-RANGE will be used as Access technology. The main advantage of this scenario is that 5G-RANGE technology could provide voice & data connectivity as far as 50 kilometers away from the site. With this in mind, the goal of this section is to determine how much of the TAM could be tackled with this technology and where the technology should be deployed.

To do this, we have used a variation of the general clustering methodology presented in previous sections of this document. In this case, we look to locate all 5G-RANGE deployments in such a way that we minimize the number of sites deployed to cover the maximum amount of population. There are two further constraints to add with respect to the general clustering methodology:

i. The coverage radius is now 50 kilometers instead of the 1-5 km of standard 4G (LTE)
ii. The site should be deployed somewhere where high capacity is guaranteed (i.e. near a Fiber PoP) so that we can give connectivity to all the unconnected people contained in the coverage area

With these specifications in mind, the results of the simulation are shown in Table 3.

Table 3 - Total Opportunity for Use Case 1 – Direct Connectivity.

Total Opportunity for Use Case 1 - Direct Connectivity			
With existing infrastructure			
	# sites	**population**	**pop. / site**
Huge - +50.000	17	1.459.771	85.869
Big - 10.000 - 50.000	45	956.322	21.252
Medium - 5.000 - 10.000	18	138.805	7.711
Small - 0 - 5.000	107	141.718	1.324
Without existing infrastructure			
	# sites	**population**	**pop. per site**
Huge - +50.000	55	4.207.428	76.499
Big - 10.000 - 50.000	132	3.234.417	24.503
Medium - 5.000 - 10.000	70	503.494	7.193
Small - 0 - 5.000	253	383.279	1.515
Total - with + without infrastructure			
	# sites	**population**	**pop. per site**
Huge - +50.000	72	5.667.199	78.711
Big - 10.000 - 50.000	177	4.190.739	23.676
Medium - 5.000 - 10.000	88	642.299	7.299
Small - 0 - 5.000	360	524.997	1.458
Total - All segments	**697**	**11.025.234**	**15.818**

As the numbers show, 5G-RANGE could attack 11 million out of the 14.7 million with direct connectivity. Doing this would require deploying almost 700 5G-RANGE sites (with several sectors each). Figure 4 shows a specific area where there are several 5G deployments.

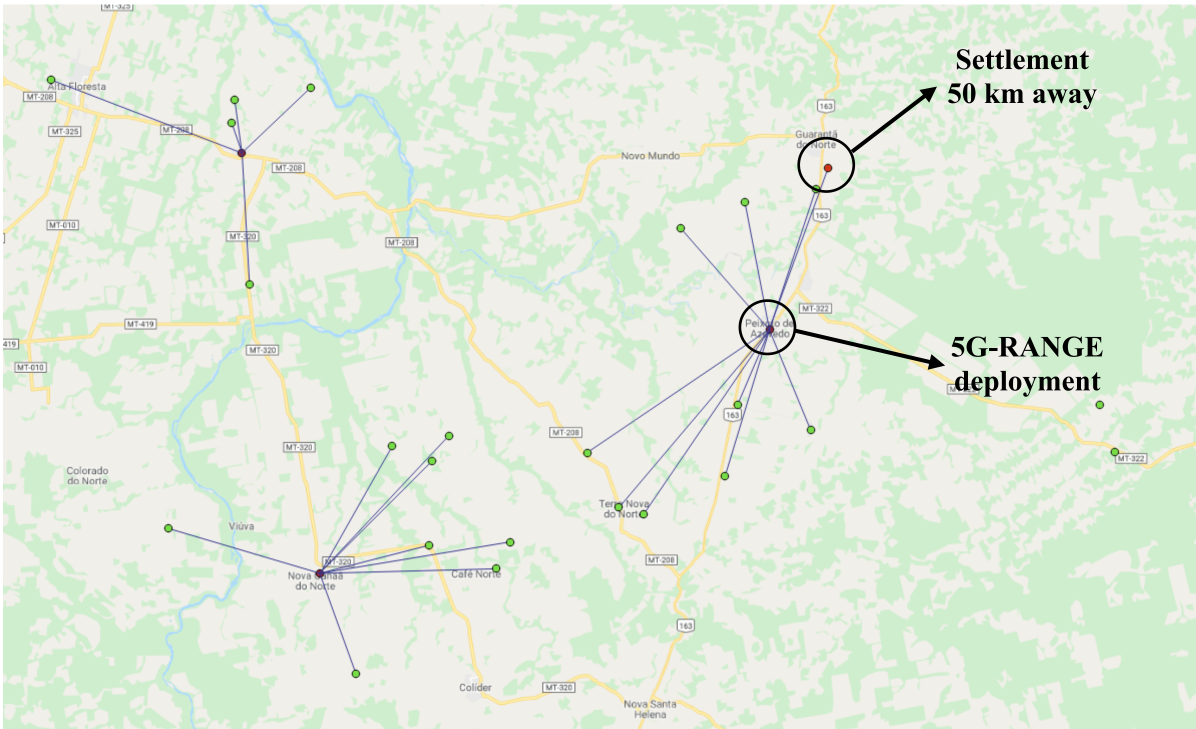

Figure 4 - Clusters of 5G-RANGE Direct Connectivity.

After seeing the first results, the opportunity was segmented based on the amount of unconnected population covered by the specific site. We have defined four different segments for a specific 5G-RANGE deployment based on size:

i. **Huge**: unconnected population at 50 km higher than 50.000 people
ii. **Big**: unconnected population at 50 km between 10.000 and 50.000 people
iii. **Medium**: unconnected population at 50 km between 5.000 and 10.000 people
iv. **Small**: unconnected population at 50 km lower than 5000 people

We have added an extra segmentation variable, which is the existence of infrastructure in the location selected. This has a big impact in costs and whenever possible we should use existing infrastructure.

This segmentation will allow us to determine which segments are more interesting to deploy and which ones should be discarded.

2.1.2.3 Backhaul Connectivity

This use case assumes that each 5G-RANGE deployment will provide backhaul to standard 4G sites. This is different from the previous use case since the service provided is different (in this case, users could use standard LTE phones to connect while in the previous one this would not be possible) and for each 5G-RANGE site deployed, there are a number of 4G sites to deploy. Therefore, this use case is more complex in terms of execution, financing and modelling although at the end it provides a more standard service. We will see the effects of this in the business case.

To obtain the numbers for this use case, the clustering methodology is very similar to the one presented in the first use case, with the following variations:

i. Instead of creating clusters where the centroid is a 5G-RANGE site and the nodes are settlements, the settlements will be replaced with 4G sites (corresponding to the standard clusters presented in previous sections of this document)
ii. Each 5G-RANGE site has a limitation of the number of 4G sectors it can connect. We will show this later in detail, but the current results assume a maximum of 20 4G sectors per 5G-RANGE site.

With these specifications in mind, the results of the simulation are shown in Table 4.

Table 4 - Total Opportunity for Use Case 2 – Backhaul Connectivity.

Total Opportunity for Use Case 2 - Backhaul Connectivity						
With existing infrastructure						
	5G-RANGE Sites	Population 50 km	4G sites WI	4G sites WOI	Pop 4G sites WI	Pop 4G sites WOI
Huge - +50.000	16	1.360.650	0	224	0	555.586
Big - 10.000 - 50.000	44	966.090	12	583	13.908	584.749
Medium - 5.000 - 10.000	19	146.471	10	191	5.445	136.227
Small - 0 - 5.000	93	133.302	6	448	1.391	130.101
Without existing infrastructure						
	5G-RANGE Sites	Population 50 km	4G sites WI	4G sites WOI	Pop 4G sites WI	Pop 4G sites WOI
Huge - +50.000	55	4.255.729	1	769	1.454	1.764.040
Big - 10.000 - 50.000	135	3.294.065	4	1.830	10.911	2.049.825
Medium - 5.000 - 10.000	64	455.817	4	727	10.284	407.966
Small - 0 - 5.000	263	403.766	10	1.210	3.404	398.693
Total - with + without infrastructure						
	5G-RANGE Sites	Population 50 km	4G sites WI	4G sites WOI	Pop 4G sites WI	Pop 4G sites WOI
Huge - +50.000	71	5.616.379	1	993	1.454	2.319.626
Big - 10.000 - 50.000	179	4.260.155	16	2.413	24.819	2.634.574
Medium - 5.000 - 10.000	83	602.288	14	918	15.729	544.193
Small - 0 - 5.000	356	537.068	16	1.658	4.795	528.794
Total - All segments	**689**	**11.015.890**	**47**	**5.982**	**46.797**	**6.027.187**

Note 1: WI = With Existing Infrastructure; WOI = Without Existing Infrastructure
Note 2: WI means there is a tower at least 50-m high for 5G-RANGE, and there is an access tower for 4G nodes

As the numbers show, the population around the selected 5G-RANGE sites is very similar (11 million people). However, in this case, only around 6 million can be connected because of the limitations of 4G sectors per 5G-RANGE site. We will see later that lower TAM does not imply lower number of connected people since penetration of standard vs non-standard service will play a big role. This opportunity would require deploying roughly 700 5G-RANGE sites and around 6.000 LTE sites. As a clarification, the TAM is distributed as follows: (i) Total TAM (14M) → (ii) TAM that can be tackled with 5G-RANGE with the 50-km radius (11M) → (iii) TAM that can be tackled after specific technical restrictions (11M for Direct Connectivity, 6M for Backhaul Connectivity). More details on this later.

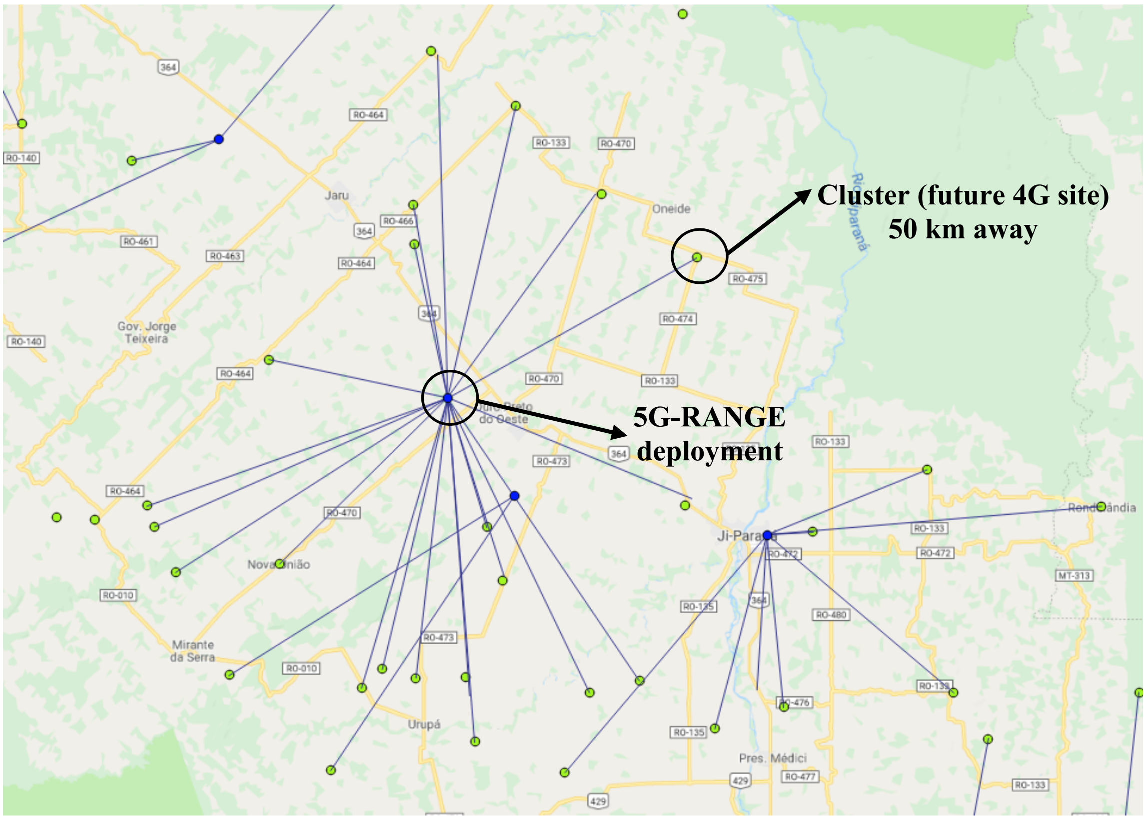

Figure 5 - Clusters of 5G-RANGE Backhaul Connectivity.

The same segmentation has been applied here, with additional information for each segment around the number of LTE sites needed for each one of them.

Table 5 summarizes the TAM results for direct and backhaul connectivity use cases.

Table 5 - Summary for TAM analysis for direct and backhaul connectivity use cases.

	Total	Direct Connectivity	Backhaul Connectivity
TAM	14.736.197	11.025.234	6.073.984
# 5G Range sites	-	697	689
# 4G sites	23.121	-	6.029

Bear in mind that although Direct Connectivity seems to have a higher TAM per site, the actual penetration of the service will be lower than that of standard 4G (LTE). More details on this in the following sections.

2.1.2.4 OTT Use cases

The previous paragraphs have described the main two use cases. The remaining two (eHealth and Smart Farming) are simpler to model. Throughout the whole industry, all Business-to-Business (B2B) OTT services are modeled as generating an income which is a proportional to standard B2B revenues. Therefore, if we know that usually IoT services provide 5% on top of B2B revenues and we have 1 million USD of gross yearly revenues, we can assume that IoT services produce 50.000 additional USD. This is how use cases (iii) and (iv) are modeled in this business case. The values have been tuned based on the experience of B2B areas.

2.2 Business Case Model

The goal of this section is to translate the previously presented TAM into financial impact (what is usually referred to as the Business Case of an opportunity). This means modelling how deploying 5G-RANGE would work: costs incurred, revenues generated, etc. In the following paragraph, we will be presenting the model, as well as the key inputs and assumptions and the final results. The end goal of this (and any) business case is to present the Profit and Loss (P&L) of that business, which gives information about its financial impact.

The current business case is structured in two main lines, as explained before:

i. **DirCon**, which refers to Use Case (i) of Direct Connectivity + OTT Use Cases (iii) and (iv)
ii. **BH**, which refers to Use Case (ii) of Backhaul Connectivity + OTT Use Cases (iii) and (iv)

Although in terms of measuring the financial impact, these lines are kept separate, the model is very similar for both of them.

Some important general notes about the model below:

- The business case models the scenario where an RMIO tackles the opportunity defined by an MNO. The RMIO executes the deployments, the MNO gets the gross revenues and there is a revenue share between both parties
- One of the goals is to ensure that the value generation is fair for both parties
- The time scope of the Business Case is 10 years
- As stated previously, OTT revenues are modeled as a mark-up on top of Gross B2B revenues
- The Business Case has been defined in such way that we can consider an optimistic and a realistic scenario by changing some of the key inputs and hypotheses

2.2.1 Model explanation

The general logic in the model is shown in the Figure 6.

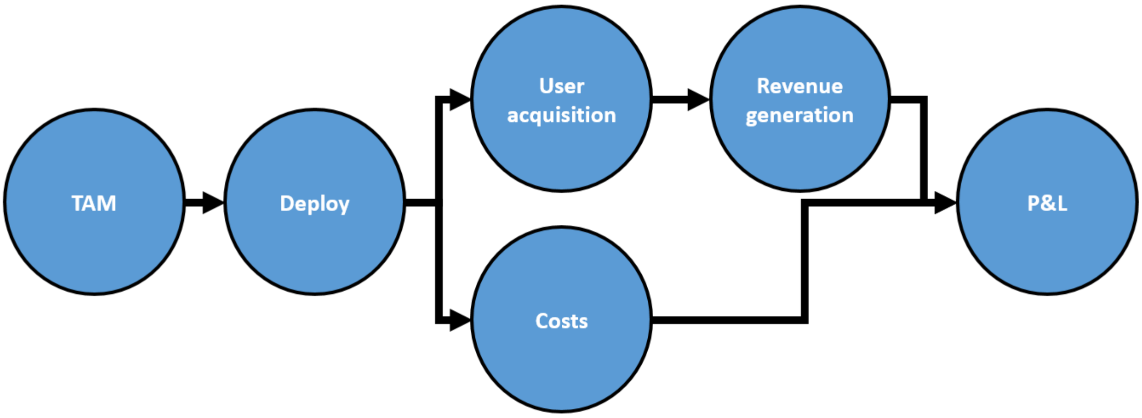

Figure 6 - General logic of the business case.

The starting point of the model is the TAM presented in the previous section. We will present the model for DirCon and then extrapolate to BH with some specific changes. Let us remind that the TAM for this use case was shown in Table 3:

Once the TAM is defined, the next step is to define the pace and structure at which the deployments will happen. In the Table 6 we can see an example of how the deployments of each segment for Use Case 1 could happen.

Table 6 - Deployment example of each segment for Use Case 1.

Use Case 1: Direct Connectivity (DirCon) - Deployments										
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
With existing infrastructure										
Deployments (%) - Huge	100%									
Deployments (%) - Big	80%	20%								
Deployments (%) - Medium		100%								
Deployments (%) - Small			100%							
Deployments (year) - Huge	17	0	0	0	0	0	0	0	0	0
Deployments (year) - Big	36	9	0	0	0	0	0	0	0	0
Deployments (year) - Medium	0	18	0	0	0	0	0	0	0	0
Deployments (year) - Small	0	0	107	0	0	0	0	0	0	0
Without existing infrastructure										
Deployments (%) - Huge	100%									
Deployments (%) - Big	80%	20%								
Deployments (%) - Medium		100%								
Deployments (%) - Small			100%							
Deployments (year) - Huge	55	0	0	0	0	0	0	0	0	0
Deployments (year) - Big	106	26	0	0	0	0	0	0	0	0
Deployments (year) - Medium	0	70	0	0	0	0	0	0	0	0
Deployments (year) - Small	0	0	253	0	0	0	0	0	0	0

This exemplary deployment plan would mean that all deployments would happen in the first three years (out of the ten considered in the scope of this Business Case) and that we would first deploy the bigger sites and then move towards the smaller. Both segments with and without existing infrastructure would be treated the same.

Since we know the unitary characteristics for each type of deployment (more on this later), such as unitary costs, unitary population covered, etc. we can model what are the costs that we will incur in during each year. Also, if we have the basic characteristics of the service provided (also more on this later) such as penetration, Average Revenue per User (ARPU), etc. we will be able to model the stream of revenues we will get thanks to the deployments done.

Once we have the costs and the revenues for all the years within the scope, we can directly obtain the P&L with some further information around things like taxes or Depreciation & Amortization (D&A) policies.

One of the main differences between Use Case 1 and Use Case 2 is that the characteristics of each 5G-RANGE site is different in terms of costs. Also, the penetration of 5G-RANGE connectivity will be modeled to be lower than standard LTE. Therefore, Use Case 1 will be less intensive in investment but will also generate fewer revenues while Use Case 2 will be more costly and also generate higher revenues.

2.2.2 Inputs & assumptions

In the following paragraphs, we will show the main inputs and assumptions used to model this Business Case.

2.2.2.1 TAM

The main assumptions to determine the TAM have already been explained in the methodology. Some further elements need to be highlighted, as shown in Table 7. These inputs come from internal knowledge from MNOs, internet sources and estimations or widespread heuristics in the industry.

Table 7 - Additional assumptions/inputs for TAM.

Inputs & Assumptions: TAM

Input	Y1	Y10
Minimum tower height needed to consider existing infra in 5G-RANGE deployments	50 m	50 m
USD vs BRL	4,17	3,75
% of pre-paid users in rural areas	76%	67%
Prize of KWh in Brazil in 2019	$ 0,18	$ 0,18
CAGR inflation of energy prizes in Brazil	8%	8%

2.2.2.2 Deployments

For both use cases, after a trial-and-error process based on our experience planning high-level rural deployments, we have determined that the best strategy is:

i. Not to deploy the segment 'SMALL' regardless of the existence of infrastructure
ii. Concentrate the deployments as much as possible in the first 2-5 years

The final deployment phasing for Use Case 1 and Use Case 2 based on the defined strategies are shown in Table 8 and Table 9, respectively.

Table 8 - Deployment phasing for Use Case 1.

Use Case 1: Direct Connectivity (DirCon) - Deployments				
	Y1	Y2	Y3	Y4
With existing infrastructure				
Deployments (%) - Huge	100%			
Deployments (%) - Big	80%	20%		
Deployments (%) - Medium		100%		
Deployments (%) - Small				
Without existing infrastructure				
Deployments (%) - Huge	100%			
Deployments (%) - Big	80%	20%		
Deployments (%) - Medium		100%		
Deployments (%) - Small				

Table 9 - Deployment phasing for Use Case 2.

Use Case 2: Backhaul Connectivity (BH) – Deployments	Y1	Y2	Y3	Y4
With existing infrastructure				
Deployments (%) - Huge	100%			
Deployments (%) - Big	25%	50%	25%	
Deployments (%) - Medium		25%	50%	25%
Deployments (%) - Small				
Without existing infrastructure				
Deployments (%) - Huge	100%			
Deployments (%) - Big	25%	50%	25%	
Deployments (%) - Medium		25%	50%	25%
Deployments (%) - Small				

2.2.2.3 Revenues

The assumptions in this section are critical to determine the dynamics of service adoption and revenue generation. Some of these inputs/hypotheses require further explanation:

i. **Penetration of Connectivity**: This penetration curve measures the % of the population that would eventually access MBB services. Usually this excludes very young and very old people and in rural Latin America this usually evolves from a 50-60% the first year of deployment to a 70-80% in the long term.

ii. **4G Adoption**: This penetration curve measures how many of the users who can access MBB would be able to use LTE. This accounts for access to LTE-compatible Smartphones, affordability, etc. In rural Latin America, this usually starts somewhere around 50%-60% the first years and reaches 100% in the long term (actually, when it is defined as number of SIM cards per person, it can reach values well above 100%. This is not considered here).

iii. **5G-RANGE Adoption**: This penetration curve is equivalent to the previous one, but applied to direct connectivity provided by a 5G-RANGE site. There is no historic data on this, so we have to make assumptions. One of the main limitations for penetration of connectivity is the compatibility of the devices (smartphones) with the connectivity. In this regard, there is yet no ecosystem of devices compatible with 5G-RANGE, so today the penetration would be somewhere around zero. For this business case, we assume that deploying 5G-RANGE would come together with the creation of compatible devices. We have estimated an optimistic curve that would start somewhere around 0.5% the first year and evolve until almost reaching 10%. This would mean that 10% of the people would be purchasing 5G-RANGE-compatible devices. The realistic curve accounts for the same but starts at 0.5% and ends at 7.5%.

iv. **ARPU**: the information from pre-paid and post-paid ARPU comes from a number of sources (internal as well as public) that measure ARPU for all countries and all customer segments.

v. **Revenues of OTT services**: these values are estimated from MNO's experience on how to model these kinds of services and the order of magnitude they generate.

Table 10 summarizes the inputs and assumptions for revenue.

Table 10 - Additional assumptions/inputs for Revenues.

Inputs & Assumptions: Revenues		
Input	**Y1**	**Y10**
Penetration of Connectivity (% of population who can access)	60%	78%
4G adoption (optimistic)	60%	100%
4G adoption (realistic)	50%	100%
5G-RANGE adoption (optimistic)	0,1%	10%
5G-RANGE adoption (realistic)	0%	7%
ARPU pre-paid (BRL/month/user)	11	12,26
ARPU post-paid (BRL/month/user)	40	44,57
RMIO Revenue share (% of gross revenues that go to RMIO)	70%	70%
Smart Farming Revenues (% on top of B2C Gross Revenues) - Optimistic	6%	15%
Smart Farming Revenues (% on top of B2C Gross Revenues) - Realistic	5%	12%
eHealth Revenues (% on top of B2C Gross Revenues) - Optimistic	5%	14%
eHealth Revenues (% on top of B2C Gross Revenues) - Realistic	4%	11%

2.2.2.4 Costs

In the Table 11, we present the main cost inputs for every element in the deployment and Operations & Maintenance (O&M) process of the RMIO and the MNO in this specific scenario. There are also some important hypotheses to highlight here (they are included in the Table 11 but some further explanations are in order):

i. **5G RAN Sizing**: in order to determine the amount of sectors needed for 5G-RANGE deployments, we have made some assumptions. First of all, we assume that there is enough capacity in the location (~300 Mbps). Second of all, the Consortium has determined that the optimal amount of sectors per site is 4. We have included this in the model and reduced the number of sectors to 3 for the cases of medium and small sites, to try and make them financially viable.

ii. **4G RAN Sizing**: Based on the distribution of population for each 4G site, and knowing the widespread heuristics in the telecom industry, we have determined that, on average, the 4G sites need 1.5 sectors.

iii. **5G-RANGE as Backhaul Sizing**: To determine how many 4G sites can be connected to each 5G-RANGE working as a Backhaul solution, we need to make several assumptions. First of all, we assume (based on industry rural standards) that we will be providing 15 Mbps per 4G sector (i.e. 22.5 Mbps per site). This means that we will be able to connect, assuming 300 Mbps available in the 5G-RANGE site, 20 LTE sectors per 5G-RANGE site, i.e. ~13-14 LTE sites per 5G-RANGE site.

Table 11 - Additional assumptions/inputs for Costs.

Inputs & Assumptions: Costs

Input	Y1	Y10
Capacity needed per 5G-RANGE site (Mbps)	300	300
Capacity per 4G sector (Mbps)	15	15
RAN sectors per 5G-RANGE site - Huge & Big	4	4
RAN sectors per 5G-RANGE site - Medium & Small	3	3
RAN sectors per 4G site	1,5	1,5
Max 4G sectors per 5G-RANGE node	20	20
Max 4G sites per 5G-RANGE site	13	13
Energy mix - off-grid for 5G-RANGE Huge & Big sites (%)	0%	0%
Energy mix - off-grid for 5G-RANGE Medium & Small sites (%)	0%	0%
Energy mix - off-grid for 4G sites (%)	25%	10%
CapEx - 5G-RANGE BTS (Optimistic) ($)	16500	13200
CapEx - 5G-RANGE BTS (Realistic) ($)	17250	13800
CapEx - 4G BTS ($)	10000	10000
CapEx - Infrastructure Huge & Big ($)	60000	60000
CapEx - Infrastructure - Medium & Small ($)	30000	30000
CapEx - Energy off grid - Huge & Big ($)	10000	10000
CapEx - Energy on grid - Huge & Big ($)	3000	3000
CapEx - Energy off grid - Medium & Small ($)	7000	7000
CapEx - Energy on grid - Medium & Small ($)	2000	2000
CapEx - 5G-RANGE CPE ($)	1500	1500
OpEx - Energy - 5G-RANGE - Huge & Big ($/year/sector)	432	432
OpEx - Energy - 5G-RANGE - Medium & Small ($/year/sector)	432	432
OpEx - Energy - 5G-RANGE CPE ($/year)	194	373
OpEx - O&M - 5G-RANGE ($/year/site)	16418	13135
OpEx - Energy - 4G ($/year/sector)	700	700
OpEx - O&M - 4G ($/year/site)	16418	13135
Taxes - % over EBITDA	30%	30%
D&A - Years to D&A new CapEx	10	10
MNO cost - Commercial channel commission (% of Gross Revenues)	15%	15%
MNO cost - HR (% of Gross Revenues)	10%	10%
MNO cost - IT upgrade - Optimistic (one-off $)	$ 2M	
MNO cost - IT upgrade - Realistic (one-off $)	$ 5M	

The following diagrams (Figure 7 and Figure 8) show the sizing issue in a more intuitive way.

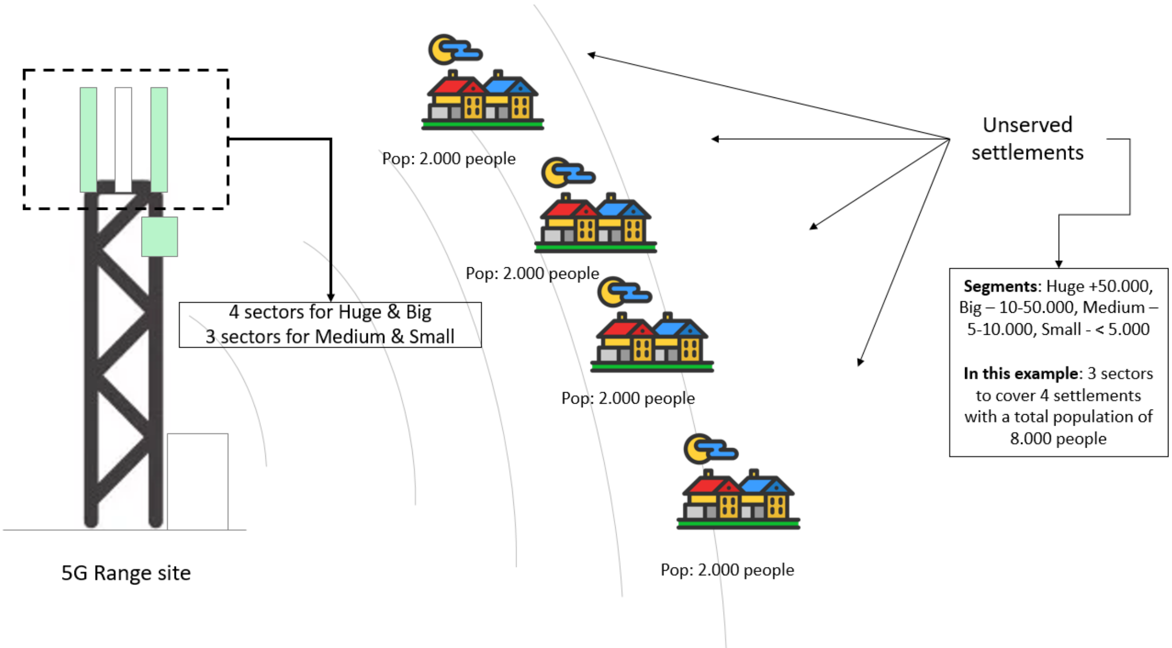

Figure 7 - Sizing example for Direct Connectivity.

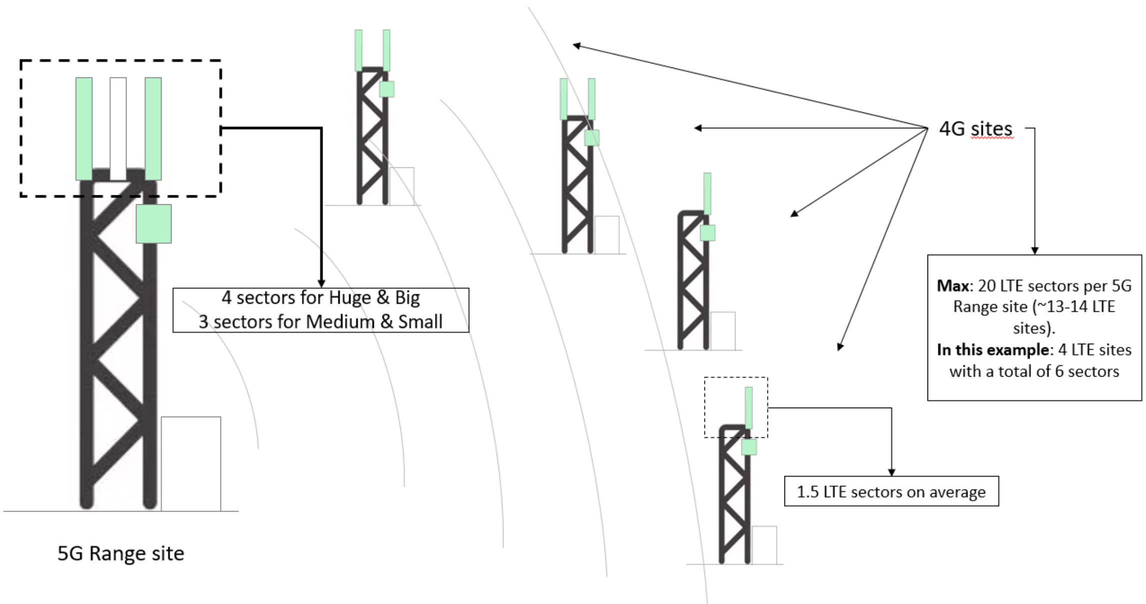

Figure 8 - Sizing example for Backhaul Connectivity.

2.2.3 Results

Once all the inputs and hypotheses have been introduced into the model and it has been properly tuned, the goal is to analyze the P&L sheet. In this section we present a summary of the results obtained for the different cases. Since putting all the outputs in this document would take up too much space, we display the final output for one of the cases (RMIO Optimistic P&L for Direct Connectivity) and then summarize all the results in a table.

The Figure 9 shows the P&L where, starting from Gross revenues we obtain EBITDA (- OpEx), EBIT (-D&A), Net Income (-Taxes) and FCF (+D&A – CapEx). A Net Present Value (NPV) analysis is also shown, that allows us to summarize the financial results throughout the 10 years and in perpetuity.

Figure 9 - RMIO Optimistic P&L for Direct Connectivity.

RMIO Business Case P&L	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Gross revenues	$112.965	$3.159.930	$7.532.444	$12.365.529	$17.780.891	$23.667.467	$30.182.710	$37.360.834	$45.236.912	$53.847.018
Operating Expenditures	$1.959.809	$4.762.818	$5.524.013	$5.247.364	$4.970.714	$4.970.714	$4.970.714	$4.970.714	$4.970.714	$4.970.714
EBITDA	-$1.846.844	-$1.602.888	$2.008.431	$7.118.166	$12.810.177	$18.696.752	$25.211.996	$32.390.120	$40.266.198	$48.876.304
D&A	$2.437.440	$3.488.428	$3.488.428	$3.488.428	$3.488.428	$3.488.428	$3.488.428	$3.488.428	$3.488.428	$3.488.428
EBIT	-$4.284.284	-$5.091.316	-$1.479.997	$3.629.738	$9.321.749	$15.208.324	$21.723.568	$28.901.692	$36.777.770	$45.387.876
Taxes over profit	$0	$0	$602.529	$2.135.450	$3.843.053	$5.609.026	$7.563.599	$9.717.036	$12.079.859	$14.662.891
Net income	-$4.284.284	-$5.091.316	-$2.082.526	$1.494.288	$5.478.696	$9.599.299	$14.159.969	$19.184.656	$24.697.910	$30.724.985
Capital Expenditures	$24.374.400	$10.509.880	$0	$0	$0	$0	$0	$0	$0	$0
FCF	-$26.221.244	-$12.112.768	$1.405.902	$4.982.716	$8.967.124	$13.087.727	$17.648.397	$22.673.084	$28.186.338	$34.213.413
FCF accumulated	-$26.221.244	-$38.334.012	-$36.928.110	-$31.945.394	-$22.978.270	-$9.890.543	$7.757.854	$30.430.938	$58.617.276	$92.830.689

NPV Analysis											
Years to discount		Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
WACC %	13%										
Discount rate		0,9	0,8	0,7	0,6	0,5	0,5	0,4	0,4	0,3	0,3
Terminal growth %	4%										
NPV FCF		-$23.204.641	-$9.486.074	$974.360	$3.055.993	$4.866.996	$6.286.278	$7.501.639	$8.528.704	$9.382.805	$10.078.873
Terminal Value											$395.354.994
NPV FCF	$17.984.933										
NPV Terminal Value	$116.466.975										
Total NPV	$134.451.907										
Payback (FCF accumulated > 0)	Less than 7 years										
Peak funding	$38.334.012										
Breakeven (FCF > 0)	Year 3										

The outputs of all the scenarios are summarized in Table 12 and Table 13 for the Direct Connectivity and Backhaul Connectivity use cases, respectively.

Table 12 - RMIO P&L results for Use Case 1 (Direct Connectivity).

Use Case 1: Direct Connectivity

	Optimistic		Realistic	
	RMIO	MNO	RMIO	MNO
Total NPV	$134.451.907	$12.105.318	$44.703.379	$3.133.466
Payback (FCF accumulated > 0)	Less than 7 years	Less than 5 years	Less than 9 years	Less than 9 years
Peak Funding	$38.334.012	$1.994.352	$41.535.491	$5.000.000
Breakeven (FCF > 0)	Year 3	Year 2	Year 4	Year 2

Table 13 - RMIO P&L results for Use Case 2 (Backhaul Connectivity).

Use Case 2: Backhaul Connectivity

	Optimistic		Realistic	
	RMIO	MNO	RMIO	MNO
Total NPV	$547.761.960	$81.081.468	$276.568.175	$59.107.482
Payback (FCF accumulated > 0)	Less than 7 years	Less than 2 years	Less than 8 years	Less than 3 years
Peak Funding	$184.279.303	$902.920	$212.322.726	$4.102.239
Breakeven (FCF > 0)	Year 4	Year 2	Year 4	Year 2

As we can see, there is a fair split of the value generated by this opportunity between the RMIO and the MNO in both use cases and both scenarios (Optimistic and Realistic). Also, as could be expected, although Use Case 1 and Use Case 2 have similar Paybacks, Use Case 2 is more capital intensive than Use Case 1. In this financial analysis, the spectrum issue is not explicitly considered due to the following reasons: firstly, the Direct Connectivity use case uses TVWS spectrum and does not need any further consideration. Secondly, although LTE spectrum would be used in the Backhaul Connectivity use case, we consider that this is an asset that the MNO already owns regardless of the new deployments. Along with brand, commercial channel, customer management, etc. it is one of the key assets brought to the table by the MNO, and is included in the revenue share.

3 Regulatory Aspects

3.1 Spectrum Regulation on TV White Spaces (TVWS)

Since 5G-RANGE technology is originally proposed to operate in TV White Space (TVWS) unlicensed spectrum, it is extremely impacted by TVWS regulation. Due to early stage of development in some regions, TVWS regulations around the world are not harmonized yet. In the previous released document of this Work Package (Report D.7.1) [1], we provided an overview and comparisons of the some TVWS regulations in the world that are relevant for this project, such USA, Europe and Brazil. Specifically, in the case of Brazil the WSD regulation is in progress with no fixed decisions yet. In this document, we focus in some updates about the TVWS regulatory actions being conducted by ANATEL and opportunities for 5G-RANGE project to influence in the definition of the rules to be adopted in Brazil.

3.1.1 Regulatory Agenda by National Telecommunications Agency (ANATEL)

In March of 2019, the Board of Directors from National Telecommunications Agency (ANATEL) had approved the new Regulatory Agenda for the biennium 2019-2020 [2]. This Regulatory Agenda contains all standardization actions that are being/will be conducted by ANATEL in the reference period. With the updates made through Ordinance No. 1371, of July 30, 2019 and Ordinance No. 1824, of September 9, 2019, the Regulatory Agenda 2019-2020, which originally contained 48 items, now has 50 items. 18 new initiatives and 32 initiatives in continuation of the previous biennium Agenda. Among them, the most important to this project are items 28 and 39, that relates to regulations for the dynamic use of the White Spaces (WS) in the bands of VHF and UHF and the regulation on short range devices, respectively. Table 14 shows the latest status of the such items in the Regulatory Agenda 2019-2020:

Table 14 - Status of the items #28 and #39 in the Regulatory Agenda 2019-2020.

Item	Project/Action	Situation at Sep. 30th, 2019	H1 2019	H2 2019	H1 2020	H2 2020
28	Regulations for the dynamic use of the White Spaces (WS) in the bands of VHF and UHF	Deliberation of public consultation proposal (Rapporteurship)	N/A	Public Consultation		Final Approval
39	Revision of the bands arranged in the regulation on short range devices (SRD)	Public Consultation	Report on Regulatory Impact Analysis	N/A	Conclusion of Public Consultation	

3.1.1.1 WSD Regulatory Impact Analysis

Regarding the WSD Regulatory Impact Analysis, two main aspects are being addressed by ANATEL:

- **Spectrum allocation and licensing regime:** the purpose is to promote the expansion of the telecommunications services that make use of radio frequencies, without harmful interference on the existing systems. A problem that has been identified is the fact that there is currently no possibility of using WSD systems for the expansion of telecommunications services mainly in rural areas, given the lack of normative forecast, which has been limiting the most efficient use of the spectrum. One alternative solution to deal with this problem being considered by ANATEL is to allocate spectrum for services that use WSD and allow the use of this type of system at specific locations.
- **Device and geolocation database administration:** the goal is to create conditions for the development and implementation of geolocation databases to be used by WSD. The problem to be solved is the development of a method that ensures the protection of the systems that operate in the VHF and UHF bands, in case of the implementation of WSD technology. Three alternatives are being considered to tackle this problem:
    1) ANATEL is responsible for the specification, development and management of databases;
    2) ANATEL is responsible for the specification and enable providers to be responsible for the development and management of databases and
    3) Providers are responsible for the specification, development and management of databases.

    From these 3, the second one is the one being promoted by ANATEL.

Other requirements that are being considered by ANATEL in the WSD regulation are:

- Establish a population criterium to select the municipalities that the use of WSD would be allowed;
- Consider WSD as a short-range device, in order to have a license free regime;
- Consider the use of geolocation database together with spectral sensing methods to identify the available radiofrequency blocks in a given locality;
- Provide that technical criteria will be created by means of technical requirements, which should dispose, for example:
    - minimum number of broadcasting channels available as a necessary condition for the start of operation of WSD in a certain locality;
    - specific technical requirements of the geolocation database;
    - maximum power (SRD criteria:1W peak power measured at the transmitter output);
    - spurious and out-of-band emissions limit

3.2 Opportunities in the Brazilian Regulatory Body

The Brazilian WSD regulation is in progress with no fixed decisions yet. Technical studies are being carried out based on international practices, for example: Electronic Communications Committee (2015), ECC Report 236, *Guidance for national implementation of a regulatory framework for TVWSD using geo-location databases*; International Telecommunication Union (2011), Report ITU-RM.2225, *Introduction to cognitive radio systems in the land mobile service* and Dynamic Spectrum Alliance Limited (2017), *Model Rules and Regulations for the Use of Television White Spaces*.

5G-RANGE is waiting for the official public consultation (items #28 and #39 of the ANATEL's regulatory agenda 2019-2020) to be open in order to effectively contribute and/or be a key influencer in the TWS rules definition.

4 Dissemination Activities

Communication and dissemination of project information including achievements, results, events, demonstrations and other related information are being done via project website (http://5g-range.eu/), social networks (@5G-Range), press releases and other media coverage. The list of dissemination activities carried out in the second year of the project (until November 6th, 2019) is presented in the Table 15:

Table 15 - Dissemination activities (achievements, results, events, demonstrations, etc.).

Title	Type of publication	Title of Journal/Conference/Book	Date	Place of publication
Pilot- and CP-Aided Channel Estimation in MIMO Non-Orthogonal Multi-Carriers	Journal	IEEE Transactions on Wireless Communications	Jan-19	N/A
Instantaneous Spectral Analysis	Journal	JOURNAL OF COMMUNICATION AND INFORMATION SYSTEMS,	Jan-19	N/A
5G-RANGE demo	Demonstration	MWC at 5GPPP booth	Feb-19	Barcelona, Spain
NFV orchestration on intermittently available SUAV platforms: challenges and hurdles	Conference	IEEE INFOCOM Workshop: MiSARN 2019: Mission-Oriented Wireless Sensor, UAV and Robot Networking	Apr-19	Paris, France
Workshop em comunicações móveis: Academia, Governo e Indústria: Perspectivas de Implantação do 5G no Brasil	Workshop	Workshop em comunicações móveis: Academia, Governo e Indústria: Perspectivas de Implantação do 5G no Brasil	Apr-19	Fortaleza, CE, Brazil
Ericsson Research Activities towards 5G and Beyond	Presentation	Workshop em comunicações móveis: Academia, Governo e Indústria: Perspectivas de Implantação do 5G no Brasil	Apr-19	Fortaleza, CE, Brazil
Low complexity GFDM receiver for Frequency-Selective Channels	Journal	IEEE Communications Letter	Apr-19	IEEEXplore
5G training course	Presentation	N/A	Apr-19	Santa Rita do Sapucaí, MG, Brazil
Solutions for Remote Area Networks: 4G and 5G Approaches for Rural Networks	Conference	5G & LTE Latin America	Apr-19	Rio de Janeiro, RJ, Brazil
Panel Discussion: Evolution of RAN	Panel	5G & LTE Latin America	Apr-19	Rio de Janeiro, RJ, Brazil

5G-RANGE: Research and challenges	Presentation	Webinar: projetos de colaboração internacional em redes 5G	Apr-19	Brasília, DF, Brazil
5G Waveforms for IoT Applications	Journal	IEEE COMMUNICATIONS SURVEYS & TUTORIALS	Apr-19	IEEEXplore
5G: Rumos da Tecnologia e as Oportunidades de Pesquisa	Presentation	National Instruments (NI)	May-19	São Paulo, SP, Brazil
Demo 5G-RANGE	Demonstration	WRNP 2019	May-19	Gramado, RS, Brazil
Workshop of ITU-T Focus Group on Network 2030	Standardization/ Regulation activity	ITU-T	May-19	Saint Petersburg, Russia
Un mundo hiperconectado, pero… ¿para TODOS?	Press release	N/A	May-19	Website
Distributed Cloud: A modern Computing Paradigm Towards 5G Network	Conference	SBRC 2019	May-19	Website
5G-RANGE Remote area Access Network for 5th GEneration	Conference	XVII Workshop WCGA 2019	May-19	Website
5G-RANGE Project Field Trial	Conference	EuCNC 2019	Jun-19	Valencia, Spain
Performance Evaluation of Windowing Based Energy Detector in Multipath and Multi-Signal Scenarios	Conference	14th EAI International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM'19)	Jun-19	Poznan - Poland
DEMO 5G-RANGE Remote area Access Network for 5th GEneration	Demonstration	EUCNC 2019 + Global 5G Event	Jun-19	Valencia, Spain
Remote Areas Radio Access Network	Standardization/ Regulation activity	3GPP Study Item proposal (Joint action with OFCOM)	Aug-19	N/A
Time-Frequency FTN Signaling for GFDM	Conference	ISWCS	Aug-19	IEEEXplore

Iterative Receiver for Non-Orthogonal Waveforms Based on the Sum-Product Algorithm	Conference	ISWCS	Aug-19	IEEExplore
CDL-based Channel Model for 5G MIMO Systems in Remote Rural Areas	Conference	ISWCS	Aug-19	IEEEXplore
Spectrum Sharing and Operator Model for Rural and Remote Area Networks	Conference	16th International Symposium on Wireless Communication Systems (ISWCS'19) - Workshop on 5G for Remote Areas including the Arctic	Aug-19	Oulu - Finland
Performance of WIBA Energy Detector in Rural and Remote Area Channel	Conference	16th International Symposium on Wireless Communication Systems (ISWCS'19) - Workshop on 5G for Remote Areas including the Arctic	Aug-19	Oulu - Finland
Cooperative Sensing with WIBA Energy Detection Under Rural Area Channel Conditions	Conference	IEEE 90th Vehicular Technology Conference: VTC2019-Fall	Sep-19	Honolulu, HI, USA
Redes Móveis de 5a. Geração: Cenários e Aplicações	Presentation	"O papel da inteligência artificial na sociedade 5.0 – A indústria 4.0 no dia a dia das pessoas"	Sep-19	Brazilian Association of Automotive Engineering (AEA), São Paulo, SP, Brazil
Automated Deployment of an Internet Protocol Telephony Service on Unmanned Aerial Vehicles Using Network Functions Virtualization	Journal	Journal of Visualized Experiments	Oct-19	N/A
Avaliação das Formas de Onda f-OFDM e OFDM Utilizando TVWS em Tecnologia 5G	Conference	ENCOM 2019	Oct-19	Petrolina, PE, Brazil
Comparing f-OFDM and OFDM Performance for MIMO Systems Considering a 5G Scenario	Conference	IEEE 5G World Forum (WF-5G)	Oct-19	Dresden, Germany
rLEDBAT: receiver-driven Low Extra Delay Background Transport for TCP	Standard contribution	ICCRG at the IRTF	Oct-19	ietf.org
Sistemas Móveis de Quinta Geração a Visão da Academia Sobre Barreiras Regulatórias	Conference	N/A	Nov-19	Website
VENUE: Virtualized Environment for Multi-UAV Network Emulation	Journal	IEEE Access	Dec-19	Dresden, Germany

Figure 10 shows the share of the dissemination activities carried out in the project until November 6th, 2019.

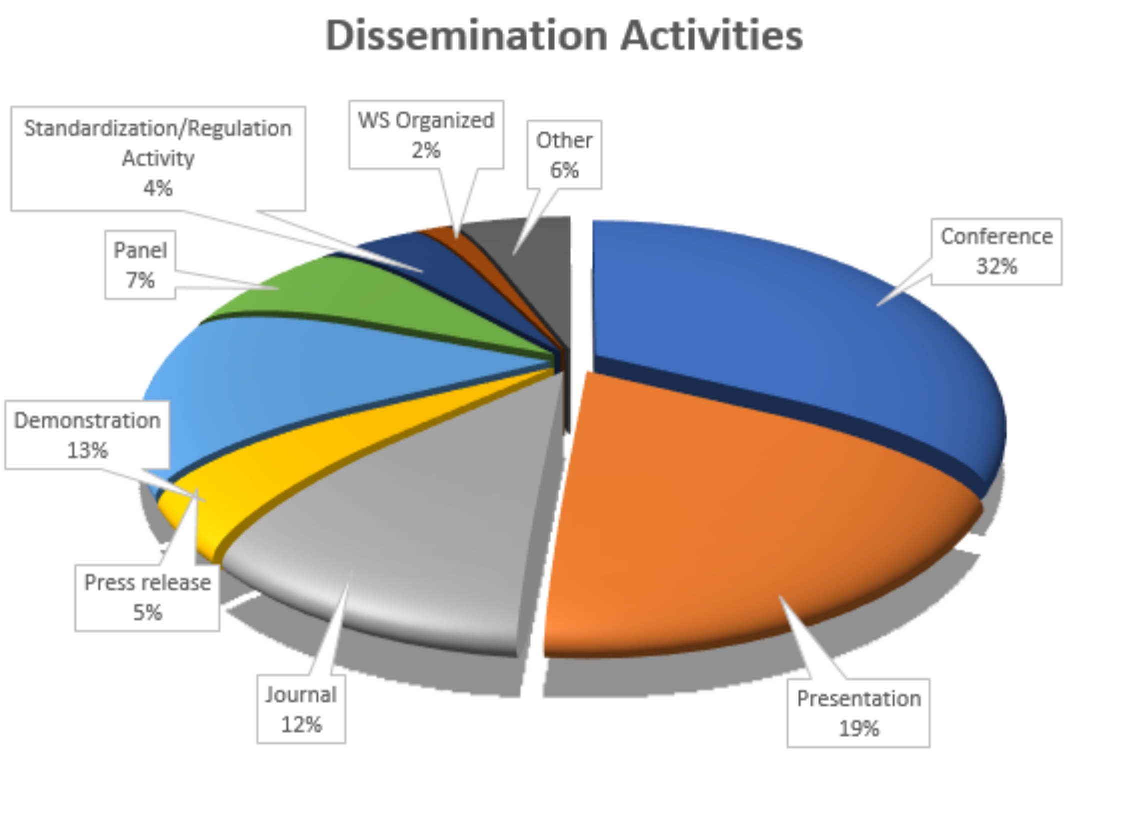

Figure 10 - Share of the dissemination activities carried out in the project until November 6th, 2019.

5 Standardization Activities

Regarding the standardization, this document is an extension of the previous deliverable Work Package (Report D.7.1) [1], following the proposed action plan with support for 5G-RANGE system solution standardization process objectives. For that, in this document a high view of the 3GPP organization and activities are provided, followed by a summary of the technical specification process, and discussion about the best approach for submitting 5G-RANGE standardization proposal is presented, with identification of relevant technical studies that would support and speed up the process of proposal inclusion in the 3rd Generation Partnership Project (3GPP) technical studies. In addition, we describe a 5G-RANGE contribution to the IRTF.

5.1 3GPP Structure and Organization

3GPP activities are related with development of technical specification that are translated into standard by regional Standards Setting Organizations (SSOs), that are also responsible for establishing and enforcing Intellectual Property Rights (IPR) policies [3] [4] [5]. There is a unified collection of six telecommunications SSOs known as organizational partners. Figure 11 shows the overall structure of 3GPP, including the SSOs and the Project Coordination Group (PCG).

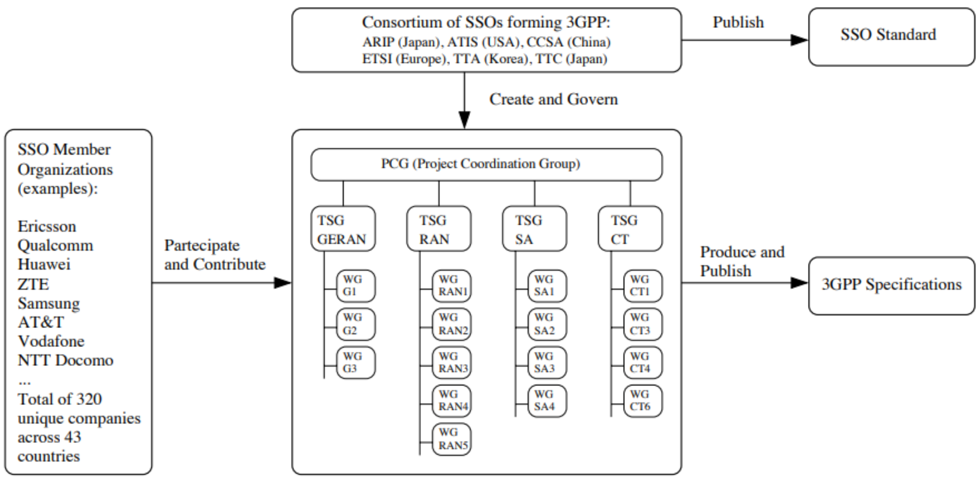

Figure 11 - Overall organizational structure of 3GPP [3].

PCG is the highest decision-making body responsible for overall management of technical work, being for example responsible for final approval of the Technical Specification (TS), ratifying election results and resources committed to 3GPP. Below the PCG there are four specific Technical Specification Groups (TSGs) with an area of expertise:

- GERAN (GSM EDGE Radio Access Networks): responsible for the radio access specification of GSM/EDGE;
- RAN (Radio Access Networks), responsible for the UTRA/E-UTRA network;
- CT (Core Network & Terminals) responsible for specifying terminal interfaces and capabilities, and the core network;
- SA (Service & Systems Aspects), responsible for the overall architecture and service capabilities of the 3GPP systems.

TSGs organize their work in different Working Groups (WGs) that focus on specific technical aspects and requirements within their specified technology areas and liaise with other groups as appropriate. The outcome of each WG is a series of Technical Reports (TRs). Agreed-upon implementation details result in TSs after approved by the TSG, and then by the PCG either creating new specifications or making updates to existing specifications. Each TSG has the responsibility to develop, approve and maintain the TRs and TSs within its terms of reference [4]. TSG SA is responsible for the overall architecture and service capabilities of systems based on specifications and, as such, has a responsibility for cross TSG co-ordination.

5.2 3GPP Technical Specification Process

Figure 12 provides the overall 3GPP process for technical specification development. 3GPP is a collaborative, system-level engineering effort, and in this way, any new feature or services proposal are done outside of 3GPP. These new features or services are made in the form of project proposal, discussion, or as a Study Item (SI), and contribution rely on the leadership of individual 3GPP members, with contributions, writing and submitting made by delegates of the member organization [3]. 3GPP work activity at quarterly plenary meetings includes approval of these contributions, and significant features results in one or more approved SIs to conduct feasibility study based on the technical contributions. The resulting output of a SI is a Technical Report (TR) that details the agreed-upon concepts from the feasibility study [4].

Figure 12 - Overall 3GPP technical specification process [4].

The SI completion with TR approved, may result in one or more Work Items (WIs). Each new 3GPP WI is first initiated by TSG SI. TSG WI agreed-upon implementation details may result in new Technical Specification (TS) with new specification, or results in Change Request (CR) with update to existing specifications. Each TSG meets separately 4 times per year. The new versions of 3GPP specifications are released after the TSG meetings, also called plenary meetings [3]. In this process, decisions in 3GPP are technology-driven and results from a consensus-based and interactive process open to all members.

Considering the 5G-RANGE system solution as a new feature or service, the 3GPP standardization process falls under on a proposal of a new SI or annex to an existing SI. According to [6] the Study Item (SI) description is the follows:

- Study Item: An initial study, resulting in a Technical Report (TR), which typically performs a feasibility study for additional functionality. If the results of the study are positive, one or more subsequent Feature-type Work Items (WI) may follow. A feasibility study may include commercial as well as technical considerations. This analysis will naturally lead to defining the new features to be added to the existing system.
- Feature: New, or substantially enhanced functionality which represents added value to the existing system.

5.3 Options for 5G-RANGE 3GPP Standardization Process

The outlining initial 5G-RANGE contributions for 5G standardization may include the following list:

- New services for long-range. Study Item (SI) description is the follows: remote area broadband access networks;
- TVWS channels use for long-range, remote area scenarios;
- New system solution for opportunistic and fragmented spectrum access on TVWS channels as an unlicensed Secondary User (SU);
- Licensed assisted access (control channel) to unlicensed spectrum access on TVWS channels;
- New services and architecture involving RAN;
- New Media Access Control (MAC) layer with new protocols integrated with Cognitive mechanism;
- New Physical (PHY) layer with reduced Out-of-Band (OOB) emissions integrated with Cognitive MAC layer;
- New User Equipment (UE) Category that supports 5G-RANGE system.

Considering this previous list, three subjects can be considered prominent for approach in the standardization process strategy: the long-range, remote area broadband access; unlicensed access; and new services and architecture involving RAN.

5G-RANGE introduces new services, that could include long-range, remote area broadband access network services, resulting new marketplace, or new business model. Considering the new RAN architecture, there is the inclusion of cognitive function in the 5G NR system, and topics of services and architecture are part of the STG SA responsibility.

Revisiting the previous report phase 1 action plan in [1], that identified the following technical studies and technical specifications: TR 38.913 – Study on Scenarios and Requirements for Next Generation Access Technologies [7]; TS 22.262 – (5G) Service requirements for next generation new services and markets [8]; RP-17185 – Overview of extreme long range coverage in low density areas (3GPP TSG RAN Meeting #77) [9]. Identifying RP-17185 as a good approach for initial contribution of the 5G-RANGE considering that there´s matching with long range, remote area scenario and services. The point is that there are no Work Item (WI) and Study Item (SI) dedicated to long range coverage being conducted in 3GPP. Other consideration is the unlicensed spectrum access, i.e. similarities with 5G 5G NR unlicensed spectrum (NR-U), coupled with licensed assisted access, i.e. License Assisted Access (LAA), having studies being carried out, and it is under normative process being part of the baseline of the Release 16 (RP-181339) [10] [11]. Coexistence studies is part of the studies considering the Listen Before Talk (LBT) mechanism for spectrum access, with coexistence with Wi-Fi services using the listed unlicensed frequency bands. Operation only in unlicensed spectrum, is designated as 5G NR-U standalone operation or MulteFire, and concentrates a lot of interest because it is an enabler for private Internet of Thigs (IoT) network, or for industry 4.0, or for unmet needs to expand the market for wireless communication to new verticals [12].

5.4 Action Plan for 5G-RANGE Standardization Proposal at the 3GPP

The previous section results in three possibilities paths for the standardization approach:

1) Long-range, remote area broadband access

Discussion with the participants of the extreme long-range coverage studies [9] (RP-17185), and a presentation of initial document about creation of a SI. Member of this discussion are: Orange, Huawei, HiSilicon, Nokia, Nokia Shanghai Bell.

2) Unlicensed access

Discussion and presentation of initial document about contribution to 5G NR-U SIs or WIs. Reference for discussion: Study on NR-based access to unlicensed spectrum [10] (R38.805, RP-181339). Member of this discussion: Ericsson, Nokia, T-Mobile, Verizon, Samsung, Broadcom, and Blackberry, among others. And to review related documents, such as coexistence studies.

3) New services and architecture involving RAN

Identification of the TSG SA WG1 (services) or WG2 (architecture) that there´s a possibility for discussion and presentation of a proposal for contribution and creation of a SI. This strategy was used for example for inclusion of the Device to Device (D2D) studies in the 4G standardization [13].

Thus, the 5G-RANGE action plan regarding standardization inside 3GPP can include one or more possibilities out of three. It requires the development of a document with the proposal including: the clear objective of the proposal, justifications, Key Performance Indicators (KPIs), technical information, differentials and gains introduced by the proposal for the standardization. Also, it requires a long discussion with the main players and stockholders acting in the mobile communication market.

5.5 Ongoing Initiatives

5.5.1 3GPP

One standardization initiative being conducted within the project is a proposal for a new SI to consider the results of the 5G-RANGE and 5G Rural First [14] projects as inputs for a future 3GPP Release. This work is being driven by Inatel and Ofcom, which are gathering support from the regulators around the world. Besides Ofcom, ANATEL has already agreed to support this initiative.

5.5.2 IETF/IRTF

As part of the 5G-RANGE project standardization activities, we have submitted for consideration our proposed rLEDBAT mechanism. As described in the technical deliverables, rLEDBAT is a receiver driven, less than best effort congestion control mechanism. rLEDBAT empowers the 5G-RANGE receiver to manage its incoming traffic, by allowing the receiver connected to the 5G-RANGE access to de-prioritize traffic making it less than best effort. This enables the 5G-RANGE client to effectively manage its access link.

In order to standardize the rLEDBAT mechanism, we selected the Internet Congestion Control Research Group (ICCRG), which is the preferred venue for standardizing congestion control algorithms for the Internet. For example, Google's BBR is also currently being standardized in ICCRG. ICCRG is part of the Internet Research Task Force (IRTF), sister organization of the Internet Engineering Task Force. Both the IETF and the IRTF produce standard documents called Request For Comments (RFCs). The process to produce an RFC starts by submitting a document for consideration of a working/research group. This document is called an Internet draft and its category is individual (because up to this point, it does not belong to any working group), but belongs to the individual author.

Upon submission for consideration to a working/research group, the proponents of the draft can be allowed to present their document in a meeting, for discussion with the group. This may happen one or several times. At some point, if the chair of the working/research group deems that there is enough interest in the group, the chair may call for adoption of the document by the working/research group. This is the critical step for the document to become an RFC. Once the document is adopted, the research group works on the document until it considers it is ready for publication.

Regarding rLEDBAT, we submitted a 00 version of the draft in june 2019. We presented the document in the IETF meeting in July 2019 and there was significant interest. We updated the document reflecting the comments received in the presentation and we submitted a 01 version in October 2019. We presented the second version in the IETF meeting in November 2019. The chair called for adoption of the document in the meeting and the document was accepted. We are currently waiting for confirmation of the adoption in the mailing list. Once this is confirmed, we will submit a third version, now as a research group work item.

The IETF/IRTF standardization process is usually fairly long. We do not expect the document to be published as RFC before the end of the project. However, we do believe having it accepted by the group is already a significant achievement.

6 Conclusions

This deliverable, as part of WP7, is an extension of the previous document [1] and expands in various areas, in particular the alternative business models explored and the outputs of the data analysis to measure the rural unconnected opportunity in Brazil and the standardization activities, as well as presents dissemination activities and standardization plans of the 5G-RANGE Project in its second year.

The sizing of the Total Addressable Market (TAM) is of the utmost importance for evaluate the market opportunities for the 5G-RANGE use cases. In Brazil, TAM presents around 14 million unconnected people for a given Mobile Network Operator (MNO), most of which are Greenfield (meaning there is no 2G in that given area). According to the adopted methodology, around 23.000 4G sites should be deployed to cover the whole opportunity. However, there is an uneven distribution of the opportunity: less than 37% of the sites concentrate more than 75% of the opportunity.

In the deployment analyses, two main use cases where 5G-RANGE technology could be used were selected for Brazil scenario: **(1) Use Case 1 – Direct Connectivity**, that means full deployment of 5G-RANGE as Radio Access Network (RAN) technology and only as RAN technology and, **(2) Use Case 2 – Backhaul Connectivity**, that means full deployment of 5G-RANGE as Backhaul technology and only as Backhaul technology. Simulation numbers show 5G-RANGE could attack 11 million out of the 14.7 million with direct connectivity. Doing this would require deploying almost 700 5G-RANGE sites (with several sectors each). For Backhaul deployment, the population around the selected 5G-RANGE sites is very similar (11 million people). However, in this case, only around 6 million can be connected because of the limitations of 4G sectors per 5G-RANGE site. This opportunity would require deploying roughly 700 5G-RANGE sites and around 6.000 LTE sites. The presented lower TAM does not imply lower number of connected people since penetration of standard vs non-standard service will play a big role.

Based on the TAM, the translation into financial impact (what is usually referred to as the Business Case of an opportunity) was done, modelling how deploying 5G-RANGE would work: costs incurred, revenues generated, etc. Once all the inputs and hypotheses had been introduced into the model and it had been properly tuned, it was analyzed the Profit and Loss (P&L) of that business, which provided information about its financial impact. Results showed a fair split of the value generated by this opportunity between the Rural Mobile Infrastructure Operator (RMIO) and the MNO in both use cases and two considered scenarios (Optimistic and Realistic). Also, as could be expected, although Use Case 1 (Direct Connectivity) and Use Case 2 (Backhaul Connectivity) have similar Paybacks, Use Case 2 is more capital intensive than Use Case 1.

Since 5G-RANGE technology is originally proposed to operate in TVWS unlicensed spectrum, it is extremely impacted by TVWS regulation. TVWS regulation is one of the pending areas of work for regulators worldwide but also a great opportunity to reduce the investment required for mobile communications in rural scenarios, due to its lower cost and good propagation qualities. In case of Brazil, only the planned TVWS regulatory actions are scheduled since no regulation has been defined at the present moment. Regarding the White-Space Device (WSD) Regulatory Impact Analysis, two main aspects are being addressed by National Telecommunications Agency of Brazil (ANATEL): (1) Spectrum allocation and licensing regime (promote the expansion of the telecommunications services that make use of radio frequencies, without harmful interference on the existing systems) and, (2) Device and geolocation database administration (create conditions for the development and implementation of geolocation databases to be used by WSD). Other requirements being considered by ANATEL in the WSD regulation are: (i) Establish a population criterium to select the municipalities that the use of WSD would be allowed, (ii) Consider WSD as a short-range device, in order to have a license free regime, (iii) Consider the use of geolocation database together with spectral sensing methods to identify the available radiofrequency blocks in a given locality and (iv) Provide that technical criteria will be created by means of technical requirements (e.g., specific technical requirements of the geolocation database, maximum power, spurious and out-of-band emissions limit). 5G-RANGE project is following the TVWS regulatory actions being conducted by ANATEL and working on opportunities to influence the rules definition to be adopted in Brazil.

In terms of standardization, during this deliverable, the work had been focused on identifying 5G-RANGE opportunities in 3GPP standardization body. 5G-RANGE introduces new services, that could include long-range, remote area broadband access network services, resulting new marketplace, or new business model. Considering the new RAN architecture, there is the inclusion of cognitive function in the 5G NR system. In this way, the consortium identified three subjects can be considered prominent for approach in the 3GPP standardization process strategy: (1) Long-range, remote area broadband access, (2) Unlicensed access and (3) New services and architecture involving RAN. We also presented the rLEDBAT contribution of 5GRANGE to the IRTF.

The next deliverable, D7.3 will be an extension of the current document which aims to conclude all ongoing activities, consolidating all results on exploitation, communication, dissemination and standardization during the project cycle.

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