Report Work Package 2

National ICT Needs Assessment Consultancy

ICT Access and e-Services for Hinterland, Poor and Remote Communities in Guyana

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Definitions

Access Technology	
Backhaul Technology	
Last mile technology	
Integrated Technology Solution	

1. Management Summary

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2. Introduction

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3. Technology Strategy

3.1 Technology Assessment

There is a variety of technologies used within telecommunication business for more the 20 years, for transport services point-to-point as well as point-to-multipoint. Most of the technologies will remain in the technology portfolio of telco operators for a long time. The main goal of this chapter is to give overview of different technologies in all network domains and provide clear comprehensive analysis of the communication technologies. Analysis should consider different aspects of the solutions selection such as feasibility to the local environmental conditions, cost effectiveness of the solution and alignment with the strategy of the eGovernment Services delivery.

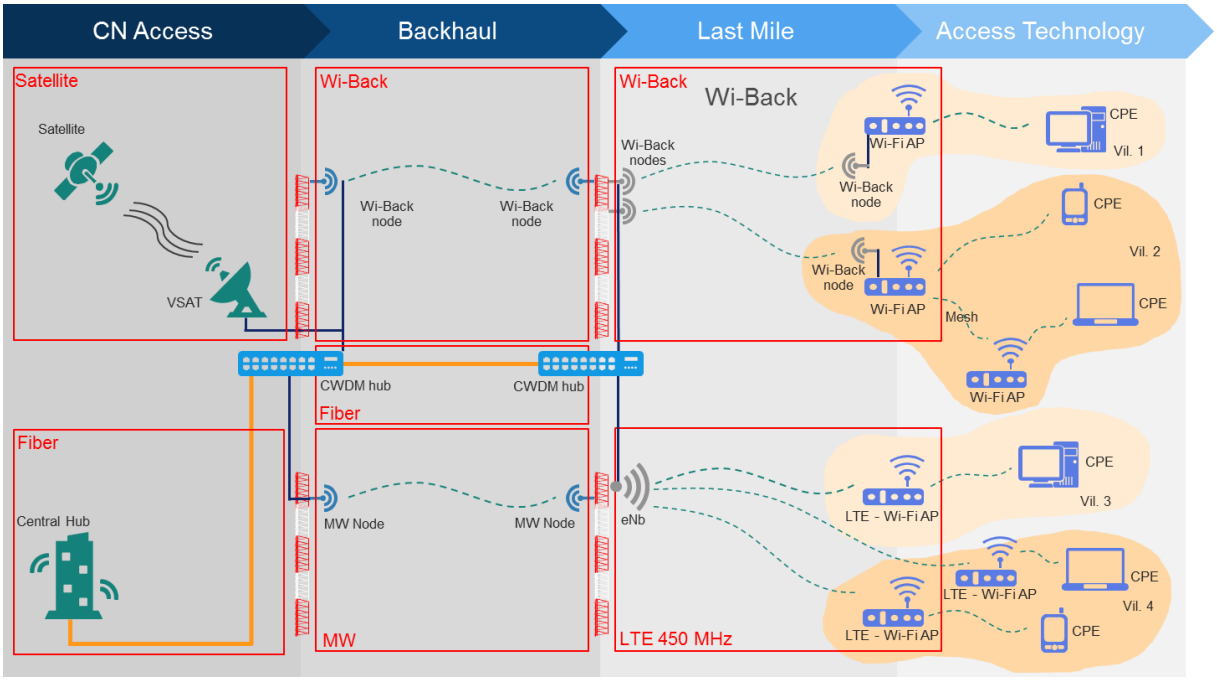
Taking into account local circumstances and demands claimed by the planned services, delivery of the packet data to the consumer in the sparsely populated areas should occur via the following network parts:

Core Network Access – represented as points of presence (PoP) of Telecommunication service provider or any other owner of the infrastructure within the country. E-services delivery task mainly converges to deployment of the communication channel between PoP and targeted locations.

Backhaul Technology – is a network of links between core network access and concentrators and hubs deployed close to the end consumer of the services

Last Mile Technology – is the most challenging part of the network for the most operators worldwide as it called to establish point-to-multipoint connection between each service consumer and local hub.

Access Technology – is the only technology which in fact visible to the service consumer.



Selection of the technology and building the network solution implemented in the following steps:

Step 1 – Selection of the appropriate technologies based on the technology specifications and its deployment capabilities in Guyana according to local environmental conditions

Step 2 – Service based selection of the technologies according to the service requirement

Communication technologies, which are state-of-the-art and fits to all requirements determined after these two steps used as a building components of the possible solutions for network deployment in Guyana. Financial assessment implemented for all derived solution to identify the most efficient, which will be used as recommendation.

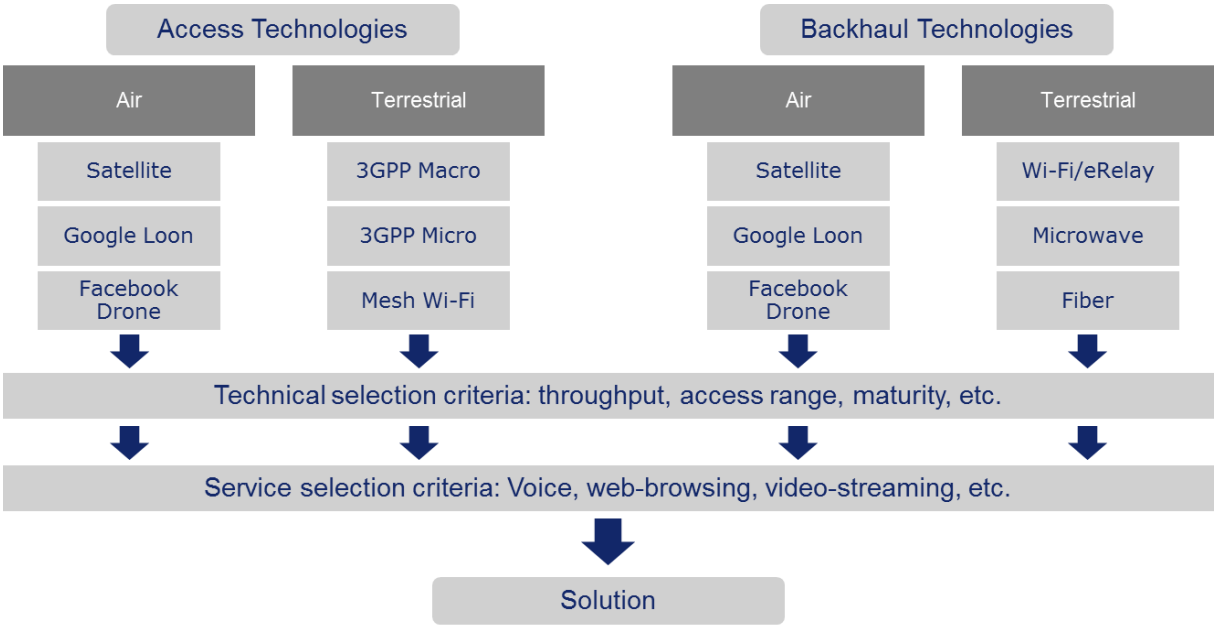


Figure 1 - General approach for selection of the best-fit technology set for the delivery of ICT services to HPR areas

3.1.1 Backhaul Technology Assessment

There are 4 main criteria are relevant for the backhaul:

- **Accessibility**
  - In case of limited accessibility (no road or rivers) no or low towers could be built.
  - Satellite remains as low capacity option with maximum rates up to 10Mbps depending on load.
- **Availability of power**
  - In best cases, power grid would be possible to connect the sites.
  - Diesel generators and fuel increase OPEX per site and need logistical effort.
  - Solar panels and battery would be at least as support to reduce (in hybrid mode) the power consumption of fuel.
- **Coverage targets and mobility of users**
- **Capacity**

3.1.1.1 Backhaul Network

Backhaul will be dominantly provided via dark fiber lease from GPL. In case, fiber lease is not possible, eGovernment own fiber or packet microwave will be deployed depending on the financial viability.

The requirements to a microwave link depend on the topology of the network, e.g. in which parts of the network microwave links are to be used and whether there are restrictions on the number of cascaded microwave links in the network. In principle, microwave links can be deployed in the licensed frequency bands 6L (6.2 GHz), 6U (6.8 GHz), 7.5 GHz, 8 GHz , 10.5 GHz, 11 GHz, 13 GHz, 15 GHz, 18 GHz, 23 GHz, 26 GHz, 28 GHz, 31 GHz, 32 GHz, 38 GHz, 52 GHz, 55 GHz.

However, considering Guyana falls into zones where heavy rain can be expected the usage of high bands (above 18GHz) will be quite limited. It is recommended to apply a differentiated approach:

- For links up to 10km the high bands (13GHz to 18GHz) to be used
- For links between 10 to 20km the low bands (6 to 11GHz) to be used

Lower frequencies are recommended due to expected large distances to the next aggregation site. If a microwave link cannot be realized via a single hop, additional intermediate hops can be introduced. For cost saving pure passive re-transmitters can be considered.

In some areas of Guyana, strong winds are possible. Therefore, the microwave antenna size should not exceed 90cm. In extreme cases where wind speed is not so high, up to 1.2m antennas can be used.

The usage of low band frequency in urban and suburban areas can be further precluded by already existing links used by the other Guyana operators.

Depending on the available bandwidth that can be in the range between 250MHz and up to 1000MHz, the transmission capacity of the Microwave is in the order of min. 240Mbps and up to 1,2Gbps or even up to 2,5Gbps with Co-Channel Dual Polarization (CCDP) in combination with XPIC functionality. The cross-polarized signals can be combined with Link Aggregation Group (LAG).

All microwave links shall employ the adaptive coding and modulation so that high throughput is ensured in most of the time and during extreme conditions (wind, rain) the throughout is gracefully reduced by applying lower modulation but the link availability is not endangered.

New generation microwave systems offer CCDP (co-channel dual-polarization) operation with LAG as protection – often designated as 2+0 with LAG; In case of a failure of a transmission path, the system still offers 50% of the transmission capacity.

The backhaul will be fully Ethernet/IP based. The backbone will connect the eNodeBs via the backhaul and aggregation network to the EPC and OSS, BSS sites. The backbone will be mainly based on dark fiber locations. In case the metrofiber of GPL would be used, it should follow a ring topology with maximum 10 aggregation nodes per ring as well as maximum 10 eNodeBs per aggregation node. The connection between aggregation nodes will be based on 10G Ethernet interfaces. The protocol will be IP/MPLS. The aggregation nodes will serve as PE routers (provider edge).

3.1.1.2 Microwave backhaul dimensioning

Microwave shall be used for the last-mile-connectivity to new and existing 4G radio sites, if the fiber connectivity to the site requires investments in fiber infrastructure above a certain limit.

The basic features of these Microwave Systems are the following:

1. Multiple Modulation steps that can provide flexibility in capacity handling. The typical throughput versus modulation matrix is depicted below

Modulation	Width of the RF Channel			
	7 MHz	13.75/14 MHz	27.5/28 MHz	55/56 MHz
QPSK	≥ 10 Mbit/s	≥ 20 Mbit/s	≥ 40 Mbit/s	≥ 80 Mbit/s
16QAM	≥ 20 Mbit/s	≥ 40 Mbit/s	≥ 80 Mbit/s	≥ 160 Mbit/s
64QAM	≥ 30 Mbit/s	≥ 60 Mbit/s	≥ 120 Mbit/s	≥ 240 Mbit/s
128QAM	≥ 35 Mbit/s	≥ 70 Mbit/s	≥ 140 Mbit/s	≥ 280 Mbit/s
256QAM	≥ 40 Mbit/s	≥ 80 Mbit/s	≥ 160 Mbit/s	≥ 320 Mbit/s

Table 1 - Typical throughput versus modulation schemes

2. Adaptive Modulation adds or removes capacity from best effort services by changing the modulation steps.
   - Normally, i.e. in about 99.9% of time, the link is operated with a high level modulation format with a high spectral efficiency.
   - In case of adverse weather conditions, the modulation format is switched to a more robust one with a lower required Signal to Noise ratio at the receiver – a conventional microwave system would show link outage. However, the link can only transport a lower data rate than with the high level modulation format.
   - Hence, instead of a hard outage threshold, microwave systems with Adaptive Modulation show a graceful degradation of the data rate under adverse weather conditions.
3. Nodal Concept: The indoor units of the Novel Microwave Systems can be considered as "Microwave Nodes" because they are able to support more than a single direction (hop) and to switch or route the traffic between the various directions. Moreover, they offer multiple interfaces. In this way, space and cabling can be saved in hub sites.
4. QoS – Quality of Service. Adaptive Modulation requires that the microwave equipment must be able to support traffic prioritization; in case that the capacity of the hop is reduced, the high priority must not be affected, only packets of the best effort traffic can be discarded.
5. Radio Link Aggregation. Multiple physical links can be combined into one logical link. The typical application for microwave is a CCDP (Co-channel Dual Polarized) configuration in which the two links on orthogonal polarizations are combined in a Link Aggregation Group. The malfunctioning or outage of one of the physical links does not cause the logical link to go down. Please note that Radio Link Aggregation is only applicable for Ethernet traffic.

To transport the expected data rates in the existing Frequency Bands in channel with bandwidths of 14 MHz, 28 MHz and, in some cases, 56 MHz, the increase of the spectral efficiency in terms of bit/s per Hz is a must. However, an increase of the spectral efficiency leads to a higher required Signal to Noise ratio at the receiver.

As the most efficient modulation scheme (256QAM) then offers a capacity of ~160 Mbit/s (27.5MHz bandwidth), there should be no need for a future capacity expansion on the "last mile" serving a single mobile radio cell site[1]. For the connection to a relay site or to a microwave hub site, however, it is expected that a capacity expansion will be required. Basically, there are three possibilities for a capacity expansion which doubles the data rate on the link:

1. Cross-polar operation: Co-Channel Dual Polarized (CCDP)
   - Requires two-polar antennas – should be installed already in the initial phase
   - An additional ODU plus IF cable is needed at each end – it is recommended to install the IF cable and to prepare for the mounting of the second ODU (OMT or polarization adjuster) already in the initial phase
   - An additional modem unit (different chassis) at each end is needed.
   - This solution offers the possibility for protection with LAG (Link Aggregation)
   - Getting the Frequency License for the cross-polar channel is normally no problem.
   - Radio planning should consider the higher rain attenuation on horizontal polarization; one of the two links must use the horizontal polarization.
   - XPIC required to counteract the crosstalk between the cross-polar signals
   - The transmission capacity then is **2 x 405 Mbit/s = 810 Mbit/s**
2. Use of 55/56 MHz wide RF channel (55 MHz in the 18 GHz band)

[1] Average(!) capacities: LTE2300: 3sectors*20MHz *1.5bps/Hz=90Mbps; LTE450: 3* 5MHz*2bps/Hz=30Mbps

- Radio planning should consider the reduced system gain of the system with the 55/56 MHz wide channel (3 dB lower than for 27.5/28 MHz wide RF channels)
- The new channel should be in the same frequency band as the old channel. Otherwise the antenna must be exchanged (at least the feeder).
- Even in the same band, it might be necessary to exchange the ODUs (tuning range is limited; does not cover the whole upper or lower part of the frequency band)
- Getting the Frequency License for the 55/56 MHz wide channel can be a problem in areas with a high density of microwave links

3. Use of a second 27.5/28 MHz wide RF channel
    - Requires a 3 dB hybrid (symmetrical) power splitter/combiner on both ends of the hop. So the system gain is by about 7 dB reduced – which must be considered in radio planning.
    - An additional ODU plus IF cable is needed at each end – it is recommended to prepare for the mount of the second ODU.
    - An additional modem unit (different chassis) at each end is needed.
    - This solution offers the possibility for protection with LAG (Link Aggregation)
    - Frequency License for a second 27.5/28 MHz wide RF channel could be easier to obtain than the license for a 55/56 MHz wide RF channel.
    - Please note that there are restrictions on the channels which can be used – Ericsson states that the two ODUs (RAUs) must use the same sub-band. This means that the two RF channels must be close to each other in the RF band.

Option 1 is standard in most cases, mainly “2+0” configurations are built instead of “1+1”. In “2+0” both links are active, while “1+1” the 2nd link is only activated for redundancy. Option 2 is feasible for high capacity short range bands (e.g. 18GHz). Option 3 is more common in long distance links, but requires splitters etc. reducing link performance.

3.1.1.3 WiFi backhauling (WiBACK®)

WiBACK® is a spin-off of Fraunhofer Institute with the product WiBACK® to support the backhauling of rural and poor unserved areas with low-cost equipments in the unlicensed ISM bands (see **Error! Reference source not found.**). The main advantage is the focus on simple to use plug-n-play hardware and software concept which makes maintenance easier by for local unskilled technical staff.

WiBACK® operates at low transmit powers and in a sparse utilization in time due to sporadic usage. This reduces the overall power consumption of the system to <20W, which makes it more suited for small to medium sized solar panel use than the high power requirements of MW and RAN equipment. The latter would require larger panels as well larger battery-sizes, which were currently more expensive and with lower duty cycle.

In addition, the light weight of the overall equipment reduces the stability on the tower equipment and consequently the price. Light tower are also used in Mobile Communications Networks, but also have a limited extendibility for further equipment for new bands. Mobile Network Operators in general tend to be future proofed with sharing options with competitors and mainly decide for more stable towers.

WiBACK® advantages (by WiBACK®)	Detecon comments
Low CAPEX / OPEX • Self-Configuration: Plug-n-Play Designed for low maintenance overhead and non-specialist operation • Self-Optimizing: Analyzes the radio spectrum to determine the best channels	• Plug-n-Play, self-configuration, self-organizing features are as well state-of-the-art of vendor solutions in mobile network, which are included in the software and license agreements. In this case the MNO experts benefit from the reduced maintenance by these features.

• Self-Healing: Establishes alternative links around failed or malicious damaged to a nodes • Energy-Efficiency: WiBACK nodes can be solar-powered due to their small energy foot-print • Cost-effective hardware components as well as overall design	• Self-healing requires additional HW for mesh networks
Flexibility • Unified management of available heterogeneous technologies Fixed Wireless (incl. WiFi), Fiber, Coax/Cable, DSL, LTE, Satellite, etc. • Licensed & unlicensed spectrum; dynamic, highly varying link characteristics • Bridge long distances/NLOS situations i.e Multi-hop or lower frequencies • Seamless integration into existing networks Infrastructure & cost sharing (Slicing/Multi-Tenancy, i.e. OpenAccess)	• The usage of unlicensed spectrum limits the effective use of the spectrum to currently unused areas (which is considered in this project). • The use near coast and higher populated area might be possible, but is less recommended.

WiBACK nodes can provide a simple WiFi AP
• Integrated, no extra power needed
• Limited management capabilities
• Carefully consider location of node (one antenna back-haul, one for access)
  ○ Often Trade-off between suboptimal back-haul link (Line of Sight requirement) vs. access coverage
  ○ Long(er) antennas, cables (extra loss) required if node is mounted outside, but AP antenna is inside
	• WiBACK® is an appropriate technology to connect larger distances of ~20km with higher towers.
	• WiBACK® is also suited to distribute the signals on a lower level within the location (~5km). Here smaller poles could be used. (See **Error! Reference source not found.**)
	• The final low range meshing should be done with standard WiFi hardware at the rooftop of a house which has limited ranges (<300m) in case of omni-antenna usage as proposed in the basic set.
	• Depending on the size of the uncovered areas the number of meshing nodes might increase significantly. Also the frequency and interference management will be influenced due to limited availability of free spectrum. A dedicated coverage planning with directional antenna is recommended.

Specifications
• Capacity per link up to 200 Mbps (up to 400 Mbps in next release)
• Up to 10 hops are supported
  ○ Range up to 200km. Latency under load <20ms; VoIP-ready
• Supports unlicensed as well as licensed frequency bands
  ○ 2.4GHz & 5.xGHz, but also 3.xGHz or other custom bands (i.e.TVWS)
• A Solar Battery (40+ Ah) and a 100W Solar Panel can power a WiBACK node in areas with regular sun-shine periods.
	• WiBACK® supports ~90Mbps maximum per polarization (or MIMO-channels): ~180Mbps peak
	• Extensions would target higher modulations (as MW) but would also suffer from signal conditions under rainfalls; In the future before any upgrade, it needs to be analyzed, in how many times the higher modulation would have been possible.
	• The transmission capacity is not affected by any overbooking factors. Overbooking is only for consideration how many users might be connected simultaneously. These users might

• Power consumption (secondary)
  ○ 5…10W (2-radio Node),
  ○ 6…13W (3-radio node),
  ○ 7…20W (4-radio node)
	be distributed over all WiFi-access points of the considered links.
	Example: 4Mbps might be requested for Video-streaming, so ~180/4=~45 users could be served at the same time, i.e. 5users in each of 9locations. Overbooking of 10 means, that 50users might get video files at different requesting times.
	• Normal WiFi would not have MIMO, so ~90Mbps.
	This capacity is still more than LTE450 could deliver which is in good conditions ~35Mbps per cell. LTE700 on top would close the gap where needed.

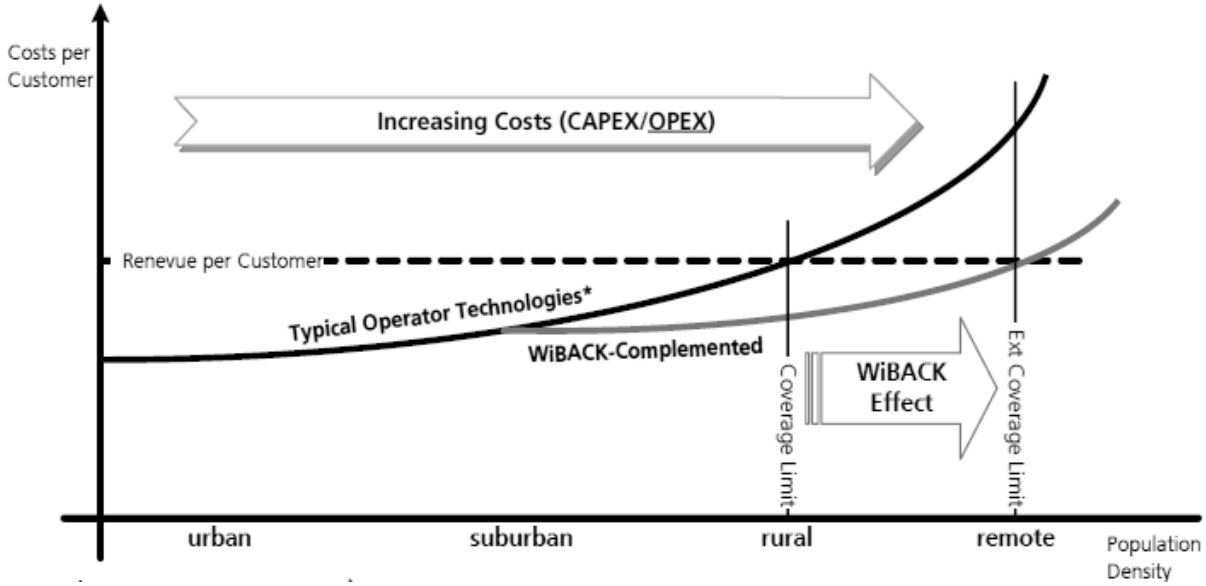


Figure 2: Cost reduction of typical equipment enlarge coverage to remote areas (taken from WiBACK®-presentation)

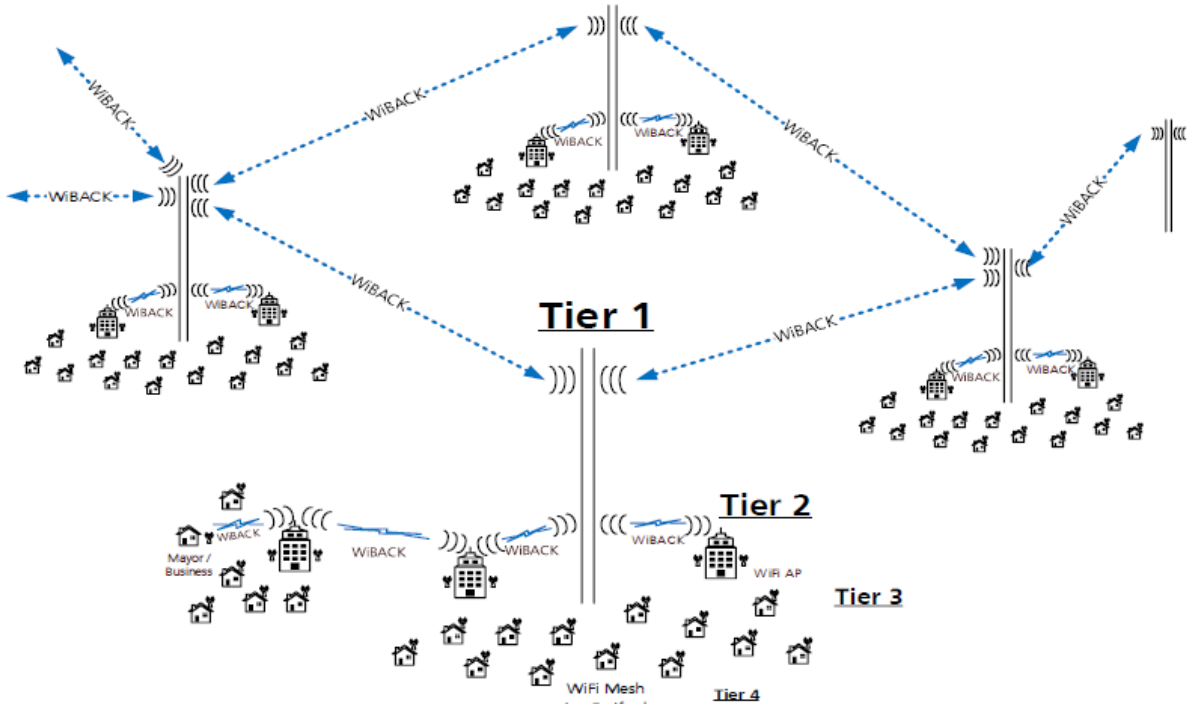


Figure 3: WiBACK®-principle of backhaul with WiFi on different layers (taken from WiBACK®-presentation)

For 1st level long distance backhaul (<20km) higher towers, for 2nd level medium distance backhauling (<5km) pols and for the final WiFi mesh network house mount antennas are needed. The latter 3rd level meshing grid is around 300m. For Guyana, it is expected to use 1st and 2nd level WiBACK®-equipment to connect the schools and public buildings.

	 **WiBACK® Node II v2,** 300mm x 236mm x 72mm; 2.1 kg; Maximum 16W, average 10W; 2x Wireless LAN High power backhaul radios	 **WiBACK® Node I**, 200mm x 140mm x 76mm; 1.4 kg; Maximum 10 W, average 5W; 2x Wireless LAN High power backhaul radios

3.1.1.4Satellite backhauling

Currently, satellite platforms serve only a small fraction of all broadband users, currently estimated at more than 500 million and climbing at a steady pace. So far, satellites have only been considered as a favorable option to complement the terrestrial broadband infrastructure. Well into the early 1990s the growth of Internet and VSAT matched each other but subsequently, the delivery of Internet over the terrestrial networks became much cheaper and grew much faster because of the easy and cheap availability of modems, ISDN equipment and ADSL.

Largest satellite operators today are ASTRA and INTELSAT. Both are operating an extensive farm of high performance satellites with various coverage areas.

SES ASTRA

- more than 50 GEO‘s
- C, Ku, Ka - Band
- 99% Coverage

INTELSAT

- more than 50 GEO‘s
- C, Ku, Ka - Band
- 99% Coverage

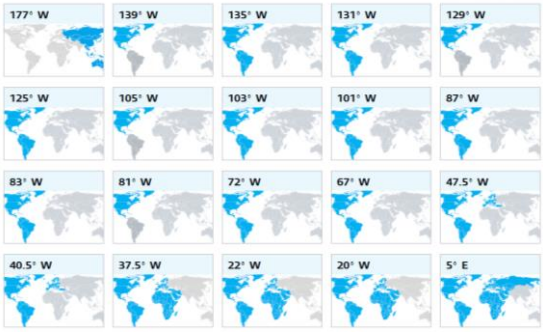


Figure 4: Main GEO[2] satellite operator overview

Nevertheless, satellite terminals can be deployed very quickly to bridge the digital divide, and at least offer a temporary solution in cases where a cheaper long-term solution could be provided by terrestrial infrastructure. Terrestrial broadband access costs depend on user density, but satellite broadband access cost is independent of user density. Among the different competing designs for the last mile solution, space systems exhibit strong flexibility. Satellite broadband access is available at any location in the satellite coverage area and the service quality is distance independent.

In an ideal implementation of satellite broadband, the satellite service element would see competing service providers leverage a common space platform with different ground segment (VSAT) equipment types to service consumers and enterprise level customers. The element of competition is very important in offering differing broadband capabilities, different contention rates on services to arrive at varying price points and capabilities to enable consumers to have a choice of broadband service offerings, download limits, equipment cost/ efficiency/reliability etc. Satellite access can be efficient for rural users. Broadband access platforms are shared by a large number of users who are not simultaneously active. The level of activity per user also fluctuates over time. These dynamics support the deployment of satellite as a shared solution which can be designed to support the specific demands of a particular country. Because the total satellite throughput is fixed, and the resource is shared between users, these systems are more efficient when they can take advantage of time-zone differences to even out the variation of service quality to users. Satellite systems often need to implement a fair use policy to restrict access or total usage for applications that require high throughput (like video streaming). Future

[2] Geostationary Earth Orbit

technologies and developments (like smarter modems/set-top boxes, multicast capabilities, and prescheduled and predictive algorithms for pre-fetching of content) will contribute to enhanced user experience for satellite services.

Thuraya Atlas IP router for private enduser

- Thuraya Atlas IP router is a fully-featured maritime satellite terminal.
- Supports voice and IP data connectivity at speeds of up to 444kbps.
- Built-in Wi-Fi.
- A range of features designed to enhance shipboard operations
- Automatic transfer of data from shipboard equipment and devices in support of M2M reporting routines.

Figure 5: Satellite dish for stationary end users VSAT

Figure 6: Satellite ground station for professional operators, also used as Sat-backhaul per site

C-band	Ku-Band
Downlink: 3.7 – 4.2 GHz Uplink: 5.9 – 6.4 GHz	Downlink: 11.2 – 12.2 GHz Uplink: 14.0 – 14.5 GHz
Main use for professional Service providers	Main use for private end users
Advantages: • Less disturbance from heavy rain fade • Cheaper Bandwidth	**Advantages:** • No interference from microwave links and other technologies • Operates with a smaller satellite dish (diameters from 0.9m) -> cheaper and more easy installation • Needs less power -> cheaper RF unit
Disadvantages: • Needs a larger satellite dish (diameters of minimum 3-5m) • Powerful (= more expensive) RF unit • More expensive mounting efforts	**Disadvantages:** • More expensive capacity • Sensitive to heavy rain fade (significant attenuation of the signal) / possibly can

• Possible Interference from microwave links	be managed by appropriate dish size or transmitter power.

Conclusion: For satellite communications, the microwave frequencies of the C-band perform better under adverse weather conditions (rainfall, moisture, etc.) in comparison with the Ku band (11.2 GHz to 14.5 GHz), microwave frequencies used by other communication satellites.

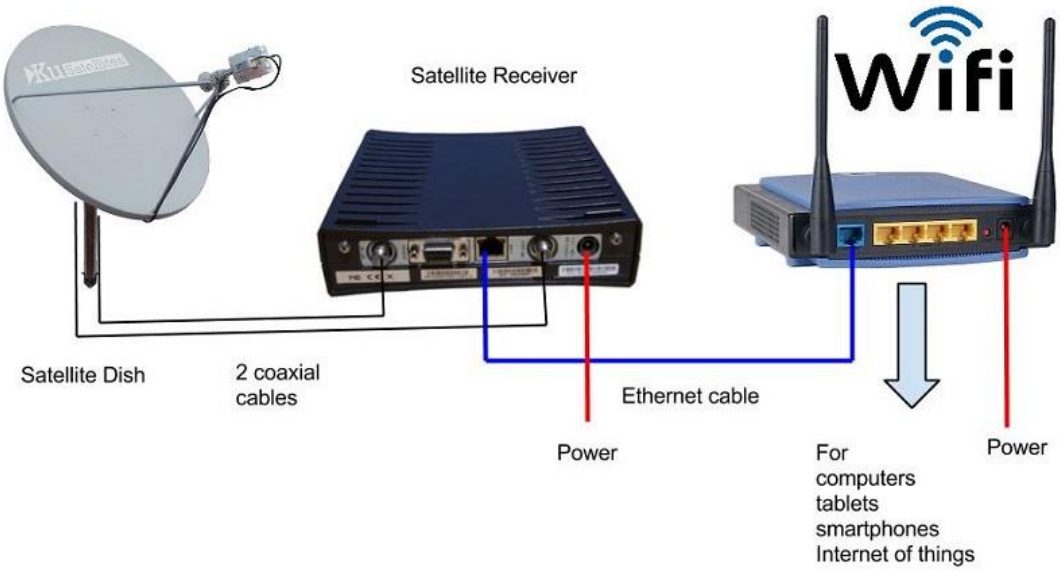


Figure 7: Satellite communication chain with satellite receiver and WiFi router in two units, but also in one unit available

3.1.2 Last Mile Technologies Assessment

3.1.2.1 Assessment Criteria

This chapter introduces the criteria by means of which access technologies compared to one another in terms of pure technical assessment. For each criteria assigned a certain value from 0 to 10 (higher – better) based on performance specification of the respective technology. The following criteria taken into account for assessment of the technologies

Technological Key Performance Indicators and valuations are used for a high level evaluation and comparison of Mobile Access technologies.

- LOS Range and NLOS Range This is basic characteristic for electromagnetic radiation based service. This criterion necessary for assessment of the maximum line-of-sight and not-line-of-sight distance service.
- LOS Throughput and NLOS Throughput This is basic characteristic for evaluation of the communication technology performance in terms of speed of data transfer over the channel. Best value equals to the requirements of the 5G standard
- Latency is the delay from input into a system to desired outcome. This parameter Is crucial for deployment of real-time services, such as voice, video conferences, etc.

- QoS Support means ability of the system to differentiate different services and assign specific rules and prioritization for each of them
- CPE Ecosystem reflects availability on the market user devices like feature phones, smartphones, USB-dongles, etc.
- Maturity – explains the market status of the technology and gives understanding of the technology confidence
- Spectrum availability explains the spectrum requirements of the technology and general assessment of the respective spectrum utilization

3.1.2.2GSM/GPRS/EDGE

EDGE is an evolutionary development of the GSM packed data services introduced to boost network capacity and data rates. It was introduced first time in 2001. Up to now it is the most widespread technology on the market due to service provisioning of the 2G only capable devices (around 670 networks deployed worldwide). In developed markets all services based on GSM planned to be swapped by LTE before 2020.

Technology Description

- Enhanced Data rate for GSM Evolution (EDGE) is considered a pre-3G radio technology and is part of ITU's 3G definition
- EDGE is standardized also by 3GPP as part of the GSM family (unofficially called 2.75G)
- EDGE increases capacity and coverage of the GSM/GPRS networks

Radio Features

- Supports 9 Modulation and Coding Schemes (MCS)
- EDGE uses in addition to GMSK high order 8PSK for the highest 5 MCSs (EGPRS2 with 16QAM and 32QAM)
- Fast ACK/NACK Reporting (FANR) and reduced TTI configuration (RTTI)
- Specified Mobile Station Receive Diversity Solution (MSRD)
- Downlink Dual Carrier Solution
- Typical throughputs 384kpbs (peak) and 200kbps (average)

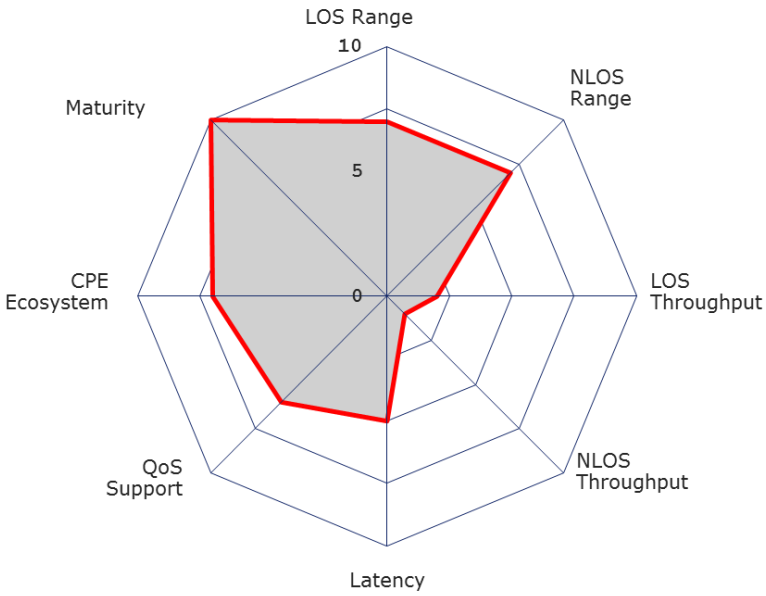


Figure 8 - Assessment of the GSM/GPRS/EDGE technology

3.1.2.3UMTS

UMTS was presented as a next step in mobile networks evolution and first time launched as commercial network in 2002. UMTS radio uses a wideband code division multiple access (W-CDMA) radio access technology to offer more bandwidth used in channels and increased spectrum efficiency comparing to second generation networks. UMTS standard consistently developed over releases R99 – R12 and evolved to HSPA+ technology. Around 514 UMTS Networks deployed worldwide, 182 networks out of them provides up to 42 Mbps throughput with HSPA+.

Technology Description

- HSPA+ incorporates technologies and features boosting HSPA downlink and uplink peak bit rates as well as the cell capacity.
- Whereas the first HSPA+ features are specified in the 3GPP TS release 7 (frozen in March 2008), the latest 3GPP TS (release 12 frozen in March 2015) still include new HSPA+ evolutions.
- The first HSPA+ features became commercially available in 2009, enabling a downlink HSPA peak rate of 21 Mbps. However, uplink HSPA+ features increasing the uplink peak rate (also made available in the 3GPP TS release 7) became commercially available only in 2012/2013 depending on the vendor.

Radio Access Features

- Higher order modulation
- MIMO transmission up to 4x4
- HSDPA multi-carrier (carrier aggregation)
- Continuous packet connectivity (CPC)
- Bands 0.85, 0.9, 1.5, 1.8, 1.9, 2.1 GHz (0.9 and 2.1 are the most popular)

- Satisfy the IMT-A requirements for 4G networks in R11

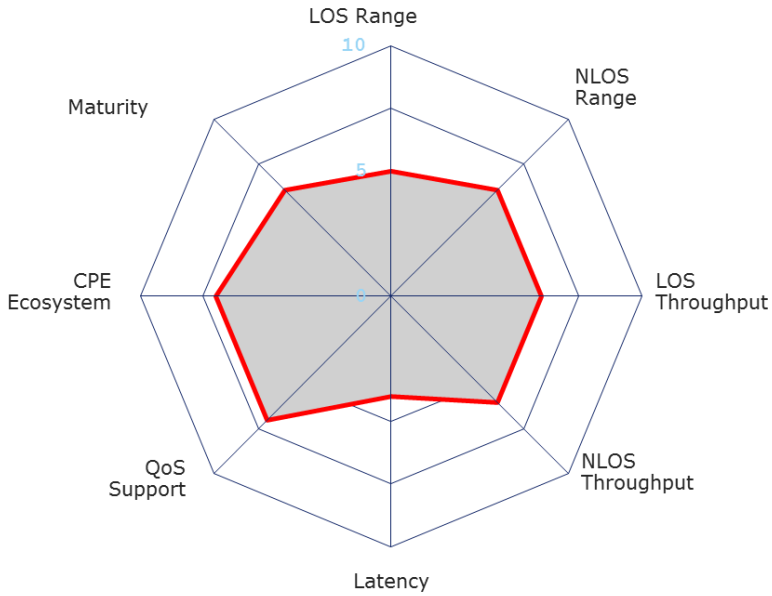


Figure 9 Assessment of the HSPA+ Technology

3.1.2.4 LTE/LTE-A

LTE (Long Term Evolution) was selected as a major technology of the 4th generation network due to potential to outperform HSPA+ and other mobile access technologies, especially when it comes to coverage availability. Operators around the globe as the preferred technology have chosen it for Next Generation Networks. The ecosystem around LTE is continuously growing. The early availability of high-frequency LTE bands greatly contributed to the current device ecosystem and operator rollouts. LTE is mostly deployed using 1,800 MHz (band 3) spectrum, currently in more than 150 commercially launched systems. LTE-A (Long Term evolution - Advanced) is an evolution of LTE introduced with the 3GPP TS R10. LTE-A potentially can boost the LTE 3GPP R8/9 peak bit rates to the requirements of 5G networks. Currently commercially launched 442 LTE networks in 147 countries.

Technology Description

- LTE was introduced with the 3GPP R8 and is the access part of the Evolved Packet System (EPS). Availavle on the market since 2010
- 3GPP R10 is the first 3GPP release incorporating LTE-A features. Commercially deployed in 2013.
- Driven from the spectrum, bit-rate and cost reduction demand, 3GPP has set the targets and expectations for evolution of HSPA+. LTE/LTE-A:
    - significantly increased peak data rates
    - increases cell edge bit rates
    - improves spectral efficiency

- reduces latency
- supports scalable bandwidth
- reduces CAPEX and OPEX

Radio Features

- All-IP based architecture for evolved UTRAN
- Simplified network reference model
- Advanced air interface and modulation DL: OFDM, UL: SC FDMA
- OFDM for downlink
- SC-FDMA for uplink
- Variable spectrum allocation between 1.4 and 20 MHz
- Enhanced RAN Performance. Targets:
- 1 Gbit/s DL for low mobility
- 0.5 Gbit/s UL for low mobility
- Flexible bandwidth: 1.4, 3, 5, 10, 15, 20 MHZ
- Up to 5 carriers aggregation for maximum bandwidth of 100 MHz
- MIMO (enhancements 8x8 MIMO)

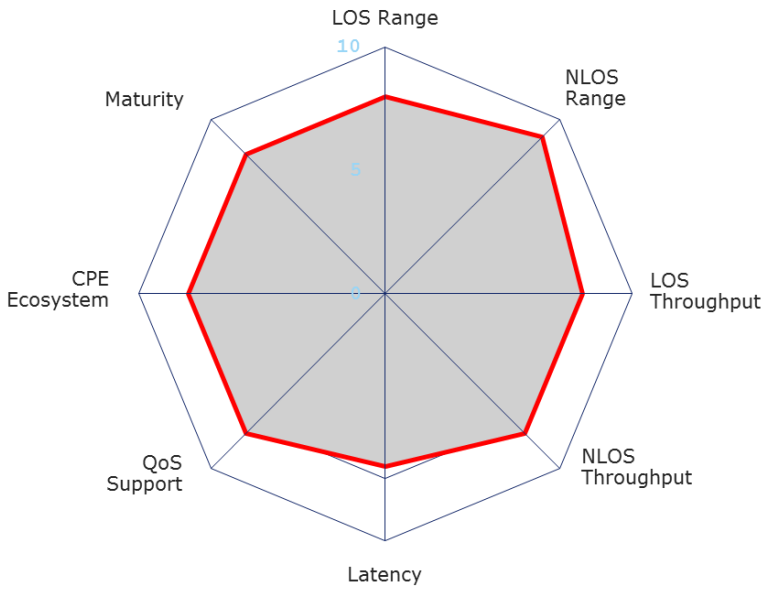


Figure 10 Technology Assessment LTE-A

3.1.2.4.1 LTE450MHz

3GPP completed the standardization process of the 450 MHz band in September 2013. The corresponding specifications of this brand-new band, designated Band 31, will become available as part of LTE Release 12 specifications, and will maintain backward compatibility with all previous LTE Releases. The global standard

for LTE450 is offering coverage of around 30 kilometers, and defining appropriate technical characteristics for the deployment of 4G systems in sparsely populated areas.
3GPP standardization recognizes the use of LTE 450 MHz technology as an adequate solution for serving rural and sparsely populated areas, and endorses its application in markets other than Brazil as long as these have similar territorial dimensions and population density. Countries that already rely on the 450 MHz band to accommodate code division multiple access (CDMA) networks, such as the Russian Federation, Norway and Argentina, are potential markets for the LTE solution. The 450 MHz band is used by over 20 million people worldwide, who could also benefit from advanced services based on LTE technology.
LTE 450 MHz technology has the potential to become an important tool for providing access to broadband services in rural and remote areas. This, in turn, can contribute to economic and social development, and promote digital inclusion in developing countries.
As in the countryside, such areas are typically characterized by the lack of backhaul and electrical power infrastructure. This challenging operational environment called for a new LTE profile designed for operation in the 450–470 MHz band, with radio frequency propagation conditions superior to those of existing profiles already standardized by 3GPP. Specifying and deploying LTE 450 MHz technology presents a number of challenges, most of which relate to interference management and system constraints to meet the need to provide extensive cell coverage.
Increased cell coverage: The deployment of cells with radii of the order of tens of kilometers places an additional burden on the development of LTE network equipment. Larger cells require higher transmission power, which directly translates into more complex power amplifiers. The longer reach offered by the 450 MHz band can compensate for part of this need, especially when high-gain antennas are used. As for the antenna, the designer should take into account aspects such as gain, radiation pattern, certification standards, ease of installation and, most importantly, physical dimension (recalling that the lower the operating frequency, the larger the radiating system).

In 2013, two companies (Huawei and Nokia) announced the availability of LTE equipment (base stations and terminals for both indoor and outdoor use) capable of operating in the 450 MHz band. The two manufacturers have been conducting interoperability tests with Brazilian carriers, and the first LTE 450 MHz commercial networks are running in compliance with the ANATEL 4G auction requirements by 2014.


Base station

Two exemplary measurements in Brazil proofed, that under excellent conditions >30km coverage could be expected, when there would not be obstructed LOS cases. **It is expected in general, that ranges from 15-20km would be more reliable and valid for most cases. Therefore ~20km circles were used in the project as estimate.**

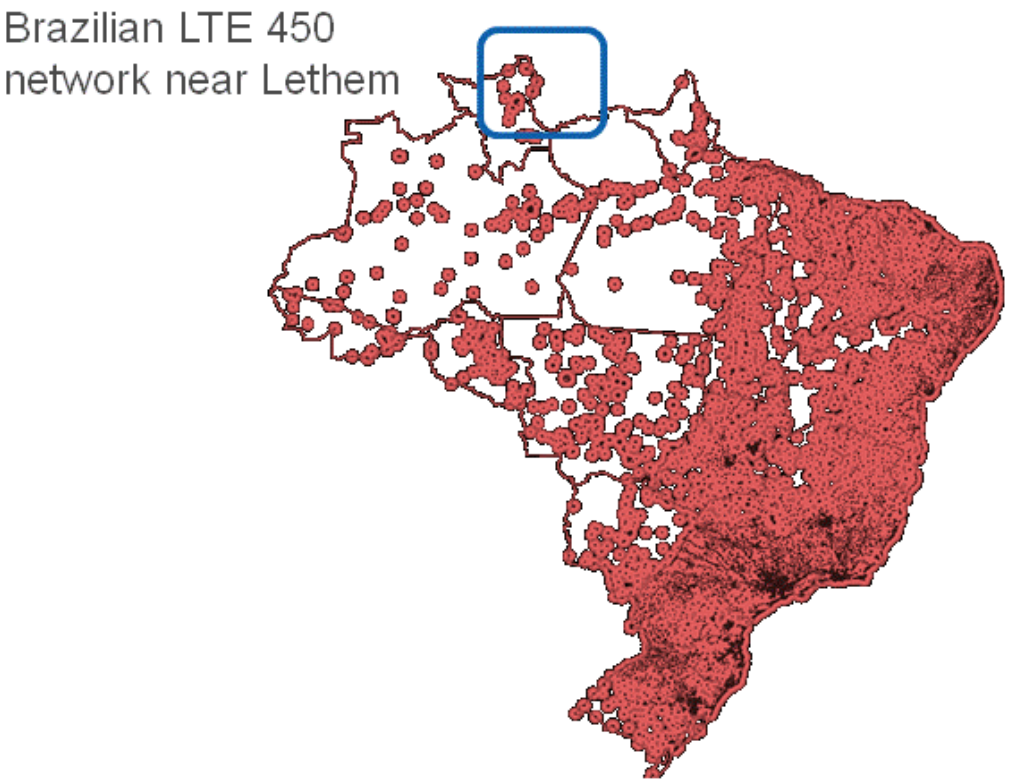


Figure 11: LTE 450 coverage of Brazil networks (with LTE450 near Lethem)

3.1.2.5 Wi-Max

Mobile WiMAX was the first 4G-like technology supporting all IP and OFDMA wireless broadband technology with advanced antenna systems

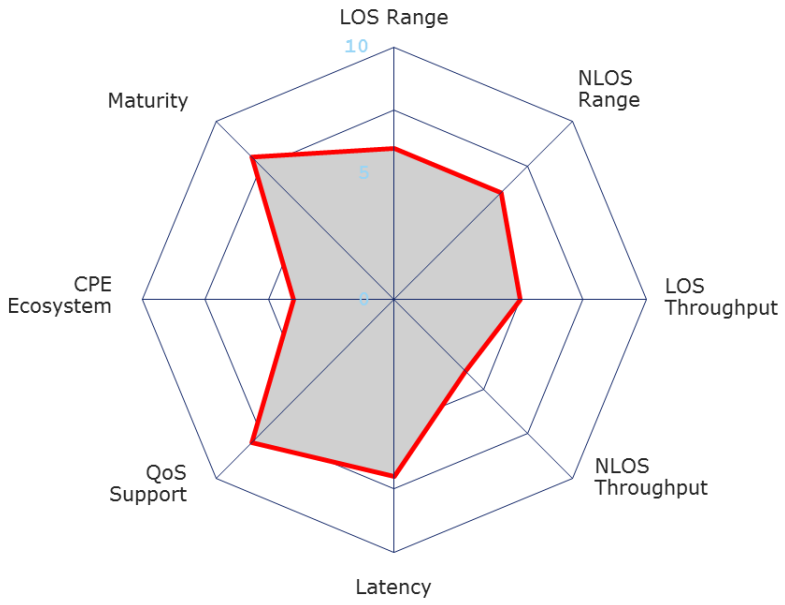
WiMAX 2 based on IEEE 802.16m standard follows the 4G requirements and replicates the most of the LTE radio interface features

Technology Description

- WiMAX is based on the modern technologies of the wireless access. 802.16m is an evolutional development of the first mobile WiMAX standard 802.16e
- IEEE 802.16m is designed to support frequencies in all licensed IMT bands below 6 GHz and include TDD and FDD duplexing schemes as well as half-duplex FDD (H-FDD)
- WiMAX was expected to be a technology of 4G networks, but LTE mass deployment totally intercepted this market
- Currently worldwide running around 360 WiMAX networks, only 2 network under standard 802.11m deployed, the rest are 802.16e. Strategy – smooth migration to LTE

Radio Features

- MU MIMO 8 Data Streams in DL and 4 Data streams in UL
- Enhanced Control Chanel design in UL and DL
- Improved open-loop power and closed-loop control
- Multi-Carrier support up to 100 MHz aggregation
- VoIP Capacity 80 calls/MHz (MIMO 4x2)
- Peak Throughput DL 300 Mbit/s / 20 MHz MIMO4x4; UL 135 Mbit/s / 20 MHz MIMO2x4;
- Interworking with other networks improved (3GPP, 3GPP2, Wi-Fi)
- Fractional frequency reuse (FFR) and segmentation



3.1.2.6 Wi-Fi

Wi-Fi is a technology from Institute of Electrical and Electronics Engineers (IEEE) and the most prominent technology of the 802.11 standards family. Widespread of this standard worldwide has resulted in availability of the Wi-Fi adapters in almost all consumers electronic devices such as mobile phones, smartphones, notebooks, game consoles. Wi-Fi equipment mainly using 2.4 and 5 GHz ISM bands. Release of Wi-Fi standard 802.11ac applicable for home, enterprise and carrier grade deployment scenarios has actually the potential to exceed the 1 Gbps threshold.

Technology Description

- Wi-Fi transmission takes place utilizing unlicensed spectrum bands
- National regulations hold true for utilization of specific sub bands and maximum transmission power
- IEEE 802.11ac is an amendment to 802.11n and provides full backward compatibility to legacy client
- Wi-Fi Alliance's Hotspot 2.0 and 3GPP Rel.11 specifications allows to provide a future-proof solution for data offload meeting the requirements of mobile operators.
- Maximum Client Data Rate with three Spatial Stream (3x3) 1.3 Gbps
- Range in ideal conditions up to 70m indoor and up to 250m outdoor
- Low power consumption

Radio Features

- Channel Widths 20, 40, 80, 160 MHz
- 1 to 8 Spatial Streams for MIMO utilization (up to 4 per client). MU-MIMO supported
- Modulation up to 256-QAM (OFDM)
- Output power 100 mW for 2,4 GHz band and up to 1000 mW for 5 GHz band

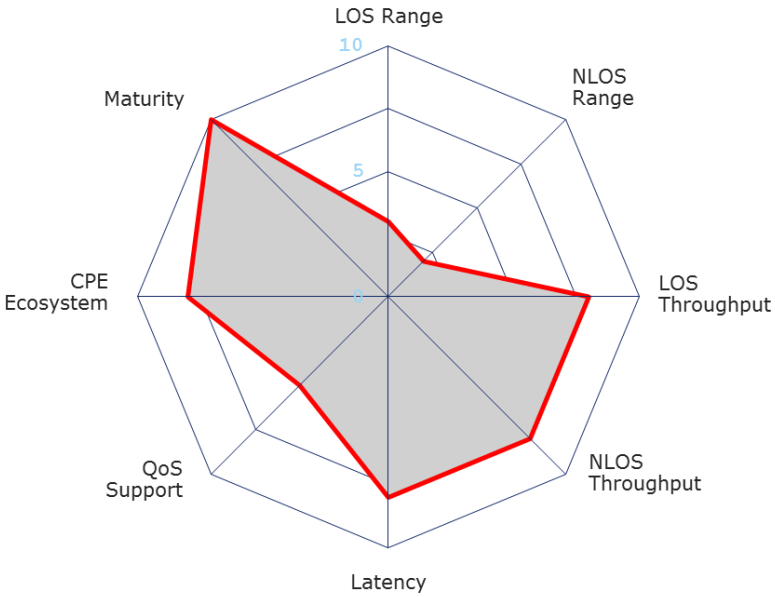


Figure 12 Assessment of the Wi-Fi Technology

3.1.3 Access Technology

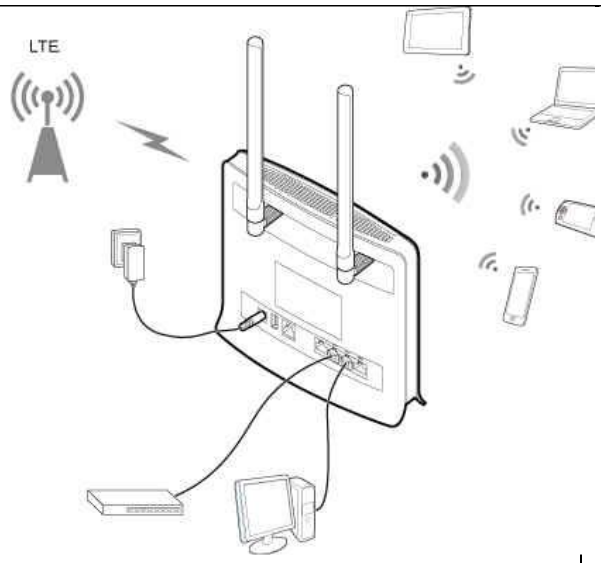
In this report, the final access is assumed with affordable WiFi capable end user devices, which have access to one router device, either

- Router with LTE last mile access together with any other backhauling technology
- Router with Satellite backhauling
- Router with WiBACK®-backhauling, which could also be input part of a WiFi mesh network

The principle is well known from 3G Fixed-Mobile-Solutions and exemplarily(!) shown in Figure 13 **Error! Reference source not found.** for LTE450 with a Huawei-router connecting LTE450 with other WiFi-devices or via Ethernet to computers, laptops, … (An example for the Satellite backhauling is shown in Figure 7)

All solutions are in principle the same, but differ in the capability of the routers to connect an external antenna to extend the coverage range in a special direction (with the principle of higher gains within reduced beamwidth, but also more knowledge about the pairing antenna for proper orientation).

These solutions differ mainly in price due to different ecosystems. Due to availability, simple WiFi-only routers are cheaper (and might prevent price erosion due to increase of more functionality) than LTE-capable routers, which also differ due to the availability of LTE-bands. The general, the most expensive Routers are the Satellite-WiFi routers due to limited ecosystem.

 **Figure 13: LTE450 device overview (exemplarily Huawei: B593s-31A)**	 **B593s-31A (band 31)** • Indoor only • >-1 dB antenna gain for 450MHz
	**Indoor unit of B2131** • WLAN at 2.4G (2400-2483MHz) • Max output power: 13-17dBm[3] • WLAN antenna gain: >2dBi • 3D peak[4]
	**outdoor unit of B2131 (for LTE450)** • Band 31 • Max output power: 23dBm • LTE antenna gain >5dBi • 3D peak value

The availability of 450 MHz LTE-capable devices is summarized as follows:

[3] 13dBm is quite low, as 53dBm are allowed according to FCC-WiFi-EIRP limits.

[4] Not clear what is meant with 3D peak, but it is expected the peak value/main lobe.

The ecosystem for 450 MHz is evolving since 2014, but still there are not many LTE assignments in LTE40. Huawei is commercially offering LTE450 solutions in China, Brazil and Belarus. This is expected to change when operators announce that they will soon be using the 450 MHz spectrum for LTE.
It is not clear if multimode smart phone terminals would be needed from the beginning. Depending on the operator's service strategy, the demand for fixed CPEs with 450-470 MHz modem and Wi-Fi capability would be sufficient for the initial phase with reduced availability of terminals. In addition, embedded solutions are more likely to be developed as LTE450 backhaul for general Wi-Fi connectivity
In a second phase with higher traffic demands there will be a need for multimode devices (fixed CPEs or smart phones) to enable efficient, traffic-steering mechanisms between different bands, especially in the case of TDD usage between LTE450 and LTE2300, LTE2600 or LTE3500, and the other FDD LTE bands
At the moment no router has LTE2300 and LTE450 in one router, which would be attractive for Carrier Aggregation of LTE450 and LTE2300 for coverage enhancements. The same holds as well for LTE700 or LTE800 with LTE2300.
Later there will be a demand for cheap M2M RF-units in this band as well as for other LTE bands. Due to the limited capacity in 450 MHz the terminals may by design remain simple

3.1.4 Technology Selection for Guyana

Keeping focus on the provisioning of related services forecasted for the next 5 years several communication technologies such as GSM/GPRS/EDGE immediately excluded from the list of optional technologies, as they do not satisfy the minimum requirements of the service demands. All Other technologies can deliver forecasted services to the consumers.

In the following the main criteria for the selection of the right backhauling technology are shown in the figure below and will be briefly summarized.

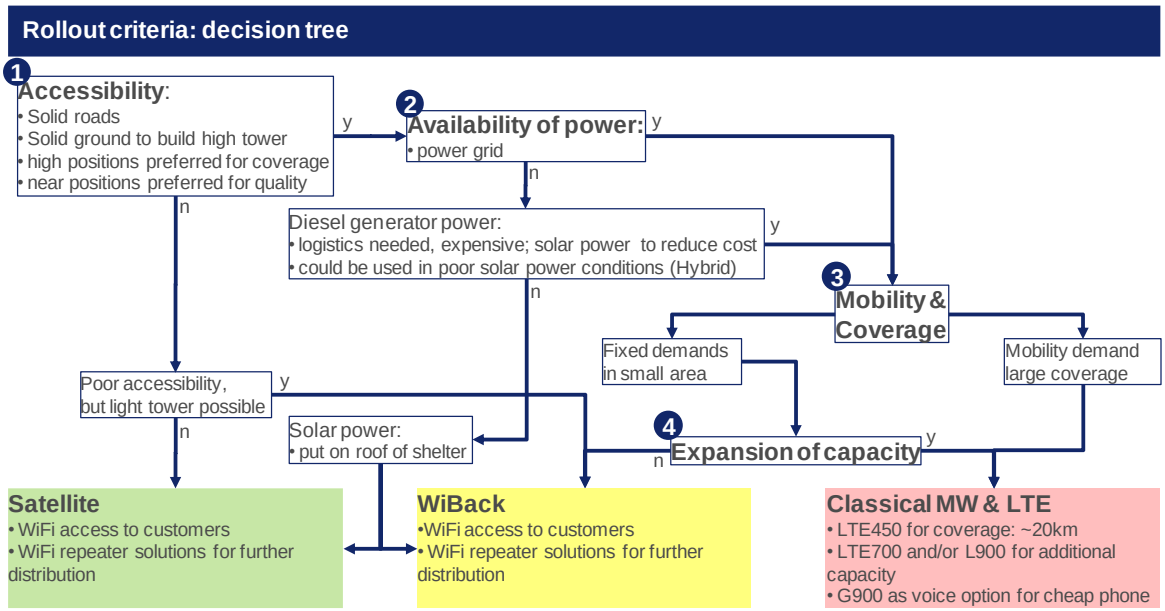


Figure 14: Backhauling technology decision tree

Solar panels needs to be larger for higher power requirements (as for classical MW&LTE)

Larger batteries are needed as well for MW&LTE. These larger batteries have higher maintenance and shorter replacement cycles.

Satellite and Wi-Fi based backhaul have low power consumptions and remain as option in case of critical power supply.

In case of lower coverage requirements, LTE also reduce transmit power and consequently power consumption. LTE also use energy saving modes in case of low utilization, but overall, the power consumptions remain higher.

Coverage

LTE is more favorable to cover larger ranges and offer high mobility in case of mobile terminals or incar-terminals, e.g. for PPDR services. LTE is not affected by rain attenuation.

Wi-Fi based backhaul need high gain directional antennas to compensate for the higher frequency propagation losses. Wi-Fi based backhaul is primarily focused to replace the conventional P2P-MW-links. The local distribution of the signals needs to be done P2P as well to reach medium range hotspots. The final WiFi meshing grid of <300m increase nodes and efforts of backhauling. Wi-Fi based backhaul is more favorable to connect stationary hotspots with high capacity density.

Capacity

LTE450 with 2*5MHz offers only a medium capacity at a quite large area. Average each LTE450 offers ~10Mbps, 30Mbps per site. LTE700 with 15-20MHz bandwidth would offer 3-4 times capacity. LTE450 is able to reach 35Mbps in excellent conditions. LTE700 with CA much more.

Wi-Fi based backhaul has highest capacity density (e.g. 180Mbps per 300*300m²) which would be in most cases too high for rural applications.

Wi-Fi based backhaul could cover large distances at low power consumption and with moderate backhauling capacities, but has two main drawbacks:

1. The final access to the end users is done with WiFi to connect cheap WiFi-capable phone. This in general is fine, but also limited to a short range of less than 500m in general propagation conditions. A higher number meshing network is required.
2. The Wi-Fi based backhaul equipment itself is cheap, but there were still high towers needed, which suppose to remain the most expensive part in the rollout. Even if Wi-Fi based backhaul is used for low range meshed backhauling without towers, the equipment is much more expensive than current WiFi-access devices with access to mobile networks.

Wi Back might connect the areas of poor accessibility and power with minimum coverage demands and will be considered as one option in the rollout for Guyana.

The LTE450 last mile access technology is more beneficial and flexible than P2P access of satellite links or the P2MP of MW or WiBACK®-links which have small antenna beams and need very tight and reliable orientation[5] and line of sight in most cases.

LTE450 covers especially potential mobility demands in rural areas, so police cars, trucks of logistic companies, etc. could implement incar router antenna solutions. These mobile LTE450-router solutions would give wireless broadband access where really needed, either in work places or resident homes, limited by the WiFi-coverage. The investments in the (mobile) LTE450-routers and fuel etc. could be covered by small WiFi-packets sold to end users, stimulating local entrepreneurs` business.

In case of higher, exclusive demands for e.g. hospital services which might not be sufficiently covered with the shared LTE-capacity, a dedicated WiBACK®- or MW-link might be needed in addition to the LTE450 rollout.

Comparison of the different technologies based on their specification reveals the following favorite technologies:

- In Backhaul Technologies **Wi-Fi based backhaul**due to support of long distance communication with use of ISM unlicensed bands and **Microwave** technology with frequency 7GHz as a carrier grade technology with support of the similar distance communication, but with significantly higher throughput rates support
- As a Last mile **LTE technology** selected as the only future proof technology standardized for use in 450 MHz spectrum. This band recognized as a best-fit band particularly for the task of bringing coverage to very rural areas.

For remote locations where PoPs cannot be achieved via traditional backhauling, satellite backhaul seen as the only possible solution and a compromise between performance and difficulty to deploy service. However rapid traffic growth in the last few years worldwide fueled by the introduction and the popularity of new devices like Smartphone, iPhone, Tablets can result in approaching the physical limits of the satellite network in the nearest future.

3.2 Design options for Guyana

3.2.1 Solution description

All selected Technology options to the determined technology options determined based on different parameters the following solutions were developed

- **Solution 1 MW+LTE+Sat** This solution describes the details of the coverage in the target sample of the locations with use only LTE 450 MHz base stations and traditional backhaul microwave solution. Remote locations where no points of access exist connected via VSAT terminals.
- **Solution 2 Wi-Back+Sat** Solution 2 based on the Wi-Fi based links, which are used in both the last mile domain and backhaul domain. Access for the very remote locations as in the solution 1 provided via satellite connectivity.
- **Solution 3 Sat only** Solution 3 brings a simple and flat network architecture with use of the satellite links only for access to services within the target sample with communities. Deployment numbers in this case represents only the number of satellite installations, which reflects the number of locations to be covered.
- **Solution 4 Combined** represents a mix of the solutions described above, where every of this solutions deployed with the highest efficiency. Selection of the solution for different locations based on the

[5] It is expected that rain and wind would lead to misalignments in reality which reduce link capacity.

landscape, capacity demands, strategy of the Guyana ICT sector development. Deployment numbers for the combined solution presented in the table below

-

3.2.2 Solution assessment

Criterion	Solution 1	Solution 2	Solution 3	Solution 4
Simplicity –flat technology, no technology zoo.	◑	◑	●	◔
Future proof – flexible, ready for new services, capacity reserve available	◑	●	○	●
Deployment simplicity, rollout speed, additional infrastructure deployment	◔	◕	●	◑
Green IT compliance Energy efficiency, solar power based deployment, maintenance free power systems	◔	●	●	◔
Ease of Operation and maintenance, no skills required for network maintenance.	○	◕	◕	◔

Table 2 - Comparison of solutions

3.3 Commercial assessment of solutions

3.3.1 Introduction

The purpose of the commercial assessment of the different technical solutions is to define the most cost effective way of offering the connectivity in the hinterland taking into account network development plans and service demands during the years 2017-2021. Commercial assessment of the different technologies extends beyond the initial capital expenditures maintenance and software assurance and calculates all potential operational costs over the full intended lifespan.

Due to the fact, that the access network consumes a major part of the CAPEX of the whole telecommunication network during deployment, network operators choose access network technologies based on a cost/benefit analysis. The main reason for deployment being for the coverage of rural areas in order to provide packet data based e-services to the broader population.

Together with technical selection criteria and service selection criteria, cost analysis serves as a solution selection criteria and gives the outline of the potential investments with many factors involved.

- CAPEX and OPEX forecast and tendency to change during the year
- Rough estimation of the investments required
- Identify the key cost drivers of each solution

According to the current situation of the eGovernment service and infrastructure availability, all locations within the country conditionally divided to the following groups

- Coastal area, which includes locations where eGovernment possesses its own LTE infrastructure, including fiber lines, towers and base stations and locations where service can be delivered by means of expansion of the existing LTE network with additional 450 MHz frequency layer
- Other locations within the country which currently have no access to the eGovernment infrastructure

Expansion of the network in the coastal area with additional frequency layer of LTE 450 on top of the existing infrastructure acknowledged as the most feasible solution for coverage of these locations. Therefore these locations not included into cost estimation for different solution. For cost estimation selected 163 locations due to availability of the location description i.e. coordinates, population, etc.

The initial approach of the cost assessments consists of the following basic steps

- Create itemized list for all foreseen expenses
- Derive the real market price based on the similar projects worldwide using the Detecon benchmarking database
- Calculate the CAPEX and OPEX based on the yearly rollout plan numbers

3.3.2 Cost components and assumptions

Typical structure of the evaluation cost of expenses for telecommunication companies based on the cost components listed below, but some cost components excepted from the scope due to specific conditions and benefits of the public institution, which is the eGovernment unit.

Solution Cost	
CAPEX	**OPEX**
Active Hardware	Licenses e.g. yearly fees
Installation	Rental fees
Feature activation and SW	Power e.g. electricity, fuel
Spare parts	Infrastructure Leasing costs
Civil work e.g. towers, etc.	Maintenance
Other infrastructure (power)	Repair services
Spectrum fee	Spectrum fee

The following cost groups used for evaluation:

CAPEX

- Active Hardware – Costs of the hardware components including radio access network, backhaul and transmission network
- Installation – One time fees required to deployment and commissioning of the active equipment in the target locations
- Feature activation and software – fee to the equipment manufacturer for the activation of the required functionality of the equipment and purchase of the operational software
- Spare parts – Purchase of the minimum required components for all types of the active equipment to reduce mean time to repair in case of equipment malfunction
- Civil work – installation of the passive infrastructural facilities such as towers, protection fences, etc.
- Other infrastructure fees includes the purchase and deployment of different power supply systems, backup solutions, etc.
- Spectrum fee – Frequency license acquisition cost (out of scope, as a public institution eGovernment have no obligations and fees for use of any free spectrum)

OPEX

- Yearly fees – periodical fee to the vendor of the active equipment for update, bug fixes, support service (depends on the frame contract conditions)
- Rental fee is a periodical fee to the owner of the land where equipment deployed (out of scope, all infrastructure will be deployed on the territory of the public institutions)
- Power, electricity, fuel – monthly fees to the power companies and refilling of the diesel generators on the sites
- Infrastructure leasing costs – leasing of the existing telecommunication or other infrastructure from other operators (out of scope, taking into account challenges in the cooperation between telecommunication companies in Guyana, use of own infrastructure assumed for the proposed solutions)

- Maintenance – periodical service of the site according to recommendation of the vendors including planned replace of the parts
- Repair fees – accidental service fees for functionality recovery on the sites after failures
- Spectrum fee – Periodical payments for operating of the frequency license (out of scope, as a public institution eGovernment have no obligations and fees for use of any free spectrum)

The following prices taken as a baseline for the rollout of all scenarios.

	Unit	CAPEX		OPEX (yearly values)	
RAN	LTE BS 3 Sector Outdoor 8 hours batteries	$ 150,000.00	HW+Licenses+ Antenna+ Mounting kits per base station with cabling	$ 3,000.00	Service Spare parts Maintenance
	LTE BS 3 Sector Outdoor 24 hours batteries	$ 175,000.00	HW+Licenses+ Antenna+ Mounting kits per base station with cabling	$ 3,500.00	Service Spare parts Maintenance
Core	Evolved Packet core	$ 3,000,000.00	S-GW P-GW (specify capacity) MME HLR OMC	$1,000,000.00	S-GW P-GW (specify capacity) MME HLR OMC
Backhaul	MW backhaul link 7GHz	$ 20,000.00	2 pieces of MW equipment link including all mountings and antennas Installation per link	$ 2,000.00	Spare parts Maintenance
	Satellite backhaul	$ 25,000.00	Carrier grade satellite active and passive equipment Installation	$ 4,000.00 1mbps/ per month	Tariff description and price
	Leased line fiber		No capex		
Tower & Power	Tower 20 m	$ 15,000.00	Civil Works Installation	$ 18,000.00 $ 12,000.00	
	Tower 30 m	$ 22,000.00	Civil Works Installation	$ 25,000.00 $ 19,000.00	
	Tower 40 m	$ 28,500.00	Civil Works	$ 25,000.00	

			Installation	$ 25,000.00	
	Tower 60 m	$ 35,000.00	Civil Works Installation	$ 30,000.00 $ 30,000.00	
	Light tower 20 m (load 12 kg)	$ 22,000.00	Civil Works Installation		
	Light tower 30 m (load 12 kg)	$ 30,000.00	Civil Works Installation		
	Diesel generator for LTE, MW and/or satellite	$ 13,000.00	Diesel generator (17kw) Fuel tank (300lt) Installation	$ 40,000.00 $ 4,000.00 $ 3,500.00	fuel maintenance
	Solar panel for LTE, MW and/or satellite with batteries 24 hours	approximately $90per watt installed	Solar panel (per watt rural) Installation (per watt install rural)	$ 30.00 $ 60.00	site visit

3.3.3 Solution I MW+LTE+Sat

The following numbers for rollout received based on high-level GIS planning.

Item		2017	2018	2019	2020	2021
1	LTE Base station	0	25	0	3	0
2	MW Link	0	20	0	5	0
3	Wi-Back link	0	0	0	0	0
4	Satellite link user	7	16	14	8	9
5	Satellite link backhaul for LTE	0	1	0	0	0
6	Core deployment Mbps		600		90	
7	Diesel generators	0	0	0	0	0
8	LTE BS Solar panels	0	3	0	3	0
9	Leased line	0	0	0	0	0

10	Tower for LTE	0	22	0	5	0
11						
12	UA devices	176	175	105	81	102
13	Wi-Back Tower					
14	Wi-Back Core					
15	Service Wi-Back people					
16	Service LTE people					
17	Satellite link user 10M	7	0	0	0	0
18	Satellite link user 6M		16	14	6	
19	Satellite link user 4M				3	9

Based on the rollout numbers the following expenses expected over the 5 years.

	Cost Component	2017	2018	2019	2020	2021
CAPEX	Active equipment	7,000	5,369,000	14,000	739,000	9,000
	Towers and facilities	0	931,000	0	251,000	0
	User access	158,400	157,500	94,500	72,900	91,800
OPEX	Active equipment	28,560	307,040	338,960	392,640	408,840
	Towers and facilities	0	1,500	1,500	3,000	3,000
	User access	17,600	35,100	45,600	53,700	63,900

This solution assumes usage of LTE base station for the most cases. This lead to installation of a large number of LTE Base stations and construction of the autonomous power system for the sites as power grid in the country is underdeveloped. Nevertheless, investments to the reliable carrier grade infrastructure permits future development of the services and network

3.3.4 Solution 2 Wi-Back+Sat

The following rollout numbers expected for this solution:

Rollout No.		**2017**	**2018**	**2019**	**2020**	**2021**
1	LTE Base station	0	0	0	0	0

2	MW Link	0	0	0	0	0
3	Wi-Back link	0	82	0	16	0
4	Satellite link user	7	16	14	0	9
5	Satellite link backhaul for LTE	0	0	0	0	0
6	Core deployment Mbps					
7	Diesel generators	0	0	0	0	0
8	LTE BS Solar panels	0	0	0	0	0
9	Leased line	0	0	0	0	0
10	Tower for LTE	0	0	0	0	0
11						
12	UA devices	176	175	105	81	102
13	Wi-Back Tower	0	77	0	13	0
14	Wi-Back Core		1			
15	Service Wi-Back people		2			
16	Service LTE people					
17	Satellite link user 10M	7	0	0	0	0
18	Satellite link user 6M		16	14	6	
19	Satellite link user 4M				3	9
20						

Based on Rollout numbers the following expenditures expected during the next 5 years.

	Cost Component	**2017**	**2018**	**2019**	**2020**	**2021**
CAPEX	Active equipment	7,000	431,000	14,000	89,000	9,000
	Towers and facilities	0	1,694,000	0	286,000	0
	User access	158,400	157,500	94,500	72,900	91,800
OPEX	Active equipment	28,560	78,160	110,080	131,720	147,920
	Towers and facilities	0	0	0	0	0
	User access	17,600	35,100	45,600	53,700	63,900

Wi-Fi based backhaul (Wi-Back) is a relatively new technology used mainly in developing country. The main benefits of the technology are simplicity, low cost equipment and low power consumptions. This makes the

technology effective for deployment in rural areas. In this calculation, main cost component of this technology is a high number of towers deployment required mainly in the areas close to coast.

3.3.5 Solution 3 Sat only

Deployment numbers presented in for this solution in the table below

Rollout No.		2017	2018	2019	2020	2021
1	LTE Base station	0	0	0	0	0
2	MW Link	0	0	0	0	0
3	Wi-Back link	0	0	0	0	0
4	Satellite link user	24	38	24	18	59
5	Satellite link backhaul for LTE	0	0	0	0	0
6	Core deployment Mbps					
7	Diesel generators	0	0	0	0	0
8	LTE BS Solar panels	0	0	0	0	0
9	Leased line	0	0	0	0	0
10	Tower for LTE	0	0	0	0	0
11						
12	UA devices	176	175	105	81	102
13	Wi-Back Tower					
14	Wi-Back Core					
15	Service Wi-Back people					
16	Service LTE people					
17	Satellite link user 10M	22	0	0	0	0
18	Satellite link user 6M	16	24	19	10	
19	Satellite link user 4M				49	

Based on Rollout numbers the following expenditures expected during the next 5 years.

	Cost Component	2017	2018	2019	2020	2021
CAPEX	Active equipment	38,000	24,000	19,000	59,000	0
	Towers and facilities	0	0	0	0	0

	User access	158,400	157,500	94,500	72,900	91,800
OPEX	Active equipment	126,240	180,960	224,280	335,280	335,280
	Towers and facilities	0	0	0	0	0
	User access	17,600	35,100	45,600	53,700	63,900

This is the cheapest solution, considering usage of the third party infrastructure, such as satellites and earth stations for realization of the project. Commercial model can be explained as pay as you use, means linear CAPEX and OPEX investments. This model is mostly OPEX based and do not require any heavy CAPEX investments during the whole lifespan period. The main obstacles hindering the satellite connectivity deployed everywhere is a limited bandwidth resource. Therefore considering satellite as a solely future-proof solution for the whole country is not possible.

3.3.6 Solution 4 Combined

Deployment numbers for the combined solution presented in the table below

Rollout No.		**2017**	**2018**	**2019**	**2020**	**2021**
1	LTE Base station	0	7	0	3	0
2	MW Link	0	2	0	5	0
3	Wi-Back link	0	20	0	11	0
4	Satellite link user	7	16	14	0	9
5	Satellite link backhaul for LTE	0	1	0	0	0
6	Core deployment Mbps		150		90	
7	Diesel generators	0	0	0	0	0
8	LTE BS Solar panels	0	3	0	3	0
9	Leased line	0	0	0	0	0
10	Tower for LTE	0	4	0	5	0
11						
12	UA devices	176	175	105	81	102
13	Wi-Back Tower	0	18	0	8	0
14	Wi-Back Core		1			
15	Service Wi-Back people		2			
16	Service LTE people		6			
17	Satellite link user 10M	7	0	0	0	0

18	Satellite link user 6M		16	14	6	
19	Satellite link user 4M				3	9
20	Tower for LTE		7			

Based on the rollout number the following expenses estimated over the following 5 years

	Cost Component	2017	2018	2019	2020	2021
CAPEX	Active equipment	7,000	685,000	14,000	389,000	9,000
	Towers and facilities	0	535,000	0	337,000	0
	User access	158,400	157,500	94,500	72,900	91,800
OPEX	Active equipment	28,560	135,640	167,560	223,000	239,200
	Towers and facilities	0	1,500	1,500	3,000	3,000
	User access	17,600	35,100	45,600	53,700	63,900

This solution is the most Sophisticated due to optimal use of each technologies in each location. This helps fully utilize all benefits of each technology. Nevertheless, technology zoo requires to have specialists for each of the technologies in staff and makes maintenance, service and spare part management a bit more complicated.

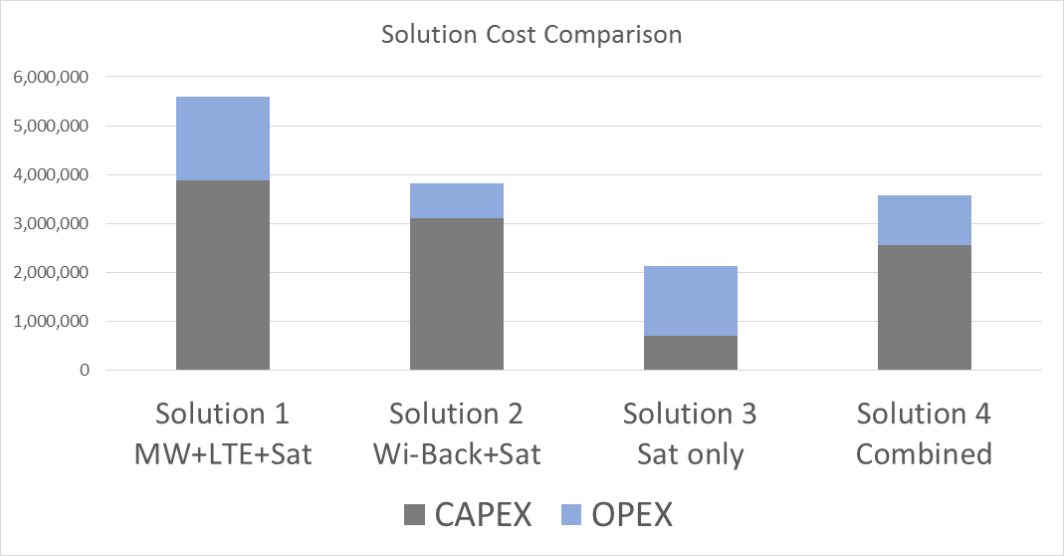
3.3.7 Conclusion

Considering that the planned network intended for provision of non-commercial services the cost effectiveness can be a main criterion for the selection a particular technology. Nevertheless, cost should not be the only parameter taken into account. In the table below, overall expenses expected in the next five years for each of the solutions presented.

		Solution 1 MW+LTE+Sat	Solution 2 Wi-Back+Sat	Solution 3 Sat only	Solution 4 Combined
	Total	**5,590,040**	**3,817,440**	**2,133,040**	**3,569,960**
CAPEX	Active equipment	2,618,000	550,000	140,000	1,104,000
	Towers and facilities	696,000	1,980,000	0	872,000
	User access	575,100	575,100	575,100	575,100
	Sub-total	3,889,100	3,105,100	715,100	2,551,100
OPEX	Active equipment	1,476,040	496,440	1,202,040	793,960
	Towers and facilities	9,000	0	0	9,000
	User access	215,900	215,900	215,900	215,900
	Sub-total	1,700,940	712,340	1,417,940	1,018,860

It is obvious that Solution 3 looks like the most attractive and flat as it is mainly OPEX based. This solution looks like "Pay-as-you-grow" pricing model that allows operator to purchase capacity incrementally as it is needed and very convenient for deployment. However, several obstacles can be discovered during the operation under this model. This model is typical for companies, which tries to reduce the risk of the investments or on the rapidly developing markets where tightening to the single technology can harm the strategy alignment and reduce flexibility of the business models. For the eGovernment Unit aimed at the long-term service provisioning OPEX models do not make any sense. After certain period of time leasing costs of the expensive satellite infrastructure override the expenses of the most the CAPEX based models. Another disadvantage is a full dependency on the third party owning the network and lack of the influence to the strategical planning of the network development.

Therefore Solution 4 looks as the most perspective as it comprises the strategical development of the own infrastructure with effective application of the suitable technologies independently for each specific location.



3.4 Proposed Guyana Solution

3.4.1 Radio Access Network for covering HPR areas

The following RAN technologies are expected for HPR areas in macro layer deployment:

- LTE450 as basic coverage layer in HPR as backhauling in the large area enabling larger coverage and flexibility
- LTE450 is primarily the HPR-last mile backhaul to the stationary WiFi-routers. In the second function, police or fire-brigade units could use LTE450 for Private Protection Disaster Recovery (PPDR) services (as long term trunking TETRA substitution or parallel use).
- GSM900 is only possible with incumbents as license holder for basic voice services. Tower infrastructure sharing might be assumed in the long run also depending on the tower load limitations and individual tower utilizations. LTE900 could be introduced by incumbents in case of new spectrum.
- LTE700 by GTT+ and Digicel and also eGovernment could also expand in the long term its network to L700/800 with 2*15MHz.

Further spectrum and network evolutions according to cooperation in ICT-broadband strategy: new spectrum for incumbents only based on agreements in liberalization and broadband initiative.

In order to use LTE450 or LTE700/800 in the future in the eGovNet, a connection to the core is essential, which is depicted in detail in Figure 15. In the coast area LTE2300 is connected to the existing EPS-core of eGovNet. The LTE450 cells of the same coast locations as well potential HPR LTE450 cells could also be connected to the same core.

In case of a potential shift of ownership or operation of LTE450 (or LTE700 as well), the cells could be connected to the incumbents' core as well without any dependency to the core from different vendors. In the case of any incumbent subscriber with LTE450-mobile terminals, they could be handled in national roaming in the eGovNet.

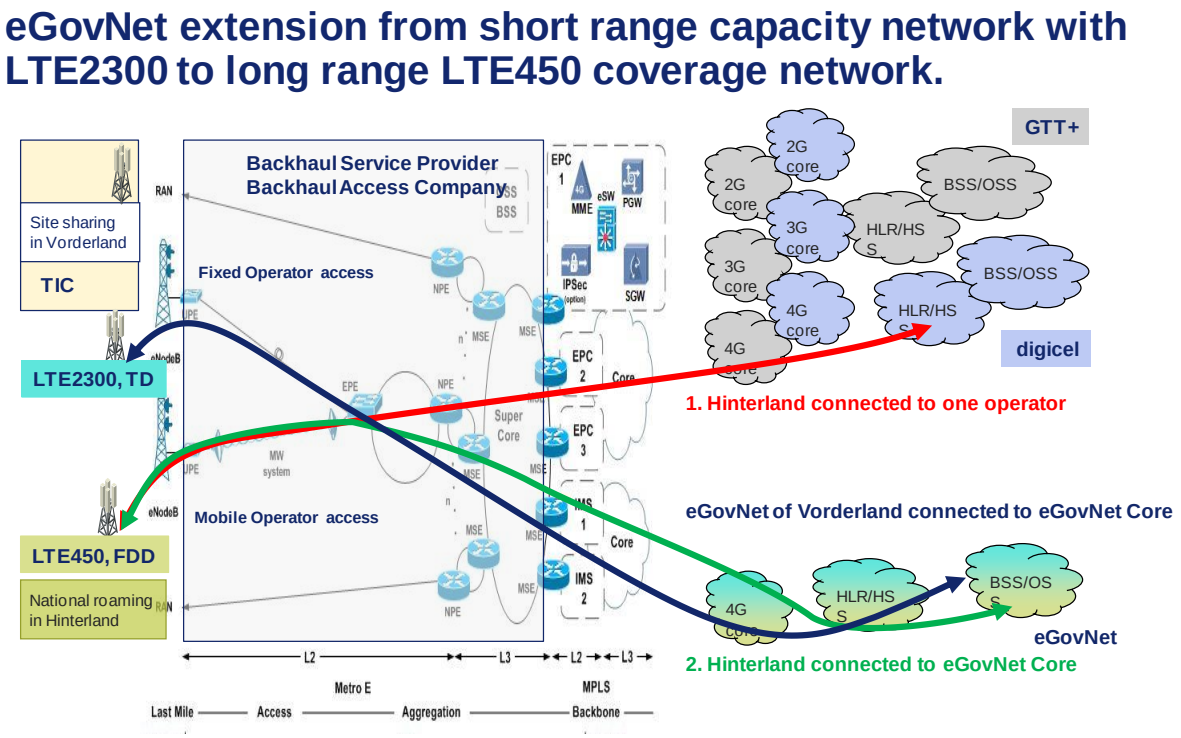


Figure 15: Hinterland connection to operator's core (1) or eGovNet's core (2)

3.4.2 Wi Fi based backhaul in HPR areas

In Figure 16one Guyana example for WiBACK® signal distribution within a location is given. In case of a new central backhaul point near the location center, e.g Toshao office, in total 4 WiBACK® units are needed. It needs to be decided per location if a tower is needed to keep Fresnel zone free.

b

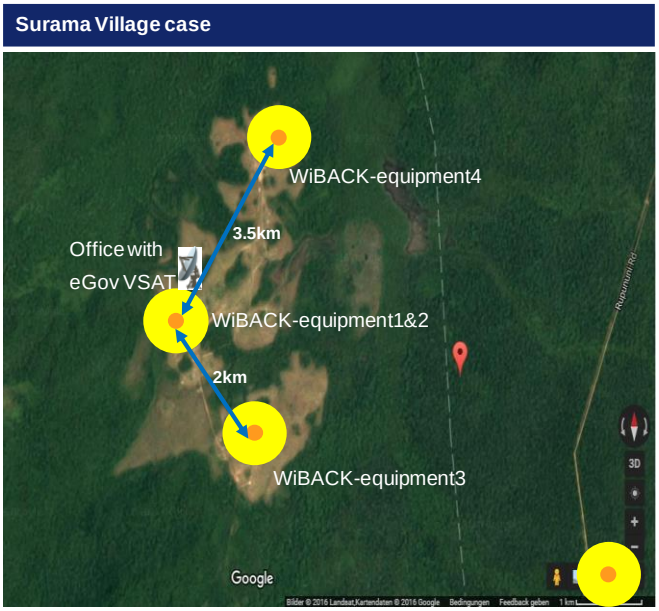


Figure 16: WiBACK® example in Surama

3.4.3 General Design Rules

The main design rules were the following:

- Terrain vegetation and topology were considered according to maps of Guyana Lands and Survey commission. It is recommended to update the maps in the next level detailed design.
- In areas with tall evergreen forest were supposed to be with reduced accessibility and reduced probability of tower deployments here. These areas remain for VSAT-rollout until higher demands and improved accessibility could be secured. The rollout would result in 55 locations with VSAT, covering 31% of the residual HPR-population starting with the high populated 7locations in the second half of 2017 after negotiations with potential suppliers, capacity building, OSS&BSS etc. In the following the average rollout speed is approximately 1 location per month.
- All other areas with medium or low forest heights were analyzed according to technical considerations.
- It is assumed to use eGovernment-own towers and infrastructure as intensive as possible, which is mainly concentrated in the coastal area, Linden and Lethem. In other areas, new towers would be considered. The same holds for power supply, in urban areas of GT to Linden, the power grid is assumed, while in Lethem and Barthica for example, independent new power solutions were chosen, ideally solar power, but this might change due to cost considerations.
- eGovernment will not provide Carrier Grade services and coverage and will not offer commercial services.
- In order to keep the rollout simple and to minimize technology mix per cluster, the focus is set on one further backhauling technology per cluster.
    - The higher the number of (potentially) covered locations per node LTE450 and MW were chosen. This is primarily the cluster along the line from Georgetown to Linden. As result, one LTE-site would have more than 10locations. The LTE450 coverage was assumed <20km which is less than the design target in Brazil to be in average on safe side with reference to rain forest coverage.
    - Otherwise, WiBACK® towers were proposed, especially to connect more hilly and mountainous areas. These would be assumed in the South-West of Guyana near Lethem.

- For the backhauling of Lethem and the assigned WiBACK® areas, the fiber connectivity to Brazil are expected to be realized as soon as possible, ideally in 2017.
- It needs to be aligned with the Guyana Civil Aviation Authority to build towers.

3.4.3.1 Population and villages

733 named locations were localized to 478 long/lat coordinates based on Census 2012 data provided. The full population was summed up as follows: 581k of 723k of the population was allocated according to list provided what represents around 80% of the total population. It was assumed that the other 20% were distributed in the same ratio near the known locations. It is observed that >83% of the known population is living in the coast area. So also >83% of the missing population is assumed in the coast area as well.

Only communities with a accumulated population number of more than 10 people have been considered in the rollout planning as it has been assumed that smaller communities don't have any public building and are therefore out of the current scope of eGovernment's plan to connect public buildings first.

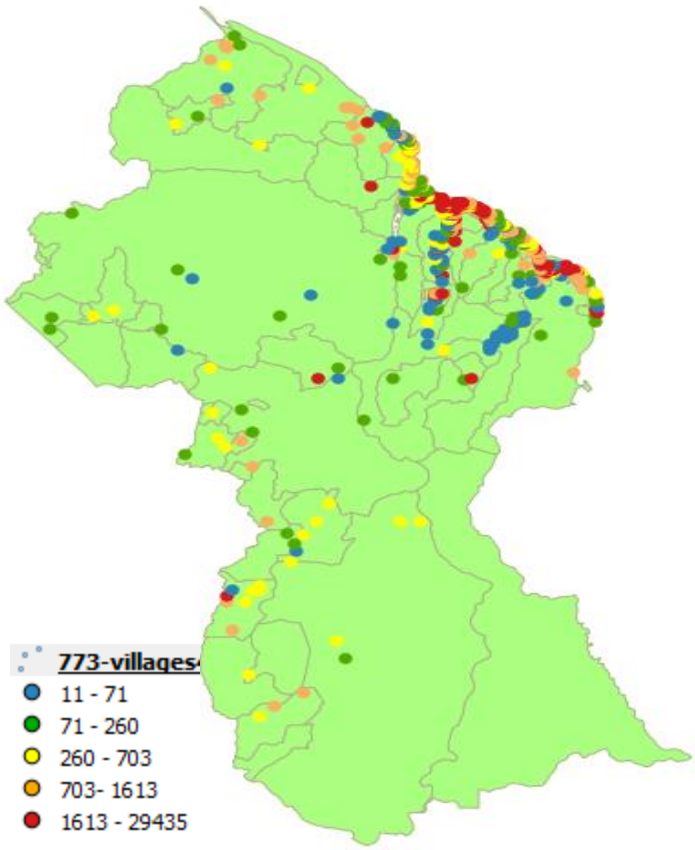


Figure 17 - 773 villages considered in the report

3.4.3.2 Solution design assumption

In the following the different underlying design assumptions over the different phases of the solution design and the rollout plan are depicted in Figure 18 to Figure 22 with their potential rollout options.

Design assumption "National Backbone step 1" – shared use of the GPL fiber network

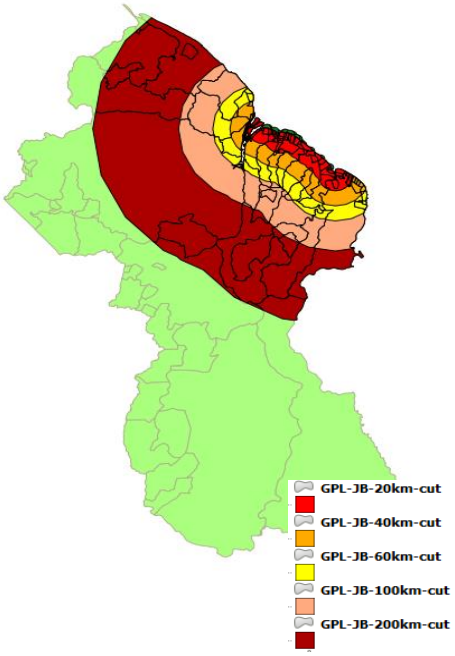


Figure 18 - National Backbone step 1

From the GPL fiber line up to 5 MW hops with ~5*20km could be built or up to 10 WiBACK® hops with ~10*20km. The colors show the different 10km, 20km, … 200km belts of *potential* coverage in case there is any interesting location and the possibility to build towers in these areas.

Design assumption "National Backbone step 2" - Connect Lethem by fiber to the Brazilian Network

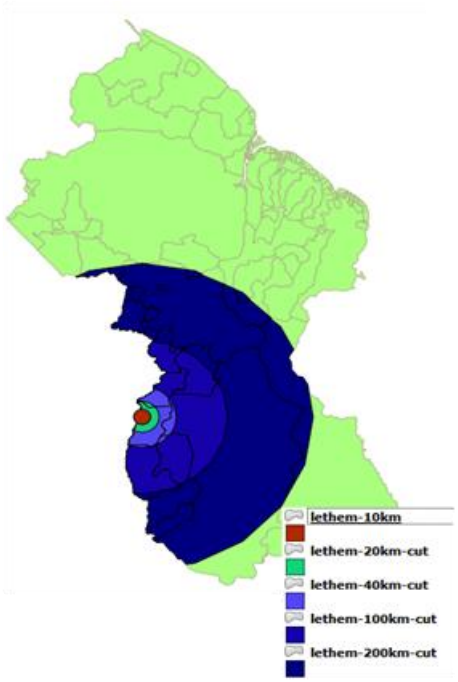


Figure 19 - National Backbone step 2

To provide broadband access to a major population spot quickly, connecting Lethem to the fiber optical network available just across the river in Brazil (in the city of Bonfim) has been assumed.
The range around Lethem is shown with up to 200km, but the different terrains and Mountains were neglected here.

Design assumption "National Backbone step 3" – connect Annai to Lethem and Linden to Georgteown via fiber

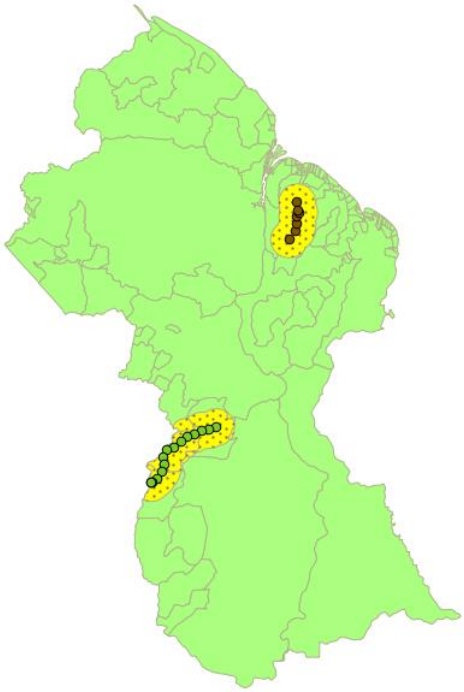


Figure 20 - National Backbone step 3

A 20km belt is assumed for LTE-coverage along the fiber line along the road Lethem to Annai as well as from Georgetown to Linden. The latter corridor has approximately 60% of the HPR-population considered in the project.

Design assumption "National Backbone step 4" – bridge the gap between Linden and Annai with fiber

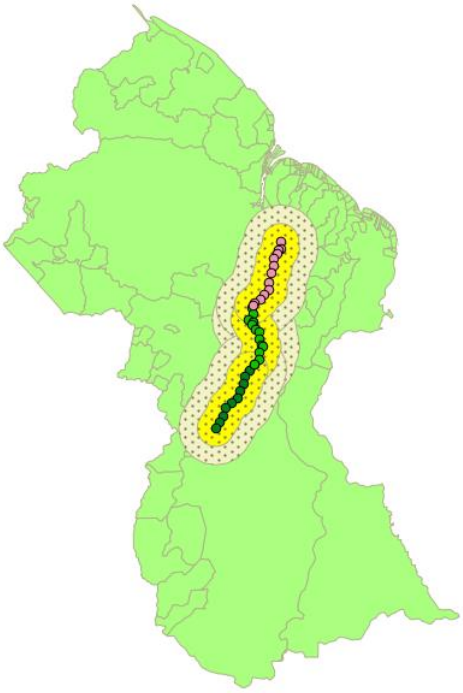


Figure 21 - National Backbone step 4

As next step, a 40km belt would be reached by 2nd Hop from the centre parts from Annai to Linden

Design assumption "tower sharing" – site tower sharing with operators

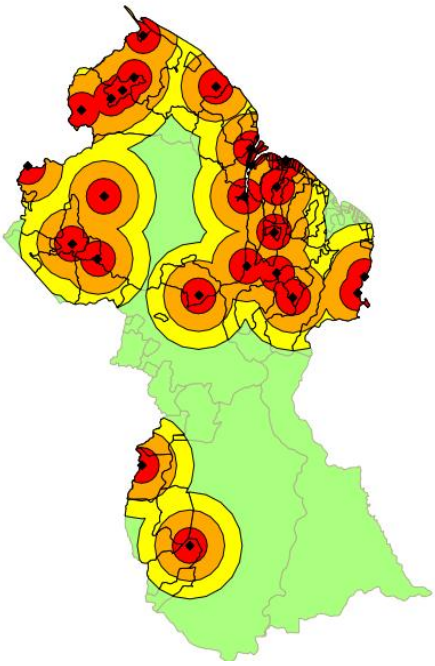
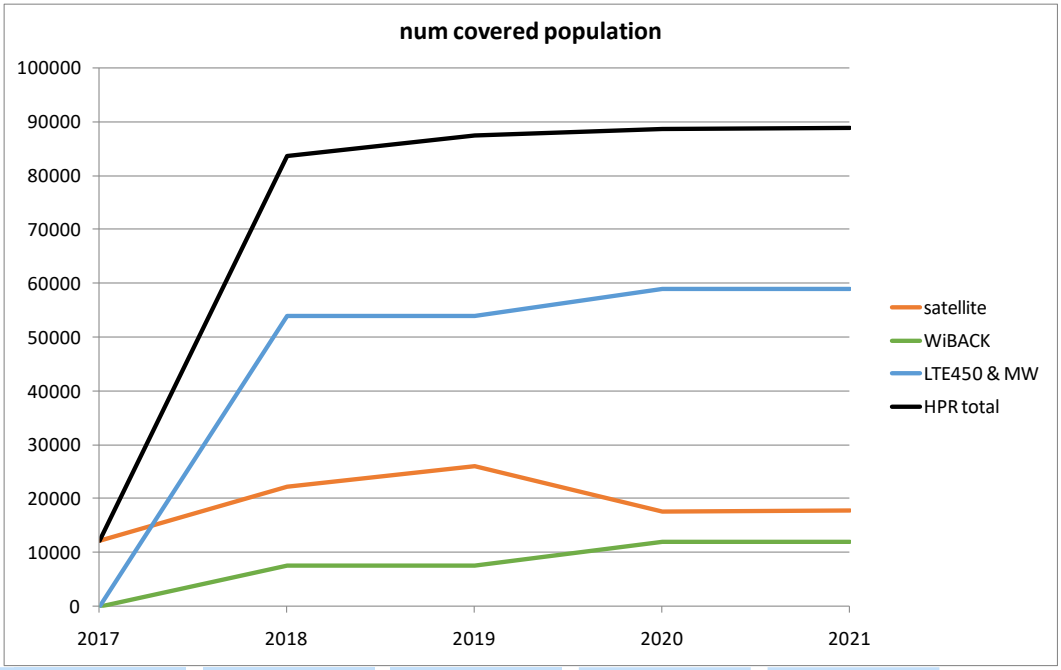


Figure 22 - National Backbone "tower sharing"

In Figure 22 the LTE 450 coverage of 20km, 40km and 60km is shown around potential incumbents' sites, expecting that not 5 hops would be possible due to already established backhauling of incumbents. The MW-backhauling of the incumbents might be upgraded.
Over all, this sharing option needs more support from the incumbent operators, as the individual backhauling option/capacity was not shared by incumbents at time of writing. Within this project, the sharing option is postponed and the rollout is fully rely on eGovernment own equipment.

3.4.4 Rollout phases

The rollout is foreseen for the next 5 years starting from 2017. It is expected that in 4-5years new technologies (like Google Loon) would arise which might replace VSAT. Phase 0 is not part of the HPR-broadband strategy, but needs to be done as initial step to cover around 82% of the population of Guyana with eGovernment services.



Phase0	Phase1	Phase2	Phase3	Phase4	Phase5
Cover 82% of Guyana population	VSAT of Top7 communities	LTE-rollout WiBACK VSAT: +16	VSAT:+14 communities	VSAT upgrade by WiBACK and LTE	VSAT of rest communities

National Backbone step 1	National Backbone step 2	National Backbone step 3	National Backbone step 4

Figure 23: Alignment of phases with National Backbone Steps within next 5years

3.4.4.1 Phase 0 (2017)

Phase 0 is aligned with the National Backbone step 1 and is the initial phase to put the majority of Guyana population including the poor pockets in urban centers within broadband signal reach. LTE450 coverage at the coastal area is based on a subset of 18 eGovernment-towers which are currently connected to MW, but will be connected to fiber backbone in the near future.

More than 82% of the population will be covered by LTE450 at eGovNet towers assuming 20-25km (yellow area) which was dimensioned with lower ranges than the 30km range as proposed by the LTE450-standard.

The red area covers with approximately 10km around the eGovernment-sites in case of potential higher LTE700 or LTE800 networks for higher capacity if needed. This is also shown in larger scale in Figure 24and Figure 25.

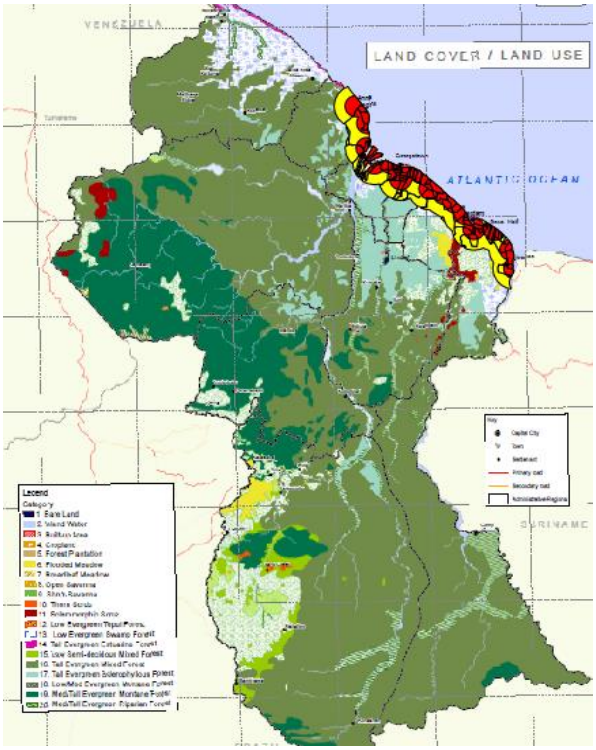


Figure 24: Coverage as result of phase 0[6]

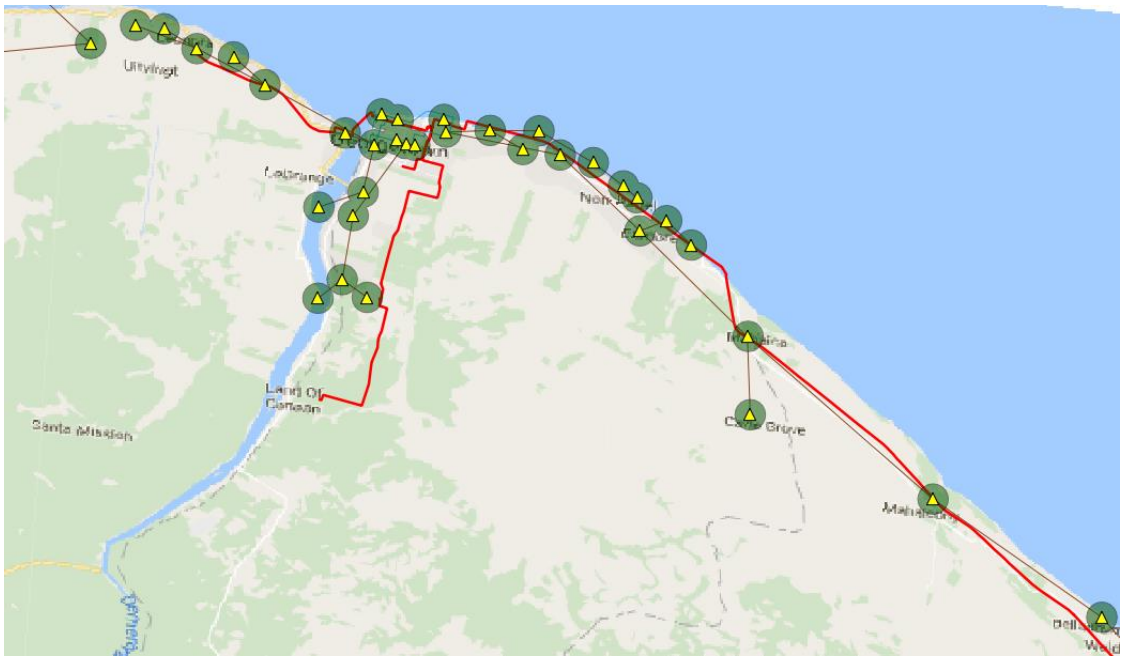


Figure 25: LTE2300 coverage approximation

[6] Map taken from Guyana Lands and Survey commission: http://www.lands.gov.gy/mapatlas.html

The yellow triangles of Figure 25 show on a larger scale the eGovernment towers with LTE2300 and green coverage approximations of circles with 1km radius. The red line is the GPL fiber line, the black line show the current MW-backhaul which would be used as backup in case the eNodeBs are connected to fiber.

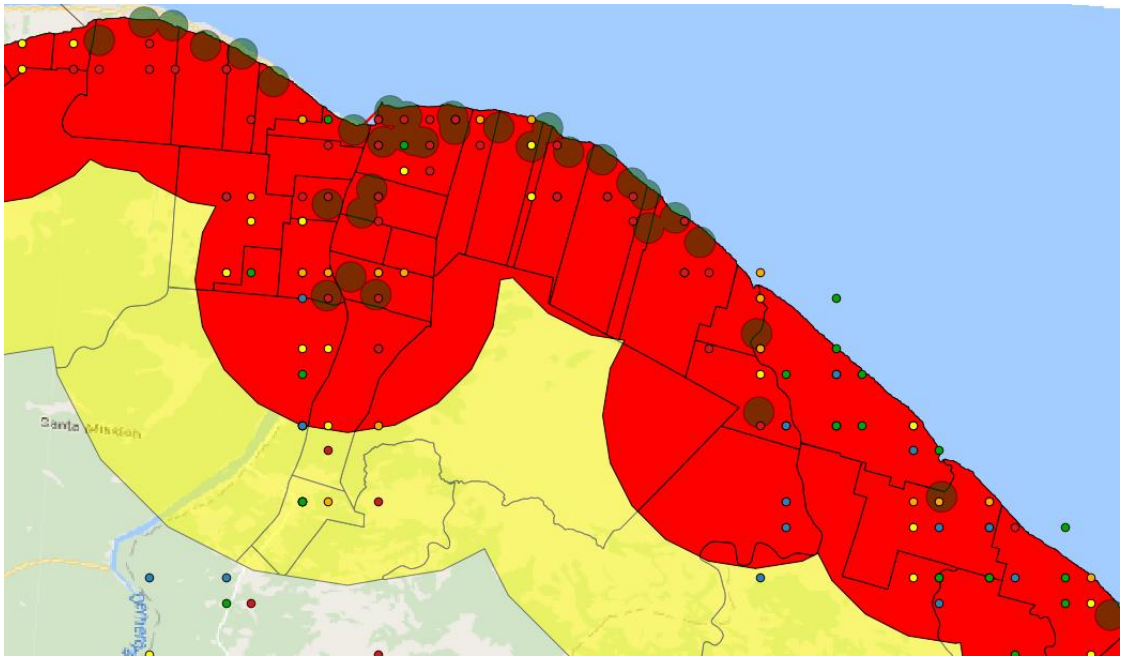


Figure 26: LTE450 coverage approximation

Figure 26 shows in the red area 10km coverage approximation of LTE700 from the sites, the yellow areas around 20kms with LTE450 resulting in more than 82% of population covered.

3.4.4.2 Phase 1 (2017)

In the following, the residual population of the HPR will be considered for rollout within 5 years, ~90k with are in 164 locations.

One major goal of Phase 1 in 2017 is to establish the connection of Lethem to the fiber line from Brazil which seams feasible as first step. In parallel capacity building activities and negotiations with VSAT providers take place so the in the 2nd half of 2017 the 7 biggest cities[7] according to VSAT-rollout: ~14% of HPR population.

3.4.4.3 Phase 2 (2018)

At start of Phase 2, it is assumed that Lethem has been successfully connected to the fiber network of Brazil and LTE450 is activated. Within the first half of the year, the fiber line from Georgetown to Linden will be activated.

To cover the area from Georgetown to Linden, 8 LTE450 towers are needed (Lethem and Linden reuse of eGovernment infrastructure and 6 towers newly build), which go live in a 1-per-month rollout speed: ~60% of HPR would be connected latest end of year 2018. These sites might need additional MW if the fiber line is not active.

[7] All locations are listed in the appendix on a per year basis for each technology

Annai might be delayed into 2019 depending on the fiber line. In this case Annai would be connected to Lethem with the WiBACK®-backhauling described in the following, which is an exemption of the general combination of LTE with MW, but it seems sufficient here until the fiber line is active.
A WiBACK®cluster should be deployed in the south-west (blue diamonds in Figure 27), resulting in 18 new WiBACK® towers to be build. So end of 2018 ~8% of HPR population is connected via WiFi and WiBACK®.

In addition, ~16 VSAT location will be connected: +11% of HPR
Finally, end of year 2018 ~94% HPR were connected which split in 25% VSAT, 60% LTE and 8% WiBACK®.

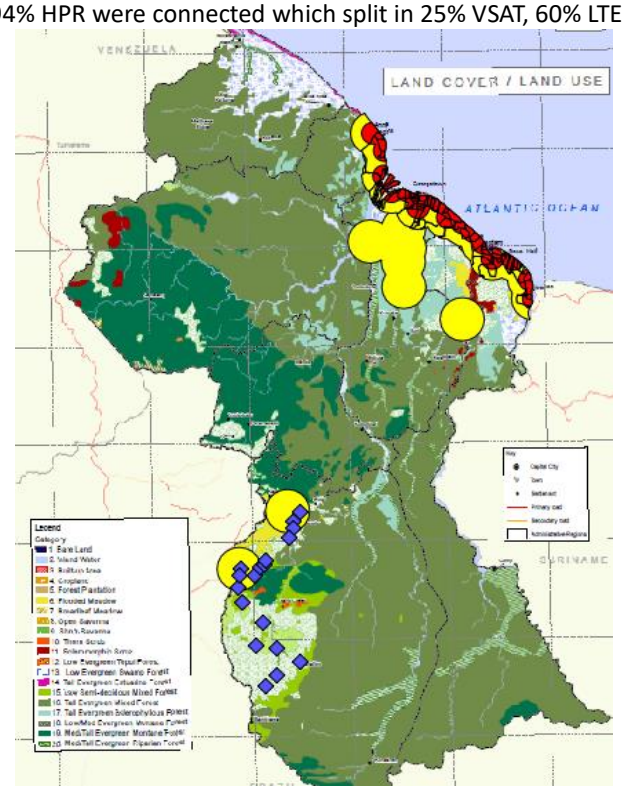


Figure 27: planning result of phase2

3.4.4.4Phase 3 (2019)

Within 2019, the fiber to Annai from Lethem needs to be finished to connect the LTE450-site in Annai with fiber as well in addition to the Wi-Fi based backhauling.
Then there is a 2nd opportunity for WiBACK®cluster2 in the south-west (red diamonds): 8 new Wi-Fi based backhaul towers need to be built in critical mountain area which needs special planning.

End of 2018 additional **~5% of HPR** population is connected with Wi-Fi and Wi-Fi based backhaul which has been previously connected to VSAT in the first 3years.

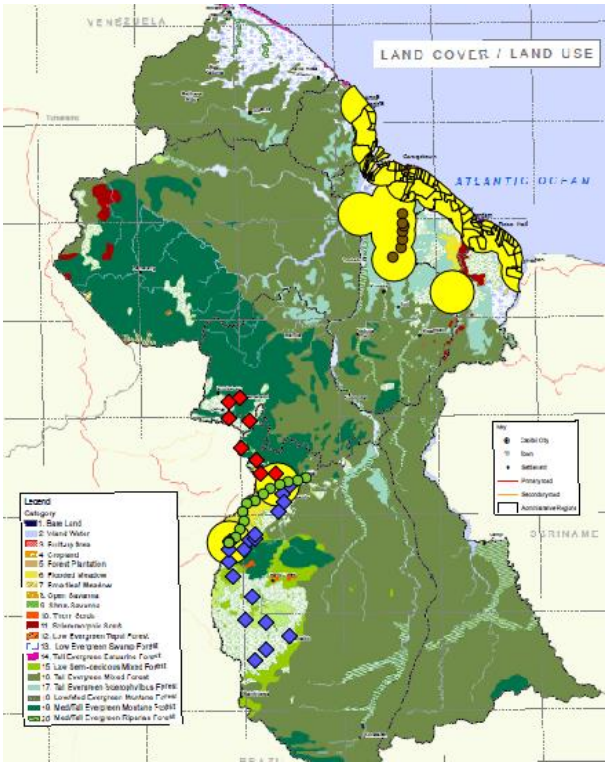


Figure 28: planning result of phase3

3.4.4.5 Phase 4 (2020)

In the long term the complete fiber line from Annai to Linden will be connected. In this case the neighbour locations with a ~40km (light green dotted area) might be covered with WiBACK® or LTE450 on a case-by-case study of the realization of high towers which are ~20m higher than the surrounding tree height.

Special solutions will be considered for:
Tuchen De Vrierden is so far supposed to be included in the LTE450-30km area around the coastal area in phase 0. Tuchen De Vrieden which might need own improved connectivity which could also built in 2018 with one own tower with MW&LTE.
Madhia and Kwakwani will get high towers with additional MW-hops to connect to the fiber: **+6% of HPR** connected to LTE450.

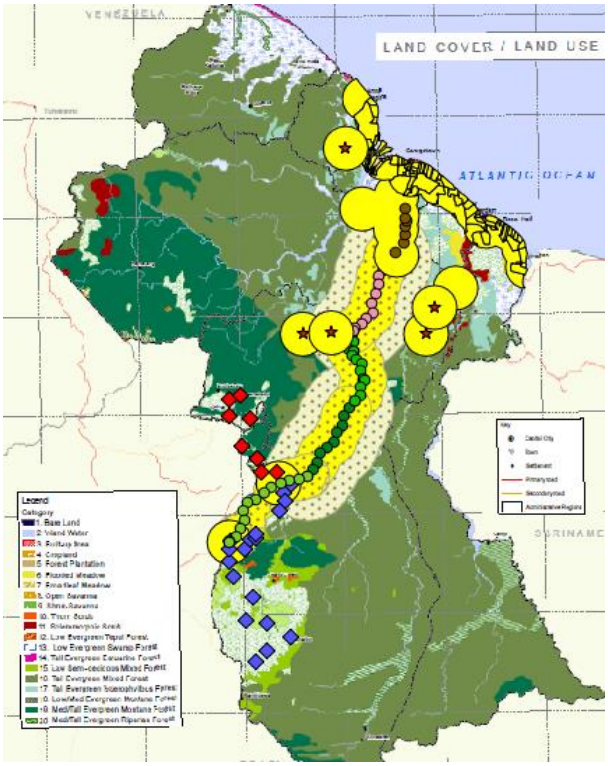


Figure 29: planning result of phase4

At the end of the 5th rollout year, the HPR population would be connected accordingly:

- 58944 (66%) to LTE450
- 17865 (20%) to VSAT
- 12026 (14%) to WiBACK®

The evolution of the population per technology within the 5years is shown in Figure 30. In the 4th year some VSAT-coverage is replaced by Wi-Fi backed backhaul in the mountains and LTE450 in Madiha and Kwakwani.

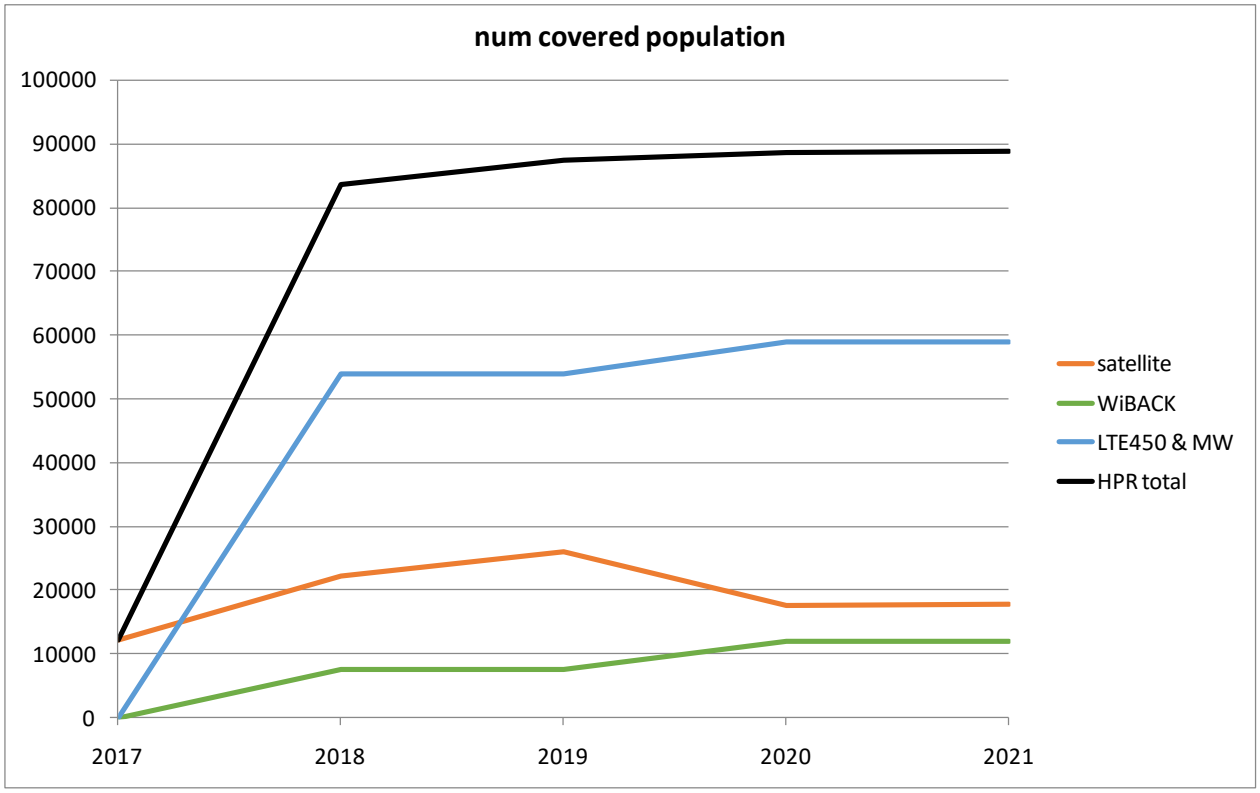


Figure 30: HPR-population coverage evolution per technology

4. Realization Framework

4.1 Stakeholder Analysis

Stakeholders, respectively their active management are a critical component in the successful realization and implementation of any planned activity in the context of this project and in the context of the larger realization program. These are people and organizations who will affect, be affected by or perceive themselves to be affected by the UNDP/eGovernment ICT program. It has to be noted that the list of stakeholders as well as their assessment can change over the time and needs to be revalidated on a regular base, as the program is being expected to have a relatively long runtime.

4.1.1 Introduction

Key principles of stakeholder management:

- Relationship: Try to build up trust with the different stakeholders.
- Communicate & consult: Ask questions and make sure that intended messages are understood.
- Plan it: Time investment and careful planning against it, has a significant payoff.
- Simple but not easy: Listen to the stakeholders and show your care
- Managing risk: Stakeholders can be treated as risk and opportunities that have probabilities and impact.
- Compromise: Compromises are needed across the stakeholders' diverging priorities.
- Understand what is success: Explore the value of the project to the stakeholder.
- Take responsibility: Project governance is the key of project success

The stakeholder can be clustered along the building blocks that define sustainable ICT Services, highlighting their specific concerns as well as needs and their possible contribution to the program success:

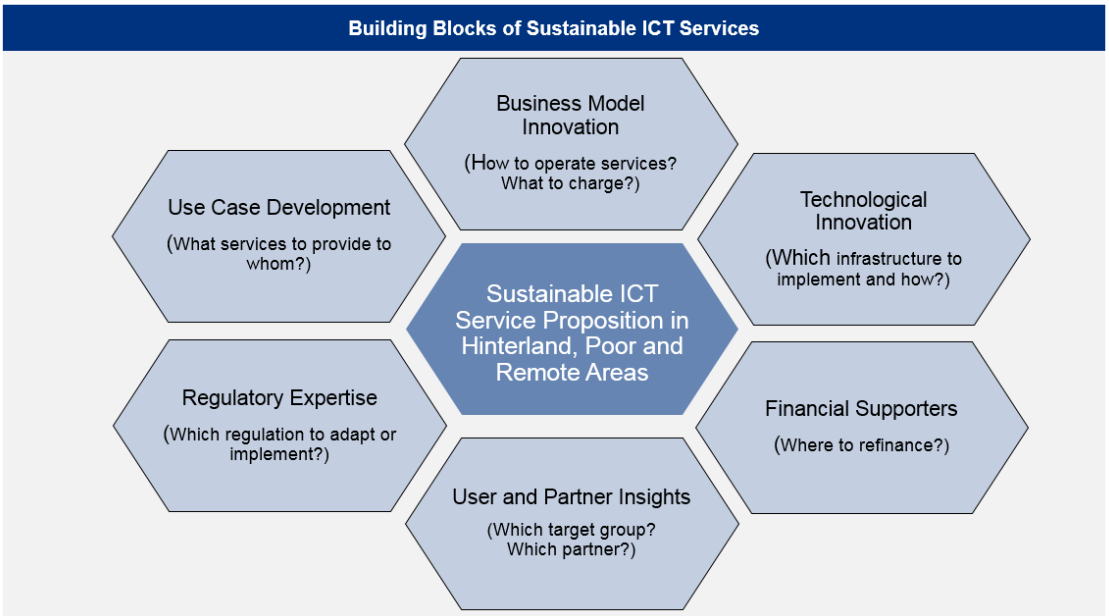


Figure 31 - Building Blocks of Sustainable ICT Services

4.1.2 Technical Stakeholders

- **GPL: Strategic partner for eGovernment's fiber backbone.**
  Aligned roadmap in rolling out infrastructure might help to reduce costs in the context of eGovernment's infrastructure plans as well as secure better access to electric power where needed.
- **GTT+: Incumbent, provides fixed and mobile networks**
  Sees eGovernment as a potential competitor in providing ICT infrastructure and is therefore reluctant to cooperate. Operator might provide infrastructure that can be shared with eGovernment - fixed (DSL) and mobile, especially in areas where no eGovernment infrastructure exists. Might be interested in using eGovernment backbone to increase their own service offering and quality.
- **Digicel: 2nd mobile operator**
  Sees eGovernment as a potential competitor in providing ICT infrastructure and is therefore reluctant to cooperate. Operator might provide infrastructure that can be shared with eGovernment - fixed (DSL) and mobile, esp. in areas where no eGovernment infrastructure exists. Might be interested in using eGovernment backbone to increase their own service offering and quality.
- **eGovernment Unit: ICT operator for government entities in the country**
  Needs to provide adequate infrastructure in the country to offer government services to government entities and the citizens in line with its mission to develop and deploy appropriate ICTs to support quality collaboration among Government Agencies. This whole-of-government approach is intended to facilitate extensive ICT adoption and usage by citizens, which will encourage continuous improvements and expansions of the reach of Government services across Guyana. Key player in achieving the country's ICT vision.

4.1.3 Legal and Regulatory Stakeholders

- **Ministry of Telecommunication: Defines the regulation and legal framework for ICT landscape.** Needs to create and maintain a competitive market environment in the telecommunication sector. Sees ICT as a driver of welfare in the country.
- **National Frequency Management Unit/Regulation authority: Defines and oversees regulation in the ICT sector.**
  Needs to create and maintain a long term vision and related activities to develop an ecosystem that provides planning safety for the operators and other players in the field. Responsible for monitoring of the operators activities and its compliance with license obligations.
- **Public Utilities Commission (PUC): Oversees operation and standards of any public utilities organization.**
  Oversees the performance of the operators. Needs to have better/good access to monitor and check the operator's compliance with service obligations and service quality.

4.1.4 Financial Stakeholders

- **UNDP: Drive Sustainable Human Development in the country.**
  Identify the right measures to reduce poverty. While ICT and related services is seen as a major driver to reach the goal of supporting sustainable Human Development, the negative impact of ICT needs to be identified and addressed accordingly.
- **IDB: Support help Guyana achieve continued economic growth, while at the same time promoting the sustainability of the country's natural resource endowments.**
  ICT can bridge the communication gap between coastal areas and hinterland. eServices will increase transparency and the flow of information and increase the social conditions in remote areas.
- **WWF: Stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.**
  eServices will increase information exchange and provide access to the right information when needed.
- **Governmental special interest vehicles like USAid and CIDA: Support health, economic growth, and democracy and governance in Guyana.**

ICT can bridge the communication gap between coastal areas and hinterland. eServices will increase transparency and the flow of information and increase the social conditions in remote areas.

- **Inter-American Institute for Cooperation on Agriculture (IICA): Help to develop the agricultural sector in Guyana**
  Identified ICT as key to drive agricultural competitiveness and managing knowledge throughout production chains. eServices can help to achieve these ideas.

4.1.5 Services/Use Cases Stakeholders

- **Ministry of Health: Responsible for health system and operates Hospitals and health posts in the country.**
  Needs online and digital communication to regional hospitals and to smaller health stations. Needs ICT infrastructure as backup for their own services.
- **Pan-American Health Organization: Supports Ministry of Health and steers projects to increase health situation.**
  Monitor health situation/diseases outbreaks. Needs real time date from regions for early identification of disease outbreaks; efficient drug control and forecast using real time date from hospitals; provide training classes trough online training.
- **Ministry of Education: Responsible for public schools and educational system.**
  Wants to provide distant learning services as soon as bandwidth is available. Furthermore the monitoring of schools in realtime (e.g. attendance) might be an additional service. Stable platforms to run and operate services are needed.
- **UNICEF: Supports ministries to build a world where the rights of every child are realized.**
  Needs services in the field of education and health (esp. Desease detection). Increased communication and online reporting. The need to educate people in the use of digital services showing them opportunities and risks is seen.
- **Ministry of Indigenous Peoples' Affairs: Help to develop a better quality of life for the indigenous peoples.**
  Wants to Increase communication to and with villages while protecting the Amerindian culture including offering services to drive the culture.
- **National Toshao Council: Represents the indigenous communities and drives their development.** Services are needed to increase the economic situation in the villages, for better communication, learning, reporting to the ministry. Support the use of Amerindian languages and to help to protect the Amerindian culture.
- **Ministry of Communities / CDCs: Represents communities on a national level.**
  Services are needed to increase the economic situation in the villages, for better communication, learning, reporting to the ministry.
- **Ministry of Public Infrastructure: Provides activities to maintain and improve public infrastructure**.
  eGovernment Infrastructure rollout should be aligned with infrastructure activities, e.g. road building.
- **Ministry of Business: Shaping the future of this country's economy by supporting the development of a strong, vibrant and competitive business sector**.
  Needs services to drive business and services that help local enterprises, including enabling services.
- **Ministry of Agriculture: Drive the development of the agricultural sector**.
  Needs digital communication services for the exchange of information in timely manner including to the ministry's agencies like Guyana Livestock Development Authority to provide technical and extension services to stakeholders of the livestock sector. Online training is seen as an important services as well.
- **FAO: Conserving biodiversity for food and agriculture and promoting its use in support of global food security and sustainable development, for present and future generations.**
  ICT based communication services are seen as an major building block for multiple activities within the country.

4.1.6 Partners

- **Ministry of the Presidency: Increase quality of life of all citizens, regardless of their place of living in the county.**
  eServices should provide equal service quality regardless of location of the community in the country. ICT should drive ICT literacy and government. ICT should serve as incubator for the private sector services
- **Iwokrama International Development: Support sustainable forest management.**
  eServices to increase communication and distant learning. ICT infrastructure will drive economic development in the area.

4.1.7 Business Model stakeholders

- **Local community representative (eg. Toshao): Secures cohesion within a community as well as being responsible for keeping peace and order in the village**.
  Might serve as care taker of the installation in the villages. Their role has to be considered as eGovernment services/Internet might have negative impact on the social life of the community members. eServices will increase the ability to communicate with other villages and support activities in the field of health, learning, farming etc.

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4.2 Business Models

For the business model of providing broadband access and services to rural areas mainly two dimensions must be considered:

Who are the relevant players involved and what part of the value chain will they cover?

What are the estimated cash flows and is additional funding required?

4.2.1 Business Models – Theoretical Framework

When it comes to deploying broadband infrastructure, public and social interests conflict with economic interest. The telecom operators act rationally when taking investment decisions, and the business case of deploying broadband infrastructure in dense urban areas is significantly better than deploying broadband in rural and/or remote areas: Lower investment is needed to cater a certain amount of users in dense urban areas because of higher population density and the purchasing power of customers often tends to be higher in cities / urban and dense urban areas.

But government strives for the maximization of socio-economic welfare and therefore also the provision of broadband services to the whole population. For remote areas the principle of (infrastructure-based) competition is deficient. Urban areas enjoy choice between two or three infrastructure networks, while large parts of rural areas have no broadband or advanced infrastructure at all, because private operators have lower incentive to invest in rural & remote areas. Therefore private sector operators are not always in the position of contributing to governmental broadband targets. Co-financing schemes for rolling out broadband are a common tool to ensure that on top of commercial aims also socio-economic interests are being attended. However, if public money has to be catered to projects in economically unviable areas, then the public sector acquires an interest in pushing towards socio-economic objectives rather than profit. Business models should be chosen in consequence. In theory six different co-financing schemes for rolling out broadband can be described:

1) **Pure Competition**
   A liberal market with competition between telco operators and/or cable companies: The competition can focus on infrastructure or services, depending on the market maturity and stage of development of the country. The government mostly relies on the market participants to push ICT Access and Service availability. To achieve high broadband penetration, strong customer demand is needed. The presence of remote or difficult-to-serve areas hinders the development of broadband penetration as commercial operators have little or no incentive at all to invest in these areas because of high CAPEX paired with low return of investment. There might be varying degrees of regulation facilitating this development, but a strong regulatory regime is always mandatory to enforce the regulatory measures.
   Under favorable conditions pure competition is highly efficient as no public funding is needed and the Broadband Roll Out is driven by the market players. But if demand is weak or population sparse the concept of competition will not be successful.

2) **Indirect Subsidies**
   The government does indirectly support the roll out of broadband via favorable interest rates or tax breaks. The success of this model depends on the market custom and the behavior of the market player: The operators must leverage subsidies and reply with investment. The right design of subsidies also is prerequisite: They must be designed to support the purpose of increasing broadband coverage in underserved areas.
   The advantages of this model are that there is only low direct government involvement and – similar to the pure competition – most of the infrastructure development and investment is left to the market. The downsides are, that the outcomes are hard to steer and depend strongly on how operators take-up the subsidies provided.

3) **Direct Subsidies**

The government does provide financial or infrastructure resources to push the roll out of broadband. Subsidies are paid to operators or to local communities, dedicated initiatives or to special vehicles. For this model to be successful the presence of a competitive market in most of the areas is beneficial: This will leave a significant part of the broadband roll-out to the market and limits the need for public funding to areas most at need. Still it is required, that subsidies are designed properly to address explicitly the designated areas (lack of service provision by commercial operators, difficult to serve, commercially less attractive). Furthermore the success of this model depends on the take-up by local initiatives. Countries with Direct Subsidy systems in general perform very well for fixed broadband penetration. But often these countries are wealthy countries, with high GDP per capita and middle-to high population densities.

4) **Public Private Partnerships**
A joint endeavor of a public body and a private entity where each party brings in specific skills: The public side provides infrastructure (e.g. frequencies) and favorable regulatory conditions and the private side brings in expertise, best practice knowledge, and/or financial strength. Public Private Partnerships require strict control of target achievement and costs. The advantage is that potential blockages from incumbent operators due to economic (dis)interests can be overcome. Still there are also some risks as citizens will continue to hold government accountable for quality of utility of services whilst both may strongly depend on the private party involved. The private sector will do what it is paid to do and no more than that – therefore incentives and performance requirements need to be clearly set out in the contract. Focus should be on performance requirements that are out-put based and relatively easy to monitor. Given the long-term nature of these projects and the complexity associated, it is difficult to identify all possible contingencies during project development and events and issues may arise that were not anticipated in the documents or by the parties at the time of the contract. It is more likely than not that the parties will need to renegotiate the contract to accommodate these contingencies. It is also possible that some of the projects may fail or may be terminated prior to the projected term of the project, for a number of reasons including changes in government policy, failure by the private operator or the government to perform their obligations or indeed due to external circumstances such as force majeure. While some of these issues will be able to be addressed in the PPP agreement, it is likely that some of them will need to be managed during the course of the project
If there is a special vehicle with government share involved, the Public Private Partnership model is very similar to the Scheme of Public Infrastructure.

5) **Indirect Government Control**
The government defines targets for telco operators and enforces the achievement of these targets. This is often the case with wholly or partly state-owned operators. With state owned operators, the government can leverage its influence on the behavior of the market player and hence push the achievement of the targets defined. Furthermore a complete and exhaustive regulatory framework is required to prevent that operators use regulatory captures and delay the roll-out. Under the right conditions this model will limit the funding needs from official state budgets and leverage capacities and skills of the commercial operators as implementation is executed by the market players. Indirect Government Control systems are typical for developing countries.

6) **Public Infrastructure**
Infrastructure is solely provided by public bodies but can be realized in different approaches that can also be combined: A national company deploys and operates the network using existing public infrastructure, the government may buy operators assets, and the business might be organized as retail or wholesale business. The Public Infrastructure model requires strict control of target achievement and costs. The advantage is that potential blockages from incumbent operators due to economic (dis)interests can be overcome. Still there are the general risks for government projects as these commonly show delays or cost overruns.

The degree of government involvement varies for the different financing schemes: Lowest involvement of government is found in the case of Pure Competition leaving the development of the market to the independent players. Partial but increasing involvement of government is reflected in the schemes of Indirect Subsidies, Direct

Subsidies, and Public Private Partnerships up to Indirect Government control. The highest degree of governmental involvement is the provision of Public Infrastructure.

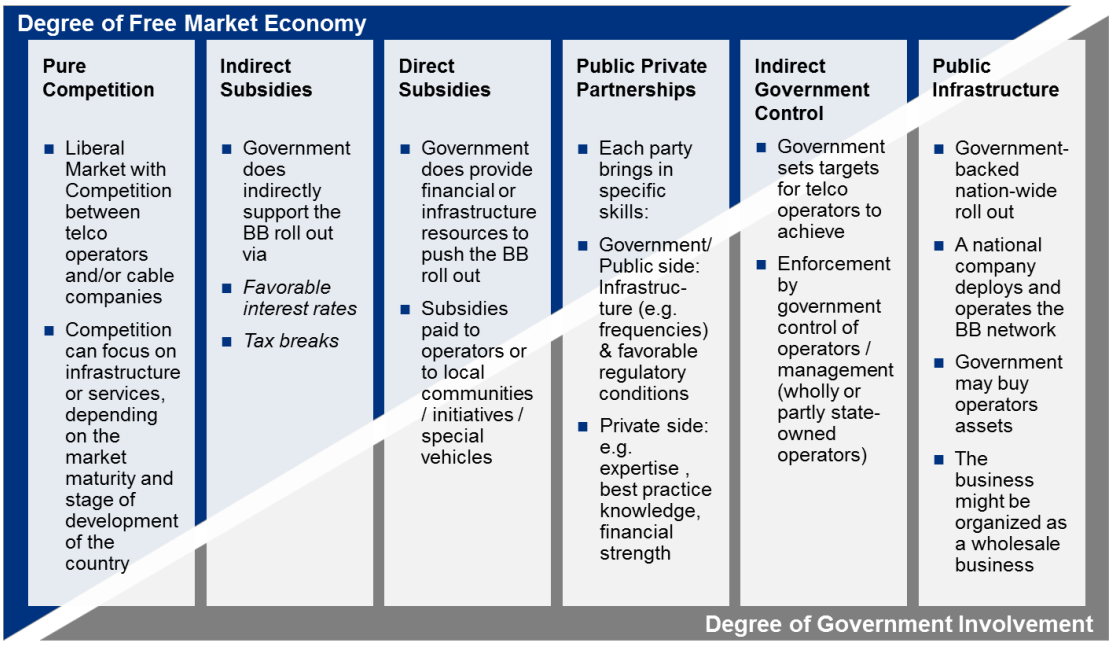

Figure 32 Financing Schemes for Broadband Roll Out and ICT Access Development

In most countries, combinations of schemes are found. Usually commercially attractive areas are left to competition and only problem areas are publicly financed. For Guyana this is already being reflected in the current situation: The commercial operators focus their efforts on the commercially more attractive areas, such as the major cities and the coastal area, and deprioritize HPR communities in the roll out of their services - leaving them with lower coverage and less advanced services.

Beside the financing scheme, there are some other factors influence the success of broadband roll-out:

1) Fixed broadband penetration is positively correlated with GDP per capita. The higher purchasing power of the population makes rolling out broadband more attractive to private investors, and richer countries are also better able to afford public BB investment.
2) There is a general tendency for broadband penetration to rise with population density. This can be best explained by the fact that it is economically more attractive to roll-out broadband in densely populated areas. But there is wide variance for countries with low – to medium densities. Comparing countries with similar densities, broadband penetration is generally higher in countries with higher GDP per capita.
3) There is also a general tendency for Mobile broadband penetration to rise with per capita GDP, but the tendency is weaker than for fixed broadband. Potential reasons are the lower costs for Mobile BB, accompanied by lower speeds, and poorer, less developed countries use mobile broadband as a cheaper alternative to fixed BB roll-out.
4) Mobile broadband penetration is only weakly positively correlated with population density. Countries with high densities have also high fixed broadband penetrations, reducing the attractiveness of mobile broadband, and countries with low densities use mobile broadband as substitute for fixed broadband, resulting in a higher mobile broadband take-up.

Comparing case studies from countries worldwide you can say that GDP per capita, population density, and a culture of good governance and competent implementation of government programs seem more important for the success of national broadband strategies, than the choice of the financing model.

Furthermore there are different parts of the telecommunication value chain to be covered: Starting from the International Gateway via passive and active infrastructure to service provisioning. The business model shall also determine who covers which step of the value chain. Possible roles a market actor can take are e.g. passive infrastructure provider (dark fiber, towers, and facilities) network provider (core, backhaul, transport network, access network) or service provider (provision of voice services, data services, and value added services to customers). A business model is referred to as a vertically integrated model when one market actor takes on all three roles. This is the case with all large telecom operators.[8]

Regulations can demand the opening up of network access to competitors, either at the passive or active layer. This means that the network owner designs the network to deliver its own services and gives access to its competitors in forms compatible with the network design.

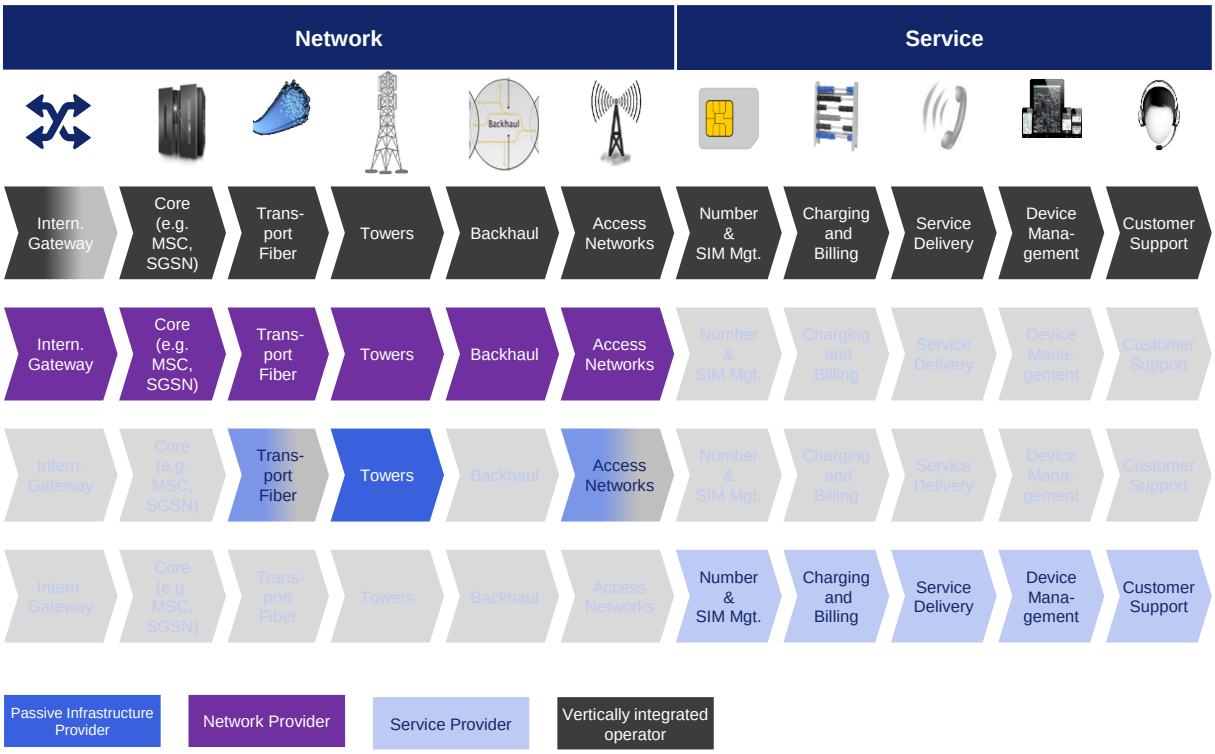

Figure 33 - The Telecommunication Value Chain

[8] Source: Socio-economic benefits of high-speed broadband, European Commission, 2015

4.2.2 Case Studies

Australia: Nationwide government-funded Public Infrastructure brings broadband services to rural areas

Australia has a population of ca. 23 million and 7,682,300 sq km of land resulting in a population density of 3 people per sq. km of land area. The GDP per capita is USD 65,400 (2015 est.) ranking Australia at place 15 in the country comparison to the world. Following two decades of continuous growth, low unemployment, contained inflation, very low public debt, and a strong and stable financial system. The services sector is the largest part of the Australian economy, accounting for about 70% of GDP and 75% of jobs.[9]

Australia is perhaps the prime example for the government funding approach. This is a result of a strong visionary policy that believes having almost universal access to very high speed services will increase the overall economy. The aim is to give fiber to 93 per cent of premises and to use wireless and satellite for the others. This provides a wholesale-only service for network operators to use and compete with each other in the downstream markets. The approach directly tackles the digital divide: the entire country is served by a standard service. The approach is not a complete government-only monopoly of supply. The NBN Co (National Broadband Network Company) supplies the access services but downstream providers compete to deliver the end users' retail services. These are based on wholesale services from NBN Co with prices that do not have the variability by location that naturally follows on from when costs are the basis of the input price. This is the case if a vertically integrated provider were to build the fiber and also deliver the end services – the costs to itself will vary depending on the customer.[10]

The approach has had to address many issues such as how the deployment interfaces to existing operators. In fact the established commercial operators have or also had planned some fiber access networks – this creates public and private competition, but each have different investor-demands to meet. Setting up the project was a lengthy process for the Australian government:

The NBN Co was created in 2009 to provide the operational monitoring of the plan. Amongst its powers, NBN Co is responsible for taking care of the relationships with the various participants in the deployment of the future network and ensuring the fiscal and time monitoring of the plan. As part of this plan, long and exhaustive negotiations were conducted with the incumbent operator. In mid-2011, they led to the signing of an agreement between Telstra and NBN Co, by which the operator commits to giving privileged access to its passive infrastructure and assure priority to NBN's future wholesale service to provide its own future ultra-fast broadband services. In parallel, the national plan included the decommissioning of the copper and HFC (Hybrid Fiber Coaxial) networks of the incumbent operator as new NBN subscriptions are taken up (decommissioning of copper and cable networks to be effective within 18 months following implementation of the NBN in a given area). Thus, the NBN would pay Telstra to progressively use its infrastructure as the decommissioning of its copper network proceeds. Estimates were that the NBN would have to spend 9 billion AUD for the use of Telstra's pipes, poles, racks and other passive infrastructure. An agreement was also signed with Optus, another major player in telecommunications and cable in Australia, which also includes decommissioning of the operator's networks.

The second major challenge this approach had to face is to run the public infrastructure efficiently. This point follows from the general economic assumption that any service that is provided by government and is not open to competitive forces is likely to be inefficient. Either way, roll-out targets were delayed several times and estimated costs rise constantly.

[9] Source: The World Factbook, https://www.cia.gov/library/publications/the-world-factbook/

[10] Source: Strategies for the deployment of NGN in a broadband environment, ITU 2013

Brazil: Blended approach including Indirect Subsidies paired with Indirect Government Control complemented by Public Infrastructure

Brazil has a population of ca. 206 million and 8,358,140 sq km of land resulting in a population density of 25 people per sq. km of land area. The GDP per capita is USD 15,600 (2015 est.) ranking Brazil at place 103 in the country comparison to the world. Characterized by large and well-developed agricultural, mining, manufacturing, and service sectors, and a rapidly expanding middle class, Brazil's economy outweighs that of all other South American countries, and Brazil is expanding its presence in world markets.[11]

Although classed as an emerging economy, Brazil is among the top ten countries worldwide when ranked by total number of broadband users. At the end of 2010 Brazil was in 9th position, with about 15m fixed broadband subscribers, as well as 20m mobile broadband (3G) subscribers. This is not particularly surprising considering that Brazil is the world's fifth most populous nation, but due to the high levels of wealth disparity and the relatively large numbers of poor and rural inhabitants scattered across its vast terrain, broadband penetration in Brazil is lower than in other countries of equivalent income levels. Regionally, Brazil is slightly above the Latin American average in terms of penetration, but behind Chile, Argentina, and Uruguay. Speed of access follows a similar pattern – Brazil is better than the regional average, but below US or European levels. Likewise, Brazil has relatively good international fibre connectivity, although it is not as well connected as some of its neighbours. Similarly, prices for telecommunication and broadband access are lower than other countries in the region yet still relatively high compared to North America and Europe, especially outside the major cities. Phones, computer and telecommunication equipment are also significantly higher in cost, partly due to import duties on IT equipment, further reducing affordability of access among the lower-income groups.

Large variation in access levels: As reflected by the wide variation in income levels within the country, broadband access is very uneven. At one end of the spectrum there is a high density of access in the industrialised urban areas, mostly in the south east of the country. In these areas, Brazil has recorded some of the world's highest levels of Internet use, and in particular, Brazilians have been early users of social networking services such as Orkut, and now Facebook. At the other end of the spectrum, there are the vast hinterlands of unconnected rural and remote areas, most particularly in the less wealthy north and west part of the country. For example in the North-East region, fixed broadband penetration languishes at 1.46%, while it is over 11% in the more industrialised Sao Paulo region in the south. The pattern of uneven access also repeats itself at the local level. Most cities have wealthy areas with high levels of domestic broadband access, while close by, in the informal townships (favelas), which house most of the country's poor, there is almost no fixed broadband and residents mostly depend on cybercafes or relatively slow and more expensive 3G connections. In the last 10 years, the federal government has had little success in disbursing its Universal Service Funds to address the digital divide, although a variety of state and municipal level initiatives have improved the availability of public access facilities to some extent.

Limited fixed infrastructure: The private sector has invested about USD80bn in telecommunications over the last 12 years, but Brazil's vast size and low population density in the rural areas has resulted in limited national pervasion of telecommunication infrastructure. This presents one of the biggest problems in broadening access to the Internet. The relatively low level of fixed infrastructure, both in the long-haul, and in the local loop for DSL-based broadband services, is one of the key constraints. However the lack of middle-mile infrastructure necessary to ensure all 5500+ municipalities are connected to the national backbones probably represents the biggest challenge to ensuring equitable broadband access across the country. Competition in the fixed-line sector is low and fixed line penetration has actually been falling due to mobile subscriber substitution. With the relatively high level of penetration and competition between mobile networks, 3G services are expanding rapidly to fill the demand for broadband, especially among lower income households. As a result wireless access is likely to be the main growth area for broadband in Brazil, especially now that some of the constraints in access to radio spectrum have recently been addressed.

National broadband initiative launched: In an effort to help to improve coverage and reduce the cost of broadband access, the government has begun a major broadband infrastructure development initiative. The

[11] Source: The World Factbook, https://www.cia.gov/library/publications/the-world-factbook/

largest ICT infrastructure project ever carried out in Brazil, called the National Broadband Plan (PNBL[12]), it aims to ensure that broadband access is available to low-income households, especially in areas that have so far been poorly served. In May 2010, when the project was officially announced, it was initially allocated up to R$1bn (US$600m) a year until 2014 to ensure broadband reaches the 4000 cities and towns without broadband services, so that at least 40 million homes (or 68% of the population) have access to speeds equal to or greater than 1Mbps, for about USD20 per month. The new government, under President Dilma Rousseff, has re-affirmed its commitment to the PNBL which was originally developed under the previous President Lula da Silva's administration. To implement the programme, the dormant former state-owned monopoly operator, Telecomunicacoes Brasileiras (Telebras), has been resurrected and given the task, working closely with the national regulator, Anatel, and the Ministry of Communications which has also set up a special secretariat to co-ordinate the PNBL in concert with the government's other digital inclusion programmes.

The initial focus of the PNBL has been to address the deficiencies in the existing telecommunication operator backbones by bringing on the oil and electricity network operators' fibre networks to help fill in the gaps. Local access is now also being addressed through a variety of other measures, such as tax exemptions, reducing broadband license fees, accelerating efforts to make additional radio spectrum available, and other incentives to encourage the provision of broadband in rural areas. In May 2011, Telebras awarded three operators contracts worth USD43mn to provide transit, wholesale and broadband services in some states.

The Internet sector in Brazil is also supported by a large number of industry, government and civil society groups, both monitoring and promoting access to ICTs. As a result the level of up-to-date information on broadband utilisation is high, and the debate over strategy is widespread.

The resurrection of the old public monopoly operator Telebras to compete with the private sector has not been without controversy, and the extent to which the poorest of the poor get access to broadband remains to be seen. But steadily rising economic prosperity for the less wealthy, along with the flurry of ICT investment made to prepare for the FIFA World Cup in 2014 and the Olympics in 2016, suggests there are much improved prospects wider adoption of broadband in Brazil. The strategies adopted and lessons learned from both public and private initiatives will be valuable for other developing countries planning to promote better access to broadband.[13]

[12] http://www.mc.gov.br/plano-nacional-para-banda-larga

[13] Mike Jensen, Broadband in Brazil: A multipronged public sector approach to digital inclusion. Washington, D.C: infoDev / World Bank. Available at http://www.broadband-toolkit.org.

Kenya: Use a Pubic Private Partnership as vehicle to increase international capacity and to decrease wholesale bandwidth costs

Kenya has a population of ca. 46 million and 569,140 sq km of land resulting in a population density of 81 people per sq. km of land area. The GDP per capita is USD 3,200 (2015 est.) ranking Kenya at place 186 in the country comparison to the world. Kenya is the economic and transport hub of East Africa. Kenya's real GDP growth has averaged over 5% for the last seven years. Since 2014 Kenya has been ranked as a lower middle income country because its per capita GDP crossed a World Bank threshold.[14] Kenya has a natural geographic advantage, being strategically positioned on the East Coast of Africa.

Its government-led "build it and they will come" approach to broadband development has leveraged that advantage, and has played a major role in dramatically increasing fiber optic backbone capacity. Many of Kenya's milestones have been realized in less than five years – three cables had landed by the end of 2010 changing the face of the broadband market. The country has gone from relying on satellite for international capacity, to having access to almost four terabits over fiber from the three cables combined. Although the landing of the cables is merely a first step, it has already resulted in an 80 percent decrease in wholesale bandwidth costs. Lower prices and greater availability are expected to increase access to the Internet as well as to promote the continued spread of sophisticated mobile applications and services and consequently improve opportunities for the creation of and access to information and knowledge. Affordable broadband is expected to increase Kenya's competitiveness, particularly in the Business Process Outsourcing (BPO) sector, and to encourage entrepreneurship and innovation.

With an estimated fixed and mobile broadband penetration rate of 2 subscriptions per 100 people in 2010, Kenya still has significant progress to make with respect to broadband uptake. Stimulating demand and usage by Kenyan citizens and the public and private sector remains a challenge. Kenya has, largely through the government, taken an innovative and pro-active approach to putting the user at the center and addressing the other elements of the broadband ecosystem, such as education, literacy, applications and content. This has been done through good regulation, the promotion of polices relating to ICT in education, the subsidization of relevant content and application projects, and facilitating creative Public Private Partnerships.

Much of Kenya's success is due to four important factors:

- A clear national vision articulated in Vision 2030
- Strong leadership and direction
- Leveraging the strength of the public and private sectors through Public Private Partnerships
- A credible regulatory, policy and institutional framework

With the new modern ICT policy framework the regulator encourages amongst other things facility sharing and co-location agreements which are to be commercially negotiated, however CCK has the right to intervene in case of a dispute. This is also reflected in the Kenyan Licensing Regime[15]:

Like its regional counterparts in Rwanda, Uganda and Tanzania the CCK has adopted a technology neutral unified licensing framework (ULF). Network operators and service providers are licensed under a market structure consisting of the following broad market segments:

Network Facilities Provider (NFP**)** - Licensees under this category can own and operate any form of communications infrastructure (based on satellite, terrestrial, mobile or fixed). The NFP category is further divided into National NFP and International NFP. Investors who wish to land a submarine cable in Kenya require a Submarine Cable Land license while those interested in building system for the provision of international voice/data services are required to get a license for international Systems and Services. An International NFP (Incl. submarine cables and international gateway facilities) costs KHS 15 million as an initial

[14] Source: The World Factbook, https://www.cia.gov/library/publications/the-world-factbook/

[15] Source: Msimang, Mandla, 2011. Broadband in Kenya: Build it and They Will Come. Washington, D.C: infoDev / World Bank. Available at http://www.infodev.org/publications

fee, and the higher of 0.5% of Annual Gross Turnover or KES 5 million (US$ 60,170) per annum. The spectrum fee payable is based on bandwidth and coverage.

National NFP are described based on the use of spectrum. National NFPs are further identified as Tier 1 (exclusive use of spectrum countrywide), Tier 2 (exclusive use of spectrum regionally) and Tier 3 (exclusive utilization of spectrum by Administrative District). The initial license fee for Tier 1 and Tier 2 NFP licenses is KES 15 million; the fee for Tier 3 NFP licenses is KES 200,000. (US$ 2400) In addition a spectrum fee is payable based on bandwidth and coverage.

Applications Service Provider (ASP) - Licensees under this category are permitted to provide services to end users using the network services of a facilities provider (NFP). The initial license fee is KES 100,000, and an annual fee of the higher of KES 100,000 (US$1200) and 0.5 percent of Annual Gross Turnover is payable.

Content Services Provider (CSP) - Licensees under this category can provide content services material, information services and data processing services. The initial license fee is KES 100,000 (US$1200) and an annual fee of the higher of KES 100,000(US$1200) and 0.5 percent of Annual Gross Turnover is payable.

Mexico: [16] Pooling of public infrastructure and (spectrum)-resources with financial power and capabilities of private investors in a Public Private Partnership to create a single wholesale shared nationwide 4G network

Mexico has a population of ca. 123 million and 1,943,945 sq km of land resulting in a population density of 65 people per sq. km of land area. 22% of the population are living in rural areas. The GDP per capita is USD 17,500 (2015 est.) ranking Mexico at place 119 in the country comparison to the world. Mexico's $2.2 trillion economy has become increasingly oriented toward manufacturing in the 22 years since the North American Free Trade Agreement (NAFTA) entered into force. Per capita income is roughly one-third that of the US; income distribution remains highly unequal. [17]

In 2013, the Mexican Government and main political parties agreed to a constitutional reform changing the legal framework of the telecom sector. The major objectives of the reform were to give Mexicans access to better and cheaper telecommunications services and to raise the competitiveness of the Mexican economy. The reform introduced an individual right for the Mexican citizen to have "access to timely information from multiple sources and to seek, receive and impart information and all types of ideas by any means of expression." This right includes that "the State shall guarantee the right of access to communication and information technologies, as well as broadcasting and telecommunication services, including broadband and internet access." The institutional framework was changed. The old regulatory body has been dissolved, and a new "Federal Telecommunications Institute (IFT)" has been created to improve the predictability and enforceability of regulatory decisions. In addition an antitrust commission (COFECO) and specialized courts for ICT cases have been founded. The status of IFT as an independent and autonomous body has been fixed in the constitution (Art. 27 & 28). Any IFT decision can only be appealed through juridical review, the decision taken by the authority is not suspended for the duration of the court case.

To ensure universal access two projects are under way - a shared mobile network (Red Compartida) and a fixed network program (Mexico Conectado) improving connectivity in schools, hospitals and other public areas on a municipal, provincial and federal level.

The cornerstone of the reform will be the project Red Compartida. Red Compartida is the constitutional mandate to create a shared network through a wholesale-only operator providing services that are unbundled and non-discriminatory. The Minister of Transport and Communications clearly stated: "Doing business as usual, mobile services will not reach unprofitable markets. Red Compartida's model will allow coverage in otherwise unserved or underserved areas."

The Model is based on the three pillars:

- The vision of the project is to provide broadband access for all.
- The mission is to deploy a shared wholesale network that enables the provision of telecom services through existing and new service providers.
- The goals are to increase coverage of mobile broadband services, to promote competitive prices, and to raise quality to international standards.

The concept of a mobile wholesale LTE network: Red Compartida will be implemented as a Private Public Partnership, where the State is represented by Telecomm and the newly created entity OPRITEL. The private developer will be selected through a request for proposals. Nonetheless, Red Compartida is envisioned in its essence as a private venture, where the Mexican Government will not be part of the shareholder base nor will it be involved in network design, deployment or its commercialization. OPRITEL is a special organization within the Ministry of Communications which will receive the spectrum license from the regulator (IFT) and pay the spectrum fees. OPRITEL together with Telecomm will close a Public Private Partnership contract with the developer, lease the spectrum to the developer, take receipt of the leasing fees, and control the wholesale and

[16] Source: Future Telco III, Detecon International GmbH, 2016

[17] Source: The World Factbook, https://www.cia.gov/library/publications/the-world-factbook/

coverage obligations of the developer. The developer will eventually consist of the operator and its equity partners and possibly other retail operators. Red Compartida will have a license for 20 years.

- The major input from the State is the allocation of a premium, unencumbered contiguous spectrum on the 700 MHz band (703-749MHz X 758-803MHz).
- In addition Red Compartida will get the right to use a fiber pair from the Federal Electricity Commission's fiber network mounted to the power grid as a backbone service. The total fiber network length is about 30.000km.

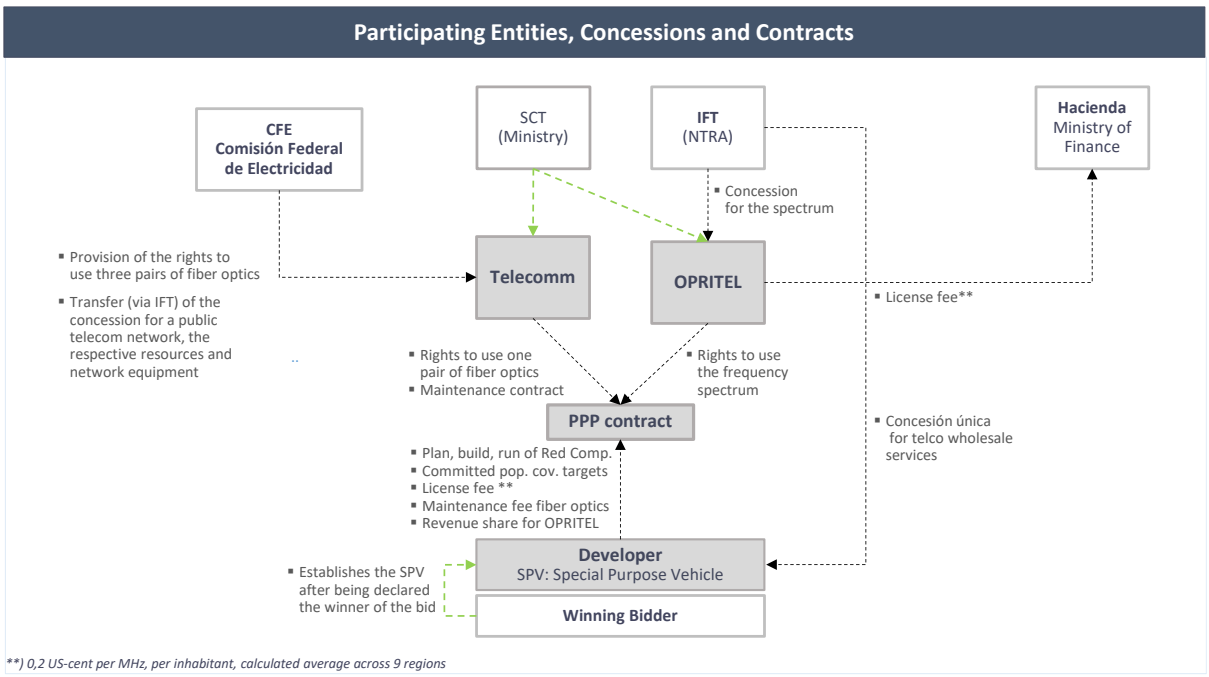

Figure 34 Mexico Case Study: Participating Entities, Concessions and Contracts

Red Compartida will not be allowed to sell directly on the retail market. Its customers are therefore the existing Mobile Network Operators (MNOs) (who may need additional coverage and capacity), fixed line operators who need to close "4-play" portfolio gaps using MVNO services, and other private and public MVNOs. It is the mandate of Red Compartida "to share its entire infrastructure and the unbundled sale of services and capacities, exclusively to marketing firms and telecommunications network operators under conditions of non-discrimination and competitive prices." Major services will be:

- National Roaming services for MNOs (providing capacity and filling rural and indoor coverage gaps)
- Hosting MVNOs on the Red Compartida network. These can be differentiated into two groups: "Full MVNOs" like fixed operators with a portfolio gap in mobile will build a complete network infrastructure except radio access and mainly buy access services. "Light MVNOs" like retail chains that sell SIM cards with their own logo will buy a number of additional network services from RC, including internet gateway access, transport, billing etc.
- Sharing of transport network and Radio Access Network with other operators may also be a part of RCs portfolio, but certainly with a minor revenue potential.

As compensation for the roll-out requirements and the prevented direct access to the retail markets the Government has decided to sell the spectrum at 0,002 USD/Mhz/inhabitant, which is well below international benchmarks. The Government expects a minimum total roll-out obligation of 85% population coverage after five years, with annual milestones before that. The first milestone is a population coverage of 30% by the end of first

quarter 2018. In fact the final population coverage will most likely be much higher than the obligation, as this target is the winning criterion for the applicants.

The concept has a number of advantages:

a) A single operator who gets an unsliced portion of the whole 700MHz spectrum should have the lowest cost for covering the country. The cell size in this band is substantially larger than in bands with higher frequencies and therefore for customers on the move (along roads etc.) and in low density rural areas fewer cells have to be constructed to provide coverage. This saves substantial CAPEX.
b) With a larger amount of bandwidth compared to sliced smaller spectrum lots a single wholesale operator can offer higher data rates per cell than several operators could. Broadband targets can be achieved much easier.
c) The 700MHz spectrum penetrates walls much better than spectrum in higher frequency bands, therefore in-house coverage is less costly to achieve.

While these advantages of a “natural monopoly” on the physical network side can be achieved, service competition in the retail markets will be intensified. The smaller MNOs will get relatively cheap and fast access to currently non-covered areas at much lower cost than they have to pay to the incumbent. Red Compartida is a specialized network to host all types of MVNOs. This will lead most likely to a boost of the MVNO market in Mexico with increased competition in price and quality for specific customer segments.

South Africa: Using Public Infrastructure to fill the gaps from Competition

South Africa has a population of ca. 54 million and 1,214,470 sq km of land resulting in a population density of 45 people per sq. km of land area. The GDP per capita is USD 13,200 (2015 est.) ranking South Africa at place 118 in the country comparison to the world. South Africa is a middle-income emerging market with an abundant supply of natural resources; well-developed financial, legal, communications, energy, and transport sectors; and a stock exchange that is Africa's largest and among the top 20 in the world.[18]

South Africa[19] has identified a need to fill gaps that were not being addressed by commercial operators. On 6 December 2013 the government gazetted a new national broadband plan for South Africa. The policy and its associated strategy is collectively dubbed 'South Africa Connect', and outlines a number of activities to improve broadband within the country. In particular, the overall vision of the policy is to give every South African access to a broadband connection at a cost of 2.5% or less of the average monthly income. The new policy has also revised the methodology used to define broadband speeds, opting to use targets that are reviewed annually rather than a fixed speed.

ICASA, the national regulatory authority, will supplement these targets, the policy states, by specifying quality of service (QoS) standards, download and upload speeds, latency, waiting time for installation and fault clearance. The initial target is to offer 90% of South Africans a minimum speed of 5Mbps by 2020, with 50% of the population set to have access to 100Mbps broadband. Among the areas of concern highlighted by the policy are: a duplication of civil work to roll out networking infrastructure and a need for the speedy assignment of spectrum. The policy also calls for the appointment of a broadband council and the creation of a wholesale open access network. It goes on to acknowledge that the scale and scope of intervention to be undertaken in South Africa requires investment from both the public and private sectors. Further, ICASA discusses several options for potential spectrum allocations in the 450MHz-470MHz band, which will be used to boost coverage in underserved areas. In order to release spectrum for the 'South Africa Connect' initiative, the migration process for rural areas is planned to start in 2016, with existing spectrum holders required to vacate the band in rural areas no later than the end of 2018. For urban areas, existing licensees will be obliged to migrate out of the band by the end of 2022.

The broadband roll out was pushed by the state-owned company Broadband Infraco: In December 2012 Broadband Infraco was appointed as interim chair to drive the implementation of the Infrastructure Project, with its main goal being to 'expand access to communication technology'. Infraco chief executive Puleng Kwele noted: 'The project aims to provide 100% broadband coverage to all households by 2020 by establishing core PoPs in district municipalities. It seeks to extend fibre-optic networks across provinces linking districts, establish PoPs and fibre connectivity at local level, and penetrate the network into rural areas'. Meanwhile, Infraco has an obligation to connect to all six neighbouring countries in order to 'address ICT infrastructure requirements'. Hence the operator by now deployed fibre-optic network extensions to Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe, with a link to Botswana completed in 2014. In June 2015 however Broadband Infraco was directed by the DTPS to undertake a valuation exercise in preparation for its possible sale. The cash-strapped enterprise – which posted profit (of ZAR22.6 million) in only the first year of its operations (2008) – subsequently made several unsuccessful submissions to the state for funding, the most recent one in September 2015, when Broadband Infraco requested ZAR243 million to continue operations (in addition to a further ZAR932 million in funding until 2019). The deputy director-general for state-owned companies' oversight, was cited as saying: 'Broadband Infraco has sustained persistent losses in its history, and has an obsolete network infrastructure … Indirectly, if the government gives these money allocations and guarantees, it will be subsidising the commercial contracts that Broadband Infraco has.' As of January 2016, the operational status of Broadband Infraco remained unclear.[20]

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[18] Source: The World Factbook, https://www.cia.gov/library/publications/the-world-factbook/

[19] Source: Strategies for the deployment of NGN in a broadband environment, ITU 2013

[20] Sourcce: Telegeography, 2016

4.2.3 Recommendations for Guyana

Guyana has a population of ca. 730,000 and 214,969 sq km of land resulting in a population density of 3 people per sq. km of land area. The GDP per capita is USD 7,500 (2015 est.) ranking Guyana at place 151 in the country comparison to the world. [21]

When looking at the overall broadband penetration in a country, population density and GDP significantly correlate with high broadband penetration, even more when the market is left to pure competition. The choice of the business model for Guyana must consider, that Guyana features very low population density as well as low GDP.

4.2.3.1 Financing Scheme

For the financing scheme for Guyana several models must be applied and a blended approach is recommended:

- For more densely populated areas (Georgetown and the more densely populated coastal area) the principle of Pure Competition between the commercial operators Digicel and GTT+ is working for the deployment of infrastructure. Access to ICT services is available to a large extent, but services are perceived as too expensive and costly. To decrease retail prices and make services more affordable also in the poor pockets of this region, several measures can be taken (see chapter 0). Regarding the financing scheme, it is beneficial to provide Indirect Subsidies in forms of tax incentives for basic ICT-services to Digicel and GTT+. Currently the operators are taxed with 40% of profit what is comparable to the other industries. Mapped against the theoretical framework of financing schemes for broadband roll out these high taxes rather hinder than foster the evolution of ICT services.
- To bring ICT access and services to the HPR-communities a different approach is needed. The pure commercial roll-out of broadband networks in Guyana started in the major cities and then slowly penetrated smaller cities along the coastline until it also reached remote and Hinterland areas. This typical development also left some unprofitable regions as “white spots” or underserved areas. To connect these areas a commercial approach is not viable. If any financing scheme is appropriate it is the Public Infrastructure. The advantage of the Public Infrastructure model is, that the government is fully in control of the target achievements and can bypass slow infrastructure roll out from GTT+ and Digicel in the commercially less attractive areas. The challenge for the government will be the foresighted development of the infrastructure roll out and management of the costs. A plus is that existing public infrastructure, such as transport network, backhaul and towers can be leveraged to set up the new network without building it from the scratch. Funding for the CAPEX will come from the GRIF fund[22] and the national budget.
  The Public Infrastructure model can be supplemented by the provision of Direct Subsidies to commercial operators to expand network coverage and capacity at a later stage. The challenge here is the appropriate design of the subsidies: They must on one hand address explicitly the Hinterland and remote areas and on the other hand must be so attractive, that operators take them up. The provision of frequency usage rights in the 900 Mhz band does meet all these requirements (see chapter 4.3.2 for further details). It is well suitable to provide mobile ICT access and services as fixed wireless or even mobile broadband services in rural areas, as the cell size in this band is substantially larger than in bands with higher frequencies and therefore for customers in low density rural areas fewer cells have to be constructed to provide coverage. For the commercial operators this implies less CAPEX but high (geographical) coverage.

[21] Source: The World Factbook, https://www.cia.gov/library/publications/the-world-factbook/

[22] Guyana REDD+ Investment Fund http://fiftrustee.worldbank.org/Pages/grif.aspx

Financing scheme	Favorable conditions to promote success	Applicability to Guyana	
Pure Competition	• Strong customer demand • No remote / difficult-to-serve areas • Strong regulatory regime	There is strong customer demand, but population is sparse in Hinterland and remote areas and the majority of the communities in scope fall under the category of "difficult-to-serve areas", either because of their geographic position, challenging terrain or poor infrastructure access (e.g. power supply, roads). This model is only appropriate for dense urban and economically well developed areas of Guyana, that are already being covered by commercial operators	✗
Indirect Subsidies	• Functioning market with operators that react to subsidies with investment • Right design of subsidies	The outcomes are hard to steer as they depend strongly on how subsidies are adopted by the commercial operators. As Guyana's government has the concrete goal to develop ICT in HPR-communities indirect subsidies are not the most effective approach.	✗
Direct Subsidies	• Competitive market that serves most areas • Strong civil society creating local initiatives	There is competition between mainly GTT & Digicel in many areas, especially the more densely populated ones. The HPR communities show strong interest in the ICT program and would probably be willing to support the process. Direct subsidies are appropriate and beneficial for the development of ICT in the HPR-communities that currently do not benefit from any competitive market structure. But subsidies must be designed properly to address explicitly the designated areas (lack of service provision by commercial operators, difficult to serve, commercially less attractive).	✓
Public Private Partnerships	• Strict control of target achievement and costs	Public Private Partnerships can help to overcome a potential blockage by incumbent operators, but requires firm and persistent control and enforcement. As Guyana has recently gone through political change this model is a big challenge for the public authorities and will take long time to be implemented due to the lengthy tender process and negotiations with private sector to elaborate the Public Private Partnership contract.	✗
Indirect Government Control	• Strong government influence on operators (total or partial state ownership) • Complete and exhaustive regulatory framework	The commercial operators in Guyana are private enterprises and act rationally and independently following their economic interest. The government influence on their behavior is limited to the formal legislative and regulatory framework. As legislations and regulation in the telecommunication sector is currently being revised and amended, this model is not appropriate to support the government in the short- to mid-term realization of its goal to enhance ICT in the HPR-communities.	✗
Public Infrastructure	• Strict control of target achievement and costs	Public Infrastructure can help to compensate the rather hesitant approaches of GTT and Digicel to build ICT-infrastructure in the HPR communities. Self-reliant and sustainable management of costs and target achievements can be carried out by a dedicated public body. The new regulator can monitor as second instance.	✓

4.2.3.2 Potential Partnerships

> *"Look at the "layers" in the value chain of the broadband economy and identify where resources need to be focused. Developed countries may focus more on the lower level investments and bottleneck supply of the access network. Emerging economies are likely to have to consider other parts of the chain. Regulation or funding inputs, may be needed to enable the other service layers to become fully established (after which they are de-regulated and become totally privately funded)."*[23]

Currently Guyana is facing the challenge that there is very limited access to ICT services in the Hinterland and remote areas. As discussed before, this is mainly because commercial operators have low incentives to build cost-intense infrastructure in rural areas. This gap in infrastructure deployment is to be filled by the eGovernment Unit.

Looking at the market participants, they are covering different parts of the value chain as depicted in the following image:

Figure 35 Guyana's Operators' Positioning along the Value Chain

[23] Source: Strategies for the deployment of NGN in a broadband environment, ITU 2013

GTT+ and Digicel are both vertically integrated operators. But unlike Digicel, GTT+ does operate the fixed network and has the monopoly on the International Gateway. Both provide services nationwide to consumers and businesses. The eGovernment Unit operates an own network connecting ministries, schools and other public buildings. iNet provides ICT-services via satellite and covers the whole country. Hinterland and remote regions, that are not catered by GTT+ or Digicel use iNet's services to connect to the internet. In addition there are several ISPs (Internet Service Providers) offering services to consumers and businesses. They don't provide connectivity. GPL's main focus is power supply, but it also has a transport fiber in the coastal area.

4.2.3.2.1 GTT+

GTT+ is the incumbent and offers fixed and mobile services. The fixed-line monopoly was renewed for 20 years in December 2010. GTT+ has been granted the only license to operate an international gateway. The license is valid until 2030.

- ~250k subscriber
- No 4G network yet, but 4G-services by HSPA+ network extensions
- Ericsson for RAN, for MW backhaul and for Core; Cisco for IP-switches
- Underutilized utilization of backhaul capacity

4.2.3.2.2 Digicel

Market leader, mobile services, but plans to provide full services for ICT solutions, meaning fixed line services like telephony, Internet and triple-play bundles (including TV).

- ~300k subscriber
- Ericcson as main Vendor due to group decision
- Underutilized utilization of backhaul capacity

4.2.3.2.3 eGovernment-Net

It has to be noted that the e-Government network doesn't fall under the current regulation in the country compared to the commercial operators *as they are not providing services to the Public*, in accordance with their mission statement: "*Our mission is to develop and implement appropriate ICT solutions that will transform the delivery of Government services*."

The Guyana eGovernment Network Project consists of an IP/MPLS network, OTN/DWDM/RTN Transmission Network, LTE Network and Enterprise Network

The IP MPLS Network is divided into four districts to which PE Routers are assigned based on their connectivity to P Routers as illustrated in the **Error! Reference source not found.**. The eGovernment IP MPLS Network consists of four P Routers (NE40E-X8) which are interconnected via a pair of 10G Optical links. IP/MPLS network implements Diff-serv model QoS. Initially, QoS will not be deployed on the Guyana eGovernment IP/MPLS Network but will be deployed in the future as the network matures and Services are defined.

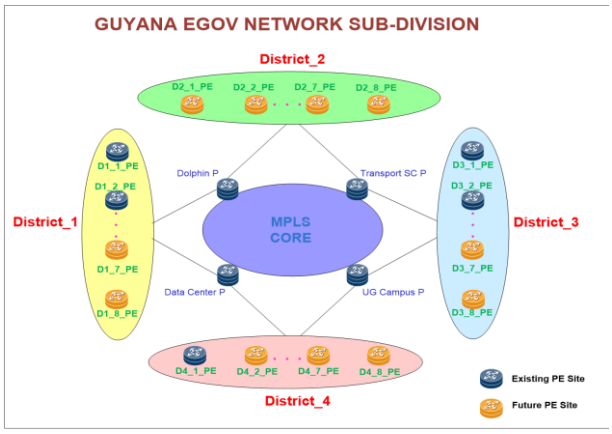

Figure 36 - Guyana eGovernment IP MPLS Network Sub-Division

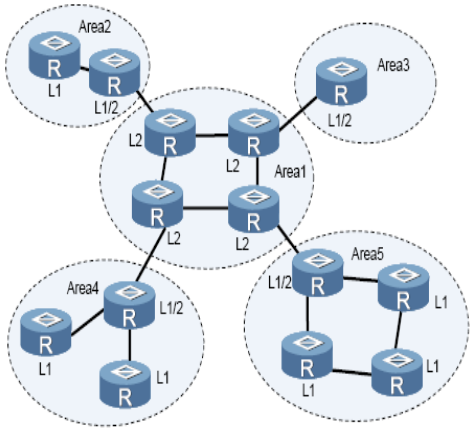

Figure 37 - Router illustration

The eGovernment's transport network consists of 54 Towers, inclusive of four core sites, a Data Center in Georgetown 48 microwave links and an outside plant (OSP) comprising of East West and South chains with in total 54 km of optical fiber. The sites themselves, are connected by microwave links, and are limited to a maximum capacity of 360 Mb/s, while the microwave backhaul is capable of delivering 150 Mb/s per LTE towers. Details on the eGovernment towers are:

- 31 towers of 36m, 16 towers of 42m, 3x 54m, 3x 60m
- Tower time to construct by Chinese standard is 28 days, actual time is 35 days. Since the project was turn-key, the costs cannot be estimated per tower.
- Solar power only in rural, but extension planned
- Urban power by GPL, generators as backup/redundancy

The capital ring currently includes a fiber optic infrastructure that spans the geographic locations that encompasses 27km of fiber. This ring provides a dedicated network for the government. eGovernment's involvement is to provide the network infrastructure in support of interconnectivity of the identified entities via fiber to the Premises (FTTP) or/and LTE to one or more of the eGovernment network nodes.

eGovernment in collaboration with GPL can make use of the dark fibers in GPL's fiber connection. The intention is to utilize GPL's spare fiber capacity to connect the LTE sites which are in close proximity to the existing GPL fiber route and assist GPL in expanding its connection to other commercial and operation centers. In utilizing GPL's spare capacity, it will form eGovernment's fiber optic backbone or primary operational network and eGovernment's microwave network in return will serve both GPL and eGovernment operational redundancy needs. This would significantly reduce the high capital investment cost for a new infrastructure; maximize the use of GPL's spare fiber optic network capacity and enhance network maintenance between the two parties.

Additionally, the eGovernment-unit is currently assessing the possibilities to provide VSAT services in several Amerindian villages, i.e. Mahdia, Annai, Lethem, Mabaruma, Kwakwani and Masikenyari. Minimum bandwidth requirements are 1Mbps for the downlink and 512 kbps for the uplink.

A feasibility study[24] has been elaborated to assess the options in regards to the broken fiber line to Linden (~40% damaged). The most probable solution might be to replace that cable with a microwave connection. Intentionally 540km fiber cable from Lethem to Georgetown need to be fixed as well, eGovernment has plans to connect to Brazil network near Lethem.

[24] No access to Detecon

4.2.3.2.4 i-Net satellite network

Satellite communication is a good opportunity for areas with poor access, but is also limited to low to medium data rates in general (<400kbps in DL in average).

i-Net in Guyana has

- 39 satellite HUBs, one central satellite server in network operation centre NOC
- IP traffic is terminated at earth station in US
- Ku band usage, 100% coverage of Guyana
- Telephony services are offered on a reselling model
- Unlimited FreeZone from (11pm GMT+1–6am GMT+1) ⇔ 5pm to 11pm in Guyana. Data downloaded during FreeZone is not counted as part of the download allowance.
- Mass Media Content Management: Edge servers store (limited) number of frequently requested internet content
- Platform with flexible infrastructure, based on WiFi-access-routers with satellite access:
  I-Net provides the required hardware at the point of usage to provide this VoIP services: Customers can either use I-Net-services via "rentals" at GUY $25,000 per month (**US $120**), on a 3 year contract, or can purchase the devices from I-Net for GUY $260,000 (**US$ 1,120**) covering all the necessary equipment (VSat, LMB, Modem, Cables etc.). In addition a bandwidth package needs to be selected according to usage demands.
- Up to 10Mbps in DL with 100ccm antenna dish

Figure 38: i-Net satellite network schema

4.2.3.3 Business Model and Commercial Relations

In the future setting, eGovernment Unit shall built and deploy ICT Access infrastructure to the currently underserved communities in Hinterland and remote areas. The overarching goal is to connect public buildings (Schools, Post Offices, Health Stations, Benabs, Police stations). In line with its mission the eGovernment Unit is not supposed to provide commercial services to the public (see also chapter 4.1).[25]

The eGovernment Unit will focus on the provision of ICT services and connectivity to the above listed public institutions and buildings. The eGovernment Unit shall not focus on the monetization of the connectivity by selling it directly on the retail market, but leave the market to the commercial operators. To facilitate the engagement of operators in the Hinterland and remote areas, we suggest to apply a wholesale model: eGovernment Unit will connect the public buildings and provide e-services to support education and social development. At the same time eGovernment Unit will grant access to its network to the commercial operators, ISPs, and other interested enterprises, enabling them to commercialize connectivity and sell services to the consumers. That can be realized in form of eKiosks and internet vouchers for example.

> *"Minimise costs, even if this might reduce some aspects of competition. Sharing of infrastructure such as masts and duct might reduce competitive investment but it lowers overall costs: the short term benefit may be better than the longer term gains from competitive infrastructure. This is probably most true in emerging and small economies."* [26]

This approach brings several advantages: On one hand the people in the HPR communities can also buy ICT access and services beyond the basic connectivity and according to their individual needs and willingness to pay. On the other hand some costs of eGovernment's network deployment can be covered by the wholesale revenues. The aim is to cover at least parts of the OPEX related to Hinterland with this model. The cost gap remaining (if so) must be closed from the national budget. OPEX comprise:

- Power consumption, operations & maintenance of RAN (Radio Access Network) and Microwave Links
- Battery backups, fuel
- Security services to prevent fraud and violation
- Backhauling transmission costs
- OSS (operation support system) and billing costs

Furthermore opening the access network to several service providers will increase competition on the service and price level what is beneficial for the consumers.

Essential for the successful implementation of the wholesale model is the proper design of prices: The retail prices (prices commercial operators charge to the consumers) must not be too high as purchasing power in the HPR communities is low. To ensure that services are still affordable prices shall be monitored and potential regulatory measures (especially ex-post price regulation) shall be considered (see also chapter 4.3.3). Prerequisite for affordable retail prices are appropriate wholesale prices. The charges of eGovernment Unit to commercial operators / ISPs must be non-discriminatory and lower than the retail prices. They must allow the commercializing enterprises to cover their costs and to still make some profit.

As eGovernment Unit's mission is also to facilitate extensive ICT adoption and usage by citizens, basic connectivity shall be provided to the consumers:

- Free internet access via WiFi is granted to the people in the currently underserved areas (in HPR-communities) by the eGovernment Unit. The volume per individual is limited to max. 250 MB overall

[25] "Our mission is to develop and deploy appropriate ICTs to support quality collaboration among Government Agencies. This whole-of-government approach is intended to facilitate extensive ICT adoption and usage by citizens, which will encourage continuous improvements and expansions of the reach of Government services across Guyana."

[26] Source: Strategies for the deployment of NGN in a broadband environment, ITU 2013

data allowance. A potential pilot should be started with 100 MB. The idea to enable access to basic information and communication services, but to still leave potential for the commercial enterprises to sell their services. The free access at limited volume allows basic communication and can also stimulate ICT adoption, motivating people to buy additional services from commercial enterprises if needed.

- Access to content is managed and monitored by basic filter in the core network to ensure fulfillment of educational mission of Guyana's government.
- Government websites are not counted against data allowance.

The planning, building, operation and maintenance of the ICT network requires dedicated resources and skills. The eGovernment Unit can follow different approaches to realize this endeavor:

- Built and operate the network: eGovernment Unit does the planning, building and the operation of the network on their own

- BOT (built-operate-transfer): eGovernment Unit contracts a private entity to build and operate the network for an explicit time. Afterwards operations are transferred from the subcontracting unit to eGovernment Unit.

- Buy the turnkey model: eGovernment Unit engages a vendor to build the network and to out it into operation. The operation and maintenance is done by eGovernment Unit.

The BOT approach is most suitable for the context and specifics of Guyana. By outsourcing the development and deployment of the network eGovernment can overcome potential shortages of resources but has still full control over the assets and the target achievement. Furthermore a prolonged period of transfer and training will significantly contribute to capacity building at eGovernment Unit for the future operation and maintenance of the network.

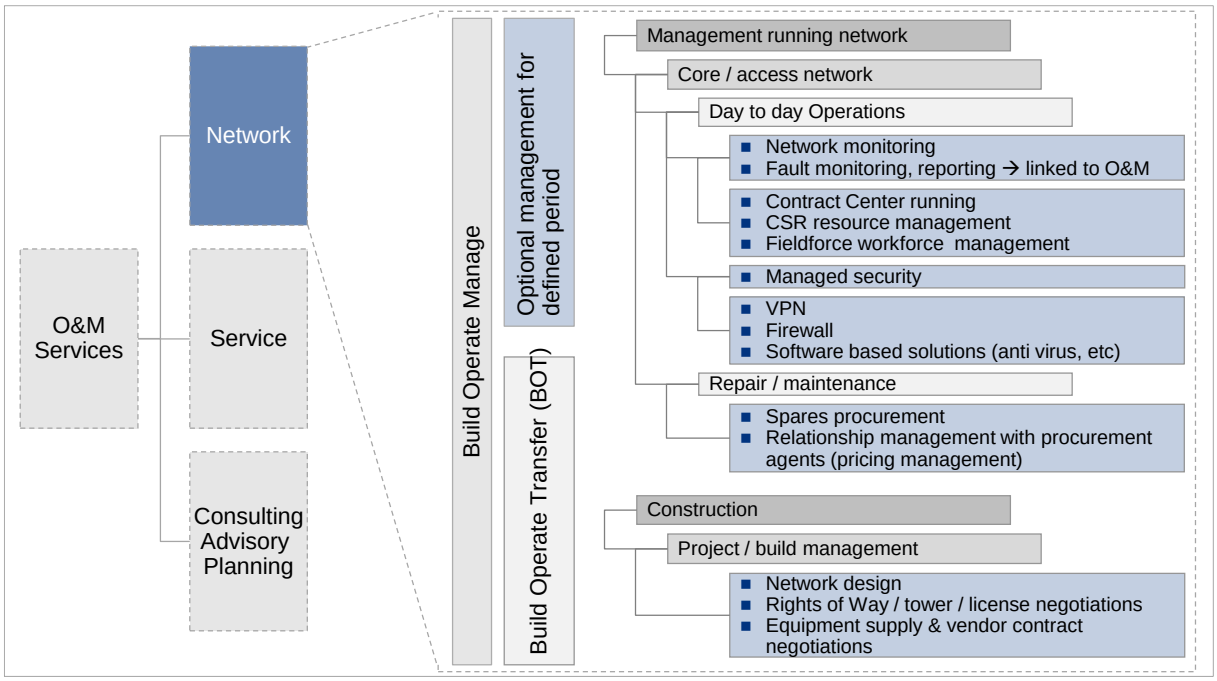

Figure 39 - Build-Operate-Transfer approach to create the future network

4.3 Implication for Legislation and Policy Development

With the move to the deployment of broadband networks, the telecom regulator's fundamental roles and the aims of regulation do not change. These should be technology-agnostic. However there are a number of broadband issues that have posed new questions for regulators. The approach must balance the needs of consumers, dominant players and competitors and yet still fulfil the overall policy aims. Regulation is easier in areas where market entry is simple and competition can flourish. In extremis, regulation can eventually be completely removed. Creating many voice competing services over multiple core broadband networks or even over one or two dominant player's core networks is relatively easy to accomplish. Once these competing retail service providers are established, retail price regulation might be removed. The access to the non-competitive wholesale markets, controlled by only one or two NGN providers, will still need to be regulated. Similarly, competing ISPs can be encouraged to deliver multiple retail Internet services: regulation can ensure these ISPs have the required wholesale access to the broadband infrastructure. Voice, Internet and other service-level competition is ensured by: [27]

- Define and stipulate concrete targets in terms of coverage and speeds and sketch the evolution plan defining also the mid-term ambition level.
- Create an environment to facilitate invest in ICT-development and efficient allocation of scarce resources.
- Promote competition: enable service providers to access the broadband network at the lowest possible physical levels and combine them with their own networks. Where competition fails regulatory measures shall be imposed, such as price regulations, to ensure affordability of basic services.

4.3.1 National Broadband Plan

To realize the business model as described above, it is necessary to establish an adequate regulatory framework that will foster the development of the market. As the current situation in Guyana is dominated by two market players (GTT and Digicel) and still lacks broadband penetration and service quality public intervention is necessary. The public intervention shall comprise both: policy making and/or funding. The commonly used instruments for this are Digital Agendas and National Broadband Plans:

A Digital Agenda comprises targets and measures for obtaining economic and social benefits from ICT and addresses the roll-out of networks, the creation of content and the provision of services. Broadband plans are one of the available measures to push the roll-out of networks. They stipulate specific plans for broadband roll-out, coverage goals, and available speeds. Often targets are differentiated for specific criteria:

- Different targets for fixed and for mobile broadband with mobile speeds being generally lower
- Geographical differentiation between rural and urban (rural speeds are set lower), sometimes definition of priority areas with especially high speeds

They contain in general minimally a target year for achievement, sometimes there is a more detailed roll-out schedule.

There is no commonly applied definition of broadband as technology innovation constantly boosts transmission rates. Hence newer policy documents normally stipulate higher broadband speeds than older documents: "Broadband" often starts at 144 Kbps Fast BB is frequently defined as above 20 – 30 Mbps Ultra-Fast broadband starts at 100 MBps Implementation Plan

- Broadband often starts at 144 Kbps
- Fast broadband is frequently defined as above 20 – 30 Mbps
- Ultra-Fast broadband starts at 100 MBps Implementation Plan

[27] Source: Strategies for the deployment of NGN in a broadband environment, ITU 2013

Hence the National Broadband Plan shall stipulate specific goals or ambition levels including a) coverage by population, households or buildings of special interest and b) specific data rates to be provided for a certain date or point in time.

Countries at different stages of ICT development tend to have different priorities and scope for their National Broadband Plans. Countries in a relatively early stage of ICT development tend to focus on infrastructure availability and measures to encourage adoption and internet take-up. On the other hand, countries in a relatively more advanced stage of ICT development are more likely to have a greater focus on demand-side initiatives and qualitative issues, such as security and privacy. Local contextual factors can also be highly influential in the scope of National Broadband Plans. For example, countries that have already achieved significant ICT integration in key sectors (sometimes as a result of previous NBBPs) do not necessarily need to continue to focus on these sectors. In other cases, the governmental or organizational framework of a country can lead to broadband initiatives being structured as local or sector plans rather than as an overarching national plan. While, at face value, all NBBPs seem to cover all levels of ICT targets (deployment, adoption and integration), in practice, the scope of the plans varies considerably, particularly in the breadth and depth of demand-side targets and implementation.

4.3.1.1 National Broadband Plans (Reference Cases)

Initiatives to boost broadband have been started in several countries in the last years. Some of the dedicated coverage and capacity goals as described in the respective National Broadband Plans are laid out in the tables below:

4G license requirements in Brazil[28]

Deadline	Counties serviced (%)	Download rate (kbit/s)	Upload rate (kbit/s)
30/06/2014	30	256	128
31/12/2014	60	256	128
31/12/2015	100	256	128
31/12/2017	100	1024	256

National Broadband Targets for South Africa[29]

Target	Penetration measure	Baseline (2013)	By 2016	By 2020	By 2030

[28] Source: ANATEL, 2012

[29] Source: Department of Communications, Republic South Africa, Government Gazette, 6th December 2013

Broadband Access in Mbps user experience	% of population	33.7% internet access	50% at 5 Mbps	90% at 5 Mbps 50% at 100 Mbps	100% at 10 Mbps 80% at 100 Mbps
Schools	% of schools	25% connected	50% at 10 Mbps	100% at 10 Mbps 80% at 100 Mbps	100% at 1 Gbps
Health facilities	% of health facilities	13% connected	50% at 10 Mbps	100% at 10 Mbps 80% at 10 Mbps	100% at 1 Gbps
Government facilities	% of government offices		50% at 10 Mbps	100% at 10 Mbps	100% at 10 Mbps

Broadband targets for Vietnam[30]

In recent years, Vietnam has issued several breakthrough directives to promote the development of the ICT field. In that respect some have been institutionalized, including Decision No. 1755/QĐ-TTg dated September 22, 2010 of the Prime Minister "Approving the Scheme to Early Make Vietnam a Country Strong in Information and Communication Technologies." This directive sets out the country's vision and targets for becoming a leading ICT nation by 2020. It envisions several economic and social goals including:

Human resources:

- By 2015: 30% of information technology, electronic and telecommunications graduate students will be professionally qualified and have good command of foreign languages so as to be able to participate in international labor markets. The rate of Internet users will reach over 50% of the population;
- By 2020: 80% of information and communication technology graduate students will be professionally qualified and have good command of foreign languages for participation in international labor markets. The total labor in the information technology industry will reach one million, including personnel working in the country and personnel as guest workers. The rate of Internet users will reach over 70% of the population.

ICT industry:

- By 2015: Vietnamese enterprises will be fully capable of designing and manufacturing equipment with gradual substitution of import details, stepping up research into the manufacture of integrated circuits, mastering the designing and production of a number of information and communication technology hardware products bearing Vietnamese brands to meet domestic consumption and export demands. Vietnam will be among 15 countries leading in the provision of software and digital content processing services. The sizes and professionalism of Vietnamese software, digital content and information technology service enterprises will be raised so that they can compete in the domestic market. To create a number of hardware, software and digital content products bearing Vietnamese brands for the domestic market, then export

[30] Source: Tuan, Tran Minh, 2011. Broadband in Vietnam: Forging Its Own Path. Washington, D.C: infoDev / World Bank. Available at http://www.broadband-toolkit.org/
Decision No. 1755/QD-TTg of September 22, 2010:
http://www.moj.gov.vn/vbpq/en/lists/vn%20bn%20php%20lut/view_detail.aspx?itemid=10749

- By 2020: To form strong information and communication technology research and development organizations, especially technological research and development organizations of enterprises, which will be fully capable of conducting new hi-tech product research and development. Vietnam's software industry and processing services will strongly develop, putting the country among 10 countries leading in software and digital content service provision. Vietnamese software, digital content and information technology service enterprises will dominate the domestic market and participate in export. Many products and solutions to serve the State's and enterprises' application of information technology will be researched, developed or localized from free open-source software.
- Information technology industry, especially software industry and information technology-based services, will achieve the highest growth rate among techno-economic sectors and represent a high GDP ratio.

Broadband infrastructure:

- By 2015: To basically complete the broadband network in communes and wards nationwide, connecting Internet to all schools; to cover 85% of the population with broadband mobile information waves; Vietnam will be ranked among 65 countries on the ranking list of the International Telecommunications Union (ITU)
- By 2020: To complete the broadband network in almost all villages and hamlets; to cover 95% of the population with broadband mobile information waves; Vietnam will be ranked among 55 countries on the ranking list of the ITU (in the one-third group of leading countries).

Universalizing information

- By 2011: Almost all households will have telephone sets;
- By 2015: 20-30% of households nationwide will have computers and access broadband Internet; over 90% of households will have television sets, of which 80% will be able to watch digital television by different modes;
- By 2020: Almost all households nationwide can use digital services; 50-60% of households nationwide will have computers and access broadband Internet, of which 20-30% access optical cable broadband; almost all households will have television sets and be able to watch digital television by different modes.

Application of ICT

- By 2015: To provide almost all basic online public services to people and enterprises at degrees 2 and 3 (receipt of dossier forms via internet and exchange of information, sending and receipt of dossiers via internet). Eighty percent of enterprises and social organizations will apply information technology to management, administration, production and business activities. To universalize information technology application in the education and health care systems. To step up the application of information technology in the fields of defense and security;
- To initially apply information technology to the settlement of important socio-economic issues of wide impact, covering application of information technology to urban traffic management, food hygiene and safety, weather forecast, etc
- By 2020, Vietnam's e-government will rank good in the world. Vietnam will rank among the 1)3 group of leading countries in the United Nations' ranking list on e-government readiness. Almost all basic public services will be provided online to people and enterprises at degree 4 (payment of service charges, receipt of service results via internet). All national key industries, enterprises and social organizations will apply information technology to management, administration, production and business activities.

Developing the information and communication technology market

- To raise the efficiency of production and business activities of Vietnamese information communication and technology enterprises and groups such as Vietnam Post and Telecommunications Group (VNPT), the Army Telecommunications Group (Viettel), the Multi-Media Communications Corporation (VTC), the FPT Joint-Stock Company and the CMC group joint-stock company, in both service provision and industrial production. To form the Vietnam Multi-Media Communications Group (VTC)
- To support and encourage the emergence of small- and medium-sized information and communication technology enterprises and boost the formation of big information and communication technology enterprises with efficient business and high competitiveness to become strong business groups,

incrementally entering regional and world markets and establishing the "Vietnam information and communication technology brand"

- By 2015: To develop information technology enterprises and groups of ASEAN level and scale, conducting business activities on the international market, including a number of enterprises each having turnover of over USD 10 billion
- By 2020: Many Vietnamese information technology enterprises and groups will conduct business activities with efficiency, reaching the world level and scale, including some enterprises each having turnover of over USD 15 billion.

In addition to these objectives the directive also establishes several broadband targets:

	Up to 2015	Up to 2020
Nationwide Broadband Network	Complete the broadband network to communes nationwide	Complete broadband network to most of the villages
Mobile Broadband Access	85% of population covered by mobile broadband signal	95% of population covered by mobile broadband signal
Fixed Broadband Access per Households & availability of devices	20 - 30% of households have computer and broadband Internet access	50 - 60% of households have computer and broadband Internet access, in which 25 - 30% use fiber optic cable
Schools	Connect all schools to internet	
Public services	Provide most of basic online public services to citizens and enterprises (download forms, interchange information and send/receive records through the network)	Most of basic public services are online provided to citizens and businesses at level 4 (service fee payment, receive results of service online).

4.3.1.2 Recommendations for Guyana

"Many strategies aim for too low an access speed. Surely an aim for 10 Mbit/s access by 2018 is too low a figure for a 2013 strategy – even for an emerging economy. Demand for capacity is never-ending and so, setting a target for something that is merely "good for today," will be overtaken by events. Such a strategy locks in a lag behind other economies and ensures an emerging economy will never catch up. The additional cost of additional speed is low, so building-in future capacity into the plan ensures the strategy is future proof." [31]

The National Broadband Plan for Guyana should be developed as part of the overall regulatory strategy. There must be considered, that there is a significant difference in terms of ICT access and service quality between the

[31] Source: Strategies for the deployment of NGN in a broadband environment, ITU 2013

densely populated coastal areas and the Hinterland and remote areas. Hence the National Broadband should stipulated dedicated targets for each of these area clusters. Based on the current situation and the network solution design the following targets for the Hinterland and remote areas are recommended:

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Communities >1000 people	20% covered at 6MBps	85% covered at 6MBps	85% covered at 6MBps	100% covered at 12MBps	100% covered at 12MBps	100% covered at 12MBps	100% covered at 12MBps	100% covered at 12MBps	100% covered at 12MBps	50% covered at 100 MBps 50% covered at 50 MBps
Communities with 101-1000 people	-	80% covered at 3MBps	95% covered at 3MBps	100% covered at 12MBps	100% covered at 12MBps	100% covered at 12MBps	100% covered at 12MBps	100% covered at 12MBps	100% covered at 12MBps	50% covered at 100 MBps 50% covered at 50 MBps
Communities with 11-100 people	-	70% covered at 1MBps	70% covered at 1MBps	70% covered at 1MBps	100% covered at 1MBps	30% covered at 6 MBps 70% covered at 1 MBps	60% covered at 6 MBps 40% covered at 1 MBps	100% covered at 6MBps	50% covered at 12 MBps 50% covered at 6 MBps	100% covered at 12MBps

Table 3 Recommended broadband coverage targets for Hinterland and remote areas

The recommendation is based on the following principles:

- All targets count for the status achieved by 31st of December of the respective year
- All targets present minimum requirements
- Total sample is the same as comprised in the technology solution design and the data base of 163 communities in Hinterland and remote areas in scope of this assessment

- Coverage is prioritized over bandwidth: first general coverage shall be ensured, required data rates are to be increased over the time
- Coverage targets are per community not per individual. A community has full coverage if the public buildings have access to ICT service with the respective bandwidth stipulated. The public buildings comprise: secondary schools, primary schools, post offices, hospitals, health stations, health huts, benabs, police stations
- Larger communities are to be covered before smaller communities to connect as many people as fast as possible
- The roll out must be supplemented by the provision of devices to be used by the people in the communities in the respective public buildings connected. When a community is covered adequate computer labs shall be installed and working especially in schools, hospitals / health stations / health huts and benabs. Ongoing governmental projects, such as the "One laptop per teacher" or the "ICT hubs" can be leveraged to achieve this goal.

In addition to the targets stipulated it is recommended to establish a process to review the targets annually and to adjust to a more ambitious level if necessary. This is to ensure the ambition is at level with ongoing technology and industry innovations.

4.3.2 Spectrum evolution strategy

In Guyana, only a small part of the established spectrum seems allocated to the mobile network operators. In the following, the potential spectrum opportunities are briefly summarized, and a recommendation will be given in section 4.3.2.2.

4.3.2.1 Discussion of valuable spectrum assets in Guyana

In the following Table 4 the most attractive frequency bands worldwide are summarized.

Table 4: E-UTRAN frequency bands of current worldwide interests

E-UTRA Operating Band	Uplink BS receive, UE transmit		Downlink BS transmit, UE receive		Duplex Mode	Notice
	$F_{UL\ low}$	$F_{UL\ high}$	$F_{DL\ low}$	$F_{UL\ high}$		
1	1920	1980	2110	2170	FDD	UMTS
3	1710	1785	1805	1880	FDD	PCS
5	824	849	869	894	FDD	CLS
7	2500	2570	2620	2690	FDD	2600 FDD
8	880	915	925	960	FDD	GSM
20	832	862	791	821	FDD	DD800
22	3410	3490	3510	3590	FDD	Rather B42 TDD
28	703	748	758	803	FDD	DD700
31	452.5	457.5	462.5	467.5	FDD	450
32	N/A	N/A	1452	1496	FDD[2]	SD1500

38	2570	2620	2570	2620	TDD	2600 TDD
42	3400	3600	3400	3600	TDD	3500 TDD
43	3600	3800	3600	3800	TDD	3700 TDD
46	5150	5925	5150	5925	TDD[8,9]	LAA
NOTE 2: Restricted to E-UTRA operation when carrier aggregation is configured. The downlink operating band is paired with the uplink operating band (external) of the carrier aggregation configuration that is supporting the configured Pcell. NOTE 8: This band is an unlicensed band restricted to licensed-assisted operation using Frame Structure Type 3 NOTE 9: In this version of the specification, restricted to E-UTRA DL operation when carrier aggregation is configured.						

The FDD-bands are state of the art with worldwide LTE-ecosystem. LTE2300 and LTE3500 operate in LTE-TD in many countries already replacing former WIMAX systems. LTE2600 also increasing especially in Europe.

LTE450 is standardized and in use at least in Brazil, Finland and Russia, especially for the rural broadband coverage.

4.3.2.1.1 Summary of 450-470 MHz band

The LTE450 band would be highly advantageous to support objectives in rural areas due to significant propagation advantages leading to reduced deployment costs. Although this band has considerable advantages in terms of propagation, there is a still a limited 'ecosystem', i.e. little equipment and terminals available worldwide, but improving step by step.

There are two alternative modes for use of the 450-470 MHz band for LTE:

1. The deployment of **Frequency Division Duplex (FDD)** which could be achieved through a paired option - 2×5 MHz FDD:
    - The main purpose of the allocation to LTE is to fulfill the aims rural broadband initiatives ensuring mobile broadband coverage at lower cost than higher frequency bands. This can be done either directly via LTE450-capable terminals or indirectly via Wi-Fi connectivity using LTE450-backhaul. Note that LTE450 can also be usefully deployed in all areas due to superior indoor coverage.
    - In addition, one potential use case of this band could be for Public Protection and Disaster Relief (PPDR) services[32]. An LTE network for PPDR broadband support might be shared with public mobile services with pre-emption in case of emergency. This could be manifested as PPDR providers (i.e. the security and emergency services) having access as closed user groups on different networks in the wide coverage LTE450 band as well as the other LTE bands (e.g. LTE700 or LTE800) because of their higher capacity.
    - The FDD option might be favorable for those band plans already having CDMA 450 established, with 3channels of 1.25MHz each. Therefore potential refarming and reassignment from 2×3.75MHz to 2×5MHz is needed.
2. The deployment of **Time Division Duplex (TDD)** could be achieved through an unpaired option – e.g. 15 MHz TDD, which is more flexible concerning future extension in digital dividend III bands, as TDD is flexible enough to support either more downlink or more uplink traffic. Therefore, deploying TDD in LTE450 is highly appropriate for uplink-focused services, like Machine-to-Machine (M2M) applications, connected cars and/or smart grid applications, especially in rural areas. TDD in LTE450 could also be bundled with other TDD bands in higher frequencies to increase flexibility of TDD applications and to build the TDD 'ecosystem' which is currently well behind the FDD ecosystem.

[32] The LTE-based PPDR services would work alongside dedicated Terrestrial Trunked Radio (TETRA) services.

In Brazil, Finland and Russia, the FDD variants are used, so in the following, the FDD-2*5MHz solution is in focus.

4.3.2.1.1.1 Demand for LTE in the 450-470 MHz band

The LTE450 band is especially needed for improved data coverage in deep-indoor environments and in rural areas to support data connectivity initiatives (e-Government, e-Health, e-Learning, etc.). The capacity of 2×5 MHz FDD or 1×15 MHz in TDD is limited compared with the 700 MHz band with 2×30 MHz or 2×45 MHz, or 800 MHz band with 2×30 MHz. Therefore, basic services are in focus with reduced capacity and data rate requirements, but improved latency of LTE. In addition operational benefits are expected due to harmonized and optimized core hierarchies.

For more quasi-stationary usage with fixed terminals (and potentially separated outdoor antennas) both technologies could enlarge their coverage significantly. The user penetration could be significantly increased by WiFi offloading of classical smart phones with WiFi capability and LTE backhauling. In general, there might be some Mobile Virtual Network Operators (MVNOs) offering hotspot broadband internet in their restaurants or WiFi kiosks to low income groups in areas that are not currently covered.

Both coverage bands (LTE450 and LTE700) are expected to be embedded in connected car solutions as backhaul technology to other WiFi-capable devices. Potentially larger antenna sizes due to lower frequency are possible within car or home environments than within small smart phones.

4.3.2.1.1.2 Value of LTE450 versus LTE700/LTE800

One general issue with the estimation of value and the demand of 450-470 MHz spectrum is the regulator`s obligations or announcements to cover the population with service by >90%. In the past, the operators (all over the world) have claimed having already reached this target for many years. This might be correct concerning the usual assumptions for coverage of the last years of the deployments of these networks, but it is a well-known fact that terminals worsened over time from the radio perspective. The smaller the terminal size and the more bands to be covered by the small invisible antennas, the higher the degradation in their performance; the larger the displays, the higher the power consumption - smaller battery sizes are also leading to reduced RF output powers. Therefore, the deployment of the networks over time was partly driven by capacity demands, but also by coverage demands to prevent customer complaints. In most cases, the users are shifted from low quality 3G conditions to better 2G coverage conditions with less performance in general. This simple trend is less obvious with more deployments of 3G in 900 MHz as well, after expensive refarming and user traffic migration to 1800 or 2100 MHz bands.

Now it is valuable to have a large coverage network to cover higher data rates at larger distances or within higher penetrations, but the operators, who know their networks best, will not provide real population coverage figures per band or service. They might have internal studies about the 'real' or 'more accurate' population coverage figures, e.g. 77% for GSM900 indoor instead of >95% outdoor as promised, or ~45% of UMTS instead of ~75% as announced to get new customers[33],but no operator will reveal the real figures which would be less than regulator obligations. Therefore, no precise studies are available to illustrate the real benefit of new, additional coverage and quality in some areas which are covered now.

LTE450 is most attractive for complementary rollout starting in rural areas and would need new larger terminals (fixed or in-car). In this case new radio access network and backhauling infrastructure has to be deployed and potential sharing is attractive for all players. LTE450, with realistic coverage and capacity obligations over time, might be attractive for a new entrant especially in the instance of non/partially overlapping customers.

But there is also value of spectrum due to competition. If an entrant uses new spectrum, there must be sufficient new spectrum available to give the entrant power of cost-effective competition. This is not the case for 450-470 MHz. If there were an entrant within 450-470 MHz, there would be a need for additional spectrum in other bands

[33] These values are just an exemplary guess!!! There is no statement made towards any operator!

as well, especially in the high capacity-density-frequency ranges. The revenues from the attractive capacity regions would subsidize the cost–intensive, rural rollout with regulator obligations.

4.3.2.1.2 Summary of 700, 800 and 900MHz bands (LTE700, LTE800, LTE900)

In Guyana 811-821//856-866MHz is announced for analogue trunking services, 821-824//866-869MHz for digital trunking services (Figure 40). These allocations are *partly overlapping* with current world wide LTE800 band evolutions mainly driven by region1 as mentioned in the following.

The new (APT) 700MHz band is auctioned many times in the world in these days. But the band opportunities are manifold dependent on the region. In region2, there exist 4 different bands in US-700 band plan, adopted first and only by the US and Canada. The region 3 (Asia Pacific) decided for the full band from 694-803MHz for LTE use, which is also largely adopted by many regulations in South and Latin America. Many others might follow in Africa and Middle East.

For the purposes of this analysis, the 700 MHz and 800 MHz bands are considered together. The two bands overlap and spectrum configurations in one affect the possible configurations in the other.

The ITU has considered two, high-level configurations for the 700 MHz band and 800 MHz band.

1. Option 1 (Figure 41) consists of the following combination of spectrum:
    - 2×45 MHz from 703 MHz to 803 MHz with 10 MHz of centre gap;
    - 2×18 MHz from 803 MHz to 862 MHz; and
    - 2*5 MHz LTE850 from 826-831//871-876MHz
    - GSM-R (876-880MHz) is with 2*4MHz not used in Guyana and would act as guard band between LTE850 and GSM
    - GSM (or their potential LTE900 successors) in 880-960MHz (Figure 43)
    - The analogue trunking service needs to be switched off, while the digital trunking service might be shifted to 823-826//868-871MHz.
2. Option 2 (Figure 42) consists of the following combination of spectrum:
    - 2×30 MHz from 703 to 788 MHz
    - 2×30 MHz from 791-821//832-862 MHz
    - potential LTE-TDD assignments in band gap 733-758 MHz (or other LTE or non-LTE assignments; supplementary downlink seems the most favorable solution)
    - 2*5 MHz LTE850 from 826-831//871-876MHz
    - GSM-R (876-880MHz) is with 2*4MHz not used in Guyana and would act as guard band between LTE850 and GSM
    - GSM (or their potential LTE900 successors) in 880-960MHz (Figure 43)
    - The analogue trunking service needs to be switched off, while the digital trunking service might be shifted to 823-826//868-871MHz.

Many countries including most of Asia and Latin America have selected Option 1. Option 1 permits 2×45 MHz in the 700 MHz band and has the advantage of a large ecosystem (network equipment and terminals) because the Asia-Pacific ITU Region 3 and large parts of Latin and South America have chosen this option. However, the complexity of the APT-700 capable terminals and equipment is high because they need two overlapping duplexers of 30 MHz bandwidth. In addition to LTE700, in LTE800, 2×18 MHz remains, so in total, 2×63 MHz will be available for LTE.

At this point, European countries have decided on Option 2 as in region 1, many regulatory bodies followed their possibilities of the digital dividend and offered first 790-862MHz as digital dividend step I, followed by step II with 703-733//748-788MHz. Region 1 solution (option2) turned out to be the best solution and is also a valid candidate for LTE700 in Africa and Middle East, and could also be for Latin America.

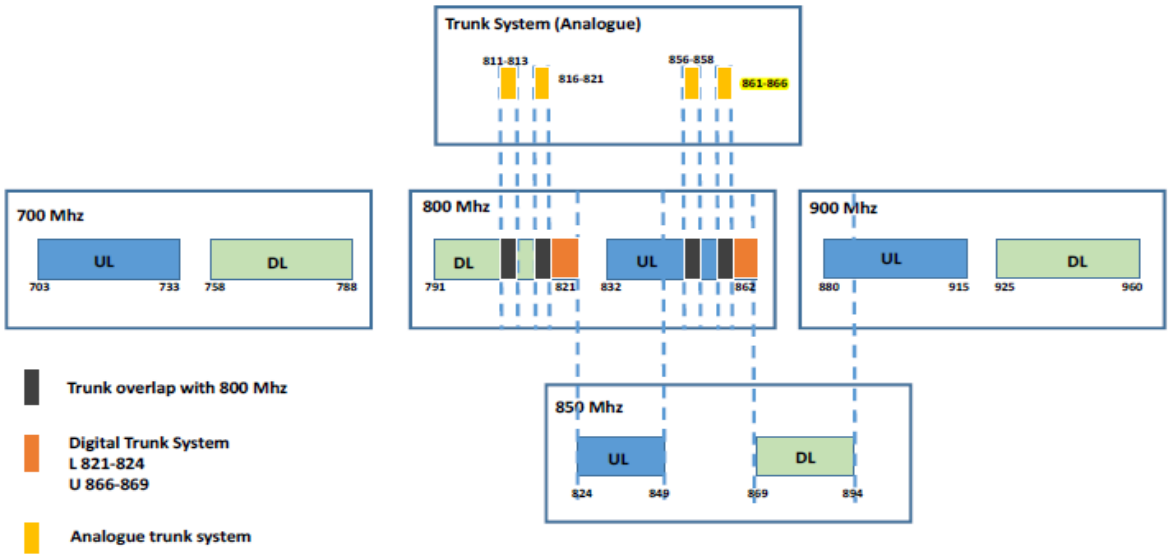

Figure 40: current usage of IMT700 / IMT800 bands in Guyana (here option 2 is depicted)

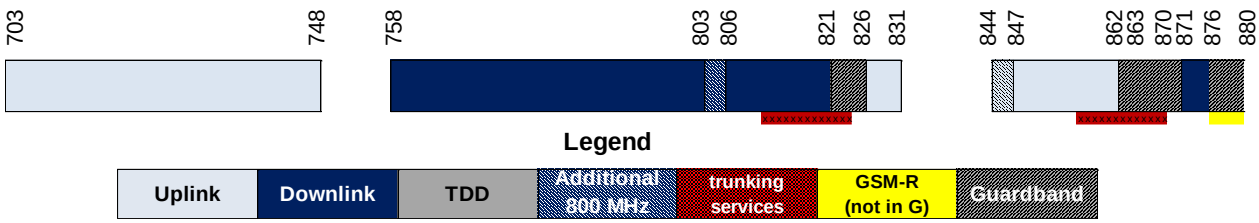

Figure 41: Option1 mainly used in region 2 and 3

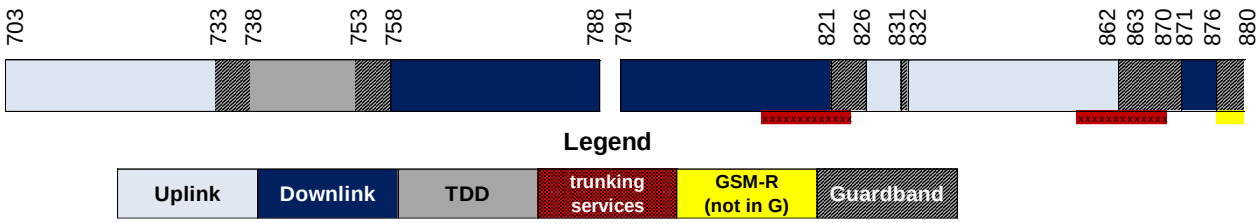

Figure 42: Option2 mainly used in region 1 and 3

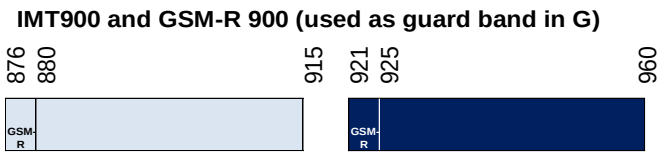

Figure 43: IMT900 solutions with GSM-R as guard band in Guyana

4.3.2.1.3 Summary of 1700-2200 MHz band (LTE2100)

It is not clear if spectrum band 1 and 3 have been assigned in Guyana. It is expected, that Guyana follows Region2 allocations with LTE1800 and LTE2100, but not LTE1900

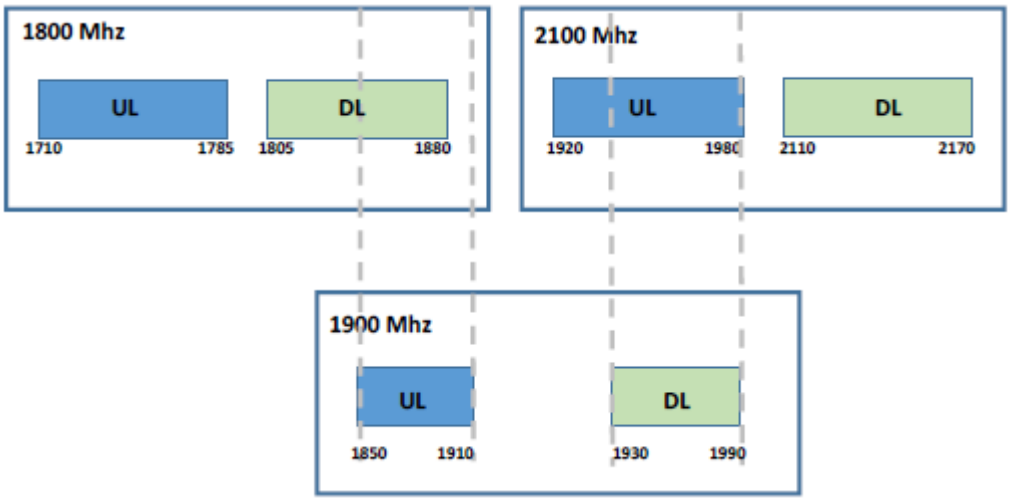

Figure 44: 1700-2200MHz allocations in region2 (LTE1800 and LTE2100) and region1 (LTE1900)

4.3.2.1.4 Summary of 2300-2400 MHz band (LTE2300)

LTE2300 is already in use for LTE TDD. In the case of different TDD-configurations, a 5 MHz guard band has to be considered within the new assignment.

A guard band of 5 MHz is not required between LTE2300 and the 2400 MHz ISM band. Where there is interference, other Wi-Fi channel settings might be selected appropriately.

4.3.2.1.5 Summary of 2500-2670 MHz band (LTE2600)

LTE2600 is already deployed worldwide as capacity layer with limited coverage. Most deployments use the 4*4MIMO option, either for 4RX-diversity, or DL-performances. In UL MU-MIMO is the next best step to upgrade performance. In LTE2600, 2*70MHz in FDD are available, in addition 40MHz TDD from 2575-2615MHz, while 2 times 5Mhz remain as guard band with limited possibility of indoor usage.

Figure 45: IMT2600 band 7

4.3.2.1.6 Summary of 3400-3600 MHz band (LTE3500)

The unpaired TDD alternative, which offers 200 MHz, is more attractive in the long term because TDD downlink is better, providing higher frequencies due to downlink schemes and therefore higher capacity-density per coverage area. Therefore, more capacity would be available for LTE TDD with 200 MHz permitted as opposed to 2×80 MHz FDD. In addition, so far LTE3500 is frequently used worldwide for WIMAX-TDD by operators - many of whom migrate to LTE. Consequently the ecosystem is favorable for TDD.

The Regulator may assign special uplink or downlink configurations to minimize guard bands. The Block Edge Masks are to be taken into consideration in order to allow unsynchronized usage as well as to minimize the need for guard bands

4.3.2.2 Proposal for usage of valuable spectrum assets in Guyana

National Frequency Management Unit follows technological neutrality, meaning the frequencies will be allocated based on planned services only, not requesting or defining a specific technology to be used. In Guyana the incumbents GSM networks have partly been refarmed to UMTS/HSPA.

Frequencies are not auctioned as per current Government Policy. This is due to the specifics of Guyana as a country and economy, with a limited population and market. It is *expected* that the companies can spend that money better in their ICT infrastructure in the country, at the end contributing more to the wealth of the country then the auctioned license fees only.

Any spectrum which is deemed necessary to service provisioning to HPR communities can be obtained following a rulemaking process within 6months.

Table 5 summarizes the current spectrum allocations in Guyana[34].

Table 5: current spectrum allocations in Guyana

LTE Band	GTT+	Digicel	eGovernment-Net	free
450[35](band31)				2*5MHz[36]
700 (band 28)				2*45MHz or 2*30MHz
800 resp. 850	Switched off TDMA and returned license back to NFMU	*Not clear if U850 or L850 are used*		L800: 2*15MHz or 2*30MHz; L850: less likely in future, 2*5MHz possible
900 (band 8)	GSM, 2*12MHz	GSM, 2*12MHz		2*11MHz unused, no new entrants
1800 (band 3)	GSM, 2*25 MHz	GSM, 2*25 MHz		2*25MHz free
2100 (band 1)				2*60MHz free
2300 (band40)			LTE TD, 1*20MHz	TD, max 100MHz
2600 (band 7)				2*70MHz FDD 1*50MHz TD, 40MHz usable
3400-3800	WiMAX, shut down			Max 400MHz

Based on the current usage in Table 5, the following recommendation for further usage are:

- The remaining 2*11MHz within 900MHz should be assigned to GTT+ and digicel as soon as possible.
    - Both incumbents get the opportunity to introduce LTE without the need to refarm their current spectrum. This would not harm the current voice and data capacities in the GSM900 or UMTS900.
    - Each operator should introduce 2*5MHz in >75% of their locations within the first 2years following the assignment. There might be different efforts for the incumbents depending on the availability of LTE-ready equipment.
    - There is a must to offer high quality broadband data rates.
    - There is no obligation to introduce VoLTE.

[34] At time of writing, the NMFU has not provided the exact spectrum assignments, so only indicative statements possible here.

[35] Assignments in the 450 MHz band are accommodated once spectrum users accept that they may be required to cease using the band and move to another band at their expense after being given about 6 months notice.

[36] 2*5MHz FDD or 15-20MHz TDD available, not assigned for LTE in Guyana yet, but could be made available to HPR depending on current licensees.

    - Each operator could extend to 2*10MHz (or 2*15MHz in the long term) based on their own capacity planning.
    - The minimum of 2*2.4MHz is required for GSM, which fits to the proposed assignments.
- The LTE700 might either have 2*30MHz or 2*45MHz. deliberately, both operators should get 2*15MHz to extend capacity in a broader coverage. The obligations need to be discussed.
- The remaining 3rd part of 2*15MHz and the 2*15MHz in LTE800 (or the entire 2*30MHz in 800MHz) could be reserved for a potential new entry or eGovernment own use in case of higher demands for eServices in the future.
    - As already proposed, LTE450 might be used as well for PPDR services. These might need some capacity extensions later.
    - Since the use of LTE800 is only fully possible, if the analogue trunking services are switched off or migrated to other bands, there should be enough time for the current users to take this into account. Same holds for the digital trunking service.
- There is also 2*5MHz available in L850. These would only be assigned directly, if there is any current usage in 850MHz band apart from Table 5 (which is unlikely because not mentioned in NMFU-Figure 40)**Error! Reference source not found.**.
- Before further higher band LTE-assignments should be made in LTE2100 or LTE2600, the incumbents have to refarm a reasonable part of GSM1800 to LTE1800 in order to use their spectrum more efficient. The 3rd part of this spectrum of also 2*25MHz would be considered as well before assigning LTE2100 or LTE2600.

At the moment of this report, it is not clear which other bands in TD or FDD would be preferred from the standard for Carrier Aggregation with LTE2300. LTE700 and LTE800 are promising candidates, since LTE450 is not on the horizon for CA so far. At time of the auction of the 3rd part of LTE700 and LTE800 this needs to be assessed in order to enlarge coverage of LTE2300 eGovernment Net due to CA with a coverage driven lower FDD-band.

4.3.3 Affordability

Affordability is a central issue for all stakeholder involved. The operators must afford the investment and the services must be affordable for consumers. ITU suggests various levers to address this: sharing of broadband (including resale); transfer of customer pre-paid credit; low cost end user devices; selective subsidies; careful use of universal service funds or obligations; avoiding unreasonable tax burdens; promotion of competition; and the targeting of aid and government investment, can all help with affordability especially in developing economies.

The findings from the baseline data collection (WP 1, Baseline Report) show that interviewees would be willing to pay up to GYD 10.000 per month to have access to Internet at home (maximum), GYD 5.000 per month on phone calls, up to GYD 4.500 to have Internet on their smartphones and up to GYD 1.200 for texting.

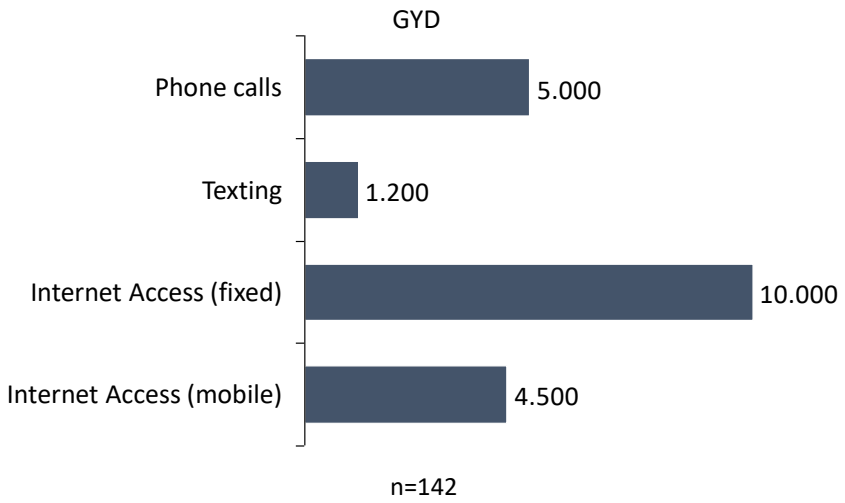

Figure 46 - Willingness to pay per month for ICT services in Guyana Dollars

A breakdown shows the willingness to pay for the different services – reflecting to certain extend the consumer's experiences with current offerings and its prices. Low familiarity with telecommunication goods and services may have influenced the distortion of the average values the respondents of segments poor, remote and hinterland would be willing to pay mainly in relation to services such as texting or phone calls. In the latter, the average values to be paid for phone calls are more than twice the overall average price. In some remote and Hinterland areas ICT services are only available via satellite, but at higher price levels than services transmitted via mobile or fixed access technologies. This might also be a reason why the willingness to pay overall is rather high.

As the willingness to pay is always influenced by the market prices perceived the willingness to pay as stated by the interviewees in the primary research is only one indicator for setting the right price point. To determine appropriate prices it is also necessary to analyze average income per capita and cost of living to cover at least basic needs in the respective regions and communities. The remaining budget can be spend for ICT services but should still leave some room for other spending, savings or invest.

In South Africa the overall vision of the policy is to give every South African access to a broadband connection at a cost of 2.5% or less of the average monthly income.

Potential policy initiatives that could yield a reduction in prices and tariffs. As it has been considerably researched, the development of competition is one of the major tools for affecting a reduction in telecommunications service pricing. The theoretical basis of competition is the notion that, in the telecommunications market, multiple operators can compete among each other and generate sufficient benefits for consumers in terms of price-reductions, while guaranteeing an appropriate rate of innovation.

A competitive market structure has a positive influence on the reduction of broadband prices. For example, in Latin America, the average monthly price of a basic fixed broadband price declined from US$21.06 in 2010 to

US$17.46 in 2012 (a reduction of 17% in two years). The following table presents price reductions in the region across fixed and mobile broadband plans.

	Plan	2Q2010	2Q2011	2Q2012	Decline
Fixed Broadband	Basic plan with 2GB cap	$ 21.06	$ 18.71	$ 17.46	17%
	Least expensive 2.5Mbps and 6GB cap	$ 77.98	$ 53.05	$ 44.14	43%
	Least expensive 6.0Mbps and 6GB cap	$89.73	$78.48	$82.70	8%
Mobile Broadband	Least expensive PC plan with 1GB cap	$19.59	$17.60	$14.39	27%
	Least expensive smartphone plan with 250MB cap	$17.68	$12.79	$9.24	48%
	Least expensive smartphone plan with 1GB cap	$23.07	$18.71	$16.33	29%

Table 6 - Latin America: Broadband Average Monthly Subscription Prices (2010-2012) (in USD)[37]

4.3.3.1 International Gateway

……

4.3.3.2 Price regulation

…

5. Implementation Plan

5.1 Overview

The previous chapters outlined the high-level technology architecture proposed for hinterland and remote regions as well as a feasible business model to finance, build, operate, and manage the infrastructure in a sustainable way. The next step in the overall rollout needs to be the detailed plan for infrastructure implementation. This plan is being created in the next phase of the e-Government and UNDP program. The following section serves as a guideline for the activities that need to be performed during the in-depth planning phase.

The final goal of the implementation phase is providing the first set of hinterland and remote communities with internet access. Therefore, the implementation partner needs to be chosen and in parallel the target business model needs to be defined and agreed with all stakeholders. Regulatory frameworks need to be adapted or

[37] Dr. Raúl Katz, 2012. Includes Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Uruguay, and Venezuela.

introduced potentially for both, implementing as well as wholesaling the technology infrastructure for hinterland and remote communities.

5.2 Next Steps towards a Detailed Implementation Plan and Technology RfP

The detailed implementation plan needs to focus on three dimensions:

I. Technology – all aspects of the technical infrastructure solution
II. Business Model – operations, processes, governance, financing, partnerships
III. Regulation – needed adjustments to the legal framework to enable business model

In each of these dimensions there are a number of activities which need to be planned. The following checklists will guide the planning phase.

Technology

- ❑ Validate list of villages in hinterland and remote areas to be connected: exact naming convention, delineation of village boundaries, exact location (lat/lon), exact population number (if possible by age group), exact number of public buildings (schools, health care facilities, town hall, benab, community center, post office, ferry terminal, police station, …)
- ❑ Revise the high-level rollout plan as proposed in Sec.3.4.4: detail prioritization criteria (e.g., village social needs, cost optimization, special needs, economic impact on particular village, rollout synergies, etc.) and select a subset of villages for rollout in the subsequent years.
- ❑ Define which of the public buildings should be connected in which order and with which data speeds: align with stakeholders as referred to in Sec.4.1.
- ❑ Validate the estimation of needed throughput capacity and volume for each selected village based on requirements of the planned e-Services, adjust if necessary: alignment with e-Service providers is needed to create buy-in and to come up with a realistic estimate
- ❑ Perform a site survey of the selected villages: map location of public buildings, map and list of power supply locations and alternative solutions, investigate right of way challenges, assess climate, surrounding terrain and natural obstacles, refine the needed e-Services based on interviews with local residents and institutions, inform residents about plan
- ❑ Create the detailed technology design for backhaul and access networks for each village: based on the available technology options as per Sec.3.2, a subset needs to be selected per village and dimensioned as per the individual site survey.
- ❑ Create the Request for Proposal (RfP) for the planning and building of the network: describe the context of the infrastructure rollout project (general conditions), the currently installed e-Government infrastructure in coastal regions, available resources, detailed target architecture for villages, incl. Bill of Quantities BoQ (technical conditions), any SLA requirements, pricing input form (commercial conditions), etc. A Request for Information (RfI) or Request for Quotation (RfQ) could proceed the RfP phase to receive more information during the architecture design phase.
- ❑ Create tender strategy and launch tender phase: choose best tender format (limited, one, two stage bidding), set pre-qualification criteria, select an appropriate channel to float the tender, set the tender guidelines, solicit responses from all appropriate vendors. This step has to be performed by an external and independent partner with in-depth knowledge of tendering approaches in general, incl. financial expertise as well as broad knowledge of the different vendors/suppliers.
- ❑ Manage vendor inquiries: hold Q&A sessions, manage information flow from and to vendor, create answer sheets
- ❑ Evaluate tender and select shortlisted vendors: define tender evaluation criteria, benchmark the received proposals, SWOT analysis, weighting scenarios, balance score board, ranking. Sample evaluation criteria:

- **Technical**: specifications, performance and extendibility, features, applications and functionality, system operability, training & system documentation, implementation management and schedule, experience and references
- **Commercial**: general conditions, total price (incl. equipment, spare parts, prices for training and other services, installation costs, shipment costs), offered discounts, projected O&M costs, warranty, payment schedule, price benchmarks, equipment availability and delivery schedule

- Enter vendor negotiations and select final vendor: based on selected tender strategy there are a few rounds of negotiations necessary.
- Plan the rollout project and execute rollout: there are three main phases which need to be executed:
  - **Rollout preparation**: check project schedule and rollout plan, verify project contract conditions, check vendor procedures, processes and resources, set reporting and controlling guidelines
  - **Technical review**: review alignment of planned to contracted for architecture design, network topology, integration strategy, BoQ estimation, dimensioning assumptions& planning methodology, service plan
  - **Rollout supervision**: inspect, report and control the project implementation w.r.t. progress and performance, QoS, monitor risks, follow up with change requests, monitor SLAs, run smooth integration, update project plans and documentation

Business Model

- Decide on the final implementation model: review the proposed BOT model and compare with alternative rollout and operations models, e.g. built and operated by e-Government Unit, turnkey model by vendor, etc.
- Align all stakeholders required for implementation model: create project structure and set up communication plan towards stakeholders, see also technical project setup and alignment
- Clarify governance with implementation partner (systems integrator): ownership and financing options need to be discussed, funds need to be secured in governmental budget
- Align all new processes with existing process framework at e-Government unit: any new process needed for maintenance of the infrastructure and end user equipment needs to be compliant with the existing process framework.
- Define training needs and execute training: existing staff needs to be able to effectively support the network and end user devices. The systems integrator should provide training to familiarize e-Government staff with the new equipment, monitoring and servicing.
- Create staff job descriptions to prepare for takeover of operations: work with the systems integrator to understand the needed skills and quantities of staff for effective infrastructure operations

Regulation

- Develop the regulatory strategy and roadmap: Define the overall vision, mission and targets for Guyana w.r.t. ICT and derive policies to support these targets.

  "Define a policy and define a plan. This should be debated and all parties should participate. Over time the policy and resulting approaches specified in the broadband plan may need to be adapted, but countries that are leading with broadband do have some direction and policy. No policy is likely to result in no change or else monopoly provision of services in only a few areas."[38]

[38] Source: Strategies for the deployment of NGN in a broadband environment, ITU 2013

- Define the Digital Agenda and National Broadband Plan for Guyana! Validate and detail the coverage targets recommended in Sec. 3.4.4. Develop and introduce a regular process to revise these targets on an annual base.

  "Ensure the national policy covers all of ICT. Next Generation Networks (NGN) and broadband may be the key investment area and are where the main telecoms issues reside, but all other aspects should be linked in to obtain the wider social benefits of a broadband economy." [39]

- Define price floors & price ceilings for wholesale & retail prices: Define relevant retail and wholesale markets and identify need for regulatory intervention especially with regards to affordability of services. Define price floors for wholesale costs in markets susceptible to regulation based on cost assessments and incremental costs e.g.LRIC (long run incremental cost)

[39] Source: Strategies for the deployment of NGN in a broadband environment, ITU 2013

6. Appendix

6.1 Rolloutplan

6.1.1 Phase 1 (2017)

Satellite rollout: 7 communities larger than 1000 people, which represent 13.6% of the HPR population

Name	population
Mahdia	2564
Kwakwani	2503
Wakapau Village	1807
Matthews Ridge - Kaituma Railway	1433
Paramakatoi	1423
Wauna & Whitewater	1220
Port Kaituma	1152

6.1.2 Phase 2 (2018)

Satellite rollout: 16 communities larger than 400 people, which represent 11.3% or HPR population

name	population
Kobarina Hill, Barrabina Hill	935
Lima Sands	853
Anabisi River	797
Akawini Village	729
Hosororo	723
Monkey Mountain	711
Kurukabaru	686
Ituni	676
Kopinang	669
Mabaruma, Kokorital Hill	569
Waramadan	492
Hururu	484
Kokerite	448
Aruau River	446
Kato	424
Matthews Ridge	409

14 communities are covered by WiBACK® representing 7593 people, which are 8.5% of the HPR population

name	population
Aishalton	1069
Karasabai, Cracrana	1024

Karaudanau, Lumidpau	909
Shulinab,Meriwau,	764
Nappi	677
Achiwib	586
Yupukari	493
Sawariwau	444
Yakarinta	438
Parishara	421
Hiawa	363
Toka	241
Kwaimatta	145
Karanambo	19

95 communities in 81 locations are covered with LTE450: 53877 people will be in reach of the network, representing 60.6% of HPR population

name	population
Bartica	8004
Amelia s Ward	6407
Timehri	4433
Wismar	4137
Hope	4131
Wisroc (Block 22)	3931
Danjou Park	2675
The Bell	2472
Lethem	1702
Christianburg	1457
St. Ignatius	1276
Akwero	1174
Half Mile	1004
Kumaka	982
Cockatara (North Mc Kenzie)	932
Agatash	740
Silver City	734
Waramuri Mission	717
Riverview, New Foundout	676
Coomacka Lands	611
Vreed En Hoop	481
Annai	481
Moco Moco	440
Sans Souci	431
Good Hope	339

Vreed En Rust	325
Fort Nassau	263
Vryheid	236
Blenheim	228
Three Friends	164
Saint Mary s	147
Friendship	146
Durban	145
Wineperu	137
Hauraruni River	136
De Maria Elizabeth	89
Uitkomst	86
Hittia Settlement	84
Kumaru	71
Mon Repos	69
Prosperite	66
Hermanstyne	62
Warida	61
De Endragt	59
Low Wood	56
Berlin	48
Makouria	42
Penal Settlement	37
Old England	37
Dora	37
Maria	34
Catherina	33
Tacama	30
Stena	29
Peter s Hoff	28
Susannah s Rust	28
Wolga	27
Manari	27
Berenstein	25
Spring Garden	25
Princess Carolina	25
Aurora	24
Hofwerk	22
Aurora	22
Charters	22
Maria Henrietta	21
Rustenburg	21
De Velde	21

De Hoop	21
Hope	21
T Fortune	20
Rusthoff	19
Zeelandia	18
De Vryheid	16
Lucky Spot	16
Richmond	16
Meyer Beck	14
Helvetia	14
Elizabeth	14
Endeavour	14
Mahaicabally	12

6.1.3 Phase 3 (2019)

Satellite rollout: 14 communities with a population of more than 200 people resulting in 3784 people, representing 4.26% of the HPR population

name	population
Massara	388
Shea	372
Kamarang	347
Ayanganna Mountain	308
Baramanni River	280
Surama	274
Apoteri	271
Imbaimadai	246
Ekereku River	244
Issano	220
Itabac	216
Mabura Hill	208
Paruima	207
Morawhanna	203

6.1.4 Phase 4 (2020)

Satellite rollout: 8 communities that are larger than 75 people: 963 people connected, representing 1% of HPR population.

name	population
Arakaka	196
Aruka River	142

Kurupung	128
Great Falls	122
Kaboyari Creek	103
Maikwak River	98
Pot Falls	88
Tumatumari	86

6 locations will be upgraded from VSAT to WiBACK technology in the mountainous areas providing higher bandwidth to 4433 people, representing 5% of the HPR population.

name	population
Paramakatoi	1423
Karasabai, Cracrana	1024
Monkey Mountain	711
Kurukabaru	686
Kato	424
Taruka	165

2 locations will be upgraded from VSAT to LTE450 in the tall forest areas providing higher bandwidth to 5067 people, representing 5.7% of HPR population

name	population
Mahdia	2564
Kwakwani	2503

In addition, Tuchen De Vrierden is so far supposed to be included in the LTE450 based 30km area around the coastal area in phase 0. Tuchen De Vrieden might have poor coverage and need own improved connectivity which can be built in 2018 with one own tower using MW&LTE. No extra population is counted here because it is already included in phase 0.

6.1.5 Phase 5 (2021)

Satellite rollout: reaching out to 9 locations larger than 10 people with 300 people, representing 0.3% of HPR population

name	population
Great Fall	74
Puruni River	52
Butakari	52
Konawaruk	49
Kumaka	22
Chi Chi	15
Saka	13
Surprise Hill	12
Eping River	11