Digital Inclusion in Amazon with Starlink Backhauling and Mobile Telephony

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***Abstract*— This work presents a cost-effective solution for extending Internet access to underserved communities in the Amazon and other isolated regions. By deploying private 4G networks using open-source software, such as MagmaCore, a core network solution, and leveraging satellite backhaul connectivity, we address the limitations of WiFi-based networks. Our approach offers wider coverage, scalability, and quality of service, making it an attractive option for rural connectivity. Through the integration of open-source software and satellite technology, we demonstrate a scalable and affordable strategy for bridging the digital divide in remote areas.**

***Keywords*— Private Networks, Open Source EPC, Satellite Backhaul, Digital Inclusion.**

I. Introduction

Brazil has been pushing projects for a long time to bring digital inclusion to the part of its population that is still unattended by the benefits of the Internet [1]. Throughout the world, there are a lot of records of communities that were assisted by different projects throughout the years, and this resulted in the creation of the so called "community networks”, which are locally owned and operated telecommunications or Internet networks built by community members (or external agents) to serve their own needs. They prioritize principles of open access, affordability, and community participation, often providing Internet connectivity, local services, and content tailored to the community’s interests. They foster digital inclusion, empower communities, and promote collaboration and self-determination in the provision of telecommunications services. Private and community networks are still incipient in Brazil.

The majority of community networks use WiFi technology instead of the LTE standard modeled in 4G networks [2], creating a mesh of one or more access points (routers) throughout the community. They also don’t follow any specific pattern related to the equipment, software or technologies used to obtain Internet access (generically called here, the *backhaul* link), some use radio links and some use optical fiber, whatever is most readily a more reliably available to the specific community at the moment.

The problem with using WiFi to build networks like this, as opposed to cellular networks for example, is that WiFi has a low coverage area, of only 10 to 100 meters depending on the equipment, it has bad scalability, and it lacks QoS policies, only applying the best-effort access principle. Compared to this, using mobile LTE telephony technology would be an improvement in all senses, since it has an average coverage of 1-10Km or more [3], can be scaled easily since it is designed to scale with time to support a growing user base, and it offers complex QoS policies [4].

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II. Difficulties with Public Mobile Telephony

Although cellular networks are more suitable to serve a high number of users compared to WiFi, the latter remains the most used option to build community networks, specifically due to its lower barrier to entry. Managing and installing cellular networks is very complex and expensive, as they require a more robust infrastructure, such as towers, base stations, and backhaul connections, and they also requires a great deal of regulatory compliance and human resources.

Along with the technical complexities other barrier to expanding public mobile telephony infrastructure in underserved areas is the cost. As example to this, we could mention the case of a company called Z (name omitted), which is an agricultural company that contacted us for a consultancy to aid in the choice of a telecom provider. The goal of the company was to bring coverage to their whole farm, amplifying the connectivity for the equipment located at the plantation sites and other production environments on the farm, as shown by Fig. 1. To implement this project there were proposals from different companies, including large cellular telephony operators.

The best project proposes to install several towers across specific high points in the terrain, and then install radio base stations in these towers for communication. The points closest to these towers would receive indoor coverage of -89 dBm, suitable for voice and data with potency for closed environments, and after a certain distance it would be used outdoor coverage, of -105 dBm, suitable for outdoor environments, using the 700 MHz frequency band.

The solution used to connect the farm sites located in remote areas with the provider’s company ground station, as well as the solution presented by this paper to easily connect isolated communities, was to use satellite backhauling. Where the satellite would act as a link between the farm and the company and its core network, thus, enabling the transport of data/voice information.

Analysing the proposal received from two of the main Brazilian internet providers in Table I we can see that it is really expansive to build and maintain this kind of infrastructure, with total costs of the whole project reaching up to more than half a million dollars. In contrast to the companies’ proposals is the total cost of the private network that we

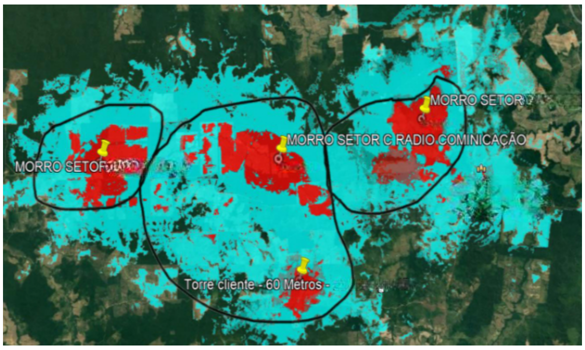

Fig. 1: Coverage area across the farm, where the red area represents indoor coverage and the blue area outdoor coverage.

Item	Company A Proposal	Company B Proposal	Our Network
Initial Payment	US$ 63,226	US$ 157,302	US$ 4,174
Installments	6	60	Undefined
Installment Value	US$ 25,290	US$ 2,985	US$ 34
Contract Duration	60 months	60 months	None
Minimum Commit-ment	US$ 5,939	None	None
Total Cost	US$ 609,304	US$ 336,417	US$ 4,208

TABLE I: Proposals comparison including our network.

created, including the cost of one outdoor eNodeB, one starlink antenna, two mid-range computers to work as the core of our network, and the monthly fee of the starlink contract.[1]

III. Private Networks

A solution to the complexity and cost of using and expanding public mobile telephony lies in the creation of private networks, where we deploy and install smaller and cheaper base stations, and use satellite connection as the backhaul of our network. In a recent project to build such network, in an isolated community in the Amazon, we used the Starlink cluster of satellites, since they provide high-speed connection from low earth orbit (LEO), as our backhaul link, by connecting the ground station to the Internet via the sattelite network.

To manage communication between user equipment, the Internet, and the core of the network we used open source, smaller LTE Base Stations, such as the baicells NOVA227, which is a 2x250mW microcell outdoor eNodeB of low power consumption, operating in Time Division Duplexing (TDD) mode. It suppports the standard LTE bands of 38/40/41/42/43/48, which is really important to us, because the majority of the user equipment (Smartphones) that will connect to this base station in these communities are simpler models, that don't connect to higher bands that other more expansive eNBs might exclusively operate on.

[1]The values presented in Table II were converted from Brazilian reais (BRL) to US dollars (USD) using the exchange rate of 1 USD = 5.10 BRL, according to data from the Central Bank of Brazil (2024), by the date of 06/06/2024.

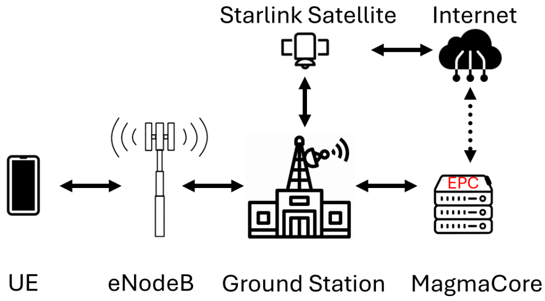

Fig. 2: Network totpology with satellite backhaul. The eNB connects to the EPC via ground station and the EPC connects to the Internet via the satellite link.

Another problem we had to tackle was the core of the network. There are a lot of possible solutions to this, ranging from buying EPCs from traditional telecom vendors (which is the most expensive option) to choosing cloud-based solutions. In our case, we opted to use an open-source solution in the form of the software MagmaCore, developed by Magma Foundation, which is part of the Linux Foundation. It is a highly flexible, scalable solution, that allows us to control the main core network functions such as QoS policies, data security and data routing.

By binding all these elements together, we can create a cost-effective yet highly efficient network, as depicted in Fig. 2. This network is particularly powerful because it doesn't rely on already pre-installed backbone infrastructure, which is often non-existent or unreliable in many remote areas.

IV. Conclusion

This work presented a cost-effective solution for expanding network coverage to remote areas without extensive terrestrial infrastructure, by using open-source software as EPC and using well established satellite networks as the backbone of the backhaul, which enables fast and simple implementation and great scalability to other isolated communities and the Amazon region. The whole architecture proved to be effective and flexible, owing to the use Magma as our core network. By using Magma, the owner of the network can establish the desired access policies to it and better manage the system. On the other hand, managing a mobile network requires expertise and substantial investments in human resources. Looking forward, a key area of future development will be the integration of the 5G technology in such networks.

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