Community Private 5G Networks in Brazil: Legislation and Open-Source Enablers

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Abstract— **Brazil faces persistent connectivity gaps in remote and underserved regions, where traditional telecommunications infrastructure remains economically unviable. In response, recent regulatory advances have opened opportunities for deploying private and community 5G networks, allowing greater flexibility in the use of electromagnetic spectrum bands, regardless of their designation in the Frequency Band Allocation Plan (PDFF). These changes enable a wider range of actors, including cooperatives, local governments, civil society organizations, and private enterprises—to take an active role in advancing national connectivity agenda and contributing to the development of the telecommunications sector. Despite this progress, widespread adoption is hindered by high deployment costs and limited technical expertise. This paper explores the current regulatory framework and practical pathways for obtaining spectrum licenses in Brazil, while also assessing the potential of open-source 5G solutions to reduce costs and accelerate deployments. By comparing community-driven and private 5G initiatives, we provide actionable insights to support inclusive and sustainable connectivity in Brazil's remote regions.**

Keywords— **Community networks, private 5G, Brazilian spectrum regulation, open-source stacks.**

I. Introduction

Brazil faces significant connectivity challenges, especially in vast geographic regions like the North, which recorded a Brazilian Connectivity Index - Índice Brasileiro de Conectividade (IBC) of 47 points in 2024, compared to the national average of 57 points. Additionally, over 37% of municipalities in the North were still without fiber optic data communication that same year [1]. While major telecommunications companies focus on strategic network expansion, the government seeks to broaden connectivity, even in areas with low population density.

Although mobile network companies are eager to expand their coverage nationwide to maximize profits, reaching remote and rural areas remains a challenge. In these regions, the combination of sparse populations, limited purchasing power, and a small number of potential subscribers undermines the economic viability of infrastructure investments. The core issue is not the absolute cost of expansion, but rather the low expected return on investment — profit margins are often insufficient to justify resource allocation from a commercial standpoint. Consequently, these areas are systematically left out of traditional expansion strategies within the telecommunications sector. Therefore, alternative approaches are necessary to increase mobile phone penetration and extend connectivity to a larger portion of the population [2].

Approaches to expanding mobile networks in remote areas include the use of experimental networks, community networks, and, more recently, exceptional networks — which require specific licensing tailored to their implementation [3]–[7]. These alternatives tend to be more cost-effective and less bureaucratic than the conventional services provided by large telecommunication operators. This article presents an overview of the 5G frequencies licensing procedures for these methods, with a particular focus on exceptional networks, which offer advantages such as greater flexibility and freedom in the use of frequencies within defined areas. As this is a relatively new approach, there are currently no studies in the literature that have employed this licensing model in the operation of telecommunication systems.

Previous studies have explored the use of community mobile networks based on earlier technologies, such as GSM, focusing on the implementation of open-source software and evaluating the social and technological impacts in the regions where these systems were deployed [8]–[10]. As an additional contribution, this article investigates the use of open-source 5G solutions as a cost-effective alternative to accelerate network deployments in remote communities. Furthermore, it presents a comparison between 5G and Wi-Fi technologies within a specific use case involving an isolated community in the municipality of Concórdia of Pará.

Fig. 1 illustrates the case study under investigation, which focuses on extending internet access to remote communities through 5G technology. In this setup, a directional antenna located in the city of Concórdia, Pará, will establish point-to-point radio communication with another antenna positioned in the community of Campo Verde, which is also capable of satellite communication. The received signal will then be retransmitted via an omnidirectional antenna using 5G Fixed Wireless Access (FWA), or Wi-Fi Mesh technology, to a local router. Finally, the router will provide and distribute the connection to end users via Wi-Fi.

The remainder of this manuscript is organized as follows. Section II presents recent advances in Brazilian spectrum regulation. Section III discusses open-source platforms designed for implementing 5G systems. Section IV provides a case study analysis of a community where such a system could

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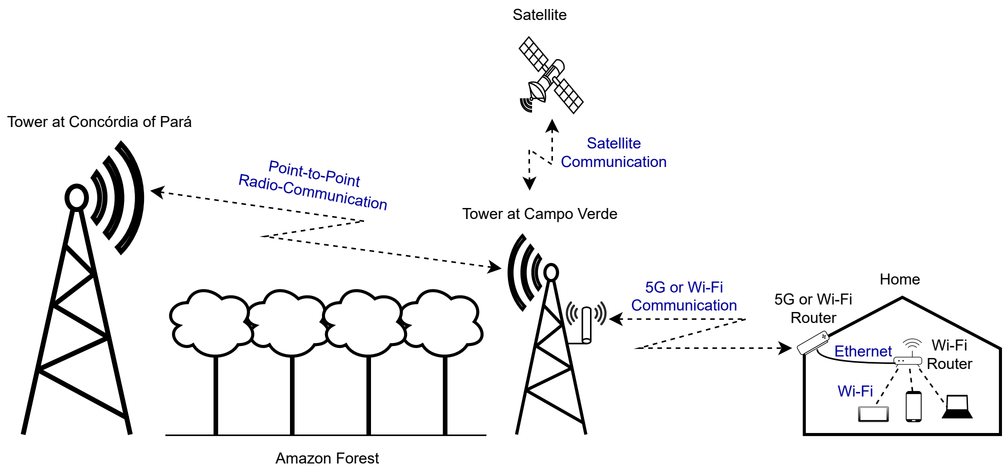

Fig. 1: Illustration of the system's operation in Concórdia of Pará.

be deployed. Finally, Section V offers concluding remarks.

II. Recent Advances on Brazilian Spectrum Regulation

The General Telecommunications Law - Lei Geral das Telecomunicações (LGT) marked the transition from a state monopoly to a regulatory environment that supports diverse network models. The Brazilian National Telecommunications Agency - Agência Nacional de Telecomunicações (Anatel) [11] now offers multiple licensing pathways—such as experimental, private, community, and exceptional networks—enabling more flexible and context-specific deployments.

Among these, the exceptional licensing model stands out for its novelty and transformative potential. It allows the use of frequency bands not originally allocated for a given service and authorizes operation within delimited geographic areas (polygons). This spatial flexibility opens new possibilities for community and local government-led initiatives in isolated regions, including indigenous territories, quilombos, and conservation areas [4]–[7].

A. *Experimental network*

The Special Service for Scientific and Experimental Purposes is a private telecom service for restricted use, aimed at supporting scientific and technological experiments. Authorizations are temporary—up to 24 months—and expire when the experiments end. Operating stations under this service requires a license from Anatel, in accordance with regulations.

B. *Limited Private Service*

The limited private service - serviço limitado privado (SLP) is a telecommunication network for exclusive use by specific users, supporting data, voice, and multimedia transmission. While typically private, regulations permit public and non-profit entities to provide internet access via SLP networks in certain cases, especially to support vulnerable or remote communities.

Obtaining an SLP license does not always require radio frequency use, as operations can occur via wired or confined media. However, if spectrum use is needed, applicants must meet regulatory requirements, including frequency band requests and station registration with Anatel. Use of non-allocated spectrum bands requires special authorization from Anatel's Superintendence of Granting and Resources for Provision - Superintendência de Outorga e Recursos à Prestação (SOR).

C. *Community Network*

Community networks are non-profit, locally managed initiatives that provide affordable broadband access in underserved areas. Built and operated by individuals or community groups, they use a cost-sharing model and may receive support from non-governmental organizations - organizações não governamentais (ONGs), foundations, and public programs to promote digital inclusion and communication rights.

Under the Anatel regulatory framework, Community Networks can be classified as operating under the Private Limited Service (SLP), a category of restricted-interest service. To implement such networks, it is generally necessary to obtain authorization to operate the SLP. Additionally, when applicable, authorization for radio frequency use and the licensing of telecommunications stations must also be secured [6].

D. *Exceptional Licensing*

The exceptional authorization for the use of radio frequencies enables the spectrum to be utilized for deploying networks associated with the Private Limited Service (SLP), even in frequency bands not originally designated for this service. This authorization also permits spectrum use under special operational conditions, distinct from those established in other Technical Requirement Acts - Anotações de Responsabilidade Técnica (ARTs), provided that such operation does not cause harmful interference to other duly authorized systems [7].

III. Technological Enablers: Open-Source 5G

An alternative to high-cost commercial off-the-shelf (COTS) equipment and software for implementing a private or community mobile network is open-source software and low-cost software-defined radios (SDRs). Currently, the OpenAirInterface (OAI) [12] and the srsRAN [13] projects are the two major open-source projects leading the RAN development. When analyzing the core network, the solutions from OAI CN [14] and Open5GS [15] are important open-source alternatives.

Both OAI and srsRAN offer a complete 5G RAN stack that works with SDRs or COTS radio equipment for generating the radio transmissions. For the core network, the OAI CN offers a 3GPP Rel.16 implementation characterized by distinct sets of network functions, while the Open5GS offers a 3GPP Rel. 17 compliant implementation with some additional functions in relation to the OAI CN [14]. The overall network performance of these open-source RAN and core network alternatives when used together for metrics such as total achieved throughput and latency is 91.7 Mbps throughput and 30.3 ms latency for srsRAN and 113.3 Mbps throughput and 19.7 ms latency for OAI when utilizing a bandwidth of 40 MHz [16]. Both OAI CN and Open5GS presented similar performances and do not significantly affect the overall network performance. It is important to emphasize that the RAN implementation needs RF processing using an SDR or an external radio unit.

The permission to use open-source alternatives for private and community networks depends on their project licenses. Therefore, the best option depends on the mobile network's purpose. Table I summarizes the licenses, commercial and non-commercial use permissions for different open-source projects. If considering non-commercial usage, such as the case of community networks, all the RAN and core network projects allow the complete usage of their software without requiring special permissions. In the case of private networks, the open-source software alternatives are more restrictive. The OAI projects require a commercial license to be obtained before implementing the radio access network (RAN) and core network, while srsRAN and Open5GS allow the utilization of their project as long as all the code modifications are publicly available. Therefore, if the private mobile network focuses on the network deployment and enhancement of network functions without concealment, the srsRAN and Open5GS solutions seem more appropriate.

TABLE I: Open-source alternatives for implementing the 5G RAN and core network.

Feature	OpenAirInterface (OAI)	srsRAN	Open5GS
License	OAI Public License v1.1	GNU AGPLv3	GNU AGPLv3
Commercial	Requires commercial license	Allowed (share code)	Allowed (share code)
Non-commercial	Fully allowed	Fully allowed	Fully allowed

Due to the high complexity involved in the development of mobile network software, the stability and maturity of open-source projects are still a work in progress. The number of users' equipment (UEs) working at the same time are usually limited, for example, the OAI RAN claims to support 16 UEs by default, with support to up to 64 when the configured bandwidth is sufficient (at least 40 MHz). We recommend the use of 5G routers when there is an interest in a higher number of UEs connected to the network since it would decrease the total number of UEs directly connected to RAN, reducing the need for RAN support to only the 5G routers, and then these routers are responsible for connecting the end users through a Wi-Fi connection. Reducing the number of UEs connected directly to the RAN network can decrease the RAN management complexity and increase stability of open-source softwares. The aforementioned information reinforce the need for careful planning in choosing between RAN options, especially in community-led deployments where technical background may be a limitation.

IV. Case study: Quilombo Campo Verde

The Quilombo Campo Verde in Pará was selected as a case study for the implementation of a hybrid community network, combining 5G coverage (3.5 GHz and 700 MHz bands) with Wi-Fi to expand local access. Also, the aforementioned scenarios are compared with a Wi-Fi Mesh scenario operating on 2.4 GHz band. Based on the ITU-R P.1812-6 model, the project simulates 700 MHz, 2.4 GHz, and 3.5 GHz coverage and estimated throughput. A FWA system was designed using a 5G base station to distribute access within community households with a reduced number of equipment. Due to the low availability of 5G devices, Wi-Fi complements the access distribution on CPEs owner's neighborhood.

In this study, each of the eleven house groups covered four families on average. All groups (from G01 to G11) have a 5G FWA owner that expands internet connectivity to nearby houses using a Wi-Fi access point. Families next to the base station (School - Campo Verde) are directly connected via Wi-Fi signal. Therefore, a Wi-Fi Mesh scenario is designed for comparison purposes, considering that each 5G FWA location would have a Wi-Fi Mesh node, and these nodes received the same marker text. A group of houses is represented by one point on the map using the identification "FWA_GXX"(where XX changes from 01 to 11), as shown in the Fig. 2.

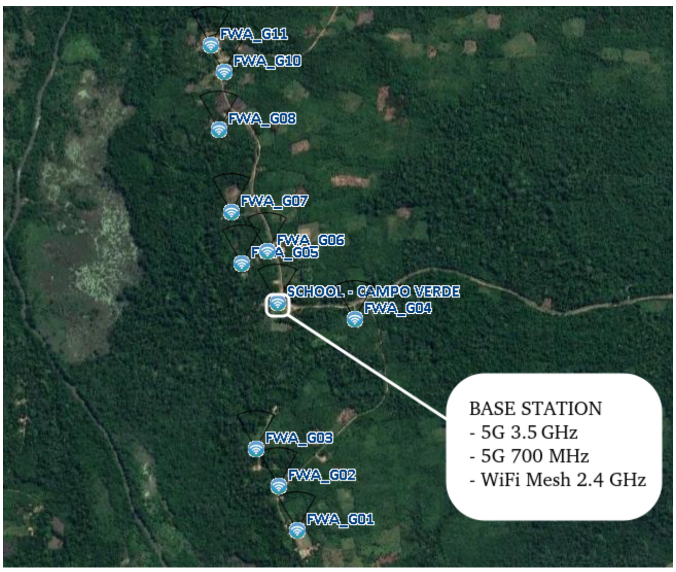

Fig. 2: Proposed Scenario.

Based on the proposed scenario, coverage simulations were carried out using the Radio Planner®, which includes built-in capabilities for computing the Signal-to-Interference-plus-Noise Ratio (SINR) and estimating throughput. The ITU-R P.1812-6 propagation model was used, as it was available in the simulation environment. Although the 3GPP TR 38.901 model was initially considered, its implementation within the Radio Planner did not support interaction with clutter data (e.g., forests, open areas). The results obtained represent hypothetical 5G and Wi-Fi Mesh deployments intended to illustrate the potential of community private 5G networks under Brazil's emerging regulatory scenario. No randomness was involved in the coverage and throughput computations of these simulations, which were not aimed at hardware-level validations or prototype testing.

A. Wi-Fi and 5G Scenarios

The Wi-Fi Mesh and 5G project comprises a Base Station (Mesh Gateway / gNodeB) and eleven client devices (mesh nodes / 5G routers), identified as 'FWA_GXX'. Each of these clients will serve a group of households through Wi-Fi extension. Additionally, both the gNodeB and the Mesh Gateway, to be installed at the school Campo Verde, will provide Wi-Fi access to nearby homes. Table II summarizes the project specifications.

TABLE II: Wi-Fi and 5G Project Information

Information	Wi-Fi	5G
Base Station (BS) high	30 meters	30 meters
Client high	6 meters	6 meters
BS transmission power	33 dBm	40 dBm
BS Antenna gain	10 dBi	10 dBi
Client Antenna gain	3 dBi	3 dBi
Frequency band	2.4GHz	700 MHz / 3.5 GHz
Bandwidth	20 MHz	10 / 40 MHz
Rx Threshold	-80 dBm	-100 dBm

B. Comparison of the proposed community 5G network and Wi-Fi solutions

The main objective of this comparison is to evaluate the benefits in terms of coverage and available throughput. Although simulations provide relevant insights, a more detailed exploration of the scenarios is beyond the scope of this work and is considered only as a supporting element of the analysis. This will guide decision-making processes that consider the differing regulatory compliance efforts associated with each technological approach. Depending on the technology adopted for a community network, there will be a trade-off between access performance and compliance with legislation to provide this service. The obtained results and corresponding discussion are presented below.

TABLE III: Comparison Between 5G and Wi-Fi

Characteristic	5G	Wi-Fi
Frequencies	700 MHz / 3.5 GHz	2.4 GHz
Mean Throughput	40 Mbps / 80 Mbps	10 Mbps
SLP License	Yes	Yes
Exceptional License	Yes	No
Served CPE Count	Required	Not required

The Table III presents a comparison between 5G and Wi-Fi technologies, highlighting key differences in frequency usage, throughput, regulatory obligations, and licensing requirements. From a performance standpoint, 5G clearly outperforms Wi-Fi, offering throughput values up to 80 Mbps in the 3.5 GHz band and around 40 Mbps in the 700 MHz band, while Wi-Fi Mesh in the 2.4 GHz band achieves only 10 Mbps on average. These differences are emphasized by the simulation results.

In the Wi-Fi Mesh scenario, coverage gaps are observed between nodes FWA_G[01–03] and the rest of the mesh network, primarily due to transmission power limitations. Even with increased power, co-channel interference remains a constraint, leading to reduced SINR and throughput values below 10 Mbps in some areas, as highlighted in red in Fig.3.

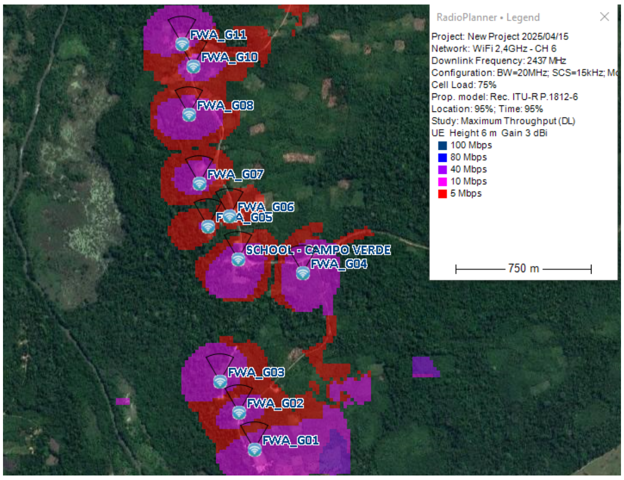

Fig. 3: Throughput on Wi-Fi Mesh – 2.4 GHz Scenario

In contrast, the 5G scenario at 3.5 GHz, despite experiencing higher path loss, achieves complete coverage of all eleven measurement points due to its 40 dBm transmission power, resulting in throughput above 80 Mbps (Fig.4). At 700 MHz, the 5G system benefits from lower path loss, providing broader coverage at the same transmission power; however, the 10 MHz bandwidth limits throughput on a range between 40 and 80 Mbps (Fig.5).

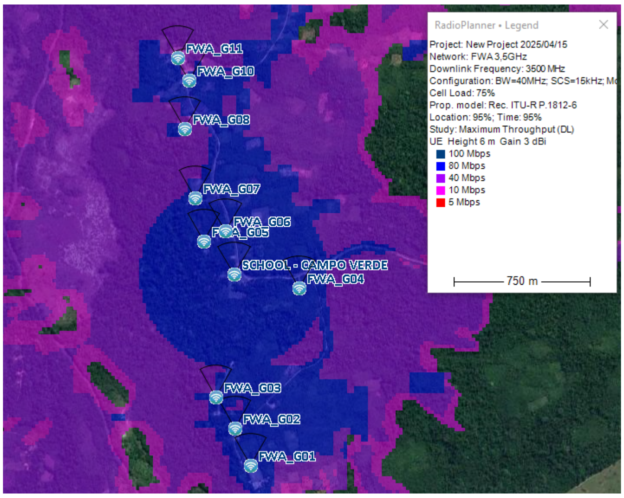

Fig. 4: Throughput on 5G – 3.5 GHz Scenario

Although both technologies require an SLP license from a regulatory standpoint, 5G additionally demands an exceptional license and additional information about the number of served CPEs, resulting in a more detailed process. While Wi-Fi offers easier and more flexible deployment, 5G can deliver higher throughput and the connectivity needed to support the data-intensive demands of modern communities. Therefore, despite the longer regulatory path, 5G remains the most effective solution for bringing robust internet access to remote rural areas.

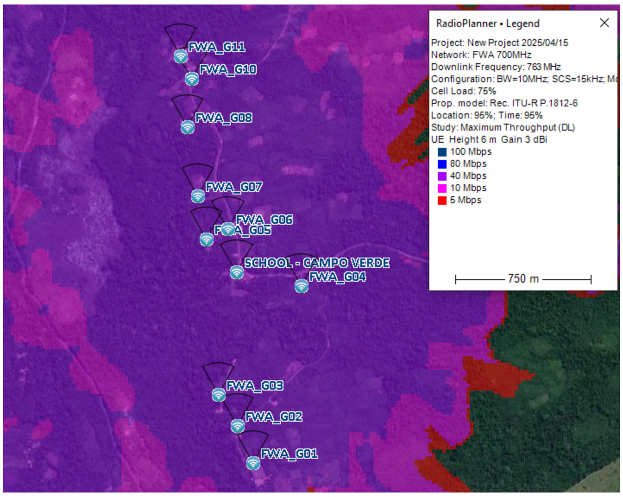

Fig. 5: Throughput on 5G – 700 MHz Scenario

V. Conclusions

Community and private 5G networks represent a strategic solution for advancing digital inclusion in remote regions of Brazil. While 5G requires a more rigorous regulatory process, including an SLP license, an exceptional license, and information about the number of connected CPEs, the performance benefits justify the additional regulatory requirements. This is highlighted on simulations where Wi-Fi Mesh, in the 2.4 GHz band, reached throughputs around 10 Mbps, with noticeable co-channel interference and coverage limitations. In contrast, the simulated 5G deployments achieved throughput levels of up to 80 Mbps in the 3.5 GHz band, indicating the potential for more robust and reliable connectivity under similar conditions.

Despite recent regulatory advances and the growing availability of open-source tools, significant challenges remain, particularly regarding cost, deployment complexity, and hardware availability. In this context, hybrid approaches that combine Wi-Fi with open-source 5G stacks offer a practical path forward to bridge current infrastructure gaps. Local case studies, such as the Campo Verde community, demonstrate that sustainable, community-driven deployments are feasible with proper planning and regulatory compliance. Therefore, 5G stands out as a promising option for delivering high-quality internet access to rural regions with limited connectivity. As future work, we intend to discuss a detailed techno-economic analysis of the proposed solutions to further support decision-making in similar deployment scenarios.

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