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SMP coverage and traffic prediction in the municipality of Chapadinha in Maranhão

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Summary:
This study focuses on the region of the municipality of Chapadinha, located in Maranhão, and explores the importance of forecasting Personal Mobile Service (SMP) coverage and traffic to meet local communication and connectivity needs. The municipality faces challenges related to the quality of coverage and traffic capacity of the SMP, which negatively affect the lives of citizens and the performance of companies. The study uses data analysis methods to evaluate SMP coverage and traffic demand in Chapadinha, with the aim of promoting technological development and digital inclusion in the region. **Key words:**Mobile connectivity, Personal Mobile Service, Chapadinha, Maranhão.

Abstract
This study focuses on the region of Chapadinha, located in Maranhão, and explores the importance of predicting the coverage and traffic of Personal Mobile Service (PMS) to meet local communication and connectivity needs. The municipality faces challenges related to the quality of PMS coverage and traffic capacity, negatively impacting the lives of citizens and the performance of businesses. The study employs data analysis methods to evaluate PMS coverage and traffic demand in Chapadinha, with the aim of promoting technological development and digital inclusion in the region.
Keywords: Mobile connectivity, Personal Mobile Service, Chapadinha, Maranhão.

1. INTRODUCTION

Mobile connectivity plays a fundamental role in people's lives and business operations, triggering a growing demand for high-quality services around the world. The region of the municipality of Chapadinha, located in Maranhão, is not immune to this reality.

Predicting coverage and studying SMP (Personal Mobile Service) traffic is crucial to meeting the communication and connectivity needs of the population and local businesses.

With the growing demand for quality mobile communications services, it is vital to understand how the telecommunications infrastructure in Chapadinha can meet these demands.

Predicting SMP coverage and traffic is essential to improve the quality of telecommunications services in the region, improve user experience and promote local technological development.

The municipality of Chapadinha faces challenges related to the quality of coverage and traffic capacity of the SMP. Connectivity problems can negatively affect the lives of citizens and the performance of local businesses (MCOM, 2023). Therefore, it is essential to address these issues to promote access to quality communication.

Thus, the general objective is to provide an in-depth analysis of the coverage and traffic prediction of the Personal Mobile Service in the municipality of Chapadinha, Maranhão.

And as specific objectives: Identify how advanced forecasting models can anticipate the quality of mobile network coverage in Chapadinha; Assess mobile traffic demand in the region.

This study employed data analysis methods to evaluate SMP coverage and traffic demand in Chapadinha. Data from telecommunications operators and demographic data in the region were collected.

Ultimately, this study sought to contribute to the promotion of technological development and digital inclusion in the municipality, strengthening its ties with the globalized world and providing opportunities for economic and social growth.

2 THEORETICAL FRAMEWORK

2.1 Telecommunications Sector

According to information provided by the Brazilian Telecommunications Association - TELEBRASIL (2017), the Telecommunications Sector is part of the Information and Communication Technology Sector – ICT.

In Brazil, the Brazilian Institute of Geography and Statistics - IBGE, in the Annual Services Survey - PAS, classifies Information Services as follows:

- Telecommunications Services: Includes Fixed Telephony, Cellular Telephony, SME (Trunking), Satellite Telecommunications, Internet Access providers, transmission and reception of TV and Radio signals, installation services and others.
- IT Services: Includes software development, data processing, data, consultancy, sale of equipment and software, outsourcing, software support and maintenance and others.
- Audiovisual Services: Includes advertising and merchandising on Open TV and on Radio, Pay TV programming, film exhibition and auxiliary services for the production of Television programs.
- Other services: Includes publishing, printing-integrated editing, news agencies and journalism services.

According to TELEBRASIL (2017), Telecommunications Services involve the transmission, emission or reception of symbols, characters, signals, writings, images, sounds or information of any nature, by means of wire, radio, electricity, optical means or any other electromagnetic process.

The provision of these services is carried out by agents who have a concession, permission or authorization. The Telecommunications Sector is conceptualized as: "Sector of the economy that encompasses Telecommunications Services, value-added services and products used to provide these services" (TELEBRA-SIL, 2017, p. 05).

According to data obtained through the Telecommunications Legislative Agenda (2017), in recent years, the telecommunications sector has been one of the infrastructure sectors that has invested the most in the country, accounting for 4.2% of the Brazilian Gross Domestic Product (GDP). and generates around 500 thousand jobs (TELEBRASIL, 2017).

Over these decades, the sector has invested more than half a trillion reais to build the fifth largest telecommunications network in the world and in recent years has collected around R$60 billion annually in taxes and sectoral funds.

TELEBRASIL (2017) classifies the Telecommunications Sector into three segments:

- Segments Private Agents - Telecommunications Services Companies that have concession or authorization to provide services, such as Fixed Telephony, Mobile Communications, Multimedia Communication, Pay TV, Radio Broadcasting and others.
- Products and services for Telecommunications Service Providers - Provided-equipment providers and service providers that support the provision of Telecommunications Services, including space capacity providers.
- Value-Added Services - Companies providing services that support main Telecommunications Services.

Among these three segments, Telecommunications Services include a variety of services, with the Personal Mobile Communication service being the most prominent.

This service is characterized by user mobility and is provided in Brazil by SMP authorization holders, regulated in 2010 by Anatel, even allowing the existence of mobile providers virtual networks regulated by ANATEL Resolution nº 550/2010.

In addition, there are other Mobile Communication Services, such as Specialized Mobile Service (SME), Special Mobile Radiocall Service (SER), Global Mobile Satellite Service (SMGS), Aeronautical Mobile Service (SMA) and Maritime Mobile Service (SMM) (TELEBRASIL, 2017).

Mobile Communication Services are provided by holders of authorization to provide the service. In the case of SMP, up to four companies can provide services in each region of the country.

2.2 Mobile Communication Services

The history of mobile telephony in Brazil is relatively recent, with its beginning dating back to approximately 25 years ago. Rio de Janeiro was the first city in Brazil to receive mobile telephony in 1990, and in the following year, Brasília also began to benefit from this system.

Thus, the era of cell phones in the country began to take shape. Other pioneering cities in using this service include Belo Horizonte, Goiânia, São Paulo and Campo Grande (MOURA FILHO; 2021).

It is important to highlight that cellular telephony in Brazil began in 1990. According to data from the National Telecommunications Agency (Anatel), at that time, the country had a modest 667 cell phone lines, a number that quickly grew to 6,700 units the following year. , exceeding 30 thousand in 1992 (RAPPAPORT, 2009).

In February 2004, Brazil already had 47,865,593 cell phones. This growth was driven mainly by the privatization of mobile telephony in Brazil (MOURA FILHO; 2021).

It is important to highlight that the development of mobile telephony in Brazil in the 1990s occurred after the privatization of the companies that operated this system (ALMEIDA, 2019).

The fundamental milestone of this period was the promulgation of the General Telecommunications Law, which regulated the operation of these companies and created the National Telecommunications Agency (ANATEL) with the purpose of supervising and regulating the sector.

According to Quintella and Costa (2009), in the beginning, operators operated in two bands (A - 825.03–834.99 MHz, covering channels 1 to 333, and B - 835.02–844.98 MHz, covering channels 334 to 666), competing with each other.

It is worth noting that it was only in 1997, in the Federal District, that band B service began, considered a springboard for opening the market in a sector that until then had not faced competition. This opening was made possible by Law No. 9,295, of July 16, 1996 (MOURA FILHO; 2021).

Before that, Telesp Celular, which began operations in 1993, providing services through the digital cell phone system, was the only operator operating in the country (ALMEIDA, 2019).

Oliveira (2013) illustrates the evolution of cellular telephony in Brazil based on the division into generations, taking into account the technologies used by operators.

With the opening of the market in the sector, several operators entered Brazil, intensifying price competition. The country has several operators, including TIM, Claro, CTBC Telecom, Oi, Porto Seguro Conecta, Vivo, Sercomtel and Nextel.

Mobile communication services can be provided by holders of specific authorizations, that is, by operators or their franchisees.

2.3 Mobile Telephony

In the face of technological advances, mobile telephony emerged, identified as devices that can be operated remotely or wirelessly and allow communication with other people and obtaining information anywhere, anytime (NOVO, 2011).

In 2013, Brazil had already reached 75 million (almost 40% of the population) Internet users, ranking fifth among the 20 countries with the highest number of people connected to the world wide web, behind only Japan, India , United States and China (LUNARDI; DOLCI; WENDLAND, 2013).

That same year, Brazil reached a significant milestone with more than 250 million active mobile phone lines, demonstrating the exponential growth of the telecommunications sector in the country. This evolution is the result of technological advances, investments in infrastructure and the growing demand for mobile communication services (RAPPAPORT, 2009).

Since the launch of the first mobile telephony services in Brazil, the sector has undergone a series of transformations, migrating from older technologies, such as the AMPS analog system, to digital technology. more advanced digital technologies, such as GSM, 3G, 4G and, more recently, 5G (ALMEIDA, 2019).

The increasing availability of affordable mobile devices such as smartphones and tablets has also driven the growth in the number of active mobile lines.

Competition between mobile phone operators in the country has led to more competitive prices and the offering of attractive packages and services to consumers (MOURA FILHO; 2021).

The expansion of mobile telephony in Brazil has brought several benefits to the country's population and economy, enabling greater connectivity and access to information, stimulating the development of innovative mobile applications and services, in addition to boosting e-commerce and facilitating communication

personal and professional (ANATEL, 2016).

In 2014, mobile internet users in the world surpassed desktop users by more than 400 million, favoring the growth of the mobile commerce sector and generating the need to develop systems that provide services for the sector (SENA; MIYAGAWA; SILVA JÚNIOR, 2013).

It is important to highlight that the characteristics of mobile telephony can be understood from three different perspectives: that of the user, that of the environment and that of the system (KELLER, et al., 2019).

From the user's perspective, Mobile Internet devices are generally more personal and individual than fixed Internet devices. Mobile devices, such as smartphones and tablets, offer a highly personalized experience, being used mainly by a single individual and always being within reach, allowing people to be connected anywhere and at any time, becoming an essential part of life. everyday life, offering instant access to information, social networks, personalized applications and entertainment tailored to each user's preferences (ANA-TEL, 2016).

Secondly, from an environmental point of view, mobile telephony generally offers instant connection to the Internet, allowing users to access the network anywhere and anytime (LUNAR-DI; DOLCI; WENDLAND, 2013).

A Mobile Internet system is portable and is always, or almost always, available. On the other hand, fixed Internet systems are typically not mobile and require long waiting processes, such as computer startup, which typically takes more than a few minutes (SENA; MIYAGAWA; SILVA JÚNIOR, 2013).

Thirdly, from a system point of view, Mobile Internet systems have a lower level of available resources compared to fixed Internet systems (LUNARDI; DOLCI; WENDLAND, 2013).

The services offered by mobile telephony can be classified into: commerce, communication and content. Commerce ranges from mobile banking to electronic tickets for purchasing physical products, while email and interactive services, such as chat, are considered communication services (MOURA FILHO; 2021).

Content includes downloads, news, traffic or stock market updates, as well as other time-sensitive or location-based services (ALMEIDA, 2019).

The adoption of mobile telephony experienced significant growth following the availability of third-generation cellular technology in Brazil in 2007 (RAPPAPORT, 2009).

With the advent of 3G networks, users benefited from more advanced services, such as high-speed internet access, video calls and more sophisticated applications (SENA; MIYAGAWA; SILVA JÚNIOR, 2013).

These advances have boosted the use of mobile devices and changed the way people communicate, access information and perform everyday tasks, making mobile telephony an essential part of modern life (LUNARDI; DOLCI; WENDLAND, 2013).

2.4 Signal propagation prediction

Predicting the coverage of an area plays a fundamental role in the planning of cellular networks, as well as in the evaluation of received power. Over the years, a variety of models have been proposed, and new models continue to emerge.

The choice of the most appropriate model for a given region depends on empirical or semi-empirical parameters, adapted to guarantee forecast accuracy. The classification of the area based on urbanization is a crucial factor in defining the models (VINHAL, 2020).

There are three main categories of areas: open or rural, where there are no obstacles such as trees or buildings in the path of spread; suburban, which is a region with trees and houses, presenting obstacles close to the receiver, but not very dense; and urban, characterized by a high density of buildings and imposing trees (VINHAL, 2020).

2.4.1 Lee Propagation Model

The Lee Model is an empirical model, also called stochastic, widely used in predicting and planning signal coverage in mobile networks (ALMEIDA, 2019).

It was developed in 1985 by WCY Lee based on experimental data in different areas and is valid for frequencies around 900MHz in relatively flat regions. In mountainous areas, values may vary in relation to theoretical values (VINHAL, 2020).

This model does not require complex details about the morphology of the region, just the type of terrain and some specific parameters. The experiments carried out by Lee allowed the definition of parameters for urban and suburban areas, dense vegetation and water. Detailed information about buildings in the area is not necessary (VINHAL, 2020).

2.4.2 Okumura Propagation Model

The Yoshihisa Okumura Model, proposed in 1968, is based on measurements carried out in Tokyo and is an empirical model for external environments. It is suitable for densely populated, suburban and urban regions, but less accurate in rural areas.

The model depends on parameters such as the frequency of the transmitting antenna, height of the transmitting antenna and the distance between the base station and the mobile (VINHAL, 2020).

2.4.3 Hata Propagation Model

The Masaharu Hata Model, proposed in 1980, is an extension of the Okumura model and is widely used to predict signal propagation. This model is empirical and suitable for outdoor environments.

It is simpler compared to other models, such as Okumura's, and can be easily implemented in computer simulations. It is preferable for specific frequencies, heights and distances (VINHAL, 2020).

2.5 Municipality of Chapadinha - Maranhão

The municipality of Chapadinha, located in the state of Maranhão, is located in the Eastern Maranhense Region and is part of the Chapadinha microregion, which covers the Citizenship Territory of Baixo Parnaíba Maranhense, composed of 16 municipalities: Mata Roma, Água Doce do Maranhão, Anapurus , Araioses, Belágua, Brejo, Buriti, Chapadinha, Magalhães de Almeida, Milagres do Maranhão, Santa Quitéria do Maranhão, Santana do Maranhão, São Benedito do Rio Preto, São Bernardo, Tutóia and Urbano Santos (ALMEIDA E SILVA, 2018).

This municipality is a transition area between the capitals São Luís, MA, and Teresina, PI, and has great tourist potential, including the creation of the Balaiada Tourist Hub.

Chapadinha is one of the municipalities that serve as an access point to the Tourist Region of the Lençóis Maranhenses National Park and is part of the route of the Rota das Emoções do Nordeste.

Furthermore, it is officially a member of the Governance Body of the Tourist Hub of the Munim Region. The total population of the municipality is 411,525 inhabitants, of which 219,641 live in rural areas, representing 53.37% of the total (ALMEIDA E SILVA, 2018).

The municipality is home to 30,020 family farmers, 6,715 settled families and 26 quilombola communities, including 04 certified by the Palmares Foundation. Its average Human Development Index (HDI) is 0.55, according to data from the Territorial Information System.

Due to these characteristics, Chapadinha strongly attracts experimental tourism and ecological tours in its region, due to the presence of several resorts along the Preto, Iguará and Munim Rivers, within the municipality and in neighboring cities, such as Rios Magu (Santana-MA), Rio Grande dos 7 Lopes (Santa Quitéria - MA), Lagoa do Cassó (Urbano Santos-MA), Lagoa da Júlia (São Benedito do Rio Preto-MA), Moisinho (Vargem Grande – MA) (ALMEIDA E SILVA, 2018).

Chapadinha is also the headquarters of the Alto Munim Planning Region, with regional offices of several public bodies, and is located on the newest “agricultural frontier” of Maranhão and MA-TOPIBA: Baixo Parnaíba Maranhense.

Being the largest municipality in the region, Chapadinha is the administrative center, with a population of 78,340 inhabitants (IBGE, Census 2016), predominantly Afro-descendant, reflecting the socioeconomic reality of the Brazilian Afro-descendant population. The municipality covers a territorial area of 3,347.385 km².

The history of Chapadinha, which evolved from a village to a city, began around 1870, when it already had

a police substation, a peace district, a national guard battalion, a vaccination commissioner and a primary school for boys, created by Provincial Law nº 268 of September 1849 (ALMEIDA E SILVA, 2018).

The town had a chapel covered in tiles, although most of the houses were simple huts. The main agricultural crops included rice, corn, beans, cotton and tobacco.

The population of the parish was estimated at a thousand people, and later, through Decree Law nº 45 of March 29, 1938, Chapadinha was elevated to the category of city.

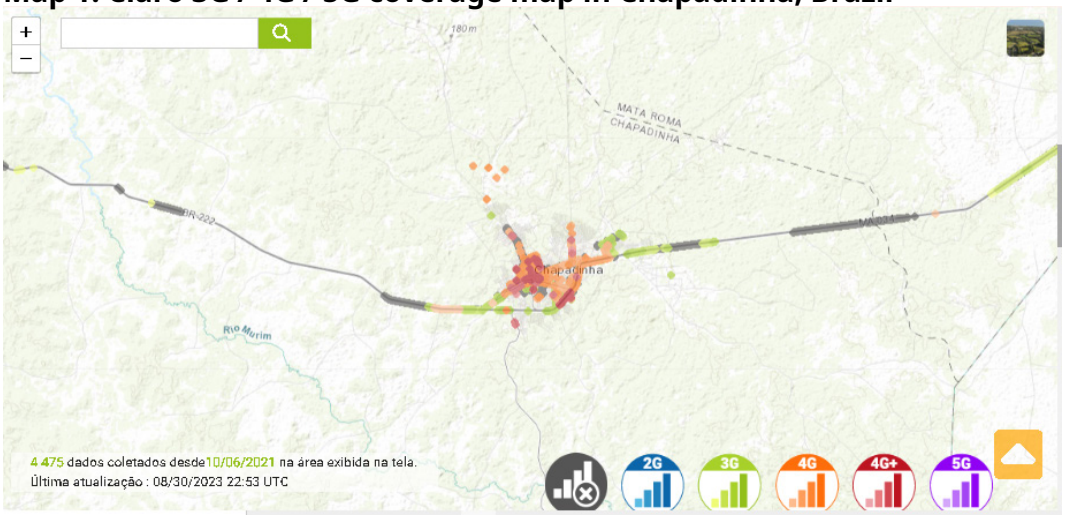
2.6 SMP in Chapadinha - MA

Mobility services in Chapadinha, MA, are made possible by the Personal Mobile Service (SMP), which allows communication between mobile stations and other telecommunications networks of collective interest.

In addition, it offers value-added services, such as messaging, voicemail, internet access and use of applications on contracted devices. Chapadinha is served with 4G or higher technological coverage, with minimum download/upload speeds of 5Mbps (five megabits per second).

Telecommunications operators that provide services in Chapadinha have different levels of coverage, as shown in the maps below.

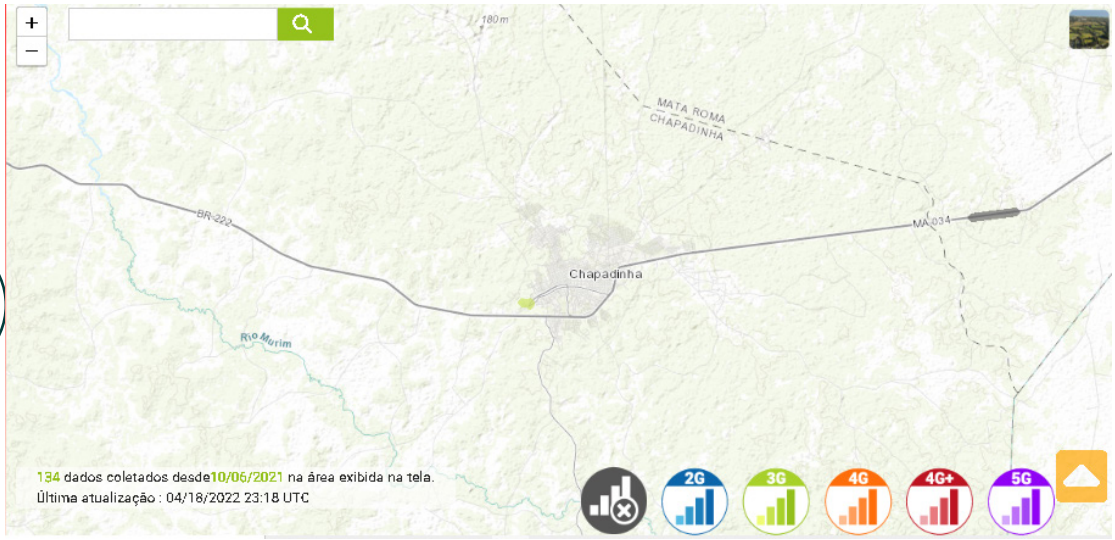
Map 1: Claro 3G / 4G / 5G coverage map in Chapadinha, Brazil



Source: nperf, 2023

Claro offers the most comprehensive coverage among operators, with support for 2G, 3G, 4G and 4G+ technologies. However, the lack of 5G coverage may represent a limitation on connection speed and the ability to support more advanced applications and services.

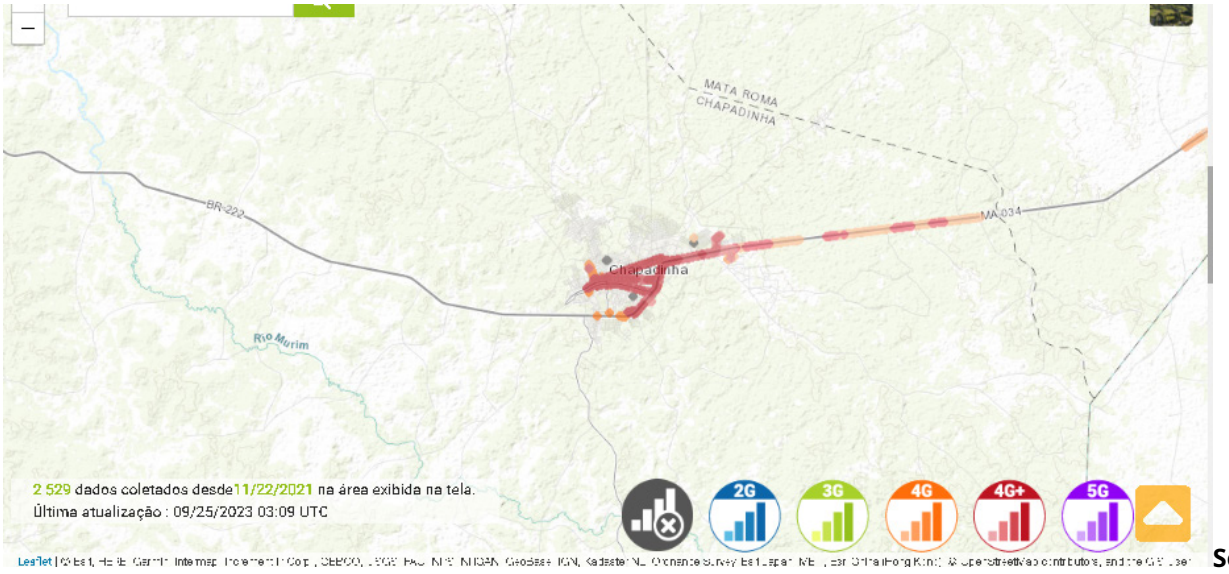
Map 2: OI 3G / 4G / 5G coverage map in Chapadinha, Brazil



Source: nperf, 2023

Oi focuses its scarce offering on 3G technology, which can result in slower connection speeds compared to 4G. Lack of 4G or 5G coverage can limit users' experience in terms of internet speed and availability of digital services.

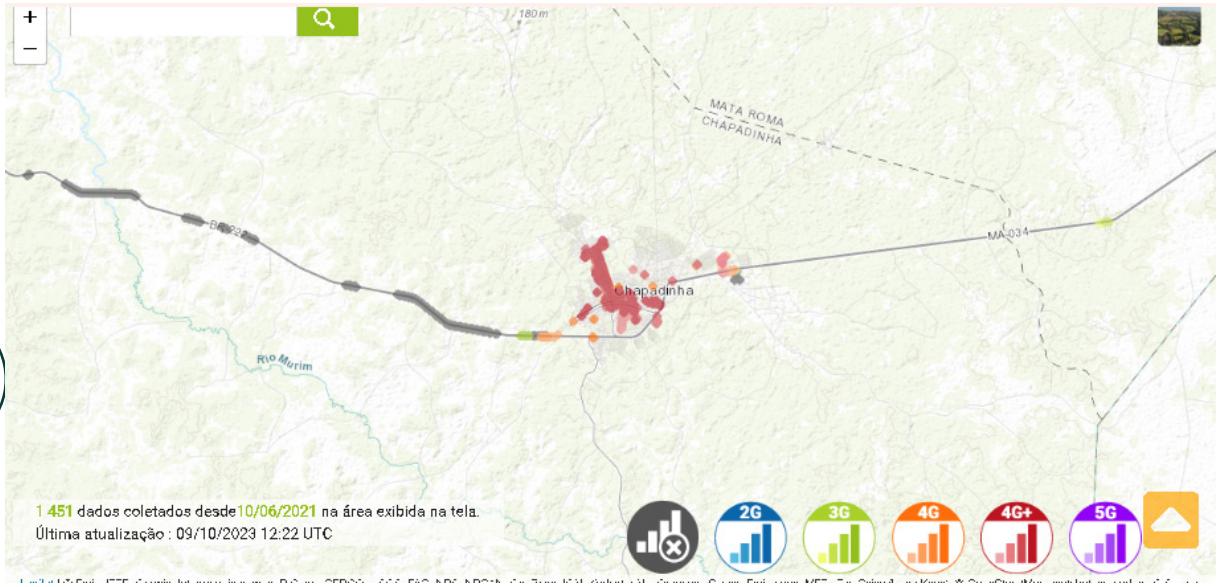
Map 3: TIM 3G / 4G / 5G coverage map in Chapadinha, Brazil



Source: nperf, 2023

Tim stands out for providing 4G and 4G+ coverage across much of the region, which should provide faster connection speeds and support for more advanced services, such as video streaming and online gaming. However, the lack of 5G coverage may affect the ability to adopt future technologies.

Map 34: Vivo 3G / 4G / 5G coverage map in Chapadinha, Brazil



Source: nperf, 2023

Vivo offers a wide range of technologies, including 2G, 3G, 4G and 4G+. This diversity of coverage must meet users' needs, ensuring connectivity in different areas. However, like other carriers, the lack of 5G coverage may limit the ability to take advantage of emerging technologies.

Overall, the availability of 4G is positive for the region as it offers a faster and more reliable internet experience. The lack of 5G coverage can be considered an opportunity for improvement for the future, as this technology tends to provide even higher speeds and support for a variety of advanced applications.

In July 2023, the Minister of Communications, Juscelino Filho, held a meeting with state deputies from Maranhão, representatives of telephone operators and the president of the National Telecommunications Agency (Anatel), Carlos Baigorri (MCOM, 2023).

The meeting was motivated by reports of problems related to mobile telephone services in the state, which led to the opening of a CPI in the Legislative Assembly of Maranhão (MCOM, 2023).

Operator representatives clarified that, although they have not identified massive problems, they recognize instability at specific points. They committed to making improvements and expansions to the infrastructure of their networks in the state.

CONCLUSION

The present study demonstrated that the expansion of mobile telephony in Brazil brought numerous benefits to the country's population and economy and the growing adoption of mobile telephony transformed the way people communicate, access information and perform everyday tasks.

From the user's perspective, mobile devices are highly personal and individual, offering mobility and accessibility anywhere, anytime.

Furthermore, mobile telephony plays a fundamental role in urban and suburban environments, offering instant connection to the Internet and allowing users to access the network anywhere and anytime.

The availability of mobile phone services covers several areas, including commerce, communication and content. Predicting signal coverage plays a fundamental role in planning cellular networks and evaluating received power.

Different models, such as Lee, Okumura and Hata, were studied and found to be effective in predicting signal propagation and ensuring effective coverage in urban, suburban and rural areas.

In the specific context of the municipality of Chapadinha, in Maranhão, mobile telephone services play a crucial role, allowing communication and connectivity for the region's inhabitants. The four main operators - Claro, Oi, TIM and Vivo - provide 4G coverage, with Vivo offering the greatest diversity of technologies.

The lack of 5G coverage can be seen as an opportunity for improvement for the future, as this technology has the potential to offer even higher speeds and support a wide range of advanced applications.

Furthermore, the meeting held in July 2023 by the Ministry of Communications, with the participation of state deputies, representatives of operators and Anatel, demonstrates the commitment to addressing and resolving problems related to mobile telephone services in Maranhão.

In conclusion, it is understood that constant evolution and the search to improve the quality of services are essential to meet the growing demands of users and guarantee reliable access to connectivity.

mobile data.

Provide better justification for the results presented, and coverage in the region

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