Geographic And Technological Challenges In The Connectivity Process Of Health Care Units In The Rural Area Of Manaus-Amazon.

1. **João Carlos Silva de Oliveira.** Department of Information Technology (SEMSA), and PhDstudent in PublicHealth (FIOCRUZ)

2.**Nazivaldo Caciocley Camelo Correa.**Department of Information Technology (SEMSA) and MSc in Automation(UFPA)

3.**Rogério Luiz Araújo Carminé.**Department of Information Technology (SEMSA) and MSc in SoftwareEngineering (UPORTO)

4.**Saymon Erickson da Silva Souza.**Department of Information Technology (SEMSA) and MBA in ProjectManagement (FGV)

5.**Fabíola Mendonça da Silva Chui.**DDS, PhD in Dental Sciences, Endodontist (SEMSA) and Associate Professor(UEA)

ABSTRACT
Introduction:*Amazon is a region of extreme geographic, environmental and socioeconomic importance, known for its vast biodiversity and natural resources. The city of Manaus, capital of the state of Amazonas, has rural areas that can face specific geographic challenges. Despite the progress of Primary Health Care and the expansion of coverage of the Family Health Strategy, it is still challenging to guarantee the right and access of rural populations to health care. This paper aimed to investigate and describe the geographic and technological challenges of the connectivity process of Health Care Units in the rural area of Manaus.*
Methodology:*An exploratory, descriptive and qualitative approach was used, with data collection from semi-structured interviews, aiming to examine and understand in depth the geographic challenges.*
Development:*It was evident that Units in rural areas had working strategies and techniques limited to paper and offline systems, postponing the sending of information about health care and programmatic actions to the Federal Government. Every record made on a computer was saved on pen-drives and transported to the headquarters in an urban area to export data to the Ministry of Health, making work logistics difficult..*
Results: *The Manaus City Health Department (SEMSA), in partnership with a company, connected 8 (eight) rural Health Care Units to the internet through radio and fiber technologies, covering the entire metropolitan area and a large part of the rural area. Connectivity technologies with terrestrial infrastructure enable high bandwidth availability, with low latency and without data package limitations, allowing for better automation by computer systems of health services in this region. Currently, with access to the internet, professionals in connected rural areas can directly operate vaccine records and have access to other information systems in the areas of health surveillance and primary care at the city, state and federal levels. In future efforts, other systems can be made available in rural health units, such as the National Regulation System (SISREG), which can contribute to improving the scheduling of appointments and exams in these more remote regions..*
Keywords:*Geographical Challenges, Connectivity, Information Technology, Rural Area.*

I. INTRODUCTION
The Amazon is a region of extreme geographic, environmental and socioeconomic importance, known for its vast biodiversity and natural resources. When analyzing health in the Amazon, it is essential to consider the different geographic scales and the complexity of the borders in the region, allowing a more comprehensive understanding of the factors that influence the health of populations in the region.

At the local scale, it is important to understand the health conditions of local communities, including access to medical services, basic sanitation and water quality. Factors such as malnutrition, infectious diseases and limited access to medical care are critical aspects that affect health at the local level. Regionally, it is possible to analyze health trends in larger areas, such as cities or states. This involves assessing health indicators such as mortality rates, incidence of endemic diseases (such as malaria and dengue fever) and availability of local health services. On a national scale, national health policies and strategies that affect the Amazon region are considered. This includes resource allocation, prevention programs, treatment of region-specific diseases, and environmental regulations that affect population health.

The Amazon also has global relevance due to its influence on climate and biodiversity. Climate change and deforestation in the region can have impacts on global health, such as the spread of tropical diseases and disruptions to ecosystems that affect the availability of essential natural resources. Borders play a significant role in the analysis of health in the Amazon region, as it covers several countries, has different types of borders and faces unique health-related challenges due to its geographic and socio-environmental complexity.

Inside the Amazon, there are diverse indigenous, riverside and urban communities with different levels of access to resources and medical care. Socioeconomic inequalities can result in significant differences in the health and quality of life of local populations. Health in the Amazon is also intrinsically linked to the environment. Deforestation, mining and excessive exploitation of natural resources can cause damage to the health of local populations due to exposure to pollutants, reduction of biodiversity and impact on living conditions.

In summary, analyzing health in the Amazon requires a multifaceted approach that considers different geographic scales, including local, regional, national and global, as well as the complexities of the political, socioeconomic and environmental boundaries present in the region. This is critical to developing effective and sustainable health policies that meet the needs of the diverse populations that inhabit this unique region.

Manaus, capital of the state of Amazonas, is an important and densely populated urban area in the Amazon, registering a notable population increase among the capitals, with a variation from 1,802,014 in 2010 to 2,063,547 in 2022, a growth of 14.5% according to EBC (2023). The city has seven geographic zones and the Primary Care health network is distributed across five Health Districts (North, South, East, West and Rural), consisting of units of different and diverse sizes and types according to SEMSA (2022).

Image 1
Manaus Rural Area map

*Note:*Adapted from Manaus City Health Plan, 2022-2025.

Manaus has a great socioeconomic diversity, with districts of different income levels and living conditions. These disparities can result in significant differences in access to health services, nutrition, and other

social determinants of health between different parts of the city. The availability and quality of healthcare services may vary inside the city. Some areas may have greater access to hospitals, clinics, and health centers, while others may experience shortages in medical resources and healthcare infrastructure.

The city is also subject to environmental issues, such as air pollution, drinking water availability and risks associated with the Amazonian weather. These factors can have impacts on people's health, affecting the prevalence of respiratory diseases, skin problems and other environmentally related conditions. Manaus is a multicultural city and is home to a variety of ethnic and cultural groups. Cultural boundaries can influence health perceptions, health care practices, and communication between healthcare professionals and patients. Literacy and educational level can affect people's understanding of health issues, including prevention, treatment and health promotion. Knowledge barriers can result in less informed health choices and risky behaviors.

The city has rural areas that may face specific geographic challenges. Rural areas often have limited transportation infrastructure and access. Unpaved roads, precarious bridges and other obstacles can make access to those regions difficult. This can affect the transportation of medical supplies, equipment and healthcare personnel to rural communities, which also face geographic barriers related to vast territory extension, significantly increasing the time needed to reach communities and impacting the efficiency with which healthcare services can be provided to reach rural residents, specially in emergency situations.

Some rural areas face problems with electricity supply. This can impact the operation of medical equipment and the ability to maintain electronic patient records. A lack of reliable communications infrastructure, such as mobile phone networks and internet access, can also hamper communication between healthcare professionals in rural areas and urban centers, affecting the coordination of medical efforts and obtaining up-to-date health information.

In summary, rural Health Districts in Manaus may face a number of geographic challenges that affect the delivery of health services in these areas. These challenges include limited access, extensive distances, complex topography, climatic difficulties, isolated communities and communication limitations. It is important that health authorities and local governments are aware of these challenges and work to find solutions that improve access to health services in rural regions.

Connectivity of healthcare facilities in the rural area of Manaus faces significant geographic and technological challenges due to the remote location and environmental conditions of the region. Many health units in Manaus rural area are located in difficult-to-access regions, such as riverside areas, tropical forests and lowlands. This remote location makes installing communications infrastructure such as fiber optic cables challenging and expensive. The region's topography is often rugged, with rivers, lakes and dense forests. This complex topography makes it difficult to install communication towers and effectively propagate wireless network signals.

The tropical region of Manaus is subject to heavy rainfall and seasonal flooding. This can damage the communications infrastructure, interrupting connectivity to healthcare facilities. Installing communication infrastructure in remote areas requires a significant investment in financial and technical resources. The costs associated with deploying and maintaining communications networks in those areas can be prohibitive. Many rural areas of Manaus also suffer from a constant lack of electricity. Connectivity depends on reliable power sources to operate communications equipment such as cell towers and Wi-Fi networks.

The study aimed to investigate and describe the geographic and technological challenges of the connectivity process of health units in the rural area of Manaus, through the qualitative, exploratory and descriptive method, justified by the need for access to the health services necessary to improve the quality of life of the rural population. The geographic and technological challenges in the connectivity of health units in the rural area of Manaus are significant due to the remote location, adverse environmental conditions and limited infrastructure. Overcoming these challenges is essential to ensuring that rural communities have access to healthcare.

II. DEVELOPMENT

The National Primary Care Policy has guidelines that guide the organization of Primary Health Care and contribute to the consolidation of the Unified Health System (SUS), however, despite the expansion of coverage of the Health Strategy of Family, ensuring the right and access to health care for the rural population has still been one of the biggest challenges (FACCHINI, 2018).

According to the PNAB, Primary Care professionals must register and keep the registration and other health data of families and individuals updated in the current Primary Care information system, using the information systematically for epidemiological, social, economic, cultural and demographic aspects of the territory. It is also up to the AB manager to ensure the quality and adequate supply of data, checking its consistency, disseminating the results and using the information to guide and plan strategies and actions. The

absence of regular data feeding into AB's information systems may result in the suspension of transfers of financial resources from the Ministry of Health to the city (MS, 2017).

The Amazon region, especially in the area where the city of Manaus is located, is characterized by a complex topography, with rivers, forests and irregular terrain. These geographic characteristics can make it difficult to build health infrastructures, such as basic health units (UBS in Portuguese), hospitals and care centers, in addition to influencing communication and transportation. The Amazon region's weather can also be challenging, with intense rainfall, seasonal flooding and other extreme weather events. These conditions can affect the functioning of healthcare facilities, cause transportation disruptions, and make the provision of medical services difficult.

Some rural districts of Manaus have isolated communities, often difficult to access via poorly maintained rural roads, making transporting patients, technical teams, healthcare professionals and medical supplies a challenging task. This can result in delays, lack of access and even the inability to reach certain locations, making regular medical care difficult.

In the study made by Ferreira et al. (2023), the interviewees' speeches showed that the lack of electricity, computer equipment and internet access have a negative effect on care, as they make access to notifications of health problems, the regulation system, difficult and obstructive. production records and other mandatory data required by SUS health information systems. Such limitations compromise care planning and make it difficult to construct the epidemiological profile of the rural district. According to the study, herculean efforts are being carried out in remote locations without connectivity, where employees travel to rural headquarters with internet access at 5:00 AM and return at 8:00 PM, once a week, aiming to record weekly production in health information systems.

Units in rural areas had a working method limited to paper and offline systems, such as e-SUS-CDS, an MS (Ministry of Health) alternative to health units without internet access, postponing the sending of information about care and programmatic actions to the federal government. Every record made on a computer was saved on pen-drives and transported to the headquarters in an urban area to export data to the Ministry of Health. After export, approximately 48 hours were necessary for the data with the actions developed in the territories to be validated.

III.   RESULTS AND DISCUSSION

An unprecedented action promoted by the City of Manaus and coordinated by the City Health Depaetment put into practice one of the actions foreseen in the Municipal Health Plan, for the four-year period 2022-2025, improving monitoring and assistance actions in basic health. Through a public bidding process, SEMSA began carrying out proofs of concept, where companies were invited to demonstrate in the field the efficiency of the technologies they had available. A technology was searched that, in addition to supporting the flow of operational activities via the Internet, was stable and fast. The proof of concept is important in the process, because it enabled a prior assessment of the technologies to be implemented, in order to ensure whether it will truly be an element of effective transformation for the business.

SEMSA's Department of Information Technology, in partnership with a contracted company, was successful in connecting 8 rural health units to the Internet using radio and fiber optic technologies with transmission bands of 10 Mbps, as seen on Table 1.

Table 1
Health Units connected to the Internel.

District	Unit Name	Tecnology Used
	UBSR Nossa Senhora de Auxiliadora	FiberOptics
Rural – River	UBSR Nossa Senhora de Fátima	Radio
	UBSR Nossa Senhora do Livramento	Radio
	UBSR Pau Rosa	Radio
	Unidade de Apoio Cooperativa	Radio
Rural - Land	UBSR Rodrigues Viana	Fiber Optics
	UBSRComunidade São Pedro	Radio
	UBSR Ephigênio Salles	Fiber Optics

Health Units in the rural area of Manaus began receiving internet providers in July 2022. The first Rural Family Health Unit (USFR) to receive the internet link was Ada Viana, located at kilometer 41 of BR-174 federal road. The installation also began at USFR Nossa Senhora Auxiliadora, on the banks of the Negro River, as well as five other rural units (land and riverside) began to receive providers continuously.

**Picture 2**
Network Topology – Served Health Units
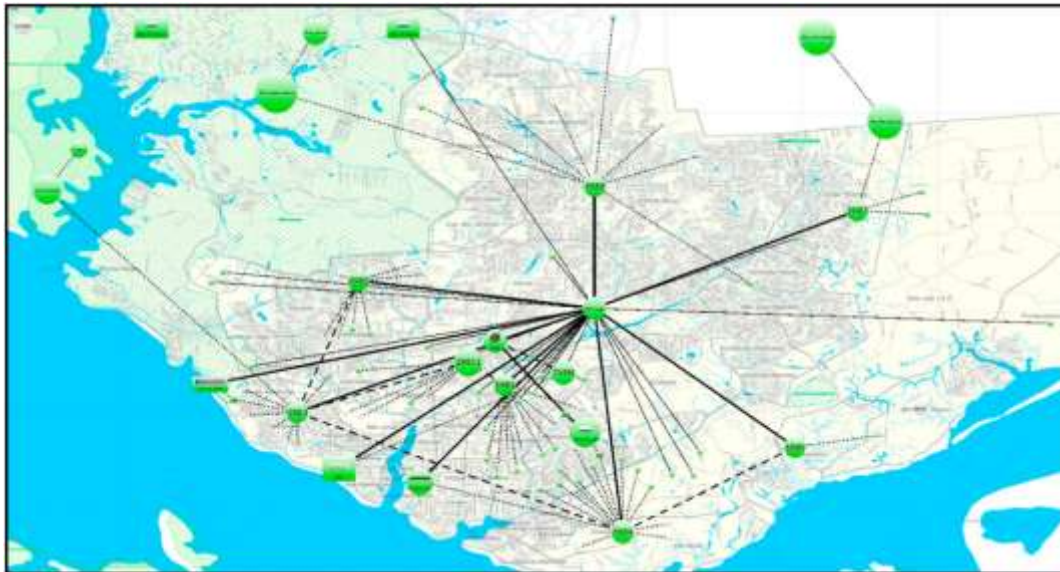
In order to reach rural distances, the Health Units are interconnected with the radio base stations (ERBs) distributed in the city of Manaus, reaching the headquarters at a speed of 1Gbps, covering the entire Metropolitan area and a large part of the rural area. There are also other IT assets, among which stand out the Fiber Optic backbones that are part of the built infrastructure network, reaching some rural SEMSA units that are close to highways.

Among the difficulties reported by the information technology (IT) technical team during the process of implementing technology for connectivity, logistical problems related to access to rural areas stand out. In some locations, river travel lasted around eight hours. By land, the road network presented a problematic infrastructure, with dangerous curves, lack of signage and absence of correct paving, compromising the safety of the technical team. The torrential rains also made land and river transportation difficult, especially due to electronic equipment that needed care in terms of ideal packaging and cushioning for its preservation.

Another point to be highlighted is the delay on reestablishing connectivity, as when it is lost, the time of unavailability of health services that require internet access increases. Currently, after the loss of the internet signal, at some point in the rural district, the time for maintenance and reestablishment of the signal is reduced due to the aforementioned logistical difficulties involved in the technician's journey from Manaus to the rural location. To solve problems of this kind, it is ideal to use a hybrid network structure with redundancy, featuring 2 Internet links, working simultaneously, with fiber, radio and satellite technologies, avoiding compromising health services.

Continuous monitoring of networks and servers in rural districts is extremely important for several reasons, especially when it comes to healthcare services and critical infrastructure, and is critical to ensuring that patients and healthcare professionals can access systems and resources when needed, without interruptions and mitigate problems that negatively affect the productivity of the multidisciplinary health team in rural areas, as illustrated on Picture 3:

Picture 3
Latency Monitoring - Efigênio Sales Health Unit
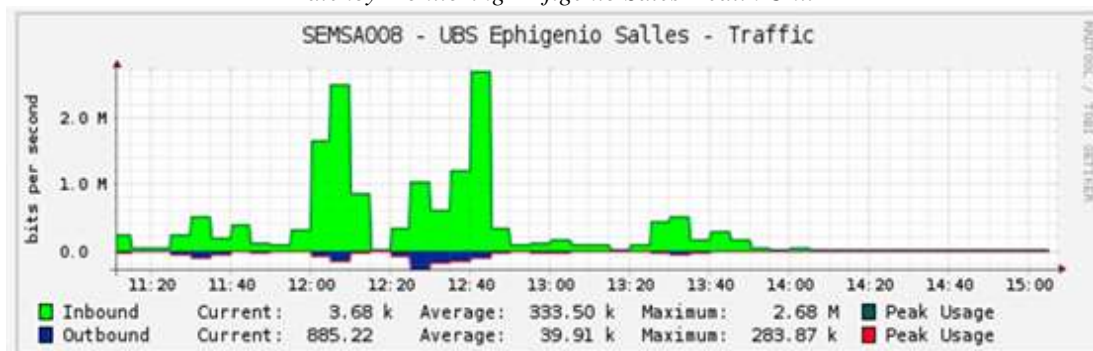
Monitoring also allows IT teams to be alerted immediately. This enables a quick response to resolve problems and minimize impacts, helping to reduce long-term operating costs, mitigating corrective maintenance

costs and increasing system efficiency. In industries like healthcare, it is essential to comply with strict data security and privacy regulations. Monitoring helps ensure these regulations are met and that appropriate measures are in compliance and in place to protect patient information.

IV.   FINAL NOTES

Technologies with terrestrial infrastructure, by fiber or radio, enable high bandwidth availability, with low latency and without the limitations of franchise or data package, facilitating the upgrade of Internet services whenever necessary. For more remote locations, satellite-based solutions are considered, such as Starlink from the company SpaceX, available on most remote regions of the Amazon, which have shown positive use cases. The company began connecting the most distant regions of Brazil, where internet access was completely non-existent, aiming to monitor the Amazon forest against illegal fires and deforestation. On the other hand, despite being a performative solution, many experts point out that its performance may decrease or saturate once many users connect to low-orbit satellite networks, not being a definitive solution like radio or fiber technology (TURBIANI, 2023).

Institutional support has been essential to mitigate barriers that limit and hinder access to healthcare for the rural population. Expanding the reach of connectivity in remote areas can contribute to greater coverage of basic care, expanding the care network, provision of actions, services and access for the population in locations that are inaccessible to this level of care.

With proper Internet access, health professionals in rural area of Manaus can directly register vaccines and access other information systems for health surveillance and primary care at the city, state and federal levels. The Regulation System can also be inserted in rural health units with a sufficient time interval between the appointment and the exam date, enabling travel to the reference unit on the scheduled date.

Manaus faces geographic challenges inherent to its rich environmental diversity. However, through a combination of technology, infrastructure development, community engagement and collaboration, it is possible to overcome those difficulties and create a more inclusive and resilient scenario. By recognizing that geography can be an obstacle, but also a source of inspiration, Manaus can pave a path towards a more accessible and equitable future for all its inhabitants.

REFERENCES

[1].   [Brazilian Communication Company] Empresa Brasil De Comunicação. (June 28, 2023). População Cresce Mais De 10% Em Manaus E Nas Capitais Do Centro-Oeste.Https://Agenciabrasil. Ebc.Com.Br/Economia/Noticia /2023-06/Populacao-Cresce-Mais-De-10-Em-Manaus-E-Nas-Capitais-Do-Centro-Oeste#:~:Text =Nos%20%C3%Baltimos%2012%20anos%2C%20Manaus,Crescimento%20de%2014%2C5% 25.

[2].   Facchini, L. A., Tomasi, E., &Dilélio, A. S. (2018). Qualidade Da Atenção Primária À Saúde No Brasil: Avanços, Desafios E Perspectivas. Saúde Em Debate, 42, 208-223.

[3].   Ferreira, F. A., Herkrath, F. J., Horta, B. L., &Garnelo, L. (2022). Apoio Institucional À Gestão E Prestação De Serviços De Saúde Em Unidade Básica Fluvial Na Amazônia. Interface-Comunicação, Saúde, Educação, 27.

[4].   [Geography And Statistics Brazilian Institute] Instituto Brasileiro De Geografia E Estatística. (August 13, 2021). Cidades E Estados. Https://Www.Ibge.Gov.Br/Cidades-E-Estados/Am/Manaus.Html.

[5].   [Health Ministry] Ministério Da Saúde. (September 22, 2017). Aprova A Política Nacional De Atenção Básica, Estabelecendo A Revisão De Diretrizes Para A Organização Da Atenção Básica, No Âmbito Do SUS. Https://Bvsms.Saude.Gov.Br/Bvs/Saudelegis/Gm/2017/Prt 2436_22_09_2017.Htm

[6].   [Manaus Health Department] Secretaria Municipal De Saúde De Manaus. (February 1st, 2022). Plano Municipal De Saúde De Manaus 2022-2015. Https://Semsa.Manaus.Am.Gov.Br/Wp-Content/Uploads/2022/ 02/Plano-Municipal-De-Saude-2022-2025.Pdf.

[7].   [Manaus Health Department] Secretaria Municipal De Saúde. (July 27, 2020). Em Ação Inédita, Prefeitura De Manaus Inicia Instalação De Internet Em Unidades De Saúde Da Zona Rural. Https://Semsa.Manaus.Am.Gov.Br/Noticia/Em-Acao-Inedita-Prefeitura-De-Manaus-Inicia-Ins Talacao-De-Internet-Em-Unidades-De-Saude-Da-Zona-Rural.

[8].   Turbiani, R. (July 10, 2023). Época Negócios- A Empresa De Elon Musk Tem Mais De 4,3 Mil Satélites De Internet Na Órbita Da Terra.Https://Epocanegocios.Globo.Com/Empresas/   Noticia/2023/07/Cientistas-Dizem-Que-Satelites-Da-Spacex-Estao-Vazando-Radiacao.Ghtml.