Selection of Internet of Things Based Communication Networks for Onshore Oil Field Monitoring

Amanda Bandeira Aragão Rigaud Lima[1*], Danielle Mascarenhas dos Santos[1], João Vitor Silva Mendes[1], Adeilson de Sousa Silva[1], Herman Augusto Lepikson[1]
[1]SENAI CIMATEC University Center; Salvador, Bahia Brazil

Onshore oil fields usually operate remotely without continuous human assistance and communication facilities. Oil transfer from the wells to the separation and storage tanks usually occurs via pipelines in these fields. This whole system is prone to failures with significant and unpredictable environmental impacts. Therefore, properly monitoring this production system is vital to mitigate relevant problems such as leakages. This paper presents a comparative evaluation of the leading candidate communication networks for this application on onshore oil field monitoring for potential leaks. Among the analyzed technologies, LPWANS, DigiMesh, and CBRS stand out.
Keywords: Internet of Things. Network. Communication.

Introduction

In Brazil, onshore oil production refers to mature and marginal fields. The vast majority of these fields are in inland regions, mainly in the Northeast. These areas lack infrastructures such as roads, electricity, telephone, and data network [1]. Information transmission in this environment is challenging. Therefore, any feasible solution shall be based on wireless communication network, and its architecture needs to be compatible with the specificities of the environment and the kind of data package to be transferred.

Developing a network depends on the analysis of latency, transfer rate, reliability, range, whether the network is licensed or not, coverage, scalability, and energy consumption, to choose a better configuration that meets the established requirements for the application [2].

Oil fields are remote environments, so developing a remote wireless network is necessary, and real-time networking is paramount. The network latency is the response time to the stimulus. The latency needs to be as low as possible to achieve real-time communication. [3,4]. It is necessary to know the packet size for transmission to send the message, and it depends on the data generated by the selected sensor. The more complex the message, the higher the transfer rate needed. Bandwidth is directly proportional to the concept of transfer rate [5,4].

Monitoring onshore oil fields aim to reduce the number of failures, so it is necessary to be sure that the message will arrive, represented by reliability, which is usually higher when the network bandwidth is licensed. Paying for the spectrum, there is a guarantee of service, but when it is not licensed, it becomes susceptible to interference or even lack of prioritization. In addition, the pipelines in the oil field are extensive, making it necessary to use a high-range network and affecting the cost of implementation because the longer the network range, the fewer repeaters are required.

The licensed network is recommended for data security, but it has an additional cost for licensing. Since the described environment has inadequate infrastructure, it becomes impractical to use most networks for not presenting coverage in the application area of the project. For network expansion, it is necessary to consider scalability [6]. It is necessary to analyze energy consumption to reduce expenses as much as possible since a high-energy expenditure will result in high costs.

Received on 13 June 2022; revised 28 August 2022.
Address for correspondence: Amanda Bandeira Aragão Rigaud Lima. Praça Igaratinga, 206, Cond. Monte Belo, Ed. Vista Bela, 1102, Pituba. Zipcode:41.830-290. E-mail: limaamanda285@gmail.com. DOI 10.34178/jbth.v5i3.225.

J Bioeng. Tech. Health 2022;5(3):185-189

This paper aims to evaluate the leading candidate communication networks for onshore oilfield monitoring applications for potential leaks. The technologies analyzed are LPWANS, DigiMesh, and CBRS.

Wireless Network

Radio wave networks make it possible to develop better equipment related to wireless technologies [7]. The wireless communication network became popular because it promotes portability and mobility to the user since it eliminates the use of cables. The rise of the IoT concept accentuated the relevance of wireless networks. Despite the advantages of this model, the network can have disadvantages if implemented or managed incorrectly, resulting in network problems [8].

It is possible to divide wireless communication into five categories: Private Radio, LPWAN, (Low-Power Wide-Area Network), Cellular Network, LAN (Local Area Network), and PAN (Personal Area Network). DigiMesh and CBRS (Citizens Broadband Radio Service) network operating in the Private Radio Frequency. Figure 1 shows their characteristics in range and power consumption.

LPWAN

LPWAN is a communication system focused on IoT featuring three different communication protocols, NB-IoT, Sigfox, and LoRaWAN, each of which has its particularities and different applications. As described by the name, LPWAN features high area coverage, high network range, low power consumption, and low bandwidth, so only sending small packets is possible [9,10].

NB-IoT

NB-IoT (Narrow Band-Internet of Things) is the only LPWAN technology that features a licensed network. 3GPP (3rd Generation Partnership Project), technology based on the LTE network. It is known for its narrowband and cellular network performance. It has a maximum transfer rate of 200 Kbps and can send 1600 bytes per packet [2]. Furthermore, it is real-time because it has a latency of 0.02 seconds. Moreover, it has a long battery life (ten years) because it does not stay connected to the cellular network, connecting just when activated [11]. Furthermore, its range in rural areas is up to 10 km. However, towers/ antennas are essential for network operation, meaning that in areas with inadequate infrastructures, such as some interiors, it is difficult to deploy an NB-IoT system [12].

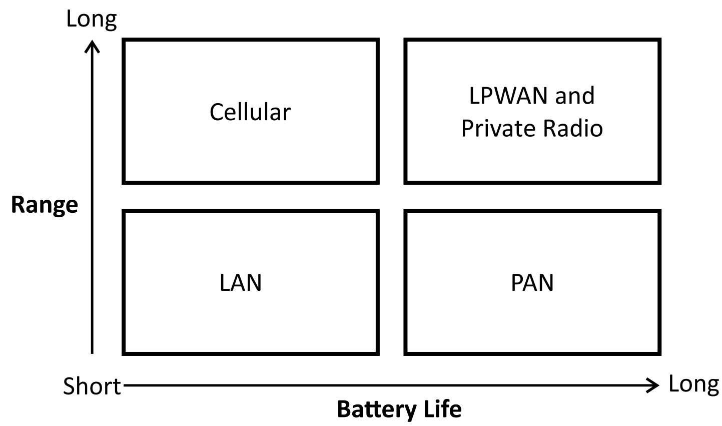
Sigfox

Ultra-narrow bandwidth characterized the Sigfox network, which makes it more resilient to interference than the LoRaWAN network. In addition, the technology developed a battery to have a life of 10 years because it is not connected all the time, but the battery only lasts 5 to 7 years. The WND'S Business Develop Manager also stated that it is possible to set up a base station in remote areas with no connection, indispensable only power, and internet, and use a solar panel, as the internet does not need to be fast [13]. It has the advantage that it is possible to export the network without additional costs [13].However, it is not in real-time; the latency of the product is 10 seconds. There is a maximum number of daily transmissions depending on the package purchased; the simplest is three daily sends, which are paid by service. Due to the low transfer rate of 100 bps and maximum sending of 12 bytes [2], it has a longer packet transmission time, increasing power consumption. It ranges from up to 50 km in rural areas [13].

LoRaWAN

The LoRaWAN protocol makes use of Radio-Frequency LoRa technology [12]. One of its advantages is that it can be developed as a private network. However, the network makes use of a shared spectrum, receiving more self-interference,

Figure 1. Range and power consumption of network categories.



which ends up limiting the scalability of the network [14,15]. In addition, it connects in two different ways; firstly, access keys are generated for each use, increasing the network's security but increasing network complexity. The second way is without the use of access keys [13]. The transfer rate is 50 Kbps, and the latency of this network is 5 seconds. There is no daily packet limit, but each packet must contain a maximum of 243 bytes [2]. The range of the network is approximately 15 Km in rural areas, and there is no coverage in remote locations [15].

DigiMesh

The module analyzed in this paper is the Digi XBee-Pro 900HP-RF Module. The technology is related to Mesh Networks, which create a wireless mesh network, and perform multiple hopping, making possible communication of all devices in the network, making the network highly scalable [16]. Furthermore, as nodes send packets to other nodes, they act as "routers" [7]. The DigiMesh network presents a latency of approximately 0.035 seconds, and its power consumption is low since it presents a hibernation mode, consuming 2.5 microamps. However, during the reception, 29 microamps, and packet transmission, it consumes up to 120 microamps [17]. However, this network does not provide coverage in remote locations [17]. The lack of licensed network results in information vulnerability [18], and the communication's transfer rate changes according to the range of the network and the environment where it is being applied (Table 1).

CBRS

CBRS is a network developed for 'military' use and can use licensed radio frequencies. Its latency is 0.02 seconds, but military activity will have priority in the network, followed by the licensed networks and, lastly, the unlicensed ones [19]. In rural areas, it presents a range of ≤16 km. It has coverage in remote areas and is cheaper than in urban areas due to its proportionality with population density [20]. The licensed spectrum refers to the LTE radio interface, and the network differentiator is in the spectrum distribution. Leaving the SAS (Spectrum Allocation Server) responsible for allocating from

Table 1. DigiMesh operating characteristics.

	Indoor	Indoor	Outdoor	Outdoor
Range	610m	305m	15.5Km	6.5Km
Transfer rate	10Kbps	200Kbps	10Kbps	200Kbps

the calculation of RF density (Radio Frequency) [20]. The CBRS network has a throughput attribute of 1Mbps [21], which is an average bandwidth. The power consumption of this system is 47 dB [22].

Materials and Methods

The research is an explanatory literature review of Google Academic and IEEE Xplore periodical articles. It aims to assist in the choice of communication networks for monitoring onshore oil fields and performing analysis to simplify the network's choice.

Results and Discussion

After knowing each network individually and analyzing Table 2, it becomes possible to make a conscious choice of the network that will be acquired. Sometimes, there will not be a network that fits all parameters, so it is essential to use two or more types to approximate the required standard.

By observing the table, it becomes clear that LPWAN and the DigiMesh network do not have coverage in remote regions, which makes their application in the oil fields difficult. Sigfox, LoRaWAN, and DigiMesh networks are not licensed, compromising the user's data security. Sigfox has the lowest data transfer rate, restricting packet size. The low scalability of LoRaWAN makes it hard to grow the system. The energy consumption is low for all the networks. However, LoRAWAN's spectrum is susceptible to interference, which compromises the system's reliability. Therefore, the CBRS and NB-IoT are configured with the lowest latency, transferring data in real time. Ultimately, the more extensive range is CBRS. For connecting, NB-IoT needs a previous antenna to act in the cellular network. The LPWANs have many positive aspects, such as high bandwidth, low latency, licensed network, low power consumption, and high transfer rate. However, it lacks coverage in areas that lack electricity and internet. CBRS network's primary use is military, and it is unlikely to be applied in another spectrum, but when this happens, the cellular network is employed. However, it results in difficult usability in the project due to the need for operation in remote fields.

Conclusion

After analyzing the information in this article, it was possible to conclude that the perfect fit does not exist, but some points are worth recording. The Sigfox has the best range; however, it has a low transfer rate. The NB-IoT is licensed and has lower latency, higher reliability, and data transfer rate, although it does not have coverage in remote areas. DigiMesh network is famous for scalability and the facility of the installation, also having a high transfer rate, but is not reliable and licensed. On

Table 2. Comparison of the wireless network categories.

	NB-IoT	Sigfox	LoRaWAN	DigiMesh	CBRS
Rural area range	10 Km	50 Km	15 Km	15,5 Km	16 Km
Coverage in remote areas	No	Possible	No	No	Yes/No
Reliability	High	Medium	Medium	Medium	Medium
Energy Consumption	Low	Low	Medium	Low	Low
Scalability	Medium	Medium	Low	High	High
Latency	0.02 s	10 s	5 s	0.035 s	0.02 s
License	Yes	No	No	No	Yes/No
Transfer rate	200 Kbps	100 Kbps	50 Kbps	200 Kbps	1 Mbps

the other hand, LoRaWAN has the lowest cost for implementation and a good range; nevertheless, this network is susceptible to interference at the spectrum. Finally, CBRS has the highest range, reliability, scalability, and lowest latency. The only factor that is not good is weak resilience.

Acknowledgments

To CNPq and ANP PRH Program for the grants, to the Competence Center in Advanced Technologies and Competence Center in Onshore Solutions for the support.

References

1. Mendes APA, et al. Produção de Petróleo Terrestre no Brasil. Disponível em: <https://web.bndes.gov.br/bib/jspui/bitstream/1408/16962/3/PRArt214594_Producaode pretroleo terrestre no Brasil_P_BD.pdf>. Acesso em: 26 jan. 2021.
2. Mekki K, et al. Overview of cellular LPWAN technologies for IoT deployment: Sigfox, LoRaWAN, and NB-IoT. In: 2018 ieee international conference on pervasive computing and communications workshops (percom workshops). IEEE, 2018. p. 197-202.
3. Minha Conexão. Entenda o que é a Latência e sua influência na conexão com a internet. 9 April. 2020. Available at: <https://www.minhaconexao.com.br/blog/entenda-o-que-e-a-latencia-e-sua-influencia-na-conexao-com-a-internet/>. Accessed on: 14 Aug. 2021.
4. Forouzan BA. Comunicação de Dados e Redes de Computadores. AMGH Editora, 2009.
5. Medeiros L. Explicando o que é Banda, Taxa de Transferência e Velocidade para Técnicos. SLA Consultorias e Treinamentos, 5 April 2021. Available at: <https://www.youtube.com/watch?v=zxNoNxZJSi8>. Accessed on: 14 Aug. 2021.
6. Ribeiro CHP. Redes de sensores sem fio. Universidade Federal do Rio de Janeiro, Rio de Janeiro, 6 June 2008. Available at: <https://www.gta.ufrj.br/grad/08_1/rssf/CaractersticasdaRede.html>. Accessed on: 14 Aug. 2021.
7. Araújo PD, Márcia L. Estudo comparativo entre redes WIMAX e redes MESH. Available at: https://silo.tips/download/estudo-comparativo-entre-redes-wimax-e-redes-mesh. Accessed on: 14 Aug. 2021.
8. Savoine MM,et al. Proposta de uso de métodos ágeis no gerenciamento e implantação de projeto de redes sem fio. Anais SULCOMP 2017(8).
9. What is LPWAN. Behrtech. Available at: https://behrtech.com/lpwan-technology/. Accessed on: 15 June 2021.
10. Behr A. How new LPWAN standard addresses challenges in connective pumps. Pumps & Systems. Available at:https://www.pumpsandsystems.com/how-new-lpwan-standard-addresses-challenges-connective-pumps. Accessed on: 15 June 2021.
11. Entenda o que é NB-IoT e LTE-M, redes dedicadas a projetos de IoT. Embratel.Available at: https://mundomaistech.com.br/iot/entenda-o-que-e-nb-iot-e-lte-m-redes-dedicadas-a-projetos-de-iot/. Accessed on: 15 June 2021.
12. Sumiyoshi L. Protocolos de IoT: qual a melhor para o seu negócio? Venturus. Available at:https://www.venturus.org.br/protocolos-de-iot-qual-e-o-melhor-para-o-seu-negocio/. Accessed on: 14 Aug. 2021.
13. Bertoleti P. Webinar: Qual LPWAN utilizar: LoRaWAN ou Sigfox? Embarcados tv, 3 July. 2020. Available at: <https://www.youtube.com/watch?v=IOoZ7tXcGpc>. Accessed on: 14 July. 2021.
14. Almeida O. Sigfox X LoRa :Qual a tecnologia ideal para sua aplicação. Connect Five, São Paulo, June, 2020. Available at: https://connectfive.com.br/sigfox-x-lora-qual-a-tecnologia-ideal-para-a-sua-aplicacao/ . Accessed on:17 June 2021.
15. Dellalibera LA. Técnicas de múltiplo acesso para redes LoRaWAN.Trabalho de conclusão de curso-Câmpus experimental de São João da Boa Vista-Universidade Estadual "Júlio de Mesquita Filho", São João da Boa Vista, 2018.
16. Brito I, et al. Openwimesh: um framework para redes mesh sem fio definidas por software. 32th Simpósio Brasileiro de Redes de Computadores e Sistemas Distribuıdos (SBRC) 2014:413-426.
17. Mosquera ED, Gonzalez JAC. Communications system for a soil monitoring network in Valle del Cauca, Colombia, 2015 Workshop on Engineering Applications - International Congress on Engineering (WEA) 2015:1-5.
18. Wireless Connectivity for Massive Scale IoT Deployments. BEHRTECH. Available at: <https://behrtech.com/resources/ebook-wireless-connectivity-for-massive-scale-iot-networking/>. Accessed on: 15 July 2021.
19. Lima GC, Fiorese V, Domingos D, Haiying R. Seminário 5G e IoT na prática, status internacional. Fórum Brasileiro de Internet das Coisas, 29 July 2021. Available at: <https://www.youtube.com/watch?v=BUCd-qAk6n8&t=3s>. Accessed on: 29 July 2021.
20. What is CBRS?-LTE in 3.5GHz Shared Spectrum and What it Means for IoT. Leverege, 9 June 2017. Available at: <https://www.leverege.com/blogpost/what-is-cbrs-lte-3-5-ghz>. Accessed on: 13 Aug. 2021.
21. Yavuz M. Private mobile networks as a foundation for smart industry.
22. Mun K. CBRS: New shared spectrum enables flexible indoor and outdoor mobile solutions and new business models. White Paper 2017(Mar).