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Exploring Low-Power Wide-Area Networks (LPWAN) for IoT Connectivity

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Abstract. Low-power wide area network (LPWAN) technologies are revolutionizing the fulfillment of requirements and addressing the limitations of long-range communication, low bit rate, and low power consumption in IoT networks. These networks target customer-facing mobile and fixed devices in diverse applications such as smart city, utility, manufacturing, smart home, smart lighting, and environmental monitoring. It is evident that these IoT apps are growing exponentially. LPWAN technologies deliver unique features that previous technologies could not efficiently provide. The design goal of these technologies is to provide high coverage, long battery life, low device cost, and efficient communication. These network technologies create a new ecosystem that bridges the gap between customers and IoT solutions. Small and medium-sized network operators will have a larger share of LPWAN, reducing barriers to entry for solution providers. These technologies have demonstrated that it won't be long before cellular technologies dominate IoT. The IoT solution based on LPWAN is almost ready for commercial deployment.

Keywords: Low-power wide area network (LPWAN), IoT, smart city, LoRaWAN.

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1. Introduction

Low-Power Wide-Area Networks (LPWAN) have emerged as pivotal solutions within the Internet of Things (IoT) ecosystem, addressing specific connectivity challenges with their low-cost, low-power capabilities. LPWAN technologies like LoRa, SigFox, and Weightless-N operate in unlicensed spectrum bands, offering long-range communication ideal for IoT devices spread over large geographic areas [1]. These technologies prioritize energy efficiency, enabling extended battery life for devices that may be deployed in remote or hard-to-access locations. LPWAN's significance in IoT lies in its ability to support diverse applications such as smart city infrastructure, environmental monitoring, and industrial automation. By optimizing for lower data rates and longer transmission ranges compared to traditional mobile networks, LPWAN technologies fill a crucial niche in IoT connectivity, catering to scenarios where cost-effective, reliable, and scalable network solutions are essential. As industries increasingly adopt IoT to streamline operations and enhance efficiency, LPWAN's role in providing robust connectivity infrastructure becomes increasingly indispensable, paving the way for broader IoT deployment and innovation in various sectors [2].

2. Previous Studies

Low-Power Wide-Area Networks (LPWAN) represent a critical advancement in IoT connectivity, tailored to meet the specific needs of low-power, wide-coverage applications across various industries, as shown in table 1. According to recent research by experts in the field (Onumanyi, Adeiza J et al., 2020) [3], technologies like LoRaWAN, NB-IoT, and Sigfox excel in providing efficient, cost-effective solutions for IoT deployments where long battery life and extensive network reach are paramount. LoRaWAN, utilizing the LoRa modulation scheme, offers interoperability and scalability through the LoRa Alliance (LoRa Alliance, 2019) [4][5], making it ideal for large-scale deployments in smart cities and industrial automation. NB-IoT leverages existing cellular infrastructure, ensuring robust connectivity with enhanced security, suitable for applications requiring higher data throughput (GSMA, 2020) [4]. Meanwhile, Sigfox's ultra-narrow band technology provides low-cost, energy-efficient connectivity over long distances, making it suitable for applications like environmental monitoring and asset tracking (Sigfox, 2020) [6]. Together, these LPWAN technologies are poised to drive the next wave of IoT innovation by enabling reliable, scalable connectivity solutions tailored to diverse IoT use cases. See table 1.

Table 1. Summary of Previous Studies

Ref	Technolog	Modulation	Fre. Bands	Data Rate	Range	Battery Life	Network Topology	Security
[3]	LoRaWAN	CSS (Chirp Spread Spectrum)	868 MHz (EU), 915 MHz (US), others	0.3-50 kbps	Up to 10 km	Up to 10 years	Star-of-stars	AES-128
[4], [5]	NB-IoT	OFDMA (Orthogonal Frequency Division Multiple Access)	Licensed bands (700 MHz to 2.1 GZ	100-200 kbps	Deep indoor coverag e	Up to 10 years	Star	AES-256
[6]	Sigfox	UNB (Ultra Narrow Band)	868 MHz (EU), 902 MHz (US), others	100-1000 bps	Up to 50 km	Up to 10 years	Star	Proprietary

3. Key LPWAN Technologies

NB-IoT has gained prominence in IoT and M2M applications due to its integration with existing LTE infrastructure, offering low power consumption and efficient uplink scheduling. It competes with technologies like LoRaWAN and Sigfox by utilizing sub-GHz bands for wide coverage and supporting diverse IoT use cases in urban environments. LoRaWAN, using the LoRa standard, benefits from the open protocol and operates in the 868/915 MHz bands, facilitating long-range communication across expansive areas. These LPWAN technologies cater to varying IoT deployment needs, emphasizing interoperability, network efficiency, and scalability in industrial and smart city applications [7].

3.1. LoRaWAN

LoRaWAN optimizes IoT connectivity with LoRa technology, using CSSA MAC for deterministic scheduling. It defines node classes, duty cycles, data rates, and ALOHA window durations. RSoTA manages trade-offs like sync and transmission issues, crucial for LPWAN environments. LoRaWAN enhances data routing, security, QoS, and network management, supporting decentralized operations with optional central functions. It leverages LoRa's features for reliable, secure IoT operations globally, across various frequency bands, tailored for long life-cycle applications [8].

3.2. NB-IoT

NB-IoT, a cellular upgrade widely adopted by operators, uses LTE and GSM bands, co-existing with base stations. It integrates non-cellular elements into the core network, evolving in 3GPP Release 14 with Release 13 implementation. NB-IoT operates in low-band spectrums, enhancing IoT via eMBB deployment. It utilizes FDD/TDD with 200 kHz channels divided into six OFDMA resource blocks. NB-IoT enables long-range, low-power communication crucial for IoT devices, leveraging existing GSM infrastructure. Its deployment supports diverse IoT applications, driven by the 3GPP's LPWA standardization efforts since Release 13, ensuring widespread connectivity in various scenarios [9].

3.3. Sigfox

Sigfox, founded in 2009, aims to connect billions of objects via an affordable, open-standard IoT network. It collaborates with initiatives like the LoRa Alliance and Weightless SIG. Sigfox rapidly deploys nationwide networks, as seen in France in 2 years, using ultra-narrow band (UNB) modulation for energy-efficient communication. Operating at 10 mW, it achieves low-cost connectivity but sacrifices QoS and transmission speed. Each 12-byte frame supports up to 112-byte messages, split and reassembled by network operators. Base stations feature omnidirectional antennas and GPS for synchronization, while gateways use basic Linux computers. Sigfox's simple radio design and spectral redundancy ensure robust performance despite minimal energy consumption [10].

4. Comparative Analysis of LPWAN Technologies

LPWAN technologies like Sigfox, LoRaWAN, and NB-IoT offer compelling solutions for IoT applications, emphasizing low-energy consumption, extensive coverage, and independence from traditional infrastructure. They utilize unlicensed frequency bands, enabling rapid deployment and shared resource potential. However, while promising, actual performance often falls short of expectations. Comparing LPWAN options such as Cellular IoT (CIoT), Sigfox, LoRaWAN, and NB-IoT highlights their respective strengths: CIoT and NB-IoT leverage licensed cellular technology, while Sigfox and LoRaWAN use unlicensed bands to reduce deployment costs [11].

Sigfox employs ultra-narrow band (UNB) modulation for energy efficiency but sacrifices QoS and speed. LoRaWAN supports varying data rates with flexibility in activation times, optimizing power consumption for extended battery life, up to 10-30 years. Cost-effectiveness and scalability vary: LPWANs offer lower connectivity costs but may require scalable pricing models to accommodate diverse IoT device volumes and sporadic connectivity needs. Overall, LPWAN technologies represent a significant step towards fulfilling IoT requirements, yet their deployment necessitates careful consideration of performance trade-offs beyond initial promises [12].

5. LPWAN Use Cases and Applications

LPWAN technologies like LoRa, SigFox, and Weightless are designed for energy-efficient, long-range connectivity, crucial for battery-operated IoT devices. Operating in unlicensed ISM bands, such as the 868 MHz band, they face challenges like transmission energy costs and reception complexity. To optimize efficiency, these technologies employ low data rates and simplified signal processing. For smart agriculture, LPWAN supports applications like livestock tracking and precision farming, benefiting from its extensive reach and power efficiency [13]. In smart cities, LPWAN facilitates diverse applications such as asset management, air quality monitoring, and smart lighting, meeting criteria like low data rates and cost-effective deployment. In industrial IoT (IIoT), LPWAN faces competition from protocols like ISA-100.11 and Profinet/IO, known for reliability in harsh environments but lacking scalability and flexibility. Despite these challenges, LPWAN technologies offer scalable solutions for various IoT applications, leveraging their low power consumption and long battery life characteristics [14].

6. LPWAN Security Considerations

Securing low-power wide-area networks (LPWAN) is critical for IoT applications like Industry 4.0, Smart Cities, and Smart Agriculture. LPWAN technologies such as Sigfox, LoRa, and NB-IoT are designed with stringent power consumption limits, posing unique security challenges including physical and radio-link access vulnerabilities. In LoRaWAN, encryption and authentication are enforced through mechanisms like over-the-air-activation (OTAA) and AES 128-bit session keys for both uplink and downlink transmissions, ensuring data confidentiality, integrity, and authentication [15]. Sigfox employs individual node keys managed by its secure cloud service. Data integrity is vital for IoT applications relying on accurate data for decisions, necessitating real-time validation mechanisms like HMAC to detect unauthorized alterations. Despite mandatory encryption, LPWAN technologies face risks of passive eavesdropping due to unprotected PHY layers, allowing potential interception and offline decryption of network traffic. Addressing these security concerns is crucial for deploying LPWAN effectively across diverse IoT use cases [16].

7. LPWAN Deployment and Implementation Best Practices

LPWAN technology proves advantageous and proposes potential services for LPWAN networks. Our aim is to support operators, system integrators, and IoT Application Service Providers in entering the Smart Cities market with competitive solutions. LPWAN represents a disruptive technology enabling low-cost networks that could drive technological differentiation and higher margins for component manufacturers and developers. Critical considerations include network planning, where gateway placement is pivotal to optimizing coverage and minimizing node energy consumption. Proper positioning of gateways can significantly enhance network capacity and extend coverage, as detailed in a simplified equation provided in this section [17]. Device management is another crucial aspect, particularly in scenarios like smart meters and water systems where devices must operate efficiently over extended periods. LPWAN technologies, characterized by asymmetrical protocols favoring uplink communication due to energy efficiency considerations, necessitate effective management strategies to handle device lifecycle and power consumption effectively. The absence of a standard downlink communication structure in LPWAN requires innovative approaches for managing device communications and ensuring operational efficiency [18]. Overall, LPWAN networks offer scalable solutions for various IoT applications, competing effectively with satellite and cellular technologies in terms of device ubiquity and cost-effectiveness. Future market dynamics will determine how LPWAN technologies continue to evolve and meet diverse industrial needs, balancing energy efficiency with expansive network coverage and effective device management strategies [19][20].

8. Result and analysis

The results illustrate a comprehensive comparison of Low-Power Wide-Area Network (LPWAN) technologies, focusing on coverage and battery life.

Figure 1, presents a bar chart illustrating the coverage range of five different LPWAN technologies in kilometers. Sigfox stands out with the highest coverage of 40 km, making it ideal for applications that require long-range connectivity, such as rural or remote area monitoring. UNB follows with a coverage of 30 km, offering a balance between range and other factors. OOK provides a coverage range of 25 km, making it suitable for mid-range applications. NB-IoT has a moderate coverage of 15 km, fitting well in urban environments where higher data rates are often needed. Lastly, LoRaWAN has the lowest coverage at 10 km, but it excels in other areas like battery life, making it a preferred choice for long-term IoT deployments with low maintenance needs. This comparison helps in identifying the most suitable LPWAN technology based on the specific coverage requirements of different IoT applications.

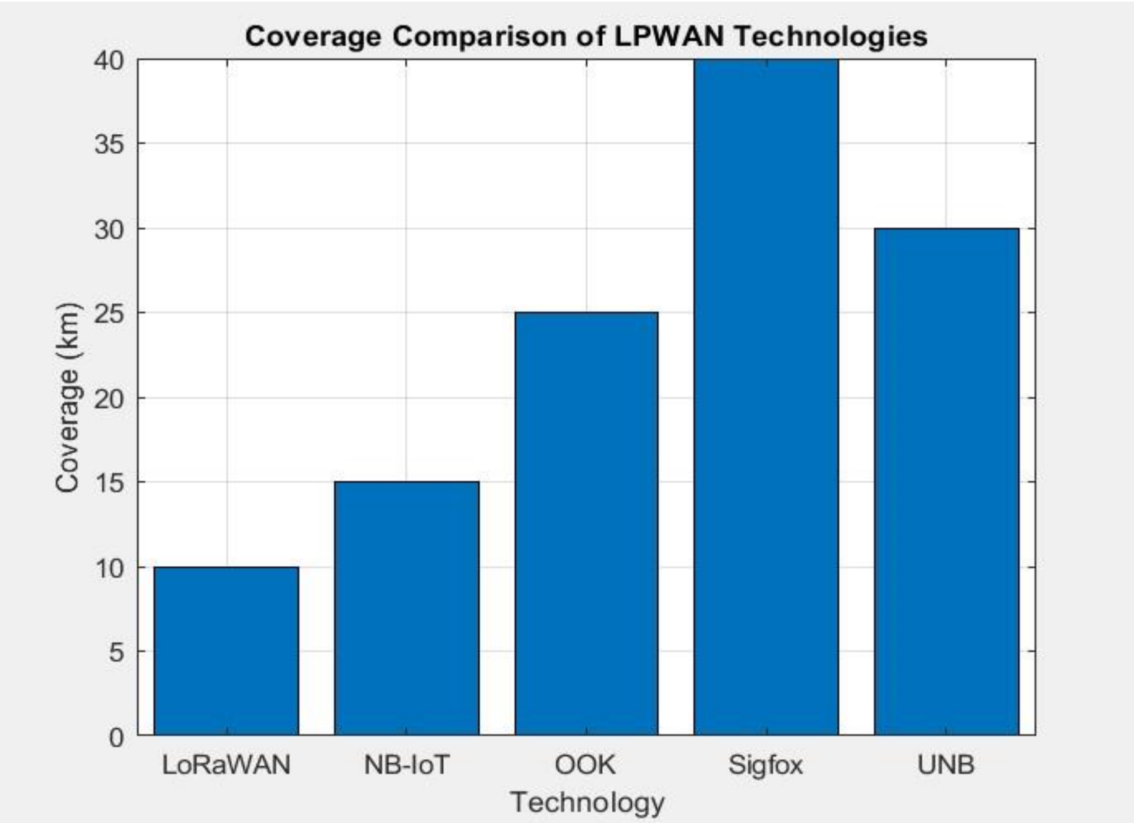

Fig.1. Converge Comparison of LPWAN Technologies

Figure 2, is a bar chart that depicts the battery life of five different LPWAN technologies in years. LoRaWAN leads the group with the longest battery life of 10 years, making it ideal for long-term IoT deployments where frequent battery replacements are impractical. NB-IoT follows closely with a battery life of 15 years, also supporting long-duration applications but with slightly better energy efficiency. OOK offers a substantial battery life of 12 years, making it suitable for medium- to long-term projects. UNB has a moderate battery life of 8 years, balancing longevity with other performance factors. Sigfox, while excelling in coverage, has a battery life of 5 years, which is the shortest among the technologies compared. This chart highlights LoRaWAN as the best choice for applications requiring the longest battery life, while the other technologies offer varying balances between battery life and other attributes like coverage and cost.

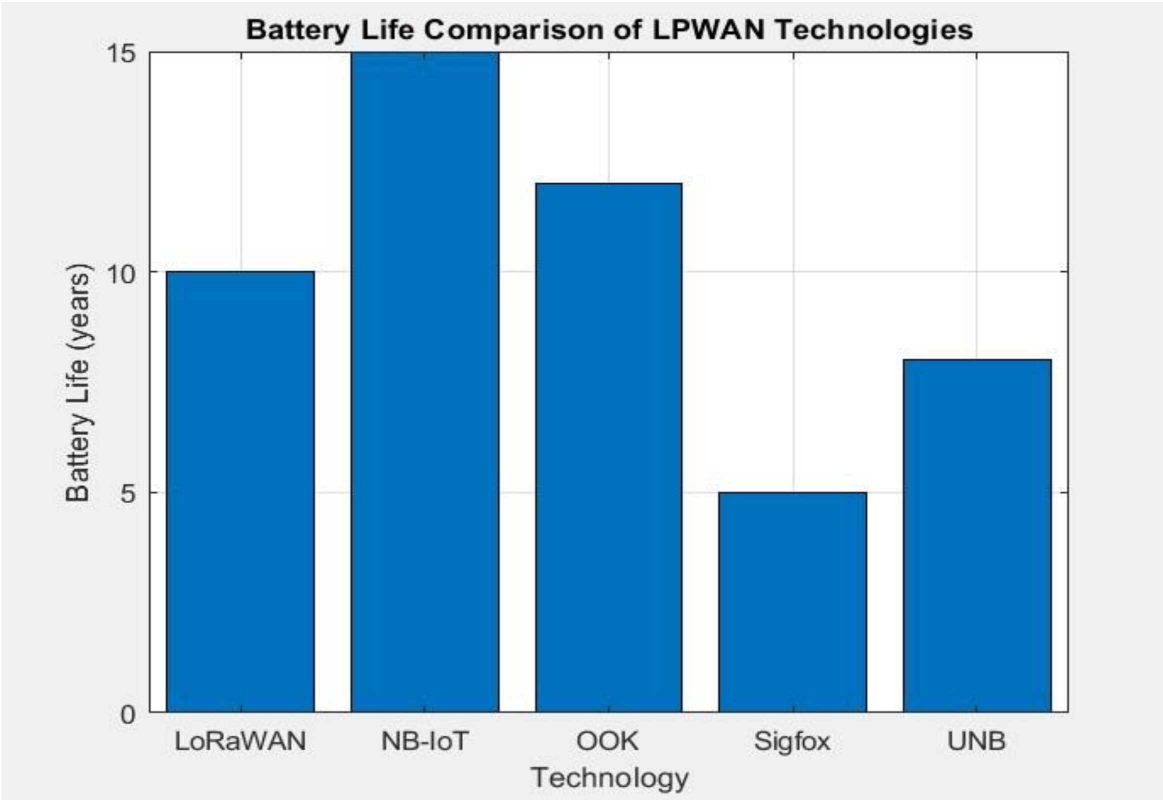

Fig. 2. Battery Life Comparison of LPWAN Technologies

Figure 3, presents a bar chart that illustrates the cost index of five different LPWAN technologies. The cost index is a relative measure, where lower values represent lower costs. Sigfox emerges as the most cost-effective option with the lowest cost index of 0.5, making it an attractive choice for budget-conscious IoT deployments. OOK follows with a cost index of 0.8, providing a good balance between cost and performance. LoRaWAN has a moderate cost index of 1, offering a reasonable compromise between affordability and other factors such as battery life. UNB is slightly more expensive with a cost index of 1.5, reflecting its higher coverage capabilities. NB-IoT is the most expensive among the compared technologies, with a cost index of 2, which may be justified by its moderate coverage and long battery life. This chart helps in understanding the cost implications of each technology, guiding decisions based on budget constraints and the specific needs of the IoT application.

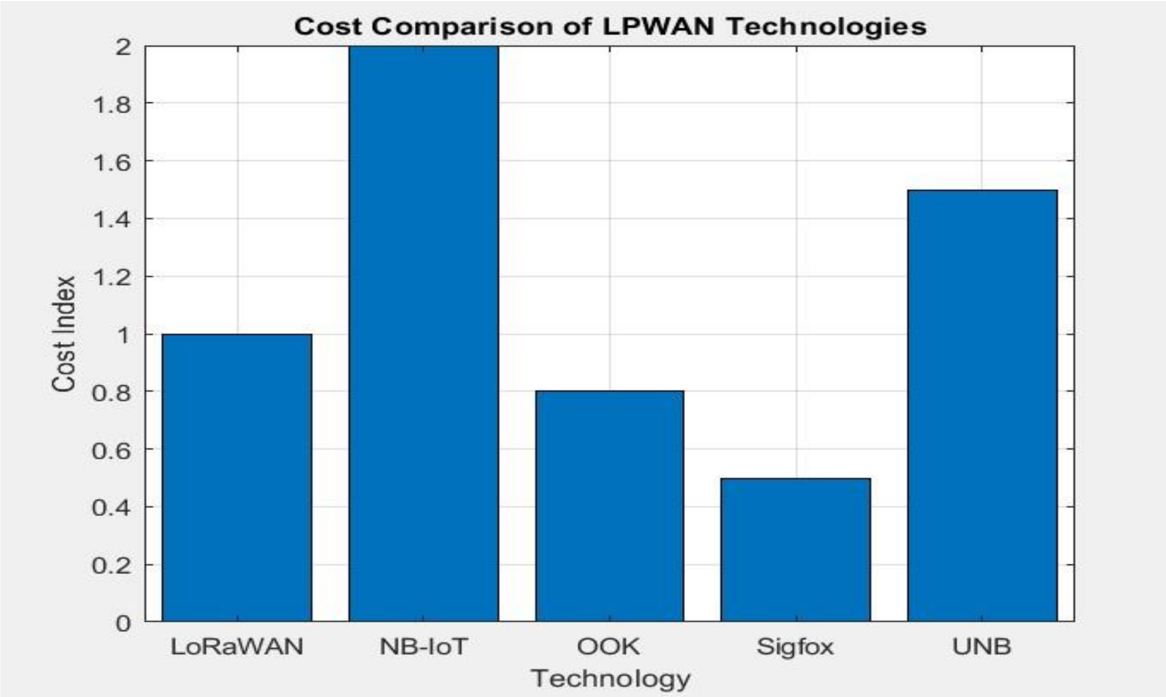

Fig. 3. Cost Comparison of LPWAN Technologies

Figure 4, is a radar chart that visually compares five key features of these two LPWAN technologies: Range, Data Rate, Battery Life, Cost, and Scalability. This radar chart highlights the trade-offs between the two technologies. Sigfox is ideal for long-range, cost-sensitive applications with moderate data needs and scalability. LoRaWAN, with its superior data rate, battery life, and scalability, is better suited for applications requiring frequent data transmission, long-term deployment, and the potential for large-scale growth.

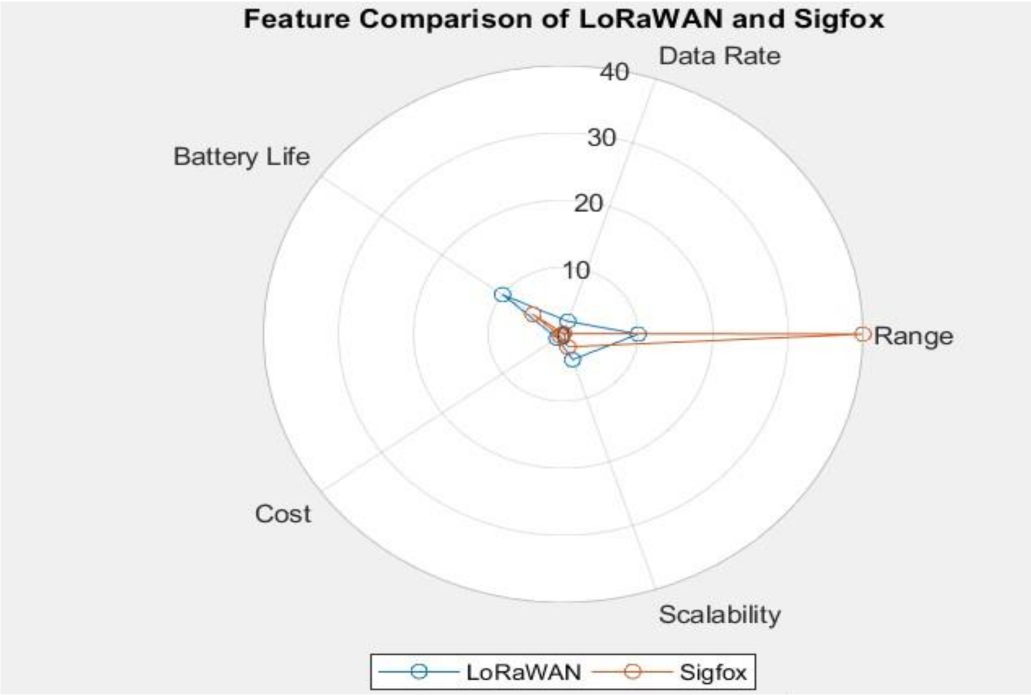

Fig. 4. Feature Comparison of LPWAN and Sigfox

Based on the comparative analysis of LPWAN technologies, several key conclusions can be drawn regarding their suitability for diverse IoT applications, as shown in table 2. LoRaWAN emerges as a robust choice with its impressive coverage range of up to 15 km, low to moderate data rates ranging from 0.3 to 50 kbps, and exceptional battery life exceeding 10 years. It stands out for its scalability, making it ideal for large-scale deployments in smart cities and industrial settings where long-term reliability is crucial. Sigfox, offering even broader coverage up to 50 km and ultra-narrowband technology, emphasizes low power consumption and extended battery life, albeit with lower data rates suited for applications like environmental monitoring and asset tracking. NB-IoT leverages cellular infrastructure to deliver higher data rates (20-250 kbps) and good indoor coverage while maintaining a battery life of over 10 years, making it suitable for applications requiring reliable connectivity in urban environments.

Table 2. Comparison of LPWAN Technologies

Technology	Coverage Range	Data Rate	Battery Life	Device Cost	Key Features
LoRaWAN	Up to 15 km	0.3 - 50 kbps	10+ years	Low	Long range, high scalability, low power
Sigfox	Up to 50 km	0.1 - 0.6 kbps	10+ years	Low	Ultra-narrowband, low power, long battery life
UNB	Up to 10 km	0.1 - 1 kbps	5 - 10 years	Low	Ultra-narrowband, high coverage, low power
NB-IoT	Up to 10 km	20 - 250 kbps	10+ years	Moderate	High data rate, good indoor coverage, cellular tech
OOK	Up to 5 km	0.1 - 10 kbps	5 - 10 years	Low	Energy-efficient, low data rate, long battery life

9. Conclusion

Low-Power Wide-Area Networks (LPWAN) such as LoRaWAN, NB-IoT, and Sigfox represent pivotal advancements in IoT connectivity, addressing crucial challenges of range, power efficiency, and cost-effectiveness. LoRaWAN excels with its extended battery life of up to 10 years, ideal for long-term deployments across diverse environments, supported by its open standard and scalability through the LoRa Alliance. NB-IoT leverages existing cellular infrastructure for deep indoor coverage and robust connectivity, catering to applications requiring higher data throughput and stringent reliability. Sigfox offers extensive coverage of up to 40 km and cost-effective connectivity, making it suitable for widespread deployments in smart agriculture and asset tracking despite lower data rates. These LPWAN technologies collectively enable scalable IoT solutions that complement traditional networks, fostering innovation and efficiency across industries. As IoT adoption continues to grow, LPWAN's role in providing reliable, energy-efficient connectivity is poised to expand, driving forward a more connected and responsive ecosystem.

References

[1] H. HaddadPajouh, A. Dehghantanha, R. M. Parizi, M. Aledhari, and H. Karimipour, "A survey on internet of things security: Requirements, challenges, and solutions," *Internet of Things*, vol. 14, p. 100129, 2021, doi: https://doi.org/10.1016/j.iot.2019.100129.

[2] S. Bansal and D. Kumar, "IoT Ecosystem: A Survey on Devices, Gateways, Operating Systems, Middleware and Communication," *Int. J. Wirel. Inf. Networks*, vol. 27, no. 3, pp. 340–364, 2020, doi: 10.1007/s10776-020-00483-7.

[3] A. J. Onumanyi, A. M. Abu-Mahfouz, and G. P. Hancke, “Low Power Wide Area Network, Cognitive Radio and the Internet of Things: Potentials for Integration,” *Sensors*, vol. 20, no. 23, 2020, doi: 10.3390/s20236837.

[4] “GSMA | GSMA.” Accessed: Jun. 29, 2024. [Online]. Available: https://www.gsma.com/

[5] K. K. Nair, A. M. Abu-Mahfouz, and S. Lefophane, “Analysis of the Narrow Band Internet of Things (NB-IoT) Technology,” in *2019 Conference on Information Communications Technology and Society (ICTAS)*, 2019, pp. 1–6. doi: 10.1109/ICTAS.2019.8703630.

[6] “Home - Sigfox 0G Technology.” Accessed: Jun. 29, 2024. [Online]. Available: https://www.sigfox.com/

[7] M. Dangana, S. Ansari, Q. H. Abbasi, S. Hussain, and M. A. Imran, “Suitability of NB-IoT for Indoor Industrial Environment: A Survey and Insights,” *Sensors*, vol. 21, no. 16, 2021, doi: 10.3390/s21165284.

[8] S. H. Silva, G. P. Koslovski, M. A. Pillon, and C. C. Miers, “Credential Lifecycle Analysis in Private LoRaWAN Networks for Industrial IoT (IIoT),” *Int. Conf. Internet Things, Big Data Secur. IoTBDS - Proc.*, no. IoTBDS, pp. 157–165, 2024, doi: 10.5220/0012615500003705.

[9] P. Kabilamani and C. Gomathy, “Implementation of Downlink Physical Channel Processing Architecture for NB-IoT Using LTE/5G Networks,” *Wirel. Pers. Commun.*, vol. 116, no. 4, pp. 3527–3551, 2021, doi: 10.1007/s11277-020-07863-5.

[10] P. Boccadoro, V. Daniele, P. Di Gennaro, D. Lofù, and P. Tedeschi, “Water quality prediction on a Sigfox-compliant IoT device: The road ahead of WaterS,” *Ad Hoc Networks*, vol. 126, p. 102749, 2022, doi: https://doi.org/10.1016/j.adhoc.2021.102749.

[11] Y. Chen, Y. A. Sambo, O. Onireti, and M. A. Imran, “A Survey on LPWAN-5G Integration: Main Challenges and Potential Solutions,” *IEEE Access*, vol. 10, pp. 32132–32149, 2022, doi: 10.1109/ACCESS.2022.3160193.

[12] M. Pérez *et al.*, “Coverage and Energy-Efficiency Experimental Test Performance for a Comparative Evaluation of Unlicensed LPWAN: LoRaWAN and SigFox,” *IEEE Access*, vol. 10, pp. 97183–97196, 2022, doi: 10.1109/ACCESS.2022.3206030.

[13] B. S. Chaudhari, M. Zennaro, and S. Borkar, “LPWAN Technologies: Emerging Application Characteristics, Requirements, and Design Considerations,” *Futur. Internet*, vol. 12, no. 3, 2020, doi: 10.3390/fi12030046.

[14] M. I. Hossain and J. I. Markendahl, “Comparison of LPWAN Technologies: Cost Structure and Scalability,” *Wirel. Pers. Commun.*, vol. 121, no. 1, pp. 887–903, 2021, doi: 10.1007/s11277-021-08664-0.

[15] H. A. H. Alobaidy, M. J. Singh, R. Nordin, N. F. Abdullah, C. Gze Wei, and M. L. Siang Soon, “Real-World Evaluation of Power Consumption and Performance of NB-IoT in Malaysia,” *IEEE Internet Things J.*, vol. 9, no. 13, pp. 11614–11632, 2022, doi: 10.1109/JIOT.2021.3131160.

[16] J. Sanchez-Gomez *et al.*, “Integrating LPWAN Technologies in the 5G Ecosystem: A Survey on Security Challenges and Solutions,” *IEEE Access*, vol. 8, pp. 216437–216460, 2020, doi: 10.1109/ACCESS.2020.3041057.

[17] K. Region-iraq, “02lpwan Technologies for Iot Applications: A Review,” *J. Duhok Univ.*, vol. 26, no. 1, pp. 29–42, 2023, doi: 10.26682/sjuod.2023.26.1.4.

[18] L. R. Philip Stoker Danya Rumore and Z. Levine, “Planning and Development Challenges in Western Gateway Communities,” *J. Am. Plan. Assoc.*, vol. 87, no. 1, pp. 21–33, 2021, doi: 10.1080/01944363.2020.1791728.

[19] M. S. Danladi and M. Baykara, “Low Power Wide Area Network Technologies: Open Problems, Challenges, and Potential Applications,” *Rev. Comput. Eng. Stud.*, vol. 9, no. 2, pp. 71–78, 2022, doi: 10.18280/rces.090205.

[20] R. Fujdiak *et al.*, “17 - Security in low-power wide-area networks: state-of-the-art and development toward the 5G,” in *LPWAN Technologies for IoT and M2M Applications*, B. S. Chaudhari and M. Zennaro, Eds., Academic Press, 2020, pp. 373–396. doi: https://doi.org/10.1016/B978-0-12-818880-4.00018-1.

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مجلة كلية العراق الجامعة للهندسة والعلوم التطبيقية

استكشاف الشبكات واسعة النطاق منخفضة الطاقة (LPWAN) للاتصال بإنترنت الأشياء

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الملخص . تُحدث تقنيات الشبكات واسعة النطاق منخفضة الطاقة (LPWAN) ثورة في تلبية المتطلبات ومعالجة قيود الاتصالات طويلة المدى ومعدل البت المنخفض والاستهلاك المنخفض للطاقة في شبكات إنترنت الأشياء. تستهدف هذه الشبكات الأجهزة المحمولة والثابتة التي تتعامل مع العملاء في تطبيقات متنوعة مثل المدينة الذكية والمرافق والتصنيع والمنزل الذكي والإضاءة الذكية والمراقبة البيئية. من الواضح أن تطبيقات إنترنت الأشياء هذه تنمو بشكل كبير. توفر تقنيات LPWAN ميزات فريدة لم تتمكن التقنيات السابقة من توفيرها بكفاءة. الهدف من تصميم هذه التقنيات هو توفير تغطية عالية وعمر بطارية طويل وتكلفة منخفضة للجهاز واتصال فعال. تعمل تقنيات الشبكات هذه على إنشاء نظام بيئي جديد يسد الفجوة بين العملاء وحلول إنترنت الأشياء. سيكون لمشغلي الشبكات الصغيرة والمتوسطة الحجم حصة أكبر من LPWAN، مما يقلل من الحواجز أمام دخول مقدمي الحلول. لقد أثبتت هذه التقنيات أنه لن يمر وقت طويل قبل أن تهيمن التقنيات الخلوية على إنترنت الأشياء. إن حل إنترنت الأشياء المستند إلى LPWAN جاهز تقريبًا للنشر التجاري.

الكلمات الرئيسية : شبكة واسعة النطاق منخفضة الطاقة (LPWAN)، إنترنت الأشياء، المدينة الذكية، LoRaWAN