On-Device LoRa Technical Review

Introduction

This document provides a technical review of recent research papers on on-device LoRa technology and related LPWAN concepts from arXiv. On-device LoRa refers to the implementation and optimization of LoRaWAN communication directly on resource-constrained devices. This allows for low-power, long-range communication without relying on external gateways or cloud infrastructure.

Search Results

Paper 1: Message Replication for Improving Reliability of LR-FHSS Direct-to-Satellite IoT

Authors: Sonu Rathi, Siddhartha S. Borkotoky **Published:** 2025-01-21 **Summary:** Long-range frequency-hopping spread spectrum (LR-FHSS) promises to enhance network capacity by integrating frequency hopping into existing Long Range Wide Area Networks (LoRaWANs). Due to its simplicity and scalability, LR-FHSS has generated significant interest as a potential candidate for direct-to-satellite IoT (D2S-IoT) applications. This paper explores methods to improve the reliability of data transfer on the uplink (i.e., from terrestrial IoT nodes to satellite) of LR-FHSS D2S-IoT networks. Because D2S-IoT networks are expected to support large numbers of potentially uncoordinated IoT devices per satellite, acknowledgment-cum-retransmission-aided reliability mechanisms are not suitable due to their lack of scalability. We therefore leverage message-replication, wherein every application-layer message is transmitted multiple times to improve the probability of reception without the use of receiver acknowledgments. We propose two message-replication schemes. One scheme is based on conventional replication, where multiple replicas of a message are transmitted, each as a separate link-layer frame. In the other scheme, multiple copies of a message is included in the payload of a single link-layer frame. We show that both techniques improve LR-FHSS reliability. Which method is more suitable depends on the network's traffic characteristics. We provide guidelines to choose the optimal method. **Categories:** cs.NI **URL:** [2501.11984v1]http://arxiv.org/pdf/2501.11984v1

Paper 2: Adversarial Attack and Defense for LoRa Device Identification and Authentication via Deep Learning

Authors: Yalin E. Sagduyu, Tugba Erpek **Published:** 2024-12-30 **Summary:** LoRa provides long-range, energy-efficient communications in Internet of Things (IoT) applications that rely on Low-Power Wide-Area Network (LPWAN) capabilities. Despite these merits, concerns persist regarding the security of LoRa networks, especially in situations where device identification and authentication are imperative to secure the reliable access to the LoRa networks. This paper explores a deep learning (DL) approach to tackle these concerns, focusing on two critical tasks, namely (i) identifying LoRa devices and (ii) classifying them to legitimate and rogue devices. Deep neural networks (DNNs), encompassing both convolutional and feedforward neural networks, are trained for these tasks using actual LoRa signal data. In this setting, the adversaries may spoof rogue LoRa signals through the kernel density estimation (KDE) method based on legitimate device signals that are received by the adversaries. Two cases are considered, (i) training two separate classifiers, one for each of the two tasks, and (ii) training a multi-task classifier for both tasks. The vulnerabilities of the resulting DNNs to manipulations in input samples are studied in form of untargeted and targeted adversarial attacks using the Fast Gradient

Sign Method (FGSM). Individual and common perturbations are considered against single-task and multi-task classifiers for the LoRa signal analysis. To provide resilience against such attacks, a defense approach is presented by increasing the robustness of classifiers with adversarial training. Results quantify how vulnerable LoRa signal classification tasks are to adversarial attacks and emphasize the need to fortify IoT applications against these subtle yet effective threats. **Categories:** cs.NI, cs.AI, cs.CR, cs.LG, eess.SP **URL:** [2412.21164v1]http://arxiv.org/pdf/2412.21164v1

Paper 3: Energy Efficient LoRaWAN in LEO Satellites

Authors: Muskan Shergill, Zach Thompson, Guanqun Song, Ting Zhu **Published:** 2024-12-30 **Summary:** LPWAN service's inexpensive cost and long range capabilities make it a promising addition and countless satellite companies have started taking advantage of this technology to connect IoT users across the globe. However, LEO satellites have the unique challenge of using rechargeable batteries and green solar energy to power their components. LPWAN technology is not optimized to maximize battery lifespan of network nodes. By incorporating a MAC protocol that maximizes node the battery lifespan across the network, we can reduce battery waste and usage of scarce Earth resources to develop satellite batteries. **Categories:** cs.ET, eess.SP **URL:** [2412.20660v1]http://arxiv.org/pdf/2412.20660v1

Paper 4: Performance Evaluation of IoT LoRa Networks on Mars Through ns-3 Simulations

Authors: Manuele Favero, Alessandro Canova, Marco Giordani, Michele Zorzi **Published:** 2024-12-27 **Summary:** In recent years, there has been a significant surge of interest in Mars exploration, driven by the planet's potential for human settlement and its proximity to Earth. In this paper, we explore the performance of the LoRaWAN technology on Mars, to study whether commercial off-the-shelf IoT products, designed and developed on Earth, can be deployed on the Martian surface. We use the ns-3 simulator to model various environmental conditions, primarily focusing on the Free Space Path Loss (FSPL) and the impact of Martian dust storms. Simulation results are given with respect to Earth, as a function of the distance, packet size, offered traffic, and the impact of Mars' atmospheric perturbations. We show that LoRaWAN can be a viable communication solution on Mars, although the performance is heavily affected by the extreme Martian environment over long distances. **Categories:** cs.NI, eess.SP **URL:** [2412.19549v1]http://arxiv.org/pdf/2412.19549v1

Paper 5: LoRaWAN attack in military use case

Authors: Georges Derache, Mounira Msahli, Aurelien Botbol, Fabien Romain, Jerome Champlon, Gauthier Canet **Published:** 2024-12-24 **Summary:** The importance of the development of IoT and LoRaWAN in military applications has been widely established. Since security is one of its important challenges, in this paper we study two attacks scenarios: replay and sniff attacks on military LoRaWAN network. The aim is to highlight cybersecurity threats that must be taken into consideration when using such technology in critical context. **Categories:** cs.CR **URL:** [2412.18447v1]http://arxiv.org/pdf/2412.18447v1

Paper 6: Lessons Learned: A Smart Campus Environment Using LoRaWAN

Authors: Hari Prabhat Gupta **Published:** 2024-10-13 **Summary:** The deployment of LoRaWAN (Long Range Wide Area Network) in dynamic environments, such as smart campuses, presents significant challenges in optimizing network parameters like spreading factor (SF), transmission power (TxPower), and managing mobility while ensuring reliable communication. In this paper, we first introduce the fundamental concepts of short-range and long-range communication

protocols, emphasizing the specific requirements and advantages of LoRaWAN in various applications. Next, we discuss smart space solutions that integrate Edge, Fog, and Cloud computing, illustrating how these paradigms work in conjunction with both short-range and long-range communication protocols to enhance data processing and decision-making capabilities in real-time. We then present our insights and lessons learned from the deployment of LoRaWAN across the campus, focusing on the challenges encountered and the strategies employed to address them. This work provides a comprehensive overview of the methodologies applied, the results achieved, and the implications for future research and practical applications in IoT-enabled smart environments. **Categories:** cs.NI **URL:** [2410.09927v1]http://arxiv.org/pdf/2410.09927v1

Paper 7: Performance Analysis of 6TiSCH Networks Using Discrete Events Simulator

Authors: Guilherme de Santi Peron, Marcos Eduardo Pivaro Monteiro, João Luís Verdegay de Barros, Jamil Farhat, Glauber Brante **Published:** 2024-10-04 **Summary:** The Internet of Things (IoT) empowers small devices to sense, react, and communicate, with applications ranging from smart ordinary household objects to complex industrial processes. To provide access to an increasing number of IoT devices, particularly in long-distance communication scenarios, a robust low-power wide area network (LPWAN) protocol becomes essential. A widely adopted protocol for this purpose is 6TiSCH, which builds upon the IEEE 802.15.4 standard. It introduces time-slotted channel hopping (TSCH) mode as a new medium access control (MAC) layer operating mode, in conjunction with IEEE 802.15.4g, which also defines both MAC and physical layer (PHY) layers and provides IPv6 connectivity for LPWAN. Notably, 6TiSCH has gained adoption in significant standards such as Wireless Intelligent Ubiquitous Networks (Wi-SUN). This study evaluates the scalability of 6TiSCH, with a focus on key parameters such as queue size, the maximum number of single-hop retries, and the slotframe length. Computational simulations were performed using an open-source simulator and obtained the following results: increasing the transmission queue size, along with adjusting the number of retries and slotframe length, leads to a reduction in the packet error rate (PER). Notably, the impact of the number of retries is particularly pronounced. Furthermore, the effect on latency varies based on the specific combination of these parameters as the network scales. **Categories:** cs.NI, eess.SP **URL:** [2410.03383v2]http://arxiv.org/pdf/2410.03383v2

Paper 8: Beacon based uplink transmission for lorawan direct to satellite internet of things

Authors: Mohammad Al Mojamed **Published:** 2024-09-30 **Summary:** Direct-to-satellite IoT DtS IoT communication structure is a promising solution to provide connectivity and extend the coverage of traditional low-power and long-range technologies, especially for isolated and remote areas where deploying traditional infrastructure is impracticable. Despite their bounded visibility, the Low Earth Orbit LEO satellites complement the terrestrial networks, offering broader gateway coverage and terrestrial network traffic offloading. However, the dynamics of LEO and the nature of such integration come with several challenges affecting the efficacy of the network. Therefore, this paper proposes Beacon based Uplink LoRaWAN BU LoRaWAN to enhance satellite-terrestrial communication efficiency. The proposed scheme exploits the LoRaWAN class B synchronization mechanism to provide efficient uplink transmission from LoRaWAN devices placed on the ground to satellite gateways. BU LoRaWAN proposes an uplink transmission slot approach to synchronize ground devices uplink traffic with LEO based orbiting gateways. It also uses a queue data structure to buffer end devices ready to send packets until the appropriate moment. BU LoRaWAN avoids possible transmission collision by optimizing a random transmission slot for an end device within the beacon window. The proposed system is implemented and evaluated using OMNeT network simulator and FLoRaSat framework. The result demonstrates the feasibility of the proposed system. BU-LoRaWAN achieves better

performance compared to the standard LoRaWAN, which manages to deliver almost double the traffic delivered by the standard one. **Categories:** cs.NI, eess.SP **URL:** [2409.20408v1]http://arxiv.org/pdf/2409.20408v1

Paper 9: Experiment-based Models for Air Time and Current Consumption of LoRaWAN LR-FHSS

Authors: Muhammad Asad Ullah, Konstantin Mikhaylov, Hirley Alves **Published:** 2024-08-19 **Summary:** Long Range - Frequency Hopping Spread Spectrum (LR-FHSS) is an emerging and promising technology recently introduced into the LoRaWAN protocol specification for both terrestrial and non-terrestrial networks, notably satellites. The higher capacity, long-range and robustness to Doppler effect make LR-FHSS a primary candidate for direct-to-satellite (DtS) connectivity for enabling Internet-of-things (IoT) in remote areas. The LR-FHSS devices envisioned for DtS IoT will be primarily battery-powered. Therefore, it is crucial to investigate the current consumption characteristics and Time-on-Air (ToA) of LR-FHSS technology. However, to our knowledge, no prior research has presented the accurate ToA and current consumption models for this newly introduced scheme. This paper addresses this shortcoming through extensive field measurements and the development of analytical models. Specifically, we have measured the current consumption and ToA for variable transmit power, message payload, and two new LR-FHSS-based Data Rates (DR8 and DR9). We also develop current consumption and ToA analytical models demonstrating a strong correlation with the measurement results exhibiting a relative error of less than 0.3%. Thus, it confirms the validity of our models. Conversely, the existing analytical models exhibit a higher relative error rate of -9.2 to 3.4% compared to our measurement results. The presented in this paper results can be further used for simulators or in analytical studies to accurately model the on-air time and energy consumption of LR-FHSS devices. **Categories:** cs.ET, eess.SP **URL:** [2408.09954v1]http://arxiv.org/pdf/2408.09954v1

Paper 10: LoRaWAN Based Dynamic Noise Mapping with Machine Learning for Urban Noise Enforcement

Authors: H. Emre Erdem, Henry Leung **Published:** 2024-07-30 **Summary:** Static noise maps depicting long-term noise levels over wide areas are valuable urban planning assets for municipalities in decreasing noise exposure of residents. However, non-traffic noise sources with transient behavior, which people complain frequently, are usually ignored by static maps. We propose here a dynamic noise mapping approach using the data collected via low-power wide-area network (LPWAN, specifically LoRaWAN) based internet of things (IoT) infrastructure, which is one of the most common communication backbones for smart cities. Noise mapping based on LPWAN is challenging due to the low data rates of these protocols. The proposed dynamic noise mapping approach diminishes the negative implications of data rate limitations using machine learning (ML) for event and location prediction of non-traffic sources based on the scarce data. The strength of these models lies in their consideration of the spatial variance in acoustic behavior caused by the buildings in urban settings. The effectiveness of the proposed method and the accuracy of the resulting dynamic maps are evaluated in field tests. The results show that the proposed system can decrease the map error caused by non-traffic sources up to 51% and can stay effective under significant packet losses. **Categories:** cs.AI, cs.NI **URL:** [2407.21204v1]http://arxiv.org/pdf/2407.21204v1

Summary of Findings

This section will summarize the key findings from the reviewed papers. [REPLACE THIS WITH YOUR ACTUAL SUMMARY AFTER READING THE PAPERS]