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Optimizing the LoRa network performance for industrial scenario using a machine learning approach

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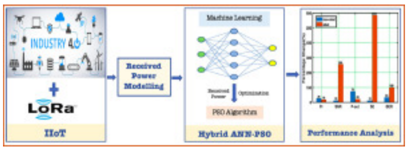
Abstract

In this article, the performance of the LoRa network for an industrial scenario has been optimized using a machine learning approach. The network performance is analyzed in terms of received power, outage probability, spectral efficiency and bit error rate (BER). A link-level performance of the LoRa network for an indoor industrial area considering both the non-obstructive and obstructive scenarios has been experimentally evaluated in terms of received signal strength indicator (RSSI) and signal-to-noise ratio (SNR). Using the measured values of RSSI and SNR at the LoRa gateway, the received power is mathematically modelled which is further considered as an optimization problem. First, an artificial neural network (ANN) model was built and trained to predict the received power. Particle swarm optimization (PSO) algorithm was further used to find the optimal values of LoRa parameters corresponding to maximum received power. Simulation results reveal that the proposed optimization approach significantly improves the outage probability, spectral efficiency and BER of the LoRa network.

Graphical abstract



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Introduction

Internet of things (IoT) endeavours to connect billions of low-end devices to a common interface communicating with one another without any human intervention. The advancement in internet technology is driving automation in factory manufacturing processes. Through condition monitoring systems and predictive monitoring, these smart industries can timely detect the deformities at various production stages and instantly respond to the unwanted events to prevent huge financial losses [1]. In the past few decades, the fourth industrial revolution or industry 4.0 has emerged emphasizing the adoption of digital technology with the help of interconnection through IoT to access real-time data and control the industrial processes. Industry 4.0 strongly relates to the industrial internet of things (IIoT) paradigm that defines intelligent, interconnected industrial equipment communicating and optimizing the whole manufacturing process [2]. The industrial scenario differs from other IoT application scenarios in certain aspects that include quality of service (QoS) requirements, industrial wireless channel, and traffic patterns. In contrast to a typical smart city setup, the industrial setup has stronger signal attenuation and higher interference. Also, the packets transmitted are more recurrent and need to be delivered with high reliability and low latency.

The focus of the current work is the high-level network performance for industrial IoT applications. To facilitate the connectivity of a broad range of factory equipment to the internet, IIoT presents a set of prevalent wireless standards such as low-cost wireless access, high power wireless access, and low power wide area network (LPWAN). LPWAN has been adopted as the key enabler of the industry 4.0 paradigm due to its competency to meet energy-efficient, long coverage, and massive scalability requirements of the IIoT deployment [3]. The main players capturing the LPWAN market are Narrow Band IoT (NB-IoT), Long Term Evolution (LTE-M), Sigfox, Weightless, and long-range (LoRa). Among these LoRa developed by the LoRa alliance is considered to be the most suitable for various IIoT use cases due to its low power consumption, extensive geographical coverage, enormous scalability, and low network deployment cost [4]. As compared to other LPWAN technologies, LoRa provides full control of the network configuration making it possible to optimize the network performance [5]. LoRa network can be customized by independently adjusting the transmission configuration of its integral device. Each LoRa device is provided with its transmission configuration such that it could reduce packet collisions. However, a particular radio propagation environment and the existence of an interfering wireless device operating at the same frequency as the LoRa device provide the ideal network configuration that sturdily depends upon the specific deployment location [6]. Thus, it is essential to characterize the type of radio propagation environment and the type of wireless link. The link quality defines the quality of the signal received at the gateway. The link quality of the LoRa network can be analyzed in terms of SNR, RSSI, received power, outrage probability, BER, spectral efficiency, etc.

This work aims to maximize the link performance of the LoRa network in an industrial scenario by optimizing the received power. An indoor industrial scenario considering both non-obstructive and obstructive environments is studied and the link-level performance of the LoRa network is experimentally analyzed in terms of SNR and RSSI at various SFs. Further, the system model for both the environments is numerically formulated using the measured values of SNR and RSSI and the network performance is evaluated in terms of received power. Evaluation reveals the dependency of the received power on various constrained as well as non-constrained LoRa parameters. A data set is generated for each SF to be utilized in building an ANN model to predict the LoRa network performance and optimal LoRa parameters. PSO technique is further utilized to optimize the non-constrained LoRa parameters on which received power depends thereby improving the SNR, outage probability, spectral efficiency, and BER of the LoRa network.

The rest of the article is structured as follows: Section2 introduces the literature review and the comparison of various optimization techniques adopted. Section3 presents the LoRa technology. Section4 highlights the measurement setup used to estimate the performance of the LoRa network. In Section5 the system model using measured values of SNR and RSSI has been formulated and its performance analysis has been described. The optimization of received power using ANN-PSO for efficient link performance of the network is presented in Section6. Simulation work and results are presented in Section7 followed by the conclusion of the work in Section8.

Section snippets

Related work

The performance of the LoRa network has been investigated both analytically as well through experimental measurements considering different scenarios in literature. A considerable amount of contribution has been made to improve the performance of the LoRa network. In Sandoval etal. [5], the average per-node throughput of the LoRa network is mathematically modelled as the maximization problem to optimize the network performance using the evolution strategy algorithm. The authors of Sandoval…

LoRa technology overview

LoRa is widely employed to provide energy-efficient, inexpensive, and easily configurable wireless networks covering a wide geographical area. It is a physical layer protocol that operates in unlicensed ISM bands at 433, 868, and 915MHz depending upon the geographical region of the deployment [11]. The LoRa end device can be configured to be deployed in any scenario by adjusting its inherent parameters such as spreading factor (SF), coding rate (CR), bandwidth (BW), and transmission power to…

Measurement setup

In this section, a LoRa network deployment in an indoor industrial scenario is considered where the gateway is connected to the end device deployed at a distance of 70m. This deployment differs from a typical smart city use case where the gateway node is connected to the LoRa devices covering an area of several kilometers. The end device is assumed to be a wireless sensor node used for monitoring purposes collecting the measurement of temperature and humidity. The block diagram of the…

System model

In this work, the uplink LoRa network to be configured in an indoor area consists of a single gateway and a single LoRa device. The gateway is deployed at a fixed location and the LoRa device is uniformly placed at two random locations to cover both the considered environmental scenarios. For both the environmental scenarios, the distance, d between the LoRa device and the gateway is fixed. The end device transmits with the transmission power, P_t in an uplink channel using various SFs with the…

Problem formulation

The optimization in the current work aims to find the optimal values of LoRa network parameters maximizing the received power at the gateway resulting in improved LoRa network performance. In this work, the main objective function is the received power at the gateway node expressed by Eqs.(8) and (15) for both the scenarios which are intended to be maximum. The measured values of RSSI and SNR obtained from the experimental setup are used to compute the value of received power. From the…

Measurement results

The link measurement is carried out by configuring the LoRa modules used at the transmitter and the gateway with the same transmission parameters cycling through various SF values ranging from 7 to 12 maintaining a constant value of CR=4/5 and 250kHz of BW. The carrier frequency considered is 433MHz since the LoRa module used is SX1278 operating at 433MHz bands. The LoRa end device periodically transmits 100 packets with the transmission power of 13dBm to the LoRa gateway for each SF.

The…

Conclusion

In this work, an approach to optimize the received power at the gateway node of the LoRa network and thereby maximize the link-level performance of the network for an industrial scenario is presented. To compute the power of the received signal at the gateway, an uplink LoRa network is configured in an indoor area aiming to consider two different environmental conditions including non-obstructive and obstructive scenarios. The link-level performance of the LoRa setup is investigated in terms of …

Future work

In the current work, the link performance of the LoRa network is analyzed in an indoor industrial scenario that is limited to a single end device connected to a gateway deployed at a distance of 70m. In the future, the link performance of the LoRa network for an industrial scenario will be analyzed using more than one LoRa device that will be deployed at a distance of more than 100m from the gateway. Also, the effect of interference and collision due to multiple LoRa devices involved will be…

Declaration of Competing Interest

All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version; This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue; The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.…

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Harleen Kaur is an Associate Professor and Chief Investigator at the School of Engineering Sciences and Technology at Jamia Hamdard, New Delhi, India. She is a visiting Professor at TWAS, Italy. She recently worked as Research Fellow at United Nations University (UNU) Tokyo, Japan, International Centre for Excellence-IIGH, Malaysia to conduct research on funded projects from Southeast Asian Nations (SEAN). She is currently working as Principal Investigator on an Indo-Poland bilateral International project funded by the Ministry of Science and Technology, India, and the Ministry of Polish, Poland. Recently, Dr. Kaur got a research funding project from the Ministry of Electronics and Information Technology (MeitY) (Govt. of India), India on the Cybersecurity and Internet of Technologies. She has published more than 100 publications in SCI, referred Journals, and esteemed Conferences. She is a member of several international bodies. Her key research areas include information analytics, applied machine learning, and predictive modelling.

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