Securing the Internet of Things in Logistics: Challenges, Solutions, and the Role of Machine Learning in Anomaly Detection

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Source Title: Digital Transformation for Improved Industry and Supply Chain Performance (/gateway/book/339902)
 | Pages: 33

ISBN13: 9798369353752 | ISBN13 Softcover: 9798369353769 | EISBN13: 9798369353776

DOI: 10.4018/979-8-3693-5375-2.ch007

Abstract

Internet of things (IoT), a network of interconnected devices capable of collecting, storing, analyzing, and transmitting data, has garnered significant attention. Its widespread adoption has transformed various industries, including healthcare, transportation, manufacturing, and agriculture, owing to its numerous benefits and innovative potential. However, the rapid expansion of IoT has raised concerns about its security, presenting unique challenges compared to traditional information technology (IT) platforms. Securing the IoT environment is particularly challenging due to inherent constraints in IoT devices, such as limited resources, as well as the diverse range of devices with varying capabilities and communication protocols. The decentralized nature of the IoT network adds complexity to ensuring its security. Consequently, employing conventional host-based security techniques like anti-virus and anti-malware software in IoT is deemed impractical and inefficient.

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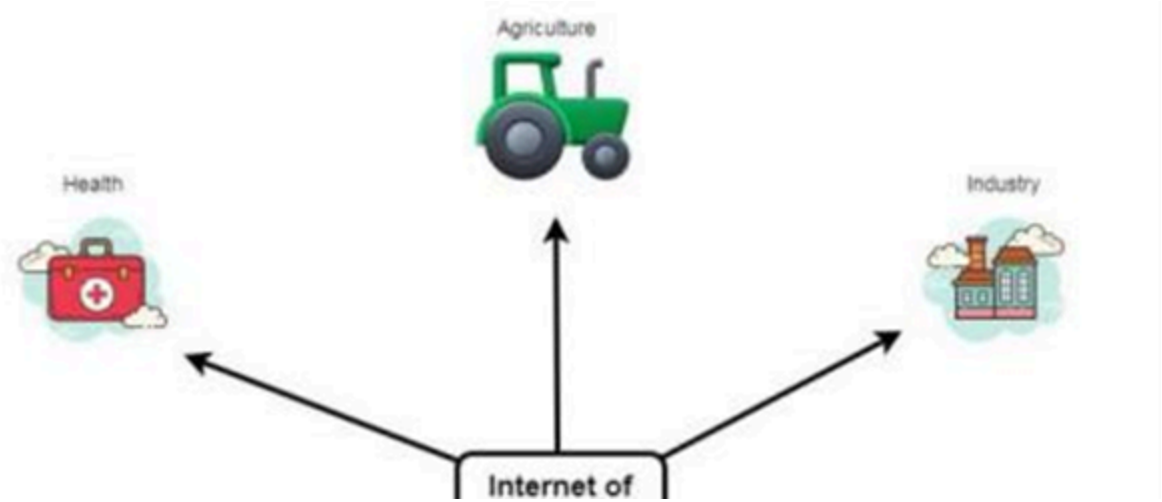
Introduction

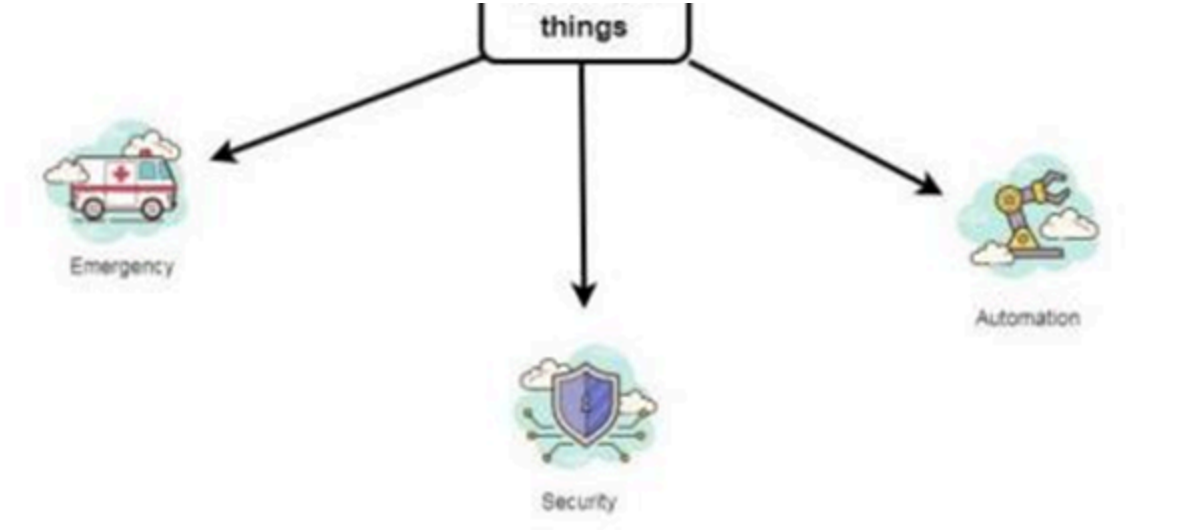
The advent of a new era marked by the rapid proliferation of Internet of Things (IoT) devices has brought about a transformative impact on infrastructure, industry, and daily life. The digital landscape is now intricately connected with diverse sensors, devices, and gadgets, offering virtually unlimited developmental opportunities (Muzammal & Ali Shah, 2016). However, the formidable challenge accompanying this unprecedented connectivity lies in securing the extensive and varied IoT landscape (Diro et al., 2021). Securing IoT networks from emerging threats has become imperious, with anomaly detection and machine learning techniques emerging as crucial strategies to address this pressing issue (Mahadevappa et al., 2021; Muzammal et al., 2022). Particularly, attacks such as Denial of Service (DoS) and Distributed Denial of Service (DDoS) emphasize the need for reliable methods to identify anomalous behavior, even when devices appear to be functioning normally (Abdullahi et al., 2022).

The Rise of Internet of Things

IoT has witnessed a significant boost, connecting a diverse range of smart devices with capabilities for data collection, processing, and transmission. This transformative technology has brought about fundamental improvements and facilities in healthcare, transportation, and agriculture. Furthermore, it opens up unique prospects for enhancing creativity and improving efficiency (Ryalat et al., 2023). Organizations can now leverage substantial information and make data-driven decisions due to the exponential growth in the volume of data generated by the increasing number of IoT devices. The potential advantages are enormous, given that IoT devices are omnipresent in various aspects of our lives – from smart homes and wearable technology to industrial sensors and autonomous vehicles (Mansour et al., 2023). These devices have the capability to enhance productivity, optimize resource utilization, facilitate the development of new services and business models, and improve decision-making. The transformative impact of IoT extends across multiple industries, contributing to an enhanced quality of life and fostering economic growth. Figure 1 depicts some of the potential areas for IoT applications.

Figure 1. Some potential IoT application areas





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Challenges in Securing IoT

Despite its advantages, the increasing adoption of IoT has raised concerns regarding its security. The interconnectivity of IoT networks exposes vulnerabilities that attackers may exploit, potentially leading to data breaches, privacy violations, and disruptions of critical services. Securing data and systems to maintain the cybersecurity standards of confidentiality, integrity, and availability (CIA triad) becomes challenging due to the vast number and diverse range of linked devices (Corno & Mannella, 2023). Furthermore, because IoT prioritizes functionality over security, vulnerabilities are often left unaddressed, providing opportunities for attackers. The security vulnerabilities in IoT can have significant consequences.

Compromised IoT devices can be utilized to execute large-scale distributed denial-of-service (DDoS) attacks or serve as access points for attacks on other systems. Unauthorized access or the disclosure of personal information can result in privacy violations (Abdullahi et al., 2022). Additionally, compromised IoT devices pose a risk of manipulating essential systems. Given these security concerns, which have raised alarms among users, organizations, and policymakers, the IoT ecosystem now requires robust security measures. Figure 2 illustrates some of the security challenges in IoT landscape. Moreover, the dynamic and evolving nature of IoT networks poses challenges for threat identification and mitigation. The substantial amount of data generated by IoT devices makes it difficult to detect anomalies or malicious activity in real-time. Detecting coordinated attacks or deviations from normal behavior becomes exceptionally challenging due to the wide range of IoT devices and communication protocols.

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