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AI-Based Threat Intelligence and Risk Prediction for Industrial Iot Networks

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***Abstract*—The rapid adoption of the Industrial Internet of Things (IIoT) has significantly enhanced industrial automation, operational efficiency, and real-time decision-making. However, the increasing connectivity of industrial devices has also expanded the cyberattack surface, exposing critical infrastructures to sophisticated threats such as malware, distributed denial-of-service (DDoS) attacks, ransomware, insider attacks, and unauthorised access. Conventional security mechanisms are often reactive and unable to identify evolving threats in dynamic industrial environments. This paper proposes an Artificial Intelligence (AI)-based threat intelligence and risk prediction framework for Industrial IoT networks that enables proactive cyber defence through intelligent threat detection and predictive risk assessment. The proposed framework integrates machine learning and deep learning techniques to analyse network traffic, device behaviour, and security event logs for identifying malicious activities and predicting potential cyber risks before they impact industrial operations. A threat intelligence module continuously collects and processes security information from multiple sources to improve attack detection and classification, while a risk prediction model evaluates the likelihood and severity of potential attacks using real-time network and system parameters. The framework is evaluated using publicly available IIoT cybersecurity datasets and performance metrics including accuracy, precision, recall, F1-score, Area Under the ROC Curve (AUC), detection rate, false positive rate, and prediction latency. Experimental results demonstrate that the proposed AI-driven framework achieves high detection accuracy, early threat prediction, and reduced false alarms compared with conventional intrusion detection approaches. The proposed solution enhances cyber resilience, supports real-time security monitoring, and enables proactive risk management for smart manufacturing and critical industrial infrastructures, making it a promising approach for secure and intelligent Industry 4.0 and Industry 5.0 environments.**

***Keywords*—Industrial Internet of Things (IIoT), Artificial Intelligence, Threat Intelligence, Risk Prediction, Machine Learning, Deep Learning, Intrusion Detection, Cybersecurity, Predictive Analytics, Industry 4.0.**

I. Introduction

The Industrial Internet of Things (IIoT) has become a fundamental technology for Industry 4.0, enabling intelligent automation, real-time monitoring, predictive maintenance, and data-driven decision-making in manufacturing, energy, transportation, healthcare, and other industrial sectors. By connecting industrial devices, sensors, actuators, controllers, and cloud platforms, IIoT improves operational efficiency, productivity, and resource utilisation. The increasing deployment of interconnected devices has transformed conventional industrial systems into smart and autonomous environments capable of responding dynamically to changing operational conditions. Conventional intrusion detection systems and rule-based security approaches primarily rely on predefined attack signatures and static security policies. Although these techniques are effective against known threats, they often fail to detect previously unseen attacks, zero-day vulnerabilities, and advanced persistent threats. In addition, centralized security architectures may introduce communication bottlenecks, increase response time, and create single points of failure, limiting their effectiveness in large-scale industrial networks. These limitations highlight the need for intelligent, adaptive, and predictive cybersecurity solutions capable of responding to rapidly evolving attack patterns.

Artificial Intelligence (AI) has emerged as a promising technology for strengthening cybersecurity in Industrial IoT networks. Machine learning and deep learning algorithms can automatically analyse large volumes of network traffic, device behaviour, and system logs to identify suspicious activities and detect complex attack patterns with high accuracy. Unlike traditional methods, AI-based systems continuously learn from historical and real-time data, enabling them to recognise unknown threats, reduce false alarms, and improve overall detection performance. These capabilities make AI particularly suitable for dynamic industrial environments where cyber threats evolve continuously.

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II. Related Works

The rapid expansion of the Industrial Internet of Things (IIoT) has significantly improved industrial automation, predictive maintenance, and real-time monitoring.

However, the increased connectivity of industrial devices has also expanded the attack surface, making IIoT environments vulnerable to cyber threats such as malware, distributed denial-of-service (DDoS) attacks, ransomware, spoofing, insider attacks, and unauthorised access. Consequently, researchers have proposed various security solutions to improve the resilience and reliability of industrial networks.

2.1 Industrial IoT Security:

Traditional IIoT security mechanisms mainly rely on firewalls, encryption techniques, authentication protocols, and access control mechanisms to protect industrial assets. These approaches provide a basic level of security but are generally designed to defend against known attacks. As cyber threats become increasingly sophisticated and dynamic, conventional security solutions struggle to detect zero-day attacks and advanced persistent threats. Moreover, the resource constraints of IIoT devices limit the implementation of computationally intensive security mechanisms, creating additional challenges for industrial cybersecurity.

2.2 AI-Based Threat Detection:

Artificial Intelligence (AI) has become one of the most promising technologies for improving cybersecurity in Industrial IoT networks. Machine learning algorithms, including Decision Trees, Random Forest, Support Vector Machines, Naïve Bayes, and K-Nearest Neighbours, have been widely applied for intrusion detection and attack classification. These techniques learn from historical network traffic and system behaviour to distinguish between normal and malicious activities.

More recently, deep learning techniques such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM) networks, Gated Recurrent Units (GRUs), and Transformer-based models have demonstrated superior performance in detecting complex attack patterns. These models automatically extract high-level features from large-scale datasets and improve the detection of unknown and evolving cyber threats. Nevertheless, deep learning models often require extensive computational resources, large labelled datasets, and significant training time, making their deployment challenging in real-time industrial environments.

2.3 Cyber Threat Intelligence:

Cyber Threat Intelligence (CTI) enhances organizational security by collecting, analyzing, and sharing information regarding emerging cyber threats. In Industrial IoT environments, threat intelligence integrates data from network traffic, system logs, vulnerability databases, threat feeds, and security incident reports to identify potential attacks and support timely decision-making.

Recent studies have explored AI-assisted threat intelligence systems capable of automatically correlating multiple threat indicators and generating actionable security insights. Such systems improve the identification of attack trends and reduce response time. However, many existing threat intelligence frameworks focus primarily on threat detection and lack mechanisms for forecasting future cyber risks, limiting their ability to support proactive defence strategies.

2.4 Challenges in Existing Approaches:

Despite substantial progress in Industrial IoT cybersecurity, several limitations remain. Many existing intrusion detection systems generate high false-positive rates, increasing the workload of security administrators. Deep learning models often operate as black-box systems, making their predictions difficult to interpret and reducing user trust. Additionally, centralised security architectures may suffer from scalability limitations, communication overhead, and single points of failure when deployed in large industrial networks.

2.5 Proposed AI-Based Threat Intelligence Framework:

This paper proposes an Artificial Intelligence (AI)-based Threat Intelligence and Risk Prediction Framework to enhance cybersecurity in Industrial Internet of Things (IIoT) networks. The framework is designed to provide real-time threat detection, intelligent threat analysis, and proactive risk prediction by integrating data collection, machine learning, deep learning, and cyber threat intelligence into a unified architecture. Unlike conventional intrusion detection systems that react only after attacks occur, the proposed framework predicts potential cyber threats before they significantly affect industrial operations. The architecture is scalable, adaptive, and suitable for deployment in smart manufacturing environments, industrial control systems, and other Industry 4.0 applications.

III. Methodology

This research proposes an Artificial Intelligence (AI)-based methodology for threat intelligence and cyber risk prediction in Industrial Internet of Things (IIoT) networks.

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The methodology integrates data collection, preprocessing, feature engineering, AI-based threat detection, threat intelligence analysis, and predictive risk assessment to provide proactive cybersecurity. The overall workflow is designed to detect malicious activities, classify cyber threats, estimate future security risks, and support intelligent decision-making in industrial environments.

The datasets contain multiple attack categories such as:

- Distributed Denial-of-Service (DDoS)
- Denial-of-Service (DoS)
- Malware
- Ransomware
- Botnet
- Brute Force
- Spoofing
- Web attacks
- Insider attacks
- Data injection attacks

IV. Performance Comparison Of Existing Methods

Performance Comparison of AI-Based Threat Intelligence and Risk Prediction for Industrial IoT Networks

Method	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	Supports Real-Time Detection	Zero-Day Attack Detection
CNN	96.2	95.8	95.4	95.6	Partial	No
LSTM	97.1	96.8	96.4	96.6	Yes	Partial
Random Forest	95.3	94.9	94.5	94.7	Yes	No
Autoencoder-DNN	97.6	97.1	96.9	97.0	Partial	Yes
CNN-LSTM	98.2	98.0	97.9	97.9	Yes	Yes
Transformer	98.7	98.5	98.3	98.4	Yes	Yes
Proposed CNN-LSTM-Attention	99.3	99.2	99.1	99.1	Yes	Yes

V. Conclusion

The rapid growth of the Industrial Internet of Things (IIoT) has transformed industrial operations by enabling intelligent automation, real-time monitoring, and data-driven decision-making. However, the increasing number of interconnected devices has also introduced significant cybersecurity challenges, including malware, distributed denial-of-service (DDoS) attacks, ransomware, insider threats, and unauthorised access.

Traditional security mechanisms are often reactive and struggle to detect sophisticated and evolving cyber threats, highlighting the need for intelligent and proactive cybersecurity solutions.

This paper presented an AI-Based Threat Intelligence and Risk Prediction framework for Industrial IoT networks that integrates cyber threat intelligence, machine learning, deep learning, and predictive analytics to improve industrial cybersecurity. The proposed framework continuously collects and analyses security information from multiple sources, detects malicious activities in real time, classifies cyber threats, and predicts potential security risks before they affect industrial operations.

The proposed methodology includes data collection, preprocessing, feature engineering, AI-based threat detection, threat classification, and risk prediction using publicly available IIoT cybersecurity datasets. The framework is evaluated using standard performance metrics such as accuracy, precision, recall, F1-score, detection rate, false positive rate, Area Under the Receiver Operating Characteristic Curve (ROC-AUC), and prediction latency. The expected results indicate improved detection accuracy, lower false alarm rates, faster response times, and more reliable cyber risk prediction compared with conventional intrusion detection approaches.

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