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Researching Issues in Information Security in Internet of Things (IoT) Systems: Challenge & Solution

Mohammed Jawad Khadim Alsayyad

Kazan National Research Technical University named after Tupolev,Kazan ,420000 Russia. realmoh91@gmail.com

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ABSTRACT

As Internet of Things (IoT) technologies and applications are widely used and spread across various fields such as industry, agriculture, transportation, health, etc., it has become necessary to continuously research and develop information security as technologies and applications evolve. Organizations need to focus their efforts on system security. Any security vulnerability can lead to system failure or cyber-attacks, which can have a wide-ranging impact. IoT security is a protection strategy and defense mechanism that safeguards against the possibility of cyber-attacks that specifically target physically connected IoT devices. IoT security teams are currently dealing with increasing difficulties, such as inventories, operations, diversity, ownership, data volume, and threats. This review examines the research related to security and IoT with a focus on the current situation, applications, issues, and future potential. IoT network security has received increasing attention from multidisciplinary and geographically dispersed researchers in recent years. Data integrity, confidentiality, authentication, and authorization must be ensured due to the large amount of data flowing through network devices. However, the field of IoT security still has a lot of room for growth.

In this paper, we will review the most important approaches for protecting Internet of Things data, the challenges, and some actual attacks.

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1. Introduction to IoT Security

The Internet of Things (IoT) has turn out to be a transformative pressure throughout various domain names, which includes industry, agriculture, transportation, and healthcare, through permitting interconnected devices to accumulate, share, and procedure data. This interconnectivity has paved the manner for smarter systems, progressed efficiency, and superior decision-making competencies. However, as IoT ecosystems keep growing exponentially, so do the challenges related to ensuring their security. The large number of interconnected devices, coupled with their numerous architectures, creates vulnerabilities that malicious actors can take gain of, fundamental to breaches, cyber-attacks, and big operational disruptions. The necessity for robust IoT safety mechanisms has consequently come to be a concern for researchers and practitioners alike.

*Corresponding author *Mohammed Jawad Khadim Alsayyad*

Email addresses: *realmoh91@gmail.com*

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IoT safety capabilities a vast range of techniques geared toward protecting IoT devices, networks, and the facts they manner from cyber threats. Despite considerable advancements in protection studies, essential demanding situations persist, together with scalability, information integrity, and the strong integration of IoT gadgets throughout heterogeneous environments. Existing solutions regularly cope with the ones worries in isolated contexts however fall quick of presenting comprehensive frameworks to address the ever-evolving protection panorama. Furthermore, actual-world IoT systems face dynamic threats, necessitating adaptive and scalable protection mechanisms that evolve alongside technological advancements. This highlights a great-sized hollow in understanding the holistic challenges and actionable measures required for building resilient IoT systems.

This paper provides an in-intensity evaluation of existing IoT security methods at the same time as addressing essential gaps inside the literature. Specifically, the important thing contributions of this paper are as follows:

1. Comprehensive Review: A systematic review of cutting-edge IoT safety mechanisms, highlighting their strengths, boundaries, and applicability across special IoT domains.

2.Analysis of Security Challenges: An exploration of the most important demanding situations faced by IoT ecosystems, together with device vulnerabilities, scalability troubles, and regulatory complexities.

3.Incident Analysis: A detailed exam of real-global IoT safety incidents to extract actionable insights and inform destiny research and improvement.

4.Future Directions: Identification of rising tendencies and demanding situations in IoT security, coupled with actionable suggestions for researchers and practitioners to navigate the evolving risk landscape.

By integrating those contributions, this paper seeks to provide a holistic expertise of IoT protection demanding situations and answers, laying a foundation for the development of greater sturdy and adaptive protection frameworks. Ultimately, the findings supplied herein intention to guide researchers and practitioners in fortifying IoT ecosystems against emerging threats and making sure their safe deployment across various applications.

2.Key IoT Security Challenges

I. Limited Security Measures: Many IoT devices have limited computing power, making it difficult to implement robust encryption or security protocols. This leaves them vulnerable to various attacks such as hacking and malware insertion.

II. Heterogeneous Devices: The Internet of Things (IoT) encompasses a multitude of devices from different manufacturers, each with its own unique level of security requirements. The lack of uniform standards can result in inconsistencies, increasing the risk of breaches.

III. Irregular Updates: IoT devices often don't receive regular software updates or patches, making them vulnerable to newly identified threats. Unlike traditional IT systems that are regularly maintained by network administrators after deployment, IoT systems can be overlooked, leaving their security outdated and susceptible to attacks.

IV. Data Privacy: IoT devices frequently store sensitive personal or business information, raising significant privacy concerns. Protecting this data is essential for preserving privacy and ensuring the integrity of IoT systems.

V. Physical Security Concerns: IoT devices can be found in various settings—some secure and others more exposed—making them vulnerable to physical tampering. Gaining access to a device's physical components can potentially harm its software or hardware, compromising the overall security of the system.

3.Best Practices for IoT Security

I. Device authentication: It's crucial to ensure that IoT devices verify the identity of users and other devices before communication begins. In instances where possible, use strong multi-factor authentication methods for enhanced security.

II. Regular updates and patch management: Keep IoT devices up-to-date with the latest security patches and software updates to minimize vulnerabilities. Enabling automatic updates can reduce the risk of exploitation significantly.

III. Encryption: Secure communication channels should be established between client and server terminals using strong encryption protocols such as TLS/SSL, helping protect sensitive data from interception during transmission or storage.

IV. Network segmentation: Isolate IoT devices on a separate network or VLAN to minimize the potential impact if one device is compromised. This way, the danger to other connected devices can be reduced.

V. Strong password settings: Devices often come with robust default passwords. Users should be encouraged to change these regularly and utilize password management tools for improved security.

VI. Analysis and intrusion detection: Regularly monitoring networks and IoT devices can help detect unusual activities or unauthorized access attempts. IoT-specific Host Intrusion Detection Systems (HIDS) can offer early warnings of potential attacks.

VII. Data Minimization: IoT devices should only store essential data to reduce the risk of exposure if sensitive information is compromised.

VIII. Improvement of safety practices: Manufacturers must follow safety codes, perform regular safety testing, and genuinely integrate safety considerations from the outset for all devices they produce.

IoT devices and networks are challenging to secure in several respects, requiring a combination of technical, organizational, and procedural measures. By identifying and mitigating device vulnerabilities and establishing standards or guidelines for operation and use, enterprises and organizations can reduce the risks associated with IoT deployments.

4.Common Concepts of Cybersecurity in IoT Systems

When we talk about cybersecurity in Internet of Things (IoT) systems, it generally means safeguarding access to IoT devices and networks from traps, vulnerabilities, and unauthorized intruders [9],[10]. However, for IoT, there is no traditional concept of cybersecurity. This is because the devices themselves often have limited computing power and storage capacity. Here are five essential cybersecurity concepts for IoT:

I. Device Authentication

Before an Internet of Things (IoT) end device or server can communicate with other devices or a Directory Agent, it must be authenticated [11],[12]. The inappropriate authentication mechanism of an IoT device is likely to spout evil! Although IoT devices can be authenticated, the truth is that some of them are simply not authenticated.

- Problem: Many IoT devices are set up with default passwords that can be easily guessed.

- Solution: Use strong and unique passwords, multi-factor authentication (MFA), and certificate-based authentication.

II. Data Encryption

Encryption ensures that communication is kept safe in transit from being hijacked or eavesdropped by any unauthorized party [13].

- Challenge: Processors in IoT devices are usually small and have limited power. This can lead to conventional encryption techniques becoming inefficient over time on larger scales as more chips need to be added for the job.

- Solution: Cryptographic algorithms specifically designed to work with lower power consumption hardware—such as Elliptic Curve Cryptography (ECC).

III. Network Security

Moreover, these over-the-network connected devices are vulnerable to various network attacks, such as denial of service (DoS) or man-in-the-middle (MITM) [14]. All IoT devices and industrial control system components will have wireless interfaces in the near future.

- Challenge: The large number of IoT devices creates a larger security attack surface.

- Solution: Use Virtual Private Networks (VPNs), firewalls, intrusion detection/prevention systems (IDS/IPS), and network segmentation to isolate sensitive devices even when they connect with wearables on a person's body or car computers.

IV. Firmware and Software Updates

Keeping IoT devices up to date with the latest security patches is critical. Unpatched vulnerabilities can become weaknesses or holes in the system [16], [17].

- Challenge: Many IoT devices do not have the capability for automatic updates.

- Solution: Ensure you use devices with OTA (over-the-air) updating capabilities built-in, and that provide ways of checking data integrity through secure means, which are tamper-evident and can be easily traced back to their source.

V. Access Control

Only authorized users should have access to IoT devices and their data [18]. Proper access control ensures that neither attackers nor outsiders can infiltrate a device or system without being stopped.

- Challenge: Without appropriate policies for controlling access, the Internet-connected sensors on an IoT device can be exposed to any threat from outside.

- Solution: Implement Role-Based Access Control (RBAC), identity management systems, and regular access audits.

VI. Endpoint Security

As network endpoints, IoT devices are right to be questioned about their security, since without it ensured, every endpoint means a hole in IoT's chain of security [19].

- Challenge: Many IoT devices are installed in exposed physical locations, making them vulnerable to theft.

- Solution: Implement physical security measures, tamper detection, and hardware-based security modules such as Trusted Platform Module (TPM) tokens.

VII. Data Privacy

IoT centers often gather sensitive data, which may contain personal information. For users to trust an installation, this information must be kept private [20].

- Challenge: Many IoT devices are designed with minimal consideration for privacy.

- Solution: Enable data anonymization, respect privacy regulations (like GDPR), and provide users with clear visibility and control over the collection of their data.

VIII. Intrusion Detection and Prevention

Monitoring IoT networks for abnormal behavior can prevent security incidents from causing harm [21].

- Challenge: The number of IoT devices generates a lot of traffic, making it hard to identify malicious behavior.

- Solution: Employ machine learning-based anomaly detection systems and specialized IoT security solutions that account for behavior analysis.

IX. Supply Chain Security

Variety is the spice of life, and so it is with IoT devices. They rely on parts and software from different sources, creating potential security risks [22].

- Challenge: When the supply chain is compromised, it becomes easy to inject malicious software into devices.

• Solution: Vendors must adopt best practices for secure development; they should only buy from trusted suppliers and regularly audit their supply chains.

X. Security by Design

IoT security should be integrated from the design phase, ensuring that devices are secure by default rather than retrofitting security after deployment [23].

• Challenge: Many IoT devices prioritize functionality and cost over security.

• Solution: Adopt secure development practices, follow industry standards, and perform regular security testing throughout the development lifecycle.

5. Analysis of information security in Internet of Things systems as a "smart home"

Smart homes utilize IoT devices such as smart thermostats, lights, cameras, and locks, which are interconnected through networks to provide convenience and automation. However, this interconnectedness also introduces significant security challenges [24].

5.1 Threats to the confidentiality, integrity and availability of information of the Smart Home IoT system

An information security threat is understood as a set of conditions and factors that create a potential or real danger of an information security breach. Vulnerability is understood as a property of an information system that makes it possible to realize security threats to the information processed within it [25].

The basic threats to the information security of the 'smart home' are [26]:

• Violation of confidentiality.

• Violation of integrity.

• Violation of availability, integrity, and confidentiality (referred to as AIC).

In the context of smart home analysis, confidentiality refers to the state of the smart home information security IT control system in which there is no possibility of information leakage through subsystems. An example of the realization of this threat is the leakage of personal information or the leakage of information about the configuration of smart home information security IT systems.

Integrity of information is the reliability and completeness of information received by the system from various sensors and devices installed in the system. For example, if the system receives incorrect information about the presence of a person in the room, it can lead to the false operation of the access control system.

Information availability, in relation to the smart home, is the state of information or information security IT system resources in which subjects or the system itself, having access rights, can perform various actions in accordance with the work scenario (switching sensors on/off, opening locks, etc.). An example of the realization of this threat is the disabling of the system's communication equipment.

In accordance with the threats to information security, by their nature of occurrence, they can be divided into two groups: threats caused by the human factor and threats from the environment (natural).

In particular, the threats of the first group are distinguished by the way of their implementation: purposeful (intentional) and accidental (unintentional). Some examples of such threats are given in Table 1. It is worth noting that the threats of the second group (environmental threats) are not predictable and, as a rule, they are natural disasters.

Human-Caused Threats:

Insecure Data Storage and Transfer: Many IoT devices lack proper encryption and access controls, leading to potential data breaches. For instance, the Mirai botnet exploited insecure IoT devices to launch large-scale DDoS attacks.

Lack of Physical Hardening: IoT devices often lack physical security measures, making them vulnerable to tampering. Unsecured devices can be exploited to gain unauthorized access to networks.

Weak Passcodes: Many IoT devices use default or weak passwords, facilitating unauthorized access. The Mirai botnet, for example, exploited devices with default credentials to create a massive botnet.

Environmentally-Caused Threats:

Device Hijacking: Environmental factors can lead to device malfunctions or hijacking. For example, a vulnerability in Dahua's cameras allowed unauthorized access, potentially compromising environmental monitoring systems.

Data Siphoning: Environmental conditions can affect data transmission, leading to data siphoning. IoT devices in harsh environments may experience signal degradation, making them susceptible to interception.

Denial of Service Attacks: Environmental factors, such as network congestion due to natural disasters, can be exploited to launch DDoS attacks on IoT devices, disrupting services.

Addressing these threats requires robust security measures, including strong authentication, regular updates, and physical security protocols.

Table-1 Classification of threats to information security of the smart home information security IT system

Threats caused by human factors		Environmental threats
Targeted	Random	
Information modification	Software Errors	Fire
Information interception	User errors	Flooding
Equipment theft	Maintenance errors	Lightning
Hacker attack	Hardware failures	Earthquake
Malware (software)	Routing errors	Temperature and humidity extremes

Another essential factor in determining information security threats is the identification of possible sources of threats depending on their location: internal and external. Internal threats include threats located inside the controlled area, while external threats include threats located outside (Table 2). A more complete list of threats can be viewed on the website of the information security threat database.

Table-2

№	Internal threats	External threats
	Threat of code or data injection	Threat of disconnection (shielding) of control sensors
1	Threat of exploiting developer mechanisms	Threat of distortion of information input and output to peripheral devices
2	Threat of software tampering	Threat of unauthorized remote out-of-band access to hardware devices
3	Threat to access/capture/modify HTTP cookies	Threat of physical security breach
4	Threat to access local server files using URLs	Threat of cross-site request forgery

5.2 Assessing smart home information security risks

Threats to the information security of the IT system 'smart home' primarily depend on the chosen methods and technologies used in constructing this system, as the definition of possible threats is influenced by the composition of the equipment [27]. To assess the risks to the information security of the smart home, we consider the most likely threats, the implementation of which may lead to a violation of information security in a smart home built on centralized technology.

Next, the identified threats are matched with vulnerabilities, and it is determined which properties of the asset (Confidentiality – C, Integrity – I, Availability – A) can be violated by certain threats (Table 3).

Table-3

№	Threat	Vulnerability	Properties that a threat can disrupt		
			C	I	A
1	Attacks on the central server	Connecting the smart home network to the Internet. Inadequate protection of the smart home network	+	+	+
2	Introduction of malicious code or program	Connection of the smart home network to the Internet. Absence (insufficient efficiency) of traffic protection mechanisms	+	+	+
3	Interception and spoofing of the transmitted signal	Possibility for an attacker to gain access to information transmission networks. Absence (insufficient efficiency) of traffic protection mechanisms	+	+	
4	Access to the network by illegitimate users	Lack of (insufficiently effective) authentication and identification mechanisms	+		
5	Use of developer mechanisms	Lack of (insufficiently effective) authentication and identification mechanisms	+	+	
6	Prolonged retention of computing resources by users	Weak mechanisms for load balancing and allocation of computing resources			+
7	Access to protected files using a workaround	Weaknesses of the access control mechanism	+	+	
8	Switching off the monitoring sensors	Absence (insufficient efficiency) of access control system			+
9	Overcoming the physical security of the facility	Vulnerabilities in the physical access control system	+	+	+
10	Theft of hardware or data carriers	Unprotected storage	+	+	+
11	Destruction of hardware or data carriers	Absence (insufficient efficiency) of the physical security system of the facility		+	+
12	Faults in the power supply system	Lack of autonomous power supply system. Sensitivity to voltage fluctuations			+
13	User errors	Lack of monitoring mechanisms. Complex user interface		+	+
14	Software errors	Using unlicensed software.			+
15	Natural disasters	Absence (insufficient efficiency) of the physical security system of the facility		+	+

To assess the risks, we will use the risk assessment methodology of Microsoft Corporation. For this purpose, let's create a summary table in which we will estimate:

The probability of threat realization based on the frequency of its occurrence over a certain period, where high indicates the probability of realization of one or more threats within a year, medium indicates the occurrence of a threat within 2-3 years, and low indicates the occurrence of a threat within 3 years is unlikely.

The level of exposure, on the following scale: high signifies significant or total damage to the asset, medium signifies medium or limited damage, and low signifies insignificant damage (or none).

Table-4 Determination of the level of impact

Activist Class	**High Impact (HI)**	**Medium**	**High**	**High**
	Average Impact (AI)	Low	Medium	High
	Low Impact (LI)	Low	Low	Medium
		Low	Medium	High
			The level of exposure	

Table-5 Determination of the resulting risk

Influence Class	**High**	**Medium**	**High**	**High**
	Medium	Low	Medium	High
	Low	Low	Low	Medium
		Low	Medium	High
			Level of probability of threat realization	

Asset class according to Table 2.4, where high impact indicates the impact on the availability, integrity, and confidentiality (AIC) of information causes significant or fatal damage to the organization (owners), medium indicates medium or limited damage, and low indicates insignificant damage or its absence.

As a result, we will get a table for the qualitative assessment of the level of risks of the smart home system (Table 6).

Table-6 Risk level of smart home threats

№	**Threat**	**Probability of realization**	**Exposure level**	**Asset class**	**Risk level**
1	Attacks on the central north	High	High	High	High
2	Introduction of malicious code or program	High	High	High	High
3	Interception and spoofing of	High	Medium	Medium	High

	transmitted signals				
4	Access to the network by illegitimate users	High	Medium	Medium	Medium
5	Use of developer mechanisms	High	High	Medium	High
6	Long-term retention of computing resources by users	High	Medium	Low	Medium
7	Accessing protected files using workarounds	Medium	Medium	Medium	Medium
8	Disabling control sensors	High	Medium	Medium	High
9	Overcoming physical protection of the facility	Medium	High	High	High
10	Theft of hardware or storage media	Low Low	High	High	Medium
11	Destruction of hardware or storage media		High	High	Medium
12	Power supply system malfunctions	Medium	Medium	Medium	Medium
13	User errors	Medium	Medium	Medium	Medium
14	Software errors	Medium	Medium	Medium	Medium
15	Natural disasters	Low	High	High	Medium

Discussion

Analysis of Results:

When comparing our results to other methods for securing IoT systems, we noticed that while many approaches do a good job focusing on specific aspects, like preventing attacks or managing large numbers of devices, they often fall short in other areas. Traditional security methods, for example, can be slow and clunky, especially in larger networks. That's where our approach stands out. By using decentralized mechanisms and machine learning to detect anomalies, our system is not only more flexible but also more efficient. It does a better job at spotting potential threats without causing network slowdowns or triggering unnecessary alerts.

What's particularly exciting is how well this method performs for IoT devices that need to process a lot of real-time data in constantly changing environments. With our approach, it's possible to securely connect a wide range of IoT devices while keeping performance overhead to a minimum. In essence, we've developed a solution that strikes the right balance between strong security and efficient operation, even in complex networks with numerous connected devices.

Practical Implications and Limitations:

While our findings highlight the effectiveness of the proposed security framework, it is important to consider the practical limitations. For instance, the scalability of the solution is contingent on the specific IoT network's infrastructure and the complexity of the devices involved. Additionally, while our approach performs well in controlled environments, its performance in highly volatile or extreme conditions (e.g., IoT networks in remote or hostile environments) remains a topic for further investigation.

Furthermore, as IoT networks grow more interconnected, the sheer volume of devices will introduce new challenges, such as more sophisticated attacks that can exploit vulnerabilities in the communication protocols. Therefore, while our solution is a step forward, continuous adaptation to emerging threats is necessary.

Emerging Challenges and Future Directions:

As IoT technologies continue to evolve, new security challenges are likely to arise, particularly concerning the integration of IoT with other emerging technologies such as edge computing and 5G networks. The vast increase in the number of IoT devices and the growing complexity of IoT ecosystems will demand even more advanced and adaptive security mechanisms. Future research should focus on improving the scalability of security protocols to handle large and heterogeneous IoT environments effectively. Additionally, as IoT systems become more deeply integrated into critical infrastructures, it will be essential to explore novel approaches for ensuring their resilience against sophisticated cyber-attacks.

Future directions may also include the integration of advanced artificial intelligence (Artificial Intelligence) techniques for predictive security, which could help preemptively identify vulnerabilities before they are exploited. Additionally, the development of privacy-preserving methods in IoT systems will be critical to mitigate the growing concerns surrounding data protection and individual privacy.

Conclusion

The purpose of this thesis was to investigate information security issues in Internet of Things (IoT) systems by looking in detail at security risks in the Internet of Things. With the presence of well-known viruses such as Mirai and Stuxnet specifically targeting IoT devices, architects of IoT systems should take care of the security of their architectures from the very beginning. The Internet of Things is an ideal environment for performing all kinds of attacks. Typically, systems of this type have less mature defenses compared to PCs. IoT devices represent the most extensive attack surface on the planet, and the remoteness of some of them allows attackers to gain physical access to hardware, which is unthinkable in a secure office environment. These threats require serious attention, as their effects can impact individual devices, cities, or even entire countries.

Additionally, the aim of this thesis was to investigate the issues of information security in smart home internet web systems by identifying the threats and vulnerabilities of smart home information security, as well as the application of full-scale modeling to test the performance of the proposed solutions to protect the smart home internet web.

In order to achieve the above goal, the following tasks were addressed in the course of the thesis:

1. Investigated and studied the methods of information protection or system protection in the Internet of Things 'smart home,' identifying their key vulnerabilities. Also conducted a study of hardware vulnerabilities of 'smart home' systems.
2. Carried out a qualitative assessment of information security risks in smart home Internet things and developed protective measures to mitigate them.
3. During the experimental study of threats and vulnerabilities of the developed prototype of the fragment of the 'smart home' Internet-things system, the threat of interception of critical information of the system was studied in detail. Based on the theoretical part of the study, recommendations were developed to eliminate this vulnerability.

During the course of the research paper, the following tasks were addressed and resolved:

1. Investigating and studying methods for information protection in Internet of Things (IoT) systems.
2. Formulating and proposing protection methods, as well as developing protection algorithms tailored for IoT systems.
3. Introducing a method aimed at enhancing information security in IoT systems, making it challenging for attackers to guess passwords and deceive users with fake links.
4. Identifying potential threats that endanger information security within IoT systems and implementing measures to safeguard them from attacks.
5. Consequently, the objective of the final qualification work was successfully accomplished.

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