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Safeguarding Tomorrow: Strengthening IoT-Enhanced Immersive Research Spaces with State-of-the-Art Cybersecurity

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Abstract: While the Next-Generation Technology is shaping the Globe with very great foundations, the importance of Internet of things (IoT), Augmented reality (AR) and Virtual reality (VR) becomes a great lead in the research and education. This wide change finds its own space in IoT-Enriched Immersive Research Spaces (IoT-IRS), which becomes a frontier that integrates these technologies will inherit its own security challenges. While IoT-IRS offers great collaboration and its impressions in analyzing the real time data analysis and explores the expansion, it also suffers from exploits via vulnerabilities exists for cyber-attacks. This paper explodes the prospects of the IoT, AR and VR interplay and delve into the dynamic domain of these IoT-IRS infrastructures. Though this paper talks about the captivating prospects of the IoT-IRS, the paper also underscores the important role of cybersecurity for these domains. Via this paper we emphasize the important role in fortifying the data integrity, by preserving the privacy within the shared virtual spaces, and establish barriers against the cyber evaluating landscape. In principle, this paper navigates the technology know-how and immersive possibilities, all the while remaining steadfast in its commitment to amplify the advancements of cybersecurity to tap the innovation and resilience of the technology they safeguard.

Keywords: convergence, immersive, IoT-enhanced, cybersecurity, paradigm shift

1. Introduction

While the new technology is progressing, the innovation becomes the crossroad of advancement and creativity. The convergence of Internet of Things (IoT) [3-5], augmented reality (AR), and virtual reality (VR) will orchestrate the transformation in a way that fundamentally it will reshape the transformation, poised not just to reshape but alter the landscape of research, education, and the experience. This change will be like interweaving threads of a complex tapestry, transcends technology where the boundaries between the physical and the digital dissolve, revealing a vivid canvas where reality and cyberspace blend seamlessly. From this transformation a phenomenon known as IoT-Enhanced Immersive Research Spaces (IoT-IRS), a juncture of evolution where the ordinary and the extraordinary converge to create immersive learning, experiential exploration, and innovative horizons that once existed solely in the realm of imagination.

As we investigate the change, the potential of IoT-IRS has become an illusion. We have never anticipated this change historically. IoT-IRS advances us with a deep shift that cross the perimeter of research and academic education. Historical methodologies given an idea for this system with not only aspirations but also realities, however in this new thought process has gained a momentum in the new generations. However, as the change and innovation has reached to its heights, the risks and the vulnerabilities are also advanced and has been impacting our lives significantly. This has become a challenge as well as journey to understand the nuances of the technology deeply with a foresight of responsibility to mitigate the threats. This brings us a critical need of incorporating the cybersecurity controls that includes vigilance and innovation. Hence, the landscape of possibilities to explore the dynamics of security controls, this paper discusses the roles of both storyteller and a coach on how best we can incorporate the controls into the evolving cyber-attacks. The journey not only covers the critical domains of AR, VR and IoT, but also discuss the underlying interface to implement them in IoT-

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IRS. The outcome of this paper not only talks about the academic disclose but also navigates deep into the technology, and their integration, and its potentials to explore the insights of the human potential. The paper at hand is to help engaging the commitment to safeguard the future by exploring the Internet of things (IoT), Augmented Reality (AR) as well as Virtual Reality (VR) in academia and Research.

While IoT-IRS helps the collaboration, near real-time data analysis, and expansive exploration, it exposes threats. This paper embarks on a thorough exploration, delving into IoT, AR, and VR [22, 24, 25] within IoT-IRS. This paper also underscores the role of cybersecurity, data integrity, safeguard privacy within shared virtual spaces, and establish defenses over cyber landscape.

2. Background

Traditionally we have witnessed various transformations that drives the innovation and brings a new era of research that drives the Globe to the new heights. At this juncture we will be witnessing how the human creativity and technology advancement transforms and reshapes the human lifestyle. The groundbreaking technologies such as Internet of Things (IoT), augmented reality (AR), and virtual reality (VR) will be the next generation that is going to transform our lives in the way we have never imagined. IoT has been transformed in such a way that it provides a key communication media between machines and humans. AR and VR have extended their footprints to take us in digital world with an un-imagined experience. These technologies became a new realm of possibilities opening doors for both innovation and a new era of science fiction.

In this landscape, IoT-Enhanced Immersive Research Spaces (IoT-IRS) has been witnessed as a new progression. These harness the superiority of IoT, AR, and VR to transform the way we live, educate and collaborate each other with both machines as well as human. These boundaries between real and virtual, offering a new ground to explore future possibilities.

3. Taxonomy of Methods and Techniques

We will discuss various techniques and methods that became an important step for IoT-Enhanced Immersive Research Spaces (IoT-IRS) and discusses important approaches of Internet of Things (IoT), augmented reality (AR), and virtual reality (VR) to create research learning and opportunities in this era.

3.1. Data sensing and integration techniques

The data being collected by the IoT has been processed after being aggregated within the IoT-IRS ecosystem. These sensing techniques will include Aggregation and Data Collection, Integration of Sensors for fusing the Data and Near Realtime Analysis.

- **IoT methodology for collecting and aggregation of data**

  Sensors, Actuators and Smart devices are being used for Analyzing and Processing of data [21] for analytical purposes.

- **Sensors integration to fuse the data**

  We need to establish a process for fusing of data.

- **Processing of near real-time data for analysis**

  This is one of the important steps for Near Realtime analysis of data for decision making purposes.

3.2. Immersive and integration techniques for visualization

We need to work on various techniques that helps to experience and facilitate visualization within IoT-IRS. Techniques includes Visualization methods, Interactions, Approaches, Analysis and Learnings.

- **Visualization using augmented reality (AR)**

  Marker based and Marker less methods being used in Visualization of AR models.

- **Interactions of virtual reality (VR)**

  User interactions has been detailed via Virtual Reality (VR) to enhance the experiences.

- **Approach for mixed reality**

  Both AR and VR gives a perspective, an approach needs to be designed to get a perspective of Mixed Reality to enhance experience for the user in a filmy way.

4. Problem Statements and Research Gaps

This section talks about various problem statements in IoT-IRS implementation and the research gaps in this discipline.

4.1. Problem statements in IoT-IRS implementation

- **Data processing and analysis in real time**

  Capturing data in the real-time for analysis to present the near-real time visuality via a mixed reality of AR and VR is practically challenge. System needs to be advanced to find innovative ways for doing this work.

- **Integration of sensors and actuators**

  As IoT is a new change, the way we integrate the sensors, actuators of the IoT devices becomes another challenge. Few protocols though exist they possess their own challenges and research is needed to build a secure ecosystem for integration of these devices.

- **Interactions**
  Interactions and capturing of natural gestures and bridging the gaps with the solutions becomes another challenge. These interactions shall be in a natural way and has been immersive.

4.2. Research gaps in security and privacy

- **Access controls and authentication frameworks**
  Access controls between the sensors and actuators possess a critical gap for securing the devices in IoT. As the sensors have limited processing and space, incorporating strong authentication and authorizing process is cumbersome. Research must be advanced to bring light weight Authentication, Authorization and Access controls to secure the IoT-IRS ecosystem.

- **Data sharing, privacy and secure communication**

  Sharing of data securely without exposing the PII, SPI [23] among IoT devices is crucial. Research must be advanced to bridge the gaps to mitigate threats without introducing the latency is a challenge.

5. IoT-IRS Architecture

IoT-IRS architecture [1, 2], built on IoT, AR, and VR blend helps to create masterpieces of immersive engagement. The architecture [15] has interconnected layers: the IoT Sensor Network, the Augmented and Virtual Reality Interfaces, and the Collaborative Cloud Platform.

Below are some reference architectures for IoT-Enhanced Immersive Research Spaces (IoT-IRS) systems [13]:

5.1. Seven layered IoT-IRS architecture

This Seven Layered architecture is organized into various layers. The below Table 1 represents the architecture

Table 1
Layers of IOT-IRS Architecture and their Significance

S. No	Layers	Representation
1	Physical Layer	Also called as Device Layer and consists of Sensors, Actuators for collecting and processing of data
2	Network Layer	Also called as Communication Layer. Uses Sensors, Actuators for collaborating the data via Network Protocols such as MQTT, CoAP and HTTP.
3	Processing Layer	Process and transforms the data
4	Virtualization Layer	Bridge realizing data and convert into visuals (virtually)
5	Presentation Layer	Transforms experiences into VR and AR
6	Collaborative Cloud	Platform for storing, processing and sharing of actors in the ecosystem
7	Security Layer	Ensures Cyber via encryption, authentication, Access controls and IPS

5.2. Decentralized IRS architecture

In this Architecture the distribution of components includes Edge devices, Fog/Edge computing, Cloud and Interfaces layer / The below is the Emphasis is on distributed components:

- **Edge devices**
  IoT devices are equipped with local processing sensor capabilities to do data filtering and analytics.

- **Fog/Edge computing layer**
  Intermediate layer between devices and the cloud.

- **Cloud collaboration**
  This layer is used to merge, store and process the collected data into the cloud.

- **Presentation layer**
  AR and VR are being used as an interface for providing VR and AR experience to the users via this layer.

5.3. Semantic architecture of IRS

This architecture is more of semantically driven and consists of Annotation, reasoning, collaboration and Interfaces.

- **Layer of annotation**
  All the metadata is being packed in this layer to present a semantic pattern.

- **Layer of reasoning**
  Proper reasoning is being applied on the meta data collected in the above layer.

- **Layer of collaboration**
  Consists of a centralized space for collaborating and sharing of data for meaningful purposes.

- **Layer of interface**
  Acts as an interface for the users for providing AR and VR experiences.

5.4. Hybrid architecture for IRS

A Hybrid architecture uses both the benefits of the above architectures. The components include Edge and Fog Nodes, collaboration cloud and interfaces.

- **Edge/Fog nodes**
  Distributed edge nodes for data processing.

- **Collaborative cloud platform**
  Centralized cloud for data storage, processing and collaboration.

- **AR/VR interface layer**

Interfaces cloud and fog resources for immersive experiences to users.

6. Key Security Challenges

As we walkthrough the talk of IoT-IRS, data integrity, device authentication, end-to-end data encryption, are the challenges for IoT, AR, and VR interfaces. We need to safeguard this expansive domain, the IoT device firmware from vulnerabilities that could cascade into catastrophic breaches. The defense against these malicious virtual entities becomes so important for this collaborative environment.

6.1. Data integrity assurance

Maintaining the authenticity, accuracy, and reliability of IoT data within immersive environments is crucial and needs to be assured.

6.2. Enhanced device authentication

Ensuring identity for IoT devices and users requires the below authentication mechanisms.

- **Gesture-based authentication**
  - **Variation**
    - Utilize gesture recognition to authenticate users.
  - **Innovation**
    - Implement machine learning algorithms to distinguish genuine and mimicked gestures.
  - **Implementation**
    - Combine motion sensors and AI-powered gesture recognition algorithms in VR/AR devices. Users perform their predefined gestures to gain access.
- **Biofeedback authentication**
  - **Variation**
    - Use biofeedback signals, such as heart rate or brainwave patterns, to authenticate users. Stress levels or concentration patterns serve as authentication.
  - **Innovation**
    - Incorporate real-time analysis of biofeedback for continuous authentication during virtual interactions.
  - **Implementation**
    - Equip VR headsets with biometric sensors support authentication patterns implementation.
- **Multi-modal authentication**
  - **Variation**
    - Combine multiple authentication factors, such as facial, voice and a physical action (e.g., a specific head movement).
  - **Innovation**
    - Employ machine learning to dynamically adjust authentication requirements based on behavior.
  - **Implementation**
    - VR/AR incorporate cameras and microphones for facial and voice recognition.
- **Dynamic biometric authentication**
  - **Variation**
    - Utilize dynamic biometrics, such as typing rhythm or eye movement to authenticate users.
  - **Innovation**
    - Implement behavioral patterns to adapt changes.
  - **Implementation**
    - VR/AR devices monitor patterns or eye movements for interactions.
- **Contextual authentication**
  - **Variation**
    - Authenticate users based on their behavior, location, and environmental context.
  - **Innovation**
    - Employ context-aware machine learning models that adapt authentication requirements.
  - **Implementation**
    - Integrate sensors in VR/AR devices to capture contextual data.
- **Virtual biometric tokens**
  - **Variation**
    - Unique biometric tokens to authenticate.
  - **Innovation**

  - Dynamic tokens to prevent replay attacks.
- Implementation
  - Virtual objects with unique patterns for gestures.

- **Emotion-based authentication**
  - **Variation**
    - Authenticate users' emotional responses.
  - **Innovation**
    - Use emotional analytics and AI to analyze user reactions for authenticity.
  - **Implementation**
    - VR/AR applications to evoke emotional responses.

These variations are innovative methods for robust authentication.

6.3. End-to-end data encryption

Encryption of data both at rest as well as transit becomes critical concern for securing sensitive data for malformed usage. Deploying end-to-end encryption techniques solves the purposes. For unauthorized access and preventing malicious entries in VR spaces.

6.4. Malicious threats in IRS

Few threats include data breaches, cyber-attacks for ransom, Identity, Propagation of malware, Espionage and un-authorized controls to breach the data are few among them.

- **Cyberattacks**
  Data breaches launch cyberattacks, such as Distributed Denial of Service (DDoS) that cause service disruptions. Hackers uses techniques such as Identify theft, propagation of malware, espionage and un-authorized controls to breach the data for launching these attacks.

6.5. Countermeasures/Mitigation techniques

- **Access control**
  Implementing strong ACLs along with Strong Authentication and Authorization process helps in mitigating these threats.

- **Secure coding**
  Implementing Secure coding practices such as Code Reviews, Code Audits, Penetration testing helps in mitigation of coding vulnerabilities.

- **Hardening**
  Patching of hardware, sensors, actuators mitigate the known and helps in mitigating zero-day vulnerabilities.

- **Intrusion prevention**
  Deploying a Layer 7 Web Application Firewall for top 10 application attacks mitigation as well as a Layer 3, Intrusion Prevention systems helps mitigating from anomalies.

- **Secure communication**
  Use end-to-end encryption techniques and secure networking protocols to protect data at rest and in-transit.

- **Behavioral and heuristic analysis**
  Deploy behavioral analysis tools and techniques to analyze patterns for mitigating behavioral attacks.

- **Segmentation**
  Segment the zones to mitigate the level of exposure, in case if it occurs.

By implementing these countermeasures mitigate the threats posed by malicious virtual elements in the IoT-IRS in ensuring the security, privacy, and integrity.

7. Secure Architectural Challenges

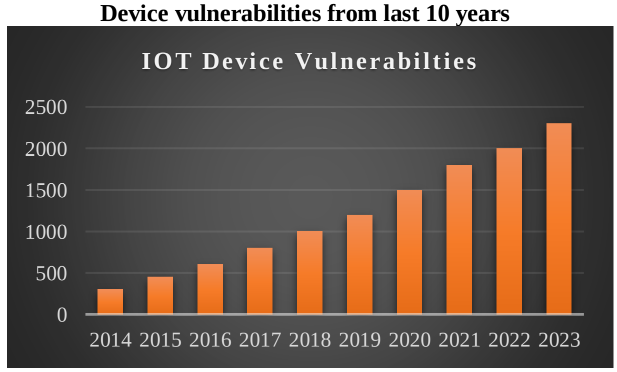
The below are the Architectural/Design security challenges that needs to eb addressed due to ever-evolving threats.

7.1. Device vulnerabilities

IoT Sensors suffer device vulnerabilities such as Weak Authentication practices, default credential usage and missing security patches. Hackers use these techniques to gain unauthorized access

Below Figure 1 showcases the device security challenges spread across last 10 years.

Figure 1
Device vulnerabilities from last 10 years



7.2. Data privacy and integrity

The flow of data from sensors and devices to the cloud and AR/VR interfaces exposes data to potential breaches and tampering. Ensuring the privacy of sensitive data and maintaining data integrity is very crucial for IoT-IRS. Encryption, data anonymization, and secure data transmission protocols [6, 16, 17] (like TLS) should be implemented to protect data during transit and storage. Table 2 shows the percentage increase in data privacy and integrity breaches over the last five years, beginning in 2017.

Table 2
Data Privacy and Integrity breaches

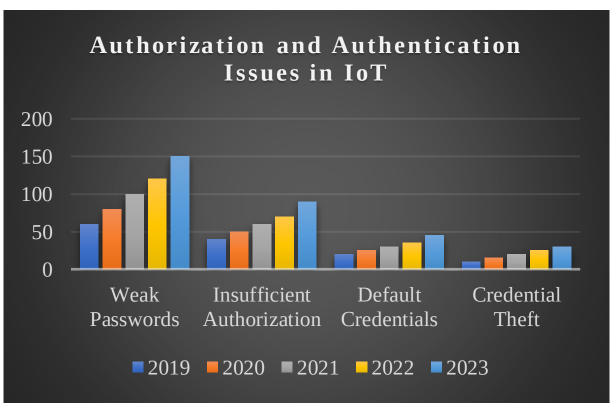
Year	Total Breaches	% increase	Average records/breach	Vulnerabilities
2021	320	25	10000	Weak IoT Auth
2020	270	15	8500	Unpatched VR Software
2019	200	30	7000	Inadequate Encryption
2018	150	20	6000	Compromised Firmware
2017	100	10	5500	Unsecured Network

7.3. Authentication and authorization

Authentication and Authorization is another challenge when it comes to the concern of designing the security for IoT. The se includes lack of Identity management, RBAC controls and missing policies of Authentication, Authorization and Availability.

Figure 2 shows the concerns from the last five years.

Figure 2
Authentication & authorization issues



7.4. Network security

This is one of the important design challenges that needs to be addressed. Implementation or identifying the strong networking protocols and their usage via Access Controls becomes a design threat for IoT.

Figure 3 shows network threat vectors from 2019 to 2023.

Figure 3

Network threat vectors

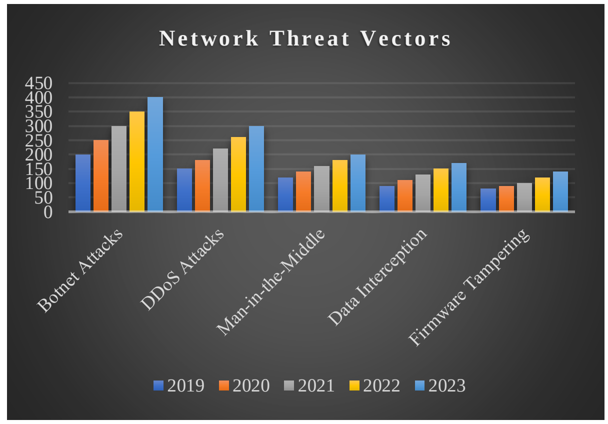


Table 3
Network threat vectors and impact

Year	Total Incidents	% increase	Avg. Downtime (hrs)	Threats
2021	250	20	6	DDOS Attacks
2020	200	10	5	Malware Infections
2019	180	15	4	Phishing Attacks
2018	150	12	5	Insider Threats
2017	120	8	6	Vulnerability Exploits

7.5. Interoperability and standards

IoT-IRS often combines devices and technologies from different manufacturers that lacks the standardized security protocols lead to compatibility issues [18] and potential security gaps. Adhering to recognized IoT security standards and frameworks can help address these challenges. The Table 3 refers to interoperability and standards concerns in 2017 through 2021. Table 4 represent the concerns of Interoperability and standards for IOT-IRS.

Table 4
Interoperability and standards concerns

Year	Total Concerns about Standards	% increase	Avg. Resolutions Time (Weeks)	Top Interoperability and Standards Issue
2021	180	10	8	Device Compatibility
2020	150	8	7	Data Format Mismatch
2019	130	12	9	Protocol Conflicts
2018	120	6	6	Security Standards
2017	100	5	7	Integration Complexity

7.6 AR/VR interface security

Managing the security without impacting the AR/VR experience becomes important at the interfaces. Table 5 showcases the concerns of interfaces from last 10 years.

Table 5
AR/VR interface security concerns

Year	Total Concerns about Standards	% increase	Avg. Resolutions Time (Weeks)	Top Interoperability and Standards Issue
2021	350	12	5	User Privacy
2020	320	8	6	Data Leakage
2019	290	6	7	Malware Attacks
2018	260	5	8	Unauthorized Access
2017	240	7	9	VR Motion Sickness
2016	210	4	6	Phishing in AR
2015	180	3	5	Device Vulnerabilities
2014	150	6	7	Location Tracking
2013	130	5	8	App Permissions
2012	100	4	9	Content Spoofing

7.7. Platform security

Collaboration and managing the data via a centralized cloud and mitigating attacks of this platform say it on-premise or on Cloud becomes a critical design challenge.

7.8. Privacy concerns

Mitigate privacy concerns such as PII, SPI data is paramount. Masking, anonymizing, Consent and managing them for auditing purposes becomes a design challenge that needs to be addressed.

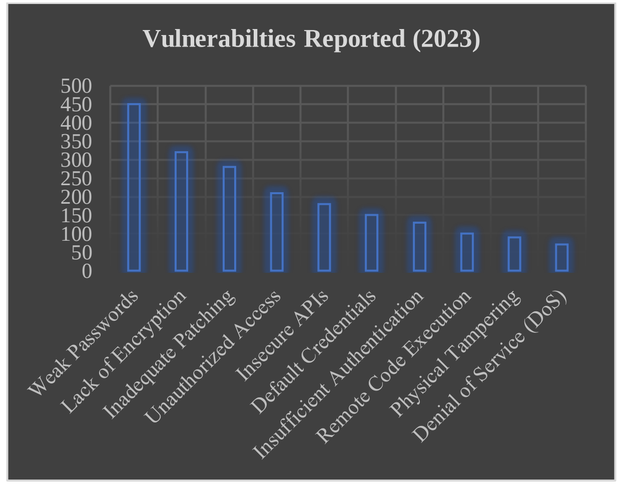
7.9. Third-party integration

Integrating third parties, ensuring their whitelisting becomes another challenge to mitigate the threats originating from third party to our environment. Methods, tools need to be deployed ensuring the third parties integrated are secure enough and perioding validation is required to ensure their compliance.

7.10. Continual monitoring and updates

Deploying a method to monitor the environment is crucial and cost implication. Proper Security operations and deploying SIEM solutions are paramount in monitoring and establishing a secure auditing team for ensuring updates on the environment and device hardening is another design challenge that needs to be taken care of . Figure 4 below showcases the vulnerabilities reported in this area in 2023.

Figure 4
Vulnerabilities reported in 2023



There has been a significant increase in reported vulnerabilities and in Figure 4 represent an aerial view.

8. Cyber Security Solutions for IoT- IRS

In the face of these challenges, encryption rises as a cornerstone of cybersecurity, enveloping data in layers that guard against unauthorized access. Multi-factor authentication emerges the thresholds against unverified entry. Secure boot processes leave IoT devices in a trusted state from being tampered. The power of block chain is creating an immutable ledger that attests authenticity and integrity of IoT-generated data.

- **End-to-end encryption**
  Implementing End-to-End encryption to shield data from unauthorized access.

- **MFA (multi factor) authentication**
  Implement MFA or 2FA (2 Factor Authentication) to mitigate the unauthorized entry of users.

- **Secure boot processes**
  Secure boot ensures unauthorized modification of the sensor's operations.

- **Quantum and block chain usage for data integrity**
  Utilizing latest technics such as block chain, Quantum to ensure integrity of data.

9. Technical Considerations

Securing IoT]-Enhanced Immersive Research Spaces (IoT-IRS) applications requires some technical considerations to ensure the security of IoT-IRS applications:

9.1. Device security

- **Sensor authentication and authorization**

Implement strong Authentication and Authorization techniques, Access controls for securing the devices.

- **Firmware updates**

  Patch and update the firmware for zero days as well as to protect the known vulnerabilities.

- **Secure boot**

  Deploy algorithms for secure boot process in case of boot failures or tampering of the devices.

9.2. Data encryption

Data encryption is the process of converting sensitive information into a code to secure it from unauthorized access, ensuring that only authorized parties can decipher and use the data.

- **Data in transit**

  Use strong encryption protocols (like TLS) to encrypt data as it travels between devices, nodes, cloud platforms, and AR/VR interfaces.

- **Data at rest**

  Encrypt data stored on IoT, nodes, and cloud platforms to prevent unauthorized access.

9.3. Network security

Network security devices such as IPS, Firewalls, proxies, NAT helps in mitigating network attacks.

- **Firewalls and intrusion prevention systems**

  Implement proxy or next generation firewalls along with Network Intrusion prevention system to filter unwanted/suspicious/malicious bi-directional traffic [19, 20] to safeguard the networks.

- **Segmentation**

  Segment High-Risk and Low-Risk based DMZ and Non-DMZ patterns will enhance security posture of the network.

9.4. Authentication and access control

Authentication places an important role to prevent unauthorized activities of users as well as systems. Few techniques include:

- **RBAC (role-based access control)**

  Implement role-based access controls using an Identity and Access Management System/software to define the roles and responsivities of the users/devices.

- **Multi-factor authentication (MFA)**

  Innovative MFA or 2Factor Authentication mitigates unwanted access controls of the users for the systems being deployed.

- **Biometric fusion**

  Biometric authentication enhances the complexity of compromise.

- **Behavioral biometrics**

  Behavioral pattern safeguards IoT-IRS authentication.

- **Continuous authentication**

  Challenge over a usage using Machine learning helps in mitigating few authentication challenges.

- **Location-based authentication**

  Leveraging location-based user and device authentication factor helps in enhancing the authentication posture.

- **Cognitive authentication**

  Analyzing cognitive responses in verifying user's identity helps in virtual reality environment security.

- **Token-based authentication**

  Tokenization reduce the perimeter of the authentication challenge.

- **Adaptive authentication**

  Adaptive authentication uses risk-based approach in authentication via user's location, device, and behavior to adjust the authentication process dynamically.

- **Visual recognition**

  Recognizing images and immersive learning will provide user-friendly authentication process.

9.5. Cloud security

Cloud security involves a set of technologies, such as:

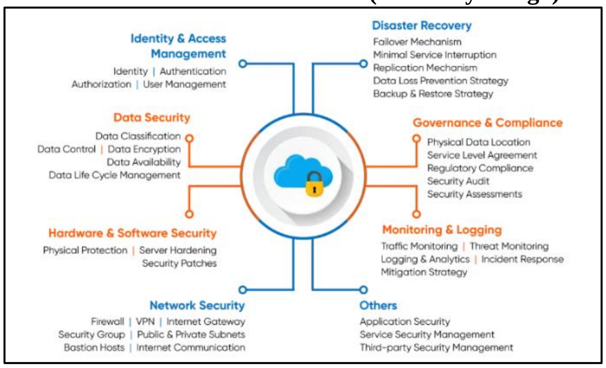
- **Data isolation**

Use virtualization and containerization to isolate data and application to prevent unauthorized access between different tenants.

- **API security**

Secure APIs for communication between IoT-IRS components and the cloud platform, using authentication, authorization, and encryption. Figure 5 below can be used as a framework for Secure by Design.

Figure 5
Secure framework for IoT-IRS (Secure by Design)



9.6. AR/VR interface security

AR/VR interface security such as Secure coding and user authentications helps in bringing security posture for AR/VR.

- **Secure coding**

Secure coding and secure auditing of code helps in mitigating injection and overflow attacks.

- **User authentication**

User and Device authentication helps in preventing illegal access to immersive experiences.

9.7. Data privacy

Data privacy security measures helps in providing transparency about how data is handled.

- **Data anonymization**

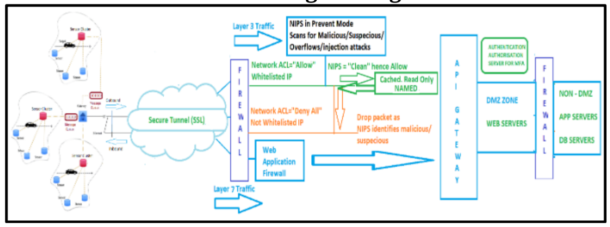
Anonymize sensitive data to ensure personally identifiable information (PII) is not exposed.

- **Consent management**

Obtaining and maintaining the user consent is crucial in collecting and processing data.

The below is a proposal for a Secure Architecture Engineering for IoT-IRS (in Figure 6) for ready reference.

Figure 6
Secure architecture engineering for IoT-IRS



10. Conclusion with Future Directions and Challenges

As we concluding the story of this paper in hand, we have discussed various challenges of the IoT-IRS systems that their road maps, security compilations and the roadmap for the times ahead. The Architectures has been evolved with wide virtual landscapes and advancements possess various strategies such as the implementation of various security controls being discussed in the above sessions. Through these measures, the integrity of IoT devices is preserved.

As we trust becomes paramount in the future cybersecurity landscape [7-12, 14] where technology and human ingenuity goes in hand in hand. The augmented reality and virtual reality models face challenges from various Artificial intelligent such as Generative AI.

In bridging the theory and practice, we have presented various methods, architectural examples, the design challenges and the architectural security controls that needs to be bridged to protect the symphony of IoT-IRS. However, there is huge research gap required to study the AI part of the cyber for mitigating the IOT-IRS security which will be the future scope for this paper

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

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