



A Pervasive Computational Intelligence based Cognitive Security Co-design Framework for Hype-connected Embedded Industrial IoT

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Abstract

The amplified connectivity of routine IoT entities can expose various security trajectories for cybercriminals to execute malevolent attacks. These dangers are even amplified by the source limitations and heterogeneity of low-budget IoT/IIoT nodes, which create existing multitude-centered and fixed perimeter-oriented security tools inappropriate for vibrant IoT settings. The offered emulation assessment exemplifies the remunerations of implementing context aware co-design oriented cognitive security method in assimilated IIoT settings and delivers exciting understandings in the strategy execution to drive forthcoming study. The innovative features of our system is in its capability to get by with irregular system connectivity as well as node limitations in terms of scares computational ability, limited buffer (at edge node), and finite energy. Based on real-time analytical data, projected scheme select the paramount probable end-to-end security system possibility that ties with an agreed set of node constraints. The paper achieves its goals by recognizing some gaps in the security explicit to node subclass that is vital to our system's operations.

Keywords: Cognitive Security Framework, Industrial IoT, Computational Intelligence Methods, Context Awareness, Co-Design.

1 Introduction

Innovation has always been a part of advances in the Cyber-Physical Systems (CPS). From inception of Internet of Things (IoT) to enhancement in its capability of providing cognitive computing solutions, the development has only taken a decade. IoT technology and its applications are creating changes in the fundamental functioning of how things work from new age transports to facilitating businesses in delivering enhanced performances. However, Tariq et al. [7] in their paper suggests that possible implementation of IoT is just surface level and nearly 9 percent of the data generated is still there to be utilized. The authors also suggest that IOT is now entering into a cognitive era and needs to be amalgamated with artificial intelligence (AI) to ensure heightened awareness and security in workflows. To understand how IOT can be used along with AI in enhancement of security aspect or working, the current study will start with relating between IoT and AI.

IoT gathers data from heterogeneous sources such as technologies used to sense, accumulate, act, process, manage and store data. Large data is collected from the heterogeneous sources are known as 'Big data.' This big data is an asset that can offer an advanced vision that makes use of machines easier and efficient by ensuring its high-level modeling and knowledge engineering [52]. However, with such a huge amount of data gathered from technological convergence environment of IoT, privacy, security, and trust are some of common concerns that can be encountered in the process. An IoT based system needs a method based approach that is required to prevent malicious attack an impact the security concern of technical aspects such as availability, confidentiality, and integrity [9].

AI can essentially be seen as a key to unlock this asset. Network collaborated AI uses natural language processing and machine learning to develop deep-learning pattern recognition of the system. This convolution of a neural network with parallel processing of big data obtained from IoT is key to enhance machine to machine learning that possesses the quality to be monitored in real time [20], [53]. AI will enable IOT to be mindful of its usage in context and environment. This enables continuous learning that guides operational effectiveness with enhanced decision-making in real time. Apart from the privacy concerns of usage of big data that can be prevented by adherence to legal and non-legal norms by firms, an amalgamation of AI with IoT can be used for enhanced attack detection and increased resilience and recovery of the system [50].

For IoT applications to function, the data scientists use data mining and machine learning tool to develop patterns and new insights from data. These applications use algorithms as a tool to handle various tasks that are learned by the system based on training data provided. However, with the amalgamation of AI with IOT, machines through deep learning develop the capability to imitate intelligent human behavior. Big data alone is concerned with the analysis of what will happen. Whereas, with AI and networking, action derived from the analysis of the data is the primary concern [39] [31].

For enhanced security, when AI and IoT together can be used in behavioral modeling for enhanced security in Smart IoT devices. The application usage enhanced intrusion detection system. The IoT in the smart device identifies DDoS/DOS attacks, by classifying the movements into normal and threat patterns. With integration of ANN, the devices use simulated IoT network for enhanced security demonstrating over 99 percent accuracy. The behavioral modeling feature allows performance of the system to increase across varied environment [16]. This data can be used to provide insight into the environments in which the system has to perform. As in the usage of AI and IoT because of the enhanced decision making based on behavioral analysis in Self-drive cars. IOT provides the data framework, from radar, a global positioning system (GPS), computer vision, and odometer. AI enhances the security of data by sensing the environment in real time to navigating with human input [8].

Additionally, AI and IoT together can also be used in the mitigation of ZeroDay Attacks. Zero-day attack on an institution exposes it to previously unknown vulnerability and there is no time to prepare for a measure to counter it. It is an opportunity attack on the system. Distributed diagnosis of IoT devices is the first stage to mitigate the risk once the attack is found in the system. While, AI modeled to recognize the risk of new malware that has different defined signature than the system users can also help in prevention of such vulnerabilities [32], [43].

Furthermore, AI and IoT together can be used in prevention of Advanced Persistent Threats (APTs) that are based on Adaptive Learning Algorithms (ALA) [5]. One of the examples, highlighting the amalgamation of IoT and AI for better security has been presented in a paper presented by Choi and Lee [12]. In this paper, authors highlight an artificial intelligence approach that can be used for financial fraud detection under IoT environment. The study highlights IoT uses supervised and unsupervised learning to predict customer behavior in case of detection of financial fraud such as credit card scam by usage of an algorithm such as BOAT [15]. The study Choi and Lee suggest that usage of Artificial neural network (ANN) can enhance the detection of fraud in the real time.

There are database mining systems such as CARDWATCH and Te module that includes Graphical User Interface Module (GUIM), Learning Algorithms Library (LAL), Global Constants Module (GCM), Database Interface Module (DBIM), and Learning Algorithm Interface Module (LAIM) for enhanced security of the users [45] [3][37]. ANN-based AI strengthens the genetic algorithm in case

of noticing any anomaly in the usage pattern of a credit card by the customers in real time, ensuring minimization of loss [5].

1.1 IoT: Key Features

IoT integrates every daily object those have sensors to the cyber-physical system for providing data that can be converted into state of the art intelligence driven services. These services are driven by the following key features:

Heterogeneity: IoT as a promising technology offers seamless and efficient interconnectivity among a large array of devices. The integration of IoT is based on data arising from largenetwork systems of internet, cloud computing, industrial and social networks that require unique interdisciplinary concepts allowing the data to be discovered and accessed. Such that different devices on various hardware, service, and network platforms can interact within the IoT [54]. With the deep integration provided by IoT, the boundaries of independent systems are disappearing and IoT is opening avenues of interoperability within different data streams. Other than interoperability IoT offers a key design requirement for scalability of the heterogeneous data with extensibility, and modularity [41]. IoT is capable of interdisciplinary territories and using the heterogeneous data arising from a different system to create a large scale usage such as in development of smart cities [22].

Self-configurable: IoT service delivery is based on adaptation created among the distributed and dynamic system that interact within the evolving environment. This is based on the role and capability of each device connected by IoT, being aware of its capabilities and roles within the system. IoT in participated approach creates resource provisioning and network organization based on information flow [1]. This information evaluation in IoT is feedback based that augments machine learning created between various devices ensure that IoT is capable of functioning in self-configuration [30].

The history of environmental changes is built in IoT with agent approach based on the variability model for that are capable of the feedback-evaluative machine learning process. Thus, if an environmental change that is previously known to the systems occur, these devices in self-reconfigure themselves to an retraining itself. Self-configuration capability of IoT is also dependent on both automatic and manual feedback received by any device of IoT [36].

Extensibility: IoT applications are based on growing clients or servers in network for both collection and distribution of data. Extensibility as a feature of network is the ease with which a number of peers can be securely connected within a given time. Extensibility feature of the IoT ensures that each application does not need to change their codes to adapt to other applications in the network. Thus, it provides a method to work around complex and un-maintainable versions of network devices with compatibility issues [27].

Additionally, developments such as one conducted by Microsoft Azure enhances the extensibility feature of IoT. With Azure, users can trigger server-less workflow functions that will be able to execute business logic and that too without any customized application or infrastructure. The feature allows no-code integrations that enable future scenario of developing Connected Field Services within organizations [42].

Context Awareness: Working of IoT is ubiquitous in nature. IoT is pervasiveness and deals with a different system that is linked within a working environment. The ability to deal with the linking changes between the devices that would otherwise be static points the context awareness nature of IoT. The concept of IoT has already proliferated to enhance the connectivity between systems, devices, and services [38].

The enormous data obtained from these sensors are raw and need context awareness from IoT modeling to create recognized information. Network model such as a Bayesian network is capable of handling flexible data collected from the uncertain environments of devices that are configured for frequent changes. Bayesian network is one such model that enable the IoT to be more flexible and context-aware to design a device-oriented modeling [55].

Usability: IoT is representative of efforts of immense digitization and enhanced utilization of network structures that are inherent to devices connected to these networks. The usability feature of IoT is enormous as it is representative of Cyber-physical systems that connects cloud computing as well as an advanced version of artificial intelligence and robotics. The usability feature of IoT arises

from the ability of IoT to eliminate the gap between the physical and digital domains. IoT has the ability to integrate with a large array of devices, even those that are in semi-finished. Additionally, IoT applications are capable of creating real-time decision eliminating the conditions of central control. IoT also offers the novelty of technology by restricting the need for integrated data processing within the standard technology. The usability of IoT allows ordinary objects to be evolved into intelligent devices that are equipped to make easy and rapid communication with the central control system [17].

Intelligence: Emergence of IoT enhanced the instructiveness of a human with their surroundings. The proactive intelligence model of IoT is derived on three components of monitoring, feedback, and analytics. The analytics are based on data recorded by sensors that enable the systems to make a decision in real time. Feedbacks ensure that IoT makes assertive decisions to suggest maximization of potential benefits for better information processing [34].

The data gathered from various devices are used by the IoT to create modeled patterns that are capable of making intelligent decisions such as automatically setting thermostat temperatures depending on external weather, number of people in the room, and time of the day. It can also be used in predicting the flow of traffic in cities depending on holidays, weather conditions, and time [21].

1.2 Safety, security, privacy Threats and Access devices

IoT middleware: IoT middleware as defined by Mohammad, Sirajuddin, and Shabana [33] is “a software layer or a set of sub-layers interposed between the technological and the application levels”.

Middleware architectures for IoT projects follow the Service Oriented Architecture (SOA) approach. Principle of SOA allows decomposition of complex systems into smaller applications that consist of a simpler ecosystem that is dependent on its well-defined components. Access devices of IoT middleware include web-based services such as in Hydra, Virtual sensors and XML deployment description in GSN as Fit programmable API as in Google Fit [35].

IoT middleware has a model checking technique based on an algorithm to check properties true to the system against the model environment. The temporal logic is enhanced safety property of the system. For security enhancement, the IoT Middleware platforms have functionalities such as filtering and aggregation of the data received to enhance data security. Tools such as Tiny DB and WiseMID provide privacy by allowing minimum overhead on IoT generated Big Data. Middleware platforms act as autonomous links between privacy-preserving techniques. This enables IoT to analyze new data entering the analytical component to examine their potential impact on the privacy of users [6].

Interaction Latency: IoT enhances value-added services for both private and business applications that face limitation arising from interaction and communication latency. Interaction latency can lead to a late response in a system that can lead to production errors or fluctuations in grid system connected through IoT [14]. Additionally, the new age devices are incorporated with integrity protection and encryption for prevention of system sabotage. These goals of secure communication are contradicted by low interaction latency between the system components. In case of Industrial IoT long-term connections and increased overhead of connection that is further enhanced with encryption and continuous process of authentication of data is a key source for latency in IoT devices [19]. However, in a study Hiller et. al. (2018) [18], suggest that for industrial usage, device implementation as in case of AES CCM implementation on tiny DTLS on a Zolertia Z1 platform prevents interaction latency. This setup is capable of providing fast security processing in IoT as the AES provides hardware acceleration at decrease costs. Additionally, Atlam, et. al. (2018) [4] are suggestive of the methods of fog computing. Fog computing prevents latency as it manages and analyzes data as well as time-sensitive actions near the end user called the fog nodes. Authors in the study also highlight that being close to the users, unsecured fog nodes can be used to wage a large-scale attack on the user and privacy is a concern that requires to be researched into by the firms.

Resource Management: The core component of IoT requires doing three activities that include, collection, analysis, and distribution of data over its platform. However, when it comes to pervasive IoT devices they are resources constrained and a single device needs to possess storage, data processing, energy, and band width as its resources. Zahoor and Mir [57], suggest that pervasive applications of IoT devices face limitation and for enhanced energy efficiency. This limitation can be overcome by lightweight algorithms and protocols that are implemented to complete the process of storing,

processing and transferring of data as required by an application to optimize the resource management. Authors in this study also suggest that Internet Protocol version (IPv) have an impact on security of resource management and suggest that IPv6 provide more security than IPv4.

Resource management in IoT can also be enhanced through Wireless Sensor Networks (WSN), inclusion of mobile sink in the WSNs, and cloud computing networking system of the WSN [29] [48] [46]. Al-Turjman et al [2] are suggestive of secure authentication and key agreement (S-SAKA) using elliptic-curve cryptosystems and bilinear pairing. The authors suggest that with enhanced resource management, the framework is based on mutual authentication process. This enhances safety and privacy concern of the users by data confidentiality, resilience to node-capture, user anonymity, and key impersonation among others.

1.3 Authenticating Communication with Artificial Intelligence

The functioning of IoT is dependent upon security of wireless communication taking place among the connected devices. With the concerns of privacy, security, and safety of Big Data, artificial intelligence can provide enhanced protection. Multi Factor authentication (MFA) based on fuzzy logic of “IF–THEN” are being increasingly being adopted for authentication of communication. Roy and Dasgupta (2018), [44] in a study highlight that fuzzy logic based AI is capable of adaptive selection for authentication modalities of the users. Authors further highlight that AI authentication of communication is capable of user verification over different modalities including non-biometric, cognitive behavior, and biometrics. The technique uses information infusion to stress on multi-factoring the authentication of communication process [40].

Additionally, AI can be used for mutual authentication for enhanced protection over mobile communication. AI can authenticate four entities of the user including a range of frequency of greeting words, facial recognition, fingerprint match, and different salutation used for callers based on the frequency of calling to predict user pattern. The ability to create mutual authentication enhances authentication of communication over the mobile network [10] [11]. AI offers enhanced message authentication process by adoption context-adaptive Signature Verification strategy. The process reduces computation and communication overhead enabling the system to recognize the pivot point between authentication of data and real-time action by the AI. This system of authentication of communication by AI is also being increasingly applied to secured wireless communications of Connected Vehicles using Vehicular Ad-hoc Network (VANET). Such, that authentication facilitates enhanced exchange of safety messages that are an effective choice for securing wireless communications for connected devices [49].

1.4 Certification Authority Using Secret Redistribution

The primary goal of Big data is to preserve actionable intelligence and pattern to ensure long-term confidentiality and availability of data. The Wireless mesh networks (WMNs) that are developed in arrangement to form either independent networks or backbone of networks using wireless channel for internet need to be self-configuring. For self-organizing, the mesh routers (MRs) need to exchange information within the MRs without the assistance of administrators. The MRs also needs to authenticate the construct of network by authenticating themselves as well as other stations in which it comes in contact to. Public key infrastructure (PKI) in general controls the certification authority (CA) that is commonly shared between network’s trusted nodes [23].

However, in self-organizing networks such as WMNs there is no trusted third party (TTP), hence, the CA need to be distributed over MRs. To be able to participate in active CA function, participating MRs require secret codes that are changed from time to time for all shareholders. Fast variable share redistribution (FSRV) is the solution that allows both secret sharing and redistribution. The FSRV scheme works towards establishing threshold cryptography that will in return minimize the chances of disclosure of secret in case anyone or some shareholders get compromised. The method use multicasting that adopts Ruiz tree, which works towards reducing the operational overheads and optimum utilization. The structure is capable of updating, revoking, and verifying certifications at each WMN nodes for well-organized and secured data transferring functions [24].

1.5 Implications for Design Theory of Secure IoT System

Design theory of Iot system is of specific importance in industrial systems as it specifies the instruments that the organization will choose to connect to intelligent technologies. These devices, in turn, become a part of large-scale data emitting objects in the universe. Configuration of IoT system will determine the security and safety of data central to the firms [25]. The design theory of IoT has implication of security of the system as it is dependent on a number of antecedents including communication strategy within the well-articulated design system, redefining the roles and responsibilities of employees who are responsible for security of the system, and keeping them aware of new developments to ensure network security [47].

Additionally, the design theory of Secure IoT is dependent on its three primary goals. First is to securely connect embedded devices of edge gateway or endnote type to the cloud backend. This includes identity management of shareholders and authentication of devices trying to get on-board on the system. Second is to allow collection of data from various sensors in devices to analyze and present meaningful interpretations. This process is accomplished by selecting the right data or object model that is compatible with backend infrastructure of cloud-based industrial IoT. Lastly, the design theory is responsible for the number of Secure Socket Layer and Transport Layer Security that are employed by the firms to stress on the need for encrypted data exchange between various devices connected in IOT and its industrial back-end [26].

1.6 IoT Derived Co-design Tools Selection

The co-design tool selection that is derived for IoT is dependent on custom hardware available along with meeting the design goals of security, privacy, reliability, energy, and performance. Other than this, the flexibility of the platform or chip area is also an important parameter as they may impact the mapping of computation of tools together. Thereafter, the selection of the portions that should be developed to have custom compute against the parts that should be left in software. Several existing IoT derived systems based on Hardware/Software co-design use C with system C or C++ with system C module to specify the system behavior. Further, co-design tool selection is based on performance of computation blocks and their usage of profiling information. Other considerations include performance requirement, area coverage required, and power consumption pattern corresponding to the hardware chosen for implementation of system design goals [56].

Further, in IoT device design system-level design space exploration is also critical. This is because the IoT design tool should be able to automate the instantiating process and quickly produce glue and control logic to implement system level design effectively. Ability to eliminate manual integration of system will improve co-design productivity. Also, the co-design tool selection needs to create high-level synthesis for balancing optimization between area and performance of the overall design. The co-design hence created using the HLS should offer automatic integrate encryption for the IPs to secure both input-output data streams, analyze the interfaces, and allow users to enhance the security for systems [51].

Hardware Requirements: The Industrial Internet of Things (IIoT) uprising is by now forming data driven industrial units bursting with unconventional sensor equipment, peer-to-peer communications, and machine learning abilities by aggregation, dissemination, processing, analyzation and visualization of real-time data. Contrasting its inhabitant oriented end user IoT equivalent, IIoT demands high-end linked nodes with applications which can be very diverse with respect to industry required provisions and necessities. As a result, IIoT will restructure its routine methods, by avoiding rigidity and refining productivity.

A decisive system is needed for various industrialized data exchange applications, so “control-as-a-service” needs to guarantee heuristic payload and control packet exchange from edge to the related aggregator nodes. Suggested communication network package is based on Terrestrial Cellular Radio, RF-mesh (802.1, 802.3, 802.11, 802.15.4, Zigbee, LORA, Cellular–NB-IoT) for ground data exchange, and portable nodes. Other IIoT hardware is based on sensors (global positioning system, gyroscopes, radars), processors (ranged (8/32/64 bit)), microprocessor and microcontroller (i.e. system-on-chip) rooted for embedded systems, power source (for energy harvesting and storage i.e. SD or HDD, DRAM

or SRAM (mb/gb)). By utilizing hardware capabilities, the refined processes convert sensor driven raw data into valuable knowledge.

1.6.1 Co-Design Tools Mapping Process based on IoT

Yang et al. (2015) [56] suggests in a study the Co-design tool mapping process based on IoT is a four-step process:

Setting up Hardware/Software (HW/SW) CoDesign: Co-Design Tools Mapping Process based on IoT starts with creating cooperative design between the hardware and software components. The unification initiates design system and functionality and movement between HW/SW. Codesign between the hardware and software is to initiate a balance between the system to optimize platform design that allows interaction between the components and provides continuous feedback. Evaluation of HW/SW codesign also introduces the user to trade-off of the particular allocation dynamics for further evaluation.

Ensuring High-level Synthesis (HLS): HLS is required to integrate the HW/SW co-design to reduce the time in-flow for information and verify the power analysis. HLS starts with compiling of functional specification with transformation of input description into functional specification. After the coding comes optimization process of eliminating dead-codes, elimination of false data dependency, folding and loop transformation. The process completes when the custom architecture automatically or semi-automatically adjust to efficiently implement the specification [13].

Creating System-level IP Integration: IoT devices use IP components such as CPU cores, actuators, sensors, and Bluetooth communication interfaces to produce HLS core. In the IP integration step, the user may use pre-defined register transfer level IPs as sub-function to accelerate the design process and meet system-level goals of design in the area or power, capacity, expansion, security, and privacy. IP level integration standardizes the tool assistance and ensures instantaneous connection appropriate for improvement of design process and enhance the effective design for IoT design system [56].

Debug, Verification, and Rapid Prototyping of the process: The last step in co-designing tools mapping process is debugging that is critical in designing flow and analysis of verification time of the design flow. Although verification effort is labor intensive backward tracing of simulations is required for identification of functional errors. Designers can also use simulations for identification of functional errors, pinpointing erroneous instruction and highlighting the difference between present and optimal working of the design system. Once the debugging process is over, prototyping of the design system is done to evaluate larger scale perform of the early designs.

1.6.2 Operational Choices to Design Tool mapping based on IoT

A systematic process is undertaken, matching among the four portions (i.e. HW/SW Co-design, HLS, System IP integration, and rapid prototyping) of IoT System Synthesis Design Tools/methods [56]. Co-Design tools and methods have been mapped based on the key features of IoT system alignment with four portions. Authors address the need to reflect on how key features of IoT devices could be analysed from a service's designer and developer perceptions. The Cognitive Security Co-Design Framework (CSCOF) is built to examine and mapping the four portions with IoT key features; the proposed framework-CSCOF is based on four relational perspectives: creating cooperative between HS/SW components, compiling HW/SW functional specification, System-level IP integration to accelerate design processes and match them with system-level goals, and finally, debugging which is responsible of design flow to identify any functional error in IoT devices. When we are attempting to design a novel CSCOF for IoT device networks, it is an essential to identify the situated co-design tools that come map out with a design process of IoT systems, which the end-user and the system perform collaboratively and automatically (Funk et al., 2018) [28]. In fact, the authors indicate that the proposed framework is useful for analyzing as well as designing. In addition, the CSCOF can motivate designers understanding how an IoT devices or systems interact with its end-users. In this paper, we presented a CSCOF which is showing design process and activity for IoT systems/devices in high-level with concentrating on specific requirements to HW/SW co-design, HLS, system IP integration, and rapid prototyping. The identified framework (CSCOF) observes different aspects of

IoT devices read through co-design tool mapping process based on IoT industries context. CSCOF has been used as first step to develop the mapping process based on IoT. A CSCOF consists of four main elements: (i) Administrative Policy, (ii) Co-Design Tool Mapping Process based on IoT, (iii) Compliance Functions, and (iv) Operational and Procedural Control.

2 Proposed Scheme

Secure Multicasting Protocol: With the amplified dependence on the Internet, and considering coagment density of legacy systems, it is gradually more sporadic for a device to toil single-handedly. Such scenario necessitates cluster-driven communications which can be exhibited by a variety of techniques: compound unicast, or multicast. Compound unicast requires transferring a point-to-point packet to each cluster node. Multicasting was technologically advanced as a feature to transmit a packet to more than one device whereas protecting properties by broadcasting the communication only as far as it desires to go to influence each cluster node, simply one time along each route. Plentiful standards were adopted to investigate protected multicast method such as cluster association administration, link resource ingestion, receiver resource requests, correspondent resource requests and reliance upon certain criteria.

To ensure secure multicasting, receiver and correspondent resource necessities reflect the subsequent: A. How and by what means each node store encryption keys and exactly how large are these secrets?

B. What is the handing out period involved for contributor to deliver or read messages?

C. Make sure if the resolution permit non-members to transmit data?

D. How many contributors are tolerable? Essentially does these correspondents be identified and acknowledged in before cluster formation?

IIoT enabled secure multicasting outbursts conditions when communications are desirable for an all-inclusive cluster as well as for rations of a crowd. Due to the overhead (in Polynomial-based Key Management) of a greater quantity of rekeying packets every time a node links or leaves that has a authorization level superior than the lowest level in the cluster, secure multicasting is functionally better when the cluster is reasonably stationary. We assume that multicast clusters are fashioned centered on core-based tree method where every node of the multicast cluster shares an undisclosed key with the central device. It is worth mentioning that key dissemination is controlled by a central node. Necessitating the nodes to embrace numerous keys may raises the concern of node resources. With a assorted cluster, some nodes are imperfect in processing resources than others. Due to this reason, to connect to the cluster to obtain any keys, the requestor must first indorse to a cluster regulator. The validating node could work as a mediator to permit future communications. Necessities parameters and tentative statistics are highlighted in table 1.

Context Awareness: The adversary does not requisite to interfere with the records; as an alternative, it can exploit the signature code that a mechanism is adopting to identify malicious activity/code and eradicate it from their particular signature data so the set of identification rules will be parallelized. This will encourage defense algorithm to tolerate specific vulnerabilities. Moreover, the controlling adversary possibly will corrupt records by interchanging malware identification labels to demonstrate it as a legitimate code. To tolerate the dangers of adversarial malfunction, we adopted various set of processes (metadata oriented machine learning, fuzzy hash, contextual policy set, base classification, vector model probabilistic threshold) with dissimilar preparatory data collections and features. During experimental analysis, we logged ‘performance throughout simulation, such as application programming interface requests & compiled code, alert timestamp, hash signature (SHA-256), identified model/malware type, malware size, process path in node/workstation/server’. We have identified that ‘logistic heap up’, where we embrace the discrete probability rates from each ‘disreputable classifier’ in the collaborative feature set, delivers amplified success of malware forecast.

In accordance with figure 1, to avoid malware insertion, we adopted ‘cluster rule set’ based on code restriction policies. In policy, we outline what is reliable code, emphasize on an elastic cluster oriented strategy for marshaling executable scripts, identify which shareware can execute on IoT nodes, and

Function Hypothesis Projected Scheme (based on encoding type: Base64)():

```

for 1, ..., n do
  | Allocate deepest node number at the level to be the central of cluster
end
for All nodes in "B* tree" do
  | Allocate deepest node number at the level to be the central of cluster
  | if node has non-zero level then
  | | Link the node to its cluster level
  | end
end
for All central (curricular nodes) of clusters superior than level 1 do
  | Link central to primary of the cluster to the subsequent deepest level
end
for level '1 to n' do
  | Establish aggregate cost to entire cost + (cost of cluster at level * level)
end

```

End Function

```

for Node feature inheritance (node) do
  | Establish aggregate cost to entire cost + (cost of cluster at level * level)
  | if Level of node is non-zero and node is a sibling node then
  | | inh-node = zero level node
  | else
  | | if The level of node is non-zero then
  | | | Update the linked node value
  | | end
  | end
end

```

end

Preserving discrete trees for every level of communication rises the sum of packets since some associations between nodes happen in various levels. During packet transmission, the message is promoted first along the subdivision from the basis to the central router, then on subdivisions from the central router to supplementary cluster participants: each router getting the message, comprising the primary router, guides it on all the edges associated to that multicast cluster distinct at the B* tree-building interval. We observed that in high mobility zones, routes are not augmented: the dissemination tree is not assembled based on the position of the basis, but all cluster associates can be bases nodes.

for Regulative Probe (opaque genre protocol) **do**

Case: Initiator State

Basis Active Control (BAC): This control is first fixed when the Initiation state node start conversions and is returned on the delivery of each payload from source to the specified cluster node. As soon as it terminates, the Initiation state node switches to the NO state. State Revive Control (SRC): This control administers when State Restore packets are produced. The control is primarily agreed. It is annulled when node switches to the NO state. This control is generally fixed to State-Restore-Intermission

```

if No rejoinder then
  | inh-node = zero level node

```

```

else
  | if Upsurge Time-to-Live (TTL) value gradually then
  | | if Time-to-Live range(max) then
  | | | Prompt failure
  | | else
  | | | R
  | | end
  | |outers don't distribute to subnets with no associates
  | end

```

end

Routers which remove TTL-terminated packets may not be capable of lopping bases, which is important to avoid unnecessary bandwidth ingesting

end

Explicit secure multicast messages types: Hello; Index; Catalogue Halt; Connection/Prune; Bootstrap; Declare State; Insert; Insert; Acknowledgement; Nominee Announcement; State Restore

Algorithm 1: Evaluating Projected Scheme Cost (based on encoding type: Base64)

Table 1: Necessities Parameters

Category	Metric	Projected Scheme (from tentative statistics)
Simplicity of Operation	Setup interval	Compound clusters
	Time Quantity of regulators	One per cluster
Concurrent communications of intensities		Allow
Resource Depletion	Address buffer	Numerous multicast addresses
	Transmitting Accesses	Multiple entries per connection
Connection Rate per message	Sparse clusters	Adequate
	Pervasive groups	Adequate
	Lightly connected network	Reasonable
	Densely connected network	Reasonable

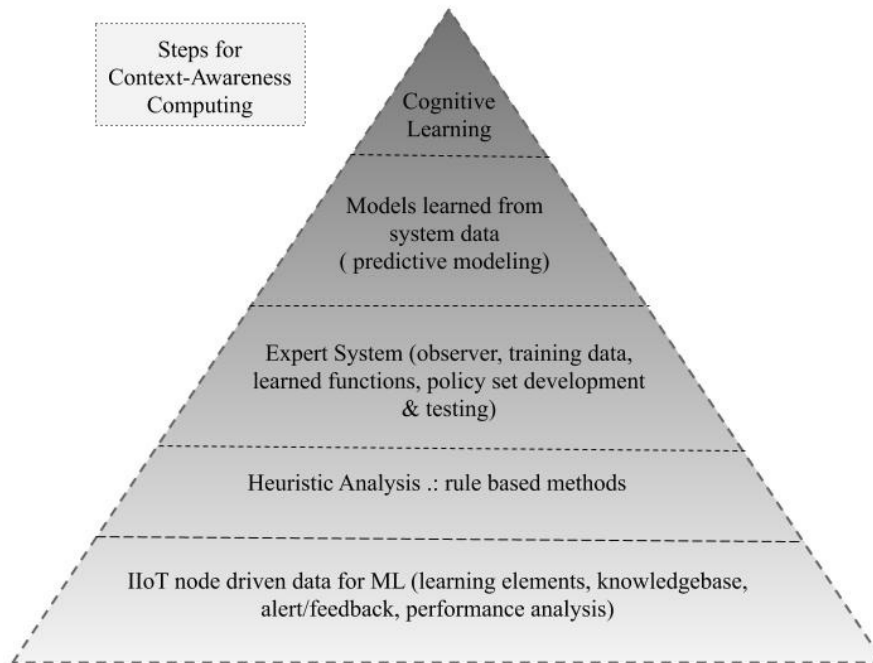


Figure 1: Steps for context-awareness computing

illustrated autonomy of the code constraint policies.

2.1 Architecture, Applications and Analytic

Packet Processor: A router was interjected inside a route of data which lies between the IIoT configuration and the communication network for transmitting data to and from the industrial embedded systems. It consists of a disturbance indicator, designed to practice a system workstation to execute interference discovery on layer 3 (i.e. network layer which can support Connectionless-mode Network Service protocol and Internet Protocol) and layer 4 (i.e. transport layer which can support Multipath TCP) of a modus operandi field, among data involved in a packet header of packets transferred to the interruption discovery system, and as soon as no imposition is sensed, categorize the packets rendering to stream and pass on the categorized packets.

It is worth noting that a network port is aggregated by the route information, in which said payload is separated into a range of packets comprising an initial required dataset which are configured rendering to a desired transmission protocol.

Unfathomable Packet Assessment (UPA): It allows progressive network supervision, handler provision, and security utilities as well as cluster based data mining for anomaly analyzation. UPA makes it a reality to ascertain the creator or beneficiary of data signature comprising precise packets. Furthermore, UPA can irradiates network behavior, assist service provider to augment bandwidth and output, and can expose node performance.

Table 3 & 4 defines the packet filtering criteria and parameters.

Table 2: Filtering Criterion

Feedback: Packet Content M, Datasets,
Output: A Boolean value demonstrating whether the packet ought to be forward to processing unit (*with clock rate: 1054 Mhz, number of parallel threads: 8, average packet length (bytes): 270 and standard deviation of packet length (bytes): 370*) for complete configuration similarity analysis.

```

for each M(i) do
  sub-pattern (xyz) M (i, i+1);
  if Mi [xyz] = 1 then base base-table (BT) to reduce the time required to get the starting
address of signature index;
  if signature index [BT]=1 then
    return true;
  else
  continue;
  end
end
end
return false;

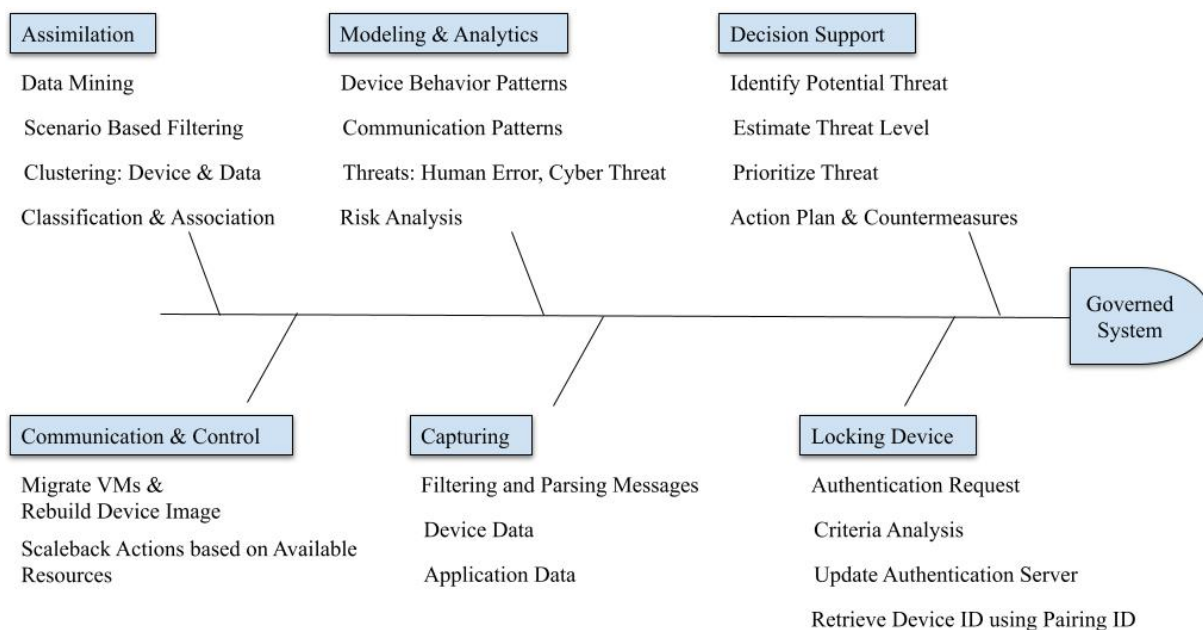
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Table 3: Filtering Environment Parameters

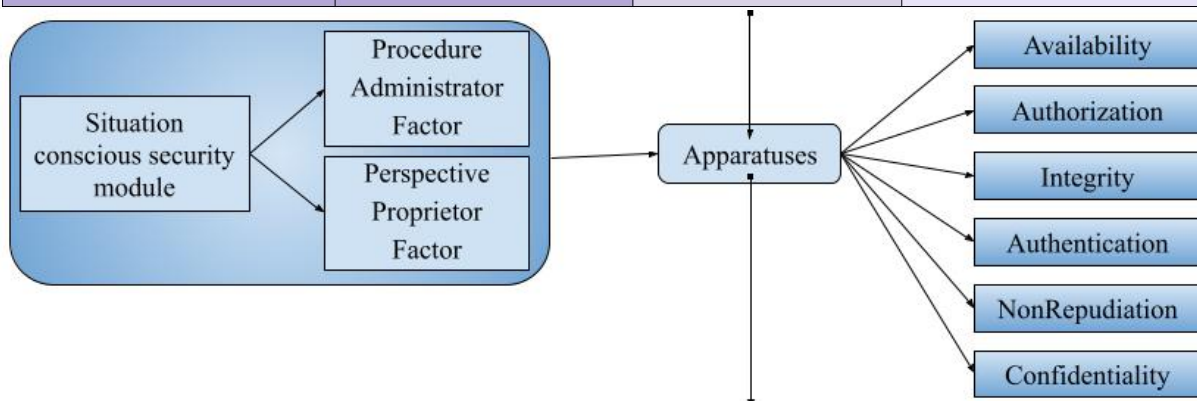
# of states/Patterns in ruleset	# of Transmissions	Scanning Deferment Depth		RAM (mb)	Time (s)	Area Slices
		Avg.	Max.			
379	80803	14.32	25	300	250	990
Header Size per Packet				34 bits		
Route Time				5000 ms (device type: NodeMCU Lua)		
Simulated Development Kit				ESP8266		
General Purpose Input Output (GPIO) PWM (pulse width modulation)				10		
Latency				112 ns		
Throughput				250 Mbps		
Non-linear Packet Filter				45 Mhz		
Filtering Pattern				Ingress, Egress		
Type				TCP, any		
Action				Permit, deny		
Source Address				Any		
Destination Port				445		

- **Precise match:** This form of similarity entails precise equivalence of the filter field, i.e. there is simply one value specified in the filter for that field.
- **Array match:** A assortment match entails the assessment of a header field to be in an array quantified by the filter.
- **Protocol impartiality:** The pass through a filter system must be a sovereign protocol, so that filtering is braced for diverse protocols and at dissimilar stages.
- **Fusion:** The packet filter is capable of managing packet disintegration.
- **Effectual regulation apprises and Auditing:** The scheme permits the insertion and deletion of procedures with least possible interruption in the dispensation of packets. It retains a record of all admittance endeavors, both putative and jammed, if necessary, as well as data that may be of analysis importance.
- **Procedures ranking:** In the case where a data matches more than one rubrics, the packet screener will permit subjective significances to be forced on ranked guidelines, so a unique policy will be in conclusion relevant.

Figure 2, illustrates the persistent Real Time Analysis based Context Aware Cognitive IIoT Security Co-design Framework



Administrative Policy	Co-Design Tool Mapping Process based on IoT	Compliance Functions	Operational & Procedural Control
Identify software/hardware risk analysis based on required policy	Setting up Hardware/Software	a. Define	<ul style="list-style-type: none"> Governance Risk Assessment and Management
		b. Plan	<ul style="list-style-type: none"> Risk Monitoring, Elimination and Management Policy
		c. Execute	<ul style="list-style-type: none"> Data Protection Risk Assessments Middleware
		d. Monitor	<ul style="list-style-type: none"> System Design Node Operations Transaction Initiation Data Access Trends
		e. Report	<ul style="list-style-type: none"> Anomaly (signature / behavior)
Risk-Driven Defense Design	Ensuring High-level Synthesis	a. Identify	<ul style="list-style-type: none"> Malicious (device/activity) Decision Ambiguity
		b. Protect	<ul style="list-style-type: none"> System, Awareness & Training Data
		c. Detect	<ul style="list-style-type: none"> Malicious Event / Data
		d. Respond	<ul style="list-style-type: none"> Analysis Communication



		e. Recover	<ul style="list-style-type: none"> • Policy • System • Communication
Testing (functional/System) Requirements	Creating System-level IP Integration	a. Trust	<ul style="list-style-type: none"> • Identity-based Trust • Knowledge-based Trust based on composite reliability
		b. Insecure Interface	<ul style="list-style-type: none"> • Implementation & Rollout Risk Assessment
		c. Data Ownership	<ul style="list-style-type: none"> • Node Preference • Trust Score Computation Data • QoS Criterion Matrix
		d. Data Leak	<ul style="list-style-type: none"> • Network Channel Temporary Lock • Content Lock
		e. Malicious Insider	<ul style="list-style-type: none"> • Node Identity Theft • Device Lock
Perceived Security Benefits	Debug, Verification, and Rapid Prototyping of the process	a. Resource Concentration	<ul style="list-style-type: none"> • Routine Security and Threat Assessment
		b. Meta Modeling	<ul style="list-style-type: none"> • Internal Filtering and Monitoring
		c. Data Protection	<ul style="list-style-type: none"> • Audit Log Change Prevention
		d. On Demand Access/Service Delivery Modeling	<ul style="list-style-type: none"> • Access Attributes and Filtration • System/Data Access • Node Privilege Assessment

Figure 2: Steps for Context-Awareness Computing

Policy Builder: It is a process for applying a range of diverse rules on a stream of packets, the routine encompassing:

- acceptance a packet in a packet-exchanged system;
- attaching an allowance to the packet;
- decisive assembly data concerning the packet;
- fill in the allowance with the assembly data;
- dispatching the packet to a packet rule protocol component;
- defining, at the packet rule imperative engine component, whether the packet resembles to a conjoint state for a course of action rule
- given that, at the packet procedure imperative engine component, a connotation concerning the first packet and the mutual ailment where it is resolute that the packet resembles to the conjoint disorder;

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Distributed Analytical and Diagnostic Platform: Information representations were generated as an instrument to explore bulky extents of data to implement distributed information analytics. Fact prototypes define the actions detected contained by an input data set, such that the information set was adhered to associate and catalogue novel data alongside the perceived performances of the input data set. Suggested platform develop the procedures to practice logical workflows and disseminate diagnostic policy messages, each of the dispersed investigative policy messages allied with an observant, which has ability to update analytic model, and computer-generated behavioral data. It is worth to mention that the information flows in coordination is by means of sensors. Sensors release and practice information from the industrial mechanism level and forward the information affiliate system link for supplementary handling. System taps (i.e. subpart of sensor), are implanted at key points for system prominence and reflection of network transmission to provision real-time processes.

Scoring Engine (SE): SE technique consist of: (a) examining data to define an occurrence or nonexistence of each of a set of predefined features of maliciousness; (b) computing a groove centered on the existence or lack of the set of rules in the data, the merit/ratio being insightful of a hazard that the data is malevolent; and (c) additional dispensation the record based on the data ratio.

Proposed scheme adopted Support Vector Machine (SVM) which is a favorable technique for information taxonomy and progression and it has also been effectively practiced in malware recognition. By assembling an undeviating state line in the feature space, the SVM yields nonlinear limitations in the novel dataset.

Process flow chart is mentioned in figure 3. Furthermore, as an outcome 'malware scoring criteria' was conceptualized and explained in table 4.

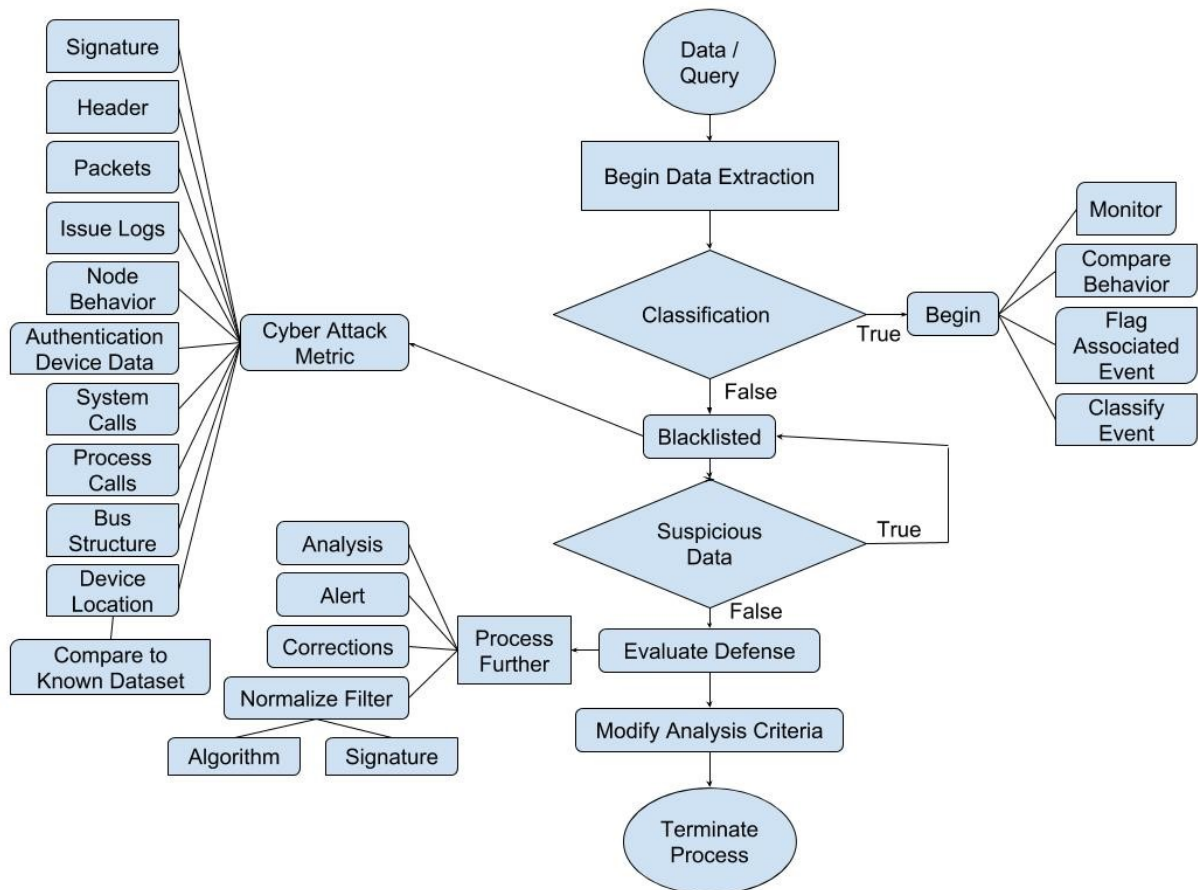


Figure 3: Data Exploration Method (Vulnerability Assessments Analysis)

Table 4: Malware Scoring Criteria

Principles for Scoring Malware		
Benchmark	Narrative	
Payload prospective	Impending of the program component to worsen or harm its board	
Propagation prospective	By what method the cypher is distributed along	
Resentment level	The set on related to the payload (i.e., whether it is intended to destroy, terminate, or simply irritate)	
Grouping Rankings for Malware		
Score	Risk Portrayal	Rating Description
0-25	Insignificant	Reinforcement accessible and functional
26-50	Perilous	Distresses bandwidth
51-75	Risky	Disturbs storage
76-100	Disastrous	Directed for system, network, data, and buffer space


Mitigate Agent: Performance outlines for nodes are primarily bred as the system remains functional, and the inconsistency sensor repetitively equates the discrepancy of the current profile alongside that of the standard signature log/code. Mitigate agent system practices intelligent agents to accomplish tasks and is an method to a scheduling problem with difficult objectives. These agents are independent and can perform without administrative intrusion. Agents are consequently instated beside the attacks at connected devices to crop the attack outlets from the risk log to evade the hazard at the core system. Furthermore agents tends to implement their programmed action plans to prevent anomalies to the system. The state of retreat identification is separated into three levels:

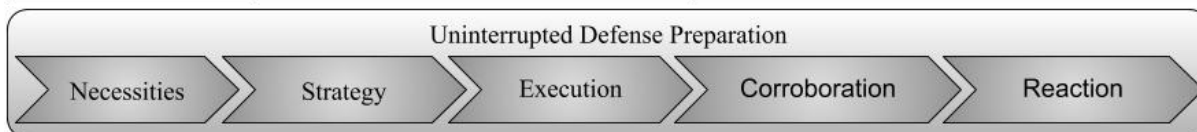
1. If the reaction agent discovers the security of the structure in the normal threshold ratio, the matching exploit plan will persist;
2. If the reaction agent discovers the security of the structure in the medium threat threshold ratio, it will introduce supplementary defense with advanced complexity to save the coordinator from stirring into the abortive state;
3. If the reaction agent discovers the security of the structure in the high risk threshold ratio, the reply agent will lock down the structure (IIoT device network) to protect it from being affected.

Control Panel Engine (Data, Services, End Point Devices): The security engine has a processor and a recollection buffer which provisions the ciphering/hashing (SHA-256) and validation bounds. The system collects a packets from the portable computing node via the communication method scrambled using the cipher keys and comprising verification factors. The system deciphers the obtained packets (TCP, ICMP if encrypted, Payload) exhausting the secrets kept in the buffering node and validates that certification factors mined from the automated security record.

Dynamic Analytical Model (DAM): Suggested approach (scores, alerts) assembles records in such a way that it presents both a real-time and past view of trials. This delivers a combined outlook of risks and security gaps from a principal system and sanctions for better forecasting, quicker perseverance and improved assessment. For analyzation purpose we collected: edge and node performance data, system communication, peripheral risk intelligence sources, admittance (link) and identity administration data, evidence of amenability throughout an assessment. Audit focused on node integration, data validity & distribution, data extraction (download/upload to secure/insecure device), blocking request of unauthorized communication channels. Such analysis (using ML with big data, ensemble learning, and cognitive computing) helped us to understand the parameters to identify insider anomaly node. Based on DAM and mitigating engine's scoring criterion, system will automatically configure itself for alert broadcast (if needed).

As per figure 4, policy driven wireless network node exploration dispensation collects a range of associated data packets which are demonstrative of an imperative in which analogous packets were

Dynamic Analytics Criterion for Basic Vulnerability Scoring		Overall Risk Severity
Attack Vector	<ul style="list-style-type: none"> • Network / Adjacent Network • Local • Physical 	<p>Percentage Threshold</p> <ul style="list-style-type: none"> • Low: (1-30)% of nodes at risk • Medium: (31-60)% of nodes at risk • High: (61-100)% of nodes at risk <hr/> <p>Probabilistic Scoring Threshold</p> <ul style="list-style-type: none"> • Normal: 0 • Low: 0.1 to 0.3 • Medium: 0.31 to 0.6 • High: 0.61 to 1.0  <p>High: servers and IoT nodes run the compromising software</p> <p>Medium: threatened system is victimized</p> <p>Low: aggravation in industrial operations, but not crippling</p> <p>Normal: Operations are smooth.</p>
Attack Complexity	<ul style="list-style-type: none"> • High • Medium • Low 	
Privileges Required	<ul style="list-style-type: none"> • High • Low • None 	
Device Interaction Required	<ul style="list-style-type: none"> • Yes • No 	
Scope	<ul style="list-style-type: none"> • Changed • Unchanged 	
Exploit Code	<ul style="list-style-type: none"> • Functional • Proof of Concept 	
Confidentiality	<ul style="list-style-type: none"> • Complete • Partial • None 	
Integrity	<ul style="list-style-type: none"> • Complete • Partial • None 	
Availability	<ul style="list-style-type: none"> • High • Low • None 	



Alert Confidence	<ul style="list-style-type: none"> • Reasonable • Confident • Unknown 	
Authentication	<ul style="list-style-type: none"> • Multiple • Single • None 	
Threat Identification	<ul style="list-style-type: none"> • Motive of anomaly • Skill used to plant anomaly • Attack Consistency • Ease of Identification • Attack Signature Awareness • Loss of Accountability • Defense/Security/Risk Standard Compliance • Deletion of device logs • Unprotected patch request 	

Figure 4: Network Analysis and Routing Metrics

passed on to the system for link layer records of every conforming packet. It is important to timestamp the harmonized data packets which are kept in the data marts with accredited gen by entitling a first apprehension node as a dominant collection node. Analysis is done based on criterion of high-end devices for packet circulation to all sort of nodes.

Routing metric is working out based on one or more related data principles for a connection between a spreader of a first link device and a receiver of a additional system device in a hyperconnected IIoT network, in which each of the shared policy includes a conjoint data significance for the association for a dissimilar or supplementary communication modes.

3 Performance Metrics and Evaluation

Co-Design is the learning of by what method individuals relate with workstations and to what magnitude workstations are or are not industrialized for effective communication with humanoids and workers. One significant co-design feature is that diverse operators from dissimilar outfits can simulate about their collaborations and have unlike behaviors of learning and holding services awareness. Whereas artificial intelligence is the replication of human cleverness progressions by technologies, specifically workstation PC's. These methods consist of knowledge (the attainment of evidence and rubrics for exhausting the data), perception (exhausting guidelines to influence estimation or certain suppositions) and autonomic behavior. The adopted Turing Test is a well-established technique systemized to regulate if a workstation can essentially contemplate like a human. We implemented supervised learning methodology where record arrays are categorized so that outlines can be sensed and used to tag different record collections. It is worth mentioning that while development of our model, we consider guidelines issued by Europe's General Data Protection Regulation (GDPR). Numerous tryouts were executed to authenticate the projected IIoT-enabled secure system. Experimental environment outline is described in table 5.

Table 5: Trial-and-Error Environment

Testbest Experimental Environment	
Testbed	Regular grid (15 m x 10 m x 5 m)
Configurations	3
Deployed IIoT Sensors	100 fixed nodes (One meter distance per sensor node)
Node Capacity	60 GB
Storage Capacity	16 TB
GPIO (general-purpose input/output)	20 pins
SoC (system on chip)	Espressif ESP8266, Adafruit FONA, Intel QM87
Network Support	802.11bgn Wifi, General Packet Radio Services (GPRS), Ethernet in U-Boot (the Universal Boot Loader)
Transmission power	(-10, -20, -30) decibels with respect to one milliwatt
Transmission Type (if wireless)	Broadcast
Antenna model	Omnidirectional CC1101 Low Power (10mW 500m)
Signal propagation	450 MHz with Spring Antenna
HoP Count	8 bits
Troubleshooting Agent	TRACERT (by applying echo packets (Internet Control Message Protocol) to visually dash the route)
Bandwidth	1000 MB per second max.
Software	Arduino Software IDE / Wiring, Wind River Intelligent Device Platform XT
Cloud Platform	Microsoft Azure IoT Suite (WISE Platform as a Service/RMM (IoT Device Remote Monitoring and Management) enabled with Gateway/Sensor Management)
Millions of instructions per second	100
RAM	Double data rate (DDR3) 4 GB, up to 16 GB, Built-in Flash
Processor	Quad core Cortex-A72 (up to 1.6GHz)
Number of CPUs in a Virtual Machine	1
Accelerations	Packet Processor, Security Engine
Power	Advanced Technology eXtended (ATX) type power connector
Function: PIN: 16	3.3-12 V

Accessing console	Serial connection, Connecting via Secure Shell
CPU	2000 MHz
Cache	5 MB shared L2 exclusive
Invalid port number	3, 4, 5, 6, 7 (No Link on this port)
Control	IFTTT ((if this, then that)), Application programming interface
Working status indicator	3 (wakeup, reset, debug)
Payload	50 bits
MAC Header Size	6 bits
Duration	200 minutes (each day)
Minimum execution time	100 seconds / session
Event Length (expressed in millions of instructions)	300
Number of events	8000 packets / 10 minutes
Generated Data Size / event	300 MB minimum
Sampling frequency	(100, 200, 400) ms
Retries (minimum)	4
Modulation model	Gaussian frequency shift keying
Receiving sensitivity	-108 dBm
Operating temperature	-2 (min), +60 C (max)
Operating humidity	20 percent

We accomplish our assessment exhausting two sets of research: (a) proof of recurrent security, and (b) endorsement of resource-conscious security. Chart.1. Illustrates that the threat recognition likelihood requires if a system can sense the anomaly accurately. Methods can be considered by the metrics precision, discovery ratio and deceitful confidence level. Respective metrics depends on the state of payload delivered over the security checkpoint, these classifications are indicated as the terms true/false positive/negative.

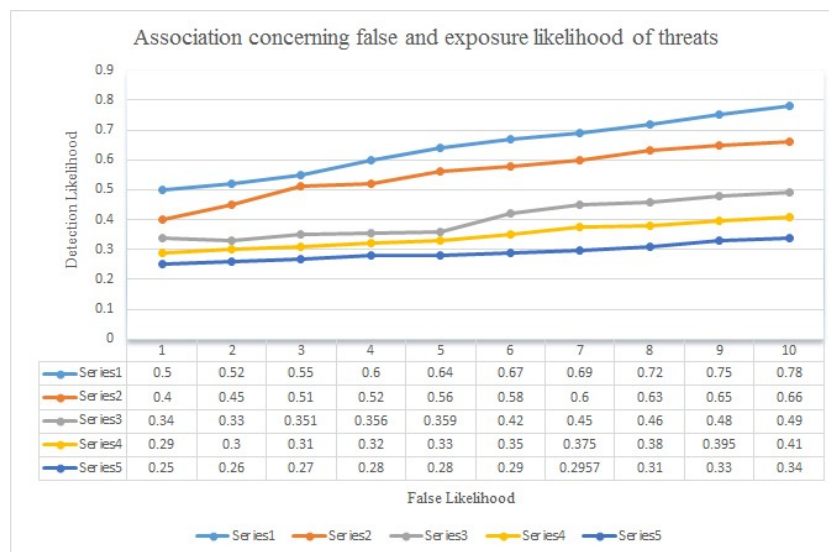


Figure 5: (Chart.1.) Association concerning false & exposure likelihood of threats

During experiment, we emphasized on device tracking, encountering application, communication, utilized platform Security, adopted architecture for IIoT based on mentioned testbest environment.

Data gathered for chart 1 helped us to calibrate likelihood of cyber threat prediction modeling. We observe that heterogeneity of devices may imitate in the usefulness of transmuting the policies into the preserving ratios, as dissimilar categories of resources might be desirable to challenge unrelated threats. Subjective to the precise requirements of the system under observation and based on the accessible information, diverse methods/policies allow to signify the unlike particularities of the system to diminish false alerts. Over the course of experiment, we constantly upgrade the system criterion based on optimization problem.

$$\min_{\mu} \sum_{m=1}^X I_m(\text{time session_time.} \sum_{m=1}^X \text{subnet} \leq \text{compile}) \tag{1}$$

where $I_m(\text{time})$ is representing random processes executed over specific time intervals.

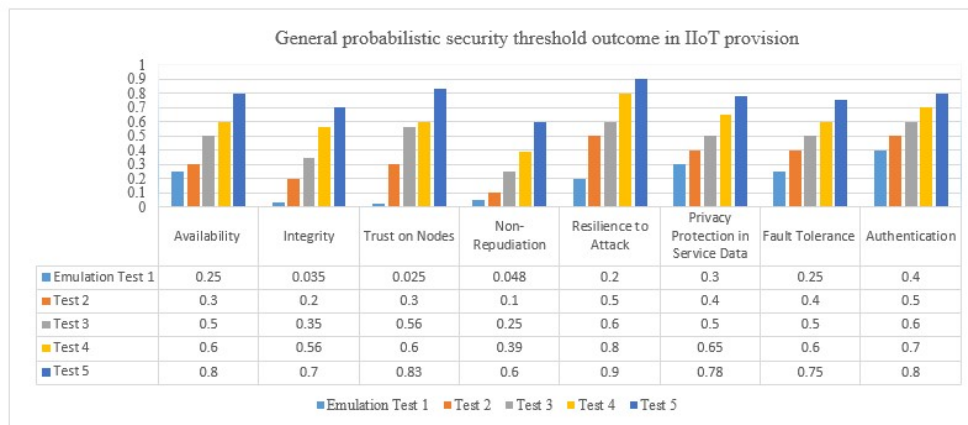


Figure 6: (Chart.2.) General probabilistic security threshold outcome in IIoT provision

The enormous number of diverse devices being coupled in IoT system escalates severe challenges in terms of security for numerous causes. Projected IIoT test-bed / emulation is considered by imperfect-experiences in terms of both energy and data processing properties. Chart 2 describes the outcome of the emulator test, which is used to develop the general criterion among security necessities for the IIoT oriented anomaly defense setting. Our prime focus of this experiment was to analyze edge node behavior during anomaly detection learning phase on system platform, service layer & network and systems improvement in intrusion detection overtime. By allocating a learning based control on how to assign security properties within the security components, framework helped autonomic nodes to handle varied attacks in context-aware IIoT defense setting.

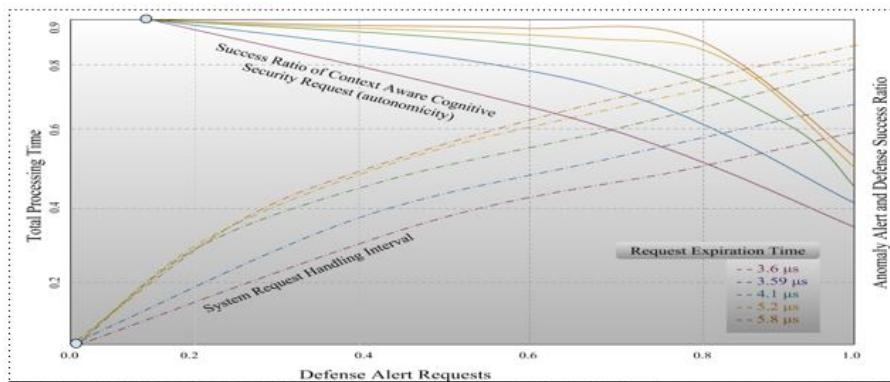


Figure 7: (Chart.3.) Alert Processing Time and Process Success Ratio in consideration with Request Expiration

Chart 3 demonstrates the over-all handling time and the realization ratio of security necessities

according to the influx level of security requirements for diverse values of ending time of security call. In this segment, we extant the outcomes gained by smearing the defense method on alert streams. We programed scenario as the alerted irregularities are not essentially attacks, but can be wide-ranging technical complications. We quarry by selectively straining out alert malfunctions to process faster to use the system resources for more appropriate alerts. Consequently the filtering is measured as vital objective as the irregularity recognition. Proposed technique establishes an extraordinary graphical depiction of the security standing of the threatened system. The consequential chart is an easy to read representation of the security status of the IIoT system. The handler can conjecture on the malevolent activity visible through the defense alert axis. If an apprehensive activity is patterned, then the context engine can go through the alerts policy to verify the rigorousness (DAM modeling) of the event.

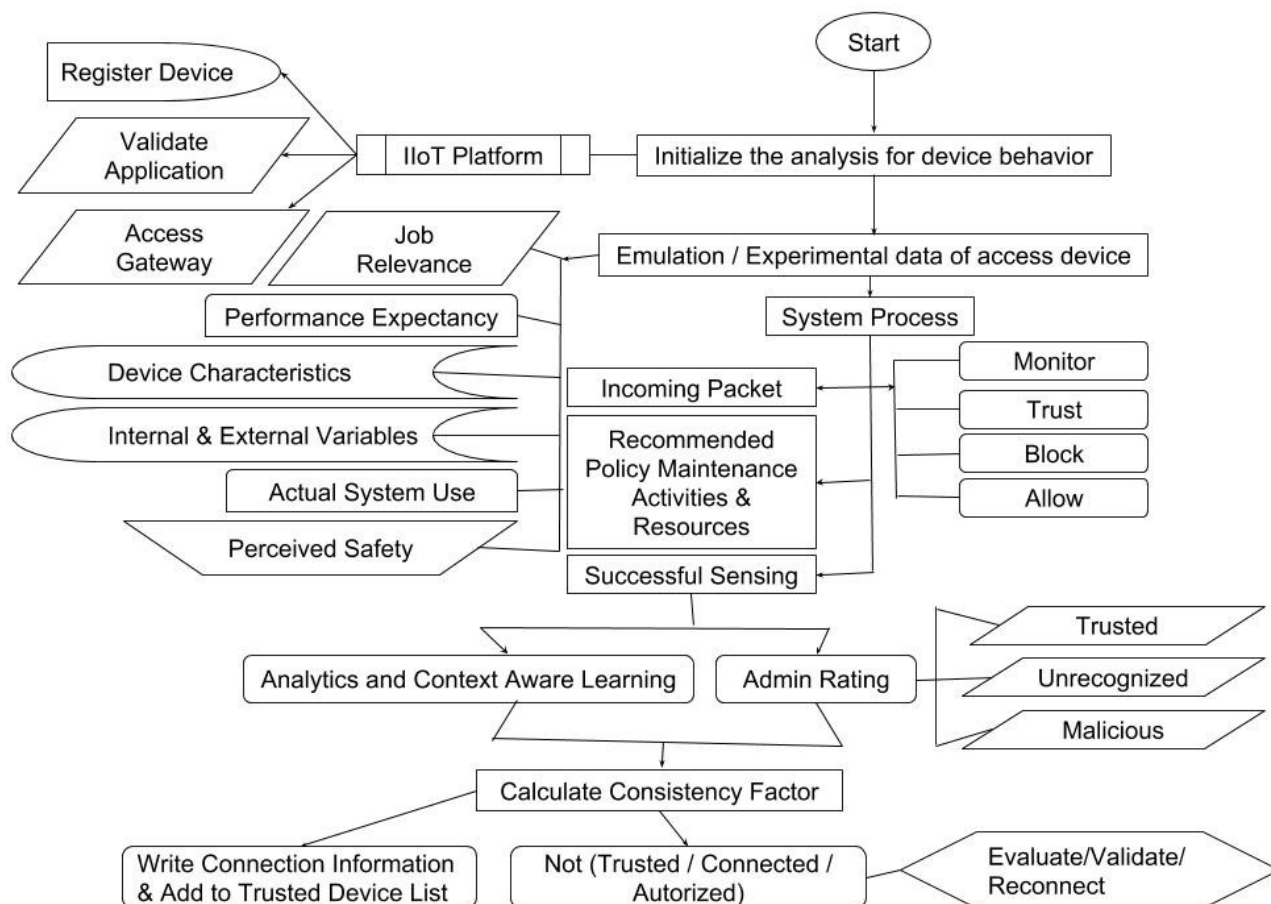


Figure 8: Node/Notification Trust Modeling

The trust model oriented performance of our scheme has also been evaluated. The time required to deliver data from the buffer and to generate the data table have not been evaluated, as they have been reflected unrelated to the scope of the data. After thorough node specification evaluation, we fixed 260 alerts/sec/zone threshold to avoid communication & processing latency. The processing ratio of our scheme 9000 alerts per second is considerably greater than specified device set and therefore our technique is proficient of handling with extendable IIoT networks with higher alert frequency rate.

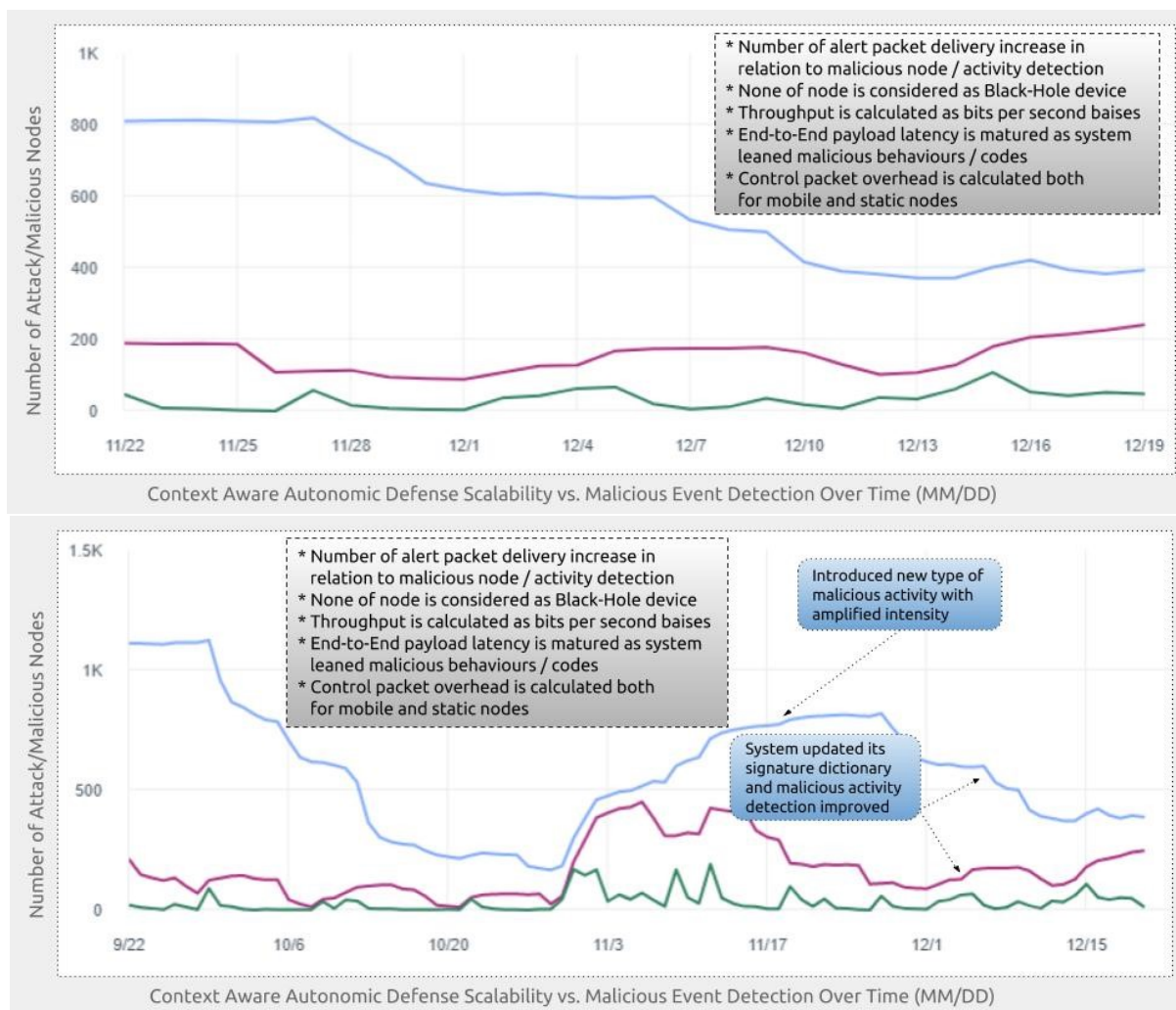


Figure 9: (Chart.4.) Attack nodes ratio vs. attack scalability

Chart 4 illustrates the evidence (gathered from 22 September 2018 to 15 December 2018) on a device’s preceding performance is one of the utmost significant characteristics of the trust modeling. Considering adopted communication paradigm, there are several hypothesis causing in the payload loss and the communications between wireless devices may become unsteady. In the course of the calculation of the endorsement confidence, the endorsements from malevolent neighbor devices are first quarantined by selecting the trust confider. Nevertheless, not all the endorsements from the admonishers are trustworthy.

4 Conclusion and Future Research Directions

In this paper, we have recognized IIoT threat representations and context aware cognitive IoT security procedures, comprising verification, malware discovery, and protected depositing, which are shown to be favorable defense for the IIoT. Numerous experiments has been conducted to emulate the security methods in applied IoT structures.

While this research projected provisions for extenuating security hazards, the defense reflects the edge node side. System makers and application systems analyst ought to work in the direction of providing nodes with extra security abilities and applications with protected and easy-to-design GUI. The projected mitigation methodology diminishes the security threats and probable risks. Effective self-governing and autonomic defense demonstrated positive control over general system usability in balanced manner. The emphasis of this study has uniquely been on the identification of security risks, influences or threats, and appropriate countermeasures for IIoT focused systems. Our impending research will be to advance a context for comprehending and assessing security risks within the IIoT

defense system.

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Author contributions

The authors contributed equally to this work.

Conflict of interest

The authors declare no conflict of interest.

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