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A Model based Test Pattern Generation and Testing Framework for IoT Applications

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Abstract: ***The whole world is entering towards the trend of smart technology. Internet of Things (IoT) is an important domain behind this enormous growth. A simple IoT system consists of a device or actuators or sensors, which are connected to software with the help of an internet. The embedded sensors can be monitored and managed from remote place through the network from anywhere in the world internet. There are various applications that are supported in this domain due to this feature. They are smart agriculture, Home automation, been applied in various domains like Home automation, Patient Health Monitoring, Smart City, Smart Agriculture and much more. The usage of these applications is increasing day by day, so there arises a need for verifying and validating the IoT devices in all aspects.***

The test automation framework that generates test pattern for various testing of IoT application domains that deploys in a sequence process of test patterns which can be easily started for the development of IoT scenarios described. To test their IoT device, there is a need for proper testing techniques for IoT applications through different IoT developers follow their own strategy. The main goal of the automation framework is to reduce the effort in the testing process and to make the test process easier for testing the IoT applications by generating various test patterns various tests depends on a number of IoT test patterns, which allows the process of various operations as the future extension.

Keywords: Test Pattern, Internet of Things, Test Model, Testing Framework

I. INTRODUCTION

The IoT network in future, the number of devices which is connected and services provided will be increased that will be reflected in a heterogeneity and diversity of embedded software, hardware platforms, network protocols, and service providers [1]. The realization of the IoT paradigm implies many challenges that need to be addressed, including availability, reliability, mobility, performance, scalability, interoperability, security and management. Healthcare is only one of the domains that will benefit from the vast range of solutions IoT can provide. There are number of faults that can be tested out by using several tools in the IoT that can be pointed out. With the knowledge that failures in IoT applications can have dire consequences, the importance of ensuring their correctness becomes apparent

II. RELATED WORK

- Identifying the exact use cases [2].
- Testing the application domains for various factors such as functionality, reliability, scalability, Performance, usability, security, and much more for it to be successful

To address this issue, this work aimed to:

- Identify the exact use cases and test cases of existing test solutions
- Identify the short-comes of existing test solutions;
- Formulating an IoT framework and designing test patterns

Table 1: Consequences of Testing in IoT

IoT research in the field of healthcare has been focused on improving the quality of care through remote health monitoring solutions, there is already some work in the area of standards and protocols, presenting solutions designed for specific deployment scenarios.

Issues	Consequences of Testing
Testing for IoT Solutions is specific	To define efficient test strategy for IoT Solutions is a difficult task
Security and privacy threats	For security testing and authorization aspects there is an increasing demand
Cost effective and energy consumption	More efficient methods and techniques are in great demand to select cost effective variants to test
Industry standardized IOT devices	There is a need for more automated integration testing, that are possibly efficient
Demand rises for the lower prices for the IoT devices	Both manual and automation process are required to test the number of variants
Ensuring the reliability of service	In edge testing multiple users under limited connection needed to be tested specifically for life-critical systems

Table 2: Deployment scenario in health care

Project	Deployment Scenarios	Protocols	Standard

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Abidoye, AdemolaP	Home	ZigBee/IEEE802.15.4 standard	3G
Yang Et al	Home, Hospital	BlueTooth,Zig Bee	N/A

III. IoT TESTING TYPES

3.1 Testing the components of IoT

Testing for IoT components generally comprises of Security, Protocol standards, Sensors, Network communication, Processors, Operating Systems and Platforms [3].

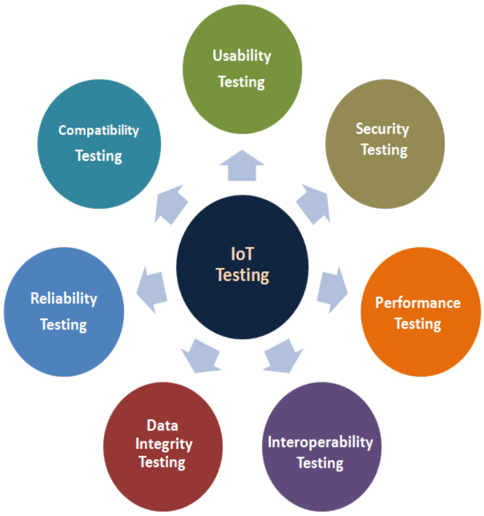

Figure 1: Testing Types of various components of IoT

As it's far a healthcare solution, connectivity plays an essential role. The device needs to accessible all of the time and to have endless connectivity with the stakeholders. Being a tester, there is a need to test the offline situations as properly. Once the device is not accessible at the network, there must be an alert that could set off the physicians in order to start to screen the fitness situations manually not relying on the device till it is up.

The following chart describes the applications of different types of testing for various devices of IOT.

Table 3.1a: Types of Testing in IoT

Testing Types	Functional Testing	Usability Testing	Security
Sensor	True	True	True
Applicatio n	True	True	True
Network	False	False	True
Back End	False	False	True

Table 3.1b: Types of Testing in IoT

Testing Types	Performanc e	Compatibility	Service s
Sensor	False	True	False
Applicatio n	True	True	True
Network	True	False	True
Back End	True	False	True

Project	Deployment Scenario	Protocols	Standard
Rahmani	Home, Pharmacy, Nurrsing Home	BlueTooth, Wi-Fi	IEEE 11073
Sapnora	Home, Nursing Home	BLE, Wi-Fi	3G

3.2 Communication Standards comparison

In the health monitoring system various technical communication standards are followed which are suitable for the transfer of data. Here are the some of the examples that are used in the domain of health care.

3.2.1 Bluetooth Low Energy

Operation Bandwidth: 2.4 Ghz
Topology: Star
Range: 150 m
Data Rate: 1 Mbps
Features: 128-AES Encryption secure pairing prior to key sharing two keys used to provide authentication and privacy protection
Suitability for Health care: High

3.2.2 Bluetooth Low Energy

Operation Bandwidth: 2.4 GHz
Topology: Mesh
Range: 30 m
Data Rate: 250 Kbps
Features: 128-AES Encryption. Network key shared towards network. Providing link key to secure application layer communication
Suitability for Health care: Moderate

IV. IOT TESTING FRAMEWORK

This type of testing framework is created to validate the IOT components. Today there is huge need to deliver quality and faster services. There is an increasing need to access, create, use and share data from any device. The fact behind is to provide better process and control, over various interconnected IOT sensors. Hence, IOT testing process is essential.

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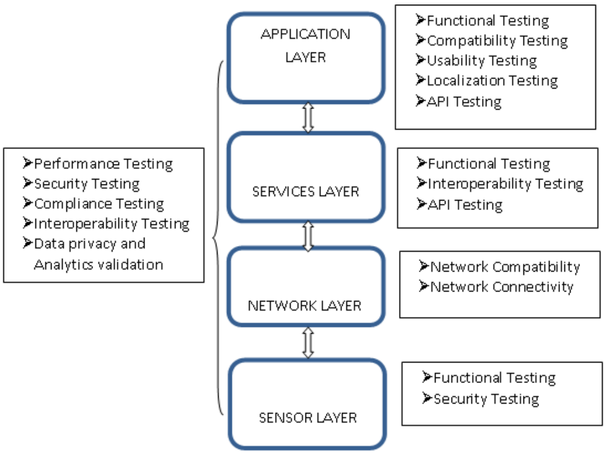

Figure 2: IoT Testing Framework

A. Application Layer

The application layer consists of functional testing and compatibility testing.

B. Functional Testing

The important concept for IoT functional testing is the process of testing in real-life environment using real devices or sensors to test those key components. The IoT smart technologies continue to increase enormously, and every test case differs as far as the functional core components are concerned [4].

C. Compatibility Testing

Compatibility testing should be a major priority in case of software development project. The complexity of Compatibility Testing will be more for QA teams in an IoT world since they will need to expand their scope of coverage to include various connected devices.

D. Interoperability Testing

Interconnectivity between devices ensures increased productivity at home or within industrial settings. This type of testing starts at a place, as the popularity rises and the number of devices and networks increases, the lack of interoperability between them becomes an issue.

E. API Testing

The main testing mechanism is the Application Programming Interface. API Testing is an essential process to achieve Quality Assurance. An interconnected world dependent on proprietary based business networks is highly reliable on the ability of these systems to exchange data.

F. Network Compatibility Testing

In Network compatibility testing, the team evaluates the various factors of a system in a network with varying parameters, such as operation bandwidth, performance evaluation, Network capacity, etc. In addition to that, it validates the application in different networks with the assistance of these attributes.

G. Network Connectivity Testing

To perform the network connectivity process, the accessibility of a remote system or test the connection to a port on a remote system can be tested.

- Testing availability of remote servers
- Testing TCP connectivity
- Sending test messages.

4.3 Sensor Layer

H. Performance Testing

This type of testing involves the speed of the network model through communication. It also includes the internal process of the software system that is embedded internally. IoT performance testing is necessary to be carry out through the Gateway and Network connectivity (protocols like HTTP, CoAP, MQTT etc), System Level (cloud Database, data processing, Cloud server), and the User Application Level. For instance: Check the throughput time against the standard time that defines the status conditions of network connectivity.

I. Security Testing

Security testing includes the factors like data authentication/authorization, data privacy, device identity, encryption/decryption, etc. In an IoT testing framework, security testing integrates both the device protection and the connectivity of network or connected cloud services.

V.TEST MODEL IMPLEMENTATION

The proposed method is the implementation of test model for internet of things. This model is divided into four categories. They are the Data Source, Data Gathering, and Data Transmission, Process Information and Cloud or Data center.

The model or design of an IoT domain can, generally speaking, be categorized and grouped according to their properties. Because the test of IoT systems is often closely related to these features, it is useful to devise a prototype that allows representing the plurality of devices and their characteristics within an IoT application domain [5]. By classifying the various core components of an IoT system and identifying each device in terms of its attributes, it is feasible to identify which functionality must be tested and to opt for which test(s) pattern(s) should be implemented accordingly.

A. Data source

It could represent some physical object such as devices, Machines, people, Tools, Vehicles etc Example: The objects can turn off the light and adjust the range of temperature inside the room

B. Data Gathering

This represents the sensors and actuators. Sensors have the ability to convert the information obtained in the outer world into data for analysis [6].

The main purpose of sensors is to gather data from the surrounding environment. Sensors and 'devices' of the IoT system form the front end. These actuators are connected directly or indirectly to the networks after signal conversion and processing.

C. Network Connectivity

The actuators or sensors will typically be connected to an HTTP **network** across the Internet worldwide. The Commercial **IoT** applications **are communicated** and the information is forwarded through Bluetooth or Ethernet (wired or wireless).

D. Communication protocol

The communication protocol is mainly implemented to enable simple, integrated devices to combine IoT through suitable networks having low bandwidth availability [7]. This protocol is mainly applied for machine-to-machine (M2M) communication and is specifically used for IoT devices that are completely depends upon IP protocols.

E. Applications

The data visualization is supported by the external applications. The data can be a real time or a stored historic database, and the triggering of alarms (either each time the condition is satisfied, or each time there is a variation in the condition).

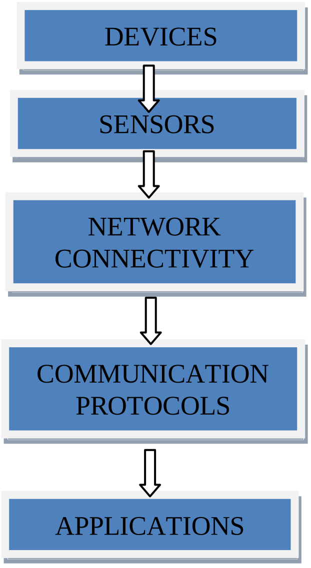

Figure 3: Test Model for IOT Applications

VI. IoT TEST PATTERN

Considering the instance of test patterns in an IoT domain, it is possible to determine the strategies of testing that specifies the behaviors of an IoT system that described the test patterns [8].

TestPattern	Description
Test Condition	Checks the status of the sensors
Test Activity	Checks the measurement levels are under the threshold values
Test Connectivity	Checks whether the links are connected between the devices
Test Alert	The System should not only give notifications, error messages and warnings
Test Service	Checks whether the service is provided with standard protocols
Test Security	Checks whether the sensor Networks are located in placed that is not accessible by the attackers

TEST CASE GENERATION

7.1 Validation

7.1.1 Functionality

In accordance to the scenario described, the system implements the following functionality:

- Monitoring and maintaining a personal record of health parameters, namely heart rate, blood pressure, and weight;
- Monitoring ambient conditions, specifically temperature, humidity, air quality and luminosity[9];
- Issuing alerts when the parameters being monitored indicate a problem: elevated heart rate

The alerts generated reflect the heart rate intervals defined in the following table. The actual intervals are calculated—in beats per minute (BPM)—using an estimated maximum heart rate [10] (MHR), following the stipulated by the American Heart Association (AHA)

Table 4: Categorization of heart rate for different intervals

Category	Interval
Normal	<50%
Elevated	51% - 69%
High	70% - 84%
Very High	85%

Various alerts were set for blood pressure values considered to be abnormal, according to the intervals defined by the AHA

Table 5: Categorization of blood pressure levels

Category	upper value	lower value
Normal Values	< 119	And < 79
Prehypertension	120-138	or 80-88
Stage1Higher Blood Pressure	140-158	or 90-98
Stage 2 Higher Blood Pressure	160 or higher	or 100 or higher
Hypertensive Crisis	Higher than 180	Higher than 110

8. CONCLUSION AND FUTURE WORK

The IoT represents the major and significant domain in the current technology development, related work addresses the key issues and challenges faced in IoT testing and the technologies used in various application scenarios.

The proposed paper provides a

new testing approach transforming standards based IoT testing into a testing model and framework that enables scalable, distributed and automated IoT testing.

Test case generation for various aspects in incorporating test cases covering various factors such as usability, scalability, network connectivity and internet protocols is a difficult task due to the distributed and heterogenous nature of IoT systems Since the IoT devices are made of different hardware and technologies so there are always difficulties in testing them. There are many critical bugs related to functionality, performance, and security. Since IOT is evolving at a faster rate so the quality of the software in IoT devices cannot be compromised. The users of the connected devices are unaware of how the IoT system is working but are very much accustomed to using IoT technology. Even though there are several tools available that can be used in the validation of IoT components, there occurs number of issues that can be addressed: a technological review of existing solutions reveals the lack of a comprehensive test solution for automated integration testing. Focusing on a specific protocol, network, or standard, decreasing the feasibility of upgrading or extension, and not providing out-of-the-box functionality are among the most common shortcomings detected. Alerts are triggered when the patient's status is validated to require immediate attention and pre-set operations are generated by the variations in the abnormal conditions.

In future Artificial Intelligence and machine learning techniques can be integrated with testing framework which can be used in software testing phases. Each phase can be implemented with AI methods like Neural Networks, CBR and Intelligence planning or statistical concepts such as Regression modeling and PCA. Thus these approaches for automatic testing have significant effect in decreasing testing costs and improving the software quality.

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