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Internet of Things Based Technology for Smart Home System: A Generic Framework

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Abstract—Internet of Things (IoT) is a technology which enables computing devices, physical and virtual objects/devices to be connected to the internet so that users can control and monitor devices. The IoT offers huge potential for development of various applications namely: e-governance, environmental monitoring, military applications, infrastructure management, industrial applications, energy management, healthcare monitoring, home automation and transport systems. In this paper, the brief overview of existing frameworks for development of IoT applications, techniques to develop smart home applications using existing IoT frameworks, and a new generic framework for the development of IoTbasedsmart home system is presented. The proposed generic framework comprises various modules such as Auto-Configuration and Management, Communication Protocol, Auto-Monitoring and Control, and Objects Access Control. The architecture of the new generic framework and the functionality of various modules in the framework are also presented. The proposed generic framework is helpful for making every house as smart house to increase the comfort of inhabitants. Each of the components of generic framework is robust in nature in providing services at any time. The components of smart home system are designed to take care of various issues such as scalability, interoperability, device adaptability, security and privacy. The proposed generic framework is designed to work on all vendor boards and variants of Linux and Windows operating system.

Keywords-*Internet of Things (IoT); Smart Home System; Sensor Networks; Security; Auto-Configuration; Communication Protocol; Access Control; Device Management; Auto-Monitoring and Control; Context-Aware Adaption Scheme; Data Analysis and Visualization;*

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I. INTRODUCTION

In recent years, Internet has grown exponentially and changed human's life by providing anytime, anywhere connectivity with anyone. The Internet technology can be further extended to connect objects that we use in day to day life. This expansion of internet services is called Internet of Things (IoT).

The term "Internet of Things" was coined by Peter T. Lewis in a 1985. In his speech he states that "The Internet of Things, or IoT, is the integration of people, processes and technology with connectable devices and sensors to enable remote monitoring, statusview/manipulation and evaluation of trends of such devices" [1]. The Internet of Things (IoT) is the inter-networking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other items embedded with electronics, software, sensors, actuators and network connectivity that enable these objects to collect and exchange data [2][3][4].

IoT can be used in many application areas such as e-governance, environmental monitoring, military applications, infrastructure management, industrial applications, energy management, healthcare monitoring, home automation and transport systems [5].

Now a day, the development of IoT based technology for home automation is gaining lot of attention and many researchers are working in that direction. The home automation will help every individual to monitor and control home appliances remotely through handheld devices and computers using internet.

The development of home automation system requires technological solutions for various tasks such as building networks of sensors, establishing communication among objects, data collection and storage, monitoring and controlling, predicting the future need of inhabitants based on history and providing security to protect things from misuse and thefts. Many works are happening to develop technological solution to each of the tasks listed above and also several frameworks are built for home automation and other IoT applications. In this paper, the survey of existing frameworks for developing IoT based applications, techniques to build home automation using existing IoT frameworks, the new generic framework for the development of IoTbasedsmart home system is presented.The proposed generic framework is helpful for making every house as smart house to increase the comfort of inhabitants. Each of the components of generic framework is robust in nature in providing services at any time. The components of smart home system are designed to take care of various issues such as scalability, interoperability, device adaptability, security and

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privacy. The proposed generic framework is designed to work on all vendor boards and variants of Linux and Windows operating system.

The rest of the paper is organized in the following sections. The frameworks available for developing IoT based applications are discussed in section 2. The various techniques to build smart home applicationusing existing IoT frameworks are presented in section 3. The various design considerations of smart home system are given in section 4. The proposed generic frameworkfor smart home system ispresentedin section 5. Section 6 concludes the work.

II. FRAMEWORKS FOR DEVELOPING IOT APPLICATIONS

The various frameworks available to develop IoT based applicationsare discussed below. The IoT based applications can be developedusing any of these frameworks based on their requirements and suite.

- *Eclipse SmartHome* [6]: Eclipse SmartHome is a framework to provide end user solutions. The framework provides uniform access to devices, information, and facilitates different kinds of interactions with them by integration of different protocols and standards through an Open Service Gateway interface (OSGi) stack. It also allows for a registry of all the parts of smart home network and makes devices work together. The framework works best with Raspberry Pi board. The eclipse smart home system is available for various platforms like Linux, Windows and MacOS. It provides APIs for data handling, to set triggers and actions, to create user interface and persistence management.
- *ThingsSpeak* [7]: ThingSpeak is an Internet of Things (IoT) cloud platform that lets you collect and store sensor data in the cloud and develop IoT applications. It provides various features like data collection, open APIs to create and update data channels using Representational State Transfer (REST) and Message Queuing Telemetry Transport (MQTT) protocol. The framework also has integrated applications to transform and visualize data, trigger and schedule actions. It works with various boards like: Arduino, Particle Photon and Electron, Raspberry Pi and Electric Imp. However, the framework requires manual creation of channels and configuration of sensors.
- *ThingWorx* [8]: ThingWorx enables developers to rapidly connect sensors, create, and deploy applications for the smart connected world. ThingWorx supports various components for developing IoT application which include: kepware for industrial connectivity (plug-ins and device drivers for communication, unmatched interoperability, quick setup), IoT analytics that enables users to find and learn past data, understand true value in the IoT data, predict and make the future decision, the studio to create a dynamic user experience through augmented reality (AR), the composer to build unique end-to-end applications (that include modeling the things, business logic, visualization, data storage, collaboration, and security), mashup builder to create rich, interactive applications, real time dashboards, collaborative workspaces, and mobile interfaces without the need for coding, SQUEAL for search, query and analysis, and live collaborations for individuals or teams to solve the problem faster and flexible connectivity options via APIs, AlwaysOn connectivity, 3rd party device clouds and direct network connections. The framework enables development of rapid applications, managing heterogeneity and diversity in building customized IoT solutions.
- *IoTivity* [9]: IoTivity is an open source software framework which enables device-to-device connectivity to address the emerging needs of the Internet of Things. IoTivity provides two layers such as: base layer and service layer. The components of base layer include: resource discovery (objects/parts/things of smart home system discovery), data transmission using messaging and streaming model. The functionality of service layer include: resource encapsulation an abstract layer to provide functionalities for both client and server side to ease the work of developers, resource container to activate and deactivate resource instance(s) dynamically on demand. The device management to support configuration and diagnostics of devices.
- *OpenHAB* [10]: OpenHAB is open source software for integrating different technologies and devices of home automation system into one single solution. It provides various features such as: web-based user interface (UI) with default runtime package and pre-configured demo house, native iOS and Android user interface, SenchaTouch-based user interface (UI) for smartphones and tablets, OSGi console to manually send commands and status updates, remote console access through eXtensible Messaging and Presence Protocol (XMPP) instant messaging console, Google calendar to schedule console commands, RESTful interface to open OpenHAB from any other system, OpenHAB designer(JBoss Drools Engine) to edit configuration files, UI definitions and automation rules, and highly integrated rule engine to allow users to write automation rules.
- *Node-RED* [11]: Node-RED is a flow-based programming for Internet of Things (IoT). Node-RED helps to connect hardware devices, APIs and online services together in new and interesting ways. Node-RED provides browser based flow editor that makes it

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easy to connect different nodes, to create JavaScript functions and to save useful functions/templates/flows using JSON. It supports various devices like: Raspberry Pi, Beaglebone Black, Arduino, Docker, and Android. It also supports cloud services like IBM Bluemix, Amazon web services, Microsoft Azure.

- *AllJoyn Framework* [12]: AllJoyn is an open source software framework that makes it easy for devices and applications to discover and communicate securely with each other. The framework enables developers to write applications for interoperability regardless of transport layer, manufacturer and without the need for internet access. The framework provides various services such as: Onboarding Service to bring a new device onto WiFi network, Configuration Service to configure certain attributes such as name, default language, and passcode, Notification Service that allows text-based, image and audio notifications to be sent and received by other devices on the network, Control Panel Service to control devices remotely using virtual control panel and Common Device Model (CDM) Service to monitor and manage Internet of Things devices, regardless of device manufacturers. It is designed to run on multiple platforms such as Linux, Linux-based Android, iOS, Windows, and any other lightweight real-time operating systems.
- *DigitalSTROM* [13]: DigitalSTROM is one step solution to have safe and lively atmosphere at home. It enables to connect all electrical household appliances using existing power lines. The framework provides intelligent protector which alerts each device in its own way, activates itself automatically, and informs other devices and users. The DigitalSTROM shows the energy consumption of each individual appliance in the house and also helps for the optimization. It also enables to define mood lighting by using your smartphone and control devices using voice commands. The DigitalSTROM also enables existing switches to retain their basic functions and can be added new functions at the same time.
- *Web Network Management System (WebNMS)* [14]: WebNMS is an IoT based end-to-end application enablement platform that enables devices, machines and people to connect and collect real-time data. WebNMS contains remote terminal unit that collects data from devices and communicates to central management system via Ethernet/GPRS/Satellite. It enables network monitoring, configuring and troubleshooting of each devices and resources in the network. It also handles scalability at both client and network side. WebNMS also has system management portal that remotely connects all the things, manages devices, collects data, allows action management, data analytics and visualization, and integrates with cloud services.
- *IPSO Alliance* [15]: IPSO Alliance is a global forum focused on enabling IoT devices, hardware and software to communicate, understand and trust each other with global interoperability based on open standards. It provides Constrained Resource Environments (CoRE) and Constrained Resource Application Protocol (CoAP) to enable low power and low bandwidth devices to connect to the real world and high level interoperability between smart object devices and connected software applications. It also provides template for constrained device management.
- *Thread* [16]: Thread is a new low power wireless protocol that uses 6LoWPAN and IPv6 for connecting Internet of Things devices. Thread is designed with a new security architecture that allows users to securely add and remove things to the network via a smartphone/tablet/computer. The Thread protocol provides numerous advantages over existing wireless standards such as robust self-healing mesh networks that scale to hundreds of devices with no single point of failure, secure and banking-class encryption, simple to install with a smartphone/tablets/computer and low-power devices to be a part of a home network.
- *Open Mobile Alliance (OMA) - Light Weight Machine to Machine (LWM2M) framework* [17]: OMA Lightweight M2M is a protocol from Open Mobile Alliance (OMA) for Machine-to-Machine (M2M) or IoT device management. The protocol allows the remote manipulation of constrained IoT devices using Constrained Resource Application Protocol (CoAP). It is designed to provide various features such as device management functionality over sensors or cellular networks, data transmission service from network to devices, security using Datagram Transport Layer Security (DTLS) and multiple server support.
- *ThingSquare* [18]: Thingsquare is a software platform that connects products with customer's smartphones. It uses a technique called channel hopping to avoid interference from other wireless networks. Thingsquare has developed a unique way to do channel hopping that works even with tiny, battery-operated wireless devices. Thingsquare system automatically configures itself and forms wireless mesh between the devices. It also supports authentication, announcement of presence of devices using Bluetooth and WiFi, device identification and registration for remote access.
- *An eXtendable Component-based Interoperable Open Model-driven Architecture (AXCIOMA)* [19]: AXCIOMA is a component framework based on eleven Object Management Group (OMG) open standards. It provides interoperability, portability for

distributed, real-time and embedded systems. It is highly scalable and adaptable for domain specific requirements. The framework has open architecture that allows integration with any system and multiple communication transports.

- *Xively* [20]: Xively is an IoT platform that provides all the tools required to build, launch and grow a connected product business. It enables users to connect products quickly and securely, manages the connected products and the data they produce. It mainly focuses on services related to scalability and complexity.
- *The Thing System* [21]: The Thing System is an open source IoT framework that provides open API to control things. It is a set of software components and network protocols. It can run on desktop/laptop or fit onto a small single board computer like the Raspberry Pi. It is both portable and extensible. The steward is the heart of The Thing System that connects the things together using WiFi, USB or Bluetooth Low Energy (BLE). The steward provides two standard protocols namely simple thing protocol for adding steward management and simple Thing Sensor Reporting Protocol (TSRP) for reporting sensor readings.
- *IoTToolKit* [22]: The IoT Toolkit is an Open Source project to develop a set of tools for building multi-protocol Internet of Things gateways and service gateways. The gateways enable horizontal co-operation between multiple protocols and cloud services. The IoTToolKit provides a middleware layer for virtualization and integration of data from sensors, actuators, and other IoT devices. IoT toolkit acts as a stateful bridge for providing interoperability among HyperText Transfer Protocol (HTTP)/Representational State Transfer (REST) protocol, Constrained object Access Protocol (CoAP), eXtensible Messaging and Presence Protocol (XMPP) and Message Queuing Telemetry Transport (MQTT) protocols. It also provides event model that allows real time event and protocol handling of resource updates and state changes.
- *ZERYNTH* [23]: ZERYNTH is an easy to use development suite for the high level design of interactive objects and the Internet of Things applications. It is composed of a set of open source tools that allows interacting with the embedded objects in few clicks. It runs on Windows, Linux and MacOS. It consists of four components such as: ZERYNTH virtual machine for hardware independence and reuse of code, ZERYNTH Studio to provide development environment, ZERYNTH Advanced Device Manager (ADM) that provides API based interface and Remote Procedure Calling (RPC), and ZERYNTH Application to allow users to monitor Zernyth based objects from mobile.
- *Cayenne* [24]: Cayenne is a drag and drop IoT project builder that empowers developers to quickly prototype and share their connected device projects. Cayenne is designed to help users to create Internet of Things prototypes and then bring them to production. There are two major components in the platform such as: Cayenne Mobile Applications to remotely monitor and control IoT projects from the Android or iOS smartphones, Cayenne Online Dashboard to create customizable widgets to visualize data, set up rules, schedule events and actions.

From the study of above frameworks and survey made by [36], it is observed that many frameworks exist in market for developing internet of things based applications. The various components of any of these frameworks includes; Developing standards for interoperability, Making system highly scalable,Facilitatingsecure APIs and management APIs,Abstracting hardware and software complexities, Integration of different technologies, communication protocols& applications, Device management, Supporting multi platforms and boards, Ease of use, User-friendly interface that helps to develop rapid applications & design of custom solutions, and Enabling constrained devices to take participate in application networks.

The frameworks are widely adopted for use in developing home automation. While devices use and adopt IoT architecture, majority of them lack in ease of configuration and management of connected devices, scalability options, user friendly monitoring and control methods/procedures, secured connectivity between connected sensors, devices, peripherals, administrators, and users, etc.

Also there exist security issues, since on Feb 11th 2015, it is reported in news analysis that, “HP fortify researchers tested 10 of the newest connected home security systems and discovered that the internet of things connected security systems are full of security fail” [25]. Also in October 2016, prime portion of the internet got shut down since internet-connected devices overwhelmed networks with junk traffic after cyber attackers seized control of these devices. These attackers’ accessed IoT devices that “weren’t properly password protected since some were running with no password and others with a factory-default password” [26].

Hence, it is very much necessary to design a new solution which takes utmost care of security in addition to addressing other issues such as ease of configuration, integrationof sensors of different vendors, scalability and interoperability.

III. Techniques for Smart Home System

The brief review of techniques for developing smart home system using IoTbased frameworks is presented below.

(F. K. Santoso et. al, 2015) presents a method for securing smart home system. The method incorporates strong security based on AllJoyn framework using asymmetric Elliptic curve cryptography for authentication. It uses a WiFi based IoT gateway to enable secure communication between IoT devices so as to allow users to setup, access and control the system. The translation is also carried out between different IoT standards through a convenient interface via android device. The system has been tested on WiFi enabled STM32F4 ARM Cortex M4F microprocessor, Raspberry Pi Linux computer and Galaxy Note GT N7000 android smartphone. However, the system needs manual configuration of every IoT device with ID (identifier), pre-shared secret key, and access point name.

(O. BeratSezer et. al, 2015) proposed a smart home ontology for six appliances in home such as refrigerator, washing machine, dish washer, television, oven and computer.The smart home system is developed using RDF and Sesame Framework. It is observed thatscaling of sensor devices at run-time is not taken care by the smart home ontology.

(V. H. Bhide, et. al, 2015) presentsan intelligent self-learning system for home automation using loT. The method self learns to control and monitor environmental conditions in homes. The system is tested for light, temperature, level and humidity sensor devices to understand the environmental conditions and also to detect the faults in devices. It is found that the system uses device-to-cloud communication model and it needs manual fault correction by technicians.

(S. K. Datta et. al, 2015) describedIoT for personalized healthcare in smart homes. It uses Machine-to-Machine Measurement (M3M) framework for discovering, managing and interacting with heterogeneous devices deployed in smart home and eHealth domains. The system performs complex data processing, discovery of necessary resources, maintenance of history of data andauto-securedmanagement. It also combines sensor data from different domains (creates cross-domain knowledge) and generate actionable intelligence using semantic reasoning engine. The system requires less than 3.5MB of memory, less than 2% of CPU load, power consumption of 259mW-298mW in Samsung galaxy s3 running android kitkat.

(M. Zehnder et. al, 2015) presents a technique for energy saving in smart homes based on consumer behavior. The system uses deterministic finite state machine (FSM) approach for mining frequent and periodic patterns in the event data. The extracted patterns are converted to association rules and current behavior of inhabitants is used to detect the opportunities to save energy and alsoto send a recommendation to the inhabitants. The method achieves useful recommendation of about 10% using frequent and periodic patterns. The results can be improved by using other machine learning algorithms and considering other criteria such as pattern length, time between two events, weekday and season when the pattern occur most and feedback of inhabitants.

(MayurBhole et. al, 2015) delivered analytics services for smart homes. The method addresses various issues related to end-user experience and recommends appropriate device settings based on usage history of devices of smart home system. It also employs an appliance usage-prediction engine to predict the status of a device at any time.The system is found to be scalable and has achieved recommendation accuracy of 90%. Further the system can be extended to optimize the energy usage.

(I. Papp et. al, 2015) developed a method for uniform representation and control of Bluetooth Low Energy devices in home automation software. It contains a generic gateway that controls any brand device. The method ensures scalability and easy plug-n-play brand free integration of new devices.It also supports manual mode and plug-n-play operational modes. The manual mode enables addition of profiles, services and device role in configuration file. Plug-n-play mode assigns profiles and services to the newly detected devices automatically.

(G. V. Vivek et.al, 2015) proposesIoT services using WiFi-ZigBee gateway for a home automation system. The gateway establishes communication among different protocols and provides access to the sensors and actuators. It helps to reduce power consumption. The system has been tested using *cubietruck* board as gateway and *Xbee* module with door sensor, temperature sensor and light sensor. Sensors were connected to different power sources and achieved reduction of 20mA.

(Ming Wang, et. al, 2013) proposed an IoT based appliance control system for smart homes. The central controller sets up a radio frequency 433 MHz wireless sensor and actuator network (WSAN) to control and monitor home appliances. The WSAN consists of switch module and RF control module to directly control all appliances. The system found to be scalable, easy to reconfigure and reorganize. However, it needs automation and optimizing the appliance operations.

(A. Chakravorty, et. al, 2013) designed a framework for privacy preserving data analytics for smart homes. The framework has planned to achieve data security at each stage of data life cycle such as: data generation, data transfer, data storage, data processing and data sharing. The performance, uncertainty level and efficiency of different data security techniques would need to be measured.

(S. D. T. Kelly, 2013) proposesIoT for environmental condition monitoring in homes. It performs condition monitoring and energy management of domestic devices such as electric lamp, water heater, battery charging units, washing machines and refrigerators. The system consists of smart sensing devices, IoT application gateway and internet server.

The sensing devices measures various parameters such as water temperature in the hot water cylinder, water temperature in the solar water heater, supplied voltage, outside light intensity, current and voltage parameters of a household appliance. The system also gathers environmental conditioning values like temperature, light intensity and humidity which are used to provide ambient intelligence to reduce the energy consumption. It provides internetworking mechanisms using IoT application gateway that helps in transforming ZigBee addresses and encapsulating data payloads in an internet protocol. The reliability of sensing information achieved an accuracy of 97%. The system can be extended to minimize memory requirements and effective retrieval of data. The sensing units can also be interconnected using 6LowPAN for better reliability and effective data transmission.

(Jihua Ye, et. al, 2012) presented research work on adaptive smart home system. In this system, the central controller uses feedback information from household appliances to learn the habits and to adjust the system automatically. The system uses*toddler* and *correlation* algorithms to learn the habits of the users. The system is found to be adaptive and eliminates portability defects of the traditional home system, but it takes longer time to learn and modify the rules.

(J. Byun et. al, 2012) proposed an intelligent self-adjusting sensor for smart home services based on ZigBee communications. ZiSAS addresses the issues such as sensors with limited power resource, limited communication, storage and processing capabilities. The system provides flexible middleware architecture suitable for dynamic environments. The systemfacilitates self-adjustment of sensor devices, auto-reconfigurationof middleware, topology, sensor density and sensing rate based on environmental situation. It also performs event based sensor control to take care of sensing rate and node density based on the location of resident. The results shows that situation based control without Sensor Management Agent (SMA) and with SMA is about 3-12% and 8-34% respectively.

(Dae-Man Han et. al, 2010) developed smart home energy management system using IEEE 802.15.4 and ZigBee. It automatically gathers sensing information using occupancy sensor, Passive InfraRed (PIR) Sensor and photo sensor. It efficiently controls various home devices such as light and heater. It also proposes disjoint multipath routing protocol using Kruskal's algorithm to automatically establish the wireless network between the sensors deployed in home.

It is observed from the literature survey that there are so many issues related toIoT for smart home system. Some of the presented research works focus on effective energy management [32, 35, 39, 42], integration of different protocols [31, 34, 35, 39], automatic monitoring and controlling of home appliances [27, 37, 42] environmental condition monitoring [29, 39], creating cross-domain knowledge [31], automatic detection of faults in devices [29], autonomous configuration [31, 34, 40, 41], security [5, 38] and context based adaption of appliances [41]. However, no single technological solution has been reported for smart home system that addresses all the above listed issues. Therefore, there is a huge potential for developing a generic framework and technological solution for IoT for smart home system that addresses all the issues.

IV. DESGIN ISSUES OF SMART HOME SYSTEM

The various design issues of smart home system are discussed below.

- *Serviceability*: The functionality/services of each sub system/component should be independent from the other subsystems/components. Any modification or addition of services to one sub system should not affect the other sub system.
- *Scalability*: Since IoT applications might include large number of objects/things and number of objects that can be connected might vary at any time hence, the employed architectures and protocols must be able to scale according to the need.
- *Programmability*: The objects must be programed such that their operations change dynamically based on the context/situation.
- *Auto-Configuration*: In IoT paradigm, the objects that come under visibility of smart home system must be configured automatically so that they will begin functioning as per the context/situation.
- *Centralized vs. Decentralized architecture*: In centralized architecture, a central hub controls the execution of smart objects where as in decentralized architecture, objects interact without the control of central authority. In centralized, smart objects acts as recipient of data while central hub enables services and capabilities. Some of the key advantages/capabilities of central hub are; objects discovery, objects management, event notifications/processing and real-time analytics. But in some of the scenarios, smart objects require autonomous communication between them without the need of a central hub which is called as decentralized architecture. The various advantages/capabilities are; objects-to-objects messaging, decentralized auditing, and file sharing. Most of the developers prefer decentralized architecture.
- *Heterogeneity*: The smart home system must take care of heterogeneous networks, sensor devices of different vendors and varying capabilities of devices.
- *Neutrality or Transparency Principle* for privacy and data protection.
- *Security*: In IoT paradigm, since billions of objects will be connected, it becomes necessary to provide strong

security for each of the objects. There may be two types of security concerns: one is object access control and another is service access control. Object access control deals with protecting objects and data from unauthorized access. Service access controls deals with prevention of misuse of services from unauthorized users.

- *Developing Open Standards*: The technologies developed must be made available globally for open access and use. The new contributors of IoT paradigm must use and extend the technologies available.
- *Robustness*: Each sub system should be fault tolerant and must have capability of providing services at any time.
- *Energy Efficient Protocols*: In Internet of Things technology, the smart objects are used to gather, process and store the data. Since the objects are not powered by direct power source, it is necessary to develop energy efficient protocols for increasing life time of objects.

To take care of all the design issues of smart home system, a new generic framework is proposed. The detailed description of proposed generic framework is given in the ensuing section.

V. PROPOSED GENERIC FRAMEWORK FOR SMART HOME SYSTEM

The generic framework for smart home system consists of various components such as auto configuration and device management, auto-monitoring & control, cross-platform communication protocol, object access control, user interface, context aware adaption scheme, and data analysis and visualization.

The architecture of proposed generic framework is depicted in fig. 1. The core components of smart home system are detailed in the following sub sections.

A. Auto-Configuration and DeviceManagement

The auto configuration and management component of smart home system self-configures/self-organizes objects and makes the objects ready for communication. It also addresses the scalability problem. This component provides plug n play connectivity to objects for achieving device compatibility. The component communicates with objects in visible range of WiFi network and enrolls them with authentication. The enrolled objects will be configured automatically to make them ready for further operation.

B. Communication Protocol

This component of smart home system will send/receive data and control information to and from connected objects. The protocol also takes care of interoperability issues.

C. Auto Monitoring and Control

This component/module monitors status and health of all objects and controls automatically based on context. The objects will also be controlled based on commands issued by the user.

D. Objects Access Control

This component of smart home system prevents and protects data and control information transmitted to and from objects from unauthorized access.

E. User Interface (UI)

The user interface module of thesmart home system enables users to interact with the smart home system to access that status of devices and control them with commands given manually. The user interface component of smart home system is remotely accessible by the computers/mobile phones connected to the internet.

F. Context Aware Adaption Scheme

The context aware adaption scheme of smart home system controls the operation of devices based on the history of usage and current situation. It uses machine learning algorithms to learn the usage history and predicts the operation of devices based on the context. The inhabitant's behavior and emotions will also be considered for determining the context and prediction of device operation.

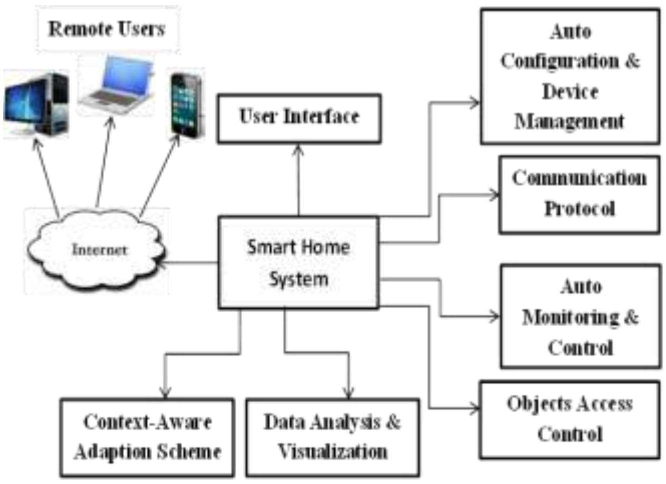

Figure 1. Generic Framework for Smart Home System

G. Data Analysis and Visualization

The smart home system also provides data analysis and visualization service. The usage reports of devices, consumption of energy and other statistical details will be analyzed and visualized.

The proposed generic framework is helpful for making every house as smart house to increase the comfort of inhabitants. Each of the components of generic framework is robust in nature in providing services at any time.

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VI. CONCLUSION

In this paper, a generic framework for smart home system is presented. The generic framework is unique in nature and addresses all the issues associated with making a house smart. It comprises various components such as auto-configuration and device management, auto-monitoring & control, cross-platform communication protocol, object access control, user interface, context aware adaption scheme, and data analysis and visualization. The components of smart home system are designed to take care of various issues such as scalability, interoperability, device adaptability, security and privacy.

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