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A SURVEY ON MIDDLEWARE FOR SMART HOME APPLICATION

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Abstract - In this Era, Internet have extended its hands as Internet of Things (IoT) making anything (sensor, watch, TV ...) with unique identification to be connected irrespective of place and time. Increase in such connectivity would in turn increase the complexity involved in creation of applications using those connectivity .Middlewares free a application developer from the behind technology. It provides an interface between the connected devices and the application that make use of data from connected devices. This paper restricted the discussions to middleware for smart home application. It also addresses the emerging growth of smart home application followed by a survey on existing IoT middleware solutions for smart home application. In addition, the paper highlighted the challenges and future research directions in this area.
Keywords - Context aware service, Internet of Things, Middleware, Security and Privacy, Smart Home

I. INTRODUCTION

The amount of data generated and communicated over internet increases with increase in connected devices. In Ericsson Mobility report 2015[1],it is estimated around 28 billion devices will be connected to the Internet by 2021, of which more than 15 billion will be connected M2M and consumer electronics devices. Home is the roof under which most of the consumer electronics include TV, Fridge, thermostat, HVAC.etc. are placed. The Home can be made smart by equipping those electronic devices with computing and information technology that helps them in anticipating and responding to the needs of the Occupants, working to promote their comfort, convenience and security through the management of technology within the home and connections to the world beyond [2] .

Through smart home, IoT allow its inhabitants to monitor and control their living space. IoT plays a major role in transforming a home into a smart home which include Nest - Wi-Fi connected smoke alarms and thermostats, Belkin – WeMoHome Control Swtich,LC – Home chat application and so on. In general, the smart home applications can be classified in to three categories [3] namely, home utility systems, home appliances and home safety and security systems. Home Utility system concerns on efficient energy management through connected things like Philips Hue color-tunable A-lamp for smart lighting. Home appliances concerns on improving the comfort zone of the users like Amazon Dash Button as Home Ordering Tool, Parrot Pot for Connected Garden. Home safety and security systems pay attention in safety aspects of the Home like Birdi for Home Safety.

With increase in Smart home products from different vendors, Configuring /installing Smart home products and developing application for home inhabitants in satisfying their needs using the data from connected devices is a challenging one .This challenge can be resolved with the aid of a middleware.

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To bring all researches around IoT under a category three visions of IOT is defined [4] Things – oriented vision (techniques to improve object visibility), Internet –Oriented –Vision (techniques related to connectivity) and Semantic – Oriented Vision (techniques related to data handling). The architecture for IoT can be divided into five layers [5] namely,

1. Perception Layer /Device Layer consisting of physical objects to collect information from the environment.
2. Network Layer /Transmission Layer for securely transferring the information from sensor devices to the information processing system.
3. Middleware Layer is responsible for the service management .It acts as intermediate layer to create an interface between lower
   level layers (physical and network) and higher level layer (Application and Business)
4. Application Layer is responsible for the proper operation of deployed application
5. Business Layer is responsible for the management of overall IoT system including the applications and services.

The survey on middleware [6] classify the existing middleware into seven categories namely, event based , service oriented ,agent based, tuple-space ,VM based, database approach and application specific based on design approach and it reviews each category of middleware based on functional, non-functional and architectural requirements as specified in [6].Another survey on Middleware [7] classify IoT middleware architecture into three types Service based, Cloud based and Actor based however, as of our knowledge no survey could be found for middleware platforms designed for Smart Home application in IoT. This paper provides a survey of existing research work in designing middleware systems for smart home application in IoT.

The remainder of this paper is organized as follows: Section II reviews the trend of smart home application .Section III provides a survey on existing middleware for Smart Home application of IoT .Section IV provides a discussion on the work reviewed in the third section. Section V discusses the technical challenges to be addressed in designing middleware systems for the Smart Home Application and Section VI have the conclusion of the paper.

II : TREND OF SMART HOME APPLICATION

Smart Home (SH) is a kind of home system based on the Internet of things, in which home appliances can be connected through the communication network to provide remote access, monitoring and control. As per IoT analytics report of Q4/2014[8] smart Home application have great impact on the everyday life of individual and have gained great popularity of 100 % as shown in Figure 1.

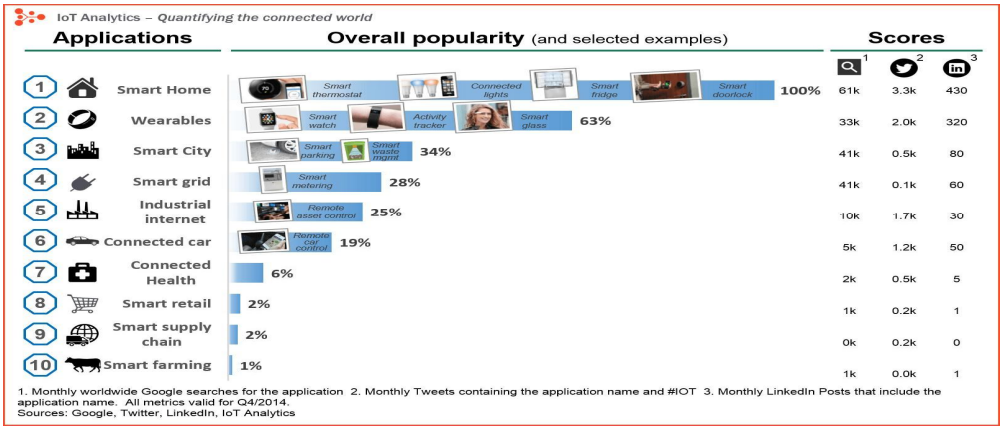

Figure 1: Chart on Popularity of IoT Application

Functions to be covered by an Smart Home Environment is identified as three dimensional hierarchical structure [9] based on importance of the function in SH, application of function in SH and type of user in SH .Further the level of services to be rendered by Smart home can be broadly classified into two categories one as Context-based service / high-level service in which services are delivered to a customer based on their necessity or preference like adjusting HVAC based on room humidity and Switch light on/off based on intensity of light in room .the second as Device-specific service / low-level service for device management like identification and configuration of devices .
In general , any application of Smart home mainly focuses on home Surveillance, Energy management and Home security and smart home can be classified into five category [2] ,based on the functionality they provide to their inhabitants. They include

1. Homes containing single standalone object which function independently in an intelligent manner.
2. Homes containing intelligent communicating objects which function intelligently on their own right and also exchange information between one another to increase functionality.
3. Connected homes having internal and external networks, for remote monitoring and control.
4. Learning homes provides service by anticipating the user needs through analysis of recorded data.
5. Attentive homes provide context aware services to their occupants by monitoring the environment around them.

III : MIDDLEWARE FOR SMART HOME APPLICATION

Middleware act as an intermediate software layer between the hardware and application that make uses of the data generated by underlying technology. It helps to hide the involved heterogeneity and simplifies the development of application. Four functional components of Middleware for IoT are identified in paper [10] as interface protocols for technical interoperability, device abstraction for syntactic and semantic interoperability, central control, context detection and management for context-aware computation and application abstraction. This paper reviews the middleware HYDRA/LinkSmart[11], aWESoME[12], GINGA[13], CASAS[14] , CAMPUS[16] and SHSM [17] applicable for Smart home application.

HYDRA/ LinkSmart [11]

HYDRA renamed as LinkSmart Project in 2014 is a middleware for intelligent networked embedded systems based on a service-oriented architecture. The Software architecture of middleware have three layers in vertical structure namely Network layer, Service layer and Semantic Layer and have an security layer in horizontal structure . Hydra achieves application abstraction and interoperability through semantic model and device abstraction through web service interface. The prototype model builds application like Give me light, Follow me light, Goodbye, stand-by and energy consumption information by considering user location context and the moment of the day context .Hydra can be applied for designing application in Smart Home, Health Care and agriculture domain.

aWESoME [12]

aWESoME is a web service middleware designed for ambient intelligence environment. It is developed as a part of smart IHU project for smart university deployment .The software architecture for the model defines three layers, namely Integration layer, Service layer and Web service layer. Integration layer provides device drivers for ZigBee Smart Plugs, Sensor Boards, Smart Clampers and Z-Wave devices in java supporting portability. Service layer provides software-based services such as Wake-On-Lan and remote shutdown to manage hardware equipment. Web service layer acts as an interface between applications and system hardware to access the functionality of hardware devices

through integration Layer. The performance of middleware is tested through two client application i)a desktop application GUI - iDEALISM and ii) a smart phone application in android platform plugDroid. It provides only syntactic interoperability and achieving semantic interoperability is listed as future work. Applicability of Middleware in developing context aware application and security aspects are not discussed in paper [12].

GINGA [13]

Ginga is the International Standard for Digital Television (ISDTV) middleware. In paper [13] component based model for the Ginga middleware is developed using OSGi framework allowing Digital TV to act as a Home Gateway The model provides centralized control as the middleware is installed only on the gateway .The architecture uses the advantage of OSGi specification, supporting for home network such as UPnP and Jini .The Ginga-OSGi Architecture consist of three structures, namely Ginga-NCL for procedural environment ,Ginga-J for Java applications and a Ginga Common Core provides common content decoders to serve both the Ginga-NCL and Ginga-J .Though the model is scalable, the focus on its capability in achieving interoperability and security is not discussed.

CASAS [14]

CASAS Smart Home in a Box is a project initiated by the CASAS research group. The project aims in providing a large-scale smart environment data and tool infrastructure. It is an light weight event based middleware providing an easy -to-install smart
home environment. The middleware provides services for assigning universally unique identifiers (UUIDs) and for adding time stamps to events. CASAS architecture supports high level of scalability but do not allow any customization.

CAMUS [16]

Context-Aware Middleware for Ubiquitous computing Systems (CAMUS) is a tuple based middleware rendering support for the development of smart home application .Its architecture have feature extraction layer, feature context mapping layer and context layer .At the lowest level, feature extraction agents are used for extraction of features from the information sensed by sensors. In feature context mapping layer, the context information from the extracted features are stored as tuples with semantic label .Upper level context layer have modules to store ontology , to support reasoning facility and to process context aware queries The middleware supports scalability and semantic interoperability through the usage of ontology but do not discuss any information related to security aspects.

SHSM [17]

Smart Home Service Middleware (SHSM), is used to implement service integration and intelligent service invocation. SHSM is based on centralized software deployment model. SHSM implements a device-service agent for integrating heterogeneous services within the home space. The architecture of SHSM in vertical structure have resource layer for integrating various service resources, adaptation layer providing compatibility service in hiding heterogeneous features among various resources. service layer for managing all the Web services provided by resource layer and adaptation layer, business process layer coordinates specific set of services from service layer into business processes based business logic and application layer provides home occupants with SH application .The architecture from the view of horizontal structure have context layer for serving context aware applications and Knowledge base for storing needed static formalized information. This open source middleware do not provide any information about the way of achieving security.

IV. SUMMARY OF RESEARCH FINDINGS FROM THE REVIEW OF LITERATURE

Comparative analysis of reviewed middleware is tabulated as table 1. The features considered for comparative analysis include middleware design approach, the way and degree of heterogeneity achieved, support for communication protocol, enforcement of security and privacy, support for context aware computing, toolkit for development, applicable application domain and about its license. Of the Middleware reviewed in this paper, only Hydra/LinkSmart handles security, while in other reviewed middleware security aspects is either not discussed or given as future work [12]. GINGA and SHSM middleware follows centralized model in which middleware components are deployed in a central device home gateway. The other reviewed middleware adapts distributed model, where middleware components can be deployed in every entity promoting high scalability and avoiding single point of failure. Apart from CASAS middleware all other reviewed middleware are open source promoting more application development using them.

Table 1: Comparative Analysis of Middleware for Smart Home.

Middleware	Approach	Device Abstraction	Interoperability	Network Connectivity	Security and Privacy	Context aware	Development Kit	Domain	License
Hydra/ LinkSmart	Service Oriented Middleware	Web Service	Syntactic SOAc Interoperability OWL,OWL-S, SAWSDL – Semantic Interoperability	Zigbee, Bluetooth, RFID,SOAP	Identity-based and credential-based framework	Location Context , Day Context	Hydra Software Development Kit Device Development Kit Integrated Development Environment	Smart home Health Care Agriculture.	Open Source
aWESoME	Service Oriented middlewa re	Integration Layer	Limited Support WSDL Syntactic Interoperability portabilit Java y	Zigbee, Z-Wave	As future work	Not Mentioned	Not Mentioned	Smart Campus Smart Home	Open Source
Ginga	VM	Using	Not Mentioned	Bluetooth,Zig	Not	Not	Not	Remote	Open

	based Middlew are	Compone nt s of OSGi		Bee,Wi-Fi	Mentioned	Mentioned	Mentioned	monitorin g and control of house hold appliances	Source
CASAS	Event Based Middlew are	Not Mentioned	Not Mentioned	ZigBee	Not discussed	activity recognitio n software, support vector machine for real time activity detection	CASAS Toolkit	Activity aware health assistance Applicatio n ,Elderly Assistance , Smart home	CASAS Research group [15]
CAMUS	Tuple based Middlew are	Feature Extraction layer	Semantic Interoperabilit y using OWL	ZigBee	Not Focused	Resoning module and context aggregator	Jena Semantic web toolkit	Home Automatio n	Open Source
SHSM	Service Based Middlew are	Web service	device-service agen t	ZigBee	Not Discussed	rule driven applicatio n trigger mechanis m	Not Mentioned	Home automatio n	Open Source

V: TECHNICAL CHALLENGES IN DESIGNING MIDDLEWARE FOR THE SMART HOME

Open problems and future directions in the field of IoT is reviewed in IoT survey paper [18] and technological challenges and open issues to be specifically addressed by an middleware of IoT is discussed in [6] [19].This paper highlights the below points as identified key challenges in designing middleware systems for the Smart Home application. The challenges are

1. Ease of Deployment : For the full success of SH Application, end user need to feel more comfort in using the API provided by middleware for configuring smart home products .Only CASAS Middleware supports quick configuration and de-configuration but it do not provide flexibility for customization .
2. Interoperability: Heterogeneity raised with more SH products from different vendors supporting different protocol can be resolved by the middleware in terms of syntactic, semantic and network. Of reviewed middleware, most of them have limited middleware support for syntactic and semantic interoperability.

3. Post Deployment Support: whenever there is an update in software used in SH products, provision must be rendered by middleware for the SH product to upgrade their software. This issue is not addressed by any of the reviewed middleware in this paper.
4. Context aware service: Middleware must have provision for the retrieval of context information from the environment, to process retrieved context information and to avail service based the processed context information.
5. Security and Privacy: Apart from HYDRA any of the reviewed middleware had not handle security and privacy.

Research work can be done in the field of middleware for smart home to address identified issues.

V: CONCLUSION

Based on the middleware reviewed in this paper, the research findings are

1. Security and privacy which is one of the prime factors for the development of any application, in any domain is not paid much attention.
2. Many of the Middleware have syntactic and network interoperability but have limited focus on semantic interoperability.
3. Post deployment support, an essential aspect for SH products remain uncovered.
4. More support need to be rendered for context aware computing

In future, middleware design for smart home may focus on the identified research areas for the betterment of SH application service providing utmost benefit to its developer and users.

REFERENCES

[1]. Ericsson Mobility Report, "On the pulse of the Networked Society", Nov. 2015.
[2]. Aldrich F K., "Smart homes: past, present and future ," Inside the smart home ," Springer London. pp. 17-39,2003.
[3]. Lindsay, Beau Woods and Joshua Corman ,"Smart Homes and the Internet of Things, "Atlantic Council Brent Scowcroft Center on International Security. Mar. 2016
[4]. Atzori L, Iera A, Morabito G. , "The internet of things: A survey,". Computer networks. 54(15):2787-805. Oct. 2010.
[5]. Khan R, Khan SU, Zaheer R, Khan S., "Future internet: the internet of things architecture, possible applications and key challenges," In Frontiers of Information Technology International Conference .pp.257-260.Dec.2012.
[6]. Razzaque MA, Milojevic-Jevric M, Palade A, Clarke S ,"Middleware for internet of things: a survey, " IEEE Internet of Things Journal. Vol. 1:70-95. Feb .2016.
[7]. Ngu AH, Gutierrez M, Metsis V, Nepal S, Sheng MZ, " IoT Middleware: A Survey on Issues and Enabling technologies," IEEE Internet of Things Journal.
[8]. https://iot-analytics.com/10-internet-of-things applications/
[9]. Hamernik P, Tanuska P, " Classification of Functions in Smart Home," International Journal of Information and Education Technology. 2(2):149.Apr .2012.
[10]. Bandyopadhyay S, Sengupta M, Maiti S, Dutta S ,"A Survey of middleware for internet of things. ," In Recent Trends in Wireless and Mobile Networks , pp. 288-296. 2011.
[11]. Eisenhauer M, Rosengren P, Antolin P, " A development platform for integrating wireless devices and sensors into ambient intelligence systems," IEEE Annual Comm Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks Workshops .Jun .2009.
[12]. Stavropoulos TG, Gottis K, Vrakas D, Vlahavas I, aWESoME: A web service middleware for ambient intelligence," Expert Systems with Applications. 40(11):4380-92.Sep.2013.
[13]. de Lucena Jr VF, Chaves Filho JE, Viana NS, Maia O, "A home automation proposal built on the ginga digital TV middleware and the OSGi framework," IEEE Transactions on Consumer Electronics.;55(3): 1254-62.Aug.2009
[14]. Cook DJ, Crandall AS, Thomas BL, Krishnan NC, " CASAS: A smart home in a box ," Computer. 46(7).Jul.2013. 15.Deployment AL , " Smart home in a box: A large scale smart home deployment ," In Workshop Proceedings of the 8th
[15]. International Conference on Intelligent Environments Vol. 13, p. 169 .Jun.2012.
[16]. Ngo HQ, Shehzad A, Liaquat S, Riaz M, Lee S , "Developing context-aware ubiquitous computing systems with a unified middleware framework ," International Conference on Embedded and Ubiquitous Computing .pp. 672-

681 . Aug.2014.
[17]. Wang X, Tao Y, Xu X ," SHSM: A Service Middleware for Smart Home , " IEEE International Conference on Mobile Services pp. 475-479 . Jun .2015.
[18]. Li S, Da Xu L, Zhao S, "The internet of things: a survey, "In Information Systems Frontiers International Conference 17(2):243-59.Apr.2015.
[19]. Chaqfeh MA, Mohamed N , " Challenges in middleware solutions for the internet of things," In Collaboration Technologies and Systems (CTS) . pp. 21-26. May.2012.