

# Implementation and Recent Progress in Cloud-based Smart Home Automation Systems

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**Abstract**— Consumers' interest in smart home concepts has been increasing due to the rapidly expanding home appliances industry that introduces Wi-Fi enabled appliances. Manufacturers provide firmware that allows users to control appliances using smartphones from anywhere. Smart appliances, firmware, and smartphones connected to a cloud server for data storage to form a simple smart home automation system (SHAS). This paper reviews how SHAS is implemented and its recent progress. The authors' observation found that there is a growing interest among researchers and developers to study software-defined network, web services, and end-user development tools within 2016 and 2018. This progress caused by researchers' and developers' interest to mitigate heterogeneity issues in SHAS.

**Keywords**— Internet-of-Thing; smart living; intelligent living;

## I. INTRODUCTION

The idea of home automation has been around since many decades ago. However, its implementation has slow progress due to the expensive cost of hardware and installation. Nevertheless, the introduction of smart living and smart home concepts get the home automation back on track. Moreover, smart home systems are increasingly sophisticated in recent years [1]. The emerging of the Internet of Things (IoT) has led smart home technology to be integrated with a variety of devices and appliances including conventional sensors and remote controls as well as various smart appliances and robots [2]. Thanks to electrical appliances industry that introduces Wi-Fi-enabled home appliances to the market which consequently offers an alternative for implementing smart home automation systems at an affordable cost by average consumers.

Forbes [3] reported that the market for smart home appliances had increased exponentially in 2017 as compared to the previous year. The reason for this is due to the two key features that a smart home system could offer; (1) simple control and (2) intelligent automation [4]. These two features aimed at providing comfort to the residents, convenient control of electrical appliances, and security of rooms or buildings. The current smart home trend also shows that the system is created to assist elderly and disabled people at home. It also promotes energy-efficient living to support sustainable and green environment. Another additional reason for the growth of smart home interest among consumers is due to the seamless integration of smart home appliances with smartphones. It allows consumers to control and manage the appliances from anywhere using their smartphone. Both smartphones and the smart home appliances are becoming

affordable to average consumers which catalyses the growth of smart home interest.

The use of smartphones to control electrical appliances remotely causes the manufacturers to deploy cloud services for their consumers' data storage and application hosting. In the case of smart home, the manufacturers used cloud services for hosting applications for controlling the appliances using the cloud providers' system software and hardware [5]. Cloud computing resources run on virtualized platforms [6]. There are available on the Internet and accessible using smartphones, computer tablets, notebook computers and desktop computers. For examples, Sharp, a Japanese home appliances manufacturer provided their customers with Sharp Cloud Smarthome System for an integrated home security system accessible through smartphones. LG, a Korean manufacturer, introduced LG SmartThinkQ, a cloud-based application that allows their consumers to manage LG smart appliances using a smartphone. These two examples are just to name a few among other cloud-based smart home systems.

Zion Market Research [7] reported that global smart home market size was US\$ 24.10 billion in 2016 and it is forecasted to reach US\$ 53.45 billion by 2022. The market growth for the smart home is a useful indicator to describe the overall economic and industrial progress in this area. However, to our knowledge, such development from the research perspective is yet to be reported. Hence, it is important for researchers to know the current developments so that the continuity between research and industry development complement each other. Therefore, this paper aims at identifying the recent progress of cloud-based smart home automation system (SHAS) by analysing scholarly articles published in 2016 to 2018. Specifically, we focus this review on the field of information and communication technology (ICT) research. The next section describes the implementation of SHAS in general and followed by the analysis of its recent progress.

## II. IMPLEMENTATION OF SMART HOME AUTOMATION

Developments in both ICT and electrical hardware industry have made smart homes easier to be implemented as compared to the past two decades. Today, various electrical appliances have been designed with the capability of connecting to wireless network, Wi-Fi. It makes the electrical appliances smarter as it can be controlled remotely using a smartphone. As compared to the past two decades, some of the home electrical appliances like TV, fan and air-conditioning units can only be controlled using the remote control units provided by manufacturers. Today, many manufacturers still supply the

remote control units. However, they come with the additional firmware that allows consumers to control the appliances through mobile applications on their smartphones. This situation supports the implementation of the smart home system easily.

There are various definitions of smart home given according to their respective areas; covering from construction, engineering, energy, to ICT. In terms of construction and engineering, smart home is more likely to be defined through the use of modern materials to produce energy-efficient homes. On the other hand, the use of software and hardware for controlling home appliances is the major focus of ICT for the smart home. Horálek et al. [8] defined a smart home as a home built using modern materials with low-energy consumption, and it uses hardware and software tools for general task automation which enhances the comfort of living and provides a cost-effective operation to the residents.

In this paper, smart home refers to a home or living environment that uses technology to allow electrical appliances and systems to be controlled automatically [9, 10]. In particular, it uses ICT to control homes including the electrical appliances and home automation such as windows and lights [11]. Mittal et al. [4] proposed a SHAS, a residential space that provides comfort to residents, facilitates the operation of electrical appliances all the time regardless of whether they are at home or away. Appliances can be controlled remotely using applications on smartphones that are connected via Wi-Fi and the Internet. Communication to SHAS is simple and affordable using the existing network infrastructure. Smartphones affordability has been significantly increasing the demand for home automation. Also, the emerging of Internet of Thing (IoT) where electronic appliances, sensors, and software are connected to home network [1] has catalyzed the SHAS.

Home automation has undergone a revolution by witnessing a wide range of electrical appliances that can be controlled remotely. In the beginning, only fans, TVs, and air-conditioning units can be controlled using remote controllers. Then the gate and garage can also be controlled remotely. Infrared (IR), radio frequency (RF) or Bluetooth technology have been used extensively for the wireless communication between the electrical appliances and the remote controllers [12]. However, today, various electrical appliances can be controlled remotely using Wi-Fi technology, including refrigerators, washers, lamps, rice cookers, ovens, and dishwashers. Consequently, the word “smart” has always been used together for marketing of these appliances to differentiate them with the old technology. For example, smart TVs, smart refrigerators, and smart lights, to name a few. Fig. 1 shows four common remote controllers for wireless technology used by the manufacturers on their electrical appliances. The description of the wireless technology as defined by Techopedia [13] is presented in Table I.



Fig. 1. Common wireless communication technology for home appliances

TABLE I. WIRELESS COMMUNICATION TECHNOLOGY FOR REMOTELY CONTROLLED HOME APPLIANCES

Wireless communication technology	Description
Infrared (IR)	A wireless communication technology used for device communication over short ranges. line-of-sight, unable to penetrate walls
Radio frequency (RF)	A wireless communication technology that uses radio waves in the range of 3 kHz to 300 GHz
Bluetooth	A wireless technology standard that is used to exchange data over short distances (less than 30 feet).
Wi-Fi	A wireless network technology used for connecting mobile devices to the Internet using the microwaves frequencies of 2.4Ghz or 5Ghz.

Smart electrical appliances can be controlled using both the remote controllers and smartphones. The manufacturers provide a firmware to allow users to control the electrical appliances from the smartphones when both devices are connected within the same Wi-Fi Service Set Identifier (SSID). In other words, both smartphones and electrical appliances should be connected to the same Wi-Fi network to allow pairing process to be successfully completed. Then only users can control the appliances from the smartphones. Apart from Wi-Fi enabled appliances, the manufacturers provide additional features for the smart electrical appliances. Recently, those appliances have been integrated with cloud-based services to provide value-added services, operations, and management [2].

Cloud enables users to control and monitor smart electrical appliances remotely using the Internet connections. For example, LG's Cloud Center provides an application that allows users to check and view the contents of the refrigerator from home or remotely. This method avoids loss of cold air when the door of the refrigerator is open, resulting in more energy to keep the cold temperature. Hence, energy can be saved. Additionally, users can plan a meal using the existing ingredients in the refrigerator or buy grocery items that are

running out of stock. Another example is the lighting system supplied by Philips Lighting. It uses Google Cloud Platform to enable users to change home lighting styles to various modes for more comfort than the ordinary lights. It also works with Nest security system that is capable of detecting human movements through surveillance cameras installed outside the house and activating the lights in the home as if the movement has been heard or known by the residents. These are just a few examples of the cloud services of smart electrical appliances that manufacturers provided to the consumers.

In this paper, we survey smart electrical appliances available in the market to understand the functionalities of cloud-based SHAS that the manufacturers could offer. We used the term “smart” and “Wi-Fi-enabled” electrical appliances on Google search engine for the searching. We also classified the smart home into rooms where the smart appliances could be needed such as the living room, bedroom, kitchen, entrance, and laundry as well general-purpose appliances. Table II lists the smart electrical appliances, the example of manufacturers and their smart features. There are two common features shared by all the appliances that are (1) smartphone control from home and away, and (2) scheduling the use of the appliances according to the time needed by the residents or users. Apart from these, there are a few smart features provided by the manufacturers to enhance the functions beyond the traditional one.

TABLE II. EXAMPLES OF SMART APPLIANCES AND THEIR FEATURES

Room	Appliances/ Devices	Examples of manufacturers	Examples of smart features			
Living Room	LED lights	- Philips - Ikea - Osram - Hive - Belkin	- Ambient creation - Selecting the preferred lighting modes	Dishwashers	- Smartypans	ingredients, temperature and humidity for simple cooking instruction
	TVs	- Samsung - Siemens - LG - Sony - Panasonic - Philips - Sharp - Toshiba	- Installed and run applications - Browse the Internet - Video call	Ovens	- Siemens - LG	- home and away - Check the salt or rinse aid
	Ceiling fans	- Haiku - Hunter	- Start and adjust speed	Refrigerators	- Samsung - Siemens - LG	- Start and monitor the cooking process - Check the content of the fridge
	Air purifier	- Dyson - GermGuardian - Blueair - Winix - Osim - Xiami	- Monitor and react to indoor air quality - Generate reports on air quality and purifier's activities - Monitor the filter	Coffee machines	- Siemens - De'Longhi - Breville - Behmor	- Control brewing options, water level and temperature
Laundry	Washers	- LG - Siemens - Samsung - Whirlpool	- Error-monitoring to detect and diagnose problems - Start and pause cycles, track progress and energy usage - Automatically order laundry supplies when they are running low	Kettles	- iKettle - appkettle	- Notification for energy saving - Temperature setting
	Rice cookers	- Panasonic - Xiami	- Search recipes from the Internet and stored in the rice cooker - Scan the barcode on the rice packaging, and it will select the cooking method for the type of rice	Slow cookers	- Crock-Pot - Black + Decker	- Adjust cook time and temperature
Kitchen	Cooking pans	- Pantelligent	- Monitor weight of	Bedroom	Window blinds	- Shut or open window blinds and curtains
				Heaters	- Crane - Holmes	- Adjust heat setting
				Air-conditioning units	- LG - Samsung	- Adjust heat setting and temperature
				General purpose	Vacuum/Mopping cleaners	- Select and adjust cleaning modes and area of cleaning
					Window cleaners	- Winbots
Entrance and security				Pet feeders	- CleverPet - Abdtect - Petnet	- Dispense pet food according to the setting - Video camera for monitoring pet movements
				Lawnmowers	- Husqvarna	- Control the start and off of the lawn mower - GPS assisted navigation of the garden
				Doorknobs	- Samsung - Yale - RemoteLock	- Lock and unlock door - Receive alerts when code is used - Manage codes for users
				Doorbells	- Ring - iSeeBell - VueBell - SkyBell	- Video camera to view and speak to the visitors - Send alert when someone approaching home
House whole Digital Assistant				Smoke detectors	- Nest - Roost - Onelink	- Send alert when carbon monoxide or smoke is detected, or, and sensor failure
				Surveillance cameras	- Amazon - Netgear - SkyBell	- Control and turn on/off of the camera - Manage recorded videos in the cloud - Send alert when someone approaching home
				Amazon Echo	- Amazon	- Play and control music - Compatible with many smart appliances for voice control
	Smart Home Assistant	- Momo				- Home security system and lights - Video and audio calls

Table II listed the examples of smart electrical appliances that can be a component of a SHAS. At present, smart electrical appliances are still expensive, and many consumers are not ready to switch from ordinary to smart electrical

appliances. However, SHAS can be developed using existing electrical appliances and connect to cloud services. The existing house with the existing appliances can be customized to SHAS by using low-cost tools such as smart switches and plugs. Table III describes the tools that can be used to achieve simple SHAS using traditional electrical appliances.

TABLE III. TOOLS TO CREATE A SIMPLE AND LOW-COST HOME AUTOMATION SYSTEM

Tool	Example of manufacturer	Function
Smart switches	- iDevices - Sonoff - Belkin	Smart switches can be used to replace traditional switches for lights, ceiling fans, and air-conditioning units. They are Wi-Fi-enabled devices, and the manufacturers provide firmware to control these appliances using smartphones from home and away.
Smart plugs	- Belkin - Xiaomi - TP-Link - Zuli Smartplug - iDevices - iHome	Smart plugs can be used on the existing plug. They are Wi-Fi enabled devices and users can control them using smartphones from home and away. Technically, any electrical appliances operate on these plugs would be able to be controlled using smartphones from home and away.

Apart from using smart switches and plugs, users who have advanced programming skills related to mobile applications and IoT prefer the "do it yourself" (DIY) approach. They install sensors and actuators on traditional electrical appliances and program their own mobile applications to control the electrical appliances from smartphones. Then, they created IoT server or subscribe to the existing cloud service such as Amazon Web Services IoT platform, Microsoft Azure IoT hub, IBM Watson IoT platform, Google Cloud IoT and Cisco IoT Cloud Connect. The DIY is an alternative solution to build SHAS rather than purchasing smart electrical appliances or hiring professionals to transform the house into a smart home which is definitely expensive.

Research and development related to cloud-based SHAS have started since 2010 about the same time cloud computing technology emerged such as found in [14-18]. In the context of smart home, cloud enables direct interaction between users and sensors/actuators through the home network and the Internet [19]. Mittal et al. [4] highlighted that a smart home consists of three main components namely (1) home network, (2) intelligent controller and (3) gateway that control home automation through wired/wireless access. Table IV describes the basic components that make up a cloud-based SHAS. Fig. 2 shows the illustration of the components in the cloud-based SHAS.

TABLE IV. THE COMPONENTS OF THE ARCHITECTURE OF SMART HOME SYSTEMS

Components	Description
Home network [20]	A communication network that connects smart appliances or sensors and the intelligent controller seamlessly.
Intelligent controller [18]	Software that can manage appliances and services including auto-discovery and auto-deletion of the appliances and services, auto-transformation of data between different appliances, and auto-switching of tasks.

Gateway [18]	A bridge to link cloud server and home network. It gathers services and submits them to cloud server. It also information services suitable to the users, and then store them as the format that can be used by appliances easily.
Firmware/ Software tool [21]	An interface for a client application that provides predefined functions that connect smart appliances to the cloud server.
Cloud server [22]	A logical server that is built hosted and delivered through a cloud computing platform over the Internet.
Smart appliances [23] OR	Wi-Fi enabled home electrical devices that can be controlled remotely using smartphones or computer tablets.
Sensors [20]	Self-configurable devices that can be connected to traditional electrical appliances and can be controlled remotely.
Smartphone	A client device which the firmware is installed.

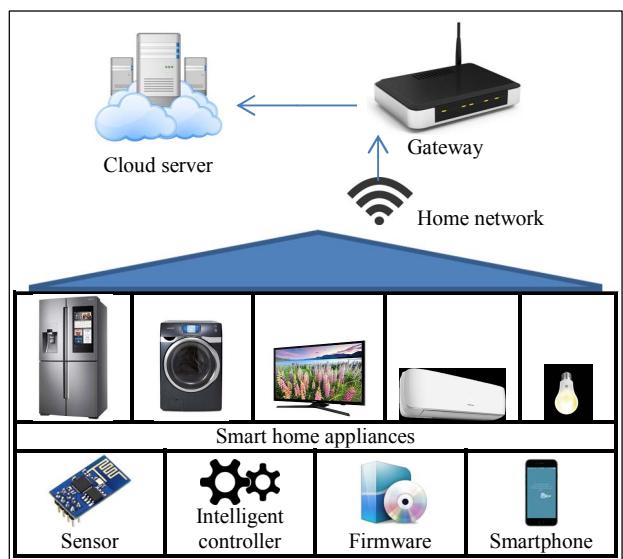


Fig. 2. The components in the cloud-based SHAS

Based on the analysis of the literature and smart appliances market presented in the early part of this section, this paper concluded that cloud-based SHAS implementation could be either outsourced to the experts or "do-it-yourself" (DIY). For consumers who interested to go for DIY, they can either purchase the smart appliances or use Wi-Fi enabled switches and plugs for setting up their own SHAS. Consumers may also explore the possibility of installing sensors or actuators on the appliances and develop their own mobile application for controlling them remotely. Table V summarizes the possible approaches for setting up SHAS.

TABLE V. POSSIBLE APPROACHES FOR CLOUD-BASED SHAS IMPLEMENTATION

Approaches	Description
Outsource	Consumers hire consultants and contractors for installing SHAS. Consultants and contractors may go for a wired or wireless cloud-based SHAS and include all the necessary hardware, appliances and mobile applications as a package of the service
"Do-it-yourself" (DIY)	Consumers purchase smart electrical appliances (e.g., refrigerator, washer, dishwasher, air-conditioning unit) and use the firmware provided by the manufacturers to set up a cloud-based SHAS and manage the appliances using smartphones from anywhere.

	<b>Consumers retain and use the conventional electrical appliances and use smart switches and plugs for the appliances. The manufacturers of the smart switches and plugs usually provide firmware to set up a cloud-based SHAS and manage the appliances using smartphones from anywhere.</b>
	<b>Consumers program a mobile application to connect sensors or actuators to control the conventional electrical appliances. Software tools and basic programming knowledge are needed to set up a simple SHAS using the sensors or actuators.</b>

### III. RECENT PROGRESS IN CLOUD-BASED SMART HOME AUTOMATION SYSTEMS

Wi-Fi enabled appliances have catalysed the development of cloud-based SHAS. This technology certainly attracts researchers' and developers' attention to study and introduce various forms of its extended technology with the aim of improving the performance of SHAS. Exposure to on-going developments in this area would provide useful information to researchers and other developers; hence drive them to explore or streamline SHAS. The remaining of this section describes the authors' observation on the recent progress in the area of SHAS. Scholarly articles published from 2016 to 2018 were analysed so that new development in the area of cloud-based SHAS could be highlighted.

The consumers have long awaited for smart electrical appliances. With remote control capabilities through smartphones and affordable prices of the appliances, this technology is seen as attractive and gives consumers convenience and comfort. However, SHAS technology is still new and not yet entirely stable. Further, different appliances are connected to home network [24]. Manufacturers of electrical appliances use their firmware to control the appliances respectively. In reality, consumers do not always be loyal to one manufacturer as sometimes the required features are not available in the appliances manufactured by specific manufacturers. Then the consumers will buy appliances from other manufacturers. Let us imagine if a consumer uses a refrigerator, washer, lights, and dishwasher from different manufacturers; the consumer needs to install firmware on the smartphone for each appliance. Consequently, it is cumbersome to open different applications for each appliance. Simply said, working with multiple firmware for controlling home appliances do not align with the goal of a smart home. Hence, it is clear that there is a need to address heterogeneity issue of the smart appliances so that consumers can have centralized control of those devices.

Analysis of recent progress in cloud-based SHAS research and development found that heterogeneity is one of the dominant issues and requires immediate resolution. Heterogeneity refers to the diversity of smart electrical appliances, interconnectivity and user preferences [25]. With the use of firmware, a generic application for controlling these electrical appliances is difficult to develop. Current studies proposed the use of the software-defined network (SDN) to overcome it [19, 24-26]. SDN is a technology that provides functionalities for changing the network configuration using remotely-controlled software named SDN controller [27]. It is a promising technology that could integrate heterogeneous

Wi-Fi enabled appliances to communicate in a smart home network and the cloud smoothly. For example, Demetriou et al. [28] proposed HanGuard; an access control policy for home area network (HAN) built based on SDN. The HanGuard uses a smartphone app to monitor the process for establishing network connection of IoT devices (including Wi-Fi enabled appliances). It also provides a bridge to manage heterogeneous devices and appliances in HAN to smoothly interact with other components of the network.

We have noticed that heterogeneity has been the main issue in cloud-based SHAS where various smart electrical appliances from different manufacturers need to communicate with each other harmoniously within a HAN using only a single interface. Since cloud-based SHAS uses hypertext transfer protocol (HTTP) for communication between HAN and cloud, web services can be an alternative to SDN for mitigating heterogeneity issue. Consequently, they provide interoperability between various smart appliances and the cloud. Web services are a type of middleware that provides an interface for components to communicate to each other [29]. In the context of SHAS, web service allows home appliances to communicate independently by providing means that enable consumers to create a SHAS. Consequently, smart appliances from different manufacturers can be easily integrated. The authors' observation on the recent progress in cloud-based SHAS found a growing interest among researchers studying and improving web services to support cloud-based SHAS. For example, Wall et al. [30] proposed device profile for web services and configuration services that allow configuration of multiple smart appliances in a more user-friendly manner. As a result, the configuration service provides interoperability functions for the SHAS. In addition to this study, Anya and Tawfik [31] created a middleware for managing interactions between an elderly person and smart appliances at home. The middleware adapts elderly persons' habits, lifestyles, and preferences towards providing a homogeneous and adaptive interface. Apart from these two studies, Kim et al. [32] studied the use of internal message in a web service for communication of software modules at the home gateway. It is anticipated that more studies related to web services will evolve in the near future due to the heterogeneity issue in SHAS.

In addition to SDN and web services, there is also a growing interest among researchers and developers on the tools to support the concept of end-user development (EUD) for the smart home. Digital information sources from the Internet have encouraged many end-users to make simple configurations and build applications for their personal use. They use visual tools with minimal programming knowledge and efforts to design and built their applications. EUD is an approach to resolving issues in IoT specifically with respect to user preferences and their specific requirements for smart home [33]. As smart home users in the future will involve different layers of our society, there is a need for a personalized user interface that takes into account the user's needs and individual preferences [34]. Further, end-users have diverse requirements and personalized features of their SHAS. In particular with the growing number of appliances, system complexity, and role of SHAS in their everyday life, there is

an increased need for tools that enable the end-users to create their programs [35]. Eclipse Smart Home and Universal Remote Console are among the tools that would empower end-users with a personalized SHAS.

The main aim of this section is to observe the progress occurred in cloud-based SHAS during 2016 and 2018. It is observed that many works focus on addressing heterogeneity issue in the SHAS resulting from variability in manufacturers' hardware and programming platforms. The result of the observation suggested three main trending developments related to cloud-based SHAS namely SDN, web services, and tools for EUD as summarized in Table VI.

TABLE VI. SUMMARY OF RECENT PROGRESS IN CLOUD-BASED SHAS

Recent progress in Cloud-Based SHAS	Description
Software-defined network (SDN)	A technology that provides functionalities for changing the network configuration using the remotely-controlled software.
Web service	A type of middleware that provides an interface for components to communicate to each other.
Tools for end-user development (EUD)	Visual tools used by end-users to design and build their applications with minimal programming knowledge and efforts.

#### IV. CONCLUSION

The concept of the smart home received high attention from consumers lately due to fast-growing development of smart electrical appliances in the market. Various Wi-Fi enabled appliances are available to enable consumers to build a SHAS at lower costs. The use of Wi-Fi enabled appliances has introduced the cloud-based SHAS where control of these appliances is made over an Internet connection and data is stored on a cloud server. It causes heterogeneity issue, in which each manufacturer uses their custom firmware, and communication protocols. This study found that researchers and developers pay attention to SDN, web services and EUD tools for SHAS. These three areas are expected to gain a high level of attention from researchers, developers, and users, in particular, to provide interoperability functions for SHAS.

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#### REFERENCES

- [1] M. Alaa, A. Zaidan, B. Zaidan, M. Talal, and M. Kiah, "A review of smart home applications based on Internet of Things," *Journal of Network and Computer Applications*, vol. 97, pp. 48-65, 2017.
- [2] Y.-T. Lee, W.-H. Hsiao, C.-M. Huang, and T. C. Seng-cho, "An integrated cloud-based smart home management system with community hierarchy," *IEEE Transactions on Consumer Electronics*, vol. 62, pp. 1-9, 2016.
- [3] J. Koetsier, "1.5B Smartphones, Triple-Digit Growth In SmartHome Tech: Top Trends For 2018," in *Forbes*, ed, 2018.
- [4] Y. Mittal, P. Toshniwal, S. Sharma, D. Singhal, R. Gupta, and V. K. Mittal, "A voice-controlled multi-functional Smart Home Automation System," in *2015 Annual IEEE India Conference (INDICON)*, 2015, pp. 1-6.
- [5] H. Hassan, M. Nasir, M. Herry, N. Khairudin, and I. Adon, "Factors influencing cloud computing adoption in small and medium enterprises," *Journal of Information and Communication Technology*, vol. 16, pp. 21-41, 2017.
- [6] M. Firdhous, O. Ghazali, and S. Hassan, "Statistically Controlled Robust Trust Computing Mechanism For Cloud Computing," *Journal of Information & Communication Technology*, vol. 13, 2014.
- [7] Zion Market Research, "Smart Home Market (Smart Kitchen, Security & Access Control, Lighting Control, Home Healthcare, HVAC Control and Others): Global Industry Perspective, Comprehensive Analysis and Forecast, 2016-2022," Zion Market Research2017.
- [8] J. Horálek, J. Matyska, J. Stepan, M. Vancl, R. Cimler, and V. Soběslav, "Lower layers of a cloud driven smart home system," in *New Trends in Intelligent Information and Database Systems*, ed: Springer, 2015, pp. 219-228.
- [9] G. Demiris, M. J. Rantz, M. A. Aud, K. D. Marek, H. W. Tyrer, M. Skubic, et al., "Older adults' attitudes towards and perceptions of 'smart home' technologies: a pilot study," *Medical informatics and the Internet in medicine*, vol. 29, pp. 87-94, 2004.
- [10] S. Solaimani, W. Keijzer-Broers, and H. Bouwman, "What we do—and don't-know about the Smart Home: an analysis of the Smart Home literature," *Indoor and Built Environment*, vol. 24, pp. 370-383, 2015.
- [11] B. L. R. Stojkoska and K. V. Trivodaliev, "A review of Internet of Things for smart home: Challenges and solutions," *Journal of Cleaner Production*, vol. 140, pp. 1454-1464, 2017.
- [12] A. Z. Alkar and U. Buhur, "An Internet based wireless home automation system for multifunctional devices," *IEEE Transactions on Consumer Electronics*, vol. 51, pp. 1169-1174, 2005.
- [13] Techopedia. Available: <https://www.techopedia.com>
- [14] S.-Y. Chen, S.-F. Chang, and Y.-F. Chang, "Exploring a designer-oriented computer aided design interface for smart home device," *Computer-Aided Design and Applications*, vol. 7, pp. 875-888, 2010.
- [15] M. G. Golzar and H. Tajozzakerin, "A new intelligent remote control system for home automation and reduce energy consumption," in *2010 Fourth Asia International Conference on Mathematical/Analytical Modelling and Computer Simulation (AMS)*, 2010, pp. 174-180.
- [16] E. Stroulia, "Smart services across the real and virtual worlds," in *The smart internet*, ed: Springer, 2010, pp. 178-196.
- [17] Z. Wei, J. Li, Y. Yang, and D. Jia, "A residential gateway architecture based on cloud computing," in *Software Engineering and Service Sciences (ICSESS), 2010 IEEE International Conference on*, 2010, pp. 245-248.
- [18] Y. Yang, Z. Wei, D. Jia, Y. Cong, and R. Shan, "A cloud architecture based on smart home," in *2010 Second International Workshop on Education Technology and Computer Science (ETCS)*, 2010, pp. 440-443.
- [19] A. Botta, W. De Donato, V. Persico, and A. Pescapé, "Integration of cloud computing and internet of things: a survey," *Future Generation Computer Systems*, vol. 56, pp. 684-700, 2016.
- [20] M. Khan, S. Din, S. Jabbar, M. Gohar, H. Ghayvat, and S. Mukhopadhyay, "Context-aware low power intelligent SmartHome based on the Internet of things," *Computers & Electrical Engineering*, vol. 52, pp. 208-222, 2016.
- [21] I. Horvat, N. Lukac, R. Pavlovic, and D. Starcevic, "Smart plug solution based on bluetooth low energy," in *Consumer Electronics-Berlin (ICCE-Berlin), 2015 IEEE 5th International Conference on*, 2015, pp. 435-437.
- [22] M. Al-Amin and S. Z. Aman, "Design of an Intelligent Home Assistant," in *Intelligent Systems, Modelling, and Simulation (ISMS), 2016 7th International Conference on*, 2016, pp. 69-71.
- [23] J. Joshi, V. Rajapriya, S. Rahul, P. Kumar, S. Polepally, R. Samineni, et al., "Performance enhancement and IoT based monitoring for smart home," in *2017 International Conference on Information Networking (ICOIN)*, 2017, pp. 468-473.
- [24] R. Abhishek, S. Zhao, D. Tipper, and D. Medhi, "SeSAMe: Software defined smart home alert management system for smart communities," in *2017 IEEE International Symposium on Local and Metropolitan Area Networks (LANMAN)*, 2017, pp. 1-6.
- [25] K. Xu, X. Wang, W. Wei, H. Song, and B. Mao, "Toward software defined smart home," *IEEE Communications Magazine*, vol. 54, pp. 116-122, 2016.

- [26] P. Hu, S. Dhelim, H. Ning, and T. Qiu, "Survey on fog computing: architecture, key technologies, applications and open issues," *Journal of Network and Computer Applications*, vol. 98, pp. 27-42, 2017.
- [27] J. B. Hong, S. Yoon, H. Lim, and D. S. Kim, "Optimal Network Reconfiguration for Software Defined Networks Using Shuffle-Based Online MTD," in *Reliable Distributed Systems (SRDS), 2017 IEEE 36th Symposium on*, 2017, pp. 234-243.
- [28] S. Demetriadou, N. Zhang, Y. Lee, X. Wang, C. A. Gunter, X. Zhou, *et al.*, "HanGuard: SDN-driven protection of smart home WiFi devices from malicious mobile apps," in *Proceedings of the 10th ACM Conference on Security and Privacy in Wireless and Mobile Networks*, 2017, pp. 122-133.
- [29] D. Al-Shammary, "Enhanced web services performance by compression and similarity-based aggregation of SOAP traffic," Doctor of Philosophy (PhD), Computer Science and Information Technology, RMIT University, Melbourne, 2013.
- [30] A. Wall, V. Altmann, J. Müller, H. Raddatz, and D. Timmermann, "Decentralized configuration of embedded web services for smart home applications," in *2017 Annual IEEE International Systems Conference (SysCon)*, 2017, pp. 1-6.
- [31] O. Anya and H. Tawfik, "Toward a Cognitive Middleware for Context-Aware Interaction in Smart Homes," in *Technology for Smart Futures*, ed: Springer, 2018, pp. 41-54.
- [32] J. E. Kim, T. Barth, G. Boulos, J. Yackovich, C. Beckel, and D. Mosse, "Seamless integration of heterogeneous devices and access control in smart homes and its evaluation," *Intelligent Buildings International*, vol. 9, pp. 23-39, 2017.
- [33] B. A. Chagas, D. F. Redmiles, and C. S. de Souza, "End-user development for the Internet of Things OR How can a (smart) light bulb be so complicated?," in *2017 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*, 2017, pp. 273-277.
- [34] L. Smirek, G. Zimmermann, and M. Beigl, "Just a Smart Home or Your Smart Home—A Framework for Personalized User Interfaces Based on Eclipse Smart Home and Universal Remote Console," *Procedia Computer Science*, vol. 98, pp. 107-116, 2016.
- [35] T. J.-J. Li, Y. Li, F. Chen, and B. A. Myers, "Programming IoT Devices by Demonstration Using Mobile Apps," in *International Symposium on End User Development*, 2017, pp. 3-17.