A Review on Improving Performance of Multi-Users Smart Homes Applications Based IoT

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***Abstract*--The Internet of Things (IoT) connect various devices together and to the Internet to send many streams of data. That framework is giving benefits to human life through the smart home environment by utilizing every activity. All these services are in different applications which are performed in the IoT environment. Applications with modern technologies in the IoT environment are increasing. A smart home is considered has highest important applications of IoT that manages all entire system by monitoring and controlling remotely home appliances. IoT smart homes technologies and architectural improvements are growing rapidly with many problems. Many challenges and limitations exist in smart homes. Overview for different IoT architectures, applications and challenges is introduced, and then overviews of the technologies for smart home. The paper focuses on smart home performance challenges. Recommender systems are used frequently in smart homes, so the paper introduces the data collection manners, techniques, characteristics, and context-aware recommender system. Current related works with analysis and limitations were introduced. Finally most important current problems and challenges that help to overcome some problems were discussed.**

Keywords-- Internet of Things, Smart Home, Monitoring, Decision Making, Home Automation, Performance, and Recommender Systems.

I. INTRODUCTION

The Internet of Things (IoT) transmits thousands of bits of data and information by connecting devices to the Internet. Things will be active participants in real or virtual environments as things-to-things or interact with humans as things-to-human communication. These things can operates automatically without us and can configure with no users actions [1]. IoT is changing the world when derived or are on the market to buy home needs. Many complex sensors and intelligent devices are sharing data and information everywhere around us. IoT arranges device sensors' data and offers information to the applications that make industrial processes. Gathering data from all these sensors and then sending it to another vehicle application that manipulates it. Evolving such IoT applications is hard because of circulated registering manufacturing with an enormous number of programming languages and communication protocols [2].

Creating IoT applications with sensors, smart devices, and servers are increasing rapidly to enhance the quality of our life. The most important and efficient application that stands out is a smart home and similar applications in the field [3]. IoT smart home interpreted operation provided by smart devices besides security concerns related to IoT. Just like smart homes, wearable remains important IoT applications that enhance user's life. Smart cities are a big technology like distribution of water, traffic management and environmental tracking. Smart networks promise to extract data to improve effectiveness, and power control [4].

IoT smart homes have technologies enabling home appliances to be in an automatic and remote-controlled manner through the internet [5]. Smart homes will enable users to open their garage while arriving home and control home televisions and various machines. This improvement rising advances and progressions, and organization applications need to grow moderately facilitating occupants' needs. The smart home is founded as an important domain in IoT applications. It is a connected home with devices communicating with each other via the Internet. This helps to automate the home by making it intelligent [6].

However, unfortunately, smart homes raise a great challenge of performance when controlled remotely. Providing users more flexibility when provide services keeps the management of the smart home correctly under controlled conditions to avoid conflicts of multi-users personal activities that are challenging for the researcher to manage. Much research has been conducted targeting smart homes linked to context-aware IoT [7]. In this paper, a review of different architecture, applications, and challenges of IoT was presented. Then discuss smart homes technologies and benefits then discuss some of the important challenges founded into smart homes. Reviewing of performance of homes was introduced with systems summary for improving performance. Finally, conclusions are presented.

II. IOT ARCHITECTURE, APPLICATIONS, AND CHALLENGES

This section starts by presenting an overview of different IoT architectures than applications and challenges as it became an emerging research topic that enhances our lives with applications and smart systems.

1. IoT architecture

Figure 1 introduces IoT layers divided into two parts. The first is IoT applications such as smart homes, smart cities, hospitals, transportation, and industries. The second part is IoT infrastructure which has three other layers (the platform layer with middleware and Database, the Network layer with network session protocol, and the physical layer with sensors [8].

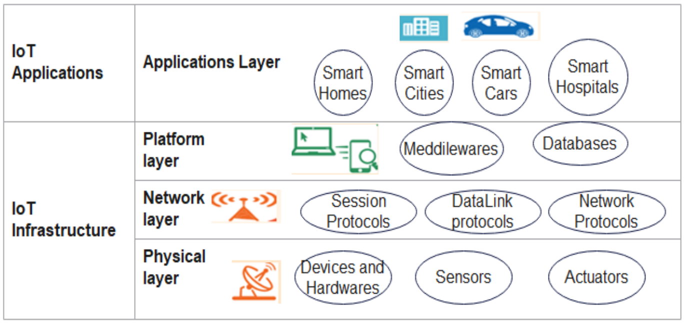

Fig. 1. IoT Architectures

2. IoT Applications

IoT was implemented on many platforms for many different applications. Architecture differs related to the platform. Different researchers have proposed different architectures [9]. Many applications have been introduced with IoT using many types of sensors, smart appliances, and web servers. Many different applications make use of IoT platforms introduced in Figure 2. Important applications are considered the Smart places in houses with the use of intelligent devices and actuators are very used. One of the attractive smart houses for the IoT is intelligent light systems. Devices were introduced as smart watches called wearable is very popular. The possibilities of the IoT for life-saving applications industry has been utilized on the healthcare. Smart devices and embedded sensors technologies on IoT and intelligent transportations have been evolving with artificial intelligence. Helping peoples in farm and researchers in this area in finding more fine ways and less cost ways to increase resulted production is introduced by smart farms.

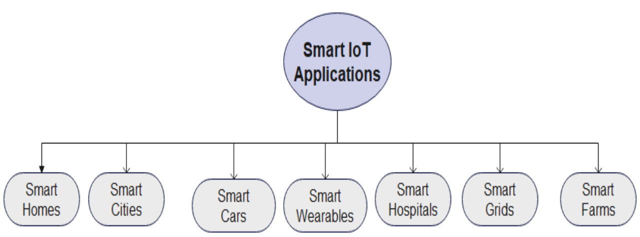

Fig. 2. IoT Applications

3. IoT challenges

IoT is behind building smart homes, smart hospitals, and driving vehicles. In general, any technology has many challenges including problems and threats to securing the applications for using the Web of Things and hard of configurations in the real world. Below are basic challenges for the future of IoT [10]. Security challenges in IoT like (Lack of encryption, Insufficient testing, and updating, Brute forcing, risk of default passwords, home security, and vehicles. Outdated programming, Use of weak and default certifications, Malware, Difficult to discover if a gadget is influenced, and Use of self-ruling frameworks for information). IoT devices lose the connection and lose the device's capabilities also the interoperability and compatibility.

III. Smart Homes Technologies and Benefits

Creating IoT applications with sensors, smart devices, and servers are increasing rapidly to enhance the quality of our life. The most important and efficient application is a smart home. IoT smart home operation is provided by smart devices, besides security concerns related to IoT. Smart homes are a big technology like distribution of water, traffic management, and environmental tracking. Smart networks promise to extract data to improve effectiveness, financial problems, and the quality of power control [11].

IoT smart homes have technologies enabling home appliances to be in an automatic and remote-controlled manner through the internet. Smart homes will enable users to open their garage while arriving home and control home televisions and various machines. This improvement raises advances and progressions, and organization applications need to grow moderately, facilitating occupants' needs [12]. The smart home was founded as an important domain in IoT applications. It is a home where all types of things relate to each other via linked networks. This helps to automate the home by making it intelligent. Smart home benefits such as lighting control, motion detection, entertainment, comfort, disabilities helping by robotic devices, energy management, control appliances, and health monitoring [14].

The good results of using smart locations based on IoT like apartments are Light control and devices managements, motion detection, entertainment, comfort, disability helping, energy management, and remote health monitoring. Energy management is found to be important automation process at our homes. IoT devices in locations like smart kitchen or smart living are used to produce an advanced ways that controls smart appliances and reduces energy consuming.

These applications and actuators work to give us best results and energy is reduced in term of usage. Care for users who is elderly and disabled is enhanced in intelligent parts of homes by using intelligent devices. Enormous electronic devices are designed for occupants of smart homes to reduce financial resources. Network wireless technology reduces cost and energy. Energy management reduces costs. Automation systems provide comfort to participants [13].

IV. Smart Homes Challenges

Smart homes present a significant challenge to the operation of field signals, user scenarios, and environmental variables. Challenges include data loss management, unstructured databases, energy consumption, cost, and resource usage management. Smart homes may be controlled remotely, so security and privacy challenges are presented to user data authentication and sensor data in transmission authentication. The main challenges in adopting smart home applications are data management, marketing, device connectivity, security and privacy, energy consumption, and healthcare) [14].

This review focused on performance challenges: as figure 3 introduces. The most important recommendations to mitigate the challenges and facilitate the safe and effective use of smart home applications were summarized (recommendations for users of smart homes exist to reduce power consumption and the cost of home appliances efficiently, recommendations for health organizations to offer good services to healthcare, recommendations for instructions on how fire systems and electrical devices' utilization) [15].

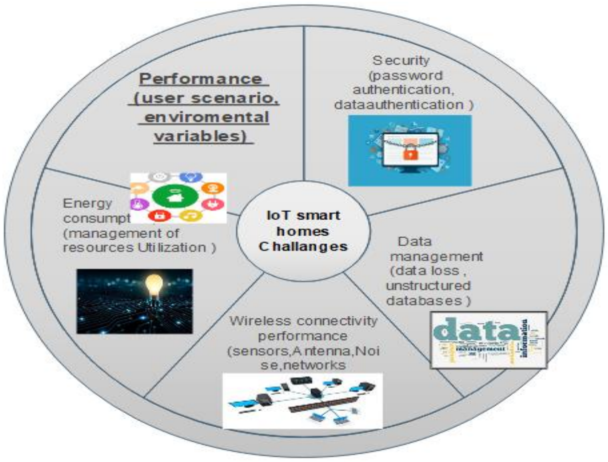

Fig. 3.IoT Smart Home Challenges

V. Performance challenges for smart home Applications

An important requirement for the smart homes is the performance of its applications in term of responsively and interactivity that must be enhanced. The data mining in sensor based IoT devices is popular very fast in our life, those require performance be considered in actuators at the many layers at smart environments [16].

Smart homes make life simpler, easier to control, save energy based on user's behavior and interaction with the home appliances. Smart home is functioned with many sensors configurations to on different IoT devices. These devices can be controlled and managed remotely on any electronic devices such as smartphones. It is very useful for collecting frequent patterns related to the user behavior of the IoT devices in the smart locations [17].

Information and data at a location of user choice can be stored, such as their remote server or on remote cloud. Users can also share many data on their social media. Data for users life frequent actions is collected in process of getting input for data acquisition like (e.g., food, quality of air), current actions or states (e.g., users mood, blood pressures), and parameters for (mental and physical activities) at hospitals, mobile and social, places for communication that defined as data collecting and analysis [18].

Recommender systems can exploit knowledge collected from the users' usage and offer some helpful recommendations to them. They give more comfort, help older and disabled individuals, and facilitate user's life. They have methods that facilitate users' choices based on their preferences. Smart home recommendation applications become available to analyze the actions that match the user's interaction profile. They provide recommended services that users may need to perform. The goal is to help users control their lives in the best and most comfortable manner [19]. In the next background information about Recommender systems was introduced.

VI. Recommender Systems for smart homes

In these section data collection manners, techniques, Characteristics, and context aware recommender system are introduced.

1. Recommender System Data Collection Manners

The three steps of data mining process consists of: data preprocessing, data analysis, and result interpretation as shown in Figure 4 [20].

2. Techniques for Recommender Systems

Recommender systems is viewed in [21] addressing that the collecting of knowledge about the user's work into the recommendation framework can result in to fine and useful services. (Collaborative Filtering (CF) systems that analyze only historical interactions; Content-based Filtering systems are based on profile attributes, while Hybrid techniques combine both collaborative and content-based approaches are techniques for rrecommender frameworks to classifying the acquisition of data are. CF mean offer services and recommends to users, based on what similar pattern of other in past time or situations. Model-based technique produce a models that predict based rating all users.

Content-based filtering on recommendation frameworks systems, called content-based recommenders offering useful services by classifying findings of patterns of an item to findings of next current content. The content-based and CF functions to generate ranked lists of recommendations have been introduced to allow hybrid filtering techniques, and finally link the results to get a final recommendations.

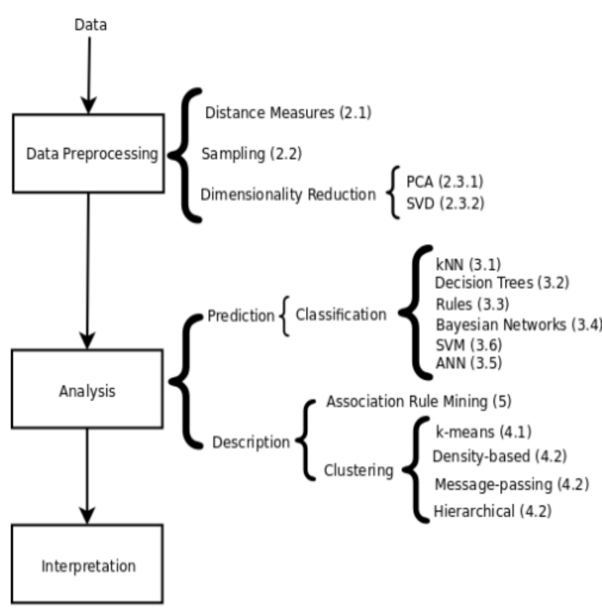

Fig. 4. Data Mining problem main methods [20]

3. Recommender Systems Characteristics

Recommender System characteristics are defined by [22]:

Recommender techniques called context awareness configures in a two ways from User and Service. Other approach operates in a pervasive space called pervasive recommender techniques must. Systems provide personalized services to the user called proactive rrecommender. Anticipate next contexts to serve the user continuously called Anticipation Pervasive rrecommender systems. Anther system which is able to evolve over time to support any changes that may arise in user's context called sscalability pervasive rrecommender systems.

4. Context-Aware Recommender System

Context-aware system collecting information's has three stages:

A. Acquisition: on it the collected information of the context is resulted from the physical or virtual sources and devices sensors. Several problems are found in the generations of real datasets. A problem of collecting data forms the sensors' data. The annotation algorithm for the users' activities is considering another problem.

The current dataset generation in simulated way solves the problems of generating real datasets. These programs enhance fast dataset foundation also provide efficient techniques to collect the sensors' data. Find a way such as the ability to stop and fast speed program to offer efficient data collection with fine representations. When developing machine learning and focusing on exact problems, researchers depend on providing a well-defined dataset. This section discusses three ways of current research around simulation program.

- Approaches called Model-Based: easy way to collect data based on activity models.
- Approaches called Interactive: that describe the use of virtual spaces devices sensors that help found pattern of users interaction.
- Approaches called Hypered: merge Model-based approaches and the interactive approaches.

B. **Modeling**: modeling for data is required after acquiring data, change states of the values from the sensors to be understood by programs. The current techniques for data modeling are [23]:

- Key-value Modeling: context data use key-value pairs for formatting.
- Scheme Markup: tags like XML is used Models information.
- Model use Graphic: specify relationships using graphical notations for context information.
- Modeling uses Objects: generate data and information by implementing class building and relationship is called Object-oriented concept.
- Logic-Based Model: Facts, expressions, and rules are used to represent context information.
- Ontology-Based Model: ontologies used to organize context, using semantic annotations.

C. Reasoning Context: The techniques founded for reasoning data context are as the following:

- Learning Supervised: collect Training information data and labeled as expected results formalized and then a function is derived to generate the expected results by using the training example data.
- Learning Unsupervised approach: This category of techniques can find hidden structures in unlabeled data.
- Approach Rules: IF-THENELSE format is used to describe what should be done in a straightforward way.
- Approach Using logic and Probability: decisions to making allowed on probability and to the facts of the situation generate the problem.
- Approach logic and Fuzzy: In normal logic that use truth values are as zero or one. This method is like reasoning using probabilistic, and degree of confidence is set identifying but not use like previous probability approach.
- Ontology approach: Its implementation that describe the description logic, group formalisms representing of logic-based knowledge.

In the next section the techniques for smart home recommender systems are introduced, and analyzed with limitations.

VII. PERFORMANCE IMPROVING FOR SMART HOMES RELATED WORKS

This section introduces recommender systems-related works then the summary with analysis and limitations is introduced.

The recommender system starts with the training phase in which a smart home learns a model of the user activities. There are many algorithms for learning user's actions like deep learning, machine learning, CF, content-based, knowledge-based, and context-aware. Context-aware recommendations enhance the performance in managing the activities considering the contexts like location, identity, and actions of users and physical sensors on devices with applications.

Following this, some of the existing techniques reviewed for smart home performance systems.

In [24] authors introduce a smart healthcare system using the information collected to create a recommendation framework from preferences of the patients' and his health conditions. Implementation of the architecture and details of a smart health application described and foundations for further research lines is set that are pointed out. A recommender framework CF is used define a large group of methods.

The CF aims to make recommendation services on a set of pattern and actions based on the user preferences. The system defines many actors and resources that collect interaction, descriptions that follow: Citizens could suffer from health conditions (patients) have mobile phones that allow the exchange data. Smart city sensors Databases: that contains information from users. Context-aware recommender system (CARS): apart from users, this is the important factors of current approach.

In [25] authors introduce a recommender framework to handle health issues were implemented based on IoT applications. They improve a way to collect user preferences considering IoT sensors and devices. Then offer services that increase the quality life solutions for the patients. They prefer to use semi-supervised and supervised techniques and run them to data collected from devices handle information like blood pressure, and measure heart rate.

In [26] authors a database to capture all user preferences related to a given activity is described as a framework. An activity performance supervised recommender framework to recommend missions to various states in smart houses is presented. It is important to improve user quality of life in applications in their environment that is very good to consider smart agents for elderly persons, which can very well serve them in user preferences, as well as recommend actions or services or activities.

In [27] authors introduce Atomic Level Activity classifying implement several difficult actions with activity that were analyzed and the consistent results were found to be with analytical and logical learning. These preferences contain activities related to leisure, eating, working, and socializing, in a smart houses life style.

In [28] authors designed a framework for finding useful user preferences and delivering relevant context-aware recommendations. They use Pervasive Recommender Systems (PRS) to provide user recommendations in their environments. It transforms data into useful formats by applying unsupervised algorithms to find frequently occurring activities and to learn useful rules over those activities. Then, construct a contextual profile from the original none edited data and merge it to the resulted rules. Finally, it applies supervised learning algorithms to predict user action in the current contextual profile and provide recommendations.

In [29] authors describe framework that considers the user's current contextual profile to suggest automation services for smart apartments sensors called a personalized recommender framework. Unsupervised learning technique implemented to collect current rules and action behavior from past interactions and supervised algorithms to offer services based on those rules and considered as recommendation useful for users. Process used employs machine learning approaches twice, first in the unsupervised Learning step to find the rules, and second in the supervised Recommendation Phase to predict the user action.

In [30] authors presented a system based on a data to make a complete modeling that define user interactions and the unsupervised and supervised classification is implemented to specify and collect useful or not useful persons like students at school behaviors while cooperates randomly with learning environments. An approach implemented for this environment of educational style is challenging because the unconstrained types of the preferences that they occurs and the lack of a well-defined specifications of correctness for student behaviors makes it hard to explain different all possible user behaviors and preferences patterns may relate to learning.

They experimented with applying this framework to build user models for two such exploratory environments of striking satisfaction for helping youth get meanings an approach and explore functions that is difficult equation in math. The implemented method can predict meaningful group of students' preferences and reasonable accuracy can achieved for new students on the online learning of in terms of the effectiveness of their learning process quality.

In [31] authors introduce a framework for context-aware services that simulate the design of home living. They introduced to use of context-aware three ways for machine learning, namely Naïve Bayes, fuzzy logic, and case-based reasoning approaches by using them. By focusing on context specifying and context gathering the context-awareness implementing tackled in useful way. Their method enhances its flexibility and gives high quality for learning process.

In [32] authors proposed to implement a recommender model to offer useful services on application in a smart part of home like kitchen. It uses recorded interaction information to extract by prediction then offer useful services. The proposed model has three processes: food kind taxonomy, recipe taxonomy, and condition feature data. The first process is to decide the food sections that exist in the refrigerator and cupboard in the smart place. Second, the model finds only those recipes which can be provided from the current different types in the smart location for cooking out of all the possible inputted data. Finally, profiles provide useful recipe options for the user.

VIII. Summary of Improving smart homes performance Systems

Table 1 provides a summary of performance systems-related works. The summary includes the use of mining algorithms, IoT applications, collecting data that is real or from smart home simulations, contextual data are considered or not, whether parallel computing or centralized approaches are being used, and whether multiple users in smart environments are being managed or not.

Table 1 show that research performed uses data from unsupervised or supervised algorithms for learning and predictions in real or simulated smart home environments. But few of them add contextual information that is especially useful in context awareness. Related work focuses on building a model for a recommender system that helps users in their smart environment. However, none of the models deals with a high number of users and manages cases where a lot of activities are interleaved (i.e., complex activity definitions for multi-users in the smart home).

It is observed that multi-user smart home recommender systems need more research to manage their problems. They also use centralized data mining algorithms that find frequent user actions and give useful recommendations for the next actions. Such algorithms are efficient in small contexts but are not efficient in larger contexts and larger datasets. As a result, the limitations of existing recommender systems focus solely on single-user smart homes and use centralized data mining algorithms in learning users' preferences. So, the motivation is to provide a context aware multi-users recommender system that considers parallel computing to improve performance of smart home with more responsiveness and interactivity.

TABLE 1. Performance Related Works Analysis

Ref	Mining algorithm	Application	Focus	Context	Multi-users	Parallel
[24]	CF	health	Real	No	No	No
[25]	Supervised	Smart health	Real	No	No	No
[26]	supervised	Smart Home	Real	No	No	No
[27]	Unsupervised	Smart Home	Real	Yes	No	No
[28]	Unsupervised	Smart Homes	Visualize	No	No	No
[29]	Unsupervised	Smart Homes	Simulation	Yes	No	No
[30]	Unsupervised	Educational	Visualize	No	No	No
[31]	prediction	Living Room	Real	Yes	No	No
[32]	Machine learning	Smart Kitchen	Visualize	Yes	No	No
Proposed Approach [33]	Unsupervised	Smart Homes	Simulation	Yes	Yes	Yes

IX. PERFORMANCE SYSTEMS LIMITATIONS AND SUGGESTIONS

In this section the limitations firstly introduced then the suggestion to overcome the limitations were introduced.

1. Performance Related Works Limitations

The performance related works mentioned before providing many services like helping people by designing home agents, location-aware resources optimization in homes, predicting actions and constructing interaction profiles that help user in his smart kitchen or living room or any part of home.

However, there are limitations when multiple users exist at the same time and location. It results in complex scenarios with conflicts between users in using different active appliances, and how to deliver many services for the proper user related to their priority on using devices.

Another limitation is considering traditional centralized data mining algorithms in learning preferences. Centralized algorithms are efficient in small datasets but when datasets increase their efficiency is reduced.

2. Suggestions For Improving Performance Related Works

The proposed approach introduced in this section to overcome previously discussed limitations. Started by introducing briefly block diagram of proposed approach, then summarizing the results also introduced.

a. proposed Approach for Improving Multi-users Smart Homes Performance

Reference [29] selected in the proposed approach that introduced in [33] as a previous published paper of the research area. In [29] authors proposed a personalized recommender system that considers unsupervised algorithm with the user contextual preferences, extract behavior rules from past interactions to make recommendations based on those rules, but has previously discussed two limitations in previous section. So the proposed approach introduced in [30] improves it by two suggestions are:

- Improve smart home performance by making homes more interactive by building a context-aware recommendation framework that provides useful recommendations for multiuser homes.
- Improve smart home performance by making homes more responsive using parallel computing that accelerates the performance of learning algorithms.

The proposed approach block diagram for performance improvement of smart home applications is shown in Figure 5. The proposed approach to improve performance starts with capturing sensors data. Then, the history of interaction formalization is recorded in the datasets and data is pre-processed to address the complex situation of multiple users. After that, conflicts are managed; frequent items and association rules are learned with a priori algorithm in parallel. Finally, contextual profiles like location and time of the day are added to the rules to provide useful services for smart applications.

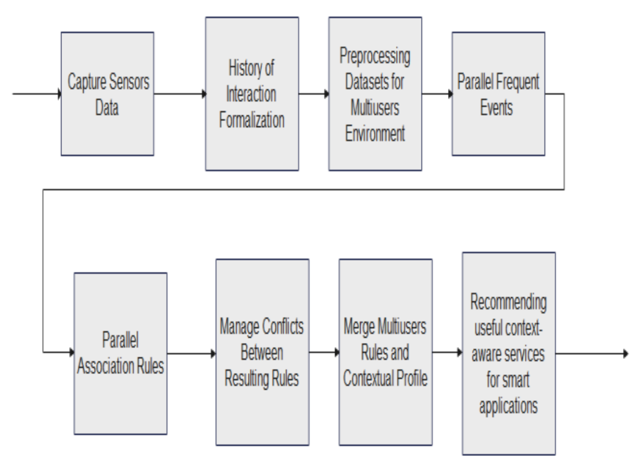

Fig. 5. Proposed Approach Block Diagram for Performance Improving [33]

b. Results for Improving Multi-users Smart Homes Performance

The resulted of learning phase by association rule algorithms for multiusers and parallel computing results was introduced for different number of users four, six and eight. Figure 6 show the rules of user id one in different ten values of confidence. This is done for all other users. The number of rules generated by varying the thresholds can also be graphically analyzed to find points of convergence as shown below. Results were simulated by introducing association rules for eight different users based on ten values of confidence from zero to one.

	confidence	number of rules
0	0.0	58
1	0.1	58
2	0.2	49
3	0.3	47
4	0.4	47
5	0.5	47
6	0.6	38
7	0.7	38
8	0.8	38
9	0.9	38
10	1.0	38

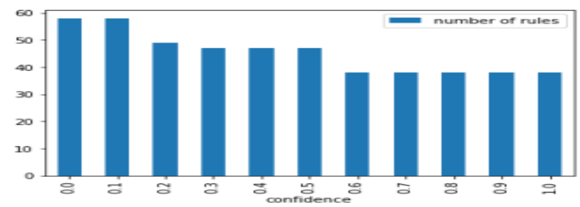

Fig. 6. Rules of User Id One in Different Ten Values of Confidence

Figure 7 shows user one for two parameters support and confidence for its rules. The point to the top right can be shown to have good support and confidence. It says that this rule will stand true in almost every instance or is causally related. A high support means that the rule occurs very frequently, while a high confidence indicates that the rule has a high predictive power (meaning the antecedent occurs, the consequent tends to occur).

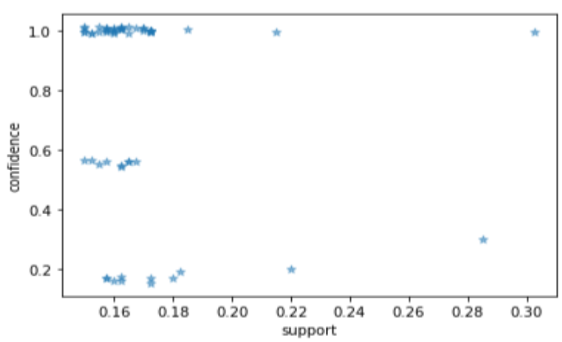

Fig. 7. Rules of User Id One in Different Ten Values of Confidence and Support

Figure 8 shows the user one execution time for parallel computing of association rules for different users.

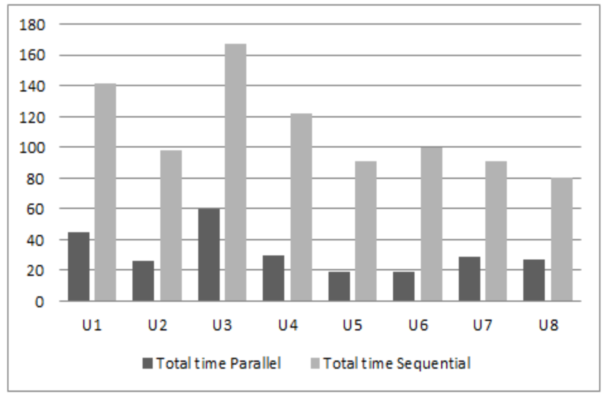

Fig. 8. Association Rules Parallel Excution Time for Eight Users

The results for association rules numbers based on location after adding priority based on multiuser framework for eight users are 19 for kitchen ,20 for hallway, 13 for office, 18 for bathroom, 20 for bedroom, and 12 for living. Total execution time for learning algorithms for eight users (Total time Parallel and Total time Sequential) for eight users are for u1 (45, 142), for u2 (26, 98), for u3 (60, 167), for u4 (30, 122), for u5(19.5, 100), for u6 (19.4, 100), for u7(29, 91), and for u8 (27 ,80).

Results for priority adding to overcome problem of multi users existence at same time and same location also introduced. As in figure 9 shows rules for 6 user's office location when 6 users exist at the same time there are 23 rules before priority.

	Antecedents	Consequents
0	(u2Office)	(u2bedroomDooron)
4	(u2Office)	(u2bathroomDooron)
8	(u2Office)	(u2Bathroom)
12	(u2Office, u2Bathroom)	(u2bedroomDooron)
13	(u2Office, u2bedroomDooron)	(u2Bathroom)
15	(u2Office)	(u2Bathroom, u2bedroomDooron)
18	(u2Office, u2Bathroom)	(u2bathroomDoorLock)
19	(u2Office, u2bathroomDoorLock)	(u2Bathroom)
21	(u2Office)	(u2Bathroom, u2bathroomDoorLock)
3	(u5Office)	(u5bathroomDooron)
7	(u5Office)	(u5Kitchen)
9	(u5Office, u5Kitchen)	(u5bathroomDooron)
10	(u5bathroomDooron, u5Office)	(u5Kitchen)
13	(u5Office)	(u5bathroom, u2bedroomDooron)
0	(u6Office)	(u6bedroomDooron)
4	(u6Office)	(u6bathroomDooron)
8	(u6Office)	(u6Bathroom)
12	(u6Office, u6Bathroom)	(u6bedroomDooron)
13	(u6Office, u6bedroomDooron)	(u6Bathroom)
15	(u6Office)	(u6bedroomDooron, u6Bathroom)
18	(u6Office, u6bathroomDoorLock)	(u6Bathroom)
19	(u6Office, u6Bathroom)	(u6bathroomDoorLock)
21	(u6Office)	(u6bathroomDoorLock, u6Bathroom)

Fig. 9. Six User's Office Location Rules Before Priority

Figure 10 show rules after priority, there are conflicts between (u2 and u5) and (u2 and u6) so u2 was given higher priority so reduces the number of rules that causes conflicts. They were reduced to 15 rules.

	Antecedents	Consequents
0	(u2Office)	(u2bedroomDooron)
4	(u2Office)	(u2bathroomDooron)
8	(u2Office)	(u2Bathroom)
12	(u2Office, u2Bathroom)	(u2bedroomDooron)
13	(u2Office, u2bedroomDooron)	(u2Bathroom)
15	(u2Office)	(u2Bathroom, u2bedroomDooron)
18	(u2Office, u2Bathroom)	(u2bathroomDoorLock)
19	(u2Office, u2bathroomDoorLock)	(u2Bathroom)
21	(u2Office)	(u2Bathroom, u2bathroomDoorLock)
7	(u5Office)	(u5Kitchen)
9	(u5Office, u5Kitchen)	(u5bathroomDooron)
10	(u5bathroomDooron, u5Office)	(u5Kitchen)
15	(u6Office)	(u6bedroomDooron, u6Bathroom)
19	(u6Office, u6Bathroom)	(u6bathroomDoorLock)
21	(u6Office)	(u6bathroomDoorLock, u6Bathroom)

Fig. 10. Six User’s Office Location Rules After Priority

X. CONCLUSION

Many challenges and limitations exist in IoT smart homes. This paper overviews the different IoT architecture, applications, technologies, and challenge. The paper focuses on smart home performance challenges. Data collection manners, techniques, characteristics, and context aware recommender system are used frequently on smart homes. The current related works with analysis and limitations were introduced as it summarized as the related work don’t handle multi user’s context and problems also they consider only centralized data mining algorithms that is not efficient on large databases. Finally discussing the most important current problems and challenges that to help to overcome some problems.

As a future work, the plan is to continue improve smart home via improving more challenges like security, privacy, data management, and network.

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