International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-3, June 2015

ISSN: 2395-3470

www.ijseas.com

# Complex Event Processing In Smart Homes

**Pooja K S, Chandrashekar K T, Dr.Thungamani M , Gireesh Babu C N**

Department of Information Science & Engineering, BMS Institute of Technology & Mgmt., Bengaluru, Karanataka

***ABSTRACT*-The advancement in Internet of Things that is beating human population, meeting the needs of people, providing easy access to scalable servers and clouds of services anytime anywhere has given rise to the domain of Smart Homes or Automated Home Systems. A Smart Home is an integrated home system that has sophisticated technologies equipped within it which allows people to have a control or monitor the various electronic devices at home through a single command or tap of a button. This development of Smart Homes uses various sensors and the data that is collected from various sources is analyzed to take desired action. The management of this large amount of data is a great challenge for Smart Homes. A technology that can efficiently process the data and give real-time response is Complex Event Processing (CEP). It is a new development for processing of streaming data to detect relevant information from the data received through various sources. It can correlate the various events that occur in IOT. In this paper an Event processing technology CEP is illustrated that receives events from multiple sources and can be used to give immediate responses to the events detected in Smart Homes. CEP Engine extracts useful event patterns on continuous incoming streams of data and gives immediate response that is required.**

***Keywords: CEP Engine, Event Processing Network, EPA***

## I. INTRODUCTION

The advancements in IT has provided good basis for domain like smart homes that is an emerging technology growing at a competitive rate. The aim of smart home systems is to create an environment aware of the activities taking place in it. The Information and Communication technology (ICT) in homes is referred to as Smart Home [5]. A Smart Home can have control on various activities of a person at home and operate the devices or systems as the user desires. Smart Home technology is being applied in various aspect of our home and environment to increase level of comfort and convenience, provide security, entertainment, save money and time and thus making life easier. There is use of sensor technology; video and audio analysis which involves reading sensor data from the sensors placed at homes. This Smart Home idea can be achieved through various approaches. One such approach is Complex Event Processing. In this technology real-time data is processed and a decision is made on past data or it may also predict what the future events can be.

CEP is an approach that identifies data and application traffic as "events" of importance, correlates these events to extract predefined patterns, and responds by generating "actions".It involves observing complex composition of events that occur and evaluate them to give better information in real time. The main module of this architecture is the CEP engine that detects patterns on continuous incoming stream of data.

## II. RELATED WORK

### *A.WHAT IS A SMART HOME?*

Smart Home is the term for houses with smart home technology installed. It gives a flexible functionality or operation compared to the old systems as they are integrated with other machines and they are programmed to respond to data received from sensors. A conceptual SMART HOME model is shown in Fig.1. It is therefore defined as the integration of technologies and services, applied to homes, flats, apartments, houses and small buildings with the purpose of automating them and obtaining and increasing safety and security, comfort, communication, entertainment and technical management [4][8].


Fig.1. Conceptual SMART HOME model

The Fig.2 below shows how a home is made to behave smart. The various home network devices like air-conditioning & heating control, the security & alarm system, the remote

control, motion detector and the usage of digital contents connected to provide convenient services to its users. The Smart Home recognizes the present state of home and analyzes the detected information from various sources. It alerts the user whenever an unexpected event occurs from the detected data.

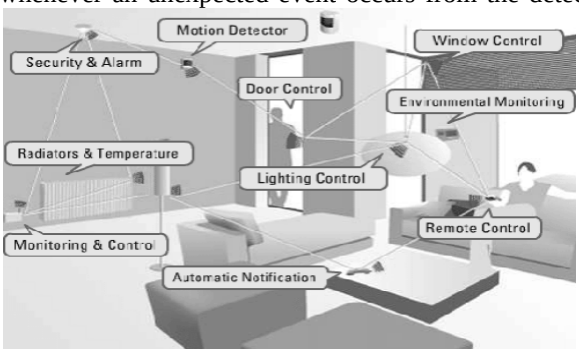


Fig.2. Smart Home Technology Automation

## A. BENEFITS OF SMARTHOME

The various benefits of having a Smart Home can be summarized as follows.

*a) Safety*

Increased safety is of primary concern for a person living in smart home. The safety is based on the possibilities to register regular and irregular incidents in the house. Such registrations can trigger off reminders or alarms. Alert incidents like fire, a fall or unfortunate consequences can be prevented.

*b) Independence*

Automates every task for human operators in tasks that involve hard physical or monotonous work. An important bonus regarding independence is the possibility to live in your own apartment, to govern your own life, and to lock your own door. Independence increases when the resident can master several tasks, and determine the time and way it should be done.

*c) Remote Monitor*

User interface is provided by smart home technology through which users can have a control or monitor various activities from a remote location through their phones. Eg: activate sprinklers in garden, heat up the room before returning from work.

*d) Efficiency*

Smart homes offer enhanced energy-efficiency. Lights can shut off automatically when no one is in a room, and the thermostat can be set to let the indoor temperature drop during the day before return it to a level just before residents arrive in the evening. All these automated tasks, along with modern, energy-efficient appliances, combine to save on electricity, water and natural gas, thereby reducing the strain on natural resources.

*e) Accessibility*

For elderly or disabled residents, a smart home may feature accessibility technologies. Voice-command systems can do things like control lights, lock doors, operate a telephone or use a computer. Home automation allows an individual to set a schedule for automatic tasks like watering the lawn, removing the need to perform these labour-intensive tasks on a regular basis.

*f) Comfort:*

Every task done manually is automated that eventually reduces burden on people making their tasks easier. Homes give users remote access to systems including heating and cooling systems, intercoms, music and multimedia devices throughout the home. These systems thoroughly enhance the convenience and living by providing various benefits.

## B. TRENDS USED IN SMART HOMES

The development of Smart Home Technology is assisted by various communication protocols and technologies. Each has potential advantages and disadvantages so a hybrid of different technologies is likely to be found in a Smart Home

*a) Bluetooth Technology*

Bluetooth (IEEE 802.15.1) is the well-known technology used in mobile telephone and other objects (printer, digital camera) that can be used for home automation. It allows using radio frequencies to control the system. The devices can be controlled using a phone with just a tap of a button. But this approach is not compatible and secure, data transfer rate is medium and it can connect devices at shorter range [7].

*b) Bus Operated Systems*

Bus line technology uses a long cable. This cable connects to various devices in home and enables these devices to communicate with each other. The data is transferred through the cable. The system requires additional wiring which makes the installation difficult. It can be used in critical areas such as alarm states.

*c) X10 Standard*

It is a well-known standard that is commonly used in smart home technology. The computer is central device in this system. The devices cannot communicate with each other. It receives instructions from the computer.

*d) Main Borne Communication Systems*

It is also called Power line systems as these devices are connected to the main power supply. The data is sent to the devices along the standard wires to activate or deactivate them. It is easy to configure the system and it can be up running cheaply and quickly. But the major problem is the interference due to power cuts or dirty power lines.

*e) Radio Frequency Transmission*

Sensors can be located anywhere without extensive rewiring, and modern battery technology means sensors can operate for years without battery replacement being needed. But due to the interference of walls shorter bandwidth of radio waves it can connect devices at a shorter distance.

*f) Infrared Communication*

Well established as a communication medium for home systems, and ideally suited to controlling existing home devices such as televisions and video recorders. It can also be used to provide freedom of operation of any component. It also provides some flexibility for the connection of more specialist assistive devices for severely disabled people such as environmental control systems and communication devices. However it is limited to line of sight operation, and is also not particularly suitable for transmitting secure information.

*g) Insteon*

It is a wireless network system that provides flexibility to connect to devices. It provides a dual mesh network for homes facilitating communication over both electrical and radio waves. As it's a dual network it uses other platform if message is not getting through one. Insteon broadcasts the messages instead of routing and the devices that receive the message broadcast it until the action is performed. These devices encounter the problem of interference as in power lines and for better message more devices have to be installed which is not efficient [5].

## III.CEP AND ITS ARCHITECTURE

### *A. OVERVIEW OF CEP*

The emergence of Smart Homes has resulted in the collection of enormous amount of data from various sources for analysis to take an action. And with the maturity of IOT, a lot of useful information will be produced. The storage and management of this huge amount of information is an issue .To meet the needs of real-time streaming of information processing, it is necessary to design a data processing architecture enabling immediate response in smart homes. Complex Event Processing (CEP) is emerging as a new technology for processing the above continuous real-time stream of data and provides real-time response to the events detected. CEP is based on observation that in many cases actions are not activated by a single event but by a composition of events that occur at different times and in different contexts. A high-level overview of CEP is illustrated in the Fig.3. The central processing module is the Complex Event Processing Engine that detects patterns from incoming stream of data through various Event Sources and outputs the Detected or Predicted complex event for further use to event customers or can be sent back to CEP forming a loop.

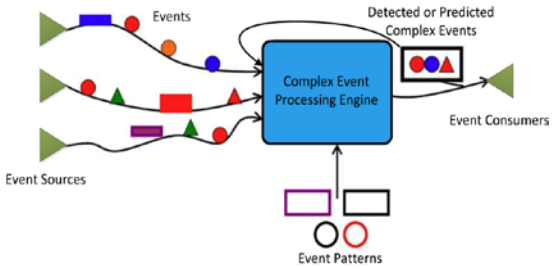


Fig.3. High-level Overview of a CEP

### *B. CEP SYSTEM ARCHITECTURE*

The Fig.4 below shows the entire System Architecture of CEP and each of its components in detail. The CEP Engine which is the core of this architecture and web interface is shown [1].

*a) Web Interface*

Users could manipulate CEP via the web interface. Since we may have many CEP engines in one test bed, we should have a convenient interface to control all CEP engines. With the web interface, we can provide commands to start pause or stop any engine. Afterward, CEP controller will interpret our commands to the corresponding CEP engine. Users can use the same way to turn on/off the adapter gates or action gates to control the flow path out of CEP engines. If users need to extend the numbers of engines, they can dynamically add them by register the IP addresses into CEP controller.

*b) Adapter and Action*

The adapter and action components are on the right hand side of Figure 3.2. Adapter and action are two kinds of gates for communication with CEP engine.

The Adapter component is responsible to adapt stream data into CEP engine. The adapter directs stream data to Event Processing Networks (EPNs) which contain the rule set inside the application.

The Action component is for sending results to end points. After the processing of EPN the result will be send to action gate. There are many other kinds of adapter and action gates such as database, socket, REST, mail, JMX and SMS, through which we can adapt stream data from many different kinds of sources and send results to many different kinds of targets too.

*c) CEP Engine Operation*

As Figure 3.2 shows, CEP engines will be started by CEP initializers, which read series of configuration files to setup hardware. CEP initializers will activate three managers which are CEP Manager, Action Manager and Adapter Manager. These managers are to interpret commands from CEP controller and do the corresponding jobs such as initiating new instances or change instances status. An application may contain many rule sets. We call a rule set as Event Processing Network. In EPNs, users can use different kinds of modules to compose a processing progress.

There are mainly four kinds of modules which are Producer, Consumer, Channel and Event Processing Agent (or EPA in short).

The Producer's job is to connect to adapter gate and let stream data flow into EPN.

The Consumer's job is to connect to action gate and let stream data flow out from EPN.

The Channel's job is to connect different EPNs and let EPNs communicate with each other. Users could concatenate different kinds of EPAs between Producer and Consumer.

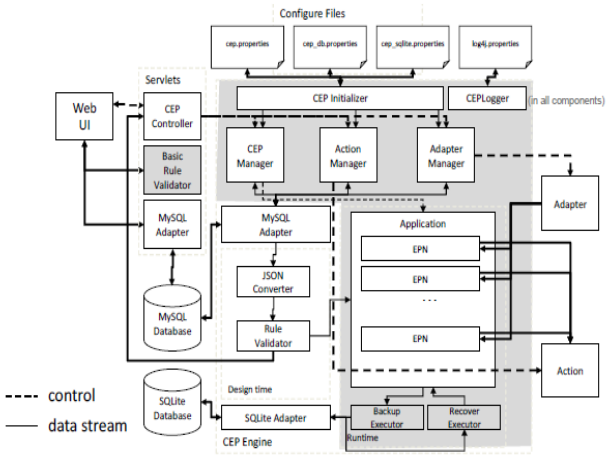


Fig.4. System Architecture

## C. *FUNCTIONAL ARCHITECTURE OF CEP*

The main components of the functional architecture of CEP are illustrated in Fig.5. When a new event is detected by an event observer, it is sent to the CEP engine by the Receiver component, which acts as a wrapper for the incoming stream of events [1].

The two phases in Event Processing are given below.

(1) Detection phase

(2) Production (result) phase

The CEP engine has been divided in two main sub-components: Decider and Producer. The role of these two components is to process the incoming events according to a set of Rules. A processing rule is defined by two components ($C \rightarrow A$): a condition C and an action A.

The condition specifies the event pattern (e.g. sensor reading exceeding some threshold) that is continuously checked by the Decider on the arrival of new events. When an event pattern is detected, the corresponding action is sent to the Producer, which generates the result (e.g. an alarm, creation of a new complex event) for the event sequence that triggered the specific rule. The result produced is sent to event consumers (through the Forwarder), or it can also be sent internally, to be processed again. Each processing unit is taken as an application by the CEP engine and this application may contain many Event Process Networks (or EPNs in short). An EPN is a group of rule set. The Knowledge Base component is an optional component that can store the static information needed for event processing.

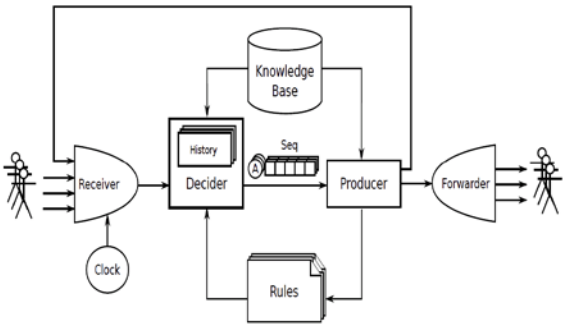


Fig.5. Function of CEP

## D. *CEP BASED SMART HOME ARCHITECTURE*

CEP engine analyses the correlations between real-time or non-real-time events and performs the corresponding actions. When this CEP technology is applied to the smart home every case happened during a resident's passage through the complex is considered as an event. Then the event is detected in real time, and its pattern and relationship are analysed. If doing so, every event in the complex can immediately be addressed. A Smart Home would look like as shown in the Fig.6 below when it is connected through various network devices or sensors. The dots represent the devices that are connected [5].

Fig.6. Connection of devices in Smart Home

The various layers and detailed architecture of CEP when used for a Smart Residential or Home System is given in the Fig.7. The components involved for this purpose, we defined Event Processing Layer for Data Collection & Event Detection/analysis, Event Specification, and Service Activation on System Architecture [2].

The Service Layer accepts the user's input and constructs a condition for the Business Logic to understand and transform the data onto a suitable form for further processing. Each module at the Service Layer provides following functions.

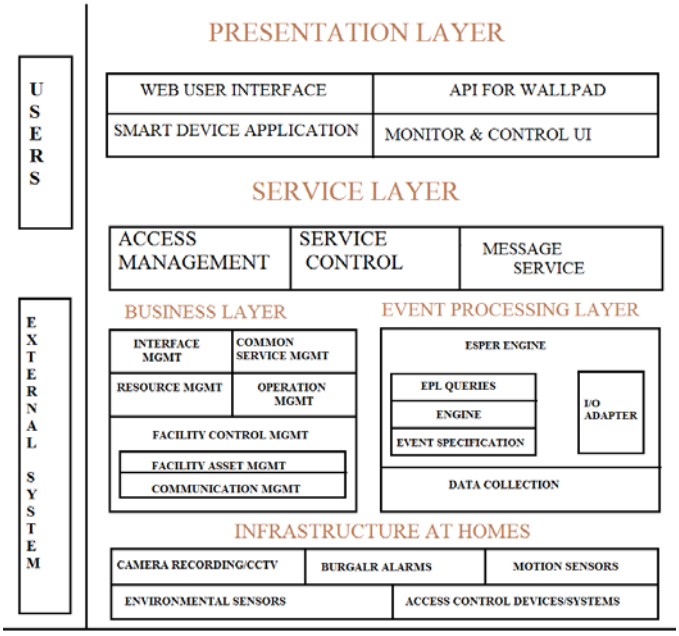


Fig.7. CEP-based Smart Home Architecture

a) *Access component:*

User Verification & Authorization, Device Certification, Device Application Update.

b) *Service Control:*

Controller Functions for Smart Home Main Services

c) *Message Service:*

Communication User's Message Standardization, Sending Module for SMS & e-mail.

The Business Layer includes the business logics of main services carried out by the Smart Home, and minimizes the complexity. Each module at the Business Layer provides following functions.

a) *Interface Management:*

Architecture of linkaged API, Data's Parsing & Save, Multimedia file-Sending Function, Linkage between Systems.

b) *Resource Management:* Multimedia File's Save &

Distribution Management, Content Information Management.

c) Unit Service Management:

Statistics, Atomization by a scheduler, Log History.

d) *Residence Operation Management:*

Complex Operation Management & Services

e) *Data Collection & Facility Control Management:*

Efficient Data Management, Setting Reasonable Collection Cycle.

In the Event Processing Layer of architecture, each module provides following functions.

a) *Data Collection:*

Sets reasonable data collect cycle and collects relevant data from the housing infrastructure.

b) *Event Specification:*

Define the events to be analysed in the CEP Engine according to the kinds and formats of data collected from the housing infrastructure. It can add or delete/modify event definition in real-time or at runtime.

c) *EPL Queries:*

Define the conditional sentences about the situations to be checked concerning the defined events in EPL (Event Processing Language), which is supported by the CEP. The conditional sentences are processed in the CEP Engine.

d) *Engine:*

Process the defined conditional sentences for the corresponding events using the CEP, and sense other situations to check in real time. Each processing unit is taken as application in our CEP engine and each application may contain many Event Process Networks (or EPNs in short).

An EPN is a group of rule set. An event enters into a rule via event producer. The event will pass through a series of Event Processing Agents and finally enters into event consumer.

## IV. APPLICATIONS OF CEP

Important application areas for Complex Event Processing (CEP) are the following:

a) *Business Activity Monitoring:*

It aims at identifying problems and opportunities in early stages by monitoring business processes and other critical resources. To this end, it summarizes events into so-called key performance indicators such as, e.g., the average run time of a process, Investments, stock exchange, Treasury Risk assessment, Transport tracking.

b) *Sensor Networks:*

The increasing interest in sensor networks has allowed the emergence of wireless sensor networks. In these conditions, CEP plays a very important role in discovering meaningful information from the vast amount of produced data. In sensor networks, besides the notions of simple and complex events there are observations which are the raw outputs of sensors. CEP finds two different approaches in sensor networks: Centralized and Distributed processing.

In the centralized approach, observations sampled by the sensors are transmitted to a gateway where powerful machines can be used for processing. But in this approach energy consumption is more and event detection is delayed due to transmission latency.

The second option, distributed processing, allows observations to be evaluated on the nodes and then transmitted to gateways as events, reducing thus communication overhead. This processing decreases the communication overhead and increases performance of the system.

c) *RFID Applications(RFID):*

Radio frequency identification is a technology used to identify, monitor, locate and track any physical object. RFID System consists of RF tags which are attached to physical objects, the RFID and the base station where all the data is collected. The companies that used RFID Systems need CEP technology to translate the raw RFID data into meaningful information which could be subjected to further processing by certain applications like access control, document tracking, smart box, supply chains, healthcare. Complexity in the system is reduced so CEP methods can be improved.

d) *Financial Applications:*

The financial domain expresses high interest in CEP techniques as the amount of streaming data is constantly increasing and traditional methods cannot keep up with these changes. Applications for the financial domain include: fraud detection in credit card transactions, algorithmic stock trading, and real-time profit and loss analysis.

## V. RESEARCH CHALLENGES

A. *Integration of Machine Learning to define event Patterns:*

The CEP system developed for the applications analyzed do not provide a seamless integration, but rather consider the human component to define the complex events that should be monitored and detected. The rule set in CEP has to be integrated with machine learning to detect patterns.

B. *Performance improvements due to assumptions:*

Systems built for different applications make particular assumptions such as the quality of data or the reliability of communication channels that can lead to surprises when such systems are deployed in real world environments. This requires more general CEP platforms that are then applied to real world scenarios and tested for their performance, which would indicate further improvements that might be needed.

C. *Issues related to Event Processing Languages:*

Related to the issue of general CEP systems is also that of event processing languages that vary regarding the type and the number of operators and constructors for complex events. It is not clear if any of the language is better than the others. Therefore a thorough comparison of these languages is needed, in order to identify what are the most important operators that would be sufficient for event description, detection and reaction.

*.D. Other Issues:*

Apart from the above open issues there are Research Challenges that may arise from three different situations:

• Large number of queries

• Large number of events

• Queries that need large working memory

Uncertainty Handling and Enrichment of Events.

Uncertainty if handled increases performance of CEP. Regarding the event enrichment problem, it would help in defining more complex events by adding new information to the basic events by means of computation or by pulling information from external sources.

The list of shortcomings mentioned illustrate possible research directions, which can be considered in our future work.

## IV. CONCLUSION AND FUTURE WORK

Smart Home systems are a recent development that proves to be achieved in future. It will be open to iterative and incremental integration of new technologies and appliances thus increasing convenience and comfort level for people. In this paper we have seen how a Smart Home can be monitored, controlled and built using Complex Event Processing approach. The continuous stream of data collected from different sensors or systems deployed in a Smart Home are analysed and appropriate actions have to be taken. Various trends exist and some are in use but they suffer from certain drawbacks as specified in the related work. Hence the use of CEP proves to be better compared to existing methods.

CEP is used here as events in Smart Home Systems require real-time responses. There are issues related to CEP like uncertainty handling that is required to enhance its performance, process large queries or events and incorporating machine learning algorithms to define the rule sets that are used to detect patterns on incoming stream of data. These illustrate research directions that are considered as a future work. Smart Homes built to comfort our living should be reliable, secure and safe and provide convenience to its users to enhance their style of living. Thus having a Smart Home would indeed prove to atomize every task and provide a good response by the use of CEP approach.

## REFERENCES

[1] Ching Yu Chen, JuiHsi Fu, Today SungPing-Feng Wang, Emery Jou, Ming-Whei Feng, “Complex Event Processing for the Internet of Things and its Applications”, 2014 IEEE International Conference on Automation Science and Engineering (CASE) Taipei, Taiwan, August 18-22, 2014.

[2] Yingnan Li1, Jonghyun Lee, Meilan Jiang,Sangteak Lim.” A CEP-based Smart Residential Service System”,2012 IEEE.

[3]Sajid Hussain, Scott Schaffner, Dyllon Mosey chuck “*Applications of Wireless Sensor Networks and RFID in a Smart Home Environment”*, 2009 Seventh Annual Communications Networks and Services Research Conference.

[4] Rosslin John Robles and Tai-hoon Kim,”Applications, Systems and Methods in Smart Home Technology”, A Review International Journal of Advanced Science and Technology Vol. 15, February, 2010.

[5] David Poulson,Colette Nicolle,Magdalen Galley,” Review of the current status of research on ‘Smart Homes’ and other domestic assistive technologies in support of TAHI trials”, Loughborough University 2002.

[6] Santanu Das,” Technology for SMART HOME” Proceedings of International Conference on VLSI, Communication, Advanced Devices, Signals & Systems and Networking(VCASAN-2013).

[7]Vincent Ricquebourg, David Menga, David Durand, Bruno Marhic, Laurent Delahoche, Christophe LogéThe Smart Home Concept : our immediate future in 19th International Symposium on Human Factors in Telecommunication, Berlin, 2011.

[8] Rosslin John Robles and Tai-hoon Kim,” A Review on Security in Smart Home Development”, International Journal of Advanced Science and Technology Vol. 15, February, 2010.