Semantic Interoperability for Context-Aware Autonomous Control using IoT and Edge Computing

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Abstract

The exponential development of Internet of things (IoT) services over edge computing and cloud networks has increased the utilities of remote monitoring, control systems, continuous maintenance and effective utilization of services for applications, such as smart cities. However, data modelling is required to manage such heterogeneous data sources. IoT applications gather data from diverse sources. These applications sometimes obtain data in the form of datasets. Heterogeneous datasets are used for various purposes, and the issue of seman-

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tic interoperability arises. Therefore, this paper presents an empirical study of IoT-based semantic interoperability. This study aims at combining portable and fixed sensors with an intermediate microcontroller module and annotating data semantically for the smart autonomous environment, smart home. A context model is devised for developing a mechanism over an ontology schema for managing and passing controlling and monitoring messages to home appliances effectively. The proposed model integrates the environment with the context of a person in a smart autonomous environment for efficient energy consumption and enhanced living context model experience.

Keywords: semantic interoperability, edge computing, Internet of things, computer vision, ontology-based smart system, context-aware control,

1. Introduction

Semantic web technologies are becoming more familiar and more frequently used to improve semantic interoperability within various ventures. The design and construction of RDF graphs and ontology construction also pave the way for the integration of Internet of Things (IoT) [1] with the semantic web. The semantic web is applied to reuse the available knowledge instead of regenerating it [2]. In contrast, the IoT [3] is a combination of devices that have sensing capabilities and their identification via the use of radio frequency identification (RFID). The integration of devices and sensor communication technologies forms the basis of IoT [4]. One of the largest challenges in the era of IoT is the huge volume of data that are gathered and produced by things and services. The applications of IoT include security applications, firefighting applications, healthcare applications, smart cities, smart houses, mining productions, and transportation [5]. Despite the widespread application of IoT [6], it remains in its early stages with respect to various issues. One of the most important issues is the semantic operability of devices. This issue can be resolved only by operating all smart devices under common standards. In energy efficient and remote control scenarios, these applications can yield substantial improvements in performance and lifetime when these smart devices operate properly [7]. Smart device and hardware utilization will lead to the transformation of existing cities into smart cities. Semantic interoperability is realized via the use of the resource description framework (RDF) and IoT devices. Through the use of the simple protocol and RDF, query language (SPARQL) query data can be extracted from an ontology via intelligence rule mining [4]. Due to the enhancement of technology, people have become addicted to an easy lifestyle. Automation plays a vital role in providing an easy lifestyle to humans in every field of life, such as industry. For home automation, state-of-the-art technologies are emerging. In IoT, things are interlinked via the Internet and communicate with one another to promote different concepts, such as home automation, thus, smoothing household tasks specially to disabled people [8] [9]. Moreover, home automation is expected to be implemented in most homes in the future. Things require a mechanism for communicating with each other. In the home automation, many issues including energy consumption and waste of resources [7] are encountered. A smart system should be aware of the user's context according to which decisions are made and things are turned on [4]. Therefore, background research must be conducted not only for tracking the current state of semantic interoperability but also for improving it. This paper directs the reader's intentions towards the reuse of available knowledge, including datasets, ontologies, RDF graphs, search engines and repositories of the semantic web. Through this study, the ontology methodology's related work for data transformation is utilized for the development of semantic interoperability [2]. Figure 1 shows that the development of mobile networks is moving towards smart homes and smart cities applications. Applications developed over 5G network will be enhanced and will have more connectivity with other applications. These applications have higher speed and end with much better performance because of the high bit rate and expected widespread coverage.

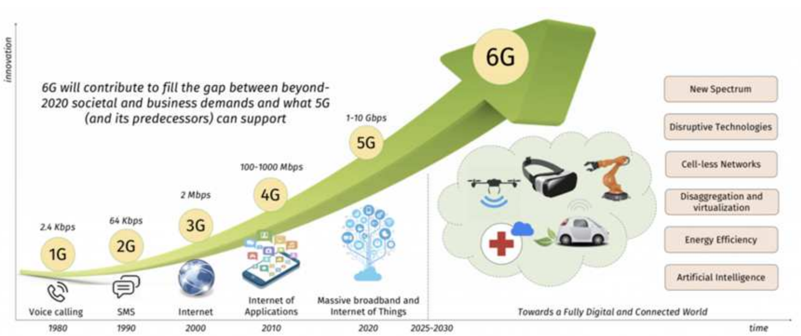

Figure 1: Application development over different mobile networks [10].

In this article, image processing is used to detect human presence in a room and to control hardware according to a sensing device measurement control mechanism. Home automation creates a smart environment. A methodology that encourages the semantic operability of the IoT's applications is designed. The interpretation of IoT data for building IoT-based semantic inter-operable applications is an important task. This paper describes the field of IoT and highlights the potential advantages of its application for the public. Embedded devices such as the raspberry pi camera and sensing devices, used to control the automation system, are also presented.

2. Literature Review

Technological development has transformed many aspects of people's lives. It has affected various aspects of the day-to-day routine and enabled stronger social affiliation, effortlessness in transportation, and the ability to appreciate incitement. The media has also helped making headway for medical solutions. The development of various devices, such as personal digital assistants (PDAs) and personal computers (PCs) [11], has influenced various people to rely upon technological advancement in daily activities [12]. The web must be transformed into a regular interface that various devices use with the objective of streamlining the everyday work of various people. The web enables us to find solutions for a few issues and to work from remote spots, which reduces our overall costs and increases ease of use [13]. Home automation appliances might be regarded as innovations that provide simplicity and insurance to its inhabitants. Thanks to IoT innovation, the examination and execution of home mechanization have become extra-normal [12]. Various remote innovations, which can bolster a few types of remote information exchange, detection and administration, such as Bluetooth, Wi-Fi and cellular systems, are utilized to provide high levels of performance inside the home. Home mechanization for the more established and debilitated will offer increased personal [14]. It might provide an interface for home machines or the mechanization framework. It can be done by using a phone line or the web to perform administration and recognition through an advanced mobile phone or PC [15]. IoT has attained substantial fame for the field of remote access and control from scientists, industries, and governments around the world for its potential range of services for cutting-edge living. IoT is envisioned as a huge number of sensors that are associated with the web through remote and other related advancements [16]. The inter-related sensors produce a huge volume of information, which should be examined, deciphered then used [5]. Via minimal effort, an adaptable automation framework is operated for the home. This automation framework upgrades the utilization of remote correspondence, which enables remote control by the customer of various electrical and mechanical apparatuses [12]. The Neon project emphasizes the reuse of available knowledge [17]. The European Research Cluster on IoT was released in 2015, which consists of recommendations for semantic interoperability [18]. Semantic interoperability concerns the ontology heterogeneity and the meanings of data that are changed by small sensing devices according to the environment [19]. Semantic-level machine-to-machine interoperability has motivated several research projects on improving traditional technologies. Important examples of these applications include the task computing environment (TCE) [20], solutions for Link Smart [21] , and COCOA, which has been integrated with OWL-S [22], leading to further application development. Smart home automation uses the raspberry pi camera for face recognition (to decide whether a human is authorized or not), for human action detection and for recognition of the background of an image for background subtraction [23].

3. Semantic Interoperability for Autonomous Control

IoT has evolved along with the troubles that are faced while directing all traffic towards the cloud. Researchers proposed the strategy of edge devices providing the nearest response points to the client of the IoT. These edge devices behave similar to a cache in resolving smaller problems in relation to the communication and response to a command instead of burdening the cloud. Prior to edge computing, communication was delayed during the rush hours of the network traffic. In Figure 2, the proposed network topology is illustrated. It consists of an edge and a cloud for realizing autonomous control of the devices. Figure 2 presents the topology that was constructed in the Mini-net emulator and the real-world network settings in parallel [24].

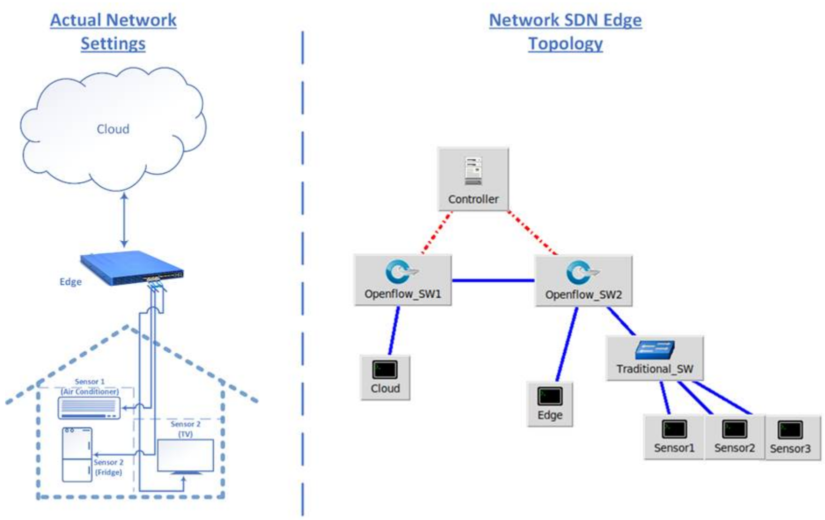

Figure 2: Edge Computing and Cloud Network Topology and Real-World Representation

Semantic interoperability is realized by transforming relational data into a semantically enriched form. Semantic data are in the form of triples, which are highly suitable for creating a rule-based inference engine. The inference engine provides more analysis data for generating commands that are built on linked data and constraints. These constraints must be satisfied while controlling electronic devices. In Figure 3, data are processed through the sending commands to the controller after undergoing a three-phased data transformation procedure. Phase 1 consists of the data model analysis. In the second phase, data are mapped with alternative representation in XML format. Finally, in the last phase, data are made available as triples in RDF format that are ready for the inference engine to carry out artificial intelligence operations. These operations are based on special rules defined for controlling the devices remotely and automatically.

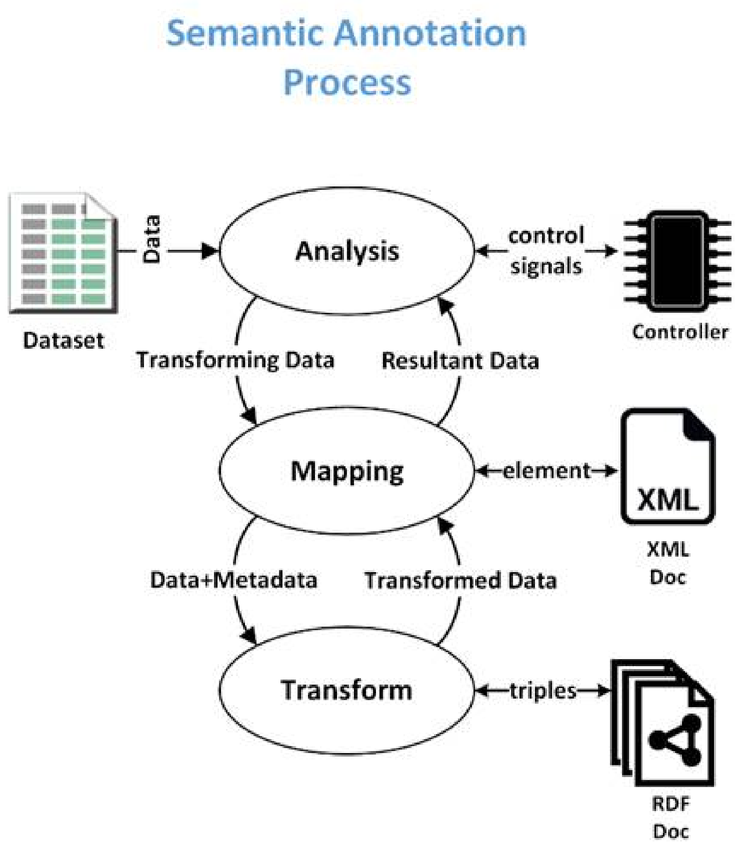

Figure 3: Remote Data Semantic Annotation Process

microcontrollers are used inside system environments to connect to the network via WIFI and send data to the cloud [25]. microcontrollers can communicate autonomously with devices and sensors via internet, although the cloud is used as the main component between these micro controllers [26]. The cloud provides a log between the micro controller connectivity and the communication network as illustrated in Figure 4.

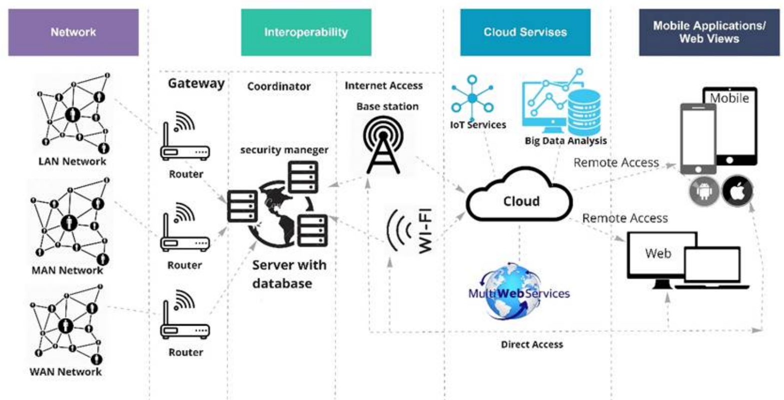

Figure 4: Proposed model for controlling and monitoring devices using semantic annotation.

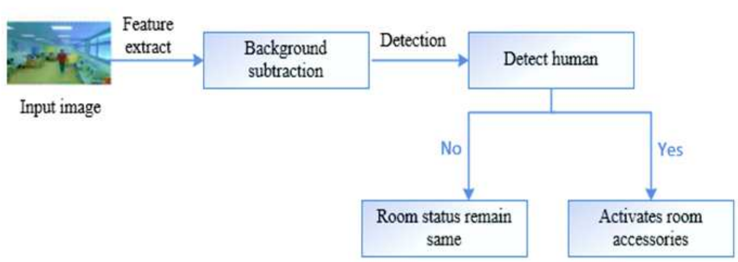

Figure 5: Detecting Human Behaviour using Image Processing.

Smart home automation applies image processing to detect a human in a room. If the human detection result is positive, a human is in the room and the control system switches to semantic interoperability status. The room environment activates as shown in Figure 5. Otherwise, the room status becomes unoccupied and no signal is forwarded to the control system of the room.

4. Case Study: Semantic Interoperability for Home Appliance Autonomous Control

In this case study, a system that detects the user context inside a home and accordingly activates the sub-portion of the system that corresponds to the user's location is modelled. This system is illustrated in Figure 6.

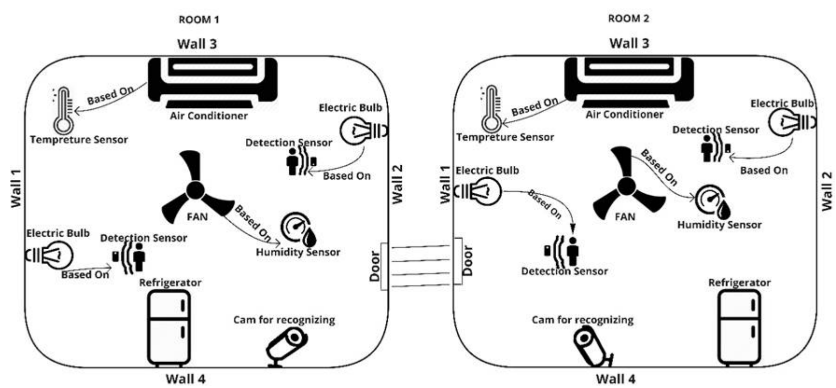

Figure 6: Setting up an IoT and sensors in two rooms for testing the model.

In Figure 6, a home automation system is illustrated, within which we represent two rooms inside a home and home appliances that exhibit interoperability. These appliances, which include an air conditioner, a fan and electrical bulbs, communicate using sensor devices reading data from the room. Based on the retrieved data from the home appliances, the output is controlled and monitored simultaneously. The fan utilizes a humidity sensor: if the humidity increases, the fan speed will slow down automatically and if it decreases, the fan speed will rise while being controlled and manipulated using microcontroller. Similarly, the air conditioner uses a temperature sensor where the ambient temperature and the air conditioner's temperature are inversely proportional. According to the temperature, the air conditioner reduces or increases the cooling control power. The electrical bulbs, inside the room, use detection sensors: if these sensors detect someone, they send a signal. In addition, according to this signal, the electric bulb state will be on or off. Cameras are used to detect the presence of a person in the rooms by using object detection through image processing. The proposed setup for home appliance automation utilizes sustainable computing. The realization of interoperability among these appliances is discussed.

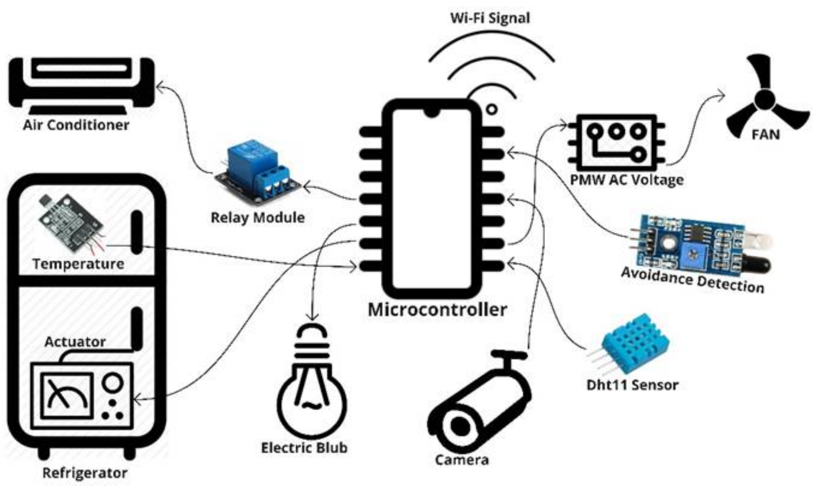

Figure 7: Centralized microcontroller that is monitoring and controlling home appliances for automation.

We use a microcontroller to interlink with other kind of devices and to make decisions, as listed in table 1. Figure 7 illustrates how the setup operates [27]. In the figure, the arrow signs represent the input and output, and the arrow direction is towards the controller or an appliance. Sensors read data and send these data to the controller which, in its turn, sends a signal to the device to control its on or off state. In Figure 7, we have a humidity sensor that collects humidity and temperature data and sends them to the microcontroller. If the temperature increases past 35 degrees Celsius, then a 3.3 v signal is relayed to the air conditioner as a command. For the fan, if the humidity reaches 18, a PWM (pulse width modulation) signal is sent to the AC voltage PWM module and according to the PWM value, the fan speed will increase or decrease. The same approach is followed by the refrigerator. We use detection sensors that detect a person and send the signal towards the controller. This latter will turn the bulb on or off depending on the IR detection sensor data that describe the context of use inside the home. Two sensors are used: a laser sensor, which emits light, and a photoresistor, which absorbs this laser light. When the user crosses this laser light, the photo resister module detects the user, and according to the user context, the microcontroller decides whether to turn on the appliances in the room where the user is present. We have implemented this system. We will further describe the system with the help of graphical images.

Table 1: Case study setup details for controlling and retrieving information from devices.

No.	Device	Description
01	LOLIN V3 (Node MCU) (ESP 12E)	Microcontroller with a Wi-Fi module for connecting with the Internet and providing the services of an Internet server for http requests. It obtains the data of sensors and sends them to web servers.
02	Dht11 (Temperature and humidity sensor)	Sensor that collects temperature and humidity information from real environment and sends the values to the microcontroller.
03	Avoidance detection	Sensor that detects something under the range of the sensor and send the values to the microcontroller
04	Relay	Electric module that is used to control high voltage of AC (alternating current) on the base signal of 3.3 V that is generated by the microcontroller output pin.
05	Temperature	Sensor that measures the temperature inside the refrigerator
06	Actuator	Electric module that takes an input from the microcontroller and sets the refrigerator cooler module.
07	PMW AC module	(Pulse width modulation) Electric module that receives input from the microcontroller in 0 V to 3.3 V and sets the AC voltage from 100 V to 220 V for controlling the speed of the fan.
08	Camera	Recognizes the user for context switching of home appliances between rooms.

4.1. Formulating the Sensor Setup

To formulate the sensors setup for data collection and for realizing semantic interoperability, it is necessary to investigate the transformation mechanism between values. Most of the sensors read values from the environment in analogue form, namely, they read the signal in analogue waveform and send values to microcontrollers according to these waves. The microcontrollers receive these analogue signals and convert them into digital values. The digital values range from 0 to 1023. Using these values, the temperature, humidity, and distance of a body from the sensor are calculated. Similarly, sometimes an analogue signal is required for representing the output in the form of on or off as 0 or 1 to enable the microcontrollers to understand the commands. In contrast, if an output is needed in signal form, we convert these digital signals into analogue form via PWM, in which the voltage is increased and decreased according to the value that is measured by the sensor. Now, well-known and newly devised formulas are used to calculate the temperature, humidity, and distance for controlling the electric devices:

- Temperature Calculation Let *temp* denote temperature and t time in milliseconds $temp \rightarrow temperature$

  $t = 5000$

  The analogue value is converted into digital form via equation 1:

  $$v = (temp/1024) * t \tag{1}$$

  Using Eq. 1, the values that are calculated for the temperature in Fahrenheit °F and Celsius °C are

  $^{\circ}C = v/10$

  $^{\circ}F = ((^{\circ}C * 9)/5) + 32$

- 2. Humidity Calculation (Analog-to-Digital Conversion) For a raw analogue-to-digital converter (ADC), the equivalent value for 1023 is RH 90, namely, 2970 mV and, such that any x value can be converted to digital as $1023 * x = 90$

  $Qx = 0.0879765395894428$

Now any reading r can be transformed into the digital equivalence de as shown in equation 2:

$$de = r * 0.0879765395894428 \tag{2}$$

For example, if $r = 920$, then $920{*}0.0879765395894428 = 80.93841642228739RH$. Hence, if the sensor value is 920, the output humidity becomes 80 and the remaining value will be ignored.

- 3. Digital-to-Analogue Conversion It is realized by using Henry's Bench LM358 Arduino PWM to Voltage Converter programme. Through this programme, PWM is specified on the output device. The analogue input is converted into digital values and the microcontroller keeps the output between 0 to 1023. Based on this input, the temperature and humidity are calculated via Eq. 1 and 2. Then, a PWM signal is produced for controlling the fan speed and the refrigerator actuator. The PWM signal moves towards the middle module AC voltage PWM and it acts as a voltage regulator, which controls the 220 v on behalf of the signal from 0 to 3.3 v from the microcontroller. Table 2 lists the mappings from temperature to voltage.

Table 2: Mappings of temperature to voltage.

Input temp	**Output voltage**	**Input humidity**	**Output**
35	220	58	0
30	180	48	100
25	140	38	140
20	100	28	180
15	80	18	220

According to Table 2, if the temperature value is above 35, the AC voltage will be at its full capacity. If the temperature value is between 30 and 35, the AC output voltage of the module will be between 180 and 220.

- Data Semantic Annotation Now, the real-time readings are recorded and stored in two formats, such as XML and RDF (as shown in Figure 8). The World Wide Web Consortium (W3C) specifications are followed in annotating the obtained data in the semantic realization. In Figure 8, (a) presents sample data that are annotated in XML and (b) presents sample data that are in the format of RDF. This helps us to link related information and to ensure change monitoring in a controlled environment.

Figure 8: Data annotation in RDF and XML formats. (a) Sample data in XML format. (b) Sample data in RDF format.

For further communication for schema at both ends of the data, either XML or RDF is needed prior to data recording and annotation. Figure 9 (a) shows a schema representation of the XML data element while Figure 9 (b) shows a schema representation for RDF data.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified" attributeFormDefault="unqualified">
<xs:element name="home_auto">
<xs:complexType>
<xs:sequence>
<xs:element ref="room_data" minOccurs = "0" maxOccurs = "unbounded" />
</xs:sequence>
</xs:complexType>
</xs:element>
    <xs:element name="room_data">
        <xs:complexType>
            <xs:sequence>
                <xs:element name="room_data_id">
                    <xs:simpleType>
                        <xs:restriction base="xs:int">
                            <xs:minInclusive value="-2147483648"/>
                            <xs:maxInclusive value="2147483647"/>
                        </xs:restriction>
                    </xs:simpleType>
                </xs:element>
                <xs:element name="Humidity">
                    <xs:simpleType>
                        <xs:restriction base="xs:int">
                            <xs:minInclusive value="-2147483648"/>
                            <xs:maxInclusive value="2147483647"/>
                        </xs:restriction>
                    </xs:simpleType>
                </xs:element>
```

(a)

```xml
<?xml version='1.0' encoding='ISO-8859-1'?>
<!DOCTYPE rdf:RDF [
<!ENTITY rdf 'http://www.w3.org/1999/02/22-rdf-syntax-ns#'>
<!ENTITY rdfs 'http://www.w3.org/TR/WD-rdf-schema#'>
<!ENTITY owl 'http://www.w3.org/2002/07/owl#'>
<!ENTITY xsd 'http://www.w3.org/2001/XMLSchema#'>
]>
<rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:owl="http://www.w3.org/2002/07/owl#" >
    <rdfs:Class rdf:about="http://www.home_auto.tms/home_auto#home_auto">
        <rdfs:label>home_auto</rdfs:label>
        <rdfs:comment>Table</rdfs:comment>
        <rdfs:subClassOf rdf:resource="http://www.home_auto.tms/home_auto#null"/>
    </rdfs:Class>
    <rdfs:Class rdf:about="http://www.home_auto.tms/home_auto#room_data">
        <rdfs:label>room_data</rdfs:label>
        <rdfs:comment>Table</rdfs:comment>
        <rdfs:subClassOf rdf:resource="http://www.home_auto.tms/home_auto#home_auto"/>
        <rdfs:subClassOf>
            <owl:restriction>
                <owl:onProperty rdf:resource="http://www.home_auto.tms/home_auto/room_data_id" />
                <owl:minCardinality rdf:datatype="&xsd;nonNegativeInteger">-2147483648</owl:minCardinality>
            </owl:restriction>
        </rdfs:subClassOf>
```

(b)

Figure 9: Schema in XML and RDF after annotation of data. (a) Sample schema part for the XML data end. (b) Sample schema part for the RDF data end.

Figure 10 presents a sample RDF graph for the resultant semantic annotation. Room Data is the main class with different attributes such as Fan. It has different sensors, such as Temperature and Humidity and different actuators, such as AC, light bulb and fan.

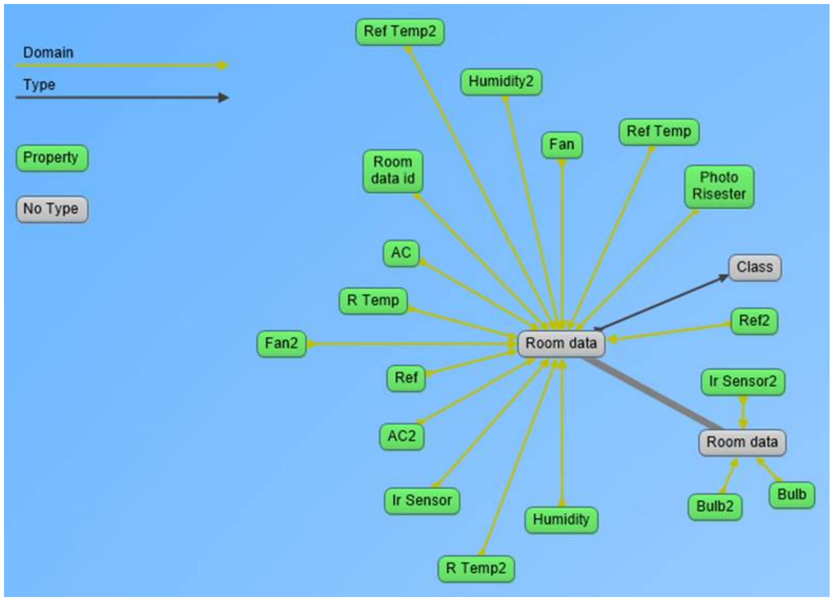

Figure 10: Sample RDF graph for the resultant semantic annotation.

5. Results and Discussion

The dataset is collected over 5-second intervals in a 4-day span in two rooms of a home to evaluate the automatic device control over sensors. Data collection is conducted according to the user context: if the user switches rooms, the control is switched to the other room while the readings of both rooms are captured. The experiment can be classified into two scenarios, namely, the person is in room 1 and the person is in room 2, as illustrated in Figure 11 and Figure 13.

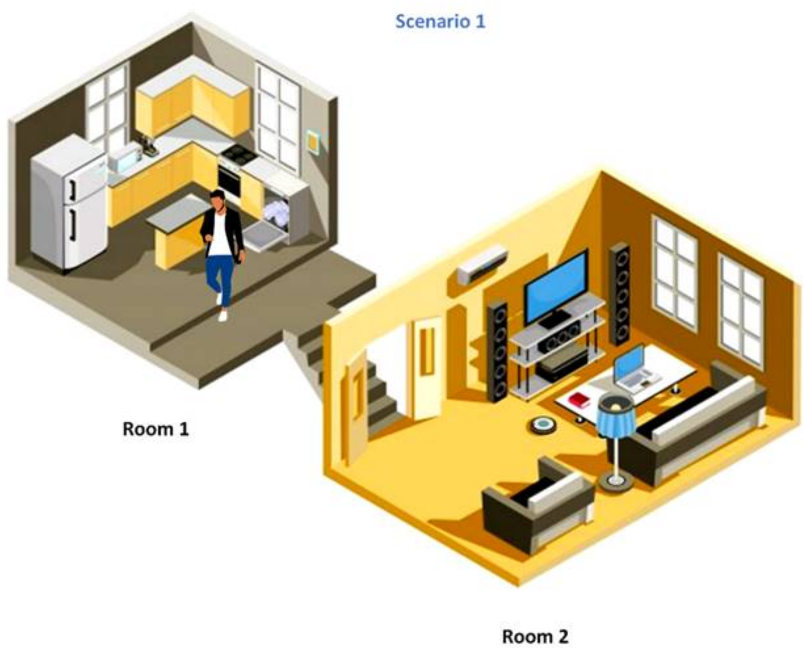

Figure 11: Scenario 1- A person is in Room 1.

Figure 12 (a) plots the data from the sensors of humidity, temperature, infrared and photoresistor inside Room 1. In Figure 12 (a), the five types of readings that are obtained by five sensors are coloured accordingly. The first section is the current time section, in which we obtain the real-time values of sensors. The most recent values appear here. The next four sections contain historic values with a gap of 10 minutes. Hence, in the last section of Figure 12 (a), the temperature of Room 1 is 35 degrees Celsius and the humidity is 16. Inside the refrigerator in this room, the temperature is 28 degrees Celsius and the photoresistor sensor value of 0 indicates that the user is not inside of Room 1 and the IR obstacle detection sensor also shows a value of 0; hence, our bulb is turned off. After 10 minutes, the room temperature decreases to 31 degrees Celsius, the humidity increases to 25, and the refrigerator temperature decreases. The photo resistor value becomes 0 and Figure 12 (b) shows the result for Room 1. Now, the IR obstacle detection sensor value is 1 and somebody is under the light bulb. The bulb will go on in Figure 12 (b). Thus, by following this pattern in the current time period, the temperature reaches 15 degrees Celsius, the humidity is 58, and refrigerator temperature is 13. Therefore, according to the user, Figure 12 (a) shows that when the user entered the room at this time, the temperature was 35 degrees Celsius, and now the temperature is 15 degrees Celsius, as specified in Figure 12 (a).

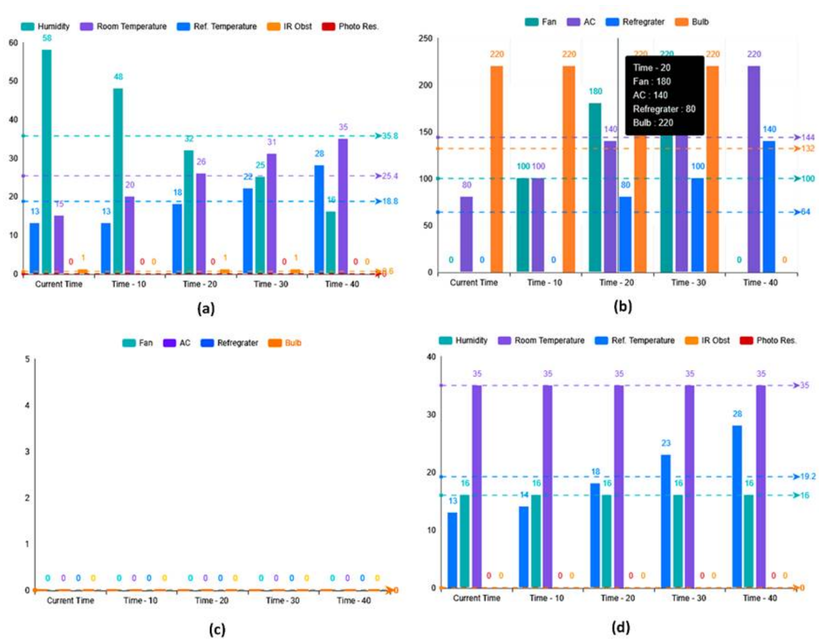

Figure 12: Sensors readings during the home automation experiment with Scenario 1: (a) Room 1 readings while the person is present; (b) Room 1 fan, AC, refrigerator and bulb readings; (c) Room 2 fan, AC, refrigerator and bulb readings; and (d) Room 2 readings while the person is not present.

Figure 12 (b) shows the output of the appliances in Room 1 behaviour in the Time-40 section when the temperature was 35 degrees Celsius. Now, the AC turns on and runs at full speed while consuming 220 volts, and according to its capacity, it consumes amperes. In addition, according to the refrigerator temperature, it consumes 140 volts as the person comes inside the room, the humidity is 16, and the fan has just started and is running at full speed. In the

Time-30 section, the fan is running. Hence, based on the input, the things automatically output data and are context-aware and interoperable. This demonstrates that if the photoresistor value is 0, the Room 1 appliances are turned on. Now, Room 2 appliances are off, as represented in Figure 12 (c). Although the appliances are not working, the sensors of Room 2 are recording the values that are specified in Figure 12 (d). The room temperature and humidity are constant when the user enters the room. Then, the appliances will be on and the temperature will change accordingly.

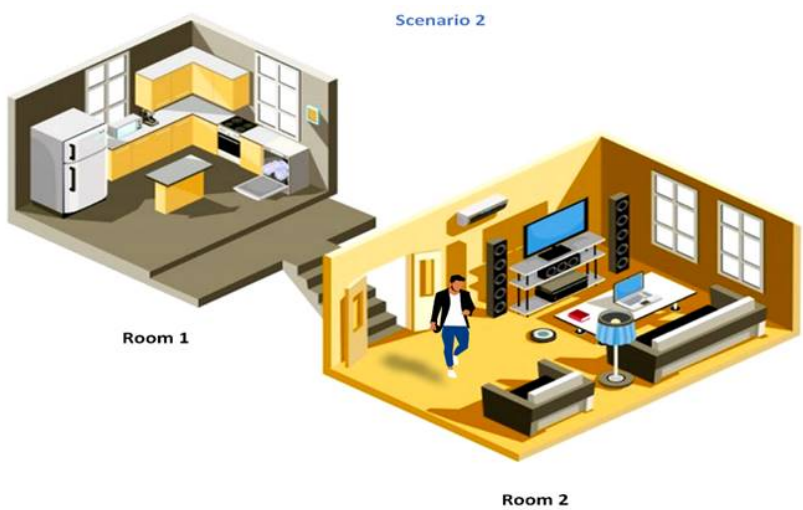

Figure 13: Scenario 2- The person is in Room 2.

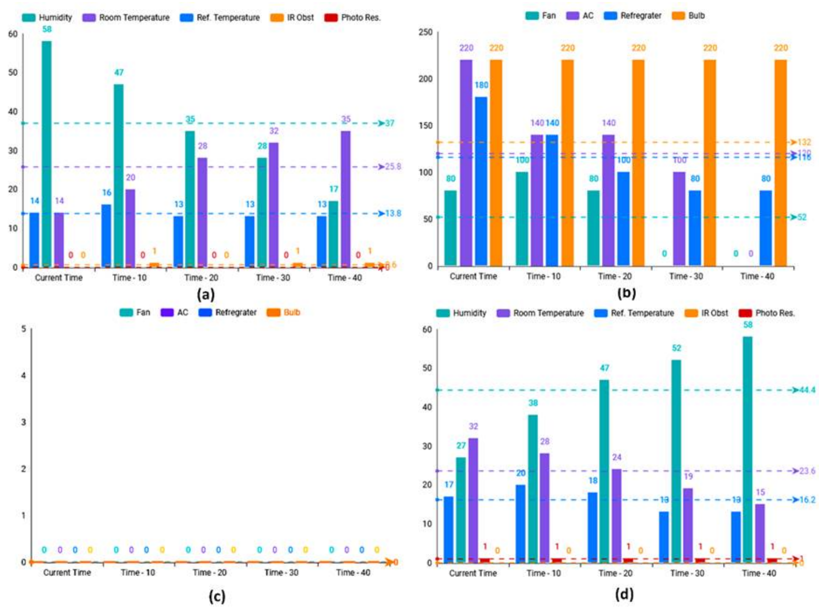

Figure 14: Sensor readings during the home automation experiment in Scenario 2: (a) Room 2 readings while the person is present; (b) Room 2 fan, AC, refrigerator and bulb readings; (c) Room 1 fan, AC, refrigerator and bulb readings; and(d) Room 1 readings while the person is not present.

When the user changes the context and is at room 2, the photo resistor detects the values for the appliances that are on in Room 2, and the Room 1 appliances will be off. Figure 14 (a) presents the readings when the user is inside Room 2. According to these values, the output of Room 2 is presented in the graph in Figure 14 (b). At that time, the output of Room 1 is presented in Figure 14 (c). Because the user changes the context by leaving Room 1 and entering Room 2, the appliances of Room 1 are turned off, and the temperature and humidity of Room 1 gradually increase, as represented in Figure 14 (d).

6. System Validation

The proposed systems have used different sensors and actuators. The sensors readings are used in the system to operate the actuators. The sensors are working all the time. The sensors used are the humidity, temperature, detection sensors and photoresistor. The actuators are the fan bulb, AC and refrigerator. From the context experiments, the trajectory of the system functionality over time when the user staying, entering or leaving a room can be validated by reviewing the system functionality. Looking again at Figures 12 and 14, sensors values are changing over time when the user enter or leaves the room. Also, the appliances are turned off when there is no user in the room. When the cooling system increases or the room temperatures decreases, the humidity rises. This is an evident fact because of the cross relation between humidity and temperature in humid environment. This has been already mentioned by J Bernan "If you raise the temperature while keeping moisture content constant, the relative humidity decreases." [23].

Figure 12 (a) and 14 (a) shows that the humidity is increasing, and the room temperature is decreasing. AC power consumption increases over time as shown in Figure 14 (b). In Figure 12 (b) Fan power consumption drops as the room humidity rises. Figure 14 (d) shows a decrease of humidity since the fan is switched off as shown, also, in Figure 14 (c). Figure 14 (d) shows an increase in room 1's temperature because the AC and other appliances are switched off. Also, in the same figure the refrigerator temperature is increasing for the same reason. The already listed Figures show correct appliances functionality and reading. Also, the change of appliances over time is following the objective of home automation. Figure shows that the system model is working well according the room usages. Home appliances are functioning together as programmed.

7. Conclusions

Environmental features can be measured as signs while sitting in the comfort of our homes. These readings can be stored on our mobiles or remotes systems. IoT devices can be used to facilitate remote monitoring and to activate notification systems if any change in the environmental scenario occur. IoT provides a reduction in cost and extends the scope of energy-efficient facilities to remote areas; it also enhances the quality of services. The full economic benefits of IoT-based semantic interoperability for smart home appliances are due to the availability of the data in a structured format. Many semantic-level data sources will be obtainable for the integration of datasets with IoT sensing devices. Based on data that are produced by these devices, smart decisions will be made for maintaining a controlled environment. The system data are used by the system according the model mentioned using the RDF data. The system is ready for extension because the system is developed using the latest trend in technology and web standards. It is highly expected that in 6G networks that the support for intelligent systems will be higher which will increase the Edge computing functionality and enhancing home automation systems. 6 G networks can bring much facilities for home automation, it is the role for the cloud and the edge computing level to coop with. However, the IoT devices will need to coop with the edge new expected capabilities.

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Figures

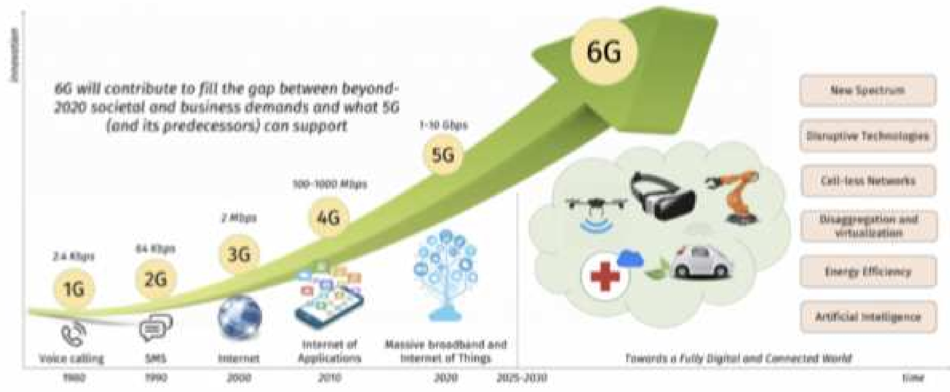

Figure 1

Application development over different mobile networks [10].

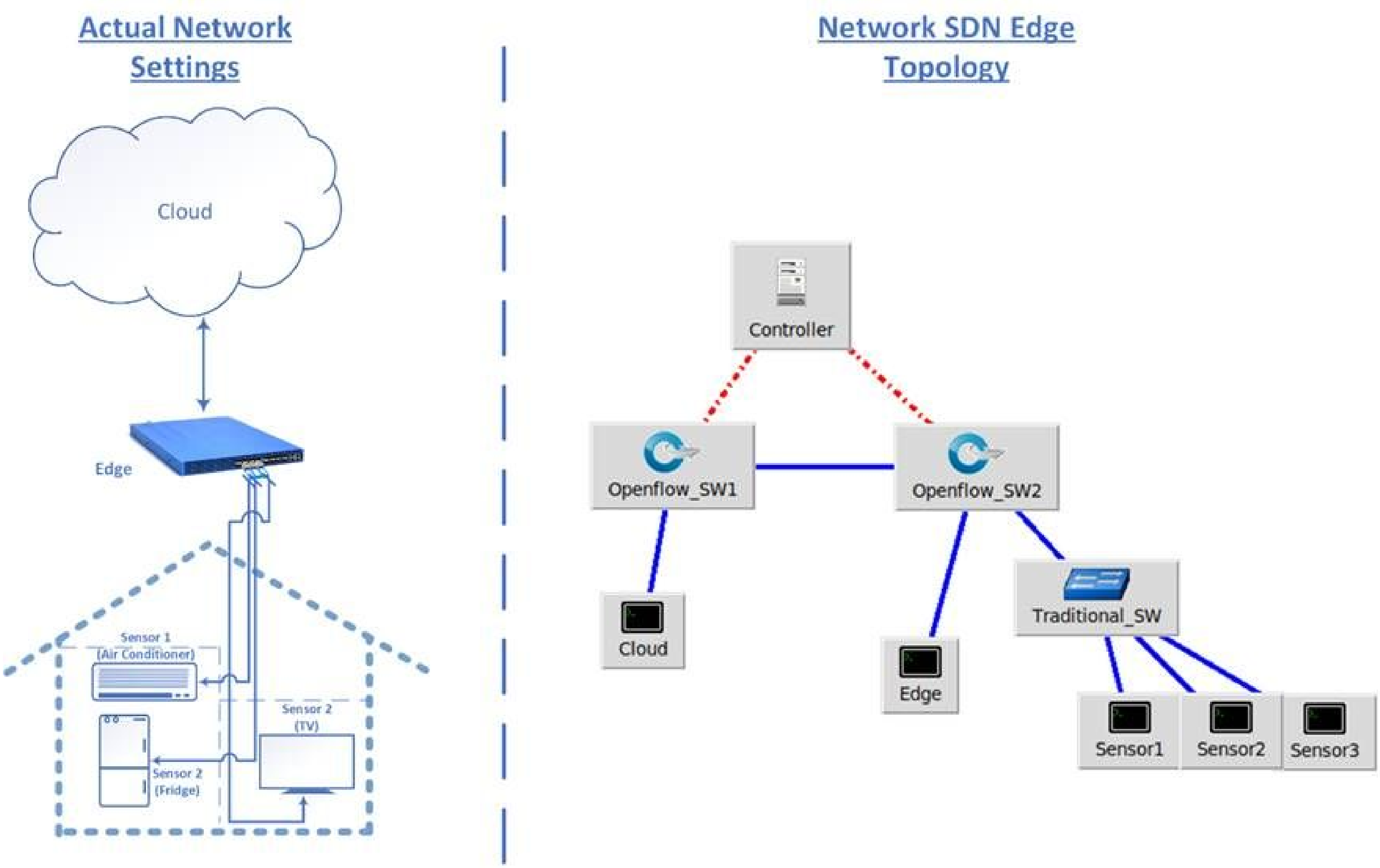

Figure 2

Edge Computing and Cloud Network Topology and Real-World Representation

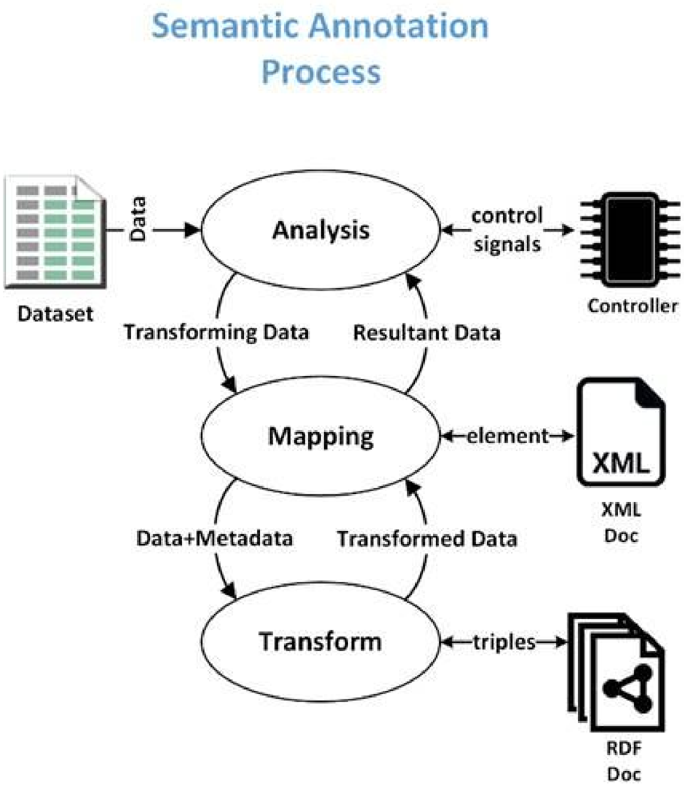

Figure 3

Remote Data Semantic Annotation Process

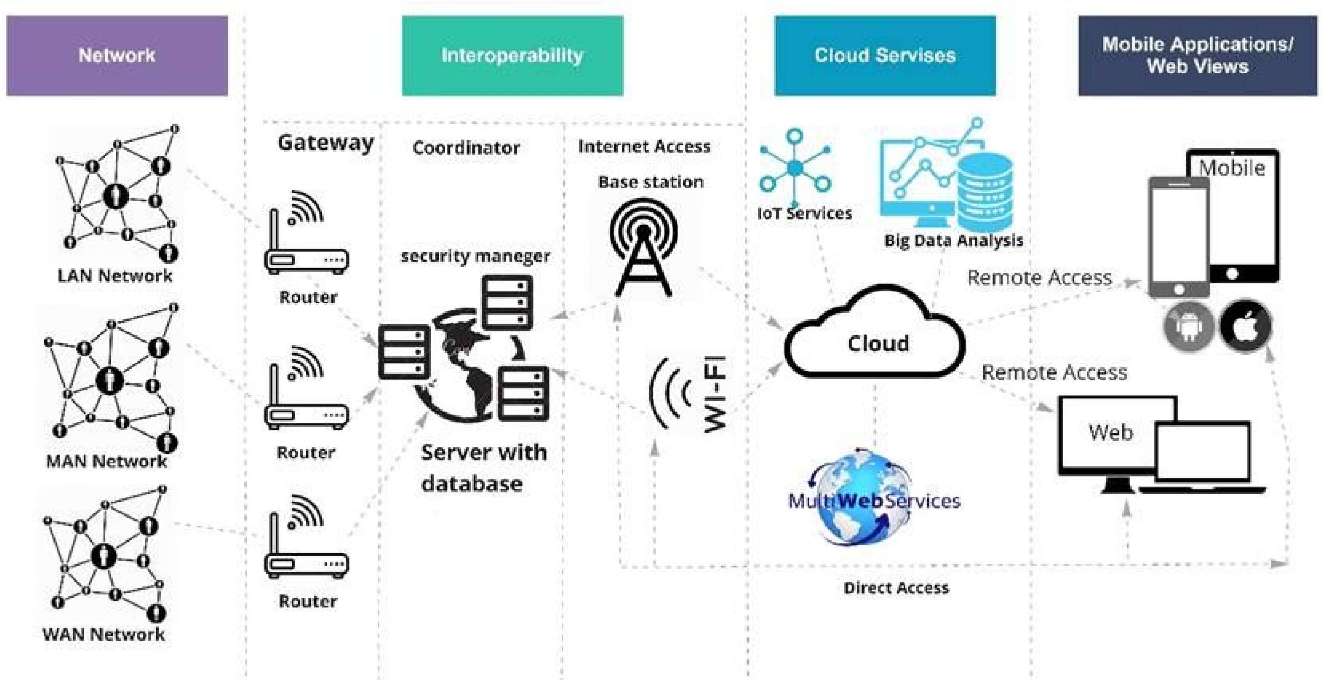

Figure 4

Proposed model for controlling and monitoring devices using semantic annotation.

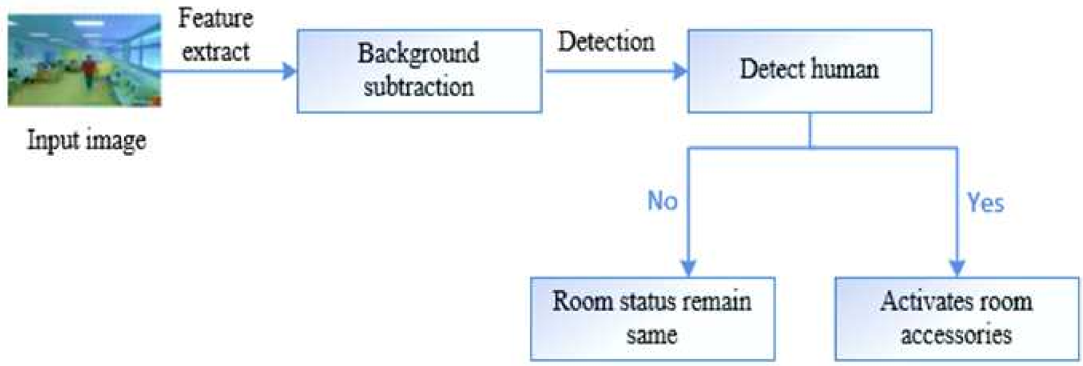

Figure 5

Detecting Human Behaviour using Image Processing.

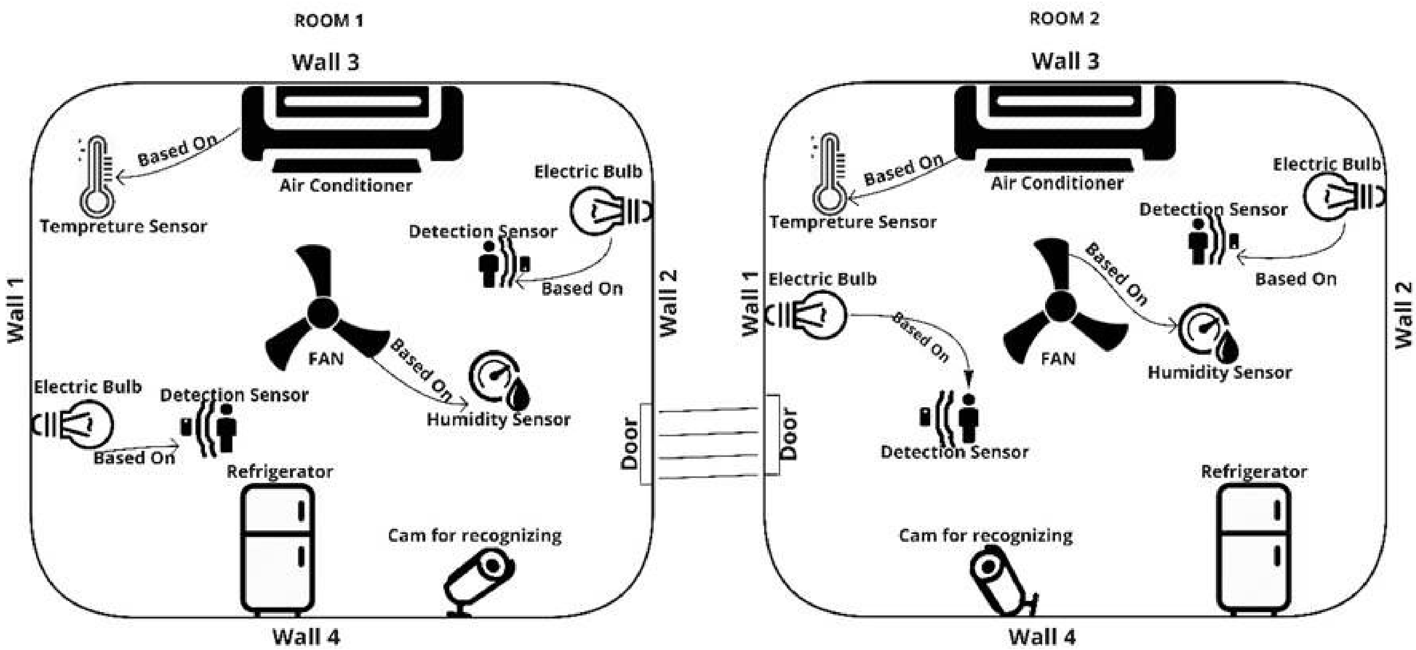

Figure 6

Setting up an IoT and sensors in two rooms for testing the model.

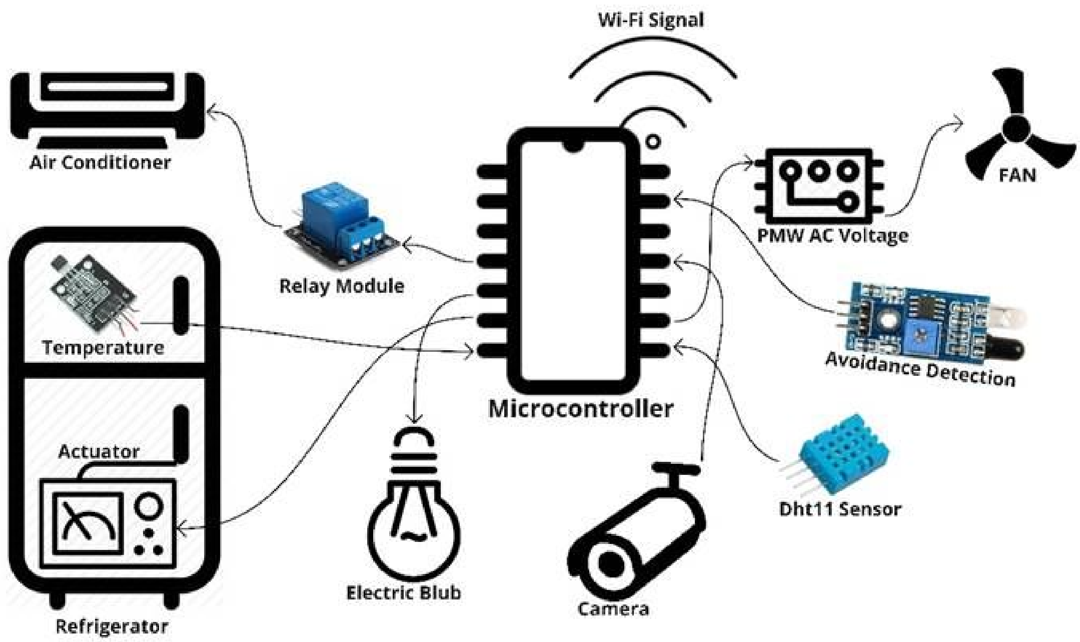

Figure 7

Centralized microcontroller that is monitoring and controlling home appliances for automation.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<home_auto xmlns:xs="http://www.w3.org/2001/XMLSchema"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.w3schools.com XSD_output_home_auto.xsd">
    <room_data>
        <room_data_id>1</room_data_id>
        <Humidity>16</Humidity>
        <R_Temp>35</R_Temp>
        <Ref_Temp>28</Ref_Temp>
        <Ir_Sensor>0</Ir_Sensor>
        <Humidity2>16</Humidity2>
        <R_Temp2>35</R_Temp2>
        <Ref_Temp2>28</Ref_Temp2>
        <Ir_Sensor2>0</Ir_Sensor2>
        <photoRisester>0</photoRisester>
        <Fan>220</Fan>
        <AC>220</AC>
        <Ref>180</Ref>
        <bulb>0</bulb>
        <Fan2>0</Fan2>
        <AC2>0</AC2>
        <Ref2>0</Ref2>
        <bulb2>0</bulb2>
</room_data>
```

(a)

```xml
<?xml version='1.0' encoding='ISO-8859-1'?>
<rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:owl="http://www.w3.org/2002/07/owl#"
xmlns:home_auto="http://www.home_auto.tms/home_auto/">

<rdf:Description rdf:about="http://www.home_auto.tms/home_auto#room_data">
<home_auto:room_data_id>1</home_auto:room_data_id>
<home_auto:Humidity>16</home_auto:Humidity>
<home_auto:R_Temp>35</home_auto:R_Temp>
<home_auto:Ref_Temp>28</home_auto:Ref_Temp>
<home_auto:Ir_Sensor>0</home_auto:Ir_Sensor>
<home_auto:Humidity2>16</home_auto:Humidity2>
<home_auto:R_Temp2>35</home_auto:R_Temp2>
<home_auto:Ref_Temp2>28</home_auto:Ref_Temp2>
<home_auto:Ir_Sensor2>0</home_auto:Ir_Sensor2>
<home_auto:photoRisester>0</home_auto:photoRisester>
<home_auto:Fan>220</home_auto:Fan>
<home_auto:AC>220</home_auto:AC>
<home_auto:Ref>180</home_auto:Ref>
<home_auto:bulb>0</home_auto:bulb>
<home_auto:Fan2>0</home_auto:Fan2>
<home_auto:AC2>0</home_auto:AC2>
<home_auto:Ref2>0</home_auto:Ref2>
<home_auto:bulb2>0</home_auto:bulb2>
</rdf:Description>
```

(b)

Figure 8

Data annotation in RDF and XML formats. (a) Sample data in XML format. (b) Sample data in RDF format.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified" attributeFormDefault="unqualified">
<xs:element name="home_auto">
<xs:complexType>
<xs:sequence>
<xs:element ref="room_data" minOccurs = "0" maxOccurs = "unbounded" />
</xs:sequence>
</xs:complexType>
</xs:element>
    <xs:element name="room_data">
        <xs:complexType>
            <xs:sequence>
                <xs:element name="room_data_id">
                    <xs:simpleType>
                        <xs:restriction base="xs:int">
                            <xs:minInclusive value="-2147483648"/>
                            <xs:maxInclusive value="2147483647"/>
                        </xs:restriction>
                    </xs:simpleType>
                </xs:element>
                <xs:element name="Humidity">
                    <xs:simpleType>
                        <xs:restriction base="xs:int">
                            <xs:minInclusive value="-2147483648"/>
                            <xs:maxInclusive value="2147483647"/>
                        </xs:restriction>
                    </xs:simpleType>
                </xs:element>
```

(a)

```xml
<?xml version='1.0' encoding='ISO-8859-1'?>
<!DOCTYPE rdf:RDF [
<!ENTITY rdf 'http://www.w3.org/1999/02/22-rdf-syntax-ns#'>
<!ENTITY rdfs 'http://www.w3.org/TR/WD-rdf-schema#'>
<!ENTITY owl 'http://www.w3.org/2002/07/owl#'>
<!ENTITY xsd 'http://www.w3.org/2001/XMLSchema#'>
]>
<rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:owl="http://www.w3.org/2002/07/owl#" >
    <rdfs:Class rdf:about="http://www.home_auto.tms/home_auto#home_auto">
        <rdfs:label>home_auto</rdfs:label>
        <rdfs:comment>Table</rdfs:comment>
        <rdfs:subClassOf rdf:resource="http://www.home_auto.tms/home_auto#null"/>
    </rdfs:Class>
    <rdfs:Class rdf:about="http://www.home_auto.tms/home_auto#room_data">
        <rdfs:label>room_data</rdfs:label>
        <rdfs:comment>Table</rdfs:comment>
        <rdfs:subClassOf rdf:resource="http://www.home_auto.tms/home_auto#home_auto"/>
        <rdfs:subClassOf>
            <owl:restriction>
                <owl:onProperty rdf:resource="http://www.home_auto.tms/home_auto/room_data_id" />
                <owl:minCardinality rdf:datatype="&xsd;nonNegativeInteger">-2147483648</owl:minCardinality>
            </owl:restriction>
        </rdfs:subClassOf>
```

(b)

Figure 9

Schema in XML and RDF after annotation of data. (a) Sample schema part for the XML data end. (b) Sample schema part for the RDF data end.

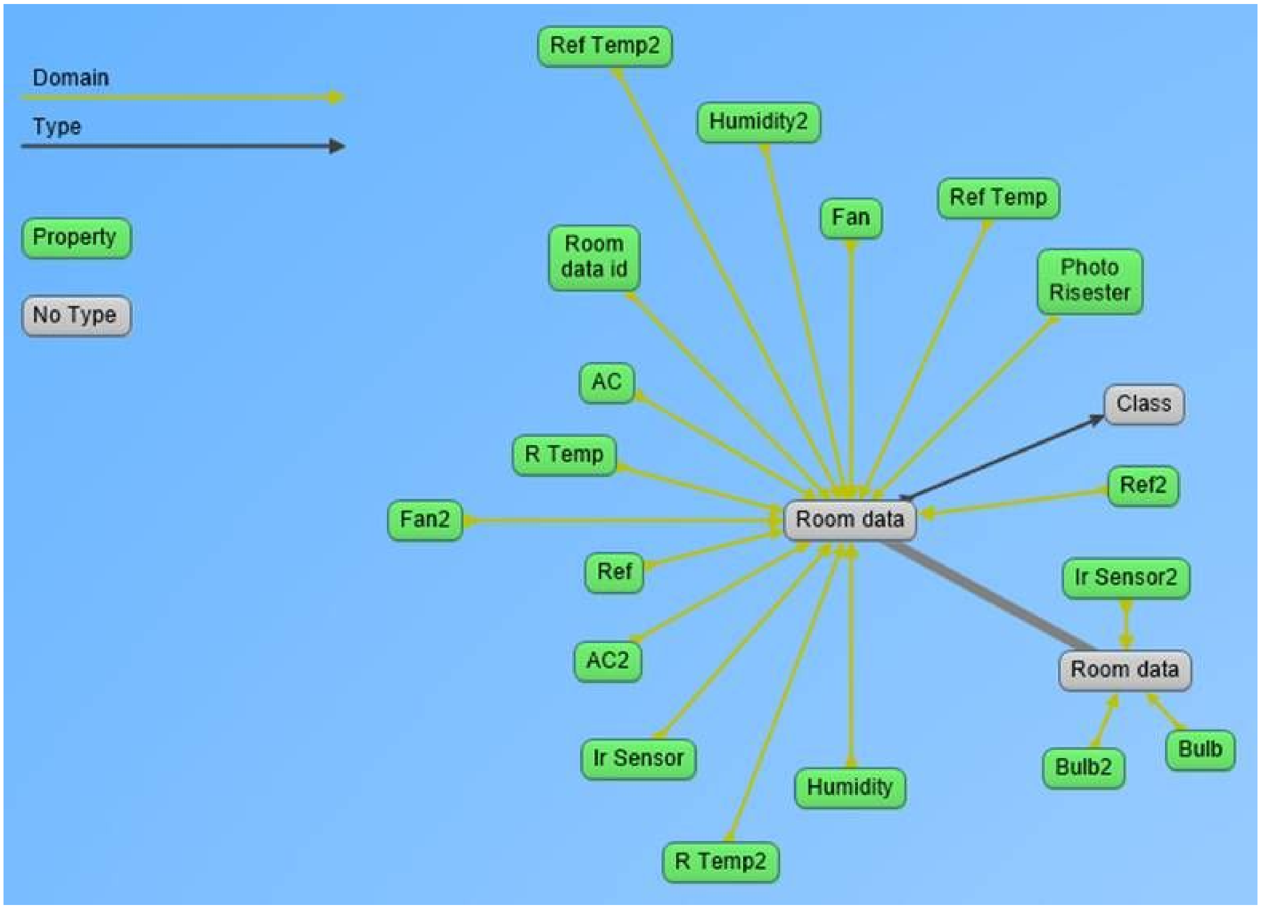

Figure 10

Sample RDF graph for the resultant semantic annotation.

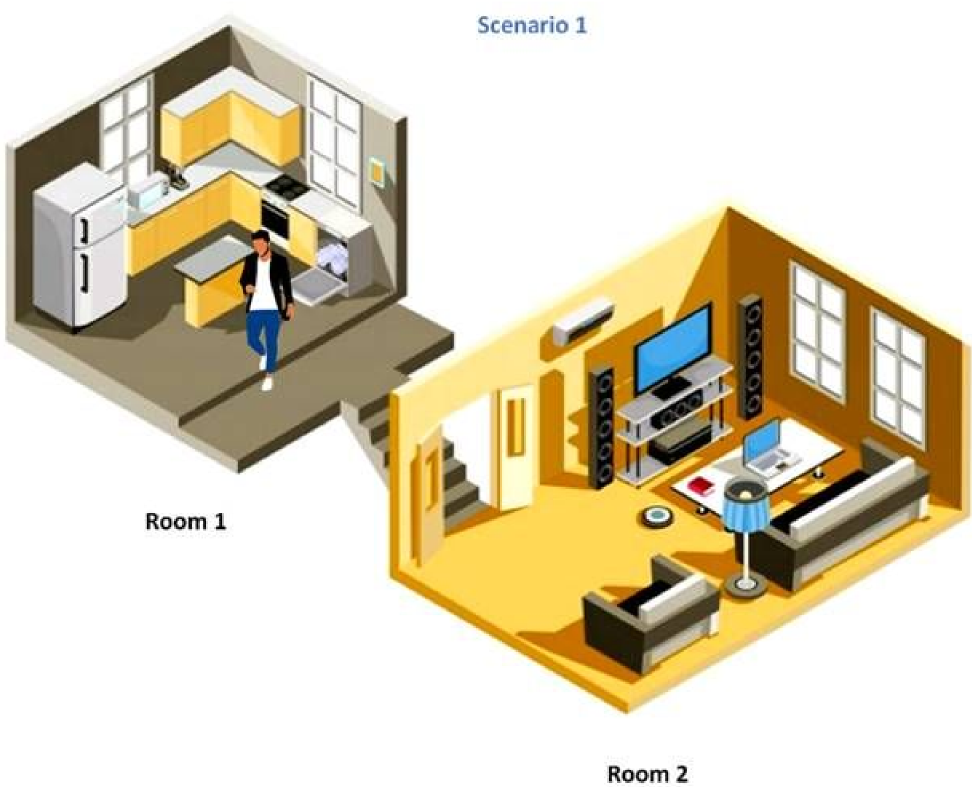

Figure 11

Scenario 1- A person is in Room 1.

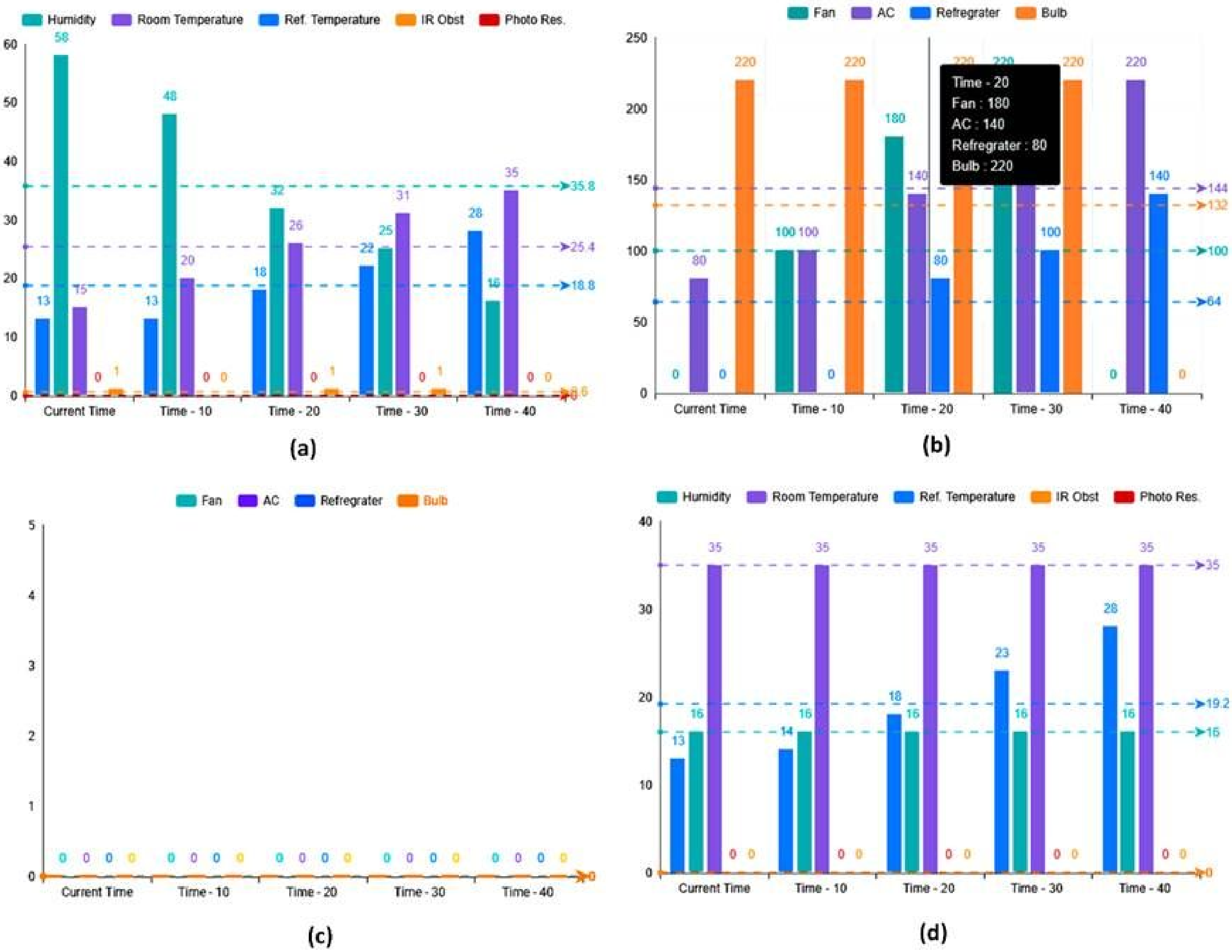

Figure 12

Sensors readings during the home automation experiment with Scenario 1: (a) Room 1 readings while the person is present; (b) Room 1 fan, AC, refrigerator and bulb readings; (c) Room 2 fan, AC, refrigerator and bulb readings; and (d) Room 2 readings while the person is not present.

Figure 13

Scenario 2- The person is in Room 2.

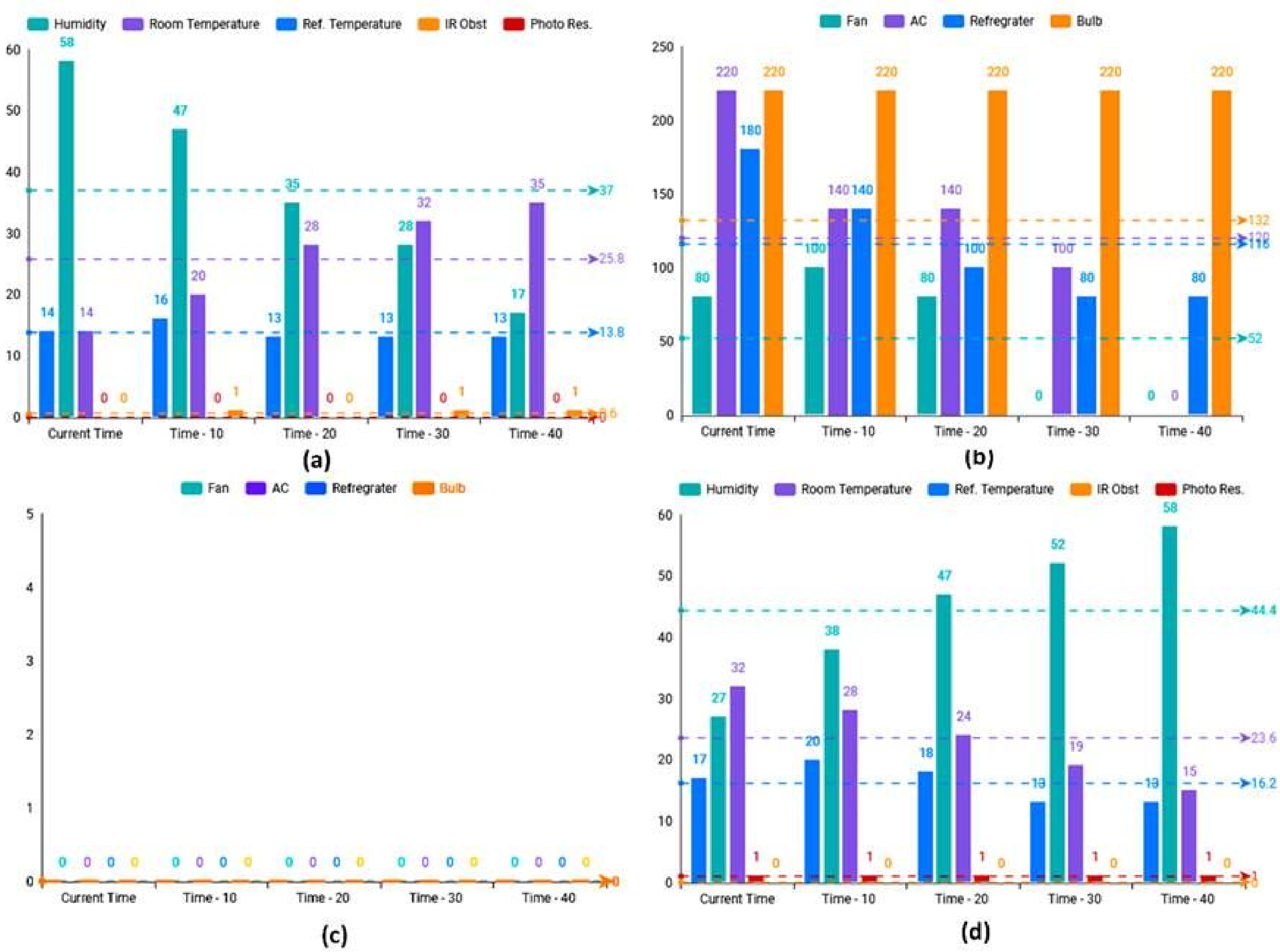

Figure 14

Sensor readings during the home automation experiment in Scenario 2: (a) Room 2 readings while the person is present; (b) Room 2 fan, AC, refrigerator and bulb readings; (c) Room 1 fan, AC, refrigerator and bulb readings; and(d) Room 1 readings while the person is not present.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

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