JDBC Project Report

Smart Home Energy Monitoring Solution

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Introduction & Motivation:

Irish homeowners have begun to adopt smart home technology rapidly. This technology promotes sustainable living and is enabled by smart devices communicating with each other, thereby relaying their status and allowing other devices to act based on this information. The adoption of smart devices has moved to the forefront of homeowners' minds when shopping for new appliances such as refrigerators, dishwashers, or even something as simple as a lightbulb. Nowadays, a vital criterion when choosing a new home appliance is its connectivity, automation, and energy consumption.

A prime example is a smart thermostat that monitors and controls the home's temperature, ensuring optimum energy usage and reduced costs compared to traditional counterparts that operate on a set schedule[1].

The drive toward smart technology adoption results from the increasing cost of living and electrical dependence in our modern homes. With the rise in smart devices, a smart home can have more than 30 devices, which can be challenging to monitor and manage.

Given that smart devices are managed through a central hub, this project aims to develop the first iteration of this Central Hub. In this iteration, the user will be able to:

- Manage smart devices
- Monitor live device status
- Track device location and connectivity
- Log daily Energy consumption
- Enable device operation schedule planning

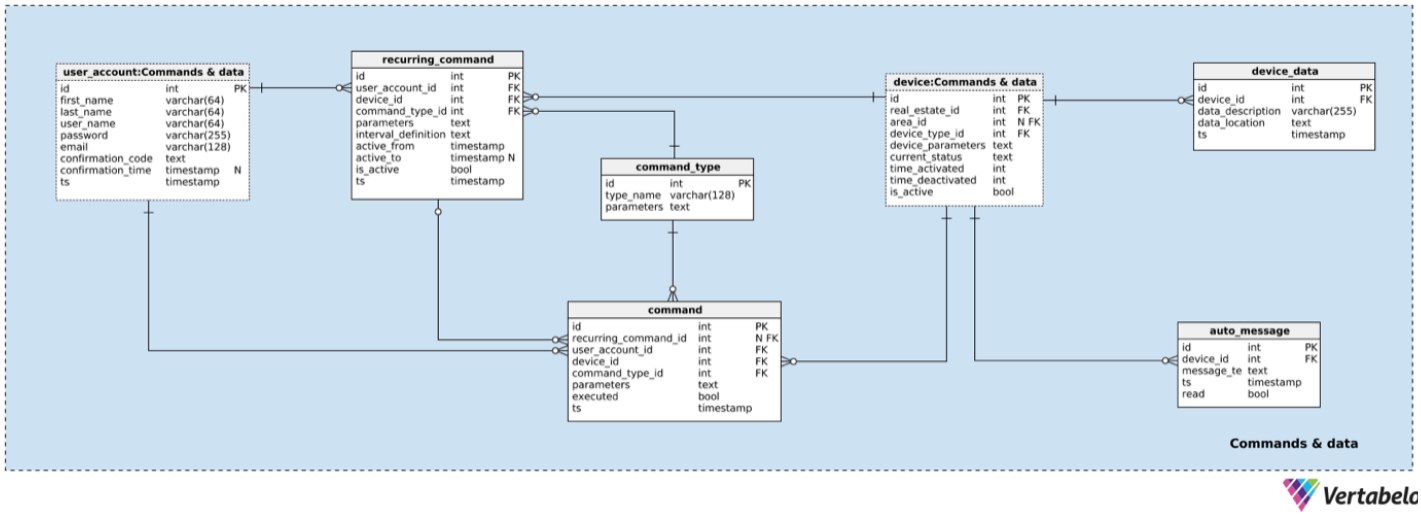
System Overview and Design:

The system was developed in 3 stages.

1. Database Schema design
2. Stored Programs
3. JDBC GUI design

Database Schema design

Research was conducted to understand the commonalities in smart homes, the base tables (strong entities), lookup tables (reference tables), and the typically defined derived tables in a smart home.



Referenced Sample Database Schema for smart home[2]

Subsequently, research was focused on identifying the information that typically represents a smart home device.

Table 1. Attributes IoT Devices

IoT	Computational Power	Communication Range	Data rate	Storage capacity	Communication	Battery Life	Data Security
Ethernet: LAN IEEE 802.3 -cross over cable	100 baseT1	100 meters	100 Mbits/s	N/A	LAN/WAN	N/A	High
Laptops: -Dell Inspiration i7559 -Lenovo G70 core i7	2.6GHz 300000 D MIPS@3.0 GHz	150 m	300000 D MIPS	8GB 8.1 64 bits	Wifi Bluetooth	4-8 hrs -4-9 hrs	High
Wearables: -Samsung Gear s3	1Ghz	100 m	30 to 45 mbps	4GB	4G LTE	380 mAh Li-ion	Average

Referenced Attributes that capture IOT device characteristics [3]

This information guided the design of the following tables:
- device_info (Base Table)
- device_type (Reference Table)
- device (Base Table)
- device_msg_log(Base Table)
- device_energy_log(Derived Table)

The **device_info** table was designed to contain all the device information, such as name, description, active power, range, etc. (*Figure 1)*.

The **device_type** table holds a reference to all possible smart home device types. (*Figure 2)*

The **device** table represents all devices managed by the central hub, holding information such as status, location, and date and time of activity.(*Figure 3)*

The **device_msg_log** table contains all messages sent, categorised by types {*Warning, Alert, Status Update, Maintenance, Event, Command, Schedule}*.(*Figure 4)*

The **device_energy_log** table maintains a log of the daily energy consumption of all devices, along with a count of the number of hours they are active/inactive. (*Figure 5)*

Finally, the dummy data used to populate the database was generated through ChatGPT and was scrutinised to ensure that it was as realistic as possible so that initial phase of development and data analysis can be performed.

Stored Programs

To fulfil the central role of monitoring energy consumption, a daily log of device consumption must be recorded. This process should occur automatically at intervals set by the owner.

To achieve this, three stored programs were created:
1. DailyUpdateDeviceEnergyLogs (Event)
2. UpdateDeviceEnergyLogs (Stored Procedure)
3. CalculateDeviceEnergyConsumption (Stored Procedure)

The stored procedure **CalculateDeviceEnergyConsumption** computes the daily energy consumption for a given device, requiring the **device_id** and the number of active and inactive hours.

The **UpdateDeviceEnergyLogs** stored procedure inserts a new **device_energy_log** record by iterating over the **device** table and invoking **CalculateDeviceEnergyConsumption** for each device.

The **DailyUpdateDeviceEnergyLogs** event is scheduled to trigger at midnight daily, executing the **UpdateDeviceEnergyLogs** procedure.

JDBC GUI

Three features were developed in the GUI. (Figure 6)
1. Viewing Tables in the Database
2. Table CRUD {Create, Read, Update, Delete}
3. Querying and Exporting Table data

A **JComboBox**<String> was employed with an action listener to facilitate table selection and navigation. Upon every selection, the table name is passed as an argument to the **TableModel.refreshDB**() method.

Implementing the Table CRUD functionality was more complex, as the fields needed to adjust based on the selected table dynamically. Utilising the factory design pattern, the table classes created and implemented an interface named **TableCrudOperations**. Before refreshing the table, the field panel is repainted, thus updating the CRUD fields to correspond with the selected table. The various table CRUD operations were executed through polymorphism. All fields, except for Text/VarChar, were safeguarded using Java classes such as **NumberFormat**, **JXDatePicker**, etc.

Table querying and exports were facilitated by creating an interface named **ExportCSV**, which was then implemented by all table classes and the main class.

Conclusion

The developed Central Hub program has several limitations, such as the absence of a comprehensive device operating history—currently, only the last period of activity is recorded. The granularity of energy readings could be further refined. Additional reference tables could be utilised to ensure data consistency. The GUI could be enhanced with better error feedback and incorporating data analysis and visualisation within the program rather than solely exporting the data.

In summary, although the developed Central Hub meets its design objectives, it should be considered in the initial development phase and has significant room for improvement.

References

[1]. "https://www.bordgaisenergy.ie/home/smart-home-guide"
[2]. "https://vertabelo.com/blog/the-smart-home-data-model/"
[3]. "https://www.researchgate.net/publication/323121920_The_Future_of_Internet_IPv6_Fulfilling_the_Routing_Needs_in_Internet_of_Things"

Figures

Figure 1:

Table Content

device_i...	device_t...	device_n...	device_d...	device_r...	device_c...	device_d...	device_s...	device_s...	device_s...	device_e...	device_a...	device_s...	device_r...
1	1	Nest The...	Regulate...	30	WiFi	100Mbit	WPA2	v5.3	No Storage	A+	1.2	0.2	2023-11...
2	2	Philips H...	Controls l...	10	ZigBee	250Kbit	None	v2.1	No Storage	A	0.01	0.001	2023-11...
3	3	Dyson Air...	Monitors ...	50	WiFi	100Mbit	WPA2	v1.7	128GB	A++	0.5	0.3	2023-11...
4	4	LG Smart...	Smart air...	100	WiFi	1Gbit	WPA3	v3.0	No Storage	A++	2.5	1.0	2023-11...
5	5	Dyson Pu...	Smart fan...	30	WiFi	100Mbit	WPA2	v4.2	No Storage	A+	0.045	0.02	2023-11...
6	6	Nest Cam...	Outdoor ...	25	WiFi	100Mbit	WPA2	v3.2	No Storage	A	0.3	0.1	2023-11...
7	7	Ring Vide...	Monitors ...	30	WiFi	1Gbit	WPA2	v2.5	No Storage	A++	0.15	0.03	2023-11...
8	8	August S...	Secures t...	10	Bluetooth	1Mbit	AES256	v4.1	No Storage	A+	0.2	0.05	2023-11...
9	9	Lutron Se...	Automate...	20	ZigBee	250Kbit	None	v1.8	No Storage	A	0.075	0.02	2023-11...
10	10	Samsung ...	Smart fri...	50	WiFi	1Gbit	WPA2	v6.0	1TB	A++	1.8	0.9	2023-11...
11	11	Bosch Ho...	Smart co...	50	WiFi	1Gbit	WPA2	v3.7	512GB	A+	3.5	1.5	2023-11...
12	12	Nespress...	Connecte...	10	Bluetooth	1Mbit	None	v2.2	No Storage	A++	0.25	0.1	2023-11...
13	13	LG Twin ...	Smart wa...	30	WiFi	100Mbit	WPA2	v5.0	No Storage	A	2.0	1.0	2023-11...
14	14	Sony Brav...	Smart tel...	50	WiFi	1Gbit	WPA2	v7.3	2TB	A++	0.3	0.1	2023-11...
15	15	Sonos Be...	Smart co...	40	WiFi	1Gbit	WPA2	v2.4	No Storage	A	0.5	0.15	2023-11...
16	16	Amazon ...	Voice con...	20	WiFi	100Mbit	WPA2	v4.0	4GB	A	0.4	0.1	2023-11...
17	17	Rachio S...	Controls ...	100	WiFi	100Mbit	WPA2	v3.9	No Storage	A+	0.2	0.05	2023-11...

device_info Table

Figure 2:

Table Content

device_type_id	device_type_category	device_type_name
1	Thermostats	Smart Thermostat
2	Lighting	Smart Light Switch
3	Environmental Sensors	Air Quality Monitor
4	Climate Control	Smart Air Conditioner
5	Climate Control	Smart Fan
6	Security	Smart Camera
7	Security	Smart Doorbell
8	Security	Smart Lock
9	Security	Smart Blind
10	Appliances	Smart Refrigerator
11	Appliances	Smart Oven
12	Appliances	Smart Coffee Maker
13	Appliances	Smart Washer & Dryer
14	Entertainment	Smart TV
15	Entertainment	Smart SoundBar
16	Entertainment	Smart Speaker
17	Irrigation and Gardening	Smart Sprinkler System

device_type Table

Figure 3:

Table Content

device_id	device_info_id	device_location	device_parameters	is_active	active_from	active_to
1	1	Living Room	Temperature set to 2...	1	2023-11-01 08:00:...	2023-11-01 20:00:...
2	2	Kitchen	Brightness level: 70%	0		
3	2	Hallway	Brightness level: 60%	1	2023-11-02 18:00:...	2023-11-02 23:00:...
4	3	Master Bedroom	PM2.5 level: 12 µg/m³	1	2023-11-01 09:00:...	2023-11-01 17:00:...
5	3	Bathroom	Humidity level: 40%	1	2023-11-02 08:00:...	2023-11-02 08:30:...
6	4	Office Room	Cooling to 24°C	1	2023-11-01 09:30:...	2023-11-01 17:30:...
7	4	Bedroom	AC set to 22°C for ni...	0		
8	5	Living Room	Fan speed: Medium	0		
9	5	Dining Room	Fan speed: High duri...	1	2023-11-02 20:00:...	2023-11-02 22:00:...
10	6	Front Yard	Camera mode: Survei...	1	2023-11-01 00:00:...	2023-11-01 23:59:...
11	6	Backyard	Camera mode: Dayti...	0		
12	7	Main Door	Doorbell ring volume:...	1	2023-11-01 07:00:...	2023-11-01 19:00:...
13	8	Back Door	Lock status: Engaged	1	2023-11-01 23:00:...	2023-11-02 07:00:...
14	8	Main Entrance	Lock status: Auto-loc...	1	2023-11-02 22:00:...	2023-11-03 06:00:...
15	9	Bedroom Window	Blinds position: Half-...	0		
16	9	Living Room	Blinds schedule: Ope...	1	2023-11-02 06:30:...	2023-11-02 18:00:...
17	10	Kitchen	Temperature: 3°C, Ic...	1	2023-11-01 10:00:...	2023-11-01 22:00:...

device Table

Figure 4:

Table Content

device_msg_id	device_msg_type	device_id	device_msg	createdOn	is_read
1	Status Update	1	Temperature reached se...	2023-11-01 08:30:00	1
2	Status Update	2	Kitchen lights turned off	2023-11-01 22:00:00	1
3	Status Update	2	Hallway lights turned on t...	2023-11-02 18:00:00	0
4	Warning	3	PM2.5 level in Master Be...	2023-11-01 15:00:00	1
5	Status Update	3	Bathroom humidity return...	2023-11-02 09:00:00	1
6	Status Update	4	Office Room AC reached ...	2023-11-01 10:00:00	1
7	Schedule	4	Bedroom AC scheduled t...	2023-11-01 21:00:00	0
8	Status Update	5	Living Room fan turned off	2023-11-01 23:00:00	1
9	Status Update	5	Dining Room fan set to hi...	2023-11-02 20:00:00	0
10	Alert	6	Motion detected in Front ...	2023-11-01 01:30:00	1
11	Status Update	6	Backyard camera turned ...	2023-11-01 20:00:00	1
12	Event	7	Doorbell rung at Main Door	2023-11-01 12:45:00	1
13	Status Update	8	Back Door locked	2023-11-01 23:01:00	1
14	Status Update	8	Main Entrance auto-lock ...	2023-11-02 22:00:00	0
15	Command	9	Bedroom Window blinds ...	2023-11-02 08:00:00	1
16	Schedule	9	Living Room blinds open...	2023-11-02 06:30:00	0
17	Status Update	10	Fridge temperature set t...	2023-11-01 10:15:00	1

device_msg_log

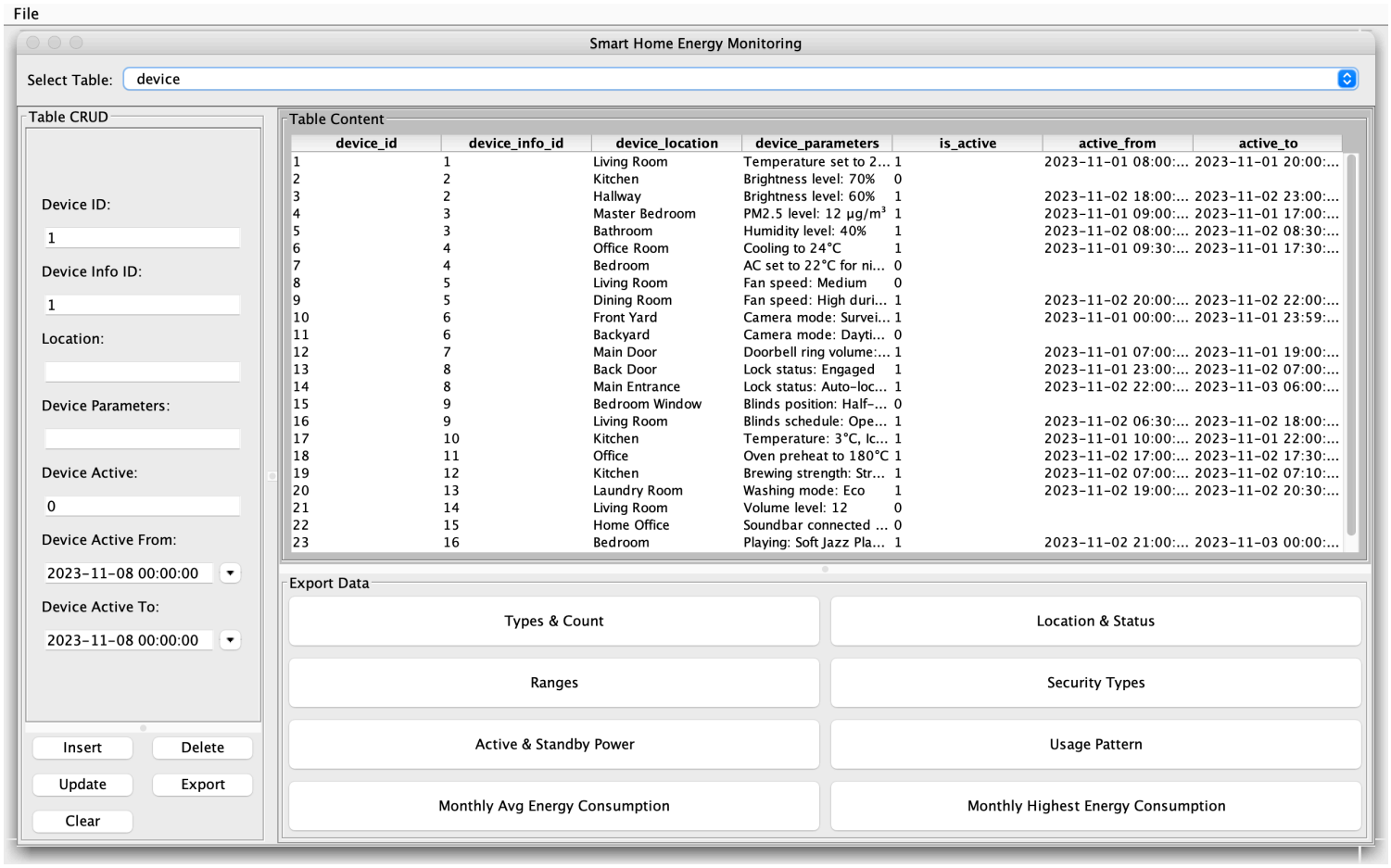
Figure 5:

Table Content

device_log_id	device_log_date	device_id	hours_active	hours_inactive	energy_consumed
1	2023-11-06	1	12.0	12.0	16.8
2	2023-11-06	2	0.0	24.0	0.024
3	2023-11-06	3	5.0	19.0	0.069
4	2023-11-06	4	8.0	16.0	8.8
5	2023-11-06	5	0.0	24.0	7.2
6	2023-11-06	6	8.0	16.0	36.0
7	2023-11-06	7	0.0	24.0	24.0
8	2023-11-06	8	0.0	24.0	0.48
9	2023-11-06	9	2.0	22.0	0.53
10	2023-11-06	10	23.0	1.0	7.0
11	2023-11-06	11	0.0	24.0	2.4
12	2023-11-06	12	12.0	12.0	2.16
13	2023-11-06	13	8.0	16.0	2.4
14	2023-11-06	14	8.0	16.0	2.4
15	2023-11-06	15	0.0	24.0	0.48
16	2023-11-06	16	11.0	13.0	1.085
17	2023-11-06	17	12.0	12.0	32.4

device_energy_log

Figure 6:



JDBC GUI