Evaluation Study on Smart Home Appliances and Voltage Consumption Patterns

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***Abstract*—In the most recent decade, smart home technologies have been the center of focus for the development of networking protocols to transport data regarding power consumption from the consumer to the producer. Although many smart homes can dispense useful information, such as data usage, to the consumer, many smart homes lack the ability to predict patterns in power consumption and report that information to the producer's command center so that the adequate and optimal amount of energy shall be dispense to each consumer and household. The goal of this paper is to examine a predictive smart appliance protocol that can predict and simulate a cloud of smart homes operating in a 24-hour environment with voltage consumption as the output data based on type of appliance, household, and neighborhood.**

I. INTRODUCTION

The development of wireless technologies in recent years has led to the dramatic increase in wireless networking protocols that transfer information from the producer and the consumer and vice versa. A specific application of wireless technologies is the ability for the consumer and the producer to control smart home appliances. Theoretically speaking, smart home appliances allow users to interact with the electronics with minimal communication occurring. Sometimes it is beneficial as it easies effort on both the consumer and the producer's side to maintain the quality of service. However, the technology could provide overhead in terms of letting the user and the energy company know the optimal voltage consumption that would benefit both the user and the energy company in terms of supply and demand.

The predictive simulation protocol discussed in this paper primarily examines the voltage consumption pattern in terms of mathematical function, such as linear, power, and exponential, to simulate an environment where multiple cluster of energy-consuming neighborhood compete for voltage available distributed by the command center, simulated as the cluster, in the simulation protocol. The simulation protocol shall be able to predict the pattern of voltage consumption through mathematical relationships given the initial voltage consumption per hour for the specific type of appliance, household, and neighborhood. The voltage consumption pattern can be used by researchers to adequately provide the optimal voltage to each household within each neighborhood based on demand.

II. SMART APPLIANCE SIMULATION PROTOCOL

The simulation protocol, given initial voltage input, randomly generated for each smart appliance, will simulate a smart cloud environment consist of different neighborhoods controlled by a command center cluster. Within each neighborhood, the simulation protocol will randomly select popular mathematical functions such as linear, power of two, and exponential for each household within the neighborhood. The mathematical functions are based on the amount of voltage consumed over time. The mathematical function is assigned to each household based on the patterns regarding day-focused, night-focused, or 24-hour consumers within the household. The simulation protocol will automatically assign linear relationship for the 24-hour consumers, power of two relationship for night-focused consumers, and exponential relationship for day-focused consumers given the assumption that night-focused consumers spends more money on energy than day-focused consumers, and day-focused consumers spends more money on energy than 24-hour household consumers.

A. Smart Appliance Simulation

The smart appliance simulation sub-protocol combines some dumb device or common household electronics such as refrigerators, air conditioner, or light bulbs with a wireless control line that is directly connected to the control-center of the smart home. The control-center of the smart home will directly transmit randomized values to the smart appliances if the control line between the smart appliances and the smart home control center is available. The smart appliances will communicate with the smart home control center with the latest information regarding the amount of voltage consumed by the device.

B. Smart Home Simulation

The smart home simulation sub-protocol utilizes a random generator to randomly assign mathematical patterns based on the type of home in question whether it is day-based, night-based, or 24-hour. The protocol then randomly assigns voltage values to the appliances directly connected through the control line. The protocol will then output data sets generated based on the mathematical functions. Additionally, it will calculate the total amount of voltage consumed by the household and then forward that information to the neighborhood control center so that the adequate amount of power can be assigned.

C. Smart Neighborhood Simulation

The neighborhood simulation mechanism collects voltage data from the house holds that is directly connected to its control center through multiple control lines wirelessly. Based on the voltage data, the neighborhood simulation protocol will reassign and readjust the type of households based on a random number generator to simulate real-life scenarios where the neighborhood control center distributes voltages throughout the household in the neighborhood.

D. Smart Cluster Simulation

The cluster simulation mechanism will randomly assign voltage available and the number of neighborhoods economically based on whether the neighborhood is median income, upper income, or metropolitan district. Observe that the low-income families are excluded under the assumption that low income families would not be able to afford a smart home and smart appliances. Also note the assumption that income is directly associated with the amount of voltage consumed in a neighborhood. In other words, the higher the income, the more voltage a neighborhood consumes.

III. NOVEL CONTRIBUTION

For this simulation project, a variety of novel contribution is utilized to build the functionalities of the protocol:

A. Randomization Algorithm

To make the scenarios of voltage consumption as realistic as possible, a random number generation mechanism is utilized to assign the initial voltage consumption from top to bottom (from a cloud to individual appliances in a smart home) and the number of appliances in a home, the number of homes in a neighborhood, and the number of neighborhood in a cluster.

B. Mathematical Functions

To make the scenarios of voltage consumption even more realistic, mathematical functions of linear, power of two, and exponential to generate data sets instead of relying on traditional constant functions to simulate a household environment.

IV. ERROR HANDLING MECHANISMS

A. Control Line

The control lines variables are implemented throughout each layer of the cloud environment to ensure that when irregular mathematical patterns occur within the lower layers that can consume all the voltage at the current, the current layer can respond by simply setting the control line to false so that the voltage availability is preserved at the current layer.

B. Voltage Consumptions Exceeds Voltage Available

When dealing with an enormous number generated by the randomizing protocol, the neighborhood simulation sub-protocol will respond by only allowing that specific household to consume a certain amount of voltage before shutting it down so that the voltage consumption will not reach to the non-ideal bound set by the random number generator. Additionally, the mechanism will echo the handling of the household to its upper layers so that the quality of service is preserved.

V. ANALYSIS OF RESULTS

Result is obtained after the experiments have been conducted. The aim of this paper is to present the evaluation performance of each mathematical pattern with respect to time in hours. The performance of the mathematical functions simulated is evaluated based on the idealization of the time-bounds, start and finish, set by the random number generator and the idealization of the voltage consumption increase given the initial voltage consumption provided by the random number generator.

A. Linear Function Consumption Pattern

Figure 1 shows the data set of a 24-hour home with its initial voltage generated randomly. The mathematical pattern here is clear linear as the voltage consumption of the hour increase gradually by increments of a random number generated between the previous two voltage consumption. In other words, the mathematical relationship is more like the Fibonacci sequence. From a researcher's perspective, the relationship is ideal given that the upper bound of the data set is not set to an enormous number and the increments of increase is ideal since most 24-hour homes consumes more voltage as the day goes on.

```
Hometype: 24hourHome


0.36
12.72
37.08
61.44
89.8
118.16
154.52
198.88
243.24
287.6
331.96002
388.32004
448.68005
513.0401
585.4001
657.7601
730.12006
802.48004
874.84
951.2
1027.56
1111.92
1200.28
1288.64
```

Figure 1. Energy Consumption data set for a 24-hour home

B. Exponential Function Consumption Pattern

Figure 2 shows the data set of a day-focused home with its initial voltage generated randomly. The mathematical pattern here is clear exponential as the voltage consumption of the hour increase gradually by increments of square of the initial voltage in addition to the current hour plus a random number generated between the initial voltage consumed and the current voltage. In addition, note that the time bounds for the mathematical function dictates when the exponential increase occurs. This scenario is idealistic and realistic in the sense that most day homes gradually decreases their power consumption as the time of the day goes. From the data set, it is clearly visible that the function returns to constant later in the day.

```
Hometype: DayHome


0.0
0.0
0.0
0.0
0.36
4.7200003
73.08
465.44
1881.8
5798.16
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
14898.5205
```

Figure 2. Energy consumption data set for a day-focused home

C. Power Function Consumption Pattern

Figure 3 shows the data set of a night-focused home with its initial voltage generated randomly. The mathematical pattern here is clear a power of two as the voltage consumption of the hour increase gradually by increments of the power of the initial voltage to two in addition to the current hour plus a random number generated between the initial voltage consumed and the current voltage. In addition, note that the time bounds for the mathematical function dictates when the increase occurs. This scenario is idealistic and realistic in the sense that most night-focused homes dramatically increases their power consumption as the time of the day goes. From the data set, it is clearly visible that the function is constant earlier in the day before the power of two increase occurs during the middle of the day.

```
Hometype: NightHome


0.0
8.360001
32.72
121.08
1233.44
264489.8
1.71803976E10
7.3786976E19
7.3786976E19
7.3786976E19
7.3786976E19
7.3786976E19
7.3786976E19
7.3786976E19
7.3786976E19
7.3786976E19
7.3786976E19
7.3786976E19
7.3786976E19
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7.3786976E19
7.3786976E19
```

Figure 3. Energy consumption data set for a night-focused home

D. Constant Function Consumption Pattern

Figure 4 shows the data set of a 24-hour home with its initial voltage generated randomly. The mathematical pattern here is obviously constant since the amount of voltage consumed does not change with respect to time. This scenario simulated here is also realistic in the sense that most unoccupied homes does not consumed any voltage during the day. Additionally, the random number generator successfully generated a non-random number zero to indicate that constant mathematical functions only occurs when the household is unoccupied.

```
Hometype: DayHome


0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
```

Figure 4. Energy Consumption data set for a day time home

VI. CONCLUSION

In this paper, analysis and investigations were carried out algorithmically through simulating the voltage consumption of two smart clouds of neighborhoods that's consist of mainly smart homes during a day. The simulation protocol demonstrates the primary mathematical patterns of voltage usage and generates data sets that are useful to the producer to obtain the optimal voltage assignment based on supply and demand.

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