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Electricity Smart Meters Based on Wireless Networks in Saudi Arabia

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Abstract Electricity Smart Meter provides a great service for managing an electricity bills system. One of the main issues in Saudi's electricity company is extensive distance and difficult terrains. This study aims to reduce the wasted time in reading of electricity consumption as manually, and to manage the service provided by using wireless networks topology. The proposed smart meter system contains a description and explanation for its design, type of wireless connectivity, and a service provider center. This study has been shown that smart meter can be implemented with the least possible hardware required consisting of a Sim-card, which is capable of sending signals to an access point, and routing the information to the centralized system.

Keywords: *smart meter, wireless, networks, topology, Sim-card, 4G/LTE*

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1. Introduction

It is seen that lot of time and effort is required to produce an electricity bills and distribute them as per the addresses. In Saudi Arabia, the locations and addresses are quite difficult to trace, and specifically at remote areas. Therefore, there is a need to reduce the burden of printing, cost calculation, cost estimation, billing, bill printing, build distribution, bill reading process, electric's service connection/disconnection process, and bills collection process. In Saudi Arabia, one of the main issues is measurement of electricity units and billing process. Smart meters have been accepted worldwide, and they are very easy to operate and install. Consumers can use an application to pay the bill online on the click of certain events so that all the aforesaid obstacles can be resolved and minimized. Various communication technologies are required for this purpose which includes: power line carrier (PLC), broadband over power lines (BPL), optical fiber networks(OFN), cellular technology(GSM/3G/4G), Gen packet radio service(GPRS), Internet, satellites, P2P, ZigBee etc. The use of any of the above communication techniques can be done to send the packets from one position to another [1].

In the idea proposed the use of mobile Sim cards can be done to send the information from the smart meters to the access point/mobile towers. As per Kim and Kwon the communication over power line can result in various problems regarding the security of the information and the threats that can arise for the same [2]. A secure smart metering protocol to avoid any kind of problems over power line communication channel [2].

A data communication system comprises of server, plurality of smart meters, and an access point coupled to the server. Whereas, the server sends commands to the coordinator via a control register, and the control register is utilized to coordinate activities of the plurality of smart meters. The coordinator includes a data register system which comprises a pair of registers configured, such that performance of data transfer is enhanced by eliminating the chance of collision when both read and write operations are accessing a same register.

Wherein, the local server places each of the plurality of smart meters in a calibration mode. A calibration voltage is applied across a resistor connected as a load in a power line of each of the plurality of smart meters. A voltage scaling factor is calculated by dividing a calibration voltage root-mean-square value by a measured average voltage root-mean-square of N-samples [3]. A current scaling factor is calculated by dividing calibration current root-mean-square by a measured average current root-mean-square of N-samples [3], and an effective time period is calculated by dividing a calibration energy value measured in a time period by a measured power and a number of samples in the time period [4].

A high capacity cellular mobile communication system arranged to establish, and maintain continuity of communication paths. Mobile stations passing from the coverage of one radio transmitter into the coverage of another radio transmitter [5]. A control center determines mobile station locations, and enables a switching center to control dual access trunk circuitry, and to transfer an existing mobile station communication path from a formerly occupied cell to a new cell location [6]. The switching center subsequently enables the dual access trunk to release the call connection to the formerly occupied cell [5].

The radio frequency system that was proposed contains a series of schematic diagrams that can be helpful to give the complete introduction about a high capacity cellular mobile communication system, the data which is in an

existing unit can be combined, and sent to the terminal station from where the radio frequencies are sent to the main server system[5]. The same technology can be used based on GSM/ 3G/ 4G/LTE etc. 4G wireless routing can be is used to send signals from a simulcast integrated inside the smart meters to the centralized server with the help of any of network model[7].

Recording of the consumable units into the 4G enabled Sim card that is attached to the smart meter using a Digital Meter. The smart meter is programmed when installed; or soon after; to send meter readings automatically. A typical communication with a smart meter will contain the total meter reading, and a half-hourly profile of energy consumption or generation for the previous day [8]. The half-hour profile gives a graphical display of the energy user's consumption or generation [9]. This information is quite invaluable for analyzing energy usage, and enables businesses to change their practices to reduce energy costs and carbon emissions. This would not be possible without accurate, and frequent data from the utility meter to monitor how a building uses energy, and the impact of changes aimed at reducing that consumption [9].

The ESN is a permanent part of the phone [10]. Whereas, the MIM and society are temporarily, and can be activated or deactivated as per the requirement [9,10]. Whenever, a person tries to use the mobile phone service, the help of the digital network on the mobile phone price to control the channel with the help of SIT the spatial frequency between the phone and the base station. This frequency changes from various mobile service providers, and as ID unit is given to a mobile phone which is under the registered unit of any mobile phone network[9]. The phone transmits registration request to the society, and it tracks the phone's location in the database of the network. The Mobile Transfer Agent (MTA) communicates with the mobile phone with the control channel [11], which is frequently used. The bases station in the cellphone is quite similar [12]. In which, the phone is going, and will be able to see the telephone signal strength increasing. The mobile gets the signals from a control channel which is stronger the switched channel [13].

The same circuit that is available in the smart phone, is actually trying to cover all the frequencies, and connections which is connected with one of the cell units in a mobile phone system network [14]. Whenever, the Sim card connects to the network online, and it tries to send the information to the unit, which is responsible for storing the data obtained by the Sim card, and which is sent via wireless medium using the help of any mobile phone network service provider unit [9].

Wireless metering can enable the user as well as the utility, to obtain that necessary control by providing real time data reading, and by facilitating command and control [15]. Smart power meter based on ZigBee communication has been proposed in for the Advanced Metering Infrastructure (AMI) of smart grid [16]. The system of advanced metering infrastructure will be helpful, to provide the information from the smart meter to the nearest tower of the mobile services, that can be used to round the information into the nearest terminal station for processing, and billing queries [17]. The information that will be sent to the processing station shall be redirected from the station into the database of the administration, and any simple push event can be triggered to supply the necessary information on the mobile application of a consumer.

An information which is sent from the Sim card, should be available in the same slot of the smart meter, and will be stored in the database of the system, which is available in the nearest network unit terminal [16]. An information could be redirected towards the main database unit provider, which can be any kind of server is available at a nearest network unit. The recording of information can be done with the help of sophisticated database controller by Oracle, or any other organization that maintains the data warehouse, or data mart for the information that is sent via network, which gets data collection automatically, into a main database network of an organization responsible for taking care of the maintenance of the system as a whole [18]. In this study, the architecture details of the outing mechanism varies from router to router [19], and the protocol which is used by the router that can be replied automatically, to send the data packets in the network, and collect data from smart meter to the server.The frequency division multiple access, and code division multiple access are developed protocols, which are used to distinguish signals from one source to another source using transmitters [20]. The main principle of data transfer in these cells is the complex, and distributed trans receiver mechanism, which takes place by polarization division multiple access, and time division multiple access from the domain of digital signal processing [16]. Generation of bills depending on the information received from the intermediate tower by an administration unit. An administrative office can take the help of automated services; like SMS system, or an e-mail; to send the readings available from a smart meter to a user. Once the bill has been paid by the customer, it becomes a necessity to make the record of all the information that is available at the server side. Sending the updates as a push event by the database onto the mobile, or mobile application. This event can be triggered at various intervals to notify the user about the consumption of the electrical units in his/her account.

2. Related Work

The economic use of electrical energy is very necessary. Therefore, the abruption of electricity must be avoided, and proper calculation of electricity consuming is required. Energy sources are limited, and should be a better use of energy to avoid misuse of electrical energy. One of a better option is to use a smart meter, which are different from the traditional electromechanical meters. Internet of things can be used for billing and consumption information with the help of a centralized server machine over the web [21].

The problem for maintaining the records, and managing a consumption of information to be sent to a website from the smart meter. However, the idea prescribed in the research use the channel to save data from the billing system after the collection from the smart meters. The structure of the Internet of things was well used for obtaining the results and calculating the averages of the billing cycles that will be used after the information has been sent from the machine to the server [16].

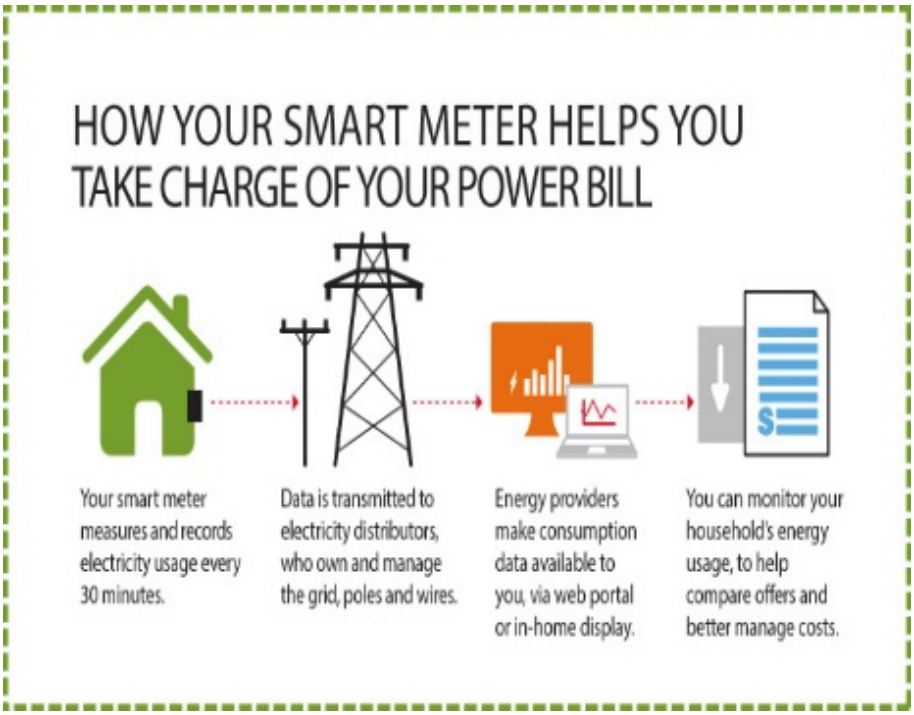

Figure 1. SMART METER LIFECYCLE [17]

The statistics in the pastimes given information that across the whole world a lot of changes have occurred with the revolution in the smart meter market. Some statistics have been collected over the same across various parts of the global players in smart meter manufacturing units, and the results are as follow:

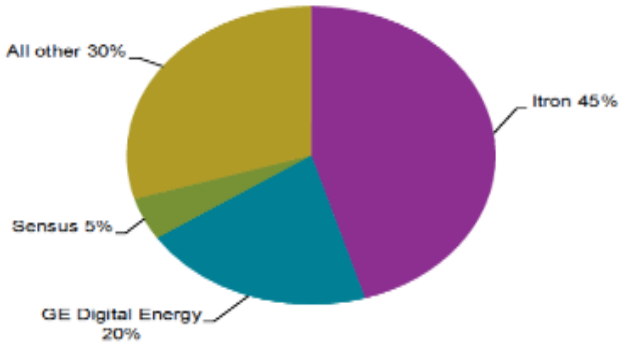

Figure 2. U.S. Smart Meter Market Share, 2012[22]

The United States of America smart market meter share for the year 2012 is depicted up, and it reveals that a major portion of the United States was trying to use the smart meters per consumables, and home products. Therefore, by looking at Figure 2, it can be well protected that a larger portion of United States was capturing the market with smart meters, and it went as high as 45%. The digital energy and other senses, including different options of energy was consuming 55% of the total market share. However, still the need for the smart meters was arising since 2012, and till date.

It is increasing as it can be seen from the statistics shared by Samadi study [22].

The import of smart meter in United States of America started in 2013 and 2014, and it is visible from the report that is submitted in US ITC (2014) report. According to the report, it is very clear that a larger portion of 59% share was said by Canada, and 89% percent by Mexico, which means that the consumption of smart meters has started up to a larger extent. Not only for the domestic purposes, but also for the imports. However, the smart meters that are imported will utilized up to a larger level.

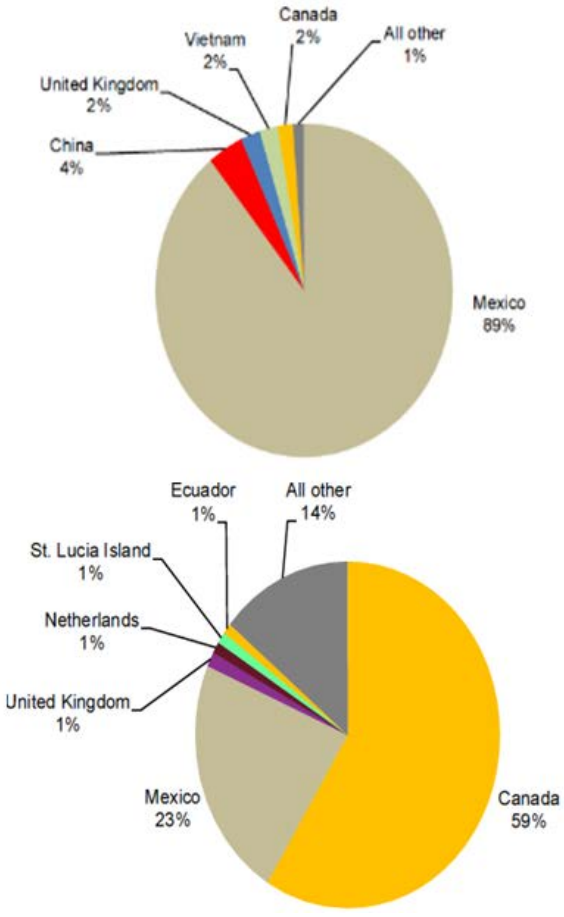

Figure 3. U.S. Smart Meter Imports 2013 and 2014 [23]

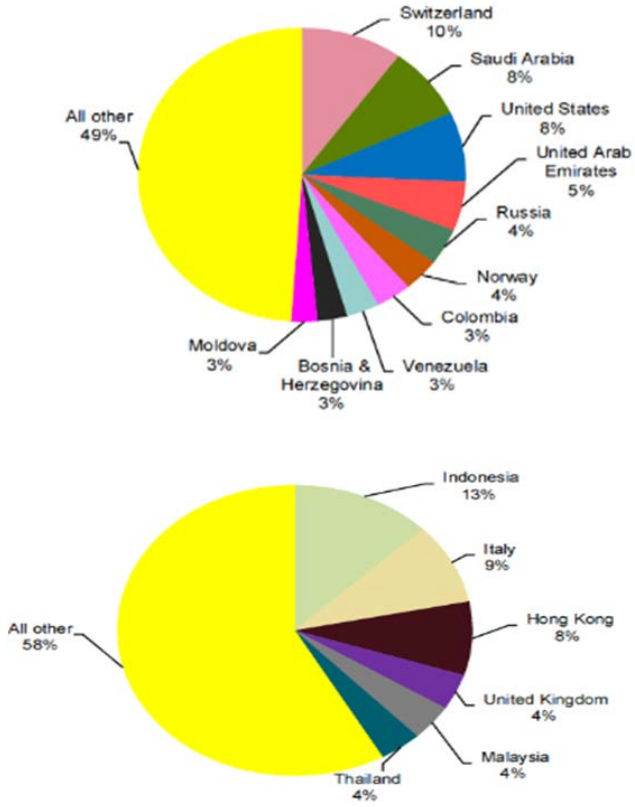

Figure 4. Share of European Export of Smart Meters [24] and China [24]

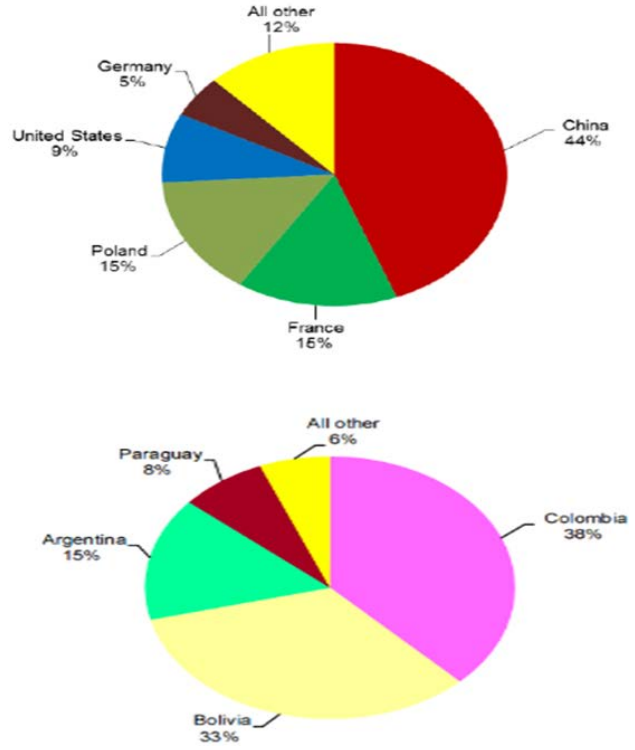

Figure 5. Share of America's Export [24] and Import of Smart Meters [24]

The European share of smart meters say that 49% of the share comes from different places, and a major contribution is given by Switzerland, United States, United Arab Emirates, Russia, Norway, Columbia, Venezuela, Moldova, and many more. The European markets have sold and exported a huge number of smart meters to various parts of the world, which indicates that the utility of smart meter mechanism is immense importance for the humanity. As far as digital electronics are concerned, China had been a long-term player, and a large number of sports from China have been observed in the year 2014 pitches were directed by the [24].

Statistics of the import and export of American smart meters were seen in the report given by GTIS [24]. In GTIS report (2014) indicated that both the export and import have drastically increased from initial level to a large level across the world, and the requirement for the smart meters is increasing.

3. Smart Meter Model

Smart Meter Model is a proposed model to be useful in Saudi's terrains for electricity. The smart electricity meter is based on wireless networks. It can be installed, and utilized in the locality. Therefore, it provides ease of billing and reduce manual labor to automated technical systems. The proposed Smart Meter Model connects smart electricity meters with the wireless access point/mobile tower. An electricity provider will be find it easy way in order to view customers' details of electric bill and their consumption. The smart meter should communicate with a centralized server unit, which is in electricity provider center, via access point to analyze and receive the updates, and required information.

It will communicate with service providers to send information from the meter, and send server in the desired operational response method. Secure and reliable transfer of data can be done. The system should elect the data from the meter authorized, and then send the data to the nearby station. So that it can be further sent to a centralized database server. The billing information can be generated and can be sent on the mobile application of the consumer or by email automatically during a specified period of time. The proposed system can be developed with various points in consideration, including the design for Smart Meter, access point which is mobile tower, server, and data base.

The entire system can be shown in picture-based format using the flowchart in Figure 1. The smart meter which is available at the consumer house will send the data to a service provider. This data will reach the access point using wireless topology. If the data is not reached properly, a recent request will be given to the access point and the data will be again sent for further processing. From the access point, the data is further redirected to a server system that checks the integrity of the data using a firewall. In case of any virus detected the data shall be sent to quarantine. However, if there is no any virus, or confused data then the data will be stored in the database. The database will hold all information, and a backup server will be available for application of the information for future references. The billing system server will communicate to generate the bills, and send it to the consumer. The submission of the bill will be done automatically, and it will reduce the manual labor for reading, connecting, or disconnecting the service, and to reduce the cost of processing.

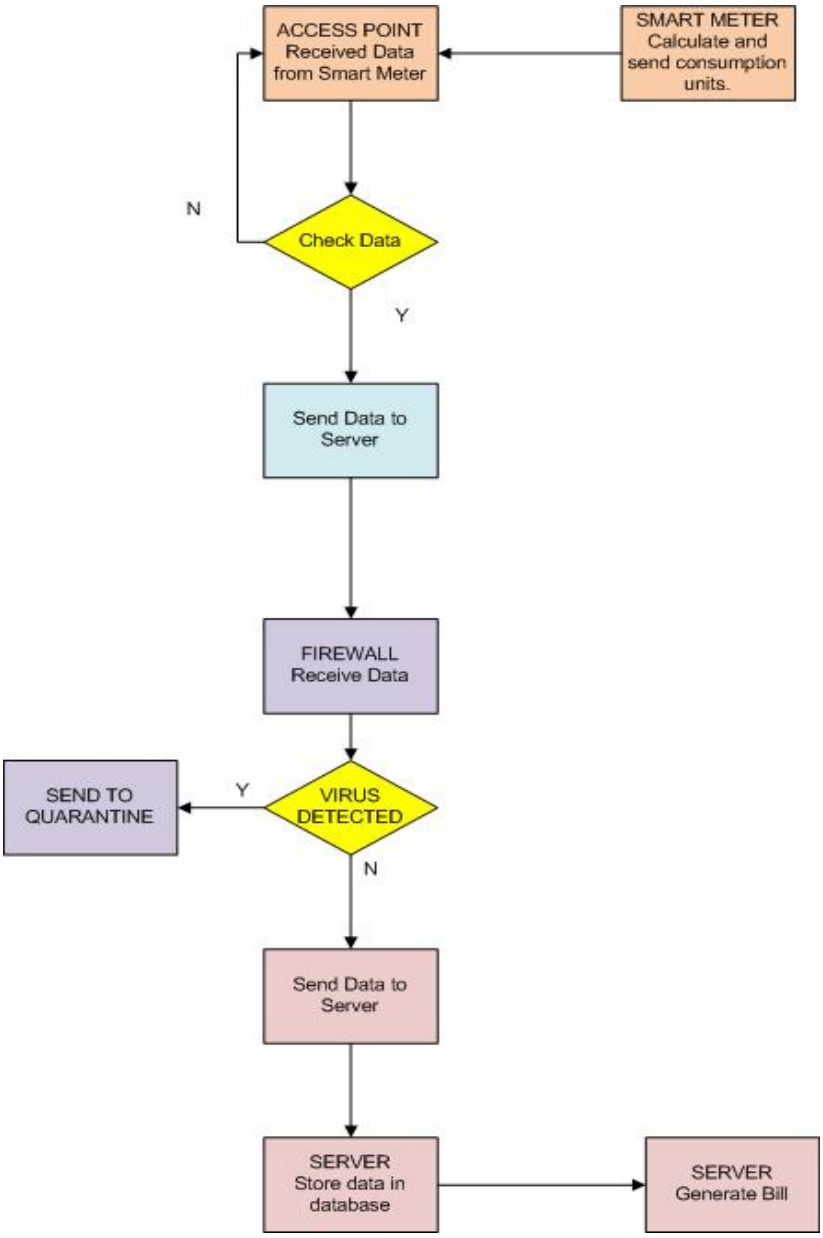

Figure 6. Flowchart for Proposed System

3.1. Smart Meter Design

The smart meter model contains three important elements in its design. The most important is the design of the smart meter which will be integrated at the consumer house. The design of the smart meter contains a Sim card, meter for reading electrical units and converting the units from analog to digital format, and a processing unit.

- Sim Card Circuit: a small Sim card circuit can be used to integrate with the smart meter, which will be helping to send the information from the smart meter to the access point using the wireless networks technology. The consumption units for the consumer house can be calculated using traditional mechanism. The data collected after the calculation should be changed to from analog to digital format. Once the data will be converted the Sim card will be able to send the data to the main center via access point.
- Metering / Reading Circuit: the metering system of the smart meter will be capable to read the number of units of electricity consumed by the customer. After reading the complete number of units, this circuit will convert the analog reading to the digital reading. The complete digital reading should be sent to a processing unit that can be a Micro controller, to convert the data into the prescribed format. Once the data is made ready by the processing unit, metering circuit can send the information to the final processing unit.
- Processing Unit: this circuit will be taking the input from the metering circuit. Once the information about the usage is received, the processing unit will try to change the format of the data that is compatible with the wireless topology. The creation of data packet and the addition of information required by the access point will be done by the processing unit. Finally, after the complete data packet is created, this circuit will send the information to the access point by using wireless topology.

```
Step 1:   Set value of Reading as 0
Step 2:   Calculate( )
Step 3:   While data received from ElectroMechanicalReader  do
Step 4:   Get the value of StartReading and EndReading
Step 5:   Set the value of Consumption to EndReading - StartReading
Step 6:   If ConsumptionMonth = 1 then
Step 7:   Set Consumption to Billed
Step 8:   Else
Step 9:   Calculate( )
Step 10: Set the value of Billed = Consumption
              End of While loop
Step 11: Calculate the Total Billed Amount = Consumption * Cost Per Unit
Step 12: Send BilledData to Access Point.
Step 13: Reset Consumption = 0 and Goto Step 1.
```

Figure 7. Pseudo Code for Smart Meter Model

Calculation for power consumption of the Smart Meter.

- Measuring of the power consumption units into the smart meter using a Micro Controller [25].
  Formula Used to obtain power consumption:

$$\text{Watts} * \text{Time Used} / 1000 = \text{kWh}. \quad (1)$$

- Measuring the Cost per unit consumption of energy:

$$\text{Total Electrical Cost} / \text{Total Electrical Consumption} = \text{Cost Per Unit}. \quad (2)$$

- Total Watt Energy Consumed by the appliances:

$$(3600 / \text{number of seconds}) * \text{kH} = \text{watts consumed}. \quad (3)$$

$$(3600 * \text{beats}) / \text{Seconds} * \text{kH} = \text{watts consumed (For Digital Smart Meters)}. \quad (4)$$

3.2. Access Point Design Based on Wireless Networks Topology

The traditional protocol stack is composed of the protocol modules TCP over IP over a link layer (e.g., Ethernet). Alternatively, RTP/UDP is sometimes used instead of TCP. The link layer (Ethernet) provides connectivity to other hosts in the same network segment, but not to hosts in different networks. The network layer, IP, uses the primitives from the link layer (sending and receiving frames to hosts) to deliver datagrams across multiple networks. Finally, the transport layer, TCP, uses the services provided by the network layer (sending and receiving datagrams) to provide a connection-oriented communication service, adding reordering, error recovery, flow control, and congestion control [26]. Therefore, 4G/LTE technology can be used to communicate between the smart meter and the access point.

The Wireless topology is suitable for the geographical situation of Saudi Arabia. A large part of the country is covered with wireless-based systems and network. Therefore, the selection of Wireless topology is done for sending data from the smart meter to the access point. The Wireless topology can be granted by the service provider but it should be fast in service. However, TCP and IP along with UDP are less used, and so any protocol which is fast and effective in nature can replace the communication between smart meter and the access point. It must be taken into consideration that security plays an important role for the sender and the receiver.

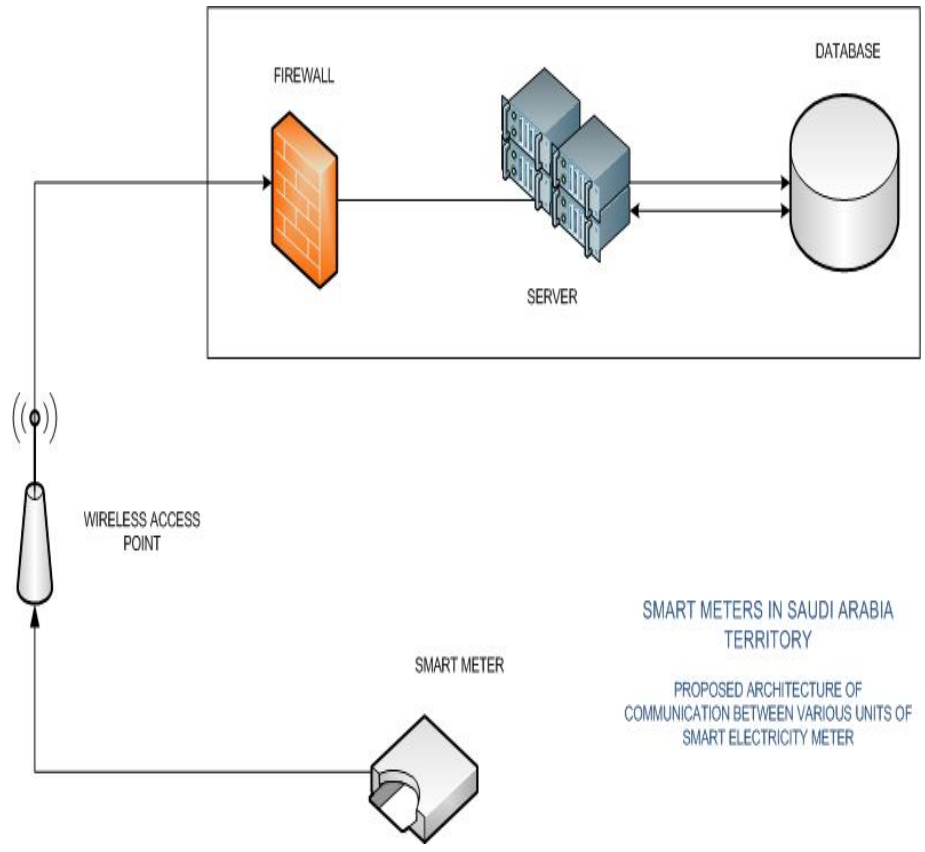

Figure 8. Proposed Architecture of Communication between various units of Smart Model

3.3. Data Processing Center

The data processing center will comprise of the processes that are required for handling the information received from wireless access point. It can be seen that the peak data that will be received by various access points need to be updated for processing and billing. Several components need to be designed for the data processing center.

3.3.1. The Proposed Model

The proposed model will contain two types of servers which are application server and billing server. Application server will be responsible for handling the data that is received from the wireless access point. This application server will not be accessible by a client fulfil any request. The billing server will use the database system and generate the bill required.

3.3.2. Firewall

Since the information received from the access point is critical and the billing will be done based on it, it is very necessary to save the information in a system which is secure. To ensure the safety of the data, firewall is required between the access point and the application server. This firewall will ensure the security of the system and will contain a complete range of tools to check virus, spam, malware, Trojans, malicious codes, and any harmful program for the system.

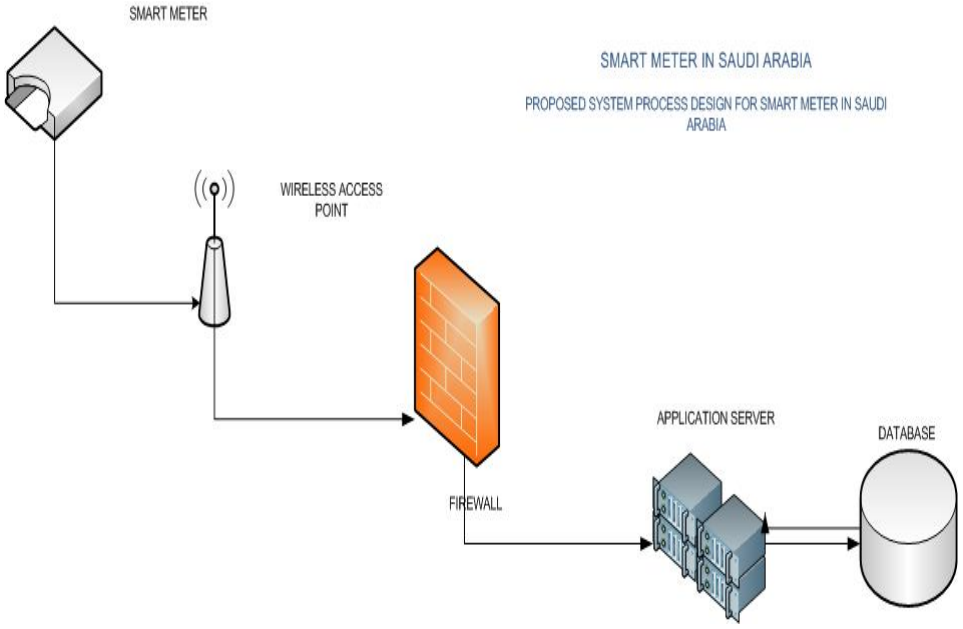

Figure 9. Proposed System Process Design for Smart Meter in Saudi Arabia

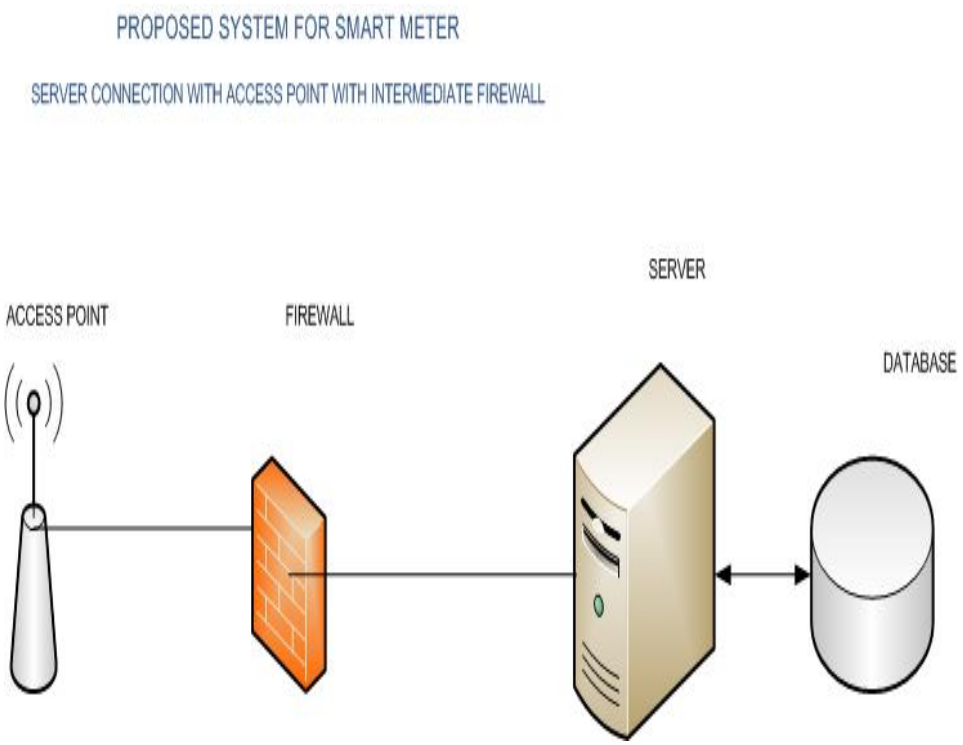

Figure 10. Server Connection with Access Point

3.3.3. Database System

The data that will be calculated, sent, and received by the application server using an intermediate application will be stored in the backend database system. This database system will be responsible for all many clinicians and calculations for billing enquiries. The database system will be able to communicate with the application server for retrieval of information. The application server will be receiving the information behind a firewall to ensure security of the system, and storage of information at the database system without any problems.

3.3.4. Billing System

THE billing server will be a small machine server that will be connected to the database unit. An intermediate application will run on the server which will fetch the data from the database only. It will not be able to update any content on the database system. The billing system will be responsible for sending the bills to the consumer. A firewall will be applicable between the consumer handheld device and the billing server to ensure that the information remains secure. The billing server will be able to send information via push notifications or email messages on automated basis.

4. Results and Discussion

The model proposed is indeed a great help for the humanity specifically in Saudi's geographical region. Whereas, a lot of problems can be resolved starting from the collection of electric energy consumption information till the dispatch of bills by the municipality of a city or country. The idea proposed in this study can be implemented with the least possible hardware required consisting of a Sim-card, which is capable of sending signals to an access point, and routing the information to the centralized system. A lot of models have been proposed in the past, however all the models were trying to utilize the electromechanical signals to transmit data information from the smart meters to the centralized billing system unit by using grids, which are connected underground. The proposed model is suitable for type of Saudi's topology, and it is not limited to only electromechanical signals, it is also trying to simplify the processes, submitting, and managing the bills by the consumer from a smartphone device. Furthermore, this model will increase the ROI for the electricity provider by reducing a manual reading to be automated reading. The idea that was proposed in the earlier times contains the sending of information from the smart meters to the intermediate hours was done with the help of electrical signals which may lead to various problems like signal-to-noise ratio, signal fading, loss of information, loss of data, incorrect information retrieval, mismatch of system bandwidth, delay in system retrieval, electromechanical signal loss, wear and tear loss, etc. all these problems were caused due to sending of electromechanical signals with the help of wires from the smart meter to the electricity tower and from the electricity tower to the centralized billing station. The communication over power lines can lead to all such problems [2]. The service stations can also lose the information which is sent from the smart meter to the substation and it can also provide problems. Use of wireless networks will be immensely helpful to provide the complete information with the help of a wireless medium in which there will be no loss of any information which will be sent from a consumer unit to the main administration station. Thus, in the proposed model all the problems are stated above can be minimized and removed completely with the use of one small LTE/4G enabled Sim-card. The recent worldwide measures for energy savings call for a larger awareness of the household energy consumption, given the relevant contribution of domestic load to the national energy balance. On the other hand, electricity smart meters together with gas, heat, and water meters can be interconnected in a large network offering a potential value to implement energy saving, and other energy-related services, as long as an efficient interface with the final user is implemented. Unfortunately, so far, the interface of such devices is mostly designed and addressed at the utilities supervising the system, giving them relevant advantages, while the communication with the household is often underestimated [27].

This study tries to overcome the problems with the help of wireless networks so that the communication can be done in the best way without any loss of information in the system. This communication can also result in acquiring better results to mine the characteristics of a particular consumer based on his past records. This will further help to predict results for a particular type of customer, a particular area, or a particular city. Therefore, the energy consumption by the particular domain selected can be obtained and further records, and observations can be concluded from the data which are collected.

5. Conclusion

This paper produced a proposed model for a smart meter based on wireless networks in Saudi Arabia. According to Saudi's terrains, the proposed model is having a high area of impact, and can be very useful for the Saudi Arabian requirements and its environment. Therefore, this paper presented a simple yet effective system that can be done with simple changes in the old design of the electrical meters. The design that is proposed allows the digitization of the manual system to save time, and human effort that is required at any instance. The diagrams, and comparative graphs prove that the need for change in the system is required, and it is need for the hour to update the existing traditional system. It is an updated model which is self-sufficient, and effective to be used for the Smart Monitoring of the Electricity consumption in Saudi Arabian cities. The system design uses effectively wireless mode of data transmission, and database driven triggers which generate the complete bill of the consumer for various intervals. The system can further be extended to be used on a mobile phone application to get notifications, and can manage and observe an electric consuming.

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