Wireless Sensor Networks For The Optimum Energy Expenses In The Smart Home

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ABSTRACT

The grid with the information and communication technologies is termed as smart grid. Smart homes are the residential buildings with automation tools and it is connected to the smart grid. Residential energy management is very important in the case of demand side energy management in smart grid. And the wireless sensor network has a key role in this. However consumers wish to start the appliances at the real time. The iHEM application is coming to solve the problem on that matter. Here we can show that iHEM application is helpful for to start the appliances at a time, reduce the energy expenses, carbon emission, and also its outputs are close to the output of OREM scheme, which is an optimization scheme used for to reduce the energy expense of the consumers. Hence here shows that these two schemes together will help to create the optimum energy consumption bill.

Index Terms*—*Energy management Unit (EMU), Time of Use (TOU), Wireless Sensor Networks.

I. INTRODUCTION

Energy has an inevitable influence in this modern world. In the recent annual energy outlook report [1], concluding that energy consumption is more increased during the last years. And the existing power grid is not adequate to fulfill the energy demand. Moreover the carbon emission is also increased due to the large power consumption. At peak hours the utility has to use fossil fuel to accommodate the demands. And so it makes large carbon emission.

Modern technologies help the power grid to become the smart grid by the use of information and communication. As a result the consumer can cooperate with grid in power generation through the windmill, solar panel etc. In [2] proposed that home owners can generate the power at home and can sell the excess power to the grid. The smart grid is established with the smart meter, it helps in knowing the current price of electricity in the actual market and the smart home can follow the TOU pricing scheme. In TOU pricing scheme the rate of electricity is varying during a day and it is on three levels: On Peak, Mid Peak and Off Peak.

Residential energy management is needed to attain the Efficient demand side energy management. And it is possible through the wireless communication, smart meter and with the automation tools. In this paper we are proposing an in Home Energy management (iHEM) scheme for to reduce energy expenses with an optimization scheme OREM.

II. RELATED WORK

For residential energy management, so many schemes are proposed in the literature survey. In the residential load control scheme [3], proposed a price prediction filter and scheduler are installed inside the smart meter to schedule the home appliances appropriately. The utility is providing the real time price information only one or two hours ahead of time. The price prediction filter is performing based on the past scheduling horizon and price information from the utility.

In microchip-based scheduling [4], saying that a local controller is used for a group of houses to balance the generation of the supply and demand of the supply. The local controller is used as a steering signal to control the load to each house. A real time control algorithm is used to determine how much time the appliance switch on/off, how much energy flows from or to buffer.

In optimal consumption scheduling [5], proposed an ECS (Energy Consumption Scheduling) device installed inside the smart meter to balance the load among residential subscribers that share a common energy source. By using a game theoretical approach, utilities are providing an incentive to the homeowners, those who are making lower consumption by actual use of the ECS device. And these schemes are not considering about the real time start of the appliances. But here proposing iHEM application based on ACS [6], [7] is helpful for the consumers to start appliances at a time through the interaction between the consumers. Moreover it is following the TOU rate. In residential energy management application, communication between the appliances and the energy manager uses Zigbee with short-range wireless links. Zigbee is a low data rate, short-range, energy-efficient wireless technology that is based on the IEEE 802.15.4 standard. The spectrum allocation of this standard as, 16 channels in the 2.4GHz ISM band worldwide, 13 channels in the 915MHz band in North America and one channel in the 868MHz band in Europe and it can support data rates of 250 kbps, 100kbps (available in IEEE 802.15.4-2006), 40kbps, and 20 kbps. The range is 10-75m nominally, depending on the consumption for a given application. Moreover recently developed IPv6 over low power wireless personal area network [8] is proposing IPv6 addressing in Zigbee.

III. OPTIMIZATION BASED RESIDENTIAL ENERGY MANAGEMENT (OREM)

An LP model is proposed for to minimize the total cost of electricity usage at home. In OREM scheme, assume that one day is divided into equal length consecutive time slots according to the price of electricity i.e., TOU rate. The aim of the OREM scheme is to reduce the electricity usage at home by properly shifting the demand to suitable time slot. Here consumer request is given as input and optimum scheduling is taken as the output. The objective function is defined in (1).

$$Minimize \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{t=1}^{T} \sum_{k=1}^{K} E_i\, D_j\, U_t S_t^{ijk} \quad (1)$$

Where S_t^{ijk} is the ratio of time slot occupied by request k of appliance i on day j. E_i is the average energy consumption of an appliance i for a cycle. If new appliances accept waiting times between cycles, then the OREM scheme can be extended to schedule sub cycles. D_i is the length of the cycle of appliance i and U_t is the unit price for slot t. In OREM scheme, it schedule the cycle of appliances to a convenient timeslot. Then it may change appliances starting time than the time they are actually turned on. And it creates a delay. Appliances could be scheduled to less expensive timeslot to minimize the cost of energy usage, but this generates bursts in those timeslots and it may increase the waiting time (i.e., delay). This scheme, bounds the maximum delay, D_{max} , to two timeslots to reduce consumer discomfort and to avoid bursts of request.

The consumer requests are given in advance in OREM scheme. Therefore it arrives at an optimal scheduling for the appliances. In practice, this information might not be obtainable and the appliances may have to be scheduled as the consumers turn them on. The aim of this paper is to find the solution that gives a lower bound for the iHEM application. Hence, here do not use a dynamic optimization scheme as it may yield to suboptimal solutions.

IV. iHEM APPLICATION

The iHEM application is used for reducing electricity expenses, while it leads to decreased consumer dissatisfaction. Initial settings will be done so as to which device will be powered ON at which time. If any device / appliance want power apart from the schedule then it must follow the message flow protocol (Fig.1) using ZIGBEE. The iHEM employs a central Energy Management Unit (EMU) and appliances with communication capability. EMU and appliances communicate via wireless links where their packets are relayed by a WSN. It attempts to shift consumer demands at times when electricity usage is less expensive according to the local TOU tariff.

In the iHEM application, consumers can turn on their appliances at any time, irrespective of peak time concern, and the scheme recommends start times to consumers. According to iHEM, when a consumer presses the start button of an appliance, the appliance generates a START-REQ packet and sends it to EMU. EMU communicates with the smart meter regularly to receive the price updates of the TOU tariff applied by the grid operator. Here assume that the smart home is also able to produce energy by solar panels or small wind turbines. Therefore when EMU receives a START-REQ packet, it communicates with the storage unit of the local energy generator to obtain the amount of the available energy by sending an AVAIL-REQ packet. Upon reception of AVAIL-REQ, the storage unit responds to the EMU with an AVAIL-REP packet. This packet contains information about the amount of available energy.

` After receiving the AVAIL-REP packet, EMU computes the convenient starting time of the appliance by using flowchart. The flowchart for the scheduling is shown in Fig.2. EMU computes the waiting time as the difference between the suggested and requested start time**.** The waiting time is sent back to the appliance in the START-REP packet. The consumer decides whether to start the appliance right away or wait until the assigned timeslot depending on the waiting time. The decision of the consumer is sent back to the EMU with a NOTIFICATION packet.

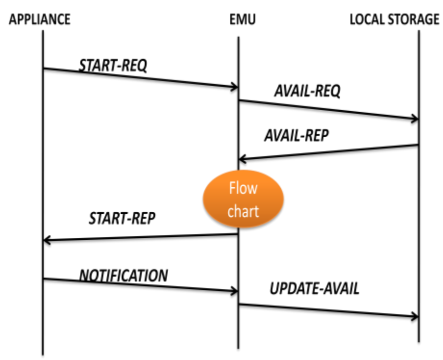

Fig.1. Message flow for iHEM

Afterwards, EMU sends an UPDATE-AVAIL packet to the storage unit to update the amount of available energy (unallocated) on the unit after receiving the consumer decision. This information is required to allocate energy on the local storage unit when it is used as the energy source. As mentioned before, since it is further possible to sell excess energy to the grid operators, the amount of energy that needs to be reserved for the appliances that will run with the local energy has to be known ahead. In the case of failure of stored energy the appliances start with the energy from the grid. Here the consumer may be willing to negotiate with the EMU and wait for the suggested start time or start immediately. In this case, the EMU does not force an automated start time on the appliances because this could cause discomfort on the consumer side.

EMU first checks availability of locally generated power and it is adequate for accepting the demand. If it is available, the appliance starts operating. When there is not enough local energy and the flowchart check if the request has arrived at a peak hour, based on the requested start time, S_{t_i} , then it is either shifted to off-peak hours ormid-peak hours as long as the waiting time does not go beyond D_{max} , i.e., maximum delay. The computed delay d_i is returned to the consumer as the waiting time. D_{max} parameter limits the delay, hence it guarantees a maximum delay for the consumers, and at the same time it prevents the requests to pile up at certain off-peak periods similar to OREM. Start Immediately and Start Delayed functions determine the scheduled time of operation.

The packets of the iHEM application are relayed by the WSHAN. The distance between the appliances and the EMU may exceed the length of the Zigbee links and multiple hops may be required. Moreover construction type or interference on a link may necessitate multiple hops. Deploying a WSHAN only for energy management could be costly. In this case, the existing WSHAN in the smart home that has been initially set up for inhabitant health monitoring, air conditioning, etc., can be used to relay the packets of the iHEM application.

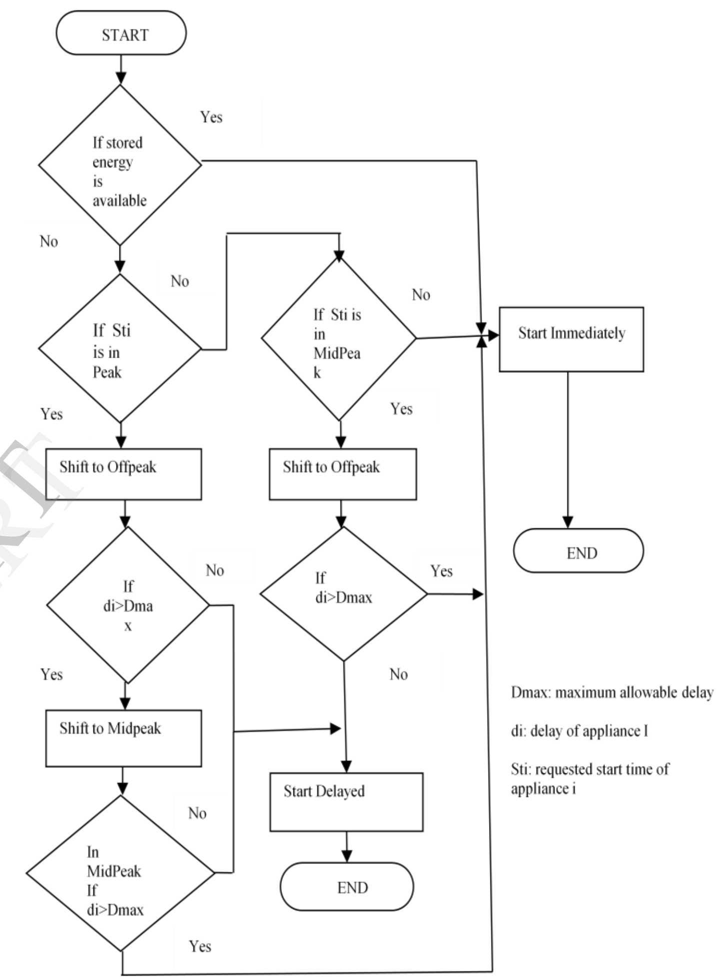

Fig.2. Flowchart for the scheduling in EMU.

V. SIMULATION RESULTS

Here we are using Matlab programming for the simulation. Two classes namely mynode representing the nodes and sink representing the sink node are written. The mynode class consists of basic parameters of a node in ad hoc wireless sensor network like node id, sensing range, neighbor list, energy, data, delay, deployment details. As per the requirement objects of this class is done for the nodes of ad hoc wireless sensor networks. As we run the code objects of mynode are made for each home representing electrical appliances with one sink node is created representing EMU. A single node with less constraint is made to represent the power grid. Then these nodes are deployed in random order. Then these nodes will exchange beacon messages which uses send_pckt.m to exchange the neighboring node information. Then the list of neighbors is updated.

The whole day is divided into slots of one hour and then scheduling for energy consumption by the appliances is done using SG_scheduled.m and schedule.m simulating the OREM scheme. Using events.m and SG.m unscheduled requests are simulated in the form by clicking on the sector (home) in which unscheduled request is required which is in turn iHEM scheme. When an unscheduled request is generated in a mid peak hour then it is delayed, but the delay is maintained less than the maximum tolerable in order not to degrade the performance. Then the unscheduled request is requested at a different scheduled time from the local battery power in EMU. If there is no enough power in the local EMU battery then power is taken from the grid.

When we are using only iHEM the average delay is less because of the possibility of starting immediately. But in the optimal solution (OREM+iHEM), iHEM is used for the request apart from the predefined schedule OREM.So average delay is higher in the former case. Hence the contribution of appliances to the energy bill is optimum in this case. Fig.3 shows the average delay for optimal solution and for iHEM.

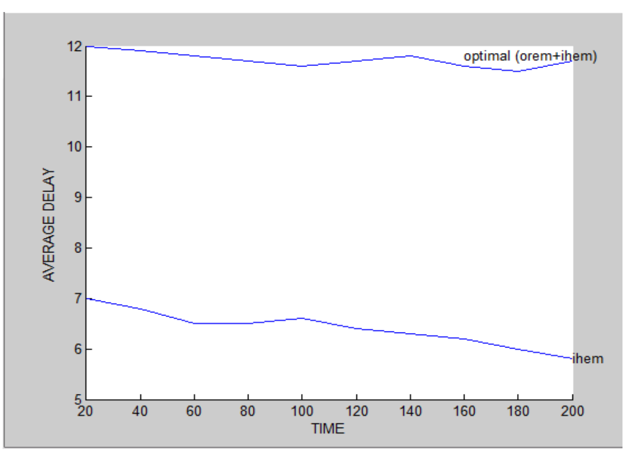

Fig.3.Average delay for optimal solution (OREM+iHEM) and for iHEM

Fig.4 shows the percentage of contribution of appliances to the energy bill for the optimal solution and for iHEM.

It is most favorable in OREM with iHEM and it is increasing with days and is also about 30% less than iHEM.

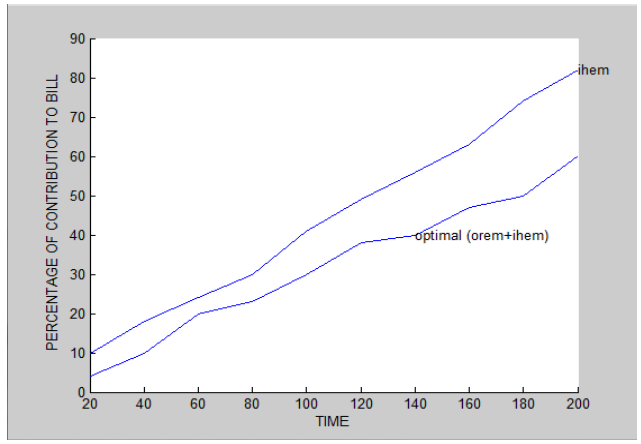

Fig.4. Percentage of contribution of appliances to the energy bill

VI. CONCLUSION AND FUTURE SCOPE

Residential energy management is a very important component in the smart grid. For that purpose we proposed OREM and iHEM Application, where OREM is the optimization scheme used to reduce energy expenses and iHEM is the in home energy management application. By the use of local generation, EMU and wireless sensor network in iHEM, it can reduce energy expenses of the

consumer; reduce the greenhouse gases and also it balancing the demand and supply of energy. And it shows that when we are using OREM and iHEM together, it will give optimum cost reduction. Moreover, it shows average delay for optimal solution and iHEM.

In future we could use real time pricing scheme and a reduction of the bill amount if a house lends power to others and decrease the delay of appliances.

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