



Distributed Energy Conserving Scheme for Residential WSN based on Behaviour of Utilization (BoU)

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Abstract

Wireless Sensor Networks (WSNs) is a composition of tiny self-operated devices that communicate with other devices in an ad-hoc fashion. WSNs find its application in real-time appliances due to its cost effectiveness and ease of deployment nature. Energy preserving in these networks while extending its support for real-time appliances is vital so as to preserve the operating hours of the system. To perform an energy efficient operation of WSN devices integrated with real-time appliances, a mutually cooperative and monitoring model is preferred. Depending on the Behavior of Utilization (BoU), energy allocated for each appliance can be shared in a distributed manner with the other appliances to cope-up with the energy constraints and improve prolonged operation. With forehand information about the operating device and its nature towards energy requirement, the energy allocation can be decided over a multi-state operative function to make a decision. The decision making follows Markov-Chain Model (MM) to make decisions between the operation states of an appliance. The outcome of the decision model will result in admitted operation time and energy conservation of an appliance.

Keywords: Energy Management Systems, Energy Conservation, Markov-Chain Model, Behaviour of utilization.

Nomenclature

EMS	Energy Management System
HEM	Home Energy Management
SHEMS	Smart Home Energy Management Systems
WSHAN	Wireless Sensor Home Area Network
iHEM	in-home energy management
MDP	Markov decision process
EMU	Energy Management Unit
TOU	Time of Use
BoU	Behavior of Utilization
E_{req}	Required energy of the appliance i
E_i	Initial energy of the appliance i
n	Number of appliances in the system
S	Total number of states
S_c	Current state of the appliance
a_i	Active appliance

1. Introduction

Recently, residential energy management has become an active topic. An energy management system (EMS) is a system of computer-aided tools employed by operators of electrical utility grids to observe, control, and optimize the performance of the generation and/or system. Traditionally in several parts of the world, there's a persistent problem of inefficient use of electrical power generation and transmission assets. This problem has partially been tackled by demand response at client premises to get a finer control of the available resources. So as to realize the demand response feature, it's necessary to deploy a totally machine controlled demand

response solution or auto demand response which might be made possible through the utilization of a Home Energy Management (HEM) system. Today, interests in HEM systems have grown considerably. Numerous HEM systems are designed based on totally different communication schemes.

The central task of energy management is to cut back prices for the provision of energy in households and residential building facilities without compromising the user's well-being. The functions of the home energy management are: controlling activation/deactivation of home appliances, collecting real-time energy consumption from smart meter and power consumption data from numerous household appliances, generating and observing a dashboard to produce feedback concerning power usage, providing control menus to manage appliances and providing a universal link to the broadband net. The improvement of a house's energy efficiency is imperative. A requirement to extend the energy efficiency of appliances was known by several researchers and amidst various approaches to do therefore a smart home was deemed as a significant answer to this challenge. Emerging trends, developments and paradigms in smart environments like Smart Homes are often based on smart devices and equipment, like Smart Meters which may manage and monitor through a network the home energy consumption. The aim of an energy efficiency driven Smart Home is to permit the network elements to dynamically work together and build their resources available, with the intention of reaching a typical goal, (i.e.), the energy saving of a house. A number of key features that apply to various energy efficiency driven Smart Homes are:

(i) The available node energy, that is usually restricted, (i.e.), a battery equipped nodes that work with restricted amounts of energy.

(ii) Smart devices and equipment that are able to provide the opportunity to observe and to remotely control key features within homes.

(iii) Decision-support tools designed to help users in creating smarter decisions and based on getting the most out of the benefits gained by the end users when they use energy saving services. It becomes then necessary that at an equivalent time with the energy management challenge, a proper communication protocol between smart devices would frequently improve the system performance.

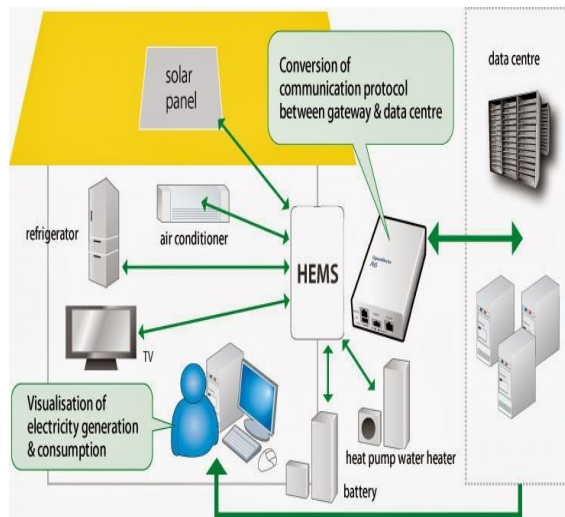


Fig. 1: A simple Home Energy Management System

A simple Home Energy Management System is shown in Fig 1. Previously, the projected energy efficiency driven Smart Home systems are based on the task assignment, integration of many physical sensing information and control of many devices. However, they do not concentrate on finding the simplest communication protocol between devices that might translate to an improvement in the overall system performance. This specific topic have numerous views regarding how the development of household's energy efficiency can be done, what resources to use and what system design to implement. Some create a reference to Smart Home Energy Management Systems (SHEMS) capable of reducing the overall electricity bill for consumers and to at the same time flatten demand peaks whereas others call it as Home Energy Management System (HEMS).

Then the concept of optimization-based residential energy management (OREM) and the in-home energy management (iHEM) schemes were introduced to reduce the share of the appliances in the energy bills and to reduce their contribution to the peak load. It is proved that the iHEM application decreases the contribution of the appliances to the energy bill, significantly. Meanwhile, the savings of the iHEM scheme is close to the savings of the optimal solution provided by the OREM scheme. From the utility perspective, reducing the peak load is an important issue. The iHEM application is shown to decrease the load on the peak hours and also the power-related carbon emissions, as well.

Since the only purpose of the Wireless Sensor Home Area Network (WSHAN) is not relaying iHEM messages but it is also responsible for the smart home monitoring application, the performance of WSHAN depends on the packet sizes generated by the monitoring application. If the packet size of the underlying monitoring application decreases, the delivery ratio increases and the delay decreases, which translates into improved network performance. But the nature of appliances utilized differs on the basis of the environment and needs. Unlike appliances exhibit different sub cycle scheduling that does not meet the requirements of the existing energy management units. This results in limited packet rate and discontinuous information transfer. To ensure seamless packet flow with appropriately sequenced information

requests, a prediction based on behavioural model of the appliances with respect to the usage cycle is proposed in this paper.

2. Literature Survey

P. Srilatha, T.Ravi kumar reported the design and development of a smart monitoring and controlling system for household electrical appliances in real time and proposed the implementation of the controlling mechanism of appliances in several ways [1]. A smart power monitoring and control system has been designed and developed toward the implementation of an intelligent building. Thus, the real-time monitoring of the electrical appliances can be viewed through a website. The sensor networks are programmed with numerous user interfaces appropriate for users of varying ability and for expert users such that the system can be maintained simply and interacted with very simply. The developed system could be a low-cost and versatile operating and therefore will save electricity expense of the consumers.

Prabhash Nanda, C.K. Panigrahi, Abhijit Dasgupta had discussed the huge stresses in the existing generation, transmission and distribution systems due to rapid economic development as they are not able to keep pace with the increasing demand. Installation and incorporation of a large number of electrical power generation units with increased capacities to deal with the surging demand have an adverse impact on the environment, therefore an efficient Energy Management is imperative [2]. The authors believe that there is an ample opportunity to explore the integration of home and building energy management systems (HEMS, BEMS), solar PV technology, and energy storage with the micro grid. The above literature clearly concludes that for improvement in smart grid as a whole, the advancement in its constituent parts like a smart meter, distributed generation, a communication system (ICT) is essential along with proper EMS.

Vaibhavi, Sunil Yardi has designed a Home Energy Management (HEM) system based on demand response [3]. HEM plays an important role in realizing residential Demand Response programs within the smart grid environment. It provides a home-owner the pliability to automatically perform smart load controls supported utility signals, customer's preference and load priority. The HEMS communication time delay to perform load control is analysed, beside its residual energy consumption. The main aim is to design how each load performs after controlled by the HEM unit and measure electrical measurements for the various loads. HEM system includes a HEM unit that offers monitoring and control functionalities for a home-owner, and load controllers that gather electrical consumption data from elite appliances and perform local control supported command signals from the HEM system. A gateway, like a smart meter, will be used to provide an interface between a utility and therefore the data base for the electrical consumption is maintained.

João C. O. Matias and João P. S. Catalão had discussed Home Area Networks (HAN) communication technologies for smart home and domestic application integration [4]. The work is initiated by identifying the application areas that can benefit from this integration. A broad and inclusive home communication interface is evaluated utilizing as a key piece a Gateway supported machine-to-machine (M2M) communications that move with the surrounding environment. Then, the main wireless networks are thoroughly assessed, and later, their suitability to the requirements of HAN considering the application area is analyzed. For energy management in smart homes, most of the low-power and low data protocols are sufficient for this sort of function (like ZigBee, MiWi, Wavenis, among others) with the exclusion of Insteon and EnOcean, that don't have adequate security services. For medical and surveillance applications, Wi-Fi is better positioned. Finally, UHD multimedia requirements will still be dependent on a wired infrastructure; however, the newer Wi-Fi protocol generations are on the right path to fulfill these requirements.

Mark Ruth, Annabelle Pratt, Monte Lunacek, Saurabh Mittal, Hongyu Wu, and Wesley Joneshad discussed about the physical and economic impact of distributed technologies under different markets or tariff structures and proved that the combination of time-of-use (TOU) pricing and Home Energy Management Systems (HEMS) controlling residential cooling systems reduces peak load during high price hours but moves the load peak to hours with off-peak and shoulder prices [5]. Home energy management systems (HEMS) reduce consumers' electric bills by precooling houses in the hours before peak electricity pricing. Utilization of HEMS reduce peak loads during high price hours but shifts it to hours with off-peak and shoulder prices, resulting in a higher peak load.

Rosario Miceli outlines the energy management ideas and the smart grid evolution and reported a specific energy management analysis by considering all the electrical value chain, and therefore the demand-side management and distributed on site control actions [6]. The necessity of considering energy management as a crucial innovation in load supplying to permit a more powerful penetration of renewable energy usage at the building and city level and to perform energy savings and CO₂ emissions reduction is pointed out. All the hypothetical scenarios related to smart grids need evolution and development processes involving many aspects, which are today very interesting areas for study and research; in fact, the new challenges that have to be faced concern Technical aspects, Technological aspects, Economical and policy-regulatory aspects, Social aspects.

Nikhil Batra, Dr. Harikumar Naidu proposed an optimization method based on genetic algorithm [7]. A distributed framework for the demand response based on cost minimization was proposed in that each user in the system will find an optimal start time and operating mode for the appliances in response to the varying electricity costs by controlled and uncontrolled devices and completely different unit reading by different time scheduled by using GA based algorithm. In this technique, each user requires only the knowledge of the price of the electricity that depends on the aggregated load of other users, instead of the load profiles of individual users. Moreover, the proposed scheme achieves a favourable trade-off between the user comfort and cost reduction.

K.B.Prasath, S.Vijayakumar, S.Prasath Kumar introduced the Optimization based Residential Energy Management (OREM) and the In Home Energy Management (iHEM) schemes to reduce the share of the appliances in the energy bills and to reduce their contribution to the peak load [8]. Since residential energy management, smart appliances, WSHANS, and their link with smart grid applications have become popular topics because the governments and the utilities are urging for migration to the smart grid. Evaluation is done based on the performance of iHEM under the presence of local energy generation capability, real-time pricing, and for prioritized appliances to determine the cost of energy expenditure and it is proved that the iHEM application decreases the contribution of the appliances to the energy bill, significantly.

Pallavi Ravindra Joshi and M S Khan have reported an effective implementation of an IOT based smart power management system [9]. Wireless sensor networks based real time power management system was proposed to control and monitor the power consumption of electrical appliances in a home. Sensors are placed at electrical load to sense the current and voltage, it calculates the power consumption of electrical appliances. This data will be transmitted wirelessly using Zig bee protocol to the Ethernet shield. The transmitted data is monitored and controlled remotely using IOT. This enables the user to have flexible control mechanism remotely through a secured internet web connection. This system helps the user to control the electric appliances automatically, manually and remotely using a smart phone or personal computer. This system is very efficient, cheaper and flexible in operation and thus can save electricity expense of the consumers.

3. Proposed Method

In this paper, behavioural model of the appliances is proposed for solving various resource management issues in Wireless sensor networks (WSNs). WSNs plays the key role in the expansion of the smart grid en route residential premises, and facilitate numerous demand and energy management applications. Economic demand-supply balance and reducing electricity expenses and carbon emissions are going to be the immediate benefits of those applications and also energy preserving in these networks while extending its support for real-time appliances is vital so as to preserve the operating hours of the system. To perform an energy effective operation of WSN devices integrated with real-time appliances, a mutual co-operative and monitoring model is preferred. Therefore, unlike the previous EMU, energy utilization need not be the same throughout the TOU of the device. Spare energy utilization is concentrated for devices with priority such that independent power allocation is distributed with conservation.

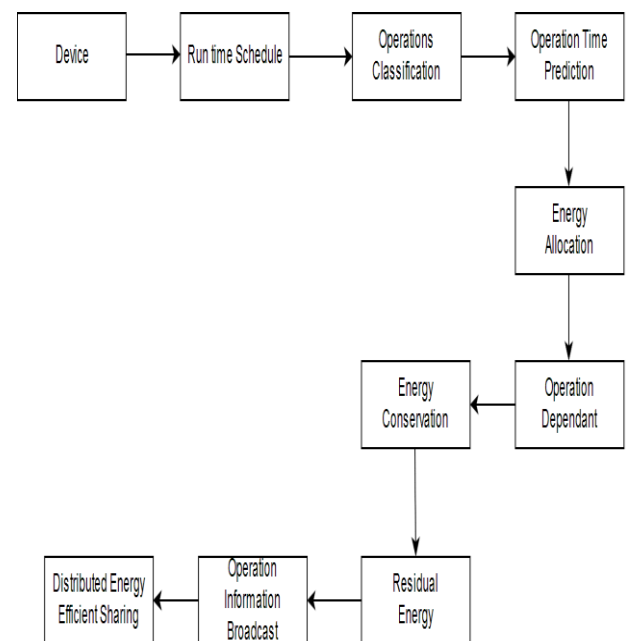


Fig. 2: Block diagram of the proposed system

Fig 2 shows the block diagram of the proposed system. The nature of appliances utilized differs on the basis of the environment and needs. Unlike appliances exhibit different sub cycle scheduling that does not meet the requirements of the existing energy management units. This results in limited packet rate and discontinuous information transfer. To ensure seamless packet flow with appropriately sequenced information requests, a prediction based on behavioural model of the appliances with respect to the usage cycle is proposed. Behavioural model analysis depends on the past histories of the appliances so as to allocate variable energy utilization considering the operation modes and time of usage of the devices. With fore-hand information about the operating device and its nature towards energy requirement, the energy allocation can be decided over a multi-state operative function to make a decision. The decision making follows Markov-Chain Model (MM) to make decisions between the operation states of an appliance. The outcome of the decision model will result in admitted operation time and energy conservation of an appliance.

3.1 Markov-Chain Model

A Markov decision process (MDP) is an optimization model for decision making under uncertainty. The a stochastic decision process of an agent interacting with an environment or system. At

each decision time, the system stays in a certain state and the agent chooses an action that is available in this state. After the action is performed, the agent receives an immediate reward and the system transits to a new state according to the transition probability.

MDP model contains:

- A set of available world states, S
- A set of available actions, A
- A real valued reward function, $R(s, a)$
- A description of each action's effects in each state, T .

In general, it is assumed that the Markov Property as the effects of an action taken in a state depends only on that state and not on the prior history. For WSNs, the MDP is used to model the interaction between a wireless sensor node (i.e., an agent) and their surrounding environment (i.e., a system) to achieve some objectives. For example, the Markov decision process can optimize an energy control or a routing decision in WSNs.

3.2 Application of BoUM

Fig 3 explains the overall process of the proposed system. The aim of the BoUM is decreasing the cost of energy usage at home while causing the least comfort degradation for the consumers. First, the number of active appliances 'n', their states (S and S_c) are given as input to the control unit. Now, energy is allotted to the active appliances by checking their state. In each and every state, the operating condition of the appliances are checked and energy is allotted according to their requirements. Sometimes a single device may operate with insufficient energy and remaining appliances may inactive or vice versa. If this is the case the energy allotted to other appliances will be unused. In this situation, the BoUM technique checks the active state of the appliance and distributes energy to the required appliance and reallocates unused energy. This process continues till the requirement of all the active appliances is satisfied. So the unused energy is also saved and all the appliances are working with sufficient energy. This is illustrated by the flowchart shown in Fig 3.

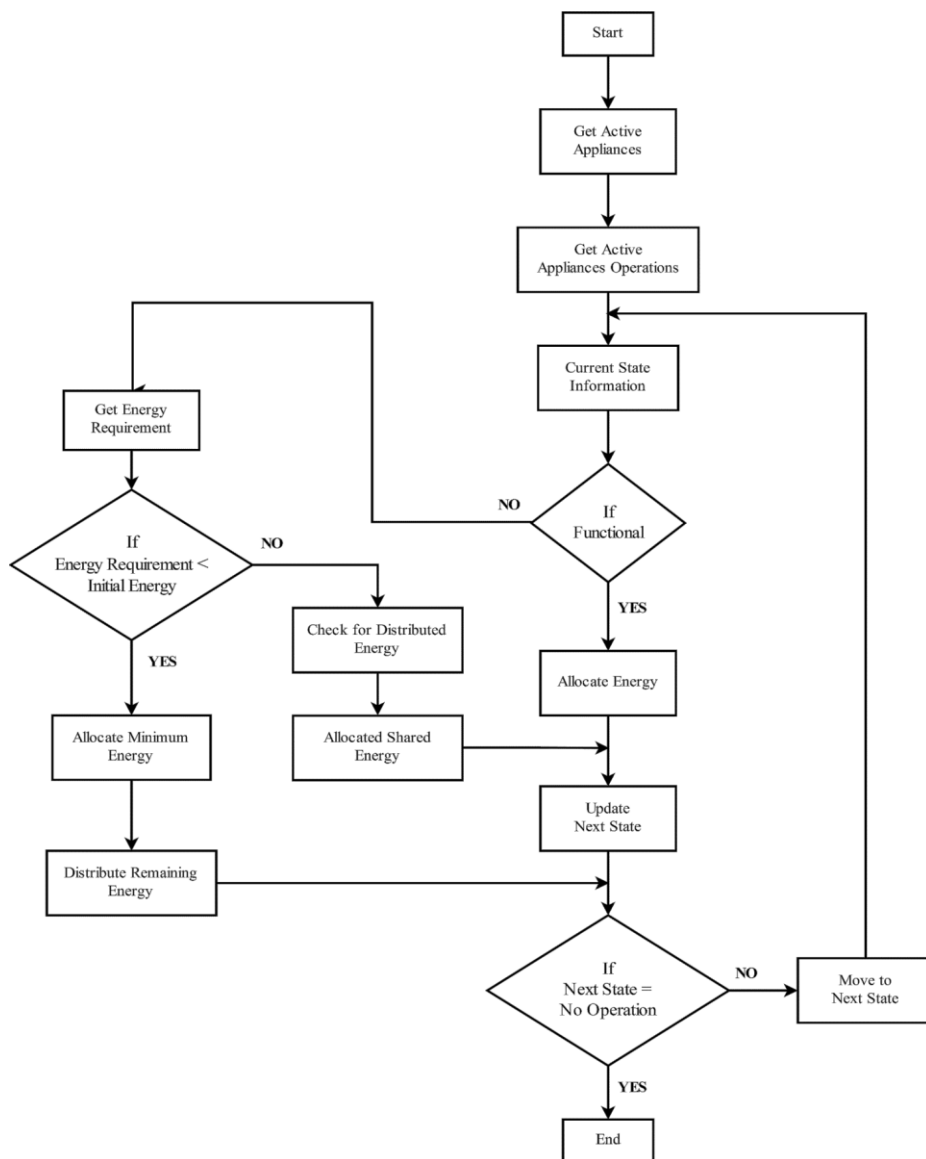


Fig. 3: Energy allocation and distribution

This scheme uses appliances with communication capability, a WSN based HEMS, and a central EMU. The BoUM accommodates consumer demands at times when electricity usage is less expensive according to the local TOU tariff. The algorithm first checks whether locally generated power is adequate for

accommodating the demand. If this is the case, the appliance starts its operation, otherwise the algorithm checks if the demand has arrived at a peak hour based on the requirement. If the demand corresponds to a peak hour, it is either shifted to

Table 1: Illustration example

Device	Operation1	OP1 Time	Operation2	OP2 Time	Operation3	OP3 Time
Washing Machine	Whirlpool Action	20mins	Rinsing	15mins	Drying	15mins
Coffee Maker	Boiling	5mins	Warming	10mins	-	-
Fan	Cooling	30mins	-	-	-	-

off-peak hours or mid-peak hours as long as the waiting time does not exceed. The operating time and preference is not a fixed one. So the energy is allocated for the appliances first and then the excess energy is shared energy. The decision of the consumer is sent back to the EMU with a notification packet. So there is no and operated. The consumer decides whether to allocate energy to the appliance right away (StartAllocate()) or to distribute the energy (StartDistribute()) or to share the surplus energy to the required appliances (StartShare()) depending on the appliance operation and excess insufficient or wasting of energy supply. This can be explained through the flowchart in Fig

Algorithm 1 – Scheduling and reallocation of energy

```

1: Read {n, ai, S}
2: get {Sc}
3: If (Sc = TRUE) then
4: StartAllocate()
5: else
6: Read Ereq
7: If (Ereq=Ei) then
8: StartAllocate()
9: StartDistribute()
10: else
11: StartShare()
12: end if
13: Sc=Sc+1
14: If (Sc=FALSE) then
15: Sc←ShifttoStop()
16: else
17: Sc←ShifttogetSc()
18: Repeat step 3
19: end if
20:end if

```

3.3 Illustration Description

- Consider a home with three electronic devices namely: washing machine, coffee maker and fan.
- Each of the devices is classified with its unique ID. The operations of the devices are tabulated as follows
- Let the washing machine consume 5J, 4J and 2J of energy for the mentioned operations from 1 to 3.
- Let, 2J and 1J be the respective energy consumption of the coffee maker and let the fan consume 5J of energy.
- The initial energy of the devices is assumed to be same and consider the IE as 10J.

3.4 Process

- When the washing machine is switched on initially, 10J of energy will be allocated rather, as we know the operation process, out of 10J, energy needed for the first operation is 50% of the IE. Therefore, reserve the rest of 50% energy for future use.
- Consider the fan is switched on as the second device that requires 50% of its IE that can be shared from the reserved energy of the washing machine.
- Now the coffee maker is switched on after 20mins (say), then the reserved energy of the washing machine (now the washing machine is in operation2 that requires 4J of energy, therefore 10% of its energy can be reserved) is converged to the coffee maker.
- The coffee maker takes 2J (1J from washing machine reserved energy and 1J from the IE allocated to the coffeemaker itself).

Almost 9J (coffee maker's IE) and 10J (from the fan's IE) can be reserved after 25mins from the start-up of the first device. An average of 0.76J/min can be saved.

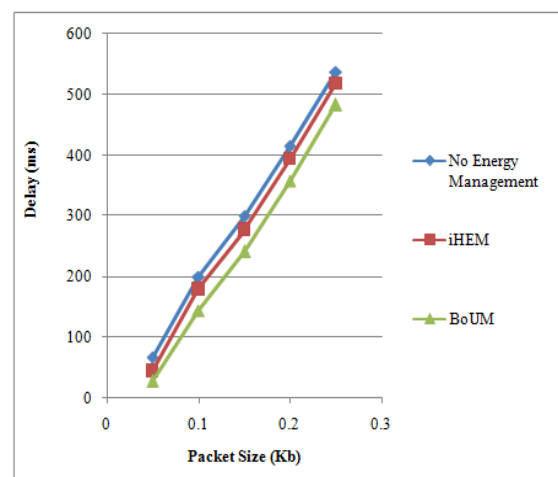
4. Simulation Results

Simulations have been performed making a comparison with an approach without energy management and with the iHEM approach in which an HEM scheme, based on the behaviour of appliances, for a smart home is introduced. In this paper, the simulations have been carried out in the same scenario considered by iHEM and BoUM in order to have a direct comparison with no energy management. The duration and the energy consumption of these appliances are vendor specific. The energy expenses vary because of variations in desired operating and their energy requirement of the appliances. The operating time and required energy of the appliance are known but not the starting time of operation. If this is the case, some devices may operate parallel so with the fore-hand information about the operating device and its nature towards energy requirement, the energy allocation is decided. In this simulation work, the performance of the network in terms of packet delivery ratio, end-to-end delay and energy consumed is analysed. The delivery ratio is the ratio of the number of successfully received packets to the number of sent packets. End-to-end delay is the interval between sending a packet from the application layer of the source and receiving the packet at the application layer of the destination. The following table 2 illustrates the simulation parameters that are used in the analysis.

Table 2: Simulation parameters

Parameter	Value
Network Region	100m*20m
No. of Devices	40
MAC	802.11
Control Message Size	256Kb
Time	60s
Initial Energy	20J
Frequency	2.4GHz
Transmission Energy	60% of IE

Delay

**Fig. 4:** Packet size vs. Delay

In Fig 4, the impact of the varying packet size of the monitoring application on the overall performance of the network is shown. Note that when the packet size exceeds the maximum physical layer packet size defined in IEEE 802.15.4 specifications (128B), it is fragmented into smaller packets. So the end-to-end delay is also reduced to a minimum value (25 ms for a packet size of 0.05 Kb) and lesser than that of iHEM and No energy management. Even though it may look like all the three techniques are having linear changes and very close to each other, BoU gives the minimum delay even for the bigger packet size. From the graph, it is clearly understood that for the packet size of 0.25 Kb BoUM gives the delay of 480 ms whereas iHEM gives 520 ms and No energy management gives 540 ms.

Delivery Ratio

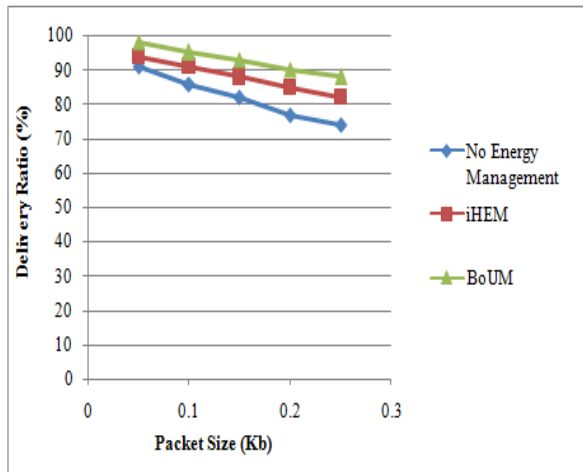


Fig. 5: Packet Size vs Delivery Ratio

In Fig 5, it is clearly understood that the packet delivery ratio of the total system decreases as the packet size of the monitoring application increases. For packet size of 32B, the delivery ratio is almost 90%. Shorter packets decrease contention period, therefore the delivery ratio is high and delay is less for those packets than longer packets. In the proposed system, BoUM have maximum delivery ratio (almost 98 % for a packet size of 0.05 Kb) compared to iHEM and No Energy Management. Whereas iHEM gives 94 % and No Energy Management gives 91 % for the same packet size of 0.05 Kb.

Energy

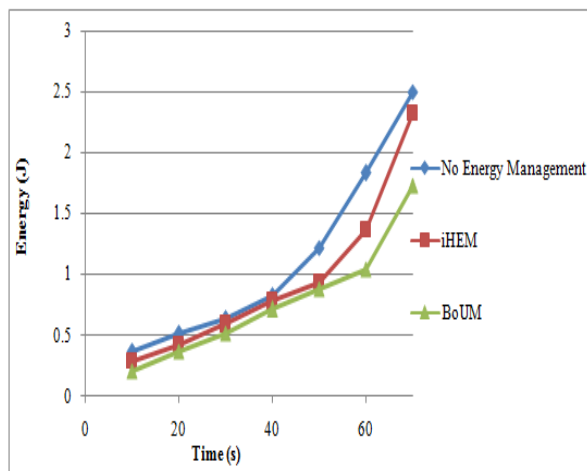


Fig. 6: Time vs. Energy

In Fig 6, the energy savings of the iHEM, the optimal solution provided by BoUM and the case with no energy management were compared. Note that total contribution of the appliances to the energy bill increases with increasing time because the bill is calculated cumulatively. As seen in Fig 6, the BoUM application decreases the contribution of the appliances to the energy bill. Initially, all the three techniques consume energy with minor difference but after a breakdown point (i.e. 60 s) BoUM reduces the energy bill gradually compared to iHEM and no energy management. This can be illustrated by the Fig 6, up to 40 s there is no major difference in energy consuming between no energy management, iHEM and BoUM but at 70 s BoUM consumes 1.73 J whereas iHEM takes 2.32 J and no energy management takes 2.501 J.

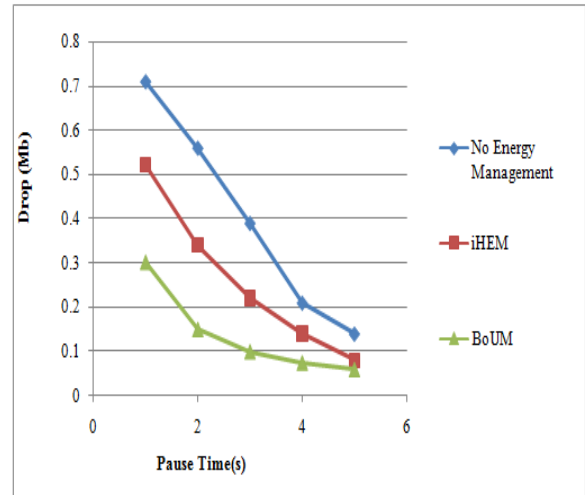


Fig. 7: Pause Time vs. Drop

Fig 7 shows the pause time vs. drop characteristics of various energy management systems. To get a fair electric utility bill or efficient system the drop should be minimized as much as possible with respect to the pause time. Compared to no energy management system and iHEM, BoUM has a minimum drop of 0.06 Mb at 5 s whereas iHEM gives 0.08 Mb and no energy management drops to 0.14 Mb. Not only for high pause time even at the very short pause time of 1 s, BoUM has a minimum drop of 0.3 Mb whereas iHEM gives 0.52 Mb and no energy management drops to 0.71 Mb. This shows when pause time increases (i.e. after 4 s) the drop is reduced to a closer margin in all the three schemes.

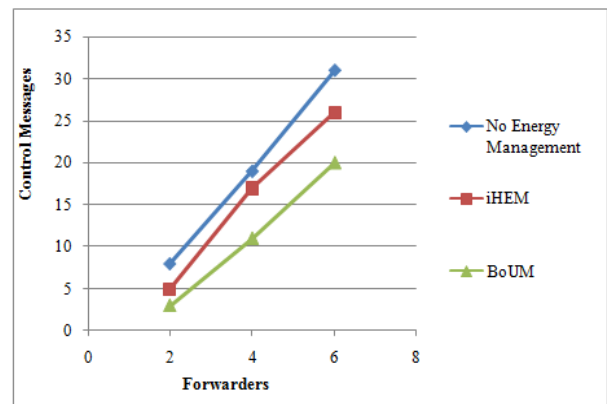


Fig. 8: Forwarders vs. Control messages

Similarly, Fig 8 shows the forwarders vs. control messages performance of different energy management systems. As there are no specific control schemes in energy management systems, frequently it should be monitored compared to iHEM and BoUM. This can be illustrated from the Fig 8, the control messages are

sent to the consumers in the range of 20, 26 and 31 by BoUM, iHEM and no energy management system with respectively for a forwarder of 6. Not only for the high range of forwarder even at the low range of 2, the control schemes sent control messages to the consumers in the range of 3, 5 and 8 by BoUM, iHEM and no energy management system with respectively.

Table 3: Performance of no energy management, iHEM and BoUM

Metric	No Energy Management	iHEM	BoUM
Delay (ms)	537.7	517.83	482.74
Delivery Ratio (%)	74	82	88
Energy (J)	2.501	2.32	1.73
Drop (Mb)	0.14	0.08	0.06
Control Messages	31	26	20

Table 3 explains the overall comparison of no energy management system, iHEM and the proposed technique (BoUM) performance. It clearly shows how the Behaviour of Utilization method plays a vital role in energy conservation and saving by checking the operating conditions of appliances frequently and then distributes the surplus energy to the required operation.

5. Conclusion

In this paper, a Behaviour of Utilization based approach to achieving a favourable trade-off between the user comfort and cost reduction has been proposed. This new technique has been implemented because residential energy management, smart appliances, WSNs, and their integration into smart home network applications are becoming popular topics. Furthermore, a HEM implementation can lead to socially and the economically beneficial environment by addressing consumers' and utility concerns. The main issue of this work is the reduction, guarantying a consumer comfort, the energy consumption and limiting the impact of standby appliances. Simulation results have clearly shown that the proposed energy management system has the capability to reduce domestic energy usage and improve the user's satisfaction degree through the management of loads and generations within the smart grid. The proposed approach is quite efficient in terms of contribution to comfort level of the consumer by reducing the peak load demand and electricity consumption charges and allows to achieve a concrete monetary cost reduction.

References

- [1] P. Srilatha, T.Ravi kumar, "Energy Management System by using Wireless Sensor Network" International Journal of Professional Engineering Studies (IJPRES), Volume V, Issue 4, August 2015.
- [2] Prabhash Nanda, C.K. Panigrahi, Abhijit Dasgupta, "Energy Management System in Smart Grid: An Overview" International Journal of Research and Scientific Innovation (IJSI), Volume II, Issue XII, December 2015.
- [3] Vaibhavi Sunil Yardi, "Design of Smart Home Energy Management System" International Journal of Innovative Research in Computer and Communication Engineering (IJRCCE), Vol. 3, Issue 3, March 2015.
- [4] Tiago D. P. Mendes, Radu Godina, Eduardo M. G. Rodrigues, João C. O. Matias and João P. S. Catalão, "Smart Home Communication Technologies and Applications: Wireless Protocol Assessment for Home Area Network Resources" Energies, July 2015, 7279-7311; doi: 10.3390/en8077279.
- [5] Mark Ruth, Annabelle Pratt, Monte Lunacek, Saurabh Mittal, Hongyu Wu, and Wesley Jones, "Effects of Home Energy Management Systems on Distribution Utilities and Feeders under Various Market Structures" National Renewable Energy Laboratory, June 2015.
- [6] Rosario Miceli, "Energy Management and Smart Grids" Energies April 2013, 6, 2262-2290; doi: 10.3390/en6042262.
- [7] Nikhil Batra, Dr. Harikumar Naidu, "Research Paper on Home Energy Management System Using Genetic Algorithm"

- International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 5, Issue VII, July 2017.
- [8] K.B.Prasath, S.Vijayakumar, S.Prasath Kumar, "An Efficient Approach for Home Energy Management System" International Journal of Engineering Science Invention (IJESI), Volume 2, Issue 12, December 2013.
- [9] Pallavi Ravindra Joshi, Prof. M S Khan, "IOT Based Smart Power Management System Using WSN" International Research Journal of Engineering and Technology (IRJET), Volume 04, Issue 06, June 2017.
- [10] Abhishek Bhati, Michael Hansen, Ching Man Chan, "Energy conservation through smart homes in a smart city: A lesson for Singapore households" Elsevier, Energy Policy 104 (2017) 230-239, February 2017.
- [11] Shiraz Latif, Amir Shabani, Allan Esser, Alex Martkovich, "Analytics of residential electrical energy profile", Electrical and Computer Engineering (CCECE) 2017 IEEE 30th Canadian Conference on, pp. 1-4, 2017.
- [12] Valentina Fabi, Gorgia Spigliantinia, Stefano Paolo Corgnatia, "Insights on Smart Home concept and occupants' interaction with building controls" Elsevier, September 2016, Energy Procedia 111 (2017) 759 - 769.
- [13] P. Dongbaare, S. O. Osuri, S. P. Daniel Chowdhury, "A smart energy management system for residential use", PowerAfrica 2017 IEEE PES, pp. 612-616, 2017.
- [14] Walid Saad, Arnold L. Glass, Narayan B. Mandayam, H. Vincent Poor, "Toward a Consumer-Centric Grid: A Behavioral Perspective", Proceedings of the IEEE, vol. 104, pp. 865-882, 2016.
- [15] Ms.Jayshri V.Ekshinge Dr. Santosh S. Sonavane, "Smart Home Management Using Wireless Sensor Network" International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), Volume 3, Issue 4, April 2014.
- [16] Melike Erol-Kantarci, Hussein T. Mouftah, "Wireless Sensor Networks for Cost-Efficient Residential Energy Management in the Smart Grid" IEEE Transactions on Smart Grid, Vol. 2, No. 2, June 2011.
- [17] Sarika Ambadas Shinde, "Home Energy Management System for Demand Response Applications International Journal of Engineering Research & Technology (IJERT), Vol. 4, Issue 06, June-2015.
- [18] Shiraz Latif, Amir Shabani, Allan Esser, Alex Martkovich, "Analytics of residential electrical energy profile", Electrical and Computer Engineering (CCECE) 2017 IEEE 30th Canadian Conference on, pp. 1-4, 2017.
- [19] Byung-Gook Kim, Yu Zhang, Mihaela van der Schaar, Jang-Won Lee, "Dynamic Pricing and Energy Consumption Scheduling With Reinforcement Learning", Smart Grid IEEE Transactions on, vol. 7, pp. 2187-2198, 2016.
- [20] Ramon F. Brena, Carl W. Handlin, Priscila Angulo, "A smart grid electricity market with multiagents smart appliances and combinatorial auctions", Smart Cities Conference (ISC2) 2015 IE E First International, pp. 1-6, 2015.
- [21] S.V. Manikanthan, T. Padmapriya "An enhanced distributed evolved node-b architecture in 5G tele-communications network" International Journal of Engineering & Technology (UAE), Vol 7 Issues No (2.8) (2018) 248-254. March 2018
- [22] S.V.Manikanthan and D.Sugandhi "Interference Alignment Techniques For Mimo Multicell Based On Relay Interference Broadcast Channel" International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE) ISSN: 0976-1353 Volume- 7, Issue 1 -MARCH 2014.
- [23] T. Padmapriya and V.Saminadan, "Handoff Decision for Multi-user Multiclass Traffic in MIMO-LTE-A Networks", 2nd International Conference on Intelligent Computing, Communication & Convergence (ICCC-2016) - Elsevier - PROCEEDIA OF COMPUTER SCIENCE, vol. 92, pp: 410-417, August 2016.