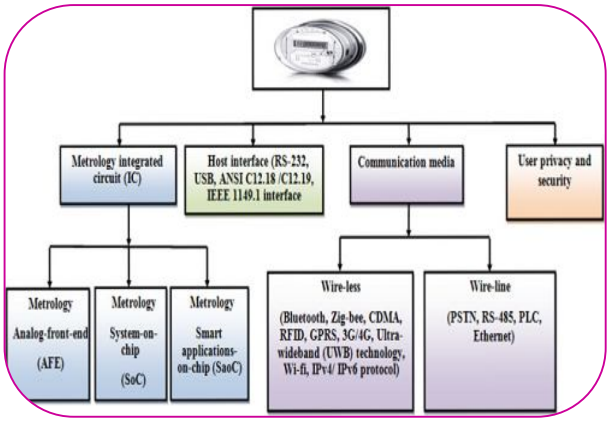
REVIEW OF RESEARCH
ISSN: 2249-894X
IMPACT FACTOR : 5.2331(UIF)
VOLUME - 7 | ISSUE - 2 | NOVEMBER – 2017

# SMART METER DEPLOYMENT OPTIMIZATION AND DEVICES LOAD MONITORING USING EFFICIENT METHOD

**Dipali Sarvate[1] , Dr. V.K. Sharma[2] and Dr. R. Ghodgaonkar[3]**
[1] Bhagwant University, Rajasthan.
[2] Bhagwant University, Rajasthan.
[3](Ret) Prof. MANIT, Bhopal(M.P.)



## ABSTRACT

*Today is the era of Smart and Green energy. Energy usage monitoring of the huge electrical appliances in buildings has attracted great attentions for sustainable living. Traditional approaches suffers from the high deployment, maintenance and data collection costs. This is due to the requirement of large-scale smart sensor/meter networks.*

*In this paper, the problem of smart meter deployment optimization (SMDO) for appliance load monitoring, that is, to monitor a number of devices without any ambiguity using the minimum number of low-cost smart meters is discussed. The importance of this problem is due to the fact that the number of meters should be reduced to decrease the deployment cost, improve reliability and decrease overcrowding.*

*The problem is Non-linear binary integer optimization with non linear constraints, where traditional binary programming methods cannot be applied.*

*A new efficient Methodology and algorithms for optimizing the smart meter deployments to monitor the on/off states of the massive electrical appliances by using the minimal number of smart meters is proposed.*

*Smart meter is generally meant to provide overall energy measurements and its communication.*

*Through this algorithm we can also provide additional information about the number of distinct devices connected and its type by a particular smart meter. Matlab is used as a tool to run the programs of New efficient algorithm . We also present computational complexity analysis of their algorithms.*

**KEYWORDS:** *Smart Meter, Binary optimization, Non-Linear Constraints, smart meter deployment optimization (SMDO).*

## INTRODUCTION

Researches in the field of smart building and smart grid are exploring an efficient energy control strategy to better utilize the energy in residential and commercial buildings .In the past decade, electricity consumption has grown at a remarkable rate, almost 2.7 percent annually on average. Recent reports show that residential and commercial buildingsaccount for 72% of the total energy consumption [1] and 30% of energy consumed in the buildings is wasted [2].

The research has provided ways to improve the current power grid,which carries power from central generators to end users. The smart grid is one such improvement, allowing for two-way flow of electricity and information, compared with the current grid that is based on one-way flow of electricity [3]. Smart grid integrates communication technology and monitoring devices in the traditional grid. This allows for the provision of real-time energy consumption to the utility office as well as the users [4][5].

Smart meter is one such monitoring device in a smart grid system that can allow active participation of the consumer to manage power delivery and reduce its cost [6].

*The digital energy meters available in the market can only provide the collective energy consumed by a whole house [7]. Individual* devices *load monitoring is needed to make demand response and time-of- use electricity prices more effective. The new digital meter i.e. smart meters should have cognitive capabilities that allow them to determine which devices contribute to which consumption . This capability can help the consumer participate fruitfully in the demand response programme. In this programme, a user may be contacted by the utility office to reduce his/her electricity consumption to save money. If the user knows how much each device is contributing to the electricity consumption, he/she may be able to correctly select and switch off the devices that would lead to a reduction in the electricity consumption.*

Smart meters are considered a key component of the smart grid as these will allow more interactivity between the consumers and the provider. Smart meters will enable two-way and real-time communication between the consumers and the provider [13]. Easy-to-deploy sensing systems to support activity detection.

The other approach (called naive approach later in this paper) is to connect low-cost smart meters to each appliance in the house- hold. These low-cost meters are energy monitoring devices with communication ability. But, naïve approach results in deployment of a large number of meters, leading to increasing costs, congestion and decreased reliability. Therefore, research on deploying a number of low-cost smart meters less than the total number of devices was presented in [14, 15]. In these references, it is shown that taking into account load patterns for different devices, we can deploy smart meters using an approximate approach.This approach leads to a number of meters that can be no more than twice the number of meters obtained using the exact approach. The exact approach consists of checking each device individually for similarity between measurements with any other device or a set of devices. Devices with similar measurements are connected to separate meters, which enables unambiguous monitoring of devices. This method neither requires any training based on load patterns nor requires deployment of high-cost high-frequency smart meters. However, the computational time becomes very high with increasing number of devices and it is important to reduce the computational time for developing realistic and practically realizable solutions.

## 2. OUR CONTRIBUTION

In this paper optimization method for smart meter deployment (SMDO) is presented.

The main contributions of our work are:

† SMDO problem is a constrained optimization problem. This optimization problem is reducing the number of rows of a matrix while satisfying all the constraints Number of columns of matrix gives connection between number of appliances and optimized rows gives number of smart meter.

† Implementation of Efficient Algorithm is done in two parts Part1 and Part2 without any approximation.

† Simulation analysis is done on Matlab, optimization time is recorded .We show that method is dependent on power distribution of the load.

† Case study on real time appliance power data is done. This data is given to efficient algorithm and checked for computation time.

### *SMDO problem formulation*

*We use X, x and x to represent a matrix, a vector and an element of a vector, respectively. When xi ≥ 0 for all components i of a vector x,we use x ≥ 0. The function diag(˜a) converts the vector ˜a to a diagonal matrix, that is, a˜I.*

### *Optimisation problem*

*We intend to find the minimum number of meters that can be used to monitor N devices. The resulting solution to this problem can be expressed by matrix ˜A. It shows the combination of devices that are connected to each of the meters. Its size is L × N, where L is the number of meters. Each row of the solution matrix A˜ shows the devices connected to a single meter.*

*As a general rule, if the devices connected to the ith meter are given by $\tilde{a}_i$, then to ensure that there is no overlap with the measurement corresponding to the kth combination, the following test is carried out [14]*

$$|\tilde{a}_i.p - z_k| > (\tilde{a}_i.dp + dz_k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

*It can be seen that by minimising the number of rows of B, we can minimise the number of meters, provided there is no overlapping of measurements in all the combinations of the devices that are connected to the meters. The resulting optimisation problem is the minimisation of the number of rows L of the matrix A. It can be formulated as*

**minimize L**

*subject to Constraints:*

S1: $|\tilde{a}_i.p - z_k| > (\tilde{a}_i.dp + dz_k) \quad \forall k = 1, \ldots, 2^N; \; i = 1, \ldots\ldots, L$

S2: $\tilde{a}_{ij} \in \{0, 1\}, \quad \forall\, i = 1, \ldots, L;\; j = 1, \ldots, N$

S3: $1 \leq L \leq N$

S4: $\sum_{j=1}^{N} \tilde{a}_{ij} \geq 1 \quad \forall\, i = 1, \ldots\ldots, L$

S5: $\sum_{i=1}^{L} \tilde{a}_{ij} \geq 1 \quad \forall\, j = 1, \ldots\ldots, N$

S1 checks that $\tilde{a}_i$ , which is the ith row of matrix B has no ambiguity of power measurement with any other kth row of matrix B.S2 checks that the entries of ˜A are either 0 or 1.S3 checks that there is at least one meter and the maximum number of meters is not more than the total number of devices.S4 checks that the ith meter is connected to at least one device.S5 ensures that the jth device is connected to only one meter and all devices are monitored by meters.

The problem illustrated above is binary integer optimisation problem as all the variables are binary.Also the presence of S1 makes the problem Nonlinear. Nonlinear constraints makes the problem complicated to solve by traditional binary integer programming methods.

In the following section, we present a two-step solution to this problem.

### Optimisation Problem Solution.

### *New Efficient Method :*

The exhaustive search is computationally expensive. For a large number of devices, the number of computations can be very large requiring significant computing resources. To deal with this issue, we propose an efficient algorithm..

## Computational complexity

The number of computations can be calculated by considering that if there are k number of active devices, the total number of combinations that can have 1 to k number of active devices is given as

$$M_k = N! / k!(N - k)! \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(8)$$

## SIMULATION RESULTS

We simulate varying numbers of devices, ranging from 5 to15, as this is a reasonable number for a typical home. We choose arbitrary load pattern and calculate the number of meters required to monitor the devices. We use both exhaustive search and efficient search methods and the results are shown in Table 1. It can be seen that both methods give similar numbers of meters ranging from 2 to 4, which means that the efficient search method is able to perform as well as exhaustive search. We also compare the savings in terms of price and number of meters obtained using our method. The estimated price of a smart meter is $200 [16], whereas based on the price of the energy meter [17], we estimate the price of a low-cost smart meter as $20. Note that this is a conservative estimate; the actual price for a low-cost smart meter can be <$20 [24]. The saving ratio is calculated as the ratio of the cost of the calculated number of low-cost smart meters to the cost of a single highcost smart meter. The maximum saving ratio is 0.4, which means that we can at least save 60% deployment cost using our method. The number ratio with respect to naive approach is calculated as the ratio of the calculated number of smart meters to the total number of devices being monitored. The maximum number ratio is 0.4, which means that we can deploy at least 60% less meters compared with the naive approach, subsequently leading to a cost saving of 60%.

**Table 1: Comparison of two approaches**

| *Number of Appliances* | *5* | *7* | *9* | *11* | *13* | *15* |
|---|---|---|---|---|---|---|
| *Total number of meters obtained using brute force method.* | *2* | *2* | *3* | *3* | *3* | *4* |
| *Total number of meters obtained using efficient method* | *2* | *2* | *3* | *3* | *3* | *4* |
| *Saving ratio with respect to high-frequency smart meter* | *0.2* | *0.2* | *0.3* | *0.3* | *0.3* | *0.4* |
| *Number ratio with respect to naive approaches* | 0.4 | *0.29* | *0.33* | *0.27* | *0.23* | *0.27* |

## CONCLUSIONS

In this paper, we examined the problem of smart meter deployment optimisation for appliance load monitoring. We formulated the problem mathematically and presented computational complexity analysis of the algorithms and showed that the efficient implementation requires less computation. We also carried out simulations that show that the performance of the efficient method is the same as the exact approach in terms of number of meters, and it takes less time to give a solution. We also showed the dependency of our method with respect to different load pattern distributions. We found out that load patterns with normal and exponential distributions lead to higher computation time.

## *REFERENCES*

*Berges M., Goldman E., Matthews H., ET AL.:Enhancing electricity audits in residential buildings with nonintrusive load monitoring' , J. Ind. Ecol., 2010, 14, (5), pp. 844–858*

*Fang X., Misra S., Xue G., ET AL.: 'Smart grid – the new and improved power grid: a survey' , IEEE Commun. Surv. Tutor., 2012, 14, (4), pp. 944–980*

*Ruofei Ma, Hsiao-Hwa Chen, Yu-Ren Huang, and Weixiao Meng, 'Smart Grid Communication: Its Challenges and Opportunities IEEE TRANSACTIONS ON SMART GRID, VOL. 4, NO. 1, MARCH 2013.'*

*Namboodiri V., Aravinthan V., Mohapatra S., ET AL.: 'Toward a secure wireless-based home area network for metering in smart grids' , IEEE Syst. J., 2014, 8, (2), pp. 509–520*

*Makonin S., Popowich F., Gill B.: 'The cognitive power meter: looking beyond the smart meter' . Proc. IEEE CCECE, 2013*

*G. W. Hart, "Nonintrusive appliance load monitoring," in Proceedings of the IEEE, December 1992, pp. 1870–1891.*

*Y. Wang, X. Hao, L. Song, C. Wu, Y. Wang, C. Hu, and L. Yu, "Tracking states of massive electrical appliances by lightweight metering and sequence decoding," in Proceedings of SensorKDD'12. ACM, 2012, pp. 34–42.*

*Ming Dong, , Paulo C. M. Meira,, Wilsun Xu, Fellow, , and C. Y. Chung, "Non-Intrusive Signature Extraction for Major Residential Loads." C. Y. Chung. IEEE TRANSACTIONS ON SMART GRID'2013*

*Hao X., Wang Y., Wu C., ET AL.: 'Smart meter deployment optimization for efficient electrical appliance state monitoring' . Proc. IEEE SmartGridComm, 2012*

*Wang Y., Hao X., Song L., ET AL.: 'Tracking states of massive electrical appliances by lightweight metering and sequence decoding'. Proc. Sensor KDD, 2012*