Grenze International Journal of Engineering and Technology, Jan Issue

Design and Implementation of Smart Energy Meter for Load Distribution

Dr.K.Kalaiselvan[1], M.Logesh[2], R.Praveen[3], N.Venkatadri [4] and R.Hayagreeva[5]
[1-5]Er.Perumal Manimekalai College of Engineering/Electrical and Electronics Engineering, Hosur, India
Email: kalai123selvan@gmail.com, logeshmadhesh@gmail.com, pravinrockerz2233@gmail.com
venkivenkat8220@gmail.com, hayagreeva5335@gmail.com

***Abstract*—The communication infrastructure is an important part to provide the reliability for energy management in the smart grid environment. With the aim of reducing the infrastructure cost for residential energy management, this paper introduces a more complex multi-hop wireless remote metering network model. A novel evolutionary aggregation algorithm (EAA) is proposed to obtain the minimum number and locations of the local data centers (powerful nodes) in a 2-hop wireless remote metering network which has an arbitrary number of smart meters (ordinary nodes) with arbitrary transmission ranges. In the novel 2-hop EAA, the paper designs and implements two novel adaptive operations (the switch operation and the shuffle operation) to improve the algorithm performance. Then the paper extends the 2-hop EAA method to a more generic n-hop EAA which could obtain the optimal result in an n-hop (n>2) smart meter network. Comprehensive case studies and numerical statistical analyses demonstrate that the EAA could efficiently achieve the optimal results in an n-hop (n>=2) smart meter network environment and the novel switch and shuffle operations could efficiently improve the performance of the evolutionary algorithm. The connectivity of the smart meter network could be fulfilled with the minimum number of the powerful nodes, from which the infrastructure cost for residential energy network could be minimized.**

***Index Terms*— evolutionary aggregation algorithm, Smart meter network, Multi-hop, Evolutionary algorithm, Energy management.**

I. INTRODUCTION

A Smart grid is an intelligent electricity network which has a duplex communication network in corporate into the legacy electricity network. With the development of the wireless technology such as LoRa and NB-IOT , smart applications at customers' homes or buildings could be remotely controlled by the local data centers. For example, sensor smart meters are being used for customer data collection and billing purpose. In addition, the wireless routing schemes of the smart meter network were also studied to ensure resilient and reliable meter data collection. The smart metering technology is improving the traditional power grid to be more reliable, responsive and cooperative. Furthermore, the wireless communication technology has been largely applied to the smart metering network for residential energy management. For example, studied the Sub 1GHz urban path loss models which provide optimal transmission characteristics for wireless smart grid for meter data transmissions in urban areas; discussed the physical layer security in wireless smart grid; conducted a performance analysis on Sub 1GHz wireless sensor networks for the smart grid investigated the impact on the topology and traffic

Grenze ID: 01.GIJET.7.1.627
© Grenze Scientific Society, 2021

characteristics of the communication network of the smart grid while adding or rewiring links to increase the algebraic connectivity developed an ORPL forwarding protocol to improve the reliability of the advanced metering infrastructure mesh networks proposed a data transmission priority strategy in the wireless sensor network (WSN) based smart grid. The method processes the data according to its priority and guarantees the minimum delay for the most important data. In , the paper proposed a home energy management application for the smart grid network. The performance was evaluated in terms of delivery ratio, delay and Packet Delay Variance (PDV) for varying inter-arrival times and varying network sizes. In, the work introduced an optimization- based residential energy management (OREM) scheme and an in-home energy management (iHEM) application to minimize the energy cost of appliances in smart homes proposed a distributed algorithm to reduce the aggregation latency on data collection under the WSN physical interference model. In, a random switching traffic scheduling algorithm was proposed to improve the reliability of the data collection communication network. In , in order to reduce the transmission power of each node in the network, the research presented several approximation algorithms for solving the problem developed a mathematical model of cascade connections among smart multi-power taps and proposed a solution for obtaining the location information of the tree structure.

From the above examples, we could learn that a smart meter infrastructure network is crucial for the residential energy management. Therefore, how to build a stable communication network economically is a problem needed to be investigated. In the distributed smart meter network (e.g., Figure 1), the local data aggregation centers (the powerful nodes) are es-sential parts which collect the data from the residents' smart meters (the ordinary nodes) via the wireless communication network. Each ordinary node has to connect to at least one powerful node to fulfill the connectivity requirement. After collecting the data from the ordinary nodes, the powerful nodes then transfer the collected data back to the central database. It is usually very expensive to build one powerful node in a wireless communication network. Therefore in the wireless smart meter network, given the geometry location of the smart meters (ordinary nodes) and their transmission ranges, how to optimally determine the smallest number and locations of the data aggregation centers (powerful nodes) to minimize the residential energy management infrastructure cost is an interesting topic. Little research has been done on how to optimally obtain the powerful nodes in a smart meter wireless network. Our previous work fully investigated and solved the above optimization problem in a one-hop wireless network using different heuristic evolutionary methods. In this one-hop wireless network, an ordinary node can only transfer its data to a powerful node within its transmission range. There is no relay of packets between ordinary nodes. E.g., Figure 1: Ordinary Node A, B and C could transfer their packets to Powerful Node 1; and Ordinary Node D and E could transfer theirpacketstoPowerfulNode2.

As wireless technology evolves rapidly, new wireless sensors could relay their data packets between each other. A residential smart meter in the network could use other smart meters to relay its packet to a powerful node. In this multi- hop wireless network, the powerful node required could be significantly reduced, which will further minimize the infrastructure cost of the residential energy management network. For example, as Figure 2 shows, in a 2-hop wireless network, we only require one powerful node (PowerfulNode1) to fulfill the connectivity requirement because Ordinary Node D and E could use Ordinary Node B and C to relay their packet to Powerful Node1.

Therefore, it is significant that we investigate on how to optimally obtain the least number and the locations of the powerful nodes required in an n-hop (n>=2) smart meter environment. Recently, several studies have been done for the wireless n-hop smart meter network.

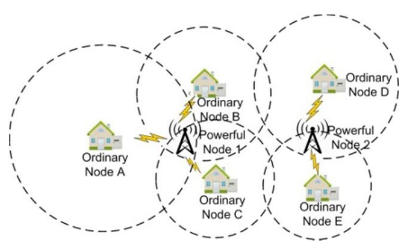

Figure 1. Powerful Nodes and Smart Meters in the One-hop Network

The number of the powerful nodes for an n-hop (n>=2) smart meter environment. Therefore, this paper first proposes a novel evolutionary aggregation algorithm (EAA) to obtain the minimum number and locations of the

powerful nodes in a 2-hop smart meters network model. Then it extends the 2-hop EAA method to a more generic n-hop EAA which could obtain the optimal result in an n hop (n>2) smart meter network.
The contribution of this paper includes: a) Designing and implementing of the novel 2-hop EAA which could obtain the optimal solution (the least number and locations of the powerful nodes) for a 2-hop smart meter network which has an arbitrary number of smart meters (ordinary nodes) with arbitrary transmission ranges. b) In the novel 2-hop EAA, the paper designs and implements two novel adaptive operations (the switch operation and the shuffle operation) to improve the algorithm performance. c) Finally, the paper extends the 2-hop EAA into a more generic algorithm (n-hop EAA) which could solve the optimization problem in an n-hop (n>2) smart meters network. Case studies and numerical statistical analysis in the paper demonstrate that the EAA could efficiently obtain the optimal results in an n-hop (n>=2) smart meters network environment.

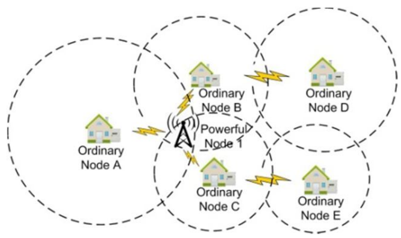

Figure 2. Powerful Nodes and Smart Meters in the Two-hop Network

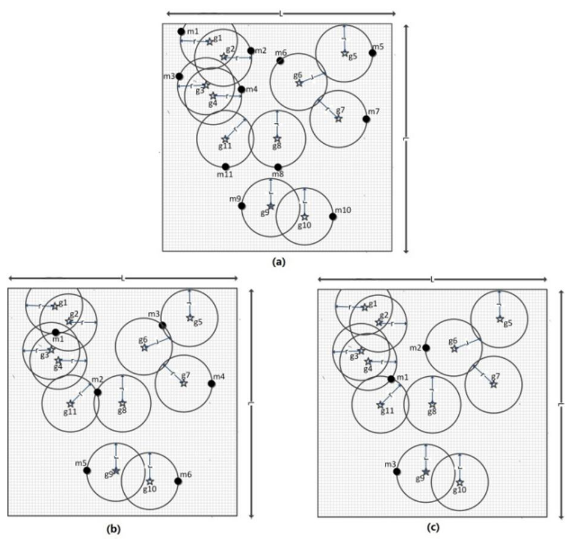

Figure 3. The Smart Metering Wireless Network

In this paper we introduce the n-hop (n>=2) wireless remote metering network model. We then design and implement a novel 2-hop EAA which could obtain the optimal solution in a 2-hop smart meter network as Figure 3 (c) shows. In the 2-hop EAA, two novel adaptive operations (the switch operation and the shuffle operation) are developed to improve the algorithm performance. Furthermore, we extend the 2-hop EAA into a more generic algorithm (n-hop EAA) which could solve the optimization problem in an n-hop (n>2) smart meters network.

II. The Evolutionary Aggregation Algorithm for Two-Hop Network

The Evolutionary Aggregation Algorithm (EAA) is developed from our previous studies, we used three different heuristic evolutionary algorithms to solve the powerful nodes optimization problem in a one-hop smart meter wireless network. In this paper, we consider that the smart meters in the network could replay packets from other smart meters, which completely changes the network model and increases the complexity. Therefore, our previous optimization methods could not be applied to solve the problem in the new n-hop smart meter wireless network and we develop a new EAA method to solve the optimization problem. In this section we firstly introduce and explain the EAA in a 2-hop smart meter wireless network and then in the next section we extend the EAA so that it is able to adapt the n-hop (n >2) smart meter wireless network. Algorithm 1 shows the high-level overview of the EAA method which could obtain the optimal results in the 2-hop smart meter wireless network.

The shuffle operation in step 12 of Algorithm 1 is used to obtain one new two-hop satisfying solutions ($X_{m+1,g}$) from one random two-hop solutions ($X_{r3,g}$). Algorithm 4 demonstrates the details of the shuffle operation. Step 2 and step3randomlyselect$p$clustersfromthesolution$X_{r,g}$. Because the network condition changes from two-hop to n- hop, the complexity makes the previous methods (Algorithm 2, Algorithm 3 and Algorithm 4) could not be applied to the n-hop EAA. Therefore, new methods (Generating random solutions, the switch operation and the shuffle operation) are developed for solving the problems in the n-hop wireless network environment.

III. CONCLUSION

In this paper, we introduce a more complex n-hop wireless remote metering network model than previous published work. Then a novel EAA to obtain the minimum number and location of the powerful nodes in a multiple hop smart meter network is proposed to reduce the energy management cost. The paper firstly designs and implements the EAA method with two novel adaptive operations (the switch operation and the shuffle operation) in a 2-hop smart meter network to obtain the optimal results. Then the paper extends the 2-hop EAA into a more generic algorithm (n-hop EAA) which could solve the optimization problem in an n-hop (n>2) smart meter network. The case studies and numerical statistical analysis show that the EAA could efficiently obtain the optimal result in an n- hop (n>=2) smart meter network environment. It could obtain the minimum number and locations of the powerful nodes to fulfill the connectivity requirement for residential energy management in then hop wireless smart meter network.

REFERENCES

[1] J.Petjjrvi,K.Mikhaylov,M.Pettissalo,J.Janhunen,and J. Iinatti, “Performance of a low-power wide-area network based on lora technology: Doppler robustness, scalability, and coverage,” *International Journal of Distributed Sensor Networks*, vol. 13, no. 3, p. 1550147717699412, 2017. [Online]. Available: https://doi.org/10.1177/1550147717699412

[2] M. Chen, Y. Miao, Y. Hao, and K. Hwang, “Narrow band internet of things,”*IEEEAccess*,vol.5,pp.20557–20577,2017. Central Electricity Regulatory Commision, www.cercind.gov.in,India.

[3] K. Mets, J. A. Ojea, and C. Develder, “Combining power and communication network simulation for coseffectivesmartgridanalysis,”IEEE Communications Surveys Tutorials, vol. 16, no. 3, pp. 1771–1796, Third 2014.

[4] X. Luan, Z. Zheng, T. Wang, J. Wu, and H. Xiang, “Hybrid cooperation for machine-to-machine data collection in hierarchical smart building networks,”*IETCommunications*,vol.9,no.3,pp.421–428,2015.

[5] Y. Cao, D. Duan, X. Cheng, L. Yang, and J. Wei, “Qos-oriented wireless routing for smart meter data collection: Stochastic learning on graph,” *IEEE Transactions on Wireless Communications*, vol. 13, no. 8, pp. 4470–4482, Aug2014.