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An Optimal Protocol for Data Forwarding in Smart Grid

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ABSTRACT

Advanced Metering Infrastructure communication network is a prime constituent of smart grid. In this paper, we propose an optimal communication protocol for AMI in smart grid where Consumer's area is distributed in zones and a smart meter become cluster head on the basis of distance from gateway, distance from neighbor node and its previous cluster head status to accomplish fairness and fault tolerance. A tree structure is used for cluster to cluster communication. The proposed routing architecture is effective and practical.
KEYWORDS: Smart Grid, Advance Metering Infrastructure, Cluster head selection, Energy Efficiency

I. INTRODUCTION

A data transmission network incorporated with electrical grid makes smart grid for the collection, and analysis of data in real time about electricity transmission, sharing and usage. The smart grid then provides predictive data for best management of electric power on utilities, supplies, and customer basis [1]. A good smart grid network depends on the efficient communication of smart meters and AMI, there for to select any technology instead of another data transmission delay, bandwidth and QoS ought to be taken in account to achieve its applications [2]. The communication networks utilized for data collection in smart grid are home area networks (HANs) used to aggregate the consumption data from home appliances, buildings area network (BANs) for aggregation of power consumption data between buildings ,neighbor area network (NANs) to integrate the smart meters data in a specific region and forward it to metering gateways which are linked to shape a wireless mesh network, (WANs) for transmission of metering data through gateways to service providers and utilities [3]. For the purpose of data collections in smart grid different routing techniques have been adopted. But every scheme has some flaws i.e. more routing overhead, more computation cost, congestion, unfairness in cluster head selection or packets delay. The proposed routing scheme offers a best solution for clustering in smart grid with fairness in data transmission.

Some of the key features of our proposed communication model are as follow

- Processing and communication overhead will be minimized on smart meters and gateway.
- To minimized communication delay.
- Efficient cluster heads will be dynamically selected for uniform load balancing.

2. RELATED WORK

Currently proposed algorithms for data collection (fusion or service) positioning or scheming in a smart grid network can be categorized as Direct data routing, neighbors trust based geo routing, hierarchal data routing using mesh topology, signal strength based routing, fixed CH based data routing and dynamic CH based data routing. Birman et al [4] proposed a road map for privacy in smart meters communication systems used for data collection and demand management. His schemes also comprising that the smart meters collects the consumption data, store for the maximum time and transmit that data to the utility servers individually. Clearly, it produces routing overhead on the network, with huge computation cost and energy dissipation on smart meter. Gharavi et al [5] proposed a wireless mesh network structure for smart grid having one separate channel for transmission of consumed data to gateway causing more bandwidth cost and energy consumption . Packet scheduling is compulsory to balance data flow load between gateways, yet cannot completely balance

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the data flow. Maraiya et al [6] introduced the associate cluster head CH node for aggregation of power consumption data in case of cluster head CH failure in a specific round to save energy consumed for re-clustering. But CH and ACH may be selected too far due to lack of any criteria for selection, which leads to huge energy misuse. The presence of an associate cluster head CH as an alternative in each round leads to extra energy consumption. Gungor et al [7] proposed a hierarchical architecture with interconnected individual sub networks and each taking responsibility of separate geographical regions to manage complicated device communication of enormous number of devices and expected smart grid functionalities. However failure of any supposed geographical region, i.e. HAN or NAN results latency, packets delay and routing over head.Xiang et al [8] set up a threshold value for all nodes and nodes with high value are placed in trust forwarding list to avoid the network availability issues. Here node with closest distance is selected for data transmission towards destination. Other alternative path may be suggested for data routing in case of non-availability of selected node resulting routing over head. Latency and packet lose in case of huge data. Zahariadis et al [9] proposed a trust based routing protocol for data transmission to evaluate the performance of target nodes in wireless mesh network by direct trust and indirect trust as parameters. Direct trust evaluation metrics for the measurement are success forwarding rate, authentication, etc having the probability of packets loss with consumption of more energy in some nodes. In geographic routing distance and energy metric are taken to discover the target node for data transmission but some nodes may face security problems from malicious attacks.

Niyato et al [12] discussed transmission of data through HEMS , NAN , and WAN. he proposed an algorithm for cluster formation having fixed cluster head for aggregation of data from cluster members and transmission of data onward. But fixed cluster head results in more computation cost, faced more energy consumption at cluster head node and congestion leading to packet loss at CH node. Khan et al [13] proposed that distance of all smart meters will be measured and the smart meter with the minimum distance will be made the first cluster head dynamically rotating after specific time for next cluster head selection. Next cluster head may be selected too far due to lack of any criteria for next CH selection resulting more routing over head and energy consumption for data transmission. Pervaiz et al [14] proposed the new smart meter position detection and joining network for data transmission using the coordinates and signal strength of existing smart meters in that specific area. GPS work is not satisfactory due to signals fading in residential area. All smart meters aware of neighbor nodes due to information exchange but message circulate as it is not loop free. Also increase of smart meters in the network degrades the performance of routing protocol.   Yoon et al [15] proposed power line communication system for smart grid where sensors nodes data is fetched, forwarded to the data controllers and at last forwarding control commands to actuators. So the micro grids MGs require speedy and precise system for the transmission of calculated data and control signals to controllers in distributed generation DG and micro grids MG. There for appropriate Information and Communication Technology ICT is needed to be developed.

3. SYSTEM MODEL Our proposed system architecture is composed of gateway for data transmission to the utility servers and smart meters. Consumption data of power consumed by home appliances is forwarded to smart meters by home energy management system HEMS. We have divided entire residential area also known as smart city in zones having uniform number of smart meters installed at every consumption point. Further the smart meters are classified into cluster head and non cluster head smart meters. Each zone is having one smart meter selected as cluster head receives the transmitted data from the non cluster head smart meter nodes. Cluster heads in zones laying far away forward the consumption data to next cluster head towards gateway. Subsequently the CHs in the vicinity of gateway forward the collected data to gateway for transmission to the utility servers utilized for proper billing and communication with utility servers and control centers.

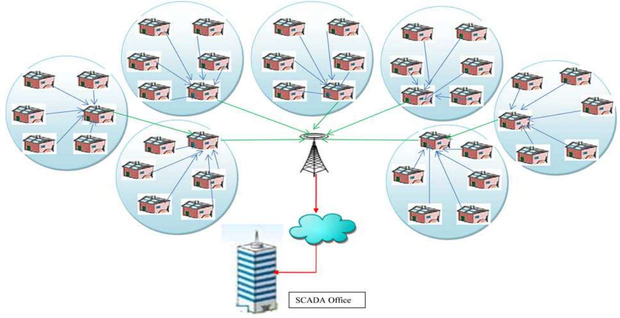

FIGURE 1. Proposed System Model

4. PROPOSED ROUTING ARCHITECTURE

An efficient adaptive cluster based routing protocol is obligatory for aggregation of data from in smart grid. All of the smart meter nodes in AMI have equal competence. This stimulates the call to improve the process of aggregation of data from the smart meter nodes throughout the smart grid network. The purpose of proposed adaptive cluster based routing protocol is to minimize the network load and reduce the routing overhead.

4.1. Zone Formation

A smart grid network consists of large amount of smart meter nodes. Assume that the smart meters installed are not movable and have no energy constraints. For best monitoring of smart grid network the regular transmission of network data to control centers is mandatory. The transmission of all the smart meters data independently to substations will lead to routing over head, more computation cost and packets delay. The distribution of the smart grid network nodes into zones each having its own cluster head for transmission of data to gateway is necessary for efficient network transmission.

4.2. Cluster Head Formation

The creation of cluster in AMI depends on the distance and signal strength from the gateway and the smart meter nodes [16]from each other. The cluster head is selected follows the given steps

Step 1: Neighbor smart meters information:
Each smart meter information broadcast throughout the zone to inform neighbor smart meters of their positions.
Step 2: Distance weights for each smart meter to smart meter and smart meter to gate way are computed in a specific zone and calculating their respective aggregates.
Step 3: Sorting aggregated weights:
The aggregated distance data are retrieved using sorting algorithms and sorted in descending order.
Step 4: Nominee for cluster head

Depending on the sorted aggregated weights the cluster head with minimum aggregated weight will be made first cluster head.All the nodes have different accumulative distance from the gateway and all the smart meters in the cluster. The probability for a smart meter node to become cluster head depends on the accumulative distance of the nodes from the gateway and the rest of all smart meters in the cluster. All of the nodes send the data in each frame. The smart meter nodes with less accumulative distance should be cluster heads as compared to the smart meters with more distance to save energy and avoid routing overhead. This is possible by setting up some criteria as function of accumulative distance calculation and comparison of the nodes within the cluster network rather than purely as a function of the number of times the node has been cluster head.

$$P_i\,(t) = min\{{}^{w_i}/_{w_T}\} \qquad 1$$

Here

$$w_j = w_{ij} + w_{2j} \qquad 2$$

And $w_{1j} = \left(D_{g-sm_j}\right)$ 3

Where D is the distance calculated by the general distance formula based on their location position i.e. $(x,\ y)$ coordinates.

$$w_{1j} = D_{g-sm_j} = \sqrt{\left(x_g - x_{sm_j}\right)^2 + \left(y_g - y_{sm_j}\right)^2}$$

In gateway to smart meter scenario , G represents the gateway location to which all the calculated data is forwarded.

And $w_{2j} = \sum_{i=1}^{N} D_{sm_j-sm_i}$ 4

w_{2i} Represents the calculated distance from any smart meter node to all of the smart meters in that cluster. w_{2i} is also calculated by the distance formula.

$$w_T = \sum_{j=1}^{N} w_j \qquad 5$$

It is the total of all the smart meter nodes distance from the gateway within the cluster and the distance of every smart meter from the rest of smart meters within the cluster.

$$w[\# \, CH] = \sum_{i=1}^{N} p_i(t) * 1 = \left(\frac{w_1(t)}{w_T} + \frac{w_2(t)}{w_T} + \cdots\cdots + \frac{w_N(t)}{w_T}\right)k = k \qquad 6$$

The smart meter with minimum distance weight will become the cluster head (CH).

4.3. MESSAGES TRANSMISSION. In ALGO (2) every smart meter send intellect data packets with a label i-e critical else normal, received to cluster head for prioritization and transmission to gateway.

ALGORITHM 2: Messages Transmission

Input: m
Output: classify and forward
Procedure
For j= 1→n
Node j=1→n send intellect labeled data packets (DP) to CH
If (DP_j == Critical Data)
Prioritized DP_j and Send it to gateway
Else
Normal Data
End

5. ANALYSIS AND RESULTS. To achieve significant results pertinent to real life scenarios, we have used the parameters related to meter deployment discussed in Smart Grid Priority Action Plan 2 published by NIST are applied. These parameters of performance for simulation are given in table no 2.

5.1. Routing Path. The basic function of our scheme is to determine the best and efficient routing path for data packets transmission to the destination. For optimum routing path selection to the destination algorithms measure different distances relating to a smart meter and selecting the minimum routing path for CH selection to transmit data to destination node.

5.2. Packets Delivery Ratio. It is the ratio of number of data packets delivered to the gateway. This shows the ratio of received data packets to the destination.

$$\sum \text{Data packets recieved} \; / \sum \text{Data packets Sent}$$

5.3. Throughput of Protocols. Our results demonstrate the throughput of existing schemes is tremendously low as compared to an optimal protocol for data forwarding in smart grid.

5.4. Numbers of CHs. In our proposed scheme the number of cluster heads is fixed because the whole consumption area is divided into uniform zones and each zone having exactly one cluster head. Proposed scheme is the most efficient routing protocol for AMI. i.e., smart meter once selected as CH have less probability of becoming CH again until all the nodes in that zone become cluster head.

5.5. Packets Drop Ratio. The failure of data packets sent from the source node to reach its destination node is called packets drop. The main factors for packet drop are typically network congestion, weak radio signal for data transmission due to long distance, multipath fading, defective network hardware or drivers. Analyzing the packets drop obtained by the uniform random model we can also observe the packets received by the gateway successfully.

6. CONCLUSION. In this paper we proposed scheme for precise zone formations, data transmission in the smart grid, cluster head selection led to better resource utilization and efficiency in terms of communication and computational cost. Our results show that the proposed scheme attains better resource utilization, than the previously proposed schemes.

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