QoS-compliant Data Aggregation for Smart Grids

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***Abstract*—The Smart Grid (SG) aims to transform the current electric grid into a "smarter" network where the integration of renewable energy resources, energy efficiency and fault tolerance are the main benefits. A Wireless Sensor Network (WSN) controlling and exchanging messages across the grid is a promising solution because of its infrastructure free and ease of deployment characteristics. This comes at the cost of resource constrained and unstable links for such networks. The management of communication is then an issue: billions of messages with different sizes and priorities are sent across the network. Data aggregation is a potential solution to reduce loads on the communication links, thus achieving a better utilization of the wireless channel and reducing energy consumption. On the other hand, SG applications require different Quality of Service (QoS) priorities. Delays caused by data aggregation must then be controlled in order to achieve a proper communication. In this paper, we propose a work in progress, that consists of a QoS efficient data aggregation algorithm with two aggregation functions for the different traffics in a SG network. We expect to reduce the energy consumption while respecting the data delivery delays for the different SG applications.**

Keywords–Smart Grid; Data Aggregation; QoS; Wireless Sensor Networks

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are a potential candidate in the transition from the actual grid to the Smart Grid (SG), where the integration of renewable energy resources, energy efficiency and fault tolerance are the main benefits. On the other hand, WSNs are resource restrained entities with limited computing capabilities, even if in a SG electricity and energy exists, but connecting sensors to such high voltage with intermittent and ill-adapted energy levels is sometimes inappropriate. For that, battery-powered sensors must be deployed all over the grid alongside with the main-powered ones. This will raise a challenge in the data collection process, specially in a SG network where billions of packets with different sizes and priorities are frequently sent within the network. Data aggregation is a feasible paradigm that consists of combining data from multiple sensors across the network and sending the aggregated data to the base station. This will reduce loads on the communication links, thus achieving a better utilization of the wireless channel and reducing energy consumption. In a SG, different applications require different Quality of Service (QoS) priorities. Consequently, data aggregation must respect these requirements (i.e, delays caused by aggregating the packets) in order to ensure a proper communication. Therefore, in this paper, we propose a QoS efficient data aggregation algorithm for the different traffic in a SG network. The rest of the paper is organized as follows: Section II presents prior work on data aggregation in WSN. Section III describes our proposed solution. Section IV discusses some relevant issues about our proposal and expected results. Finally, section V concludes the paper.

II. RELATED WORKS

Many works addressed the data aggregation in WSNs and SGs. In [1], two aggregation methods for processing data in smart meters were used: combining and manipulating. In the combining method, the concentrator removes all individual headers and includes only one single header for the large packet with no data modifications. The manipulating method consists of calculating the result of the messages thus reducing considerably the total size of the messages. Data packet concatenation in SGs was also addressed in [2], they achieved header compression on packets and formulated an optimization problem to optimally configure the sizes of the aggregated packets. However, they considered only overhead reduction, which may be insufficient alone in the presence of bigger data packets with smaller headers. Many other researches considered energy [3], delay guarantee [4] and other QoS requirements [5] [6] in data aggregation for SGs and sensor networks generally. However, none of these works addressed the challenge of having delay sensitive data traffic with different delivery priorities and sizes while reducing energy consumption and maximizing the available bandwidth.

III. PROPOSED SOLUTION

In our proposition, we consider a SG network consisting of several wireless sensors collecting data with different packet sizes and priorities. They can potentially act as aggregators, if they have enough resources, that receive the data and aggregate or concatenate it depending on their QoS requirements, and finally send the aggregated data across the network. We note that the routing process is mostly left unchanged, we only add the aggregation functionality when it is possible. Packets are generated with classifiers in their headers considering their type and criticality, we classify them into two levels: critical and regular. We note that these levels could be adjusted for other applications depending on the network characteristics. Two different queues are created on the aggregator level: Lossy and Lossless queue. The lossy queue contains delay insensitive data packets (regular) that are generally big in size [7], which will allow us to aggregate the packets with the appropriate aggregation function [8]. The lossless queue contains delay sensitive data packets (critical) with critical priorities and with a header which represents a significant overhead compared to the payload size. Header compression is thus performed on the packets.

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Algorithm 1: Aggregator node

```
Update_AD() ;     // AD= Maximum allowed delay - time
  from node to aggregator
if Free_Space() AND Battery_Node > Threshold1 then
  |  Aggregate();
  |  Send_AgPacket();
else
  |  Send_Packet();
end
```

Figure 1. Aggregator node algorithm

Algorithm 2: Lossy_Queue()

```
Init: TTL
if Earliest_Deadline > Delivery_Threshold AND AD > Delivery_Threshold
  AND AggrPktSize < MTU AND TTL > 0 then
  |  Lossy_Aggregation();
  |  Update_Earliest_Deadline() ; // Earliest deadline in the
  |    aggregated packet
  |  TTL - - ;
else
  |  Concatenate();
end
```

Figure 2. Lossy queue algorithm

The proposed aggregation algorithm

In the following, we will explain the main functionality of the aggregation algorithm and its functions. The sender node sends and receives packets from other sensor nodes with different priorities included in their headers. Routes are constructed according to the existing routing protocol with no influence for the aggregation algorithm as already mentioned. In figure 1 when an aggregator receives a packet it will firstly update its delivery time (*Update_AD()*) corresponding to the timestamp included in the header of the packet (maximum allowed delay) minus the time the packet spent to arrive to the aggregator. This will allow us to identify how much time the packet can stay in the aggregator. We store the value in the variable *AD*, we call it maximum allowed delay left. After that, the function *Free_Space()* will check whether the node can store more packets, and the function *Battery_Node()* will check whether the node has enough energy (more than a predefined threshold) to aggregate more packets. If these two conditions hold, we can aggregate packets and send the aggregated packets afterwards. If not, the packets are sent without aggregation. In the aggregate function, we check the *Pkt_type* and send it to the corresponding queue. If the packet is tagged regular, it is sent to the *Lossy_Queue()* (figure 2), where four conditions have to be validated in order to aggregate packets:

- *Earliest_Deadline* > *Delivery_Threshold*: aggregating if the packet with the earliest deadline in the aggregated packet is still within its allowed delay.
- *AD* > *Delivery_Threshold*: which means that the Delivery threshold from the aggregator to the sink must be smaller that the Maximum allowed delay left.
- *AggrPktSize* < *MTU*: aggregating as long the aggregated packet is smaller than the Maximum Transmission Unit (MTU) of the link.
- *TTL* > *0*: If the above conditions were not valid yet and after a certain time we send the packet anyway on the link.

As long as these above conditions are valid, an arriving regular packet to the aggregator will undergo a *lossy_aggregation()*, and the timers are updated. Same applies for the *Lossless_Queue()* with a packet tagged critical. If not valid, we concatenate the incoming packet with the existing aggregated packet if possible and send it immediately. We note that the sink node will send back with the acknowledgment the time the packet spent from the aggregator to the sink in order to update the *delivery threshold*.

IV. Discussion and Expected Results

First of all aggregating packets will lead to less packets sent across the network and less bandwidth consumed, which will result in reducing the load on the communication links and achieving energy savings since the communication task consumes most of the energy in WSNs. Moreover, packets criticality and sizes are taken into consideration in our proposition. For that we expect that the packets will arrive within their deadlines, thanks to the different timers and thresholds across the network. We note that the delivery delays will be longer than a non aggregation scenario where packets are not stored in the queues. Packet delivery ratio might be affected also in our proposition, since aggregating means sending bigger packets thus resulting in more losses. We will deeply investigate this issue in order to mitigate these potential losses. Moreover, we will investigate in future works the impact of disaggregation at the destination node.

V. Conclusion

In this paper, we propose a work in progress solution for data aggregation in SGs networks. QoS requirements of the different applications are taken into consideration by storing the packets in two different queues depending on their quality requirements. The expected results will reduce the energy consumption in a SG controlled by a WSN, while respecting the corresponding delays and QoS requirements. Several tests and investigations have to be performed (i.e, computer simulations) before the completion of this work, after that we will test our algorithm on a real test bed [9] to validate our theoretical approach.

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