Energy Efficient ICT in the Smart Electrical Grid

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1. Introduction

In the recent years scientists have identified a number of problems associated with the conventional power grid and tried to tackle them. This has led to the birth of the concept of a Smart Grid. The Smart Grid has three main characteristics, which are to some degree antagonistic. These characteristics are: provision of good power quality, energy cost reduction and improvement in the reliability of the grid. The need to ensure that these characteristics can be accomplished together demands design and devolvement of a rich ICT network over the power network. In this research we have developed and implemented an ICT network architecture for the neighbourhood sub-Grid level of the electrical network where monitoring has not previously been deployed. This real project is being implemented on the medium voltage power network of the University of Manchester campus.

Since energy efficiency has been identified as one of the major limitations of such networks we have utilized a number of different techniques to tackle this problem. As such, we analyze the optimal topology of network for collecting and transmitting data to the local control unit for applying finer-grained control. Also, we have developed a data reduction algorithm suitable for Smart Grid applications, which can significantly improve the energy efficiency of the communication network by minimizing the communication energy cost and optimizing the network resource consumption while maintaining the integrity and quality of data. To the best of our knowledge, this is one of the very first efforts to propose an energy efficient ICT architecture, combining power grid objectives, real data characteristics, and application-aware considerations.

2. Proposed ICT Architecture

In (Pourmirza and Brooke, 2013b) we proposed two related architectural structures and discussed our experimental results for the ICT infrastructure of an urban environment in the Smart Grid. These two architectures are; a communication network architecture and a software architecture. The proposed communication architecture is a modular architecture that integrates the peer-to-peer hierarchical architectures, tailored to hybrid communication technologies for transmitting data. It comprises five layers that cooperate to offer four main functions of monitoring, data movement, data storage and control. It is being implemented on the medium voltage power network substation 6.6kV of the University of Manchester campus which owns its own distribution grid. This allows us to validate our architectural designs on real equipment, real data, and input from experts in power engineering While Smart Grid systems provide for automated control of the electrical networks, human operators are still essential players for certain monitoring and control tasks. Thus we have developed a visualisation interface at the application layer of our software architecture, for the human operator of the grid, as the basis for Decision Support Tools. It overlays the information from the sensors and the measurements of the electrical performance of the NAN on a GIS-based view of the NAN.

3. Optimal Topology for the WSN in the Smart Grid

The first technique we have used to provide more energy efficient architecture is to optimize the wireless sensor network (WSN) topology by analysing the optimal number of clusters for specific application in our test bed. Therefore, we divide the network in to various numbers of clusters and maintain a fixed number of sensors. Then we start simulating each of these networks by varying the number of sensors in the clusters, cluster shapes and locations for 12 different configurations, all of which preserve the number of clusters. It shows that the minimum occurs at 8 clusters. This result is a function of the total size of our rectangular grid and the amount of energy consumed by the CHs; however, the methods could be used on grids of arbitrary size and CHs.

4. Developed Data Reduction for the Smart Grid

The second technique utilized is to use a data reduction algorithm. In the Smart Grid applications, where metering devices collect data with a high acquisition rate, a great degree of data correlation occurs. Taking this fact into consideration, we have developed a data reduction algorithm called DRACO (Data Reduction Algorithm for COrrelated data) that discards the redundant bits by applying XOR on each two consecutive measured values, and transmits the changing bits only (Pourmirza an Brooke, 2013a). Our analyses reveals that we are able to achieve over 70% efficiency on average in terms of data compression. Finally, we have compared the performance of DRACO with other famous data reduction algorithms and achieved satisfactory results.

5. Conclusions

Here we present a practical energy efficient ICT architecture for the Smart Grid. We evaluated the techniques to offer more energy efficient data transmission. As the result we follow two approaches, optimizing the network topology and applying a data reduction technique. Our design provides an efficient flow of information by reducing data traffic and accelerating data transmission speed. Finally since, in such networks, the bottleneck is caused by the fact that thousands of sensors are sending their data to the central point, in some cases by applying DRACO and reducing data roughly by an order of magnitude (to base 10) we can also reduce the risk of bottleneck.

References

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