Optimization Simulator for Powerline-based Communication in Smart Grid

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Abstract

In this work, we designed a scheduling algorithm to be used for testing and evaluation purposed of G3-PLC technology. The specific use cases defined from the requirement of the German smart metering system applications are the input of the algorithm. These use cases are simulated via the implemented scheduling algorithm on a real field scenario within a Power-Line Communication (PLC) network structure. In this work, we presented the advantage of our algorithm by illustrating the success rate of accomplished use cases and reduction of the transmission time.

Index Terms

G3-PLC, 150kHz-500kHz frequency, Smart Grid, Smart Metering, NEH, Scheduling, Simulation, Performance evaluation.

I. INTRODUCTION

In today's world, many information technology (IT) and telecommunication companies begin to make investments in the smart grid projects. According to Joint Research Center survey reports a total of 459 smart grid projects, launched from 2002 up until today, are invested amounting to 3.15 billion euro [1]. Essential part of this investment is to have a reliable and efficient communication technology. PLC is a widely deployed access technology especially in smart metering. In this study we use G3-PLC as a communication technology that uses frequencies in the 150-500 kHz [2]. As illustrated in Figure 1, the German Smart Meter system is composed of the Smart Meter Gateway (SMGW), meter and the communication unit. In this work, G3-PLC modem is used as the communication unit of SMGW for the wide area network (WAN) communication.

Forum Network Technology / Network Operation (FNN) committee [3] defined three types of use cases (random, regular and planning) of the SMGW to be applied in the German smart metering system (see Figure 1).

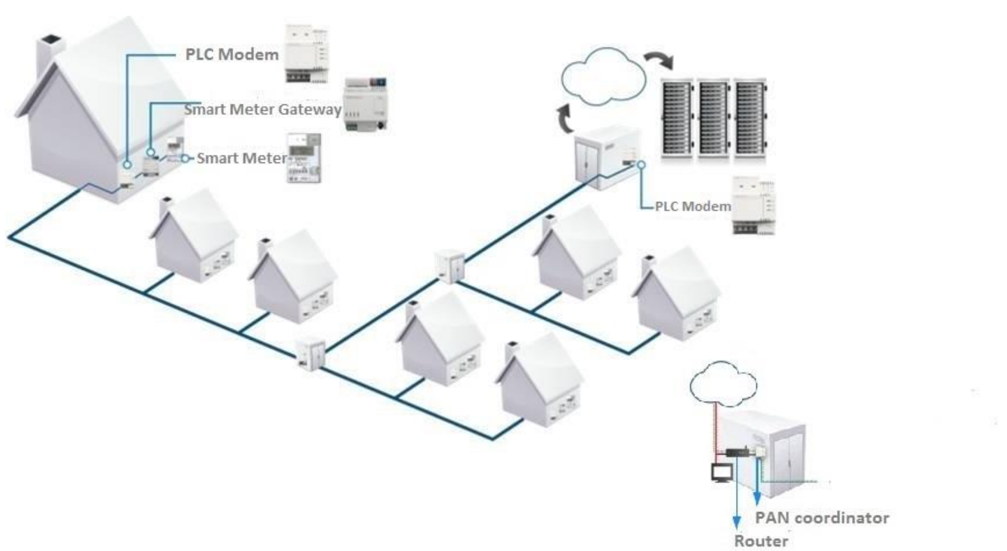

Figure 1: German smart metering scenario

In the upcoming application scenario random use cases present situations that happen suddenly i.e. alarming, whereas regular use cases describe the events which have fixed interval time i.e. bill tariff [3]. Moreover, planning use cases are organized depending on the typical working hours i.e. firmware update. The data traffic caused by these use cases requires enough bandwidth in a realistic network structure. The data of these use cases is transferred from SMGW to the PLC modem via a wired connection; in this study G3-PLC access technology up to 500 kHz frequency range is applied. Since the data rate of G3-PLC is upper bounded by the frequency in use, these use cases have to be scheduled before transferring to the SMGW in order to minimize the data collision on the PLC channel. Therefore, the aim of the work is to investigate the efficiency of scheduling by using this communication technology for sequencing different use cases on application layer of the network.

II. MODELLING AND SIMULATION

The data packets of use cases have to be sent in a scheduled way through the channel using G3-PLC technology within a frequency range of 150-500 kHz. This frequency range provides a maximum speed (throughput) 234kbit/s on physical network layer and correspondingly an estimated 80kBit/s [4] on internet protocol (IP) layer. It is expected that, under real conditions this number may decrease depending on channel noise and Electromagnetic Interference (EMI). Therefore, it is required to generate a software application which includes an efficient scheduling algorithm to distribute and schedule the use cases within the available PLC bandwidth. We apply Nawaz, Enscore, Ham (NEH) algorithm [5] in this work. This algorithm schedules all use cases by depending on the processing time which is a calculated testing time to be spent on the related G3-PLC modem. According to the FNN, data of each test case is transferred either to the uplink direction (represents from SMGW to the back-end infrastructure) or downlink direction (represents from the back-end infrastructure to the SMGW). The communicating for some use cases requires both direction and therefore we further design our equation by considering uplink and downlink communication. We introduce the unit of each parameter and calculate the processing time for each use case with (1):

$$ProcessingTime = \frac{UplinkVolume + DownlinkVolume}{MaximumThroughput * MACEfficiency} \quad (\mathbf{1})$$

Parameters	**Unit**
Processing time	Second
Uplink/Downlink volume	Kilobit
Maximum throughput	Kilobit/second
MAC Efficiency	%

The algorithm of our scheduling application is modeled in Figure 2. As an input of the algorithm, test duration and the number of modems are given by the user. After that, the user chooses *m (m* is an integer from *0..M)* FNN use cases, and/or creates n *(n* is an integer from *0..N)* use cases. This gives a chance for the user of this application to evaluate of the PLC technology and accordingly the modem with own created use case. The selected test cases are validated depending on the MAC efficiency and maximum throughput. According to the condition one in Figure 2, if the processing time of selected use case is longer than test duration, then the program aborts the test for this use case. Otherwise, the program generates the sequence order of use cases by using NEH algorithm. According to the condition two, if the interval time of selected use cases is longer than the test duration, the test is executed only one time for each chosen G3-PLC modem, otherwise it is executed *N* times (2). Our software application simulates the scheduling result for each uses cases on chosen G3-PLC modems. Depending on the data transfer way (from gateway administration to the SMGW and from SMGW to the gateway administration), we categorize the scheduling results.

$$ExecutionNumber\ (N) = \frac{TestDuration}{Interval\ (I)} \quad (\mathbf{2})$$

Parameters	**Unit**
Execution number	Integer number (*N >0)*
Test duration	Second
Interval	Second (*I >0)*

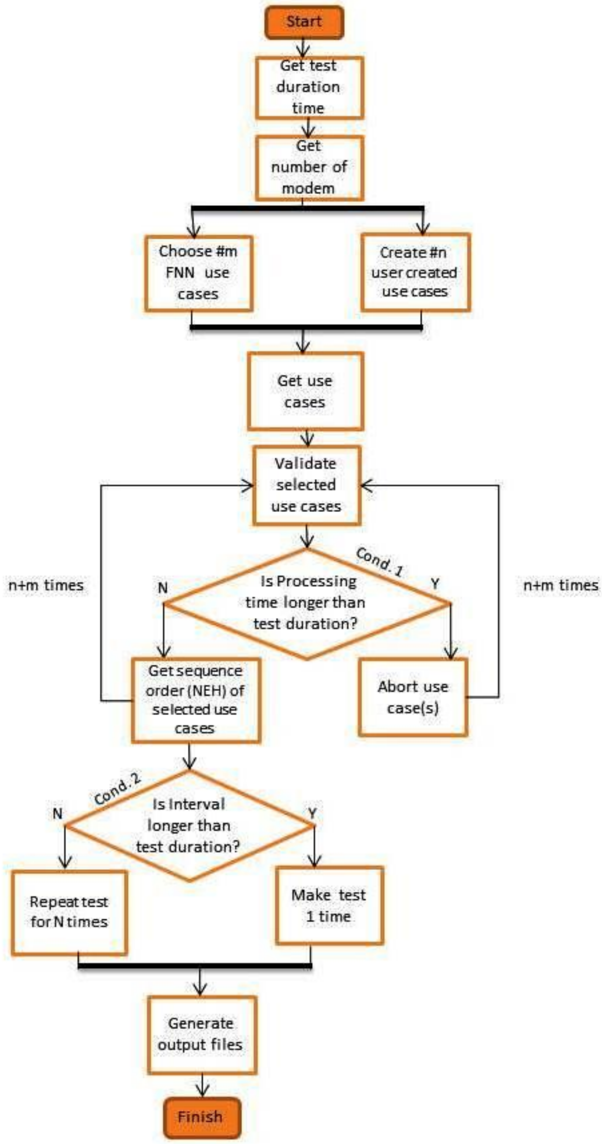

Figure 2: Flow chart of scheduling algorithm

We make diversified evaluation on two field scenarios in order to investigate the capability of this application using the G3-PLC access technology. While testing the G3-PLC modems, we use tree network topology which is divided into the segments including different groups of modems. This segmentation is depending on the data reading frequency of every modem on SMGW. Because of the expansion capability of this network topology, in the future we can easily test up to 1000 modems. Moreover, we can reproduce the testing scenarios with using different network topologies and the communication technologies by using our software application. Since the parameters which determines the communication technology such as throughput and MAC efficiency are depending on the user preferences in our application.

III. RESULTS AND DISCUSSION

The following evaluation results are made by depending on the G3-PLC technology which uses a frequency range 150-500 kHz. As presented in Figure 3, the test scenario is established only increasing the number of testing time duration and results show with a very low time spent. With increasing test duration, due to the increasing time frame of the scheduler, the complexity of the algorithm is also increased. This test scenario established with 20 G3-PLC modems and 20 use cases (m = 20). We doubled the time (from 3 hours testing to 6 hours testing) and spending time for creating scheduling result increased by 0.2 seconds. We tried the same scenario (from 6 hours testing to 12 hours testing) and this time spending time for creating scheduling result increased by 0.24seconds. With the same scenario (from 12 hours testing to 24 hours testing) spending time for creating scheduling result is increased by 0.59 seconds. The reason for these increases is also depending on the interval time (I) of each use case. The application finds the optimal scheduling for depending on their interval time.

For longer testing period it is reasonably easy to find a free slot for the use cases by comparing the short testing duration. According to the FNN recommendations and the decision of the operator, test duration is established up to monthly testing and is repeated two times in every week. With 35-day test duration, the application creates scheduling results in 9,19 seconds and as far as Nielsen [6] is concerned that 10 seconds is about the limit for keeping the user's attention focused on the application dialogue.

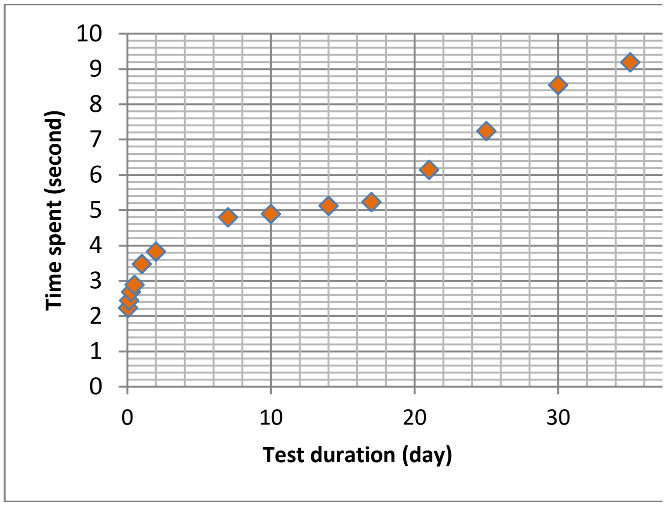

Figure 3: This graph shows the effect of increasing the test duration.

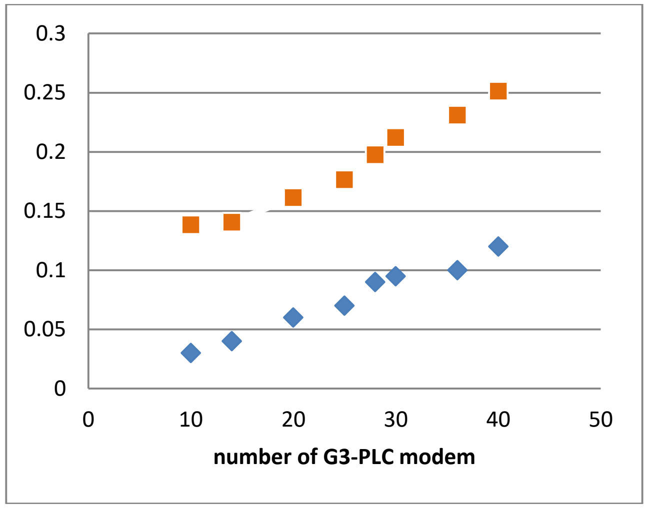

Figure 4: This graph shows the effect of increasing the modem number.

The Figure 4, the test scenario is established by comparing the performance result of our software application with the professional optimization tool ILOG CPLEX. The test scenario is established by n = 3 use cases (one regular, one random and one planning use cases) and one-week test duration and repeated up to 40 modems. As a result, the performance of our application (orange colored) is so close to the ILOG CPLEX (0,1 second).

IV. CONCLUSION

The evaluation results demonstrated that G3-PLC (150-500 kHz) technology is suitable and capable for using in the smart metering. We showed how to optimize the scheduling of data communication can improve to performance of PLC technology, especially G3-PLC. The developed tool will also improve the performance of other communication technologies, which are working with a shared medium like WLAN (Wireless Local Area Network).

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