Performance analysis among S-FSK, G3-PLC V2015 and G3-PLC V2017

Jure Germovšek [(1)] and Janez Zavašnik [(2)]

[(1)] Iskraemeco, d.d. e-mail: jure.germovsek@iskraemeco.com

[(2)] Iskraemeco, d.d., e-mail: janez.zavasnik@iskraemeco.com

Abstract

Performance analysis among different communication technologies can be done in several different ways. We can simply take lower layers of complete communication profile and make comparison. We can make analysis of complete application and we can make also performance analysis of complete solution.

In present document we would like to present performance analysis among different PLC technologies: S-FSK, G3-PLC V2015 and G3-PLC V2017. We will start with comparison of Physical Layer and then we'll add Media Access Layer and Network Layer. This performance comparison is dependent on communication technology only and does not change with time. If we want to add also application layer with application (Smart Metering) or make comparison of whole solution, then we have to add time perspective.

We would also like to stress and show that it is also crucial that application uses application layer functionality which is adapted to lower layers of communication protocol to use all their capabilities and benefits and not opposite way, that application through application layer nullifies improvements or even make it worse.

Index Terms

G3-PLC, S-FSK, DLMS/COSEM, Smart Metering, optimization, application

I. INTRODUCTION

Speaking about S-FSK (Spread-Frequency Shift keying) we have in mind PLC (power line communication) telecommunication technology defined in family of standards EN 61334 and speaking about G3-PLC we have in mind recommendation G.9903 defined by ITU-T International Telecommunication Union – telecommunication). From the first version of S-FSK in 1996 and the first version of G3-PLC in 2014 there is 18 years of time difference. Having in mind changes during these 18 years in Smart Metering applications (more data about measuring values, data about conditions in low voltage network, load profiles, more frequent readouts) and changes in low voltage network (there are many new devices installed using switching power supply, photo voltaic power plants are in the network all causing different types of disturbances) we would hardly make fair comparison of performances of both complete solutions.

Comparing lower layers of different PLC telecommunication technologies could be purely theoretical and can be done without any experiment, but there could be certain parameters which significantly influence to performance of whole application. Therefore, we have decided to present in this document theoretical comparison among different PLC telecommunication technologies and focus to complete application performance.

It was very beneficial that our meter concept supports field exchangeable communication modules with automatic module recognition and adaption of communication profile used so we could use the same meter with S-FSK telecommunication module on one and G3-PLC telecommunication module on the other hand. We have also used other two key components, namely gateway / data-concentrator and system software.

II. S-FSK

Some key properties of S-FSK telecommunication technology are: centralized (one client – many servers) architecture; FSK modulation used with two carriers 10 kHz apart, one at the time present; access to communication channel is slotted with 150 ms long slots; client dictates access to media; there is fixed data rate of 2400 bps; PHY (Physical) layer packets have fixed length; macMaxPDU size is 239 bytes; no PHY layer acknowledgment; network establishment and repeating is managed by CIASE (Configuration Initiation Application Service Element).

Slotted use of communication channel could mean certain drawback compared to not-slotted use, because there are slots when media is not used. Sometimes they would be empty anyway, because servers have to prepare reply before sending it to PHY media. However, sending frames occupying multiple PHY packets is very efficient.

Establishment of communication network is also efficient since it is managed by the only client in the network and it is based on pseudo random principle relying on unique MAC (Media Access) addresses. Also defining “routes” in the network – setting repeaters for chorus repeating is very efficient.

Drawback of very strict centralized architecture is complex and time consuming implementation of procedure when server wants to transmit something (in case of an alarm).

III. G3-PLC

Some key properties of G3-PLC telecommunication technology are: mesh (every node can be client and server) architecture with one PAN (Personal Area network) Coordinator and many modes; PSK (phase Shift keying) modulation: BPSK, QPSK and 8PSK; OFDM (orthogonal Frequency Division Multiplexing) with 36 tones all present at the time in 55 kHz wide frequency band; media access is based on CSMA/CA (Carrier Sense multiple Access / Collision Avoidance) mechanism; bitrates can be up to 42 kbps; PHY packets length is variable; macMaxPDU (Protocol Data Unit) size is 400; there is PHY layer packet acknowledgment; there is bootstrap process defined; LOADng (The lightweight on-demand Ad hoc distance-vector routing protocol – next generation) routing protocol is used.

CSMA/CA access to media brings certain fairness to media access, but it is still impossible to have a set of parameters which would be optimal for different topologies of PAN network and specially, for different number of devices in particular PAN network. Consequently, this means that we always have to have parameters prepared for worst case condition, which could be at the same time an optimal condition.

There is a discussion since the beginning of G3-PLC standardization process how dynamic conditions in the low voltage network are. Can we rely on stable conditions or do we have to check conditions for every data exchange or do we have to find optimal route for every data exchange? Our estimation of “dynamic status” results directly in the ratio between management (TMR (ToneMap Request) and RREQ (Route Request)) and data messages.

IV. COMPARISON BETWEEN S-FSK AND G3-PLC

There are obvious differences between S-FSK and G3-PLC which can be seen by reading key properties in previous two chapters. It is more difficult to estimate influence to performances. Some things we can estimate only with simulation of behaviour in real low voltage network and then question of proper model used becomes relevant.

What we can do in controlled environment is performance measurements of application performances using both PLC telecommunication technologies. We have used the same meter, once with S-FSK telecommunication module and second time with G3-PLC telecommunication module. We have also used gateway / data concentrator in the same way and system software.

We have started to analyse application performances in reference conditions using LISN (Line Impedance Stabilization Network) having one server and one client.

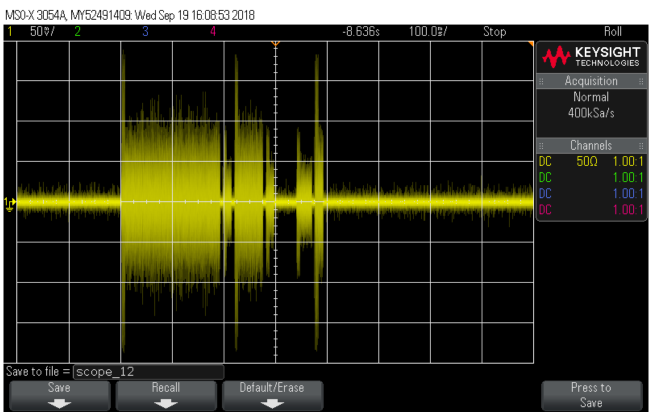
V. G3-PLC V2017 ENHANCEMENTS

Beside some clarifications, corrections and minor changes (for example introduction of POS (personal Operating Space) instead of NeighborTable for RAM (Random Access memory) savings) main changes are: reduction of number of management messages (RREQ, TMR) during join time (use default route) and connected time (use retries with reduced modulation); improved CSMA/CA algorithm (change access to media between unicast and broadcast messages).

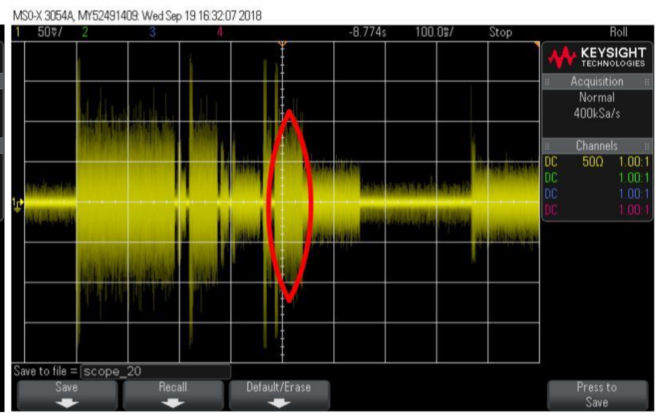
Using RREQ floods whole network and in case of temporary bad conditions it can cause complete congestion of whole PAN network. Therefore, we should use other more efficient and less time consuming functions and give more time for contention window in case of broadcast messages.

VI. G3-PLC USE OF TMR AND CSMA/CA MECHANISM

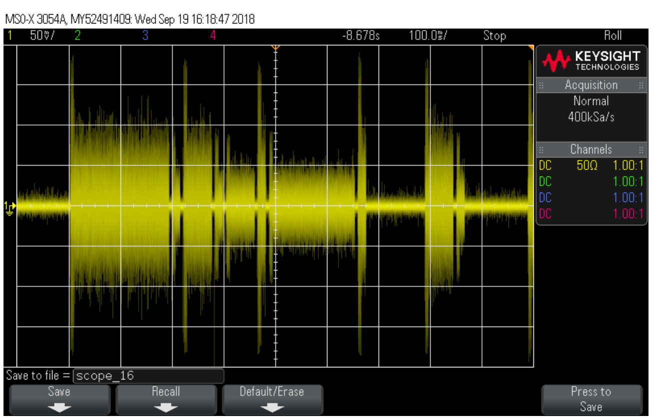
We have explicit presentation of TMR and CSMA/CA use on following figures. On Figure 1.a we can see data exchange without using TMR. We can see DataRequest from PAN-C (PAN Coordinator), which consists of 2 PHY packets and 2 PHY ACKs (Acknowledge). Among them there is time space called RIFS (Response Inter-Frame Space). After last ACK there is time space called CIFS (Contention Inter-Frame Space) and contention window. In our case contention window should be 0 ms but this is not the case since server needs some time to prepare DataResponse. After DataResponse there is time space called RIFS and the PHY ACK follows. This exchange takes 380 ms. In the Figures 1.b, 1.c and 1.d we can see the same data exchange with use of TMR. TMR Request is implemented only with setting of corresponding bit in DataRequest Message, but we need to have TMR Response message and PHY ACK. We have done 3 experiments using different macMinBE and macMaxBE for PAN-C and for PAN-D (PAN Device). In the Figure 1.b we have used for PAN-C and PAN-D macMinBE = macMaxBE = 0, which means that both devices would like to use media in immediately without any CSMA/CA. This results in collision of both TMR Responses. Since TMR Response from PAN-C has much higher amplitude it is correctly received, but TMR Response from PAN-D has to be repeated. In the Figure 1.c we have used for PAN-C macMinBE = macMaxBE = 3 and for PAN-D macMinBE = macMaxBE = 0 which results that PAN-D accesses immediately, but PAN-C waits. In the Figure 1.d we have for PAN-C and PAN-D the same setting for macMinBE = macMaxBE = 3 and we can see that both nodes use contention window for CSMA/CA mechanism. This exchange then takes 940 ms.



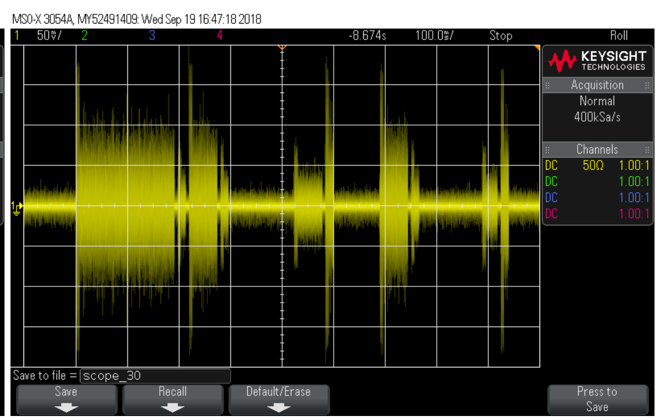
a) REQ /RSP w/o TMR



b) REQ / RSP w TMR PAN-C macMinBE = 0 & macMaxBE = 0 and PAN-D macMinBE = 0 & macMaxBE = 0



c) REQ / RSP w TMR PAN-C macMinBE & macMaxBE = 3 and PAN-D macMinBE & macMaxBE = 0



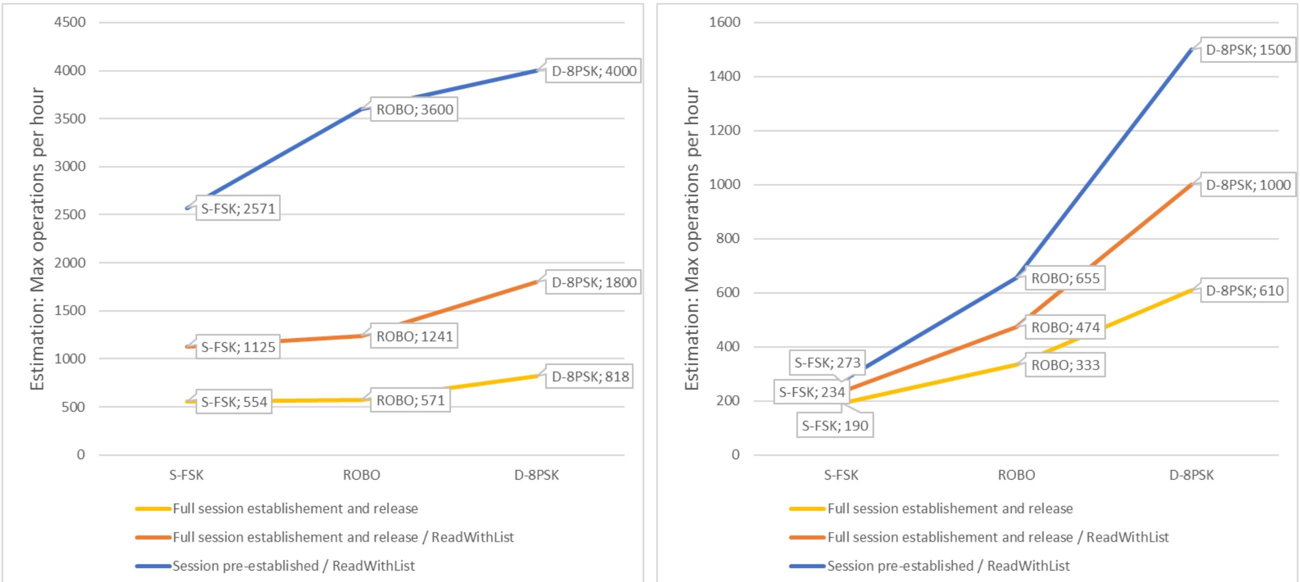
d) REQ / RSP w TMR PAN-C macMinBE & macMaxBE = 3 and PAN-D macMinBE & macMaxBE = 3

Figure 1: Increase of time needed for REQ / RSP due to use of TMR and CSM/CA contention values

VII. ADAPTATION OF APPLICATION TO CONCRETE TELECOMMUNICATION TECHNOLOGY

We can use several optimisations on application to optimize adaptation to concrete telecommunication technology, namely: DLMS/COSEM (Device Language Message System / COmpanion Specification for Energy Metering) session establishment and release; Pre-established DLMS/COSEM session; Read with List; LP Date & Time compression.

With these optimisations, we reduce number of frames needed for exchange (reducing number of slots and time spaces between packets) and merge data which results in longer frames and consequentially less time spaces between packets.



a) OnDemand Readout optimization *b) LoadProfile Readout optimization*

Figure 2: Improvements due to application optimization

At OnDemand Readout improvement with not optimized application (20 / 22 messages) is not huge (up to 60%) however application level improvements (2 / 2 messages) can speed up the process for up to 6-times.

Main reason is that there are a lot of small messages exchanged; average message size is around 50 bytes, decreasing the number of messages drastically, lower the amount of traffic generated and improves performance. Here we have to consider also system software latency.

There is much better situation at LoadProfile Readout. The higher data rates of G3-PLC bring noticable improvement of up to 5.5-times. To get the maximum out of communication line we still have to activate application optimizations; they can double the performance in the G3-PLC network for the LoadProfile Readout.

VIII. CONCLUSION

We have expected that G3-PLC will perform better and the reason why it performs better is not rocket science but following well known basic rules in telecommunications: Maximize utilization of telecommunication channel (long messages; reduction number of time gapes between them); Optimization of ratio between management (TMR and RREQ frames) and data frames; Use higher modulations whenever it is possible (depends on network conditions – we have no influence and optimal HW implementation – our task).

Main guidance for all use cases related to communication over G3-PLC networks is that the application layer should be able to merge different request for data into composed requests in order to benefit from higher available speeds. The DLMS/COSEM stack allows this kind of optimizations and our products support it.

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