D7.3 REPORT ON COMPARISON AND SELECTION OF SPACE GRADE 1GBPS ETHERNET TRANSCEIVERS

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[1] Dissemination level: **PU** = Public; **PP** = Restricted to other programme participants (including the Commission Services); **RE** = Restricted to a group specified by the consortium (including the Commission Services); **CO** = Confidential, only for members of the consortium (including the Commission Services).
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Abstract

One of the initial objectives of the SEPHY project was to define a roadmap for a second generation of space grade Ethernet UTP PHYs that would target a data rate of 1Gb/s. This would be the natural evolution of SEPHY that implements the 10BASE-T and 100BASE-TX Ethernet standards over Unshielded Twisted Pairs (UTP) supporting 10 Mb/s and 100Mb/s respectively.

This forward looking activity was divided in three phases. The first one identified the available Ethernet standards and for each of them the requirements and blocks needed. This work was summarized in the deliverable “D7.1 Report on Requirements for space grade 1Gbps Ethernet transceivers”. Based on this analysis, two options were short listed as initial candidates: 1000BASE-T and 2.5GBASE-T.

In the second phase, the two options shortlisted were analysed in more detail to produce estimates of area and power consumption for different technology nodes using the data from SEPHY Test Chip 2 as the starting point. The results of this analysis were presented in the deliverable “D7.2 Report on Technical feasibility of space grade 1Gbps Ethernet transceivers”. The conclusion was that to achieve a reasonable power consumption, an advanced (smaller than 65nm) technology node should be used. The power consumption was larger for the 2.5GBASE-T making its use more problematic. At the time of writing this report there is no such node for mixed signal ASICs based on European technology. Additionally, during the third year consortium meeting, some partners suggested that in many applications distances are much shorter than the 100 meters typically supported by the UTP based Ethernet standard. As a result, it was approved to modify the third phase of the roadmap activity to consider the option of non UTP based Ethernet standards. In particular 1000BASE-CX.

This deliverable presents the conclusions of this third phase of the activity and compares 1000BASE-T and 1000BASE-CX.

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Disclosure Statement

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List of Acronyms

ACRONYM	MEANING
AAF	Anti Aliasing Filter
ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
ENOB	Effective Number of Bits
GMII	Gigabit Media Independent Interface
ISI	Inter Symbol Interference
LAN	Local Area Network
NRZ	Non Return to Zero
PCB	Printed Circuit Board
PCS	Physical Coding Sublayer
PMD	Physical Medium Dependent
RGMII	Reduced Gigabit Media Independent Interface (RGMII)
SEPHY	Space Ethernet PHY
SERDES	Serializer/Deserializer
TC2	Test Chip 2
UTP	Unshielded Twisted Pair

Table 1 – List of acronyms.

Executive Summary

This document first briefly describes the 1000BASE-CX standard and then analyses the complexity of implementing a transceiver. A comparison with 1000BASE-T is the made. The goal is to provide information to make an informed decision for the next generation of SEPHY that will support 1 Gb/s data rates.

1 Introduction

The Ethernet standard defines protocols and specifications for the connection of systems using wireline installations. Its main focus is the connectivity for short distances in the context of Local Area Networks (LANs) [RD 1]. One of the layers covered by Ethernet is the physical layer that defines the media to be used for transmission, the distances supported and the data rate, signaling, modulation, coding and electrical or optical parameters. The physical layer is different for each media type and data rate. This means that there are many physical layer specifications within the Ethernet standard. These specifications are typically described in one or more clauses of the standard. For example, 1000BASE-T is described in clause 40 and defines the physical layer for full duplex communication over four Unshielded Twisted Pairs (UTP) at 1 Gb/s [RD 2].

The most common media types supported in Ethernet are copper twisted pairs (shielded or unshielded) and optical fibers. Transmission over copper is more complex than using fibers as cables introduce many impairments such as attenuation and crosstalk. Those in many cases need to be compensated at the receiver using equalizers, crosstalk cancellers or advanced coding schemes. This normally makes copper transceivers more complex than fiber ones for the same speed.

One of the objectives of the SEPHY project is to define a roadmap for the next generation of SEPHY targeting 1 Gb/s. The initial plan was to select one of the UTP based Ethernet standards that support 1 Gb/s or a slightly larger data rate, namely:

- 1000BASE-T (IEEE 802.3ab).
- 1000BASE-T1 (IEEE P802.3bp).
- 1000BASE-RH (IEEE P802.3bv).
- 2.5/5GBASE-T (IEEE P802.3bz).

Two of those options (1000BASE-T and 2.5GBASE-T) were shortlisted after an initial analysis [RD 3]. Then, a more detailed feasibility study was done to consider the implementation of rad-hard transceivers for different technology nodes [RD 4]. The conclusion was that to achieve a reasonable power consumption an advanced node (<65nm) should be used. This poses a limitation as there is currently no such node available for mixed signal space ASICs in Europe.

Once this information was available and discussed, it was agreed by the consortium that it would be interesting to consider other alternatives that could facilitate the development of 1 Gb/s Ethernet transceivers for space. In particular, at the third annual consortium meeting it was agreed to consider the use of 1000BASE-CX (clause 39 of the standard) that defines a physical layer for two shielded pairs of up to 25 meters. The rest of this deliverable presents such an analysis and compares 1000BASE-CX to 1000BASE-T.

2 The 1000BASE-CX specification

The 1000BASE-CX specification is defined in clause 39 of the standard and has these main features:

- Uses two pairs of balanced 150 Ohm shielded twisted pairs.
- One pair is used for transmission and the other for reception.
- Supports up to 25 meters.
- Uses 1000BASE-X PCS of Clause 36 and the 1000BASE-X PMD of Clause 38.

The use of shielded pairs eliminates crosstalk while the use of a different pair for transmission and reception eliminates echo. This greatly reduces the complexity of the transceiver. Additionally, the restriction to 25 meters instead of the 100 meters of 1000BASE-T reduces the attenuation and the Inter Symbol Interference (ISI). All this makes the design of a 1000BASE-CX transceiver much simpler than that of a 1000BASE-T one (see [RD 3] for the elements needed in a 1000BASE-T transceiver).

It should be noted that 1000BASE-CX did not gain market traction and was not adopted in commercial applications [RD 1]. However, the specification can be used to transmit at 1 Gb/s over short cables as is the case in many space applications. In fact, the 1000BASE-CX can be seen as a simple SERDES that takes the parallel data from the GMII or RGMII and transmits it serially over one pair. The same technology could be used for higher data rates by adding some complexity in the receiver, mostly for equalization.

As mentioned before, a transceiver for 1000BASE-CX is much simpler than one for 1000BASE-T. Its main blocks are:

- Encoding and decoding of 8/10 bits.

- Serialization/deserialization.
- NRZ transmission at 1.25 Ghz.
- Sampling at 1.25 Ghz.
- Clock recovery.
- Analog equalizer (optional to support longer cables).

It can be seen that there are no adaptive filters or complex coding like in 1000BASE-T. There is also no need for a high resolution ADC. This will make the transceiver much simpler.

3 Estimates for 1000BASE-CX

Unfortunately, the estimates from SEPHY Test Chip 2 (TC2) are not of much use to estimate the area and power of 1000BASE-CX as the blocks are completely different and the operating frequency is ten times that of 100BASE-TX. Therefore, the estimation is based on a SERDES design from ARQ that has a similar frequency and some common features. That device is expected to have an area of 16mm² and a power consumption lower than 550mW when implementing it on a 130nm node operating at a higher speed than 1000BASE-CX. Another reference is the Texas Instruments TLK2711-SP transceiver that has a power dissipation of 275mW when operating at 1.6 Gb/s [RD 5]. Therefore, it seems that it would be feasible to implement a 1000BASE-CX transceiver using Microchip 150nm node, the same used for SEPHY.

4 Comparison of 1000BASE-CX and 1000BASE-T

The estimates for 1000BASE-CX and 1000BASE-T for a 150nm technology node are shown in table 2. It can be observed that the 1000BASE-CX option has a significant advantage in terms of power. This, as discussed before, is a critical factor to enable the integration of multiple ports on a switch.

Mode	Power	Area
1000BASE-T	3568mW	25.8 mm²
1000BASE-CX	500mW	16.0 mm²

Table 2 – Comparison of 1000BASE-T and 1000BASE-CX for a 150 nm technology node.

Another important factor to have into account when selecting one option is the development cost as the space the market has low volume. The development cost of a rad-hard 1000BASE-T transceiver from scratch will require at least ten million euros [RD 3]. This is problematic for space ASICs. An option could be to start from an existing commercial IP of 1000BASE-T. However, there are few such IPs and most of them may be subject to ITAR restrictions even if the owner agrees to provide it (which will also have a significant cost). On the other hand, a 1000BASE-CX transceiver can have a development cost similar to that of SEPHY.

5 Conclusions

In the following, the main conclusions of the roadmap activity in WP7 are summarized in different subsections.

5.1 Transmission media and cable length

The choice of media to use at 1 Gb/s and above and the cable length supported needs to be revisited. This is due to a number of reasons:

1) The estimated power figures for a rad-hard 1000BASE-T transceiver are well above 1 Watt in current technology nodes. Even at lower nodes, consumption will be large.
2) The feedback gathered by the consortium from the industry during the development of SEPHY is that in most cases the channel will be much shorter than 100 meters.
3) The development cost of a 1000BASE-T transceiver from scratch (> 10million euros) will not be justified by the market size and is too large to be funded through RIAs.
4) There is limited availability of commercial IPs of 1000BASE-T transceivers and the cost of licensing will also be large. In many cases, the IPs are developed outside Europe and may be subject to ITAR restrictions.
5) Alternative options using short reach shielded cables or PCB traces can be implemented to support lengths of approximately 25 meters with lower power consumption and development costs.

Therefore, if a 1 Gb/s transceiver is to be developed in a short time frame (2-4 years) it seems that a 1000BASE-CX type transceiver should be targeted.

5.2 Technology node

The selection of the technology node depends heavily on the media and length choice. If a 1000BASE-T supporting 100 meters is chosen, then an advanced technology node should be used. It seems that Global Foundries 22nm would be the best choice. The issue is that the node currently does not support rad-hard mixed signal ASICs. On the other hand, if a 1000BASE-CX supporting a shorter distance is used, then Microchip´s 150nm node could be used at least initially. This would create synergies with SEPHY as all the EDA tools to support the node are in place and there will be no learning curve to use it. If a smaller node becomes available, then it could be also used.

From the previous discussion, it seems that the development of a 1000BASE-CX transceiver on 150nm is the fastest and lower risk option to get a European Ethernet transceiver at 1 Gb/s in the next 2-4 year time frame.

5.3 Evolution beyond 1 Gb/s

In the long term, data rates beyond 1 Gb/s will need to be supported. In that regard, UTP based solutions like 10GBASE-T will again result in a large power consumption (commercial PHYs are well above 1 Watt at 28nm) and development costs. Instead, SERDES based solutions scale better. For example, by adding equalization on the receiver, we could probably scale to 2.5 Gb/s reusing many blocks of the transceiver. Therefore, again it seems that a 1000BASE-CX like solution will provide an easier evolution to larger speeds.

References

[RD 1] C. Spurgeon, “Ethernet: The Definitive Guide”, Second Edition, O’Reilly Media, 2014.

[RD 2] IEEE Std 802.3-2015, IEEE Standard for Ethernet.

[RD 3] D7.1 Report on Requirements for space grade 1Gbps Ethernet transceivers, SEPHY project.

[RD 4] D7.2 Report on Technical feasibility of space grade 1Gbps Ethernet transceivers, SEPHY project.

[RD 5] TLK2711-SP 1.6-Gbps to 2.5-Gbps Class V Transceiver Datasheet, Texas Instruments, July 2006.