LIBERA GROUPING: REDUCING THE DATA ENCAPSULATION OVERHEAD

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Abstract

Libera Brilliance is a precision digital Beam Position Monitor, a building block for modern fast orbit feedback systems. Gigabit Ethernet and UDP/IP protocol are used as a standard data link for real-time beam position signal transmission to the central fast feedback CPU engines. While the UDP/IP over Gigabit Ethernet provides a standardized and proven solution that enables the utilization of COTS components, the UDP and IP protocols are subject to a large data encapsulation overhead, since the beam position data payload is relatively small. To overcome this, several Libera Brilliance units (up to 64) have been grouped together in a redundant private network via the LC optical links and/or copper "Molex" cables. The purpose of the private network is to exchange the data among the Libera Brilliance units without the protocol overhead and send the gathered data via Gigabit Ethernet. Any of the Libera Brilliance units in a group can act as a Gigabit Ethernet group transmitter.

The private network is redundant and can survive a single cable (double fibre) failure. The data encapsulation overhead has been significantly reduced, compared to standard Gigabit Ethernet solution. Libera Grouping is being tested at NSRRC, Taiwan [1].

INTRODUCTION

Libera development followed the needs of accelerator during their lifetime; first the Turn by Turn data was available for the commissioning needs, then the Slow Acquisition data followed for slow monitoring of beam movements. In addition, ADC rate data and decimated Turn by Turn data were offered to the user community. All these are available as a Libera standard feature. The Fast Acquisition data stream (typical data rate at 10k samples/s) is essential for fast feedback building. This data stream differs from all other types in one important thing; it requires predictable, low latency, dedicated type of connection and protocol. Standard 100 MBit Ethernet connection, which easily serves all other types of acquisition and is also used for complete control from the Control System, is not fast and deterministic enough. There are many possibilities of connecting Liberas around the ring [2,3]. The newest optional feature, which enables even faster communication between Liberas, is Libera Grouping.

FAST ORBIT FEEDBACK

Modern light sources rely on fast orbit feedback to stabilize the electron beam. Libera Brilliance is fast feedback ready and allows for easy integration into the fast feedback controller system via one of the two options:

- Gigabit Ethernet solution;
- Libera Grouping solution

Both solutions transmit the fast orbit feedback signals over the Gigabit Ethernet using the UDP/IP protocol. The UDP/IP protocol allows for standard commercial-off-the-shelf (COTS) component utilization for data distribution, while still maintaining the real-time data packet delivery to destination.

Gigabit Ethernet Solution

Gigabit Ethernet subsystem provides Fast Acquisition (FACQ) data formatting and interfaces to the Libera core to support minimal latency delivery of the FACQ data to the fast orbit controller system over Gigabit Ethernet physical interface.

The packets, being transmitted ofer the Gigabit Ethernet interface are standard UDP/IP packets. The data payload inside the UDP/IP packet is a single set of FACQ data of only one Libera: Va, Vb, Vc, Vd, Sum, X, Y, Q, Counter/Status. However, the minimal useable payload configuration is Sum, X, Y and Counter/Status. All the variables holding 32 bits (4 bytes).

Table 1: Data statistics of one Gigabit Ethernet UDP/IP packet.

UDP/IP	Payload	Total	UDP/IP overhead
42 bytes	9*4 bytes	78 bytes	54 %
42 bytes	4*4 bytes	58 bytes	72 %

Table 1 summarizes the packet content statistics for the Gigabit Ethernet solution for both the standard and minimal payload configuration.

Libera Grouping Solution

In a Libera Grouping solution, up to 64 Liberas are interconnected in a single redundant private network, communicating via SFP connections over LC-optics or copper crossover cables at 2.5 GHz.

The basic connection setup for three Liberas in a group is shown in Figure 1. In this Figure, Libera 0 works as a Master Libera and transmits the assembled Gigabit Ethernet data stream. The physical connection is bi-directional and done in circular mode. The Grouping connectors are SFP3 and SFP4 while the connector SFP2 is used for the Gigabit Ethernet output.

The Libera Grouping packets, being transferred over the private network are protocol-less and thus without overhead. Each Libera transmits a Libera Grouping packet on both SFP ports. Each Libera also retransmits the Libera Grouping packet and inserts it into the Gigabit Ethernet packet buffer for later transmission of the assembled Gigabit Ethernet packet. After N iterations, where N is the number of Liberas in the group, all the Liberas have the latest data assembled in their Gigabit Ethernet packet. A timeout is associated with the Gigabit Ethernet packet assembly completion in order to guarantee real-time Gigabit Ethernet packet transmission, though with partially valid data in case of timeout. Every Libera node from a group can serve as a group transmitter and is capable of transmitting the concentrated FACQ UDP/IP data stream over Gigabit Ethernet. However, the data order of appearance in the Gigabit Ethernet packet can differ according to the Libera Master selection.

Figure 2 depicts the Libera Grouping role in the context of the overall global fast orbit feedback system. The master Libera in a Libera Group transmits the assembled UDP/IP packets, carrying the data of all the Liberas in a group through a private network over the dedicated Gigabit Ethernet switch to one, or possibly many computational engines, acting on several corrector magnets.

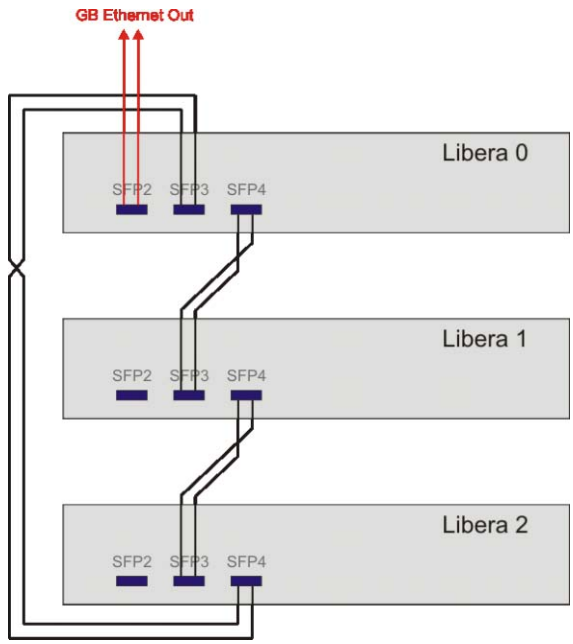

Figure 1: Libera Grouping connections.

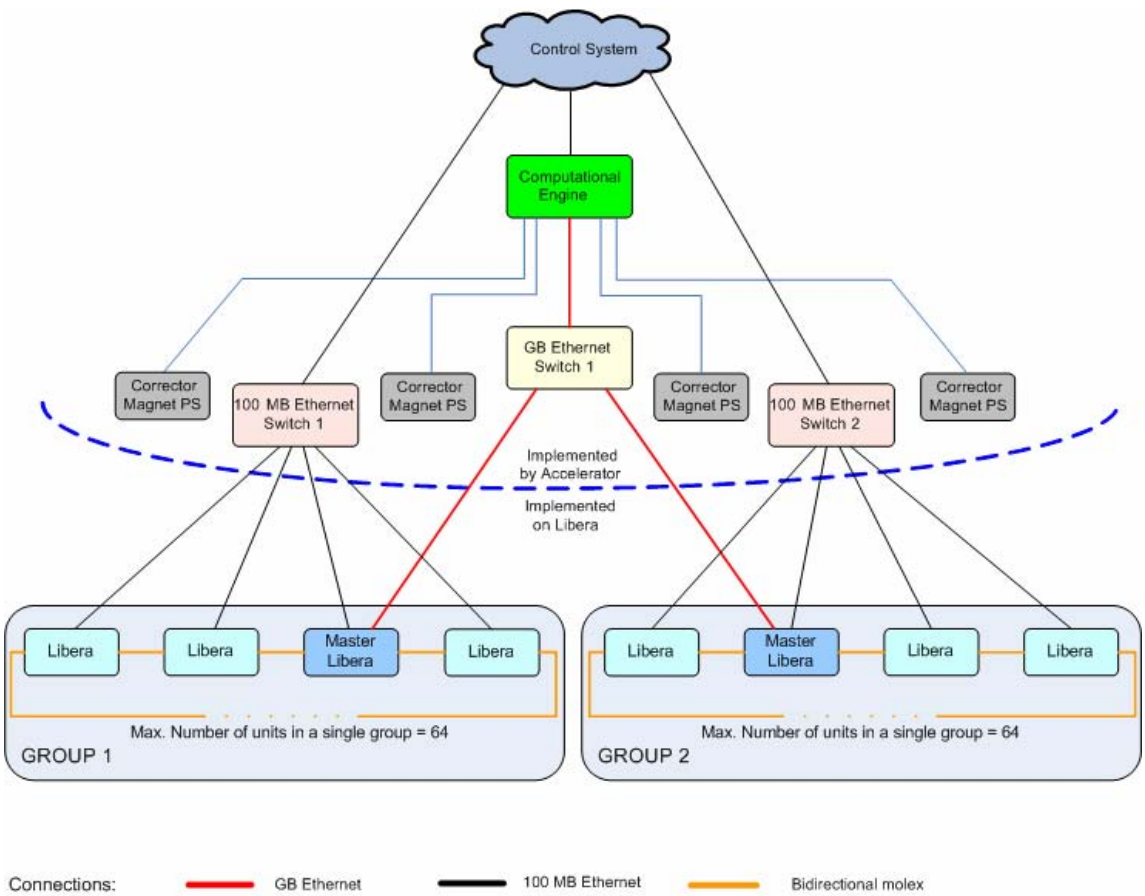

Figure 2: Libera Grouping and fast orbit feedback topology.

The data payload of the grouped UDP/IP packet in the Libera Grouping solution is an array of sets of FACQ data of multiple Liberas in a group as shown in Figure 3.

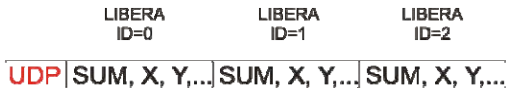

Figure 3: Libera grouping packet structure.

Again, the minimal useable and standard payload configuration is: Sum, X, Y and Counter/Status.

Table 2: Data statistics of one Libera Grouping UDP/IP packet.

UDP/IP	Payload	Total	UDP/IP overhead
42 bytes	64*4*4 bytes	1066 bytes	4 %

Table 2 summarizes the packet content statistics for the Libera Grouping solution for the standard payload configuration.

Redundancy

Libera Grouping solution supports two approaches for increasing the reliability of the global fast orbit feedback data distribution:

- Redundancy on the private Libera Grouping network level;
- Redunadancy on the Gigabit Ethernet upstream level

On the Libera Grouping private network level, the connections form two independent communication rings among the Libera nodes in the group. The data exchange can therefore survive a single link failure without loosing the data. It can even survive a double link failure, provided the broken links appear between the same two Libera nodes in the private Libera Grouping network ring.

On the Gigabit Ethernet upstream level, the transmission of the grouped FACQ data over the Gigabit Ethernet network is not limited to only one Libera node. Due to the Libera Grouping algorithm, all the Libera nodes in a group have the latest data assembled in their Gigabit Ethernet packet buffer and can therefore transmit the assembled FACQ data to the computational engines. Although, theoretically, all the 64 Libera nodes can transmit the grouped data, in practice it makes sense to only use two Libera nodes for redundancy purposes, transmitting over separate Gigabit Ethernet cabling, through separate COTS network switches.

CONCLUSIONS

The Libera Grouping solution for global fast orbit feedback data distribution has been described and compared to the standard, single Libera Gigabit Ethernet solution. By grouping the FACQ data of several Libera units into a single UDP/IP packet, the data encapsulation overhead due to fixed UDP/IP packet header, is reduced up to a factor of 7. The global fast orbit feedback network traffic is therefore significantly reduced. The user selectable redundancy has been demonstrated on several levels and allows for flexible FACQ data distribution system building, with varying degree of redundancy and reliability, according to the users cost/benefit/reliability plan.

REFERENCES

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