The CTT System (general)

communication protocols and data encoding

Version 6.1

This document is written as a result of lengthy discussions with members of the DØ Collaboration and after the Seattle Workshop.

Please read it carefully and send comments/ suggestions to J. Blazey, P. Grannis and M. Martin.

The DØ Collaboration at the Seattle Workshop adopted this final version !!

Created by Manuel J. Martin

General Notes

To make the viewing of this document more manageable I broke it into several parts as follows:

General	this document. It contains a general view of the System as a whole and the Protocols used by the different data links. These Protocols must be followed by any design of hardware/firmware/software dealing with elements of the Trigger System and by any other system that whishes to use the DFE Motherboard/Daughterboard design here presented.
CTT	A document dealing in detail with the L1CFT/CPS Axial, L2CFT and L2CPS Axial data transfers.
CPS	A document dealing in detail with the L2CPS data transfers.
FPS	A document dealing in detail with the L1FPS and L2FPS data transfers.
STT	A document dealing in detail with the L2STT data transfers.
μ-System	A document dealing in detail with the data transfers from the DFE to the L1 μ-trigger.
L3 Transfers	A document dealing in detail with the philosophy followed for data transfers to the L3 for monitoring and debugging purposes.

Each Document will be the subject of a DØ Note to be published in the near future

Glossary of terms

Track	**an object defined by hits in the eight CFT layers such that they fulfill one of the ≅16K predefined Boolean Equation for trajectories**
Isolated Track	**a Track that is the only Track in a 13.5^0 wedge**
Cluster	**an object formed by one or more consecutive PS strips with energy above a threshold**
H PS	**a cluster with hits above the High Threshold**
L Ps	**a cluster with hits above the Low Threshold**
electron	**a Track matched to a PS Cluster (H and/or L)**
Isolated electron	**an electron without other electrons in the corresponding 4.5^0 wedge or adjacent ones**
γ	**a PS cluster with no matched Tracks above a given Pt or upstream PS hits**
Isolated γ	**a γ with no other objects in the corresponding 4.5^0 wedge or adjacent ones**
Jet	**To be defined**

Glossary of terms

Frame	a set of bits (bytes) that are transferred in one tick of the clock controlling the transmission link.
Record	the set of consecutive Frames needed to transfer all the pertinent information of an event. The Record always includes a Trailer and some times a Header. The Record does not including Filler frames.
File	a Record with added Filler if necessary.
Data	set of consecutive Frames carrying the selected information about the collisions. The Data follows the Header (if there is one) and proceeds the Trailer.
Header	a set of consecutive frames located at the beginning of a Record which provide information relative to the interpretation of the Record.
Trailer	a set of consecutive frames located at the end of a Record. This provides a mean to determine the “goodness” of the transmission.
Filler	a set of consecutive ‘null’ frames that may be appended to the Record to fulfill requirements regarding the length of a File. This is used with the G Links only.

Types of Links used in the CTT System

The terms defined here are used to define a physical link between two pieces of hardware as well as the specific way to transmit data through the physical link.

FSCL Fast Serial Copper Link

Data is transmitted as electrical pulses through a balanced pair of conductors. Capable of sending signals at moderated distances (order of few meters). The transfer rates can be as high as 1.2 Gbit/s. The transmission has an error rate of the order of 10^{-14}. Negative impact: it can create ground loops that are a source of noise and unwanted couplings.

G Link Originally Glass Fiber Link

Fast Serial Link using Optical Signals over Glass or Plastic Fibers. Capable of transmitting signals over long distances (order of kilometers). Transfer rates of 1.2 Gbit/s. The transmission has an error rate of the order of 10^{-15}. Negative impact: cost and power consumption.

LVDS Low Voltage Differential Signal .

A hybrid between serial and parallel transmission of data. Several differential pairs are used to transfer information at high rates over short distances (order meters). The driver clock is carried over one differential pair. In the CTT four pairs are used for data with a driver clock of 53MHz. With these parameters, the transfer rate is 1.8 Gbit/s. The transmission has an error rate of the order of 10^{-12}. Negative impact: high error rate.

General Notes about the CTT System

The LVDS links between the Analog Front End boards and the Mixer or the Digital Front End boards do not use Headers in their protocols.

The LVDS links between the Analog Front End boards and the Mixer or the Digital Front End boards do not generate Transverse Parity. Thus, the error rate could be as high as 10^{-12}. This is tolerable because a wrong bit does not carry more penalty that the one incurred by electrical noise.

L1 information must be transferred from board to board in no more than 132ns.

L2 information going from the Digital Front End boards to the Collector or Broadcaster boards is sent through the same physical links as the corresponding L1 information. Physical links are time-shared.

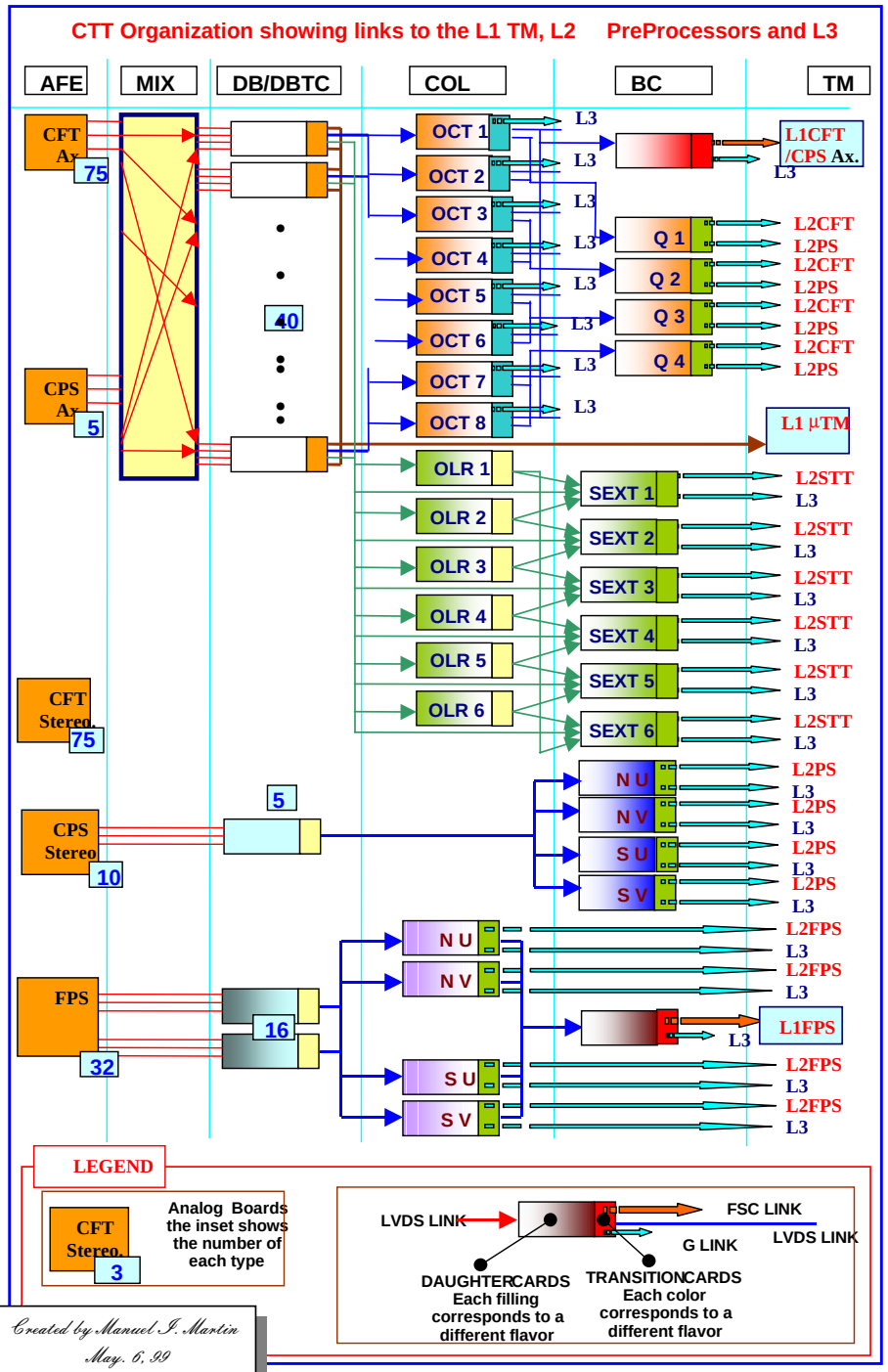

Diagram of the CTT System.

For a better view go to Manuel's Web pages at

http://D0server1.fnal.gov/users/manuel/protocols/diagram.doc

GLOSARY

AFE	Analog Front End Board
MIX	Mixing Box
DB	Digital Board
DBTC	DB Transition Card
COL	Collector Board
BC	BroadCaster Board
TM	Trigger Manager
OCT	COL serving an Octant
Qx	BC serving Quadrant x
OLR	COL serving the Overlapping Regions of the SI match
SEXT	BC covering a Sextant
N/Sx	board serving the North/South side
xU/V	Refers to the U V orientation of the PS strips

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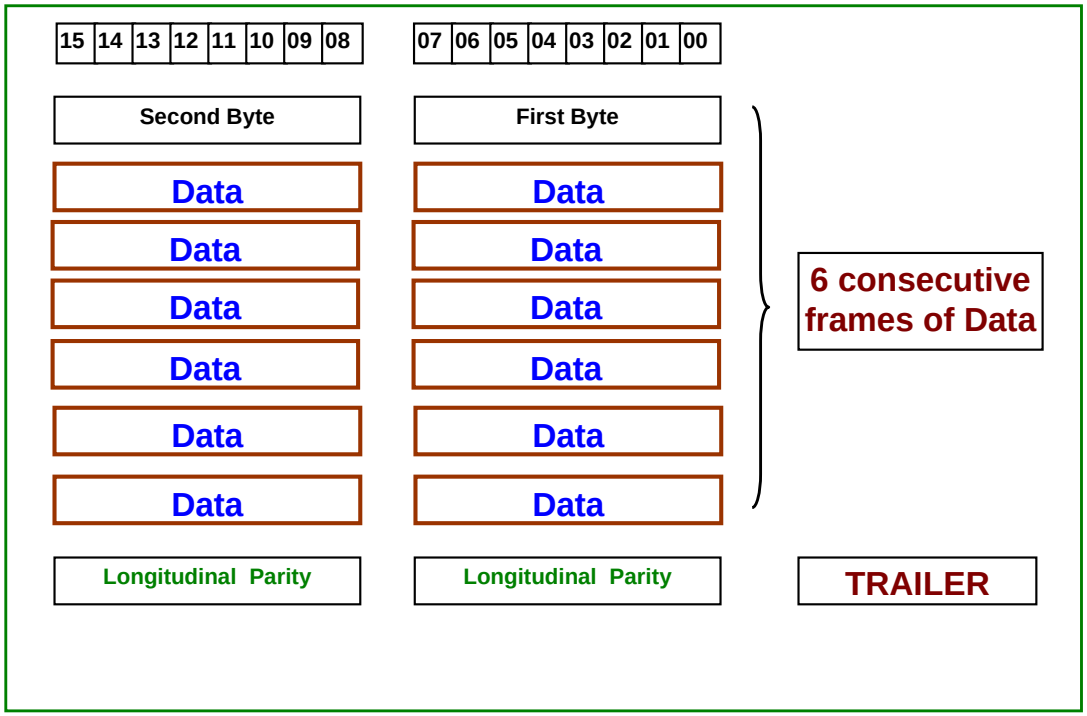
Glossary of terms

AFE Board	the Analog Front End Board collects analog signals from the VLPCs, integrates them and generates the necessary digital trigger signals from them. This board also holds the SVX II that performs the A/D conversion of the integrated signals.
Motherboard	a digital board common to all subsystems. This board supports one or two Daughterboards, up to 10 LVDS input links, a VME interface , Backplane communications and up to four independent 24bit (+4) wide output buses.
Daughterboard	digital boards where all the functionality specific to a subsystem resides. These boards hold several FPGAs with the unique firmware required for the function(s) assigned to it.
Transition Card	a card dedicated to perform the necessary signal conditioning to convert the serial data from the four output buses to LVDS and G Link or FSC Link signals.

Protocol for transfer of data via FSC Link

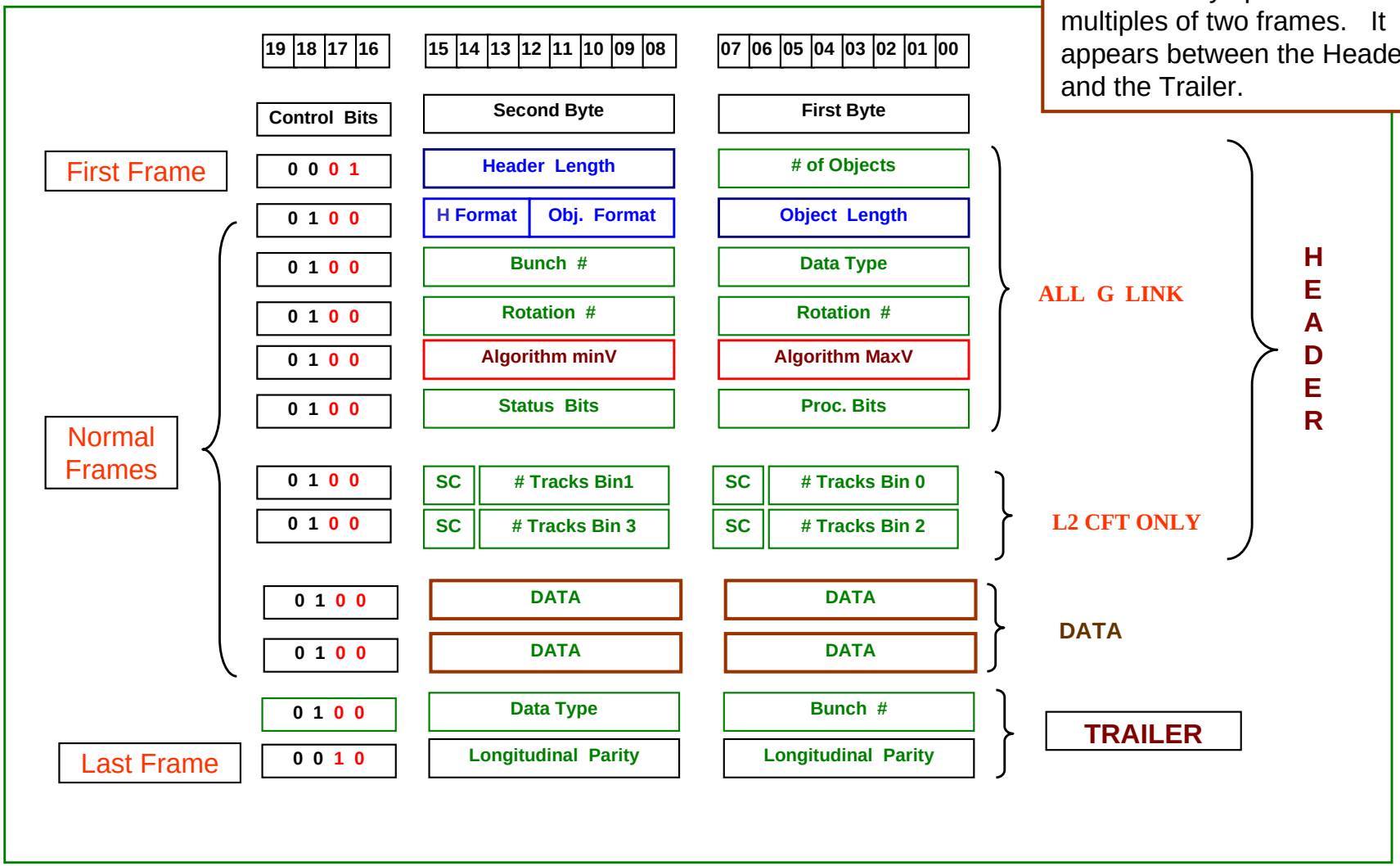


This protocol was adopted by the µ group and it is used only to interact with hardware designed by the µ group.

The major disadvantages of this protocol are the lack of Header and the lack of means to recover synchronization if it is lost. Synchronization can be recover only during the "gaps" on the collider beams.

Protocol for transfer of data via G Links

Data is always presented in multiples of two frames. It appears between the Header and the Trailer.



Glossary of terms

Header Length	Number of Words (2 frames per word) of header (3 or 4)
# of Objects	Number of physical objects (tracks, clusters, etc.). An object requires a minimum of a full word (two frames) or a multiple thereof. (0 to 48)
Header Format	Defines the structure of the header (1, 2)
Object Format	With the Data Type defines the bit pattern of the object (1, 2)
Data Type	What Type of data (CFT, CPS, etc)
Algorithm MaxV	Not used. Relates to the ALPHAS
Algorithm minV	Not used. Relates to the ALPHAS
Proc. Bits	Code to define the Firmware version used (1 to 255)
Status Bits	Specific code providing information about the data transferred

Status Bits

Bit 7	Error of any kind
Bit 6	No processing attempted
Bit 5	Data is truncated
Bit 4	Detected errors in received data stream
Bit 3	Not defined
Bit 2	Not defined
Bit 1	More Data Type information
Bit 0	Set to 0 for normal data set to 1 when special data is sent.

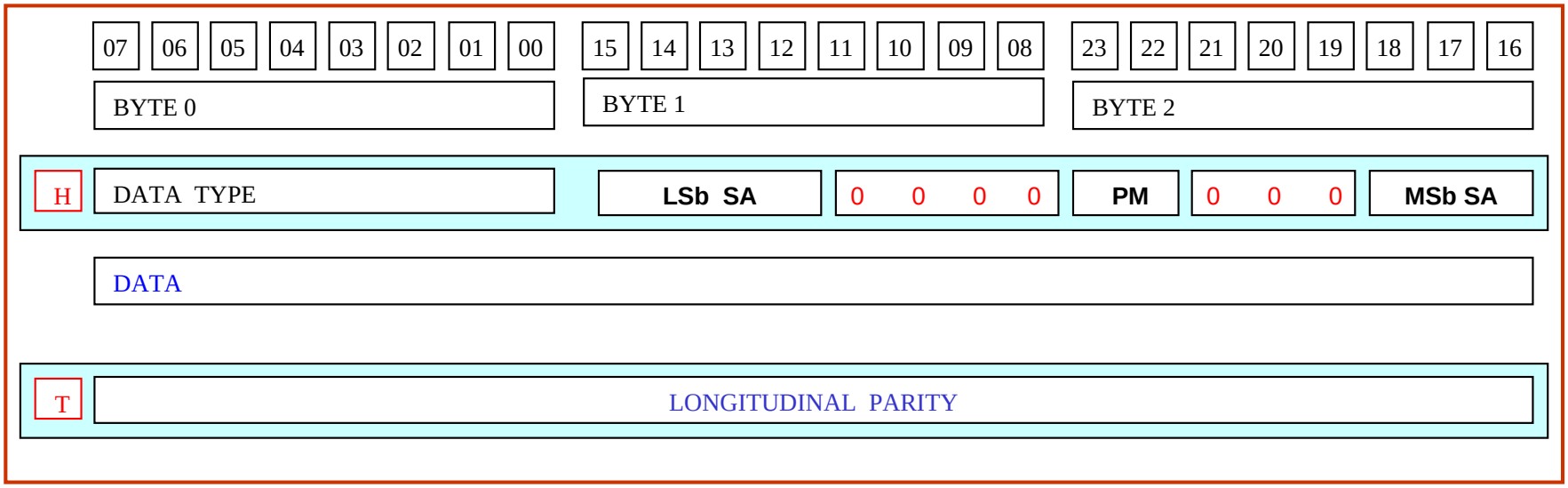
Glossary of terms

Data Type Used by the G Link Protocols

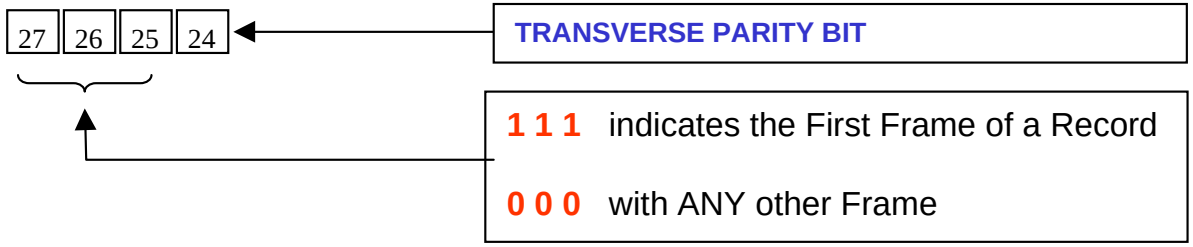
CFT Quadrant 1	162	CPS Axial Quadrant 1	130
CFT Quadrant 2	163	CPS Axial Quadrant 2	131
CFT Quadrant 3	164	CPS Axial Quadrant 2	132
CFT Quadrant 4	165	CPS Axial Quadrant 2	133
STT Sextant 1	166	CPS Stereo NU	134
STT Sextant 2	167	CPS Stereo NV	135
STT Sextant 3	168	CPS Stereo SU	136
STT Sextant 4	169	CPS Stereo SV	137
STT Sextant 5	170	FPS Stereo NU	138
STT Sextant 6	171	FPS Stereo NV	139
		FPS Stereo SU	140
		FPS Stereo SV	141

It is the responsibility of the Collector/Broadcaster Boards' Firmware to insert the proper Header in the data stream.

Protocol for transfer of L1 data via LVDS Links between DFE and COL and between COL and BC



CONTROL BITS



NOTE

L1 Data Transfers between Collector Boards and Broadcaster Boards do not use Header information

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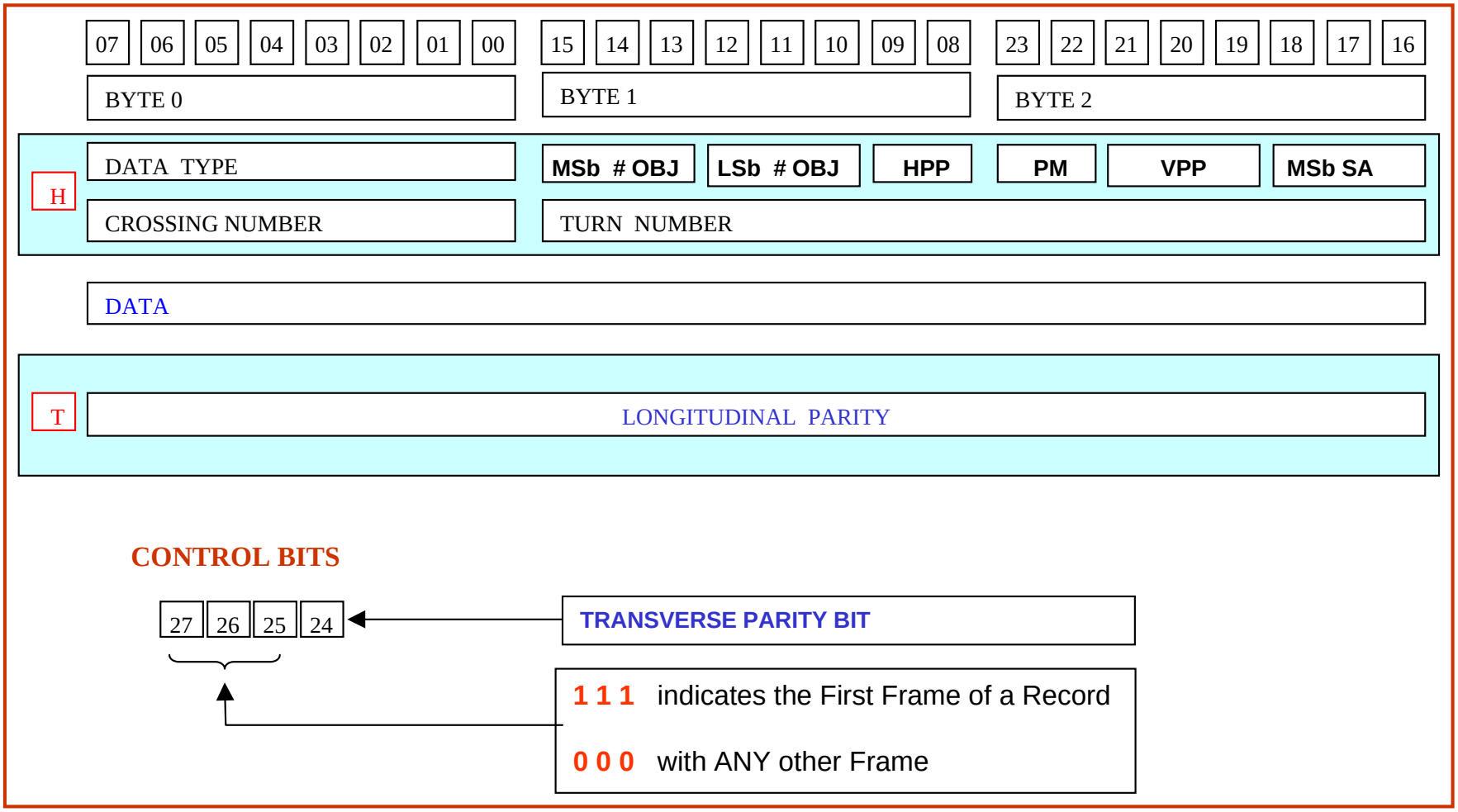
Protocol for transfer of L2 data via LVDS Links between DFE and COL and between COL and BC



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Glossary of terms

Data Type	What Type of data (CFT, CPS, etc).
MSb # OBJ	The three Most Significant bits of the number of Data Frames carrying data. It does not include Header or Trailer frames.
LSb # OBJ	The three Least Significant bits of the number of Data Frames carrying data. It does not include Header or Trailer frames.
LSb SA	The four Least Significant bits of unique number identifying the geographical position of the "source" of the data.
MSb SA	The three Most Significant bits of unique number identifying the geographical position of the "source" of the data.
TM	Code for Pass and Mark and debugging.

Notes about the LVDS Links

* With the exception of the links between the Mixer Board and the Digital Boards, error rates higher than $\approx 10^{-15}$ are not acceptable. Because the LVDS error rate ($\approx 10^{-12}$) is too high, special measures are taken to ensure transfers with virtually no errors.

* The usage of Longitudinal and Transverse parity permits to correct any single error in a transmission and detect any double error. This makes the transmission of data using the LVDS practically error free. After correction for single errors, the error rate is $\approx 10^{-24}$.

* Because the Longitudinal error is not available until the end of the record, special codes are used for Data Type and # of Objects. This is necessary because the Firmware must make decisions about how to treat the data based on these two Header fields.

    * The codes used for Data Type are self-correcting in the sense that a single bit error results in a code whose original value is known. The codes used are presented in the next page.

    * The # of Objects is coded as a normal 6 bit binary but it is though of a 3x2 matrix with 2 Transversal Parity bits (**HPP**) and 3 Vertical Parity bits (**VPP**).

It is easy to see that both schemes result in codes whose original value can be inferred even after a single bit error.

Special Codes for Data Type

	07	06	05	04	03	02	01	00	
	TRIGGER			SOURCE					
L1	1	0	1	0	0	1	0	1	L1 CFT/CPS Axial
	1	0	1	0	0	0	1	0	L1 FPS
	1	0	1	0	1	0	0	0	L1 Forward Proton
L2	0	1	0	0	0	1	0	1	L2 CFT
	0	1	0	0	1	0	1	0	L2 CPS Axial
	0	1	0	1	1	1	0	1	L2 STT
	0	1	0	1	0	0	1	0	L2 CPS Stereo
	0	1	0	0	0	0	1	0	L2 FPS

Any single error can be corrected without Parity checks