Correlator Data Processor

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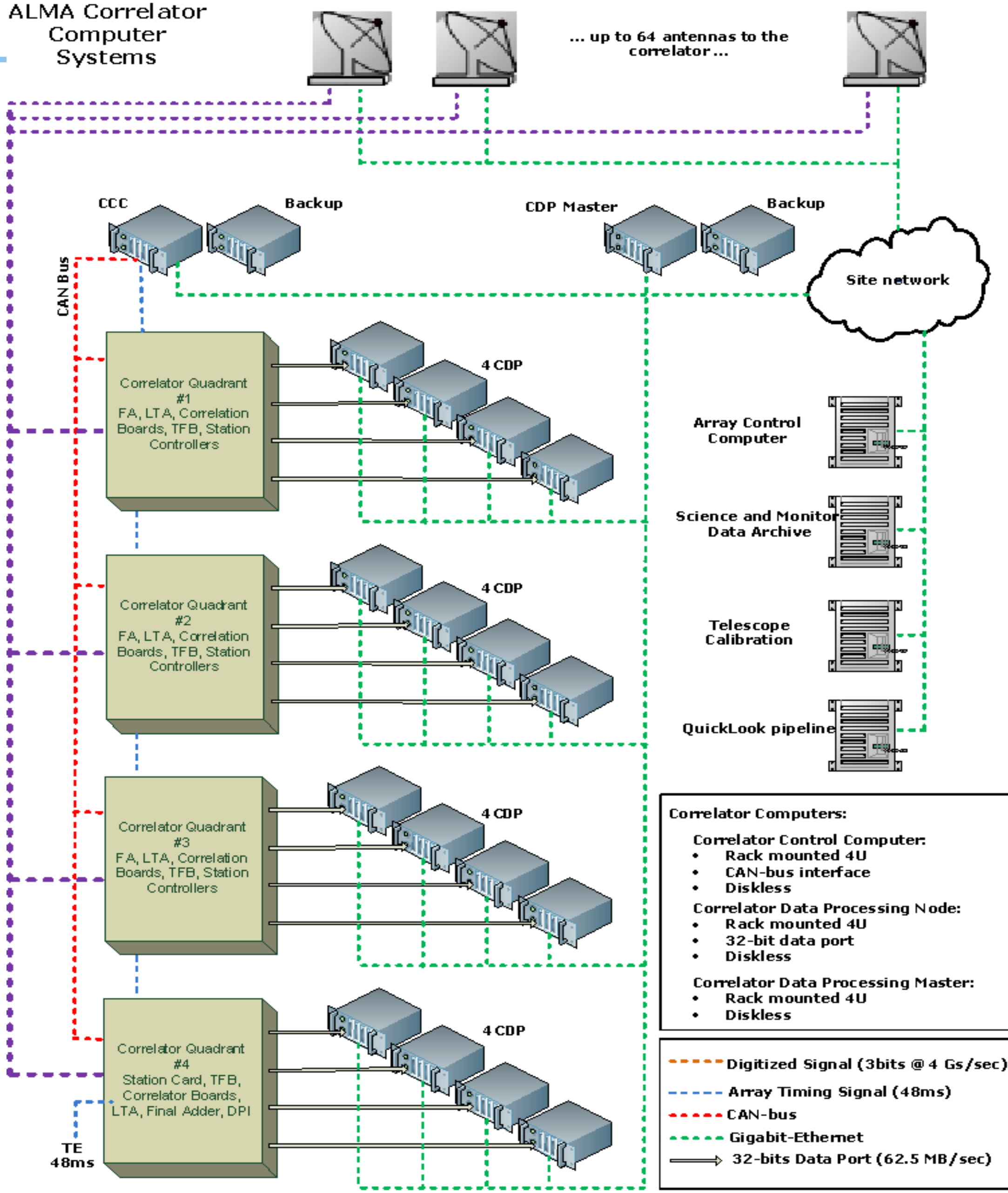
Atacama Large Millimeter/submillimeter Array
Karl G. Jansky Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

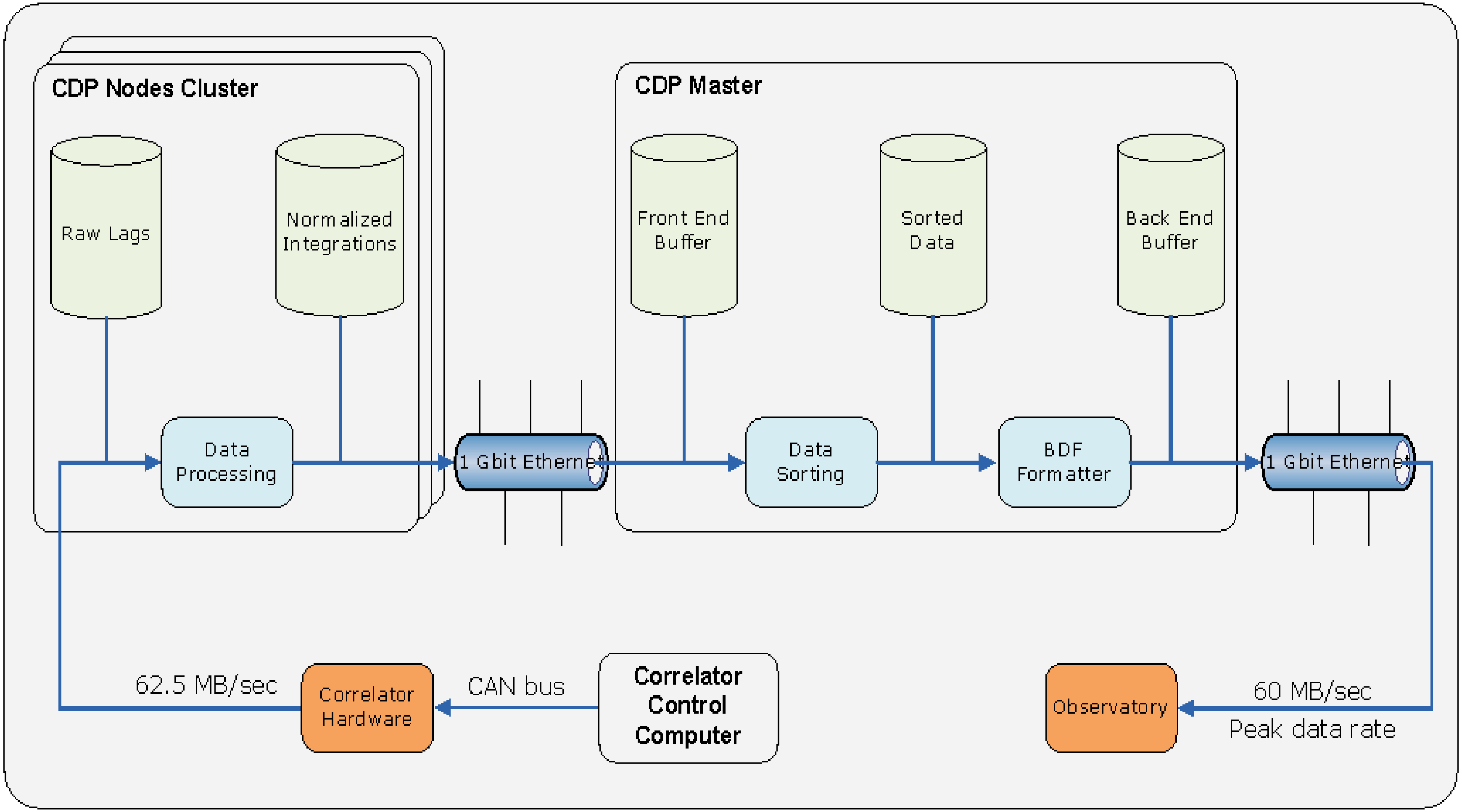
Outline

- Cluster overview
- Data acquisition: hardware interface, data content and handling in software, lags normalization.
- Data processing: on-line calibration and transformation from normalized correlator lags to auto-correlations and visibilities.
- Data delivery: data collecting from nodes and formatting into a binary data format suitable for storage.

ALMA Correlator Computer Systems

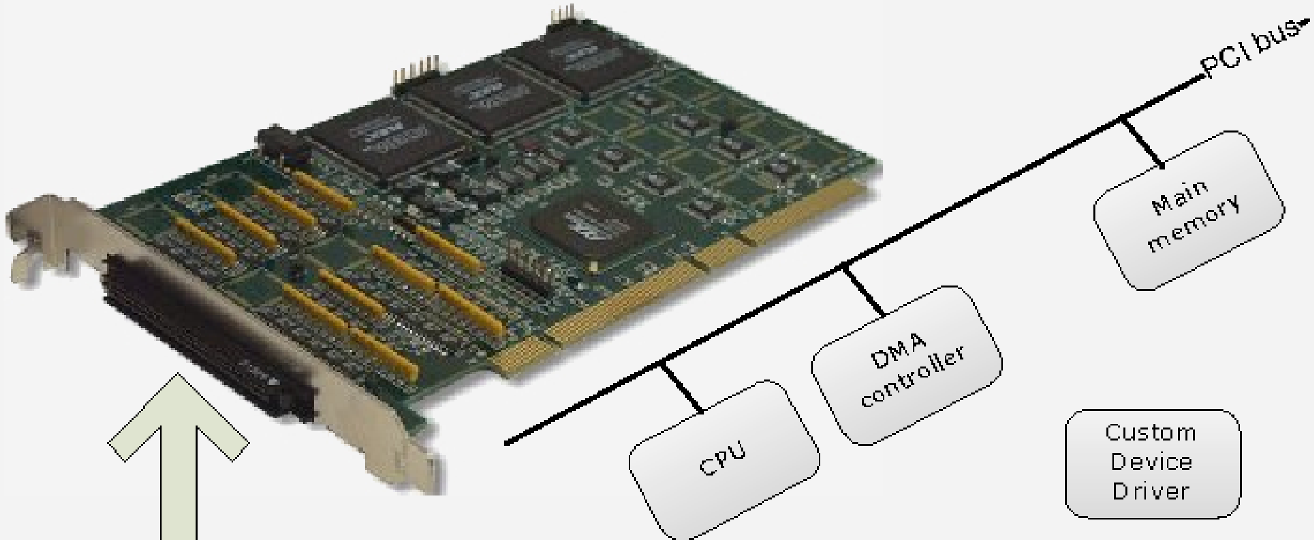


CDP Application Deployment



Data Acquisition

Data Port Interface



LVDS cable

DPI
Microcontroller and FPGA

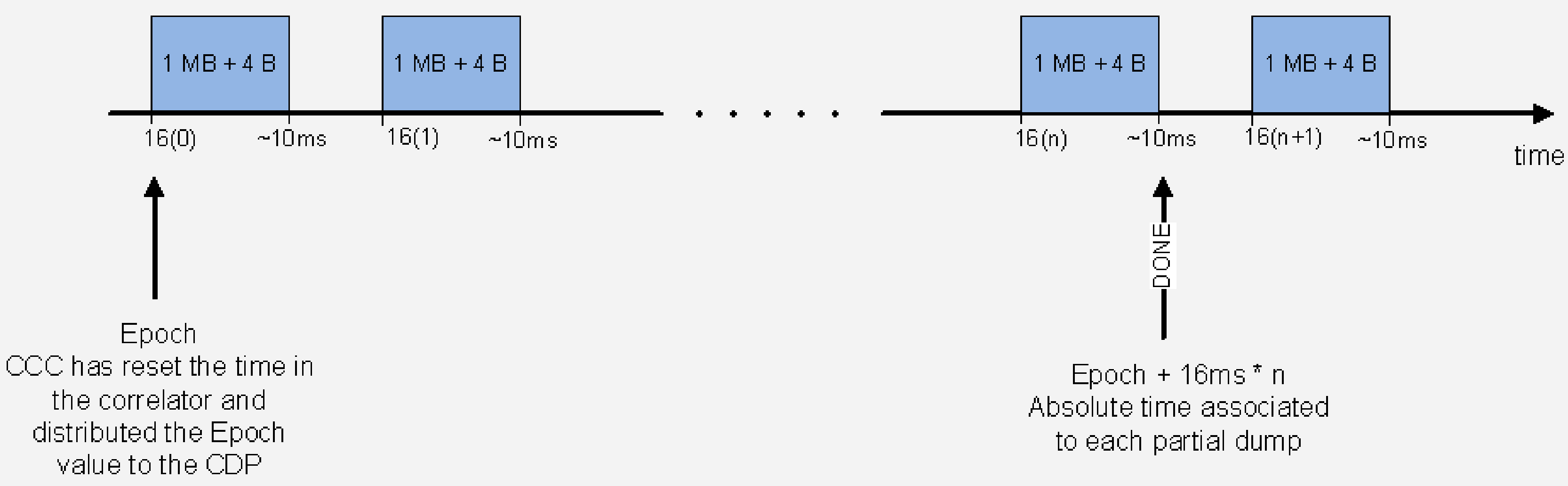
32 parallel bits
+
Protocol handshaking
and
GPIOs

General Standards Corporation
PCI64-HPDI32
High-speed 64 Bit Parallel Digital I/O PCI Board
LVDS transceivers
64-Bit, 66MHz PCI v2.2 compliant
512 Kbytes FIFO

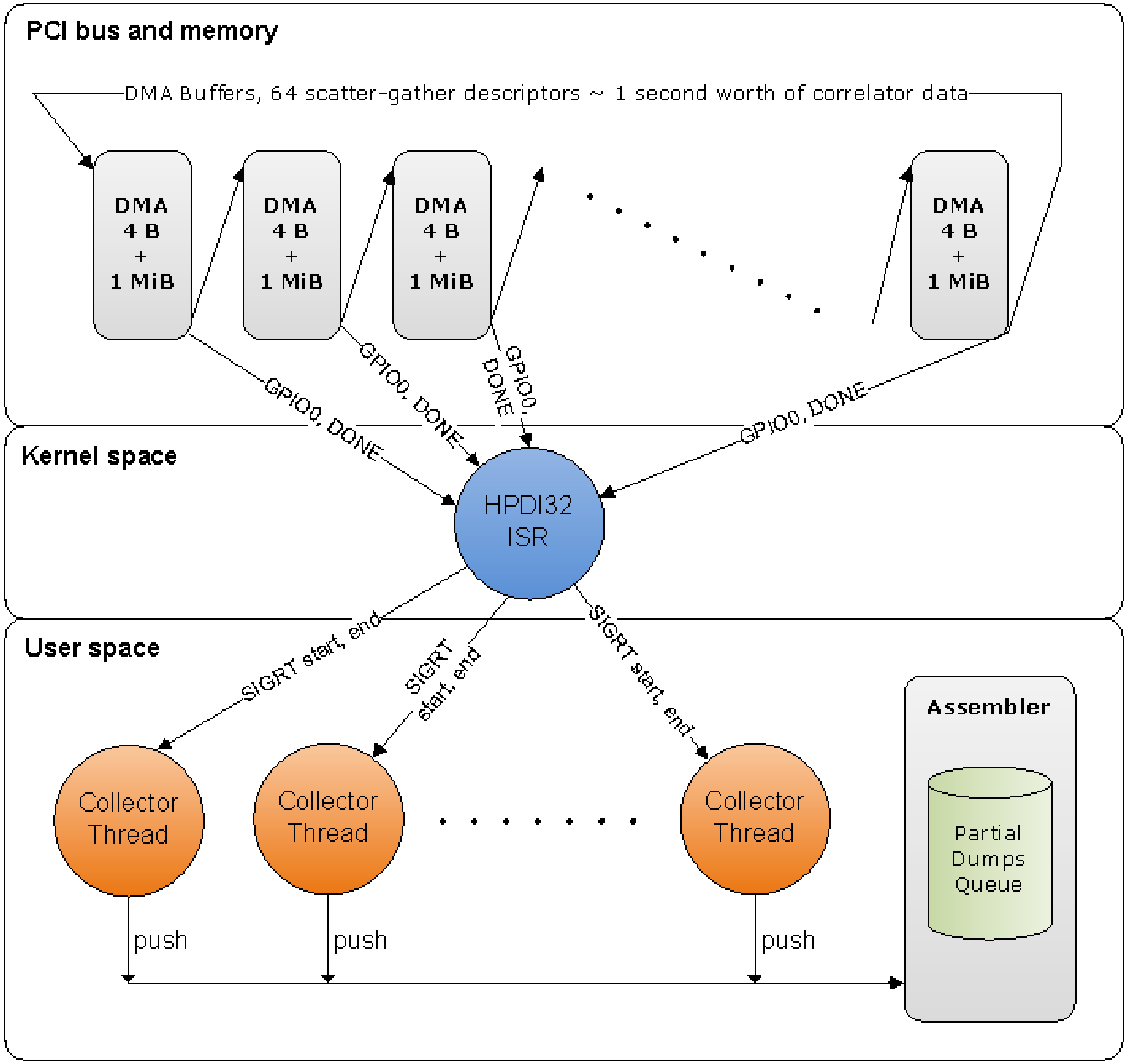
Hardware Time Stamp to Absolute time

Decoding a hardware timestamp into an absolute time value

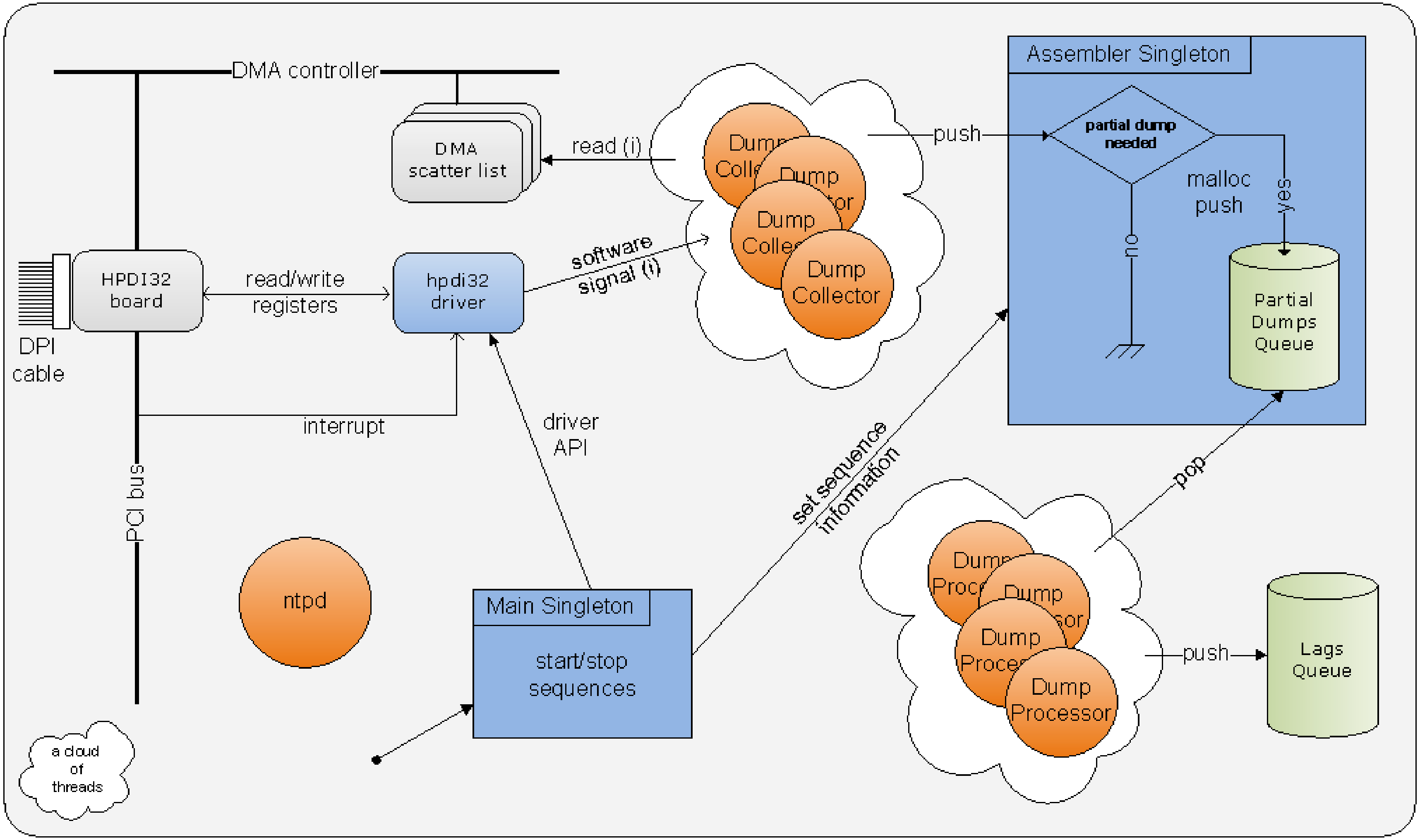
The key idea for a hardware time stamp, embedded within each correlator dump, is to remove real-time requirements from the CDP. Simplifying its overall implementation and maintenance effort. Once the system has been properly initialized by the CCC, then, figuring out an absolute time stamp for every received dump is as simple as shown below.



From DMA to Application Memory



Lag Processing Overview



Data Processing

Raw Lags from the Correlator

2-bit sampling per antenna

Analog → (4 Gsp)

Voltage	Binary	Weight
$v_l \le v$	0-1	+3
$0 \le v < v_l$	0-0	+1
$-v_l \le v < 0$	1-1	-1
$v \le -v_l$	1-0	-3

TDM

$$20 \log 10 \left(\frac{2.02}{1.71} \right) \approx 1.4\, dB$$

2-bit → (4 Gsp)

Correlator
Multiplication table and accumulation

	0-1	0-0	1-1	1-0
0-1	9	6	3	0
0-0	6	5	4	3
1-1	3	4	5	6
1-0	0	3	6	9

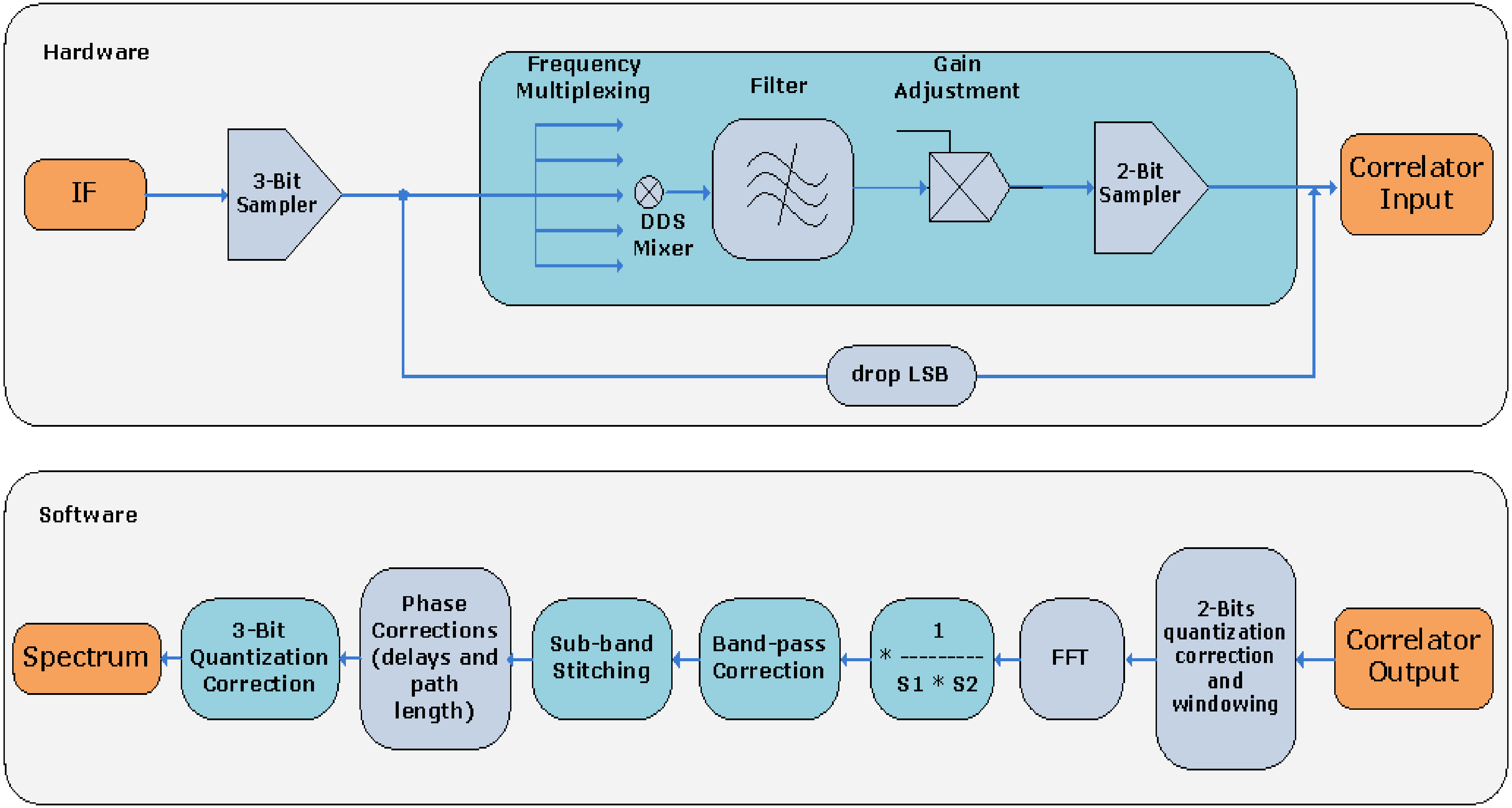
bias implies Vs

32-bit → (250 MiLags/sec)

$L(\tau)$
raw correlation function

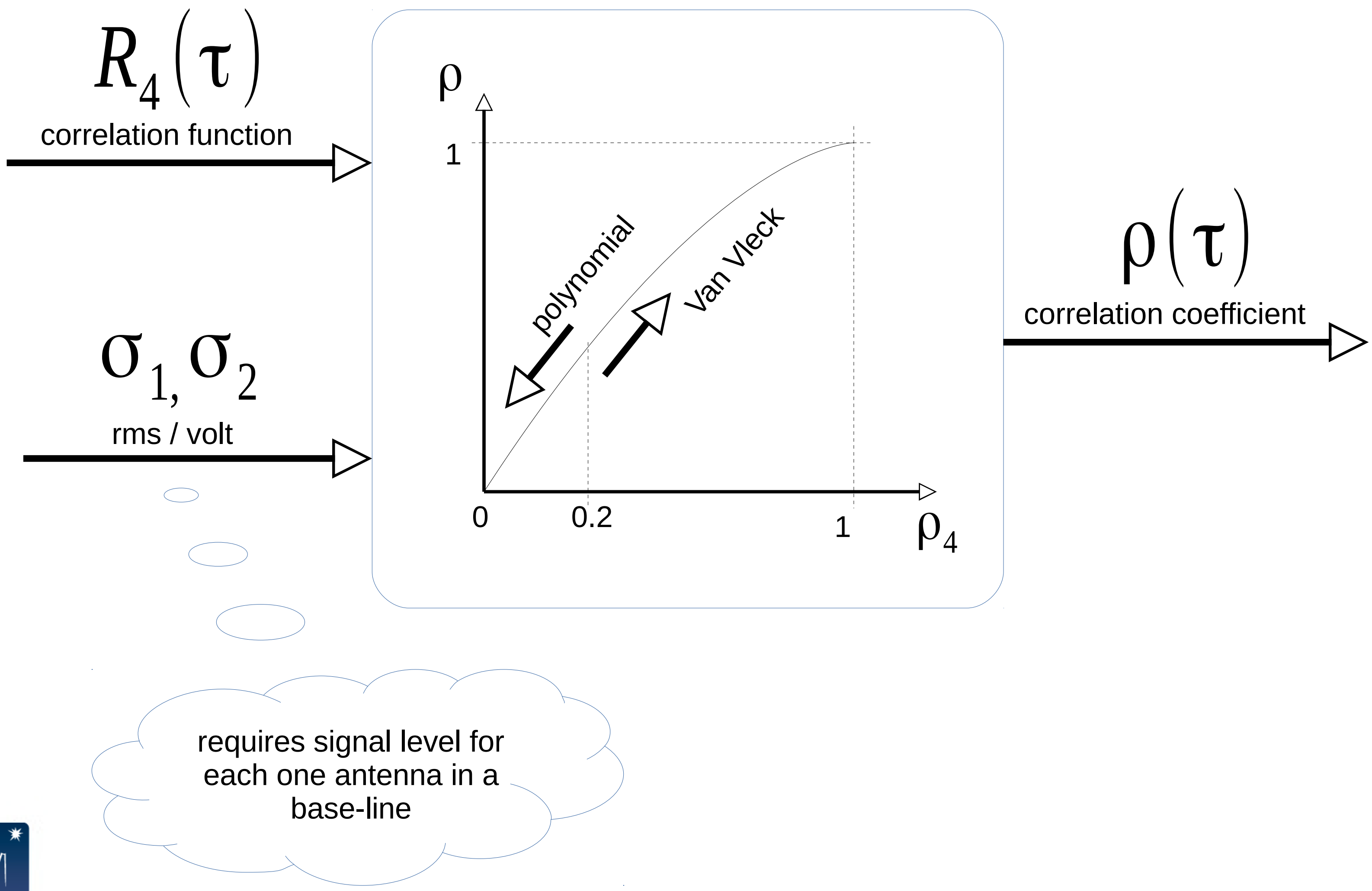
32-bit integers → (250 MiLags/sec) → CDP → 32-bit floats → (8e6 visibilities/sec) → BDF blobs within ASDM

Data Processing Stages

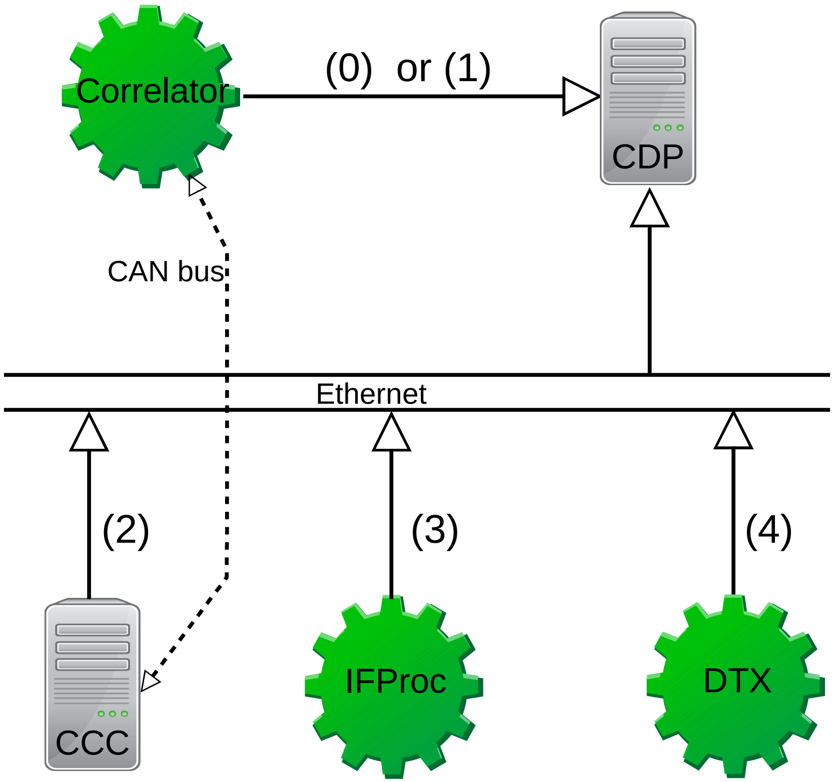


© original diagram from Gianni Comoretto's ALMA memo #583.

2x2-bit Quantization Correction



Options to Access Total Power On-line



(0)
current TDM lag zero available on every correlator dump.

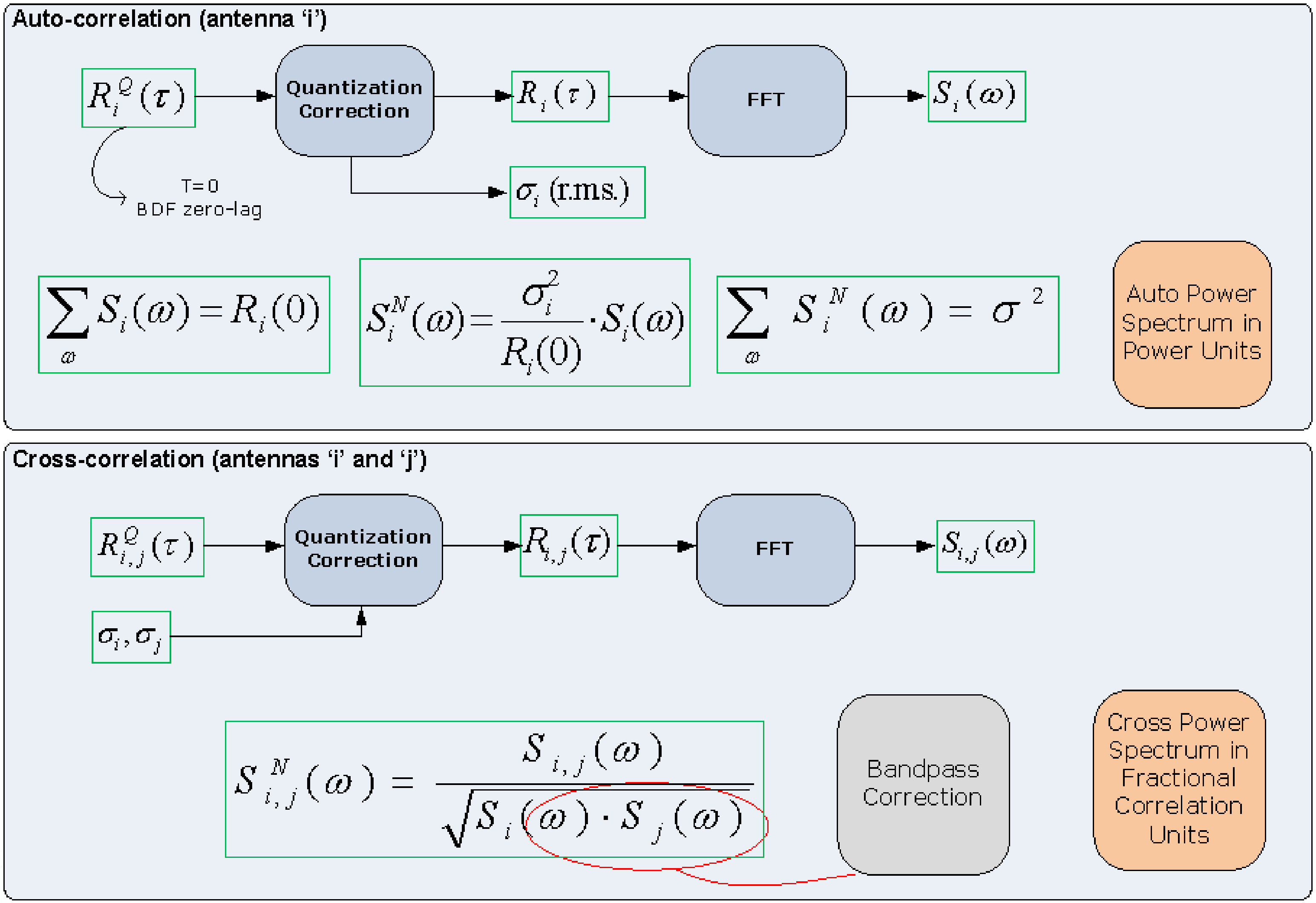
(1)
3-bit population counts added to dumps' meta-data. It would imply just 8 additional integer values per antenna.

(2)
CCC retrieves population counts through specific CAN bus protocol and forwards to CDP (ICT-1683)

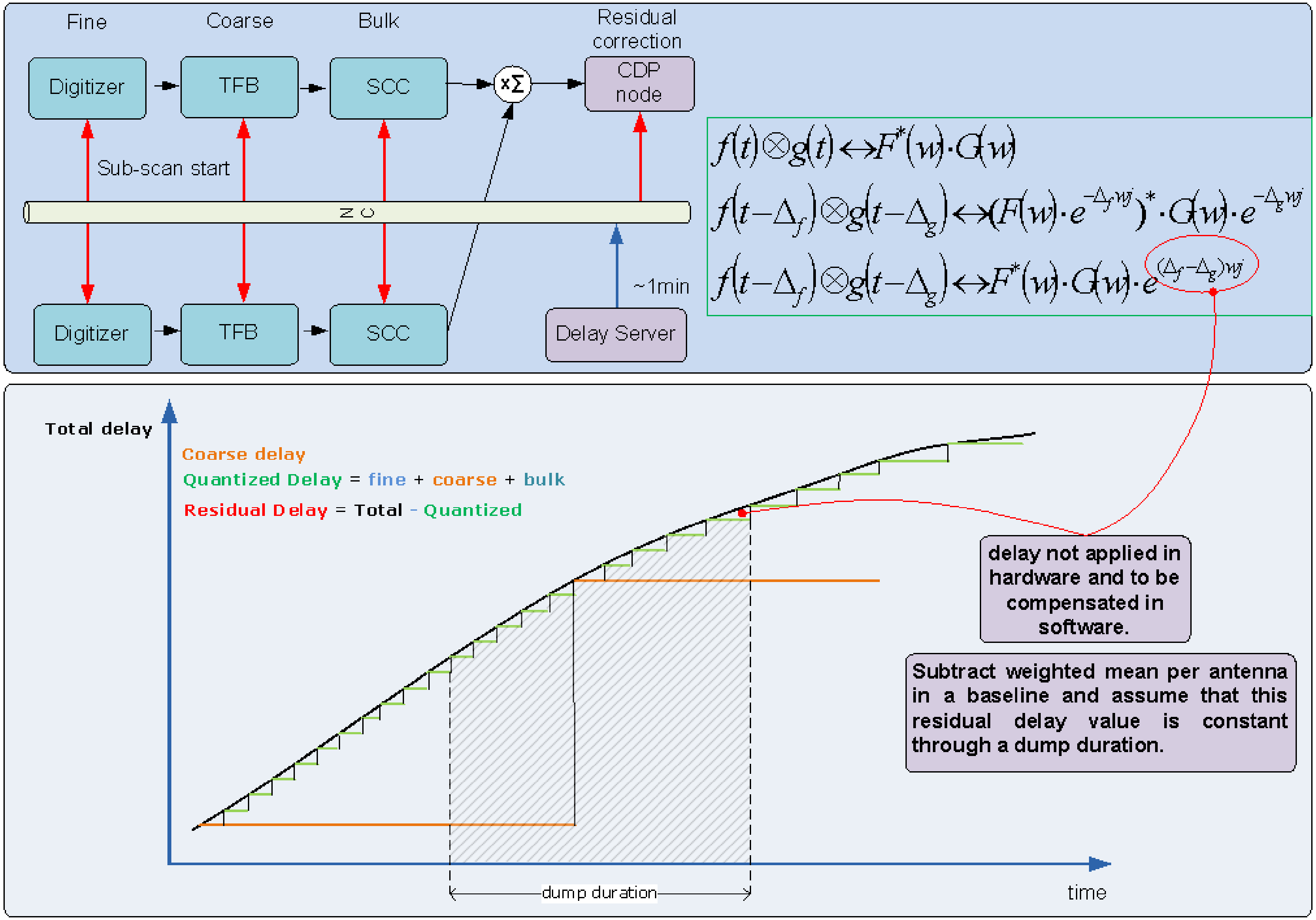
(3) & (4)
devices such IFProc (full fledged square law detector) or DTX could either publish already computed total power figures or population counts, respectively.

DTX: digital transmitter
IFProc: intermediate frequency processor

Spectral Normalization

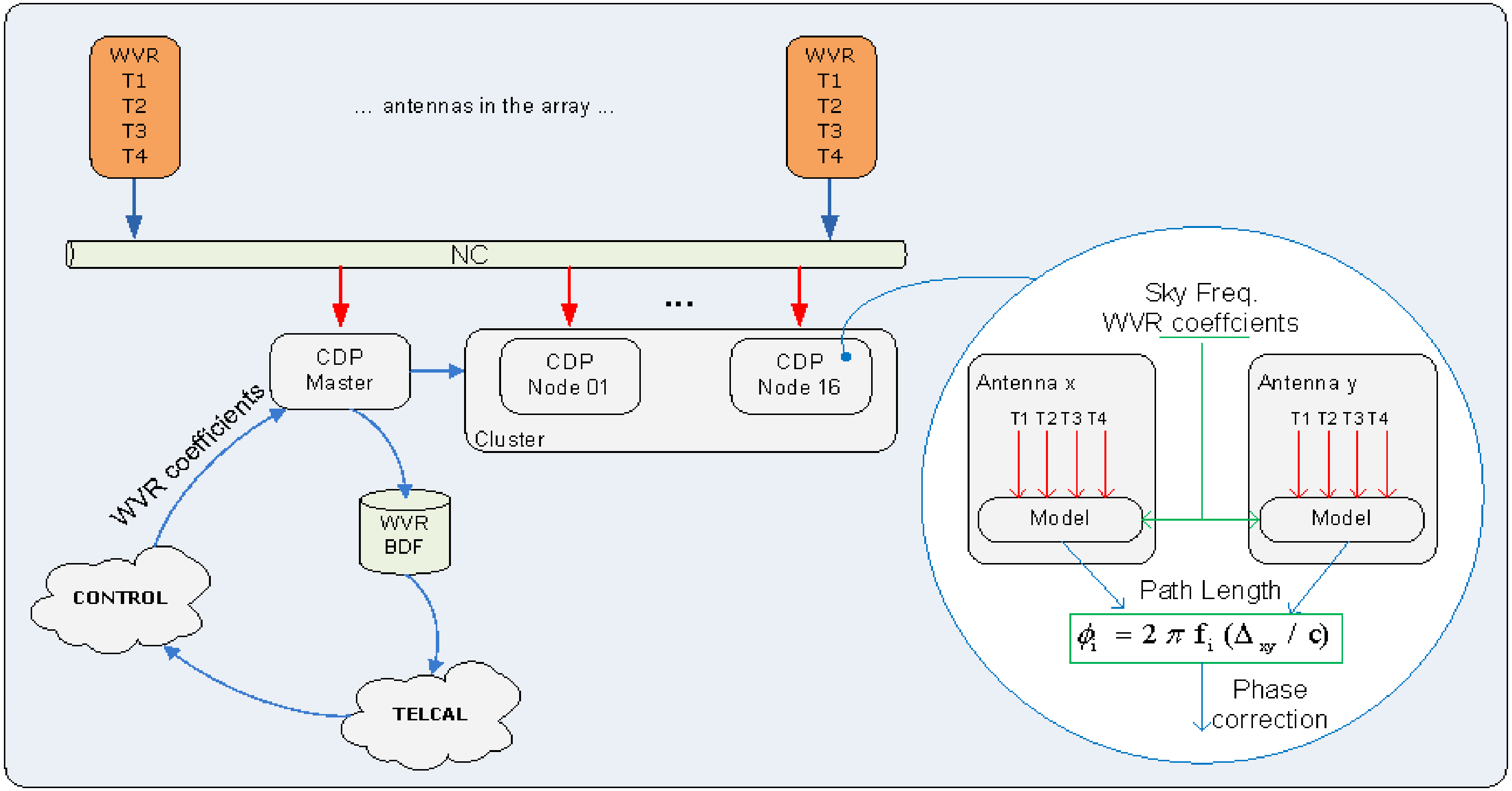


Residual Delay Correction



Atmospheric Path Length Correction

- Each 12m antenna has a 183 GHz Water Vapor Radiometer.
- WVR units produce sky brightness temperature measurements around the 183 GHz water emission line.
- Sky brightness temperature measurements let's TELCAL produce phase correction coefficients.
- Correction coefficients are used, per antenna, to model phase fluctuations across the observed IF.
- Coefficient updates received by the correlator software on scan boundaries.
- Phase corrections applied by the correlator software on each correlator dump.

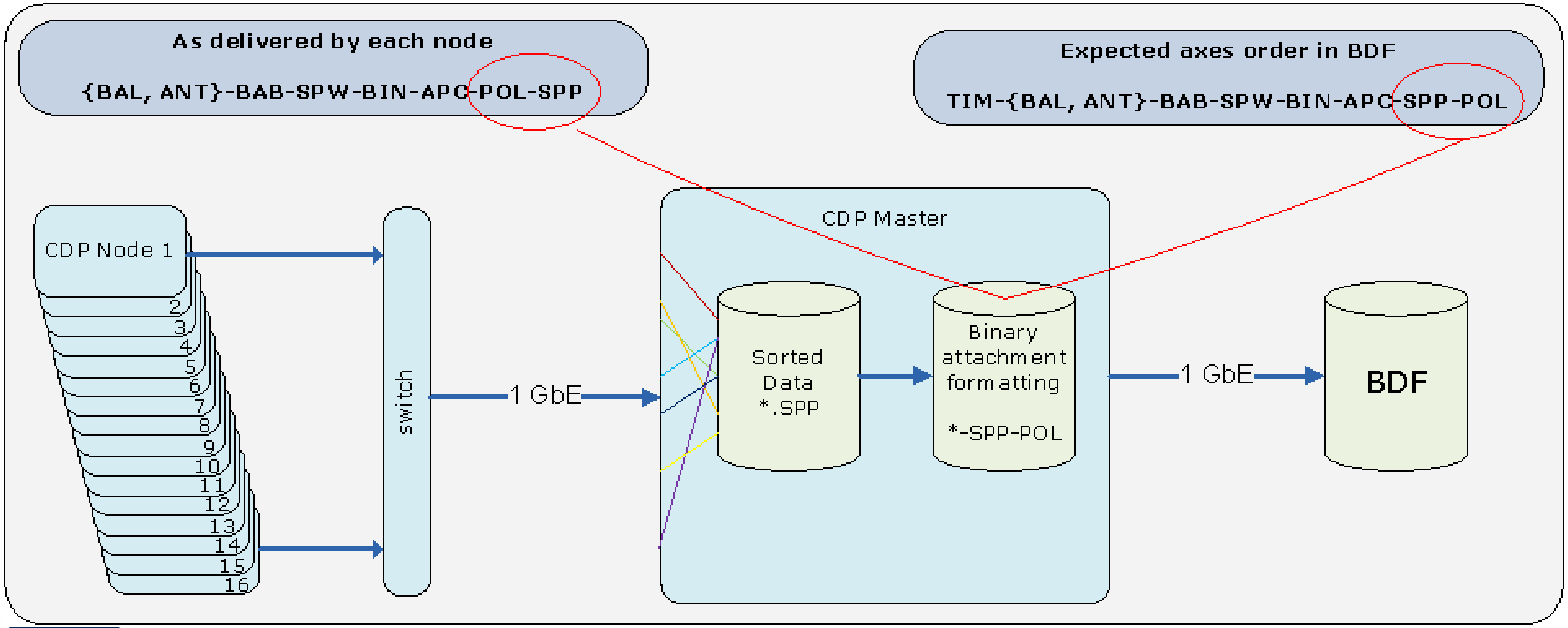


Data Delivery

Incremental Binary Data Formatting

- Nodes send data as integers and as soon as they are ready with it.
- Resize to 32-bit visibilities as required.
- Different nodes handle different base-bands and base-lines within that base-band.
- FFT implemented on continuous floating point arrays. BDF enforces spectral channel axis to be one level above polarization products.
- Data axes must be in BDF order.

- TIM – time
- BAL, ANT – base-line
- BAB – baseband
- SPW – spectral window
- BIN – bin
- APC – corrected or uncorrected by WVR
- SPP – spectral channel
- POL – polarization product



Flagging and Blanking

Bit	Name	Reason	Implies blanking
0	INTEGRATION_FULLY_BLANKED	Empty integration	Yes
1	WVR_APC	WVR coefficients not received.	Yes
2	CORRELATOR_MISSING_STATUS	Correlator status not received.	Maybe
3	MISSING_ANTENNA_EVENT	Antenna delay event was not received.	Yes
5	DELAY_CORRECTION_NOT_APPLIED	Residual delay correction was not applied.	Yes
6	SYNCRONIZATION_ERROR	CDP node(s) not properly synchronized	N/A
8	TFB_SCALING_FACTOR_NOT_RETRIEVED	TFB scaling factor not available.	No
9	ZERO_LAG_NOT_RECEIVED	Cross CDP node has no auto data.	No
12	QC_FAILED	Quantization correction failed.	No
13	NOISY_TDM_CHANNELS	First TDM channels clipped in software.	No
14	SPECTRAL_NORMALIZATION_FAILED	Cross-correlation not normalized.	No
31	ALL_PURPOSE_ERROR	Used for troubleshooting purposes.	Maybe

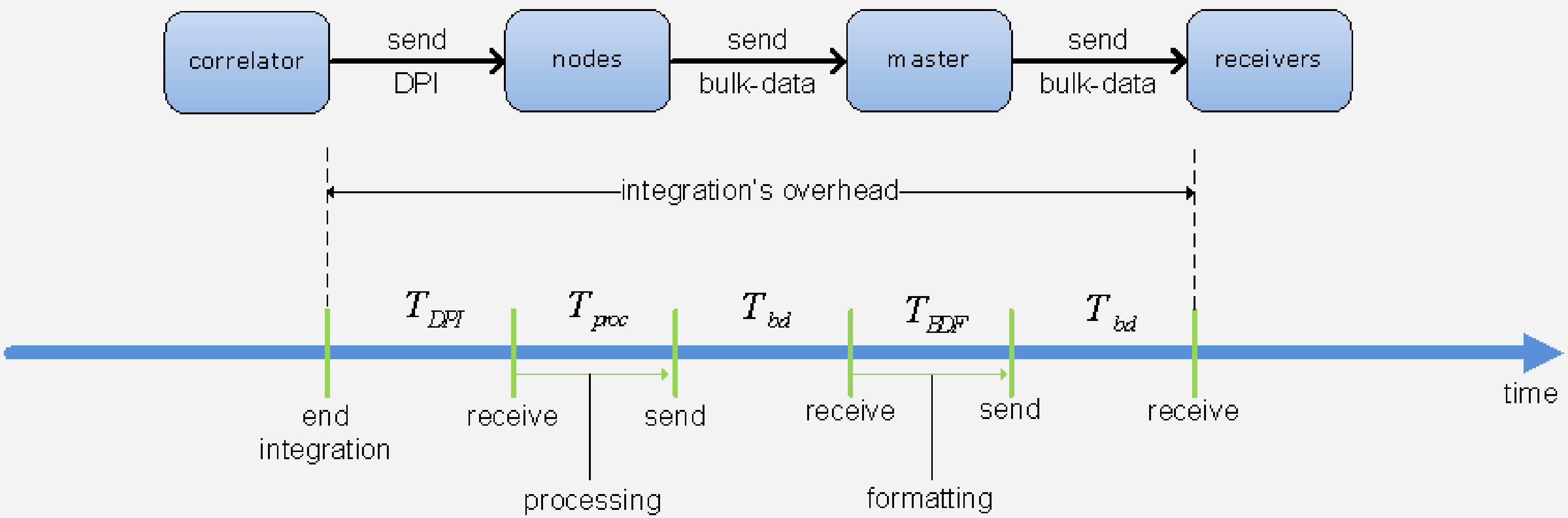
(*) Not used at this moment
(*) To become obsolete

Flagging or blanking an integration product is described by additional binary attachments within a BDF sub-header:

- Flagging implies a flags binary attachment.
- Blanking implies actual times and actual durations attachments.
- Flagging and blanking can happen at the same time.

Computation and Data Transport Overheads

Items that Build Up an Integration's Time Overhead



T_{DPI} DPI transfer time (16 x 62.5 MB/sec)

T_{proc} lags to spectra processing time

T_{BDF} BDF formatting time

T_{bd} bulk-data transfer time (60 MB/sec)

Ideal performance ➔ $T_{proc} \approx T_{BDF} \approx 0$

➔ overhead (size = integration size in MB)

$$= T_{DPI} + 2 \times T_{bd} + T_{proc} + T_{BDF} [\mathrm{sec}]$$

BDF Processing Overview