THE PAYLOAD DATA HANDLING AND TELEMETRY SYSTEMS OF GAIA

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ABSTRACT

The Payload Data Handling System (PDHS) of Gaia is a technological challenge, since it will have to process a huge amount of data with limited resources. Its main tasks include the optimal codification of science data, its packetisation and its compression, before being stored on-board ready to be transmitted. Here we describe a set of proposals for its design, as well as some simulators developed to optimise and test these proposals.

Key words: Payload: data handling; Telemetry; Data compression; Simulations; Gaia.

1. INTRODUCTION

The PDHS of Gaia acquires the data coming from the CCD focal planes, selects and prioritizes them, encodes and compresses them and finally generates the corresponding source packets to be fed into the telemetry stream. We have developed a proposal for its global operation, including the main modules and the data flux between them. For the moment we have focused on the Astro instrument, for which we describe a possible implementation of its video processing units. This proposal, however, can be extended to the Spectro instrument.

Our work includes not only the system design, but also the specification of the many operations to be performed on board. These operations include an optimal codification of timing data, as well as an optimal transmission scheme fulfilling the ESA packet telemetry standard. The main guidelines for an optimal data compression system are also described. These guidelines will be the key for fitting the huge amount of science data into the limited downlink. A global view of the overall data path is finally discussed, from the on board instruments to the on ground storage.

It is worth noting at this point that besides these designs and specifications we have also developed a set of simulation tools for determining the optimal codification parameters and for verifying the reliability of the telemetry and data compression systems. One of these simulators is designed as a large software application, receiving the output of some Gaia simulators, simulating all the telemetry and data compression system, and returning the science data to be fed into the data base and processing system.

2. DESIGN PROPOSALS

2.1. Payload Data Handling System

All the science data flux within the spacecraft is managed by the PDHS, from the instruments to the communications system. The PDHS must be optimized and designed as a pipeline, capable of concurrently processing the huge amount of data at its several stages. This turns out to be crucial because on average about 200 stellar objects per second will be measured (and processed), thus implying internal data fluxes of some hundreds of Mbps.

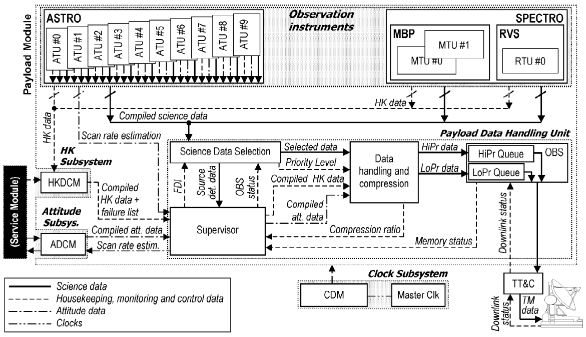


Figure 1. Overview of the PDHS of Gaia as proposed in our work.

The overall design of the PDHS is shown in Figure 1. We propose to deploy Astro in 10 identical sub-modules which we name Astro Trail Units (ATUs) operating in parallel. Figure 2 shows a possible implementation of the Astro Trail Units. Each of them will manage the measurement of stars transiting over its associated trail of CCDs. Video chains and local sequencers are used for

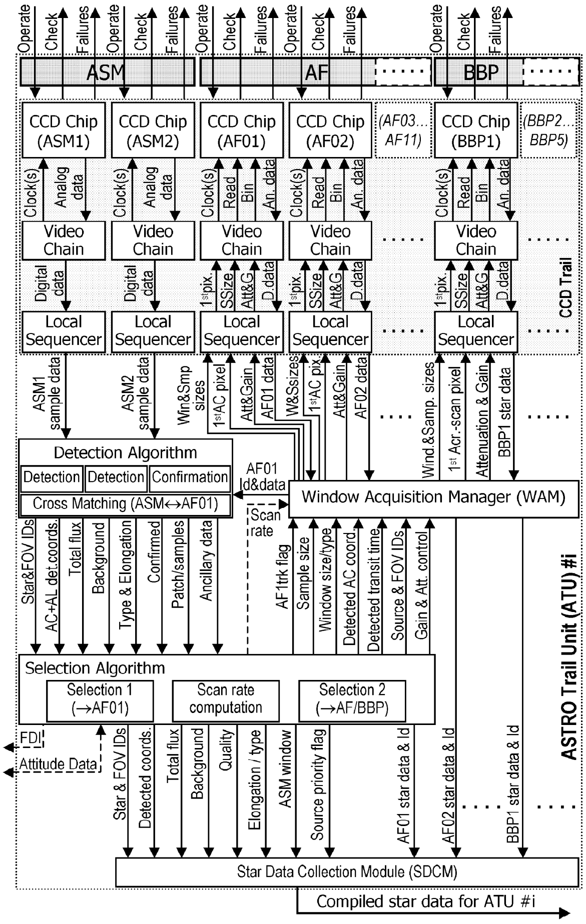


Figure 2. Possible implementation of an Astro Trail Unit.

this, which not only combine the digital data from a single star measurement but also operate as interfaces between high-level commands and CCD-level commands (Portell et al. 2003). The window acquisition manager (WAM) is in charge of commanding this, for which an acquisition protocol has been developed. Unnecessary delays are avoided and the operation is pipelined. The detection and selection algorithms indicate to the WAM which sources must be measured and with which sampling scheme option.

The use of a source priority flag is also proposed (Portell 2001) in order to ensure that low-priority data may be easily discarded during downlink shortages. Another recommended flag, the Field Density Index (FDI), would ease the control of field-dependant PDHS operations. All of these data selection procedures will be executed by the science data selection module. Afterwards, these preselected raw data shall be coded in an optimised way in order to avoid unnecessary telemetry occupation. This will be the task of the Data Handling and Compression module, which will also include an optimised data compression system. Finally, the compressed and packetised data will be stored on-board, waiting to be transmitted during the next contact with the ground station.

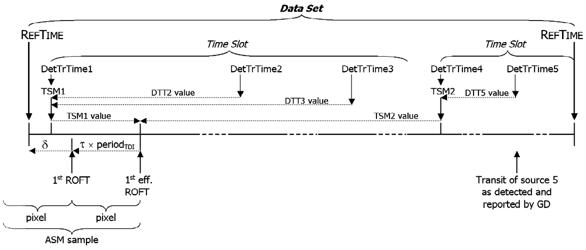


Figure 3. Proposed timing scheme for Gaia.

2.2. Optimised Time Data Codification

Some of the critical data generated by the instruments include timing data, which can produce an important telemetry occupation and, therefore, their codification must be optimised. For this, science data are grouped in data sets of 1 second length (in measurement time), as already assumed in the baseline. In order to optimise even more this scheme, we propose to partition every data set in several time slots, in such a way that fewer bits are required to time tag every measurement (Portell et al. 2004a). Figure 3 illustrates this scheme.

2.3. Telemetry Generation

We have devised a codification scheme (Portell et al. 2004a) that not only implements our optimised timing scheme, but also fulfills the Packet Telemetry standard defined by ESA. Source Packets are generated accordingly to our optimized codification guidelines, dynamically adapting to the current observation conditions. The core of this adaptive system is the *Maximum TSM Offset* (MTO) flag, which indicates the length of every time slot in which we partition a data set. Also, security systems have been introduced in order to avoid any decoding error. Figure 4 illustrates our implementation proposal for this optimized and adaptive codification system.

2.4. Communications

As ilustrated in Figure 5, our approach executes some operations in an order different to the usual one, packeting the data *before* they are compressed. By using this procedure we ensure that we keep each block of sources identified, making possible the use of optimized source packets and making easier the data priorisation while dumping the on board storage to the ground station.

We have also proposed an improved channel coding for Gaia (Geijo et al. 2004), in order to decrease the minimum elevation angle required to establish the communication. This minimum angle in the baseline is 10° above the horizon, while we proposed to reach as low as 5°. This could be achieved by adding more correcting codes within the source packet structures, which would decrease the codification efficiency but only during the

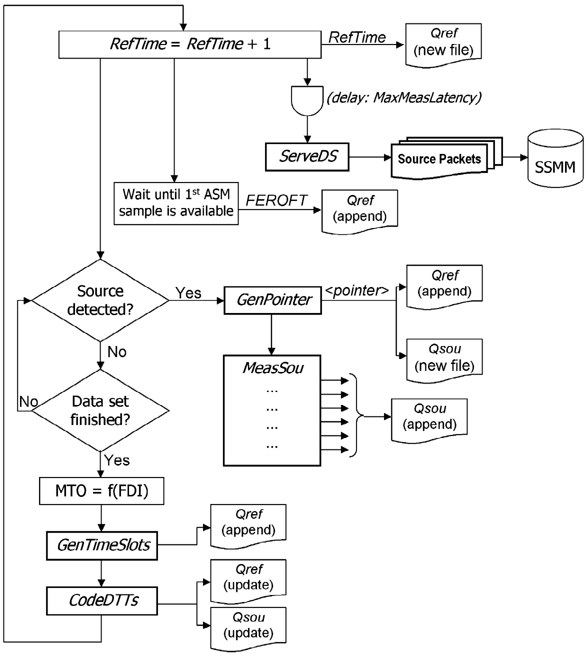


Figure 4. Implementation guidelines for our optimized codification scheme.

5°–10° interval. An adaptive system has been simulated with excellent results.

3. SIMULATORS

3.1. Optimisation of the Time Data Codification

The reliability of our optimised proposal for the timing scheme depends on several parameters. We have developed a software to simulate the average telemetry data rate as a function of these parameters (Portell et al. 2004a). The snapshot shown in Figure 6 shows a static determination of codification parameters, while Figure 7 shows the adaptive coding optimiser. It led us to a dynamic coding of the time depending on the observed field density. The telemetry saving achieved (only with this codification system, that is, without any compression yet) is about 1.2 Kbps in average, reaching up to some 10 Kbps in crowded fields. Our simulator also offers an estimate of the average data rate, which is about 1.2 Mbps including both Astro fields of view (without compression).

3.2. Telemetry CODEC

In order to obtain more accurate telemetry simulations, a *Telemetry CODEC* (coder/decoder) software is being developed (Portell et al. 2004b). A preliminary implementation of this software has already been successfully tested, receiving realistic data generated by GASS (the Gaia System Simulator) and converting it to raw binary

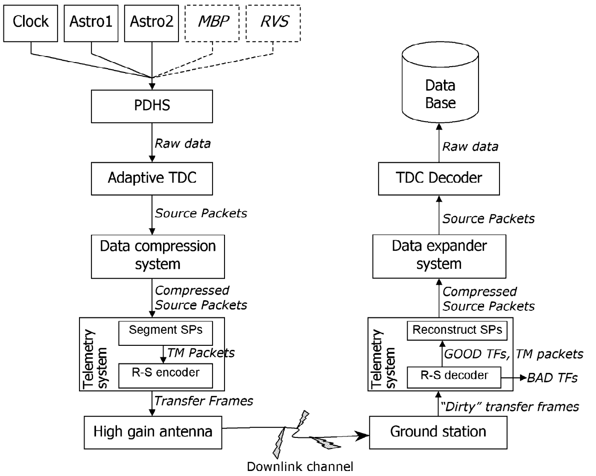
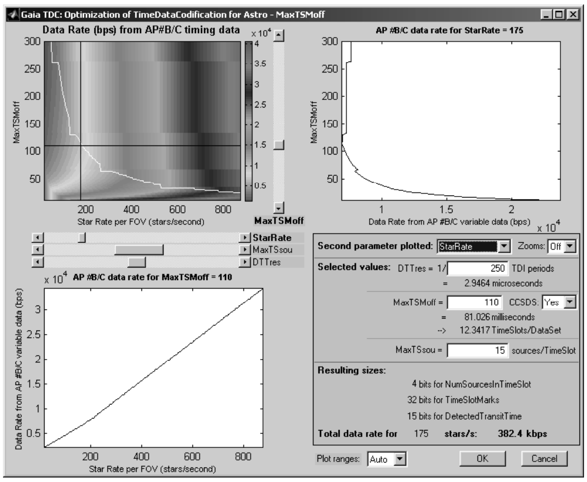


Figure 5. Communication layers including our data handling proposals.



Second parameter plotted: StarRate Zooms: Off

Selected values: DTTres = 1/ 250 TDI periods
= 2.9464 microseconds

MaxTSMoff = 110 CCSDS: Yes
= 81.026 milliseconds
--> 12.3417 TimeSlots/DataSet

MaxTSsou = 15 sources/TimeSlot

Resulting sizes:
4 bits for NumSourcesInTimeSlot
32 bits for TimeSlotMarks
15 bits for DetectedTransitTime

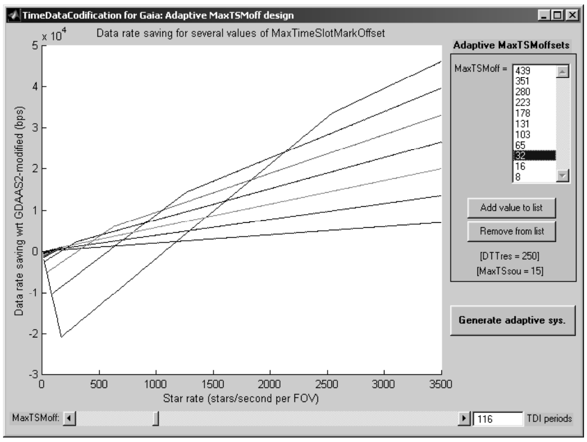
Total data rate for 175 stars/s: 382.4 kbps

Plot ranges: Auto

Figure 6. Optimisation software for the codification parameters.

data. In this way, we can obtain realistic telemetry curves, based on realistic star counts.

This software, however, is conceived as a large, dynamic software application, capable of receiving data from different data simulators and performing complex operations on them. Furthermore, it will be configured with XML files, which not only avoids the modification of the code for adapting to different telemetry models but will also make possible to fulfill forthcoming XML telemetry standards. This software is currently being coded, but preliminary tests are also offering satisfactory results. Even the data compression software shall be integrated in the Telemetry CODEC, as well as statistical studies that will determine the telemetry occupation and compression ratio achieved on every data field type.



[DTTres = 250]

[MaxTSsou = 15]

MaxTSMoff: 116 TDI periods

Figure 7. Dynamic adaptation of the codification parameters to the observation conditions.

3.3. Data Compression

One of the challenges in Gaia is to transmit the large amount of data from the satellite to the ground station. Preliminary estimates (Lammers 2004) show an average data generation rate of about 5 Mbps, while sustained downlink capability will be about 1.5 Mbps. This, in turn, implies that the data must be compressed a factor of 3 or more, using lossless algorithms whenever possible. This is, in fact, a true challenge, since tests with standard compression systems do not offer more than 1.5 in the best of the cases. Therefore, a tailored and optimised system must be developed for Gaia. We have devised a set of compression techniques, most of them based on PSF and Galaxy models, as well as differential coding, predictors and stream partitioning (Portell 2000; Portell et al. 2001, 2004b). These will operate as pre-compressors, after which the application of standard systems offer much better results, as shown in Table 1. These preliminary simulations, obtained with GASS v2.1 data, reveal that we are moving in the right direction since a factor of 2.4 is completely feasible by using our methods. Further detailed studies and developments should bring us to the desired target of 3 (or even more) in a near future.

4. CONCLUSIONS

We have proposed a set of designs for the payload data handling system of Gaia, including an overview of the system, its modules and the main data flux between them. Many of these modules have also been defined, whether as another set of sub-modules (as the Astro trail unit) or as operation guidelines (such as the data handling modules). The latter include accurate proposals for the timing and transmission schemes, as well as for an optimised data compression. All of these proposals take into account the latest design of Gaia and the need for an optimised system, in terms of hardware requirements, processing speed and reduced telemetry occupation.

Table 1. Data compression ratios obtained with different methods.

Pre-compressor	Compressor	Best ratio
None	gzip	1.35
None	bzip2	1.49
Adaptive differential	None	1.60
Adaptive differential	gzip	1.78
Stream partitioning	gzip	2.35
Stream partitioning	bzip2	2.48

Many of these proposals depended on parameters which had to be determined for a realistic case. For this, we have also developed a set of simulation tools which include the optimisation of timing parameters, the generation of realistic telemetry streams from simulated science data, and the compression of these telemetry data. Although some of these software applications are still being developed, their preliminary results are very encouraging. Our data compression simulator is specially interesting, since it is offering the highest ratio currently achieved on realistic Astro data.

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