Time and trigger distribution for NUSTAR DAQ systems *

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NUSTAR experiments will be based on a complex smorgasbord of devices and detectors of many different types with wildly varying speeds. Merging the data meaningfully together requires proper timing distribution and trigger interconnections. With detectors spread over different experimental areas, sometimes hundreds of meters apart, and often-changing experimental set-ups, a flexible integration approach is the key to success.

Time distribution

NUSTAR DAQ systems need distributed timing signals for two purposes:

- Time-of-flight measurements. The most demanding of these measurements ($<$ 10 ps at short distances) are driving the precision requirements.
- Inter-system event synchronisation. The event-wise data from different detectors, operated with common triggers but in separate dead-time domains, can be merged based on time. Requirement: a few 10 ns.

The FAIR infrastructure caters for these needs by two developments for the accelerator systems: BuTiS [1] and White Rabbit [2]. The Bunch Timing System distributes a stabilised frequency using optical fibres to distribution boxes that can be located in each experimental area. These reference signals can then be further sent to front-end boards that perform high-precision time measurements. The reference signal is effectively used to drive the front-end clock. Measurements have shown an precision better than 20 ps between systems separated by 2 km of optical fibre. For absolute timing, BuTiS-derived timing requires cooperation with an external reference to label the clock cycles, e.g. White Rabbit.

White Rabbit is a synchronous Ethernet protocol, i.e. the clocks of all switches and interface cards are synchronised to one device. It has demonstrated synchronisation better than 100 ps/km [3]; fully sufficient for all but the most demanding measurements. In addition to synchronising time, White Rabbit acts as 1 Gbps Ethernet connection.

For systems with lower timing requirements ($\sim$10 ns), which do not need a network connection, or when the overhead of aligning the local clock cycles with synchronous Ethernet is too constraining, a light-weight serial time distribution protocol is available [4]. Sender and receivers do not need to operate with the same clock frequency; the protocol is also uni-directional and medium independent.

Trigger distribution

Spatially distributed NUSTAR experiments require a very flexible scheme for connecting systems, and their triggers. The trigger logic of an experiment needs to communicate with participating detector systems, to

- receive trigger signals for coincidences.
- send master start and trigger decisions to front-end and read-out systems.
- receive dead-time information for use as veto signal.

These signals must be reasonably fast, with at most a few μs latency. (With analog delay lines this would have been a few 100 ns.) Thus, transport over any packet-switched network is not feasible, and hardware signals must be used. Manual changing of the hardware connections is very time consuming, especially so in the generally non-accessible SuperFRS tunnel. A staggering number of direct peer-to-peer connections would be needed with many detectors. Instead, remotely controlled FPGA-based switch-boxes are placed to allow the maximum flexibility. This approach works directly with trigger signals and dead-times, as those carry binary information.

For an MBS-compatible TRIVA-style trigger a few bits of information must be distributed (trigger number, event count, reset signal). For the systems to work correctly in sync, it is also necessary that the master listens to the dead-time of each involved slave. In order to avoid a dedicated electrical bus, connecting all systems in a hardwired dead-time domain, a uni-directional serial trigger protocol distributing triggers from the master module can be used, as demonstrated in a prototype environment [4].

Directing data-flow from arbitrary front-ends via event builders and time sorters to online analysis and storage is straight-forward using switched Ethernet connections.

References

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