Network Time Synchronization of the Readout Electronics for a New Radioactive Gas Detection System

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Background
In systems with multiple radiation detectors, time synchronization of the data collected from different detectors is essential to reconstruct multi-detector events such as scattering and coincidences. In cases where the number of detectors exceeds the readout channels in a single data acquisition electronics module, multiple modules have to be synchronized, which is traditionally accomplished by distributing clocks and triggers via dedicated connections. To eliminate this added cabling complexity in the case of a new radioactive gas detection system prototype under development at the French Atomic Energy Commission (CEA), we implemented time synchronization between multiple XIA Pixie-Net detector readout modules through the existing Ethernet network, based on the IEEE 1588 precision time protocol (PTP) [1]. The detector system is dedicated to the measurement of radioactive gases at low activity. Detecting coincidences will make it possible to identify each radiation event present in the sample. To allow these identifications at low activities, the Pixie-Net modules must be synchronized to a precision well below the targeted clock window of 500-1000 ns. Being equipped with a PTP compatible Ethernet PHY that outputs a locally generated but system synchronized clock [2], the Pixie-Net can operate its analog to digital converters (ADCs) and digital processing circuitry with that clock and match time stamps for captured data across multiple modules.

Detector Prototype
The detector prototype consists of a gas cell surrounded by two large segmented silicon wafers, coupled with two squared NaI(Tl) detectors (Figure 1). The gas cell has a sample volume of 30 cm³ and the silicon wafers are the active detector surface area of 3600 mm². Each wafers is segmented into four silicon pixels (50 x 30 mm²). This module is sandwiched between two plane-type NaI(Tl) detectors (83 x 263 mm² height including photomultiplier tube, 70 x 70 x 46 mm³ crystal). The thickness of the silicon wafers is such to stop any electron with a kinetic energy less than 400 keV. Geant4-based Monte Carlo simulations showed that such thickness absorbs approximately 18-20% of the 30 keV photons, and do not significantly affect photons with energy higher than 80 keV, allowing them to pass through the silicon and to be stopped in one of the NaI(Tl) crystals.

Timing Characterization
In order to detect very low activities (1 mBq/m³ of a γ-racon, isotope, the coincidence measurement technique has to be used to drastically reduce environmental background which masks such activities). In most cases, during the radioactive decay, several particles are emitted almost simultaneously (few picoseconds delay). Measuring at least two particles allows to tag the emitting radionuclide. Thus, a coincidence time window is necessary. The width of this window depends essentially a) on the charge time collection in the detectors (which is approximately 1 μs in this case), and b) on the network configuration if a common clock is used. If two particles are detected within the same coincidence window, then the event is represented by a point in a 2D histogram (Figure 3). After an acquisition, a post-processing analysis identifies radioactive elements that were present in the sample, according to the deposited energies (Figure 4).

Summary and Conclusions
A new detector system for radioactive gases is being developed at CEA. The Pixie-Net hardware, firmware and software was adapted to use network time synchronization (PTP or SyncE) to correlate clocks and timestamps in multiple modules.

• While some non-PTP switches add unacceptably large clock uncertainties, other non-PTP switches reach an acceptable precision of ~100 ns.

• All PTP configurations can reach precisions ~10-20 ns for SyncE, SyncE configurations can reach better than 1 ns for FWIRH.

For a coordinated data acquisition, the local Linux programs on each Pixie-Net were executed remotely from a Linux PC via SSH calls from a shell script.

References and Acknowledgments