A Wireless Power and Data Acquisition System for Large Detectors

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Abstract

A new prototype wireless data acquisition system has been developed with the intended application to read-out instrumentation systems having thousands of channels. The data acquisition and control is based on a compliant implementation of 802.11 based hardware and protocols. Our case study is for a large detector containing photomultiplier tubes. The front-end circuitry, including a high-voltage power supply is powered wirelessly thus creating an all-wireless detector readout. The benchmarked performance of the prototype system with several front-end channels will be presented. We also discuss how a large scale implementation of the system might be realized.

Summary

In several areas of scientific research the size and complexity of the detectors have become exceedingly large. For example, detectors in Nuclear and Elementary Particle Physics have dimensions on the order of 10-100 meters and contain thousands-to-millions of readout channels. One of the significant challenges in building large detector systems is the cabling infrastructure for data communication and electrical power. In some cases, the electronics are in a remote location or an environment that makes it difficult or impossible to use copper-based infrastructure. Wireless techniques have the potential to alleviate these problems. With the development of low-power mobile devices with integrated wireless technologies, the wireless state-of-the-art is now viable for large instrumentation systems.

The data throughput necessary for individual or small numbers of channels is already achievable with commercial hardware. For example, a single stream 802.11n access point has a payload transfer rate of ~35 Mbit/s to or from a single client at a time. The challenge for large instrumentation systems is transferring data from thousands-to-millions of readout channels over a limited frequency spectrum. Figure 1 shows a solution that has the potential to handle the large number of channels and total data rate of a large instrument. The system consists of many access points (~48) each communicating to many clients (~128), or approximately 6000 clients.

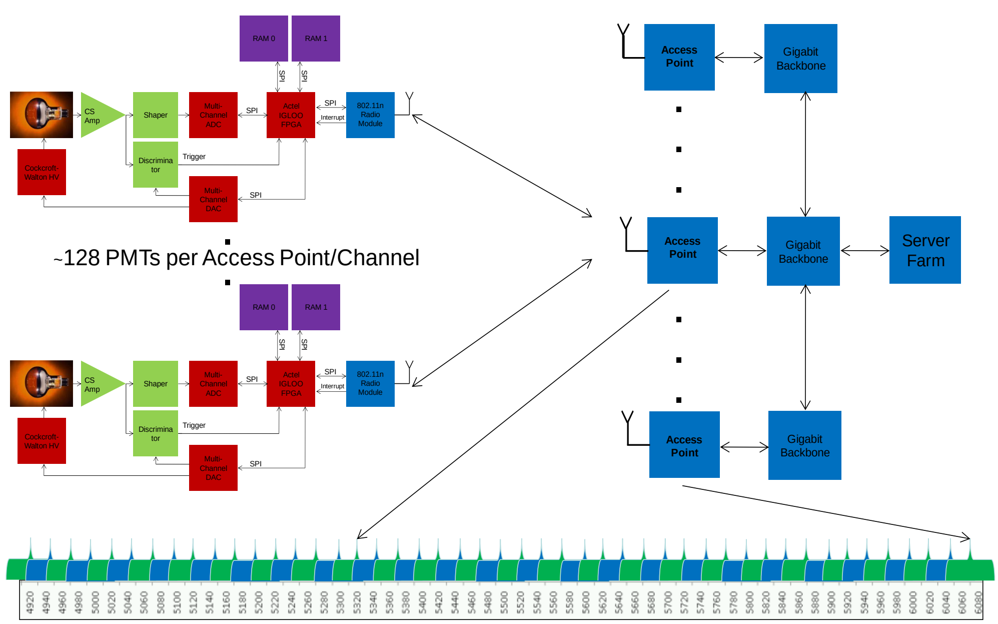

Figure 1. Large Instrument Wireless Readout Schematic
(48 Access Points per sector x 35 Mbit/s per Access Point = 1.68 Gbit/s per sector)

The objective is to fill the frequency space available with as many access points as possible. 802.11a/n hardware has a usable operating frequency band from approximately 4.9 GHz to 6.1 GHz. Single stream 802.11n access points have an individual operating bandwidth of 20 MHz. It is then possible to populate up to 48 access points within the usable 1.2 GHz frequency spectrum. This spectrum translates into a total payload data rate of 1.68 Gbit/s. If the distance between access points is on the order of 150 feet in free-space [1], or if shielding is added, the frequencies can be used again. Therefore, depending on geometry or the configuration of RF shielding, several "sectors" could be defined, each having a 1.2 GHz spectrum. This effectively multiplies the usable spectrum where the limits depend on a particular instrument and its environment.

While this concept is generic, our study focuses on a specific application - the read-out of a detector having thousands of photomultiplier tubes (PMTs). The goal is to develop a photomultiplier tube base that is powered wirelessly and transfers data wirelessly. The PMT base is dead-timeless and complies with standard 802.11n wireless and Ethernet technology for data transfer.

Figure 2 shows the prototype module we are currently testing. The prototype design consists of a charge sensitive amplifier, shaping amplifier, and constant fraction discriminator for timing and triggering. An FPGA is used to interface to an ADC, DAC, ping-ponged RAM chips, and to the 802.11n wireless radio.

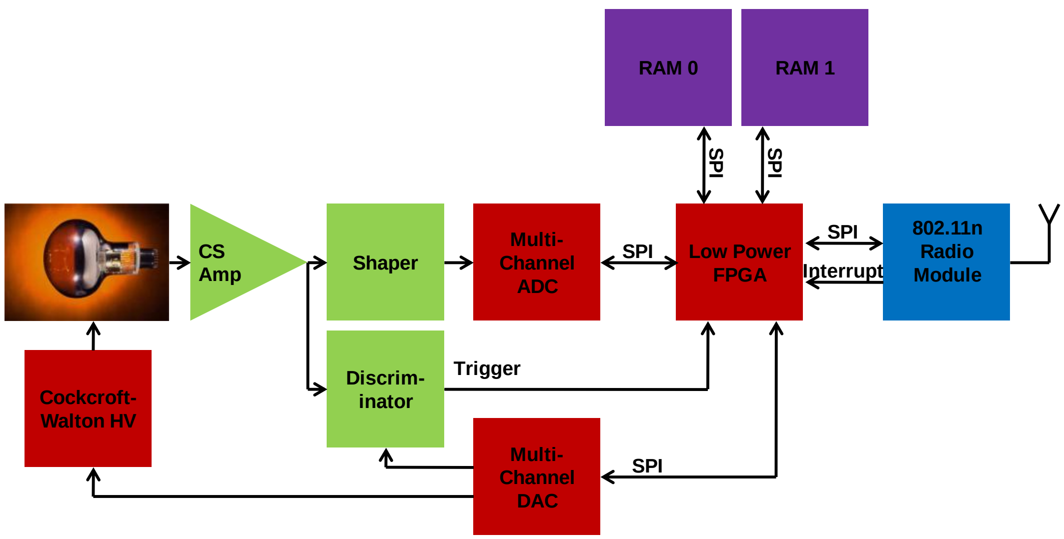

Figure 2. Wireless dead-timeless PMT front-end module.

The prototype front-end utilizes an 802.11n module whose wired interface is a single interrupt line and a serial peripheral interface (SPI) bus. To achieve the full 35 Mbit/s payload transfer rate capability of the module/802.11n, the SPI bus must run at a 50 MHz clock rate. This precludes the use of a microcontroller and necessitates an FPGA. The radio offloads all of the 802.11n protocol, but necessitates implementing the TCP/IP stack inside the FPGA. To accomplish the communication with the 802.11n radio and to handle the TCP/IP stack, an ARM soft processor is implemented.

Several techniques were investigated for wireless power. The two techniques that were selected for testing were RF and optical. Both of these methods were developed to the point where a decision could be made based on their relevant merits for the intended application. It was determined that for the small scale prototype system the easier and lower cost implementation of an optical system is most advantageous. This wireless power system is still currently under test. The results of these tests as well as a discussion of the two techniques explored will be included in the conference presentation.

The prototype system is currently being tested and with the design cycle to be completed early this summer. All indications are that the module will be capable of the full 35 Mbit/s single-stream 802.11n payload transfer rate. Subsequent to the initial development phase, a small production of several prototype modules will be constructed. With multiple modules and multiple access points, the data throughput parameter space of large instrumentation systems will be explored and included in the conference presentation.

[1] **802.11n Under the Microscope,** Vivek Shrivastava, Shravan Rayanchu, Jongwon Yoon, Suman Banerjee *Proceedings of the ACM/USENIX Internet Measurement Conference (IMC '08) Vouliagmeni, Greece. October 2008.*