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Design of a IoT based multi-channel temperature monitoring system

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In the scope of the Jiangmen Underground Neutrino Observatory (JUNO) project, 6 back-end card (BEC) mezzanines connected to one BEC base board are in charge of compensating the attenuated incoming data from 48 front-end channels over 48 100-meters-long ethernet cables. Each of the mezzanines has 16 equalizers that may be subject to overheating. It is important to monitor their temperature in real time. However, collecting data from a relatively large (1080) number of mezzanines is not a trivial task. In this work we propose a solution based on Wi-Fi mesh. Both technical details and test results will be reported.

Summary (500 words)

Gathering information from many electronic devices for real-time analysis can be a challenging task. In the context of the Jiangmen Underground Neutrino Observatory (JUNO), there is an electronic system in charge of capturing the interactions of electron antineutrinos issued from nearby nuclear reactors. This system starts at the in-water electronics, where 18000 large (20-inch) Photomultiplier Tubes (PMTs), 25600 small (3-inch) PMTs, and 2000 PMTs installed in the surrounding water pool send hit information by groups of three to the Global Control Units (GCUs). The GCUs digitize and store the received signals in a large local memory under the control of a Field-Programmable Gate Array (FPGA). They wait for the trigger decision and send out event data as well as trigger requests to the outside-water system. On the surface, a back-end card (BEC) is used as a concentrator to collect trigger requests from 48 GCUs, and each of the incoming trigger request signals passes through an equalizer to compensate for the attenuation due to the long cables. There are 180 BECs in the system, each containing 6 Mezzanines equipped with 16 equalizers. This makes up for a total of 17280 equalizers. The main challenges are measuring the temperatures of multiple equalizers and sending them to a central computer. This is necessary to make sure the equalizers perform stably and don't overheat.
Three i2c-compatible temperature sensors were placed on the bottom layer of one BEC base board to monitor 96 equalizers installed on the top layer of 6 Mezzanine cards. The three sensors can be accessed through a single i2c bus. We propose to use an esp32-pico development board to read out the temperatures from 3 sensors sitting on the same base board, and to link it to the central computer through Wi-Fi. Due to the possibility of having diminished performance caused by channel overlapping when too many devices are connected to a same Wi-Fi network, a Wi-Fi mesh group consisting of 180 ESP32 boards might be a more suitable solution to link all the boards to the central computer.
Some experiments were performed to validate the implementation. Two thermocouples were attached to two reference equalizers and were connected to a digital thermometer. This allowed to determine the difference between the equalizer's true temperatures and the temperatures measured by the sensors, which are placed 8mm apart from the equalizer. The wireless range of the ESP32 was assessed to ensure it met the requirements of our implementation. The server's bandwidth was also measured and found to be of 35000 80-byte messages per second, which is enough to deal with the required message rate of 36 80-byte messages per second. Additionally, the complete implementation was tested on a reduced network of 30 boards. The group was established successfully and run smoothly with negligible loss of information over a period of seven days. Given these results, we believe the system can scale to a 180-board mesh.

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