DESIGN OF AN IOT BASED MULTI-CHANNEL TEMPERATURE MONITORING SYSTEM

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1 - INTRODUCTION

The Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose neutrino detector. Its main goal is to determine the neutrino mass hierarchy and to precisely measure some of the neutrino oscillation parameters, using as a source electronic anti-neutrinos coming from the Yangjiang and Taishan Nuclear Power Plants. It is located at 700 m underground and consists of 20 ktons of liquid scintillator contained in an acrylic sphere [1].

Figure 1: JUNO site

2 - JUNO ELECTRONICS

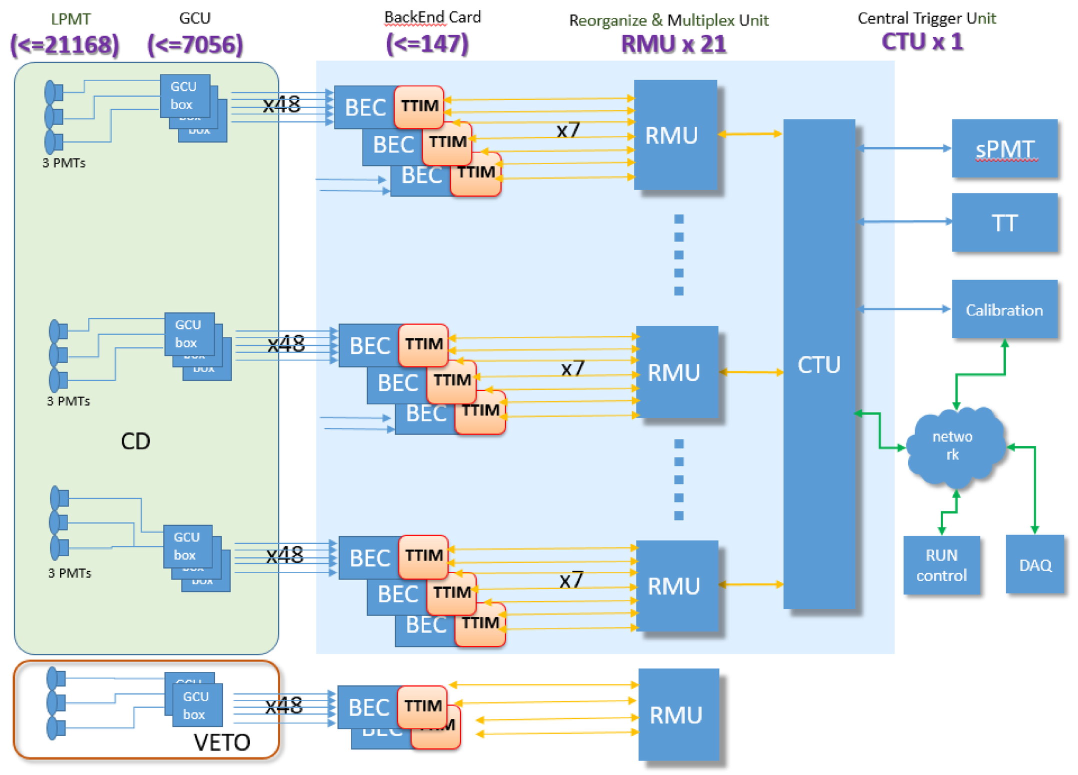

Figure 2: "Wet" and "Dry" electronic systems linked by 100 m Ethernet cables [3]

- Photomultiplier tubes (PMT) capture the light emitted by the beta decay reaction.
- A global control unit (GCU) manages data acquisition signals coming from the PMTs.
- A central trigger unit (CTU) manages trigger decisions.

3 - BACK-END CARD

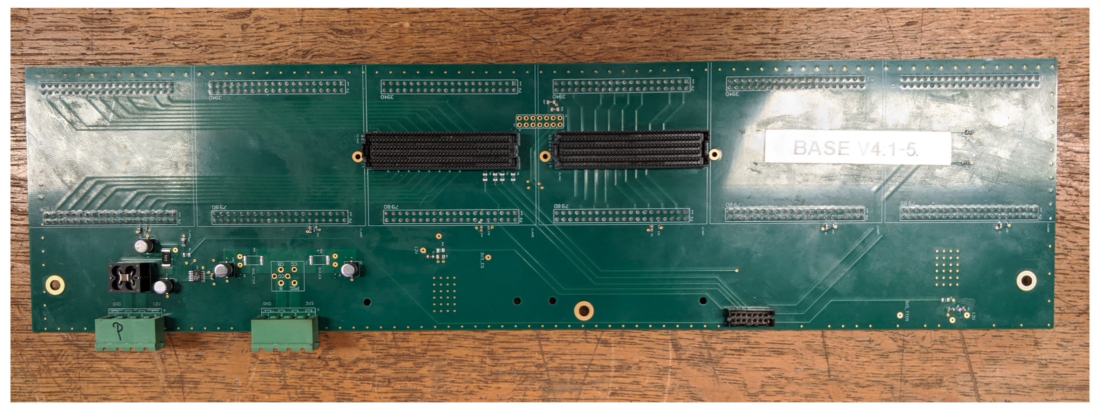

Figure 3: One BEC (front view)

- A back-end card (BEC) (see figure 3) distributes the clock signal to the GCU to synchronize the acquisition, and receives trigger decisions from the CTU [2].
- Contains 6 mezzanines which treat the signals coming from the GCU by making them pass through 16 equalizers.
- Equalizers are the hottest components of the BEC.

4 - ANALYSIS

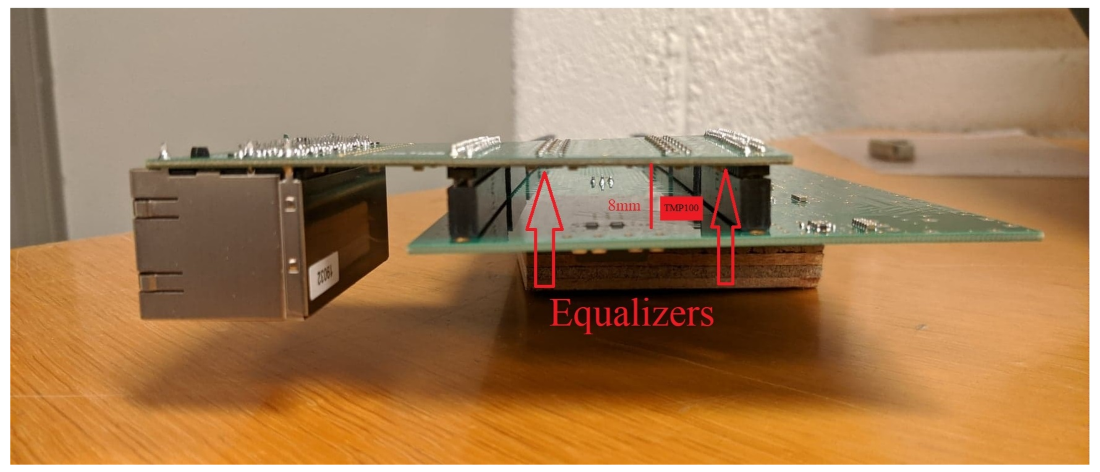

Figure 4: One mezzanine (above) mounted on a BEC (below), separated by 8 mm.

- The electronic system must run uninterruptedly for a period of 6 years.
- Keeping the 17280 equalizers from the 180 BECs cool is essential for proper operation.
- A real-time temperature monitoring system is thus needed.
- We chose to install three temperature sensors on each BEC to monitor the temperature of the hot air above the mezzanines.

5 - IMPLEMENTATION

- An ESP32 pico board is mounted on each BEC and connected to its three temperature sensors, which are TMP100s (see figure 5).
- The I^2C protocol allows a single ESP32 to act as a "master" device and control the three sensors, which are "slave" devices.
- A sampling of the temperature registers of the TMP100s is performed at arbitrary intervals.

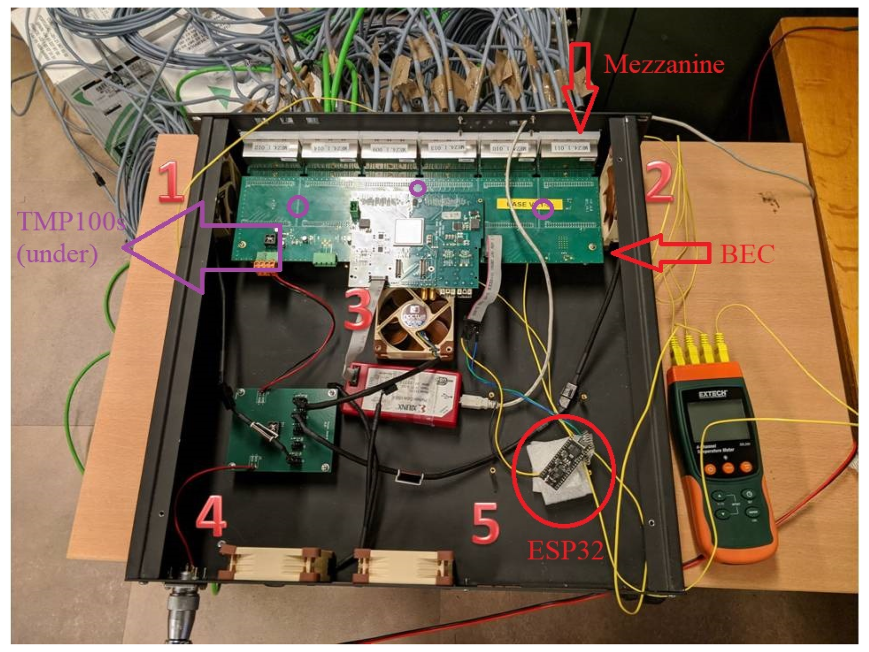

Figure 5: Box with ESP32, BEC, mezzanines, TMP100s and 5 fans (among other components).

- Temperatures are retrieved by using a Wi-Fi mesh network (see figure 6) made of one router and 180 ESP32s, maintained by the Painlessmesh library.
- ESP32 send MQTT messages containing temperatures and other information.
- A central computer is connected to the router and runs an MQTT server to receive the messages.
- Messages are decoded and stored in an SQLite database.

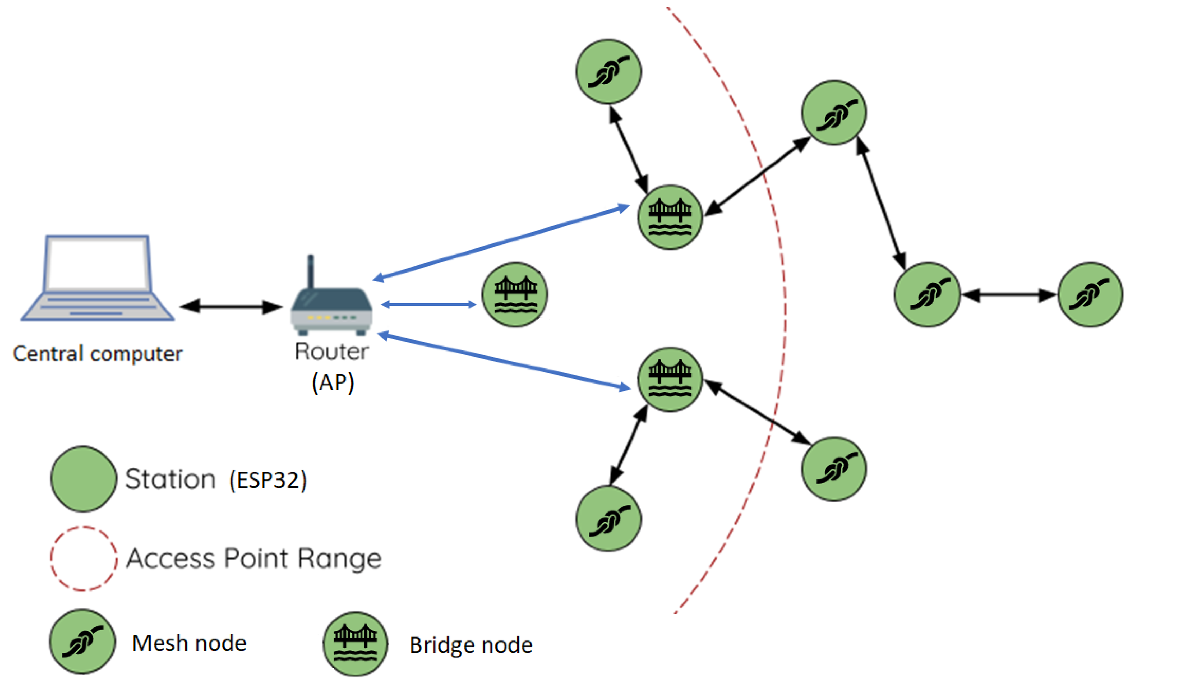

Figure 6: Wi-Fi mesh network with central computer, an arbitrary number of "Bridge" nodes, and "Mesh" nodes.

6 - VALIDATION AND RESULTS

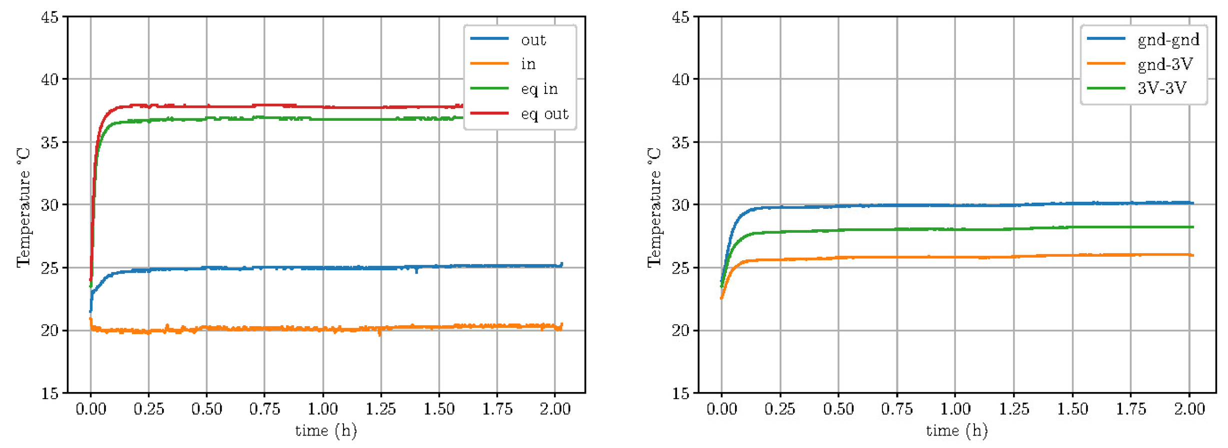

Figure 7: Left: real temperatures measured with a thermocouple at fans 1 and 2, and at mezzanines 1 and 6. Right: temperatures measured by the three TMP100 sensors (see figure 5).

- The difference between the real temperature of the equalizers and the temperature of the hot air above it (measured by the TMP100s) was assessed (see figure 7).
- A reduced scale test with 30 boards distributed on 5 hubs was performed (see figure 8).

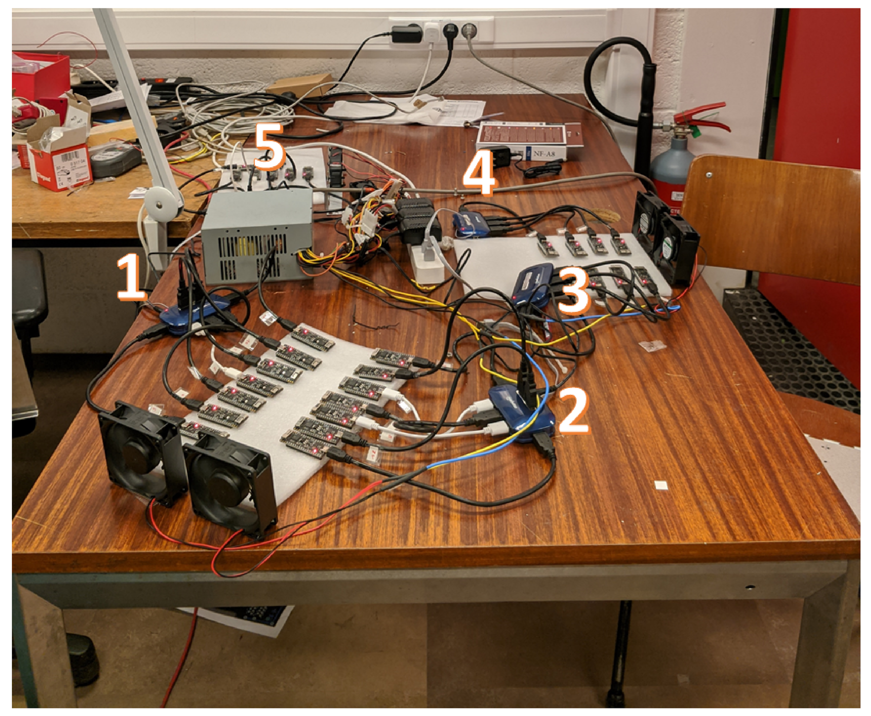

Figure 8: Reduced-scale test in the lab. Transmission rate: 0.2 Hz. Reception rate: 99.06%.

7 - CONCLUSION

- Less than 1% of the messages were lost.
- Scaling to up to 180 boards should be possible with at least 3 "bridge" nodes, and with a frequency of 0.2 Hz or lower.

REFERENCES

[1] Jiangmen Underground Neutrino Observatory. Available at http://juno.ihep.cas.cn/.

[2] Yifan Yang and Barbara Clerbaux. Design of a common verification board for different back-end electronics options of the juno experiment, 2018. Available at https://arxiv.org/abs/1806.09698.

[3] Barbara Clerbaux, Shuang Hang, Pierre-Alexandre Petitjean, Peng Wang, and Yifan Yang. Automatic test system of the back-end card for the juno experiment. *IEEE Transactions on Nuclear Science*, 68(8):2121–2126, Aug 2021. Available at https://arxiv.org/abs/2011.06823.

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