Article Summary 3: Developing an Energy-Efficient and Low-Delay Wake-Up Wireless Sensor Network-Based Structural Health Monitoring System Using On-Site Earthquake Early Warning System and Wake-On Radio.

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Abstract

In this article, the authors came up with a solution to reducing energy consumption in Wireless Sensor Networks (WSN) for Structural Health Modeling (SHM). The catch being they must still have a quick response to detect earthquakes. Earthquakes cause lots of damage, especially in places without advanced detective technology. In this study, a WSN was created using a technique called wake-on-radio (WOR) technology. What is important to note is that earthquakes release two different types of waves: Primary and secondary waves. Primary waves are faster and make less damage, causing them to be perfect for early warning systems. The WSN system actually keeps most sensors in sleep mode in an effort to reduce the energy use and is only activated when the small number of sentry nodes detect any primary waves which are the earliest seismic signal of an earthquake. This study demonstrates a relationship between network delay time (T_d) and node activation time (T_a) showing that a balance of these two minimizes the response time further reducing energy use. The results of this study showed that the average standby current was $350\mu A$ and the wake-up delay was of <300 ms. This showed that the system works quickly and efficiently while using very little energy. In conclusion, this solution is really effective for on-site earthquake early warning systems.

Methods and Materials

This study built a wireless sensor network (WSN) to efficiently monitor building safety during an earthquake. Each sensor node was comprised of two radios, a low power, deep sleep radio that listened to signals, and one for communication. This allowed the sensor to sleep most of the time and conserve energy. In addition to this, an early earthquake warning system was installed, which detected pressure waves (p-waves) caused by an earthquake, and sent them through a gateway node which activated sensor nodes and told them to start collecting data on the p-waves. Each sensor node included a Jennic microprocessor for computing, a six-axis motion sensor (MPU6050), a TI CC1101 radio chip for wake-up signals, a microSD card for data storage, a Micro Electromechanical Systems (MEMS) chip for motion sensing and orientation. Also, the Jennic microsensor also features a USB host interface with an application, which supplies firmware updates and allows for the customization and development of the tool.

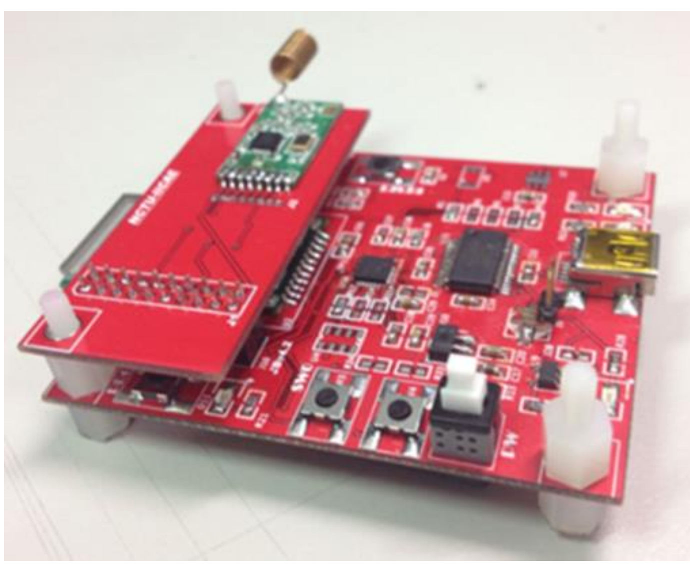

Figure 8: This picture illustrates how the device is built, displaying the stacked layers of components, including the Jennic microprocessor board, the motion sensor, and the radio-trigger board that wakes up the nodes.

Testing showed using about 350 microamps, a very small amount of power. Additionally, all nodes could wake up in less than half a second. A building model also confirmed that the device can pick up an earthquake in the 2 second warning period.

Analysis

The authors show clear evidence to show how the implementation of wake-on radios in early earthquake sensors can save energy and enhance the response times of the detectors. They conducted an evaluation of the performance by measuring the wake-up delay and energy consumption.

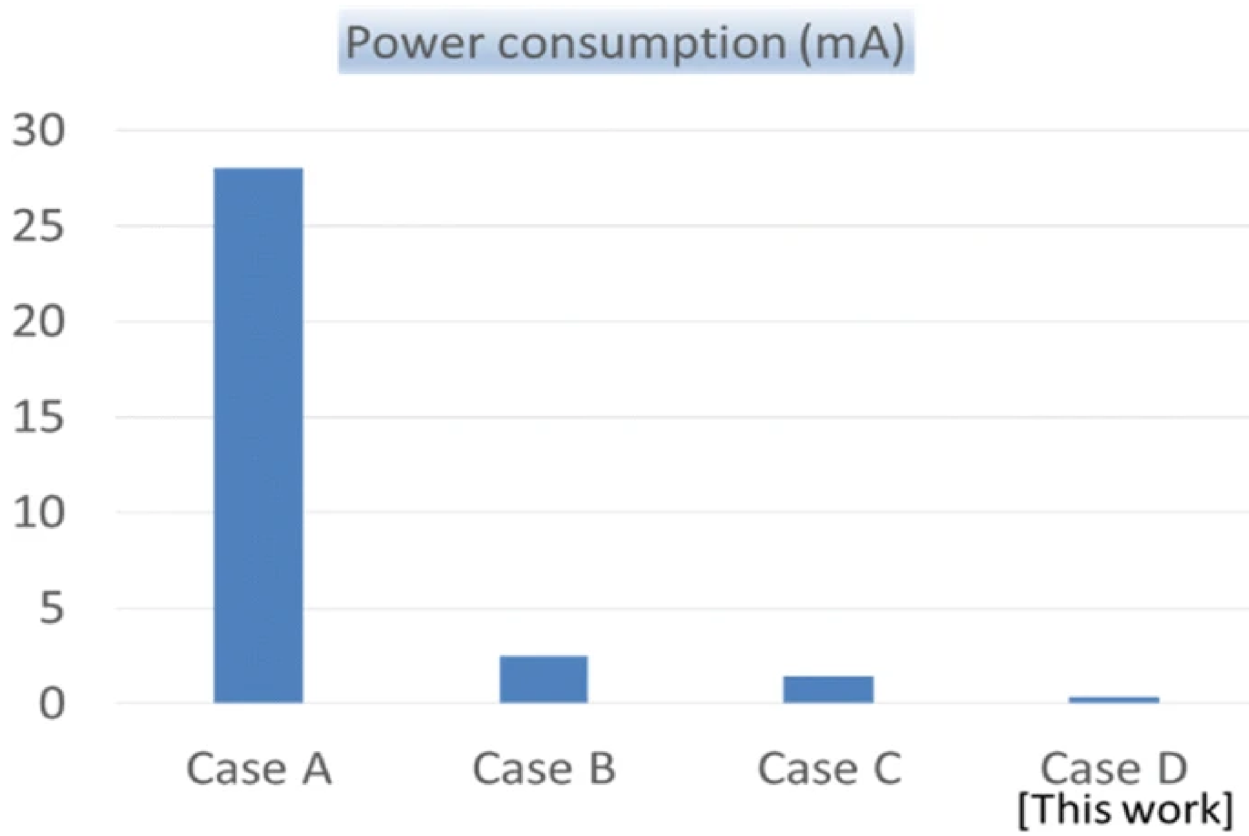

Figure 10: Comparison of power consumption between different cases. Fig. 10 displays the energy consumption of each case (measured in milliamperes). Case A is the always-on case. Case B and C had equal listening periods, but case B stayed awake longer to listen than case C. Case D was newly proposed dual-radio system that involves the wake-on radio trigger.

In Fig. 10, the newly proposed dual-radio system is, by far, more energy efficient than other test cases. This was due to the fact that case D was able to sleep the majority of the time, saving large amounts of power. The wake-on radio trigger allowed it to only wake up when necessary.

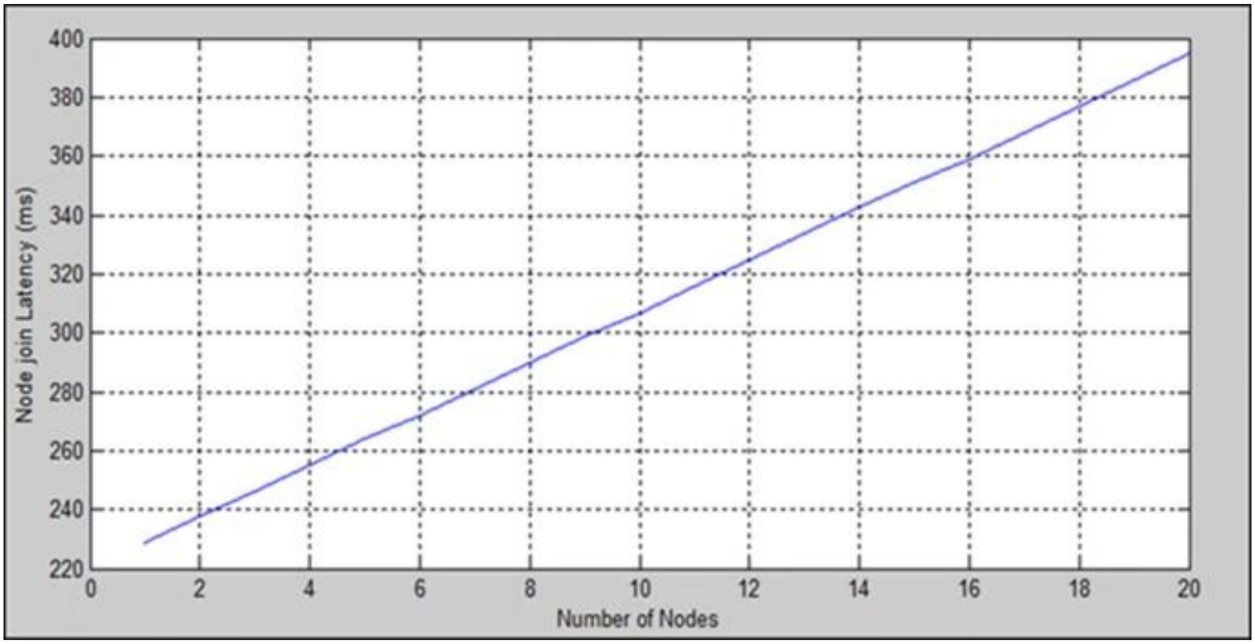

Figure 12: Results of wake-up delay test. This graph displays the delay measurements under one layer star topology where the first node begins the graph with 229 m/s and then each node adds about 9 m/s.

Fig. 12 is essential to this study because it highlights the physical performance of the wireless sensor in real-world deployment. Additionally, the graph shows the way signals move throughout the network, which is crucial for early earthquake warnings.

The information from this article and the figures that were just analyzed can be very applicable to our research project, which aims to create an early earthquake detection system utilizing machine learning for third-world countries. It explains how the implementation of a sleep and wake-up trigger can significantly save power, which will be important for our project when we decide the energy-efficiency method within our detector. Additionally, understanding node arrangement will be a key part of this project because we must ensure that the machine learning system receives the data as fast and accurately as possible. The reduction of detection latency must be mastered for this project as every second matters when it comes to early earthquake detection.

References

Hung, S. L., Ding, J. T., & Lu, Y. C. (2018). Developing an energy-efficient and low-delay wake-up wireless sensor network-based structural health monitoring system using on-site earthquake early warning system and wake-on radio. *Journal of Civil Structural Health Monitoring*, *9*(1), 103–115. https://doi.org/10.1007/s13349-018-0315-2