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Development of a Wireless Sensor Network for Hurricane Monitoring

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1 INTRODUCTION

The object of the WSN is to characterize the wind effects on the surface of residential houses. The fully developed system contains hardware and software subsystems. The hardware measures data and transfers it through the Zigbee network. The base unit of the hardware subsystem gathers data from all sensors and transfers it to the terminal computer through Universal Serial Bus (USB). The support system such as the charging system and solar system are included in the hardware subsystem. The onboard pressure transducer and temperature sensor enable the board to measure pressure and temperature without any independent electronics. The software subsystem consists of the firmware programed on the sensor board chip and enables the software graphical user interface (GUI) to calibrate the data and output as comma-separated values file (CSV file).

Calibration generates the transfer function to convert digital data to physical measurements such as the pressure in mbar and wind speed in m/s. The resolution of the sensor board is determined by that of the microcontroller (MCU) on the board, which has the original 12-bit analog-to-digital converter (ADC). With the oversampling function, this ADC resolution is increased to 16-bits.

2 SYSTEM DESCRIPTION (HARDWARE AND SOFTWARE)

2.1 Zigbee Network and sensor board

The Xbee modules generate a Zigbee network which allow communication between all nodes (sensors) and a coordinator (base unit). IEEE 802.15.4 standard network coexisting with 2.4 GHz Wi-Fi. The filtering of several Zigbee channels is used to avoid the interference with other Wi-Fi devices. Adding routers reduces the duty of the coordinator and increases the total number of knots.

The main controller unit (MCU) of the sensor board is ATSAM21 and is compatible with the Arduino IDE. The board connects to a 3.7V Li-ion battery power source. The board also supports solar panels to charge batteries for long-duration operations. The on/off port makes it possible to turn on or off the sensor using an on/off plug.

2.2 Measurement subsystem

A measurement system consists of total-pressure sensors, a reference-pressure box, and an anemometers box. A total- pressure sensor board is housed in a case, with a 3.7V 4000 mAh Li-ion battery. A 5 mm Tygon tube connects the pressure transducer with the outside port. The 4000 mAh battery powers the board for up to 48 hours. The combination of the disk probe and the reference pressure box, which includes a 4000 mAh Li-po battery and the censor board, is used for

measuring reference pressure. The Young's Anemometer with its own box is used for the wind speed and direction. All the sensors transfer the data packages through the Zigbee network.

2.3 Firmware and software

The firmware programmed in the board chip controls all tasks of measurement, including regular(pressure), wind speed, and anemometer. The software program runs in the Window 10 environment and monitors the activity of the remote sensors. The sensor data is transmitted to the USB port of a laptop computer so that the monitor can show the real-time plot of measurements. Both firmware and software provide the cyclic redundancy check-32 (CRC-32) and detect any error data received in the network. The causes of the error data might be the noise of the decoding process when the Xbee module packages the data or the disturbances from other signal sources. The error data package will not be accepted as a useful value and will not be stored. The program organizes the CRC-32 passed packages to the cluster of CVS files and uploads them to the project storage in DesignSafe through the public internet. This uploading function is optional. Users can save the data locally and upload the files later if there is no internet service available.

2.4 Performance benchmarking and calibration

With the oversampling method, the resolution of the readings is maintained at 16 bits for temperature, wind speed, wind direction, humidity, air pressure, and battery level. The resolution for ADC is $3.3V/2^{16}bit = 0.05\,mV/bit$. The overall resolution of the measurement for air pressure, humidity, temperature, wind speed, and wind direction are 0.1mbar, 0.03%RH, $0.05°C$, 0.05m/s, 0.005 degrees, respectively. The calibration for the anemometer and pressure sensor is necessary for reliability data. The Compact pressure calibrator is used to calibrate the pressure sensor. The wind tunnel, pitot tube, and pressure manometer are used to calibrate the anemometer. The zero-offset correction modifies the offset of the pressure transfer function and is necessary before every measurement job. Ideally, the number limitation of the sensors within one system is 50, which is determined by the capacity of the Zigbee network. Now the number of sensors in one system is 26, including 24 normal-pressure sensors, a reference pressure sensor, and an anemometer. Users can burn the firmware in one minute to create a new sensor in the system. The wireless transfer test shows that the maximum connection range of Zigbee modules under open air and complex in-house conditions are 179m and 35m. The tests were done in Murano Drive Melbourne, FL, and Olin Engineering Complex, Florida Institute of Technology, Melbourne, FL.

The previous field (Hurricane Eta) and experimental (Wall of Wind Test) test show that it cost 2 hours on average to deploy a system on a residential house. The combination of Velcro™ and epoxy enable the normal-pressure sensor to attach to the surface temporally and keep the strength under 90m/s, and the combination of Dual Lock™ and epoxy enhance the attachment, which the quantized maximum wind speed is to be determined in the future experience. The advantage of using Dual lock™ and Velcro™ is that users take the sensors off the surfaces without damaging the house. The M5 flanges provide the most strength of attachment but damage the house surface significantly.

Keywords: Wireless Sensors Network, Pressure Sensor, Wind Sensors, Anemometer, Design-Safe, Hurricane, Zigbee, Xbee.

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