

LabVIEW Based Wireless System for Environmental Monitoring

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Abstract – Thanks to miniaturization of the sensors as well as developments in the realm of Wireless Sensor Networks (WSN), the wireless technologies are becoming integral to a number of applications, including environmental monitoring. This paper presents the design and implementation of ZigBee enabled wireless data acquisition system for monitoring of temperature, relative humidity and illuminance. The presented system collects the signals of a number of sensors using the National Instruments' gateway and WSN modules. Finally system interface is designed on the graphical programming software platform.

Keywords –Environmental parameters, LabVIEW, WSN.

I. INTRODUCTION

In the last few years in electronics and wireless communications have progress. The networks are developing and become more inexpensive, with a lower power consumption and the sensors become more multifunctional. These sensors are small in size, with good sensitivity and easy process and transmit data one to another. They communicate typically over an radio frequency channel. Sensor networks are designed to detect and registrate different events or phenomena, to collect and process data and transmit the information to the final consumer or interested users. Main characteristics of the sensor networks are [1]:

- The opportunity to organize themselves;
- Short-range broadcast communication and multihop routing;
- Dense deployment and cooperative effort of sensor nodes;
- Frequently changing topology due to fading and node failures;
- Energy limitations, as well as energy for transmission of information, memory and computing power.

These characteristics, particularly the last three, make sensor networks different from other wireless ad-hoc or mesh networks. Clearly, the idea of mesh networking system is not new; it is assumed for some time for wireless

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internet access or voice communication. Similarly, small computers and sensors are not innovative per se. However, the combination of small sensors, computers with low power consumption and transmitters makes it possible to create a new technology platform that has many important applications. Research and commercial interest in wireless sensor networks is now growing exponentially, that occurs in many ways [2, 3, 4]. Wireless sensor networks are increasing wide application in different fields and have several advantages over standard sensor networks [4, 5, 6].

In this paper is presented an application of wireless sensor network for environmental monitoring. An introduced wireless system is built with sensor modules from National Instruments and is controlled in LabVIEW programming environment. In LabVIEW are mounted a wide variety of technologies for creating distributed applications. One of this technologies is the shared variable, with which is possible to share data between loops on a single diagram or between applications across the network. To receive data from wireless sensor modules is used just a shared variables. The lack of this technology is necessity of a project open in the Project Explorer window. In this paper is presented different approach to communicate with wireless sensor nodes by using specific application programming interface. With this approach is possible to implement standard programming techniques to create wireless applications.

II. DESIGN CONSIDERATIONS FOR HARDWARE IMPLEMENTATION

A. Ethernet Gateway

The Ethernet Gateway is a pass - through device that coordinates communication between wireless measurement nodes and the host controller [7]. In present work the National Instruments' WSN-9791 Ethernet Gateway is selected. This gateway has a 2.4 GHz, IEEE 802.15.4 radio, based on ZigBee specification and provides connectivity to a Windows via Ethernet port. The gateway can be connected up to 36 measurement nodes and has outdoor range up to 300 m.

B. Wireless Measurement Nodes

There are various type of measurement nodes manufactured by National Instruments. Each measurement node has four analog input channels and up to four digital input/output channels [8]. The analog channels provide direct sensor connectivity while digital channels can be configured for input, sinking output, sourcing output, or

programmatic control. Block diagram of such wireless node is shown on Fig. 1.

A low-power microprocessor is MSP430 from Texas Instruments. This microprocessor delivers operation and control of the measurement nodes. The nodes are powered with four 1.5 V AA battery for up to three years of operation or can be used external power with a DC supply. Up to eight end nodes for star topology or 36 measurement nodes in a mesh topology can be connected to a gateway.

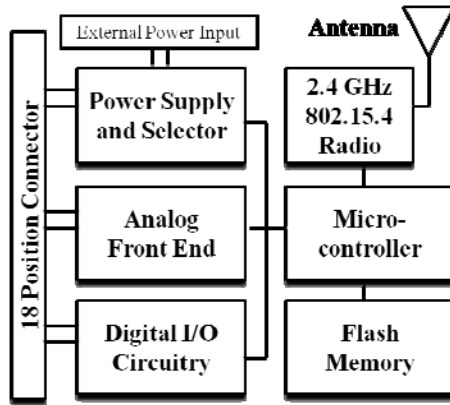


Fig. 1. Block diagram of the wireless sensor node

In order to demonstrate capability of such wireless sensor network in present project are selected two NI WSN 3212 nodes and one NI WNS 3202.

The NI WSN-3212 measurement node provides four thermocouple input channels with 24 bit resolution. It is compatible with all thermocouple types and according selected type can be configured to indicate directly temperature in degrees Celsius.

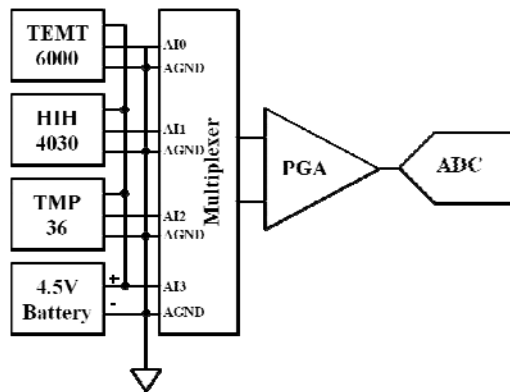


Fig. 2. Sensors connection to the analog circuitry

The NI WSN - 3202 measurement node is a wireless multifunction data acquisition system [8]. This device provides four analog input channels with four selectable nominal input ranges: ± 10 V, ± 5 V, ± 2 V and ± 0.5 V. The resolution of analog to digital converter is 16 bit with minimum sample interval of 1 second per channel. Input impedance of each analog channel is greater than 1 G Ω and input bias current is less than 3 nA. Crosstalk between channels is greater than 100 dB.

The connection between voltage signals, generated from sensors and analog inputs of the NI WSN – 3202 is shown in the Fig. 2. Each channel has a terminal for voltage signal and a AGND terminal which is internally connected to the

ground reference. The voltage signals are multiplexed, filtered, conditioned and sampled by an analog to digital converter.

C. Sensors for Measuring Environmental Parameters

TEMT6000 Ambient Light Sensor

Measurement of illuminance can be achieved by ambient light sensor TEMT6000 and 10 k Ω load resistor between emitter and ground. TEMT6000 is a phototransistor sensitive to the visible spectrum. Sensor acts like a transistor and its sensitivity is a function of the collector–base junction quantum efficiency and also of the dc current gain of the transistor [9]. Therefore, the greater the incoming light, the higher the analog voltage on the output.

In order to define transfer characteristic of the sensor a number of calibration procedures was done using lux meter. After regression the derived polynomial equation is:

$$I = -46.73V_o^3 + 366.8V_o^2 - 76V_o + 15.7, \quad (1)$$

where I is luminance in lux, V_o is output voltage from voltage divider between emitter and resistor.

HIH-4030 humidity sensor.

The HIH-4030 is an integrated humidity sensor that measures relative humidity and delivers it as a corresponding analog output voltage [10]. The output of the sensor can be connected directly to an analog to digital converter. The sensor has near linear voltage output, and the voltage is very easy to convert to percentage of relative humidity using the equation:

$$RH = \frac{\frac{V_{out}}{V_s} - 0.16}{0.0062} \quad (2)$$

where RH is relative humidity in percentage, V_{out} is output voltage and V_s is supply voltage.

Optimal supply voltage of the sensor is 5 V and a maximum consumption is about 500 μ A.

Temperature Sensors TMP36

The precision temperature sensors TMP36 provides a voltage output that is near linearly proportional to the Celsius temperature. The transfer characteristic, derived from [11] is:

$$T = \frac{V_0 - 0.10.16}{0.01} - 10. \quad (3)$$

where T is temperature in degree Celsius, V_0 is the sensor output voltage.

This sensor, without any external calibration provides accuracies of about $\pm 1^\circ\text{C}$ at room temperature. The TMP35 has low voltage supply operation from 2.7 V to 5.5 V. Its supply current is less than 50 μ A, that make the sensor very suitable for wireless applications. In addition, its low output impedance and linear output simplify interfacing to analog to digital converter.

III. SOFTWARE DEVELOPMENT

Once configured with wireless network, the measurement nodes are automatically added in the

LabVIEW Project and give immediate access to their Input/Output variables and properties. They use a particular type of protocol called NI Publish-Subscribe Protocol (NI-PSP). The I/O data can be accessed using static I/O variables from the LabVIEW Project tree or programmatically using DataSocket functions or Shared Variable functions. The Uniform Resource Locator (URL) format is the following:

ni.var.psp://gateway/node/channel,

where gateway is the IP address of the Ethernet Gateway, node is the WSN node name and channel is the I/O variable name. The default node name is NodeX, where X is the number assigned when the node is added to a LabVIEW Project. Default I/O variable names depend on the measurement node type and become active after the project is deployed to the gateway. For NI-3202 Voltage Node default names for analog inputs are AI0, AI1, AI2, AI3, and for digital inputs the default names are DIO0, DIO1, DIO2, DIO3. For NI-3212 Voltage Node the default names for thermocouple inputs are TC0, TC1, TC2 and TC3.

A National Instrument's Wireless Sensor Networks use LabVIEW shared variable engine to get data to and from each sensor node via an Ethernet Gateway. A simple approach can be to use network shared variables on block diagram by drag the I/O variable directly to the block diagram, create an indicator, and click *Run* for execution. This approach, however, can cause for a complicated block diagram if there are a large number of I/O points.

In present work a different approach is suggested, where NI WSN IOV Application Programming Interface (API) is used. An API, is a set of functions that interfaces to some set of underlying code that already exists. By using API, a developer can programmatically access existing functionality within their own application. Usually an API includes functions such as Start, Read, Write, Stop, Close etc. In such way, the user does not care about what happens inside of the subVIs, because they complete the function that they want.

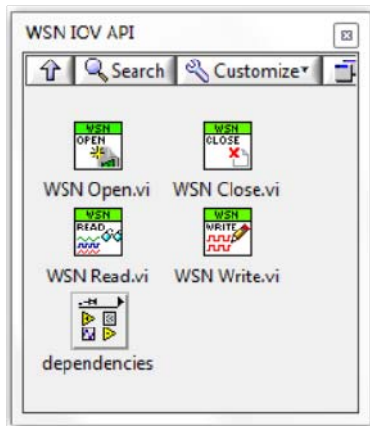


Fig. 3. WSN IOV API function palette

WSN IOV API can be downloaded from [13] and allows users to send and return data from a sensor network without having to use network shared variables on the block diagram. It is possible to pull back data from multiple nodes using an initialize, operate and close type of architecture. This high level application programming interface is built on the shared variable function and WSN

Host API and can underhanded discover all nodes and measuring points in the wireless sensor network.

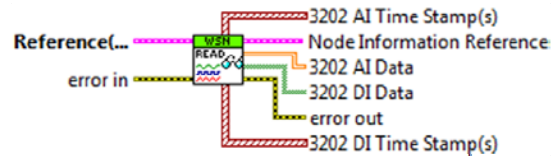
The WSN IOV API palette is installed in the User Libraries function palette and contains only four functions.

1. WSN Open.vi



This function opens a reference to the gateway and references to the analog and digital shared variables for each wireless node. If no nodes are found the function returns an error. Before using the function wireless sensor nodes must be added to an Ethernet Gateway in Measurement and Automation Explorer. The default names for a reference to variables must not be changed.

2. WSN Read.vi



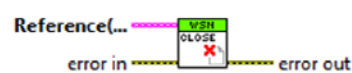
This is a polymorphic function that allows users to select what type of nodes (NI WSN 3202 or NI WSN 3212) and data to read. There is the ability to read analog data, digital data or both analog and digital data from all nodes. The function returns one dimensional array of data when configured for one node and two dimensional array of data when configured for multiple nodes. If shared variables have not been deployed or if a corresponding node has dropped off the network the function returns no data.

3. WSN Write.vi



Like the Read function, this function is based on the polymorphic instance of the VI and writes digital data to network published nodes. This VI writes one dimensional Boolean data when configured for one node and two dimensional data when configured for multiple nodes.

4. WSN Close.vi



This function closes references to all open nodes and network published variables. The function will not execute if no nodes are found by function Open.

Using described API functions and a scalable architecture it is easy to expand applications and decrease development efforts when new features are added.

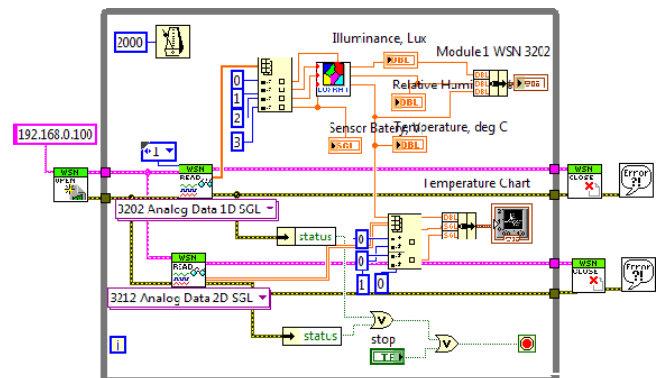


Fig. 4. Block diagram of the developed software.

The presented graphical program code or so called block diagram is shown in Fig. 4. Instead shared variables to be dragged and dropped to the block diagram form a LabVIEW project in the developed graphical code, as can be seen from figure, the data from wireless system is read in usually way. Follow the standard architecture for data acquisition system the first called function is to open a reference to the gateway. The code for reading and data manipulating is written in a while-loop. There are two Read functions. The upper one returns one dimensional data array from NI WSN 3202 with each row corresponding to one of sensors from Fig. 2. Voltage measurement from sensors is converted to illuminance, relative humidity and temperature measurements by equations from (1) to (3). The lower Read function returns 2D arrays of analog data with each row corresponding to one NI WSN 3212 node. These nodes returns data in degree Celsius. For each variable is created corresponding indicators. The last two functions are Close and Simple Error Handler. These functions terminate software connection to the WSN and indicates whether an error occurred.

IV. EXPERIMENTAL RESULTS

In order to illustrate performance of the developed LabVIEW based WSN a number of experiments was done. Front Panel of the system is shown in Fig. 5.

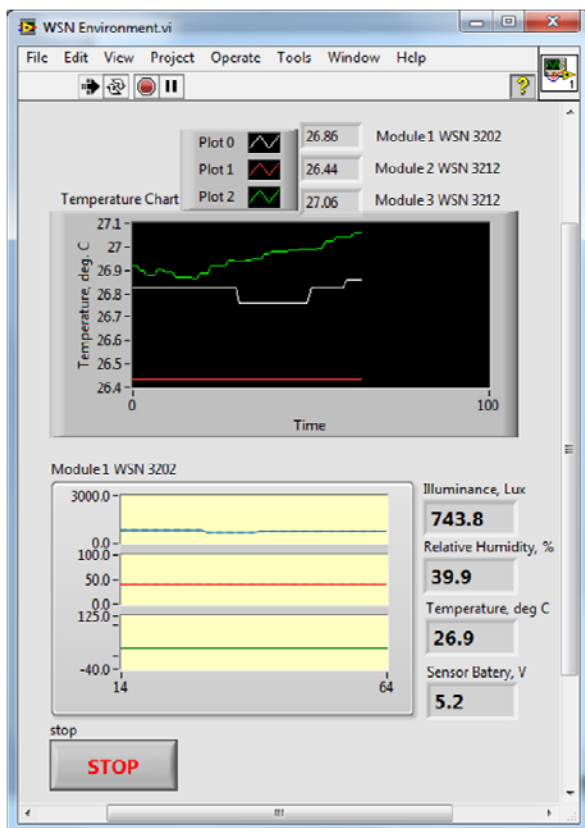


Fig. 5. The Front Panel of the WSN for Environmental Monitoring

There are temperature chart with three plots, that display temperature from three different wireless measurement nodes from three different places. The first one (white plot) displays temperature from TEMT6000 sensor and NI WSN

3202 node. The other two temperature (green and red) are measured by J-type thermocouples from two NI WSN 3212 measurement nodes. In the lower part of the Front Panel are placed indicators for illuminance, relative humidity, temperature and voltage of external battery.

V. CONCLUSION

In presented work is described design and implementation of a wireless sensor network for environment parameters monitoring, based on LabVIEW graphical system-design platform and measurement nodes from National Instruments. With introduced approach that suggest to use WSN IOV API, wireless system is easy to deploy, configure and get data from different sensors. The advantages of WSN based system according the conventional measurement method is in terms of cost, portability and reliability. In addition the developed ZigBee and LabVIEW based WSN provides mobility and networking capabilities. Graphical user interface and advanced signal processing functions distinctive for LabVIEW contributes for additional benefits.

The presented wireless sensor network for environmental monitoring can be used as for measurement of different environmental factors as for educational purposes.

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