Development of a ZigBee-based wireless sensor network node for automatic data acquisition and transfer

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In this paper we describe the development of an IEEE 802.15.4 compatible wireless sensor network (WSN) node. The sensor node will acquire and internally store data periodically. Starting times as well as the time intervals for the measurements can be freely programmed over the network system. As soon as a mobile network is detected in its proximity the node will automatically transfer data. Optionally sensor data can be delivered on demand.
When in its idle state the node remains in power-down mode in order to minimize power consumption.

The system is based on a Renesas microcontroller coupled to an RF-transceiver.
In a sample application the system is interfaced to a piezoresistive pressure sensor, typically used to determine water levels in closed tanks or open aquaculture systems.
Possible applications in the area of environmental monitoring will be presented (including tidal range measurements).

Keywords:
Wireless Sensor Networks, Embedded Systems, Microcontrollers, ZigBee, Smart Environmental Monitoring

Introduction

Since the number of sensors including required wiring constantly increases, adequate measures are necessary to keep efforts small in data acquisition.
Concerning the cost and complexity of a data acquisition system, a wireless sensor network seems to be a conveniend option. For this function, wireless network standard ZigBee is appropriate. Based on protocol IEEE 802.15.4, ZigBee has been developed for low-cost applications with little amount of data in wireless local area networks.

In addition, sensors might be difficult to access in some cases, as they might be placed in hard-to-reach areas with no electricity being available, e.g. in the countryside, the mountains or at sea.
So power consumption of a sensor node and network-independant functionality appear to be other critical factors.
As a matter of fact, a sensor node which does have idle times in between taking sensor data, can remain in a power-down mode in order to increase battery life (the sensor node could be attached to a solar panel instead).
Data might be stored internally until demanded by the network host.

Each sensor node can be programmed by a coordinator. Using a Labview GUI, the user can choose between time intervals of measurements and the mode to use the sensor node in(see applications section).
If no time interval is given, the sensor node does not store any data, only present sensor data is being sent.

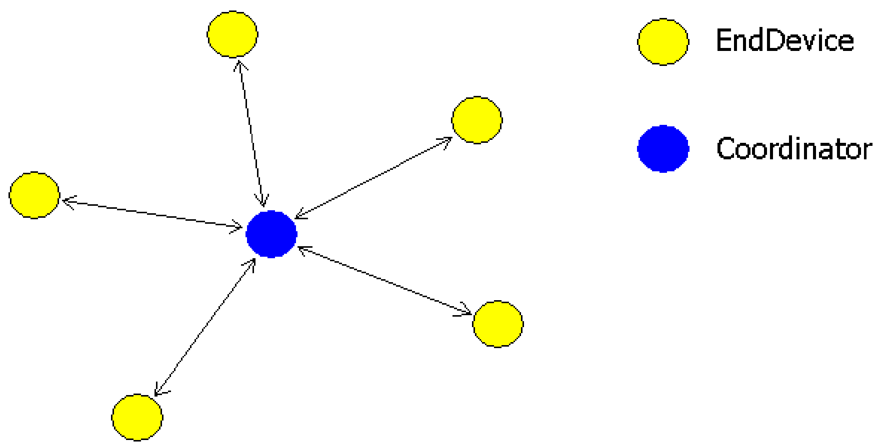
Methods and materials

ZigBee Network Topology

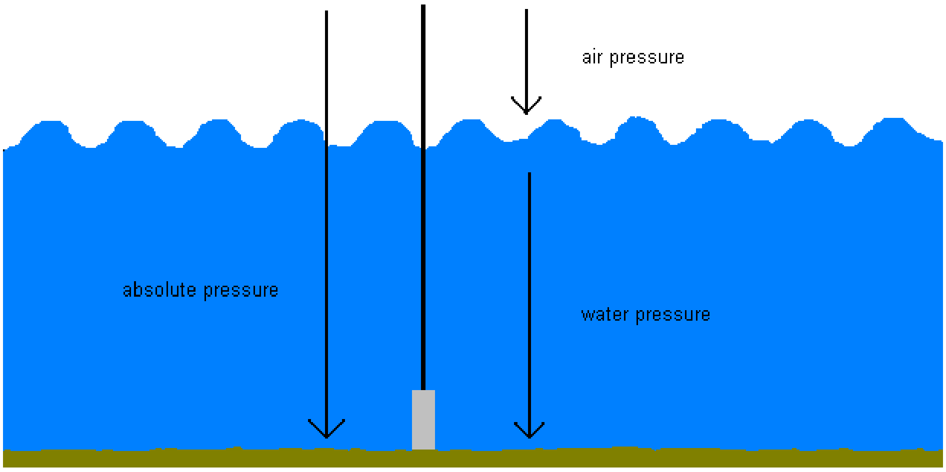
In this application, star topology is used to form a network.

The network does have one Coordinator and can have many EndDevices. The Coordinator forms and maintains a network (PAN = Personal Area Network) and is unique in its PAN.
EndDevices are physically and electrically isolated from each other, so data exchange only occurs between Coordinator and each EndDevice, which is connected to the PAN.

So, each sensor node acts as an EndDevice.



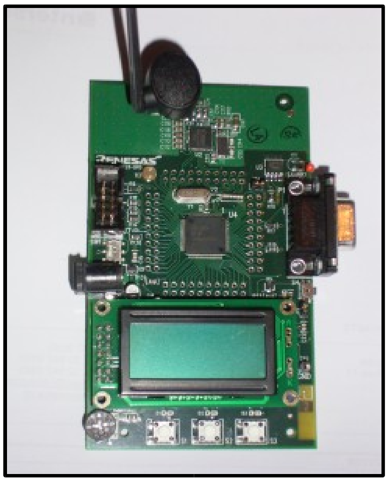
Calculating the water level



$$h = \frac{p_g - p_0}{\rho \cdot g} = \frac{p_d}{\rho \cdot g}$$

The water level h depends on the differential pressure p_d (water pressure), the density of the medium ρ and g-force g.

ZigBee Board



For this project, Renesas RZB-CC28 ZigBee-Development-Kit is used.

The main clock is set to 20MHz for 16-bit M30280 MCU.

In addition, an AD-Converter and a Real-time Clock have been attached.

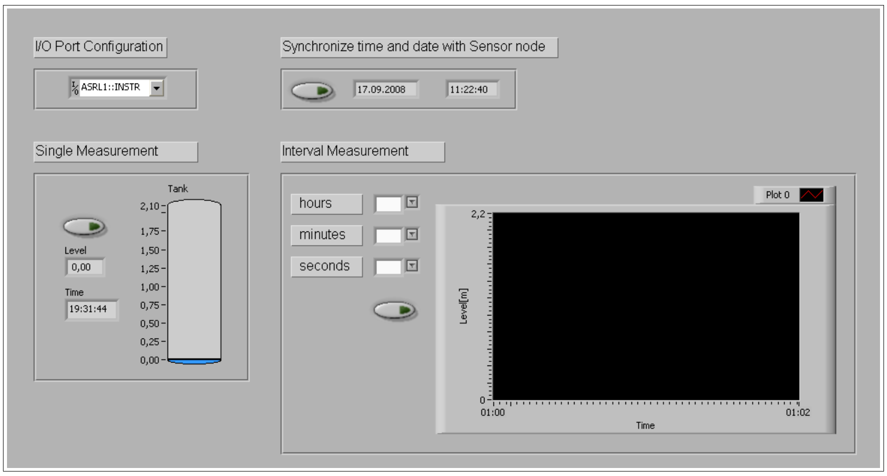
Sensor node and Coordinator node are based on identical boards, but they do differ in software stack and in additional hardware for the sensor node.

Pressure sensor

For measuring water levels, a piezo-resistive ceramic sensor is used. It performs a pressure range of 0 to 5 bars (about 72 psi) relative pressure. The differential output voltage is being amplified to fit a range of 0.5 volts up to 4.5 volts.
Both, amplifier and sensor, are supplied with 5 volts and are connected to the sensor nodes AD-converter with a 3-wire cable. The pressure sensor has a high linearity over the whole range.

Graphical User Interface

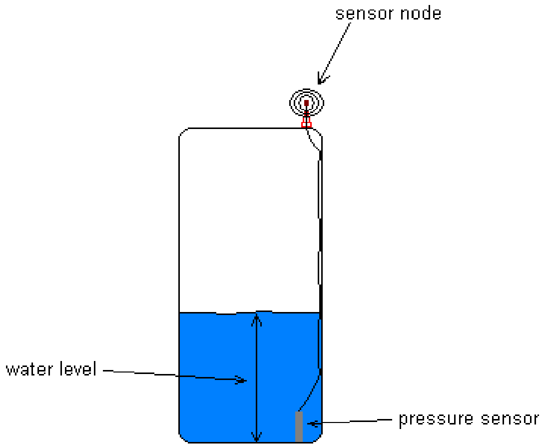
For programming the sensor node and displaying received data, the coordinator node has been interfaced to LabView, simplified shown in the picture below



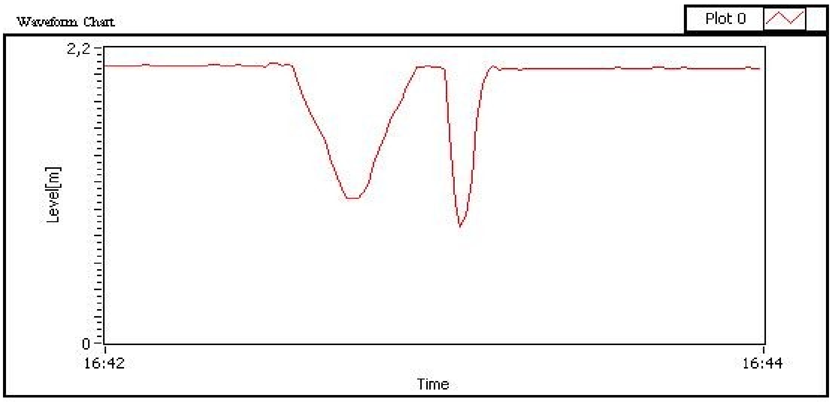
Sample applications

Level mode

In level mode, time intervals can be chosen accordingly to the change of water level in e.g. a water tank. If water level changes quickly, a short time interval for measurements is appropriate.

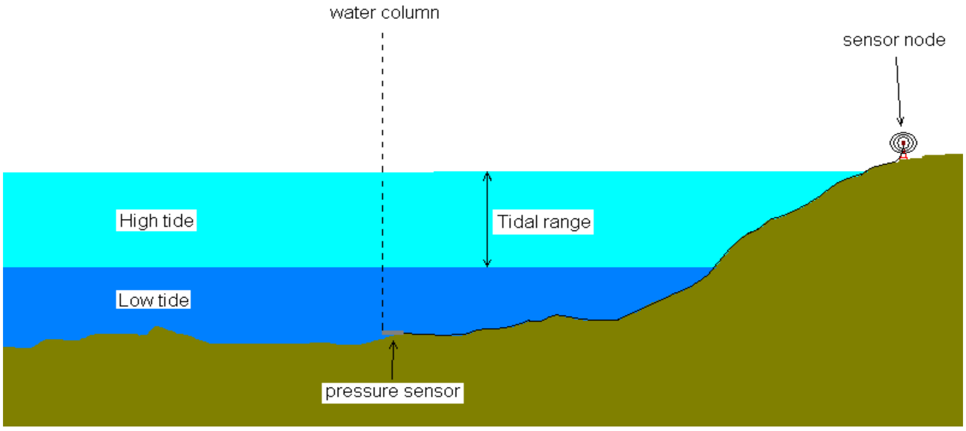


An interval measurement would be displayed in LabView as shown below



Environmental monitoring: Tidal range mode

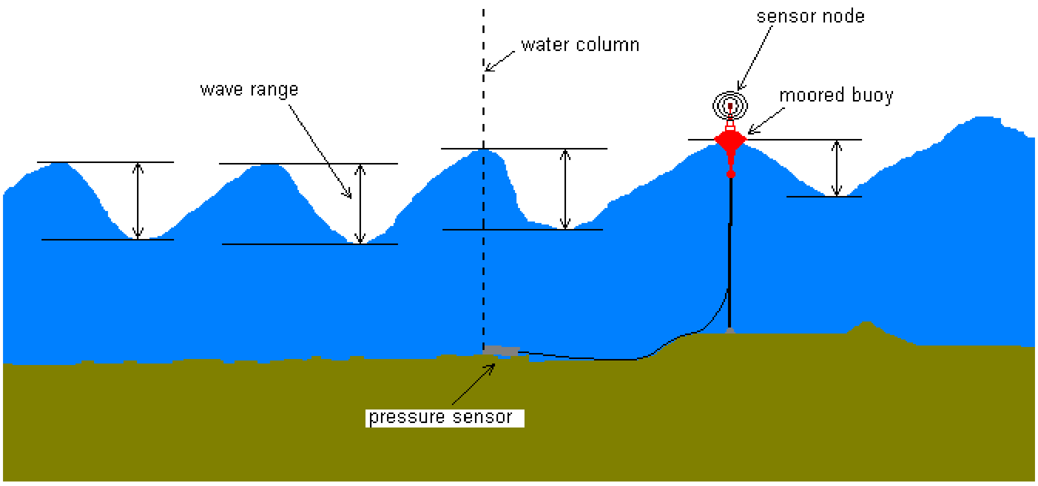
The tidal range is the difference in height between high and low tide



In this mode, time intervals must not be set too widely, such as 24 hours would not be appropriate. The closer intervals are chosen, the more accurate tidal range is calculated.

Environmental monitoring: Wave range mode

The wave range is the difference in height between wave crest and wave trough



In this mode, time intervals cannot be set. Each time a wave range is calculated, it is stored internally.