Instrument of Things
WIZnet Connect the Magic 2014 Design Challenge
WZ1295
Abstract

The Instrument of Things (IoT) shows how to extend your custom electrical instruments with industry standard capabilities for remote control via a TCP/IP interface. The WIZnet WIZ550io module is used to enable a basic web server, a port mapping service and a server for remote control of the instrument using the VXI-11 communications protocol by SCPI messages. Although development has not been completed yet, feasibility is shown using an instrument for accurate measurements of a water color test kit. The ultimate goal of the Instrument of Things is to easily add the VXI-11 communications protocol and LAN eXtensions for Instruments (LXI) technology to any electrical instrument project.

The WIZnet WIZ550io module makes it very easy to add Ethernet capabilities to custom electronics instruments, especially when it is still under development on a breadboard. The module takes care of four layers of the OSI model for networking (see table 1), is preprogrammed with a unique MAC address and features automatic configuration of network settings. The remaining three layers of the OSI model have been implemented for this project in software running on the Atmel SAM3X8E ARM Cortex-M3 CPU of the Arduino Due microcontroller board.

Table 1, the layers of the OSI model for networking and the (partial) implementations in this project.

	OSI model layer	**implementation**
7	application layer	HTTP, VXI-11, port map
6	presentation layer	XDR
5	session layer	RPC
4	transport layer	TCP, UDP
3	network layer	IPv4
2	data link layer	MAC
1	physical layer	IEEE 802.3

The three networking-related applications are a basic web server (HTTP), a port map service and a server for remote control of the instrument using the VXI-11 communications protocol. The web server can be reached at the default port 80 on the instrument. The port map service operates at standard port 111 and processes RPC port mapper procedures using TCP or UDP. The VXI-11 server actually consists of up to three services: a VXI-11 Core listener, a VXI-11 Asynchronous listener and a VXI-11 Interrupt listener. The VXI-11 services can be set to listen at any available TCP port number, as long as the service is registered with the port map service for directing clients to the correct port. See table 2 for the unique program numbers of the VXI-11 listeners, which are registered with the port map service when available for clients.

Table 2, RPC program numbers of the VXI-11 listeners.

program number	
0x0607AF	DEVICE_CORE
0x0607B0	DEVICE_ASYNC
0x0607B1	DEVICE_INTR

The implementation of the XDR layer (eXtended Data Representation) consists of a library of functions, which are used to enable conversion to and from a standard data format for transmission. Incoming data on the physical interface of the WIZnet WIZ550io is first processed up to the transport layer of the OSI model. When the data is actually intended for one of the services running on the Arduino Due, the module will indicate that data is available in its buffers. This data is unpacked using the XDR library and processed further by the service running on the Arduino Due. The process of sending data from the instrument to the client follows the reverse route through the layers of the OSI model.

The parts of the instrument not related to networking are a 20x4 LCD character display, a micro SD card reader and the RGB color sensor. The ease of use of the Arduino platform and availability of an extensive set of add-on modules, makes it trivial to add other sensors or components for local operation by the user.

Figure 1 shows a block diagram of the Instrument of Things as presented in this document. The microSD card and the Wiznet WIZ550io ethernet module are connected to the SPI interface bus of the Arduino Due. Separate slave select signals (CS) are available for the modules on the SPI bus. One digital I/O pin of the Arduino Due is used to reset the WIZ550io module. The interrupt and ready status signals of the WIZ550io module are connected to two other digital I/O pins of the Arduino Due.

Let's get to the point of the specific Instrument of Things presented here: a water color test kit meter. Water color test kits are chemical test sets, which can be used to measure the quality of water in e.g. an aquarium, swimming pool or rain water reservoir. Each set is specifically designed to measure a specific property or content, like acidity (pH-level) or concentration of nitrides. The result of a water color test is typically a specific color of the water sample, which can be compared to a color chart to obtain an approximate value of the measured parameter. Unfortunately, no electronics are involved here at all.

The color chart that comes with a water color test kit typically has a scale of only 3 to 5 different colors. Interpolation between to colors can be challenging and will probably not result in reproducible results. Exposure to direct sunlight or prolonged storage in darkness will affect the quality of the color chart and thus the accuracy of the measurement. The visually impaired and people with color blindness will prefer an alternative method of reading the results of the water color test kit. Last but not least, some take performing measurements really serious. Instead of relying on the calibration of the color chart by the supplier of the test kit, calibration measurements become part of the sample measurement procedure. The color chart is disposed of and replaced by a more accurate color scale. Electronics are used to get accurate color readings, perform calculations on the measurement data and to store results.

The RGB sensor selected for the Instrument of Things features a white LED to light the sample. This LED is mounted on the same PCB as the RGB sensor, thus only reflected light will be measured by the sensor. Optionally, a second white LED is easily connected to spare pins on the Arduino Due to measure by

transmission of light through the sample. A third option is to place a reflective surface, e.g. aluminum foil, on the opposite side of the test vial.

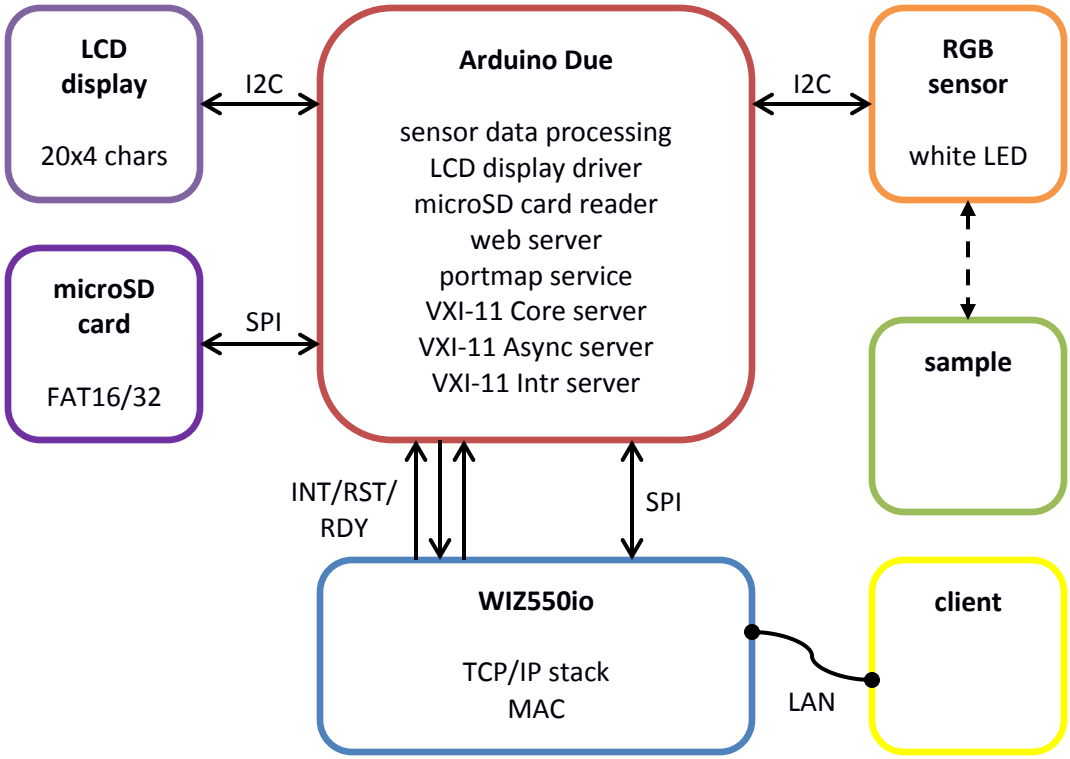

Figure 1, block diagram of the Instrument of Things.

Prototype 1

The first prototype of the Instrument of Things has been built on a breadboard. The Arduino Due development board is the center of the set-up and all peripherals are connected to the I/O-pins as defined below:

1. SD card module attached to the SPI bus of the Arduino Due

   MISO pin 74 (SPI MISO)
   MOSI pin 75 (SPI MOSI)
   CLK pin 76 (SPI SCK)
   CS pin 4 (SPI CS1)

2. WIZ550io module attached to the SPI bus of the Arduino Due

   MISO pin 74 (SPI MISO)
   MOSI pin 75 (SPI MOSI)
   CLK pin 76 (SPI SCK)
   CS pin 10 (SPI CS0)
   INT pin 46 (interrupt from module, active low)

RST pin 48 (reset module, active low)
RDY pin 50 (module ready)

3. A third module could be attached to the SPI bus:

   MISO pin 74 (SPI MISO)
   MOSI pin 75 (SPI MOSI)
   CLK pin 76 (SPI SCK)
   CS pin 52 (SPI CS2)

4. LCD module (note: 5V logic levels) attached to the I2C bus (address 0x20):

   SDA pin 20 (I2C TWI1 SDA)
   SCL pin 21 (I2C TWI1 SCL)

5. Adafruit TCS34725 breakout board attached to the I2C bus (address 0x29):

   SDA pin 20 (I2C TWI1 SDA)
   SCL pin 21 (I2C TWI1 SCL)

Figure 2 shows a photograph of the first prototype. After taking a sample in the test vial, reagents have to be added in a specific order and quantity. Two different water color test kits have been used: for nitrite (NO_2^-) and for nitrate (NO_3^-). The test vial with the sample and reagents for nitrite is shown on the left. The other test vial, with sample and reagents for nitrate, is placed in the sample holder with RGB sensor. The white LED on the sensor board is on and lights the orange liquid in the test vial.

The base plate shown on the right contains two breadboards, the Arduino Due, the LCD character display and the sample holder with test vial. The Wiznet WIZ550io module is placed on the top breadboard with the SD card module. The bottom breadboard contains BSS138 bi-directional level shifters, which enable control of the 5V LCD character display by the 3.3 V I2C bus of the Arduino Due.

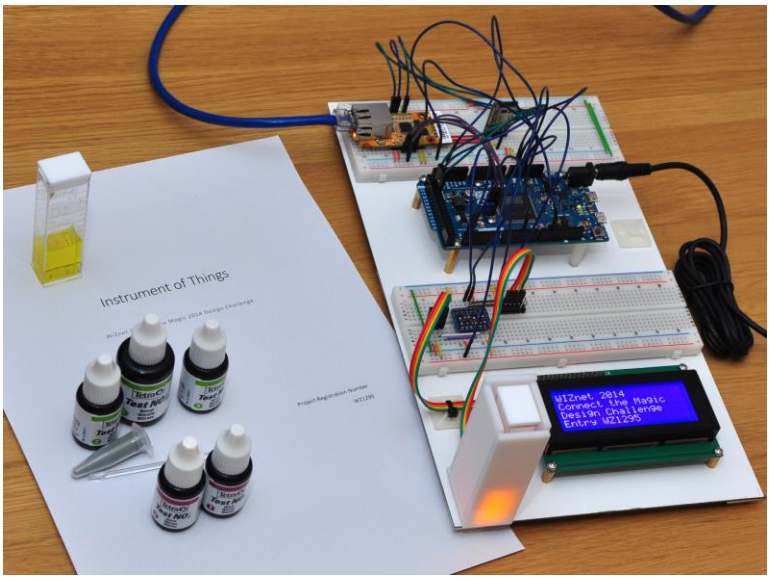

Figure 2, photograph of the first prototype of the Instrument of Things.