# Hardware Specification for Wireless Sensor Node for Real Time Data Acquisition

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***Abstract*-The paper describes designing of a system with the help of the sensors to detect the different parameter. We have designed a compact wireless modular sensor architecture, which contains a number of circuit boards (nodes), we can use it in environmental monitoring systems. Each node has a major function i.e. inertial sensing, tactile sensing, data collection and transmission. Their primary goal is to collect the data and transmit towards the server and then it is transmitted towards http or web for browsing from different locations. In this paper we present the design of complete IPv6 based network architecture for Wireless sensor network. We validate the architecture with the quality implementation that approaches many techniques in the sensor network community, link protocol, header compression, hop-by-hop forwarding, and efficient routing with effective link estimation with less power-large data transmission. For real time data acquisition system microcontroller Atmega32u4 is easily interfaced with nRF24.This sensor continuously generates enormous amount of data in the form of packets and frame (date, time,source address, destination address, data, ERC and CRC) which can easily reach to the destination.**

***Keywords*- Internet of Things, IPv6, nRF24, Thingspeak**

## I. INTRODUCTION

A wireless sensor network consist of devices equipped with sensors, microcontroller, radio transceivers that cooperate to form fully connected network of a sensor node[1]. The wireless nodes are autonomous devices, which are often battery-powered with sensing, processing and communication capabilities [2]. Sensors are electronic devices which are capable of sensing environmental parameters such as temperature, humidity, light intensity, pressure, soiletc. This sensor measures the different parameters around the sensing device and converts the sensed data into the electrical signal[3].The sensed data is sent via radio transmitter i.e. nRF24 to the sink node or server .Sink node combines with software for processing the sensed data collected by sensors and it is often connected to the API's for example, thingspeak.

During the Data transmission in the wireless media large energy may consumed. For energy conservation, the data reports are often sent to the sink node through a multi-hop short-distance communication, with intermediary sensor nodes forwarding their own and neighbors data. Intermediate node can perform the task to receive and filter the data from other nodes and send it to server through shortest path distance process [3].

Challenges-

- To know several sensor networks and protocol specific details. Operating system for low level abstraction [4] and simulation or directly are the sensor hardware[5]
- Extraction and use of sensor generated data in the proper format that can be accessed by final user in graphical format with their predefined queries.
- Concern the semantic gap between the representation of high level application received at the server and low level data transmitted from the sensor node.

There are large numbers of devices which are already monitoring different parameters in the physical world and available to use. Above this the main constraint is how to enable people to create applications on such WSN systems. To achieve this goal, a crucial requirement is to provide a layer of abstraction to distribute the sensing tasks and queries to the WSN and to gather the sensor generated data [2].

This paper provides following contributions:

- To develop a complete IPv6 based network architecture that allows end-to-end communication between the sensor nodes and IP devices too.

- To develop software architecture to process the sensed data and further it is linked to the server.

To present the implementation of efficient IPv6 based architecture for WSN.

## II. BACKGROUND

In 2001, *Schurgers* et al worked on 'Energy Efficient Routing in Wireless Sensor Networks'. His first approach was to use a concept termed as Data Combining entities or DCE's. This concept is similar to clustering, instead of designating a cluster head; it picked up a node that has other streams of network traffic flowing through it as the DCE [6]. The second approach discussed by *Schurgers* et al to reduce energy consumption in a wireless sensor network is the spreading of network traffic over the entire network. In the same year, *Slijepcevic et al* in the paper 'Power Efficient Organization of Wireless Sensor Networks' discussed on reducing the overall power in the network system by grouping the sensor nodes into mutually exclusive sets in 2001 [7]. This technique assumed that the nodes are placed stochastically.

"Maximizing System Lifetime in Wireless Sensor Networks" by *Dong*, is one of the first papers to differentiate between the "time" and "transmission" approaches to overall lifetime of a wireless sensor node network in 2005 [8]. He considered many different times based and packet based models. *Chao-Lieh Chen et al* authored the paper "Energy-proportional Routing for Lifetime extension of Clustering-Based Wireless Sensor Networks" in 2007. He presented an algorithm to determine the energy usage for nodes in an upcoming round of data collection and transmission; it then determines if a cluster-head or a node should be used for forwarding tasks or transmits data to intermediate hops [9].

In 2008 *Kim et al* in his paper 'Minimizing Delay and Maximizing Lifetime for Wireless Sensor Networks with Anycast' pertained a unique type of wireless sensor network, namely an event-driven network that uses ''Anycast". Utilized a wake-sleep cycle for the sensor nodes, i.e. instead of having one node that a sensor node will transmit its messages to, a node will have a group of candidate nodes that it can transmit to [10]. *Jiang et al* worked on classification of WSN clustering schemes based on 8 clustering attributes in 2009. He also analyzed popular WSN clustering algorithms and also comparison between those algorithms [11]. *Vipul Gupta* worked on developing a web-based service called Sensor network that facilitates a heterogeneous mix of devices to interact with one another in the paper 'Sensor Network: An open data exchange for the web of things' in year 2010 [12].

## III. HARDWARE

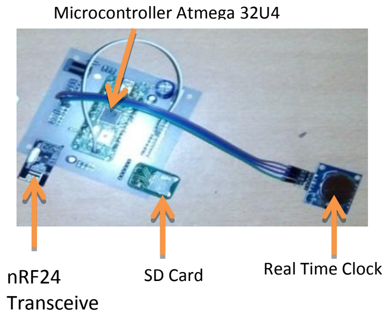


Fig. 1Wireless Sensor Node Specification

### A. *Atmega32u4*

The ATmega32U4 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. ATmega32U4 achieves throughputs approaching 1 MIPS per MHz allowing designer to optimize power consumption versus processing speed by executing powerful instructions in a single clock cycle. It combines a rich instruction set with 32 general purpose registers. These 32 registers are directly linked to the Arithmetic Logic Unit (ALU), which allows two independent registers to be used in one single instruction executed in one clock cycle [13].

The ATmega32U4 provides the following features:

- 32K bytes of In-System Programmable Flash with Read-While-Write capabilities,
- 1K bytes EEPROM,
- 2.5K bytes SRAM,

- 26 general purpose I/O lines (CMOS outputs and LVTTL inputs),
- 32 general purpose working registers,
- Four flexible Timer/Counters with compare modes and PWM,
- One more high-speed Timer/Counter with compare modes and PLL adjustable source,
- One USART (including CTS/RTS flow control signals)
- A byte oriented 2-wire Serial Interface,
- A 12-channels 10-bit ADC with optional differential input stage with programmable gain,
- An on-chip calibrated temperature sensor,
- A programmable Watchdog Timer with Internal Oscillator,
- The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning.
- The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or Hardware Reset.
- In Standby mode, the Crystal/Resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption.

The device is manufactured using ATMEL's high-density nonvolatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed in-system through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the ATMEL ATmega32U4 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications. The ATmega32U4 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, in circuit emulators, and evaluation kits.

Table I. Analysis on ATMEGA32U4

| Speed (MHz) | Power Supply | Ordering Code | Defaulter Oscillator | Package | Operation Range |
|---|---|---|---|---|---|
| 16 | 2.7-5.5V | ATmega32U4-AU | External XTAL | 44ML | Industrial (-40$^0$ to +85$^0$C) |
| | | ATmega32U4RC-AU | Internal Cabin. RC | | |
| | | ATmega32U4-MU | External XTAL | 44PW | |
| | | ATmega32U4RC-MU | Internal Cabin. RC | | |

### *B. Real Time Clock*

Real Time Clockis placed on server node, to collect real time environmental information/data through different sensors which are interfaced with microcontroller as a sink/server node.In Wireless sensor nodes, Real time clock is used for periodic node wakeup. The periodic node wakeups in WSN context refers to wakeups based on events and it also allows the processor to enter into deep sleep modes [14]. The real time clocks can also activate the sensor nodes. Time synchronization can also be maintained by RTC's [15].The RTC is also used to reducethe time synchronization overhead due to its betteraccuracy, compared to software based solutions, withminimal cost overhead.These real time clocks are the replacement for industry standard real-time clocks.It provides an automatic backup supply with integrated trickle charger. Backup supply may be implemented by using a capacitor or a non- rechargeable battery. The RTC registers include an Oscillator Failflag that indicates the status of RTC oscillator. And a STOP bit which allows the processor to disable the oscillator. Time registers of RTC's are generally updated once per second and to prevent timekeeping glitch, all the registers of RTC's are updated at the same time.The device also includes automatic leap-year compensation. RTC are used in general consumer electronics. The real time clock provides following features [16]:

- It automatically switch over to backup supply
- I2C Interface supports serial clock upto 400 kHz
- It uses 32.768-kHz Crystal with -63 ppm to +126 ppm adjustment

- It has integrated oscillator-fail detection
- 8-Pin SOIC Package
- Ambient operating temperature of RTC: –40°C to 85°C.

*C. SD Card*

SD memory cards may also support a second security system based on commonly used standards, such as ISO-7816, which can be used to interface the SD memory card into public networks and other systems supporting mobile e-commerce and digital signature applications [17].This compatibility includes mechanical, electrical, power, signaling, and software. The intent of the SD I/O card is to provide high-speed data I/O with low power consumption for mobile electronic devices.

*D. Sensors*

The integration of sensors requiring some type of electronic adaptation stage or signal processing prior to reading by the microprocessor is carried out by the various microprocessor sensor boards. Connection between these and the mote takes place pin to pin using the two 2x11 and 1x12 connectors mentioned in the section "Hardware" I/O.

*1. DHT11 Temperature and humidity sensor*

DHT11 temperature and humidity sensors are digital sensors. DHT11 elements are extremely accurate on temperature and humidity calibration.Calibration Coefficients are stored in the OTP memory of DHT11 in the form of programme, which are used by internal signal detecting process of sensors [18].The sensor provides single-wire serial interface, this makes the system integration easier. DHT11 sensors are small in size, it consumes less power and up to20 meters signal transmission. Because of these advantages of DHT11 sensorsare used in various applications.It is a 4-pin single row pin package. It is convenient to connect to the sensor node. The interfacing of DHT11 sensor with microcontroller is shown in fig. 2.

Fig. 2 DHT11Temperature and humidity sensor

Table II. Technical Specification of DHT11

| Item | Measurement Range | Humidity Accuracy | Temperature Accuracy | Resolution | Package |
|---|---|---|---|---|---|
| DHT11 | 20-90%RH 0-50$^{0}$C | ±5%RH | ±2$^{0}$C | 1 | 4Pin Single Row |

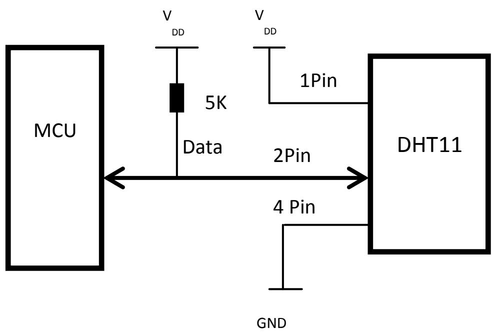


Fig. 3 Interfacing of Microcontroller with DHT11

*2. BMP180 Digital Pressure Sensor*

Fig. 4 BMP180 Digital Pressure Sensor

The BMP180 digital pressure sensor is the function compatible successor of the BMP085. It is a new generation of high precision digital pressure sensors for various applications. It is an ultra-low power, low voltage electronic component. The

BMP180 offers superior performance with a low altitude noise of merely 0.25m at fast conversion time [19]. The sensor provides I2C interface due to which there is ease of system integration with a microcontroller. The functioning of BMP180 is based on piezo-resistive technology. These sensors are highly accurate, linear and stable. The interfacing of BMP180 sensor with microcontroller is shown in fig. 5.

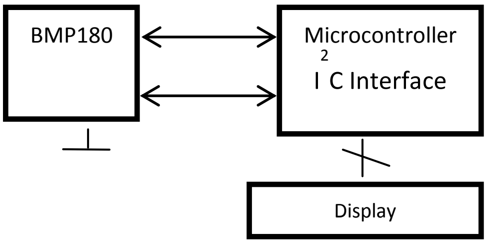


Fig. 5 Interfacing of BMP180 with microcontroller

These sensors are so designed to be connected directly to a microcontroller via the I2C bus. The sensed pressure data has to be compensated by the calibration data of the E2PROM of the BMP180. It consists of a piezo-resistive sensor, an A to D converter and a control unit with E2PROM and a serial I2C interface. This sensor delivers the uncompensated value of pressure. The E2PROM has stored 176 bit of individual calibration data. This is used to compensate offset, temperature dependence and other parameters of the sensor.
UP = pressure data (16 to 19 bit)

*3. Internal Sensor*

3.1 *Accelerometer :* Acceleration sensor LIS3331LDH senses the acceleration variations experienced on each one of the 3 axes (X, Y, Z). The integration of this sensor allows the measurement of acceleration on the 3 axes (X, Y, Z), establishing 4 kinds of events: Free Fall, inertial wake up, 6D movement and 6D position. It is capable of measuring accelerations with output data rates from 0.5 Hz to 1 kHz. This sensor features ultra-low-power operational modes that allow advanced power saving and smart sleep to wake-up functions. The accelerometer has 7 power modes, the output data rate (ODR) will depend on the power mode selected. The power modes and output data rates are shown in this table:

Table III. Power modes and output data rates of Accelerometer

| Power Mode | Output Data Rate |
|---|---|
| Power Down | -- |
| Normal Mode | 1000 |
| Low-power1 | 0.5 |
| Low-power2 | 1 |
| Low-power3 | 2 |
| Low-power4 | 5 |
| Low-power5 | 10 |

This accelerometer has an auto-test capability that allows the user to check the functioning of the sensor in the final application. Its operational temperature range is between -40ºC and +85ºC. The accelerometer communicates with the microcontroller through the I2C interface. The pins that are used for this task are the SCL pin and the SDA pin, as well as another INT pin to generate the interruptions. The accelerometer has 4 types of event which can generate an interrupt: free fall, inertial wake up, 6D movement and 6D positions.

*3.2 RTC temperature sensor :* The sensor node RTC (DS3231SN from Maxim) has a in-built internal temperature sensor which calibrates the chip temperature of microcontroller. Wireless sensor node can access the sensed value of chip temperaturevia I2C bus. The RTC temperature sensor is in a 10-bit two's complement format and has a resolution of $0.25^0$C. The measurable temperature range is between -40ºC and +85ºC. The RTC temperature sensor is used to measure the temperature of the boardand can thus compensates for oscillations in the quartz crystal it uses as a clock. The RTC temperature sensor is a in-built sensor to the RTC, the applications which requires probe temperature sensor, it must be integrated from micro analog and digital inputs.

*E. Transmitter/Receiver Section*
*nRF24L01*
*(Single Chip 2.4GHz Transceiver)*

We are using nRF24L01 transceiver in our design. It is a single chip 2.4GHz transceiver featuring embedded baseband protocol engine. It is designed for low power wireless applications. The nRF24L01 operates in the world-wide ISM frequency band at 2.4 – 204835 GHz [20]. It is operated through a Serial Peripheral Interface (SPI.) Register map is available to the transceiver through Serial Peripheral Interface. The map contains all the configuration registers in the nRF24L01 and it is accessible in all operating modes of the chip. The embedded baseband protocol engine is based on packet communication and supports advanced autonomous protocol operation. Internal FIFOs of nRF24L01 makes sure that the data is flowing smoothly between the radio end and the system's Microcontroller. Enhanced ShockBurst reduces system cost by managing all the high-speed link layer operations. The radio end uses GFSK modulation. Frequency channel, output power and air data rate are user configurable parameters ofnRF24L01 transceiver. The air data rate supported by this transceiver can be configured to 2Mbps. The high air data rate featured with two powers saving modes makes nRF24L01 well suited for low power applications. Internal voltage regulators provide avery high Power Supply Rejection Ratio (PSRR) and a wide power supply range.As nRF24 is well suited for low power designs, we are using to reduce power consumption of the prototype.

Fig. 6 nRF24(Single Chip 2.4GHz Transceiver)

nRF24 includes following features:

- Radio
  - Worldwide 2.4GHz ISM band operation
  - 126 RF channels
  - Common RX and TX pins
  - GFSK modulation
  - 1 and 2Mbps air data rate
  - 1MHz non-overlapping channel spacing at 1Mbps
  - 2MHz non-overlapping channel spacing at 2Mbps
- Transmitter
  - Programmable output power: 0, -6, -12 or -18dBm
  - 11.3mA at 0dBm output power
- Receiver
  - Integrated channel filters
  - 12.3mA at 2Mbps
  - -82dBm sensitivity at 2Mbps
  - -85dBm sensitivity at 1Mbps
  - Programmable LNA gain
- Enhanced ShockBurst
  - 1 to 32 bytes dynamic payload length
  - Automatic packet handling
  - Auto packet transaction handling
  - 6 data pipe MultiCeiver for 1:6 star networks
- Power Management
  - Integrated voltage regulator
  - 1.9 to 3.6V supply range
  - Idle modes with fast start-up times for advanced power management
  - 22uA Standby-I mode, 900nA power down mode
  - Max 1.5ms start-up from power down mode
  - Max 130us start-up from standby mode
- Host Interface
  - 4-pin hardware SPI
  - Max 8Mbps

nRF24 is used as Wireless PC Peripherals like mouse, keyboards and remotes. It has applications in advanced media center remote controls, Voice over IP (VoIP) headsets and low power wireless sensor networks.

## IV. SOFTWARE

### A. Arduino

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language and the Arduino development environment (based on Processing). Arduino is serving as the basis of breathalyzers, for home automation systems, screens with Twitter messages of DNA testing kits, traffic lights, art installations, 3D printer, or system to detect earthquakes and report via Twitter if the tremor occurs less than five kilometers. A major milestone has been connecting Arduino to mobile phones with Arduino boards.

### B. ThingSpeak

ThingSpeak is an open application platform designed to enable meaningful connections between things and people. ThingSpeak has an open source API to store and retrieve data from things using HTTP over the Internet or via a Local Area Network. With ThingSpeak, we can create sensor logging applications, location tracking applications, and a social network of things with status updates.The ThingSpeak API is available on GitHub for download and installation on your own servers. We can also take the source code and make changes and contribute new features. ThingSpeak is a modern Ruby on Rails 3.0 application and includes everything to get started including, a full web application, User Management, API Key Management, Channel Management, and Charting. The license for ThingSpeak is under GPLv3 for open source use and can be licensed from ioBridge for closed source applications. ThingSpeak has been installed on over 500 servers and licenced commercially since its release on GitHub in March 2011.

## V. WORK IN PROGRESS

Thus we have designed sensor nodes which are capable of sensing different environmental parameters i.e. temperature, pressure, humidity etc. This sensed data is interfaced to the sink node via nRF24 transceiver. These sensed values are processed by the Arduino software. If the sensor nodes are connected to the API's like Thingspeak, the designer can observe the sensed data globally. Our next step is to connect these sensor nodes to the web or http, so that the data can be accessed from anywhere rather from a single sink node.

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