Abstract

Internet has evolved from connecting computers to connecting everyday things that interacts with the environment. Embedded devices that are IP-enabled can be employed for real time remote monitoring in the Internet of Things (IoT) environment. This work demonstrates an efficient method of real time remote monitoring of environmental parameters using Intel Galileo—an IP sensor node that acquires the data from the environment like temperature, pressure etc. and a server that is connected to the Wi-Fi router that acts as a gateway for this network. The Web server provides the real time sensor information with dynamic updates in the form of webpage to the remote client.

Keywords: Intel Galileo, Internet of Things, IP-Sensor Node, Remote Monitoring

1. Introduction

Devices utilizing internet for communication has grown tremendously in this decade. Nowadays, Internet has advanced from connecting computers to connecting everyday objects. Internet of Things (IoT) is an idea that comprises of acquiring data from the environment and communicating through the internet exploiting the IP protocol. This concept of Internet of Things has become prominent because it is possible to access the information from anywhere with the internet connectivity. Internet of Things has become one of the successful technologies as it utilizes the existing IP protocol and it is global.

Innovation in embedded devices, communication technologies and the advent of smart mobile devices have made remote monitoring of various physical parameters of the environment an effortless task. Remote monitoring of physical parameters has numerous applications such as Industrial monitoring, Health care monitoring, Environmental monitoring etc. IP-enabled device can be deployed as a sensor node for obtaining the data and these values are stored in the database. Web server provides the real time data to the remote client in the form of web page. This system will make real time monitoring of environmental conditions naive in various applications.

2. Internet of Things Architecture

Development in technologies like Wireless sensor networks, MEMS and Nanotechnology, RFID etc. has propelled the growth of Internet of Things. Pervasive computing capabilities that have been successfully incorporated in miniaturized embedded device along with communication technologies like WiFi, Ethernet, Bluetooth, Zigbee, NFC etc. have maximized the progress of Internet of Things. These advancements generates various smart embedded products in to market that can be used in diverse applications like home automation systems, remote monitoring, health care etc. thereby widening the vision of Internet of Things in building a connected world. Unlike the architecture of traditional Internet communication, Internet of Things has certain
adaptations. I. Mashal et al.\textsuperscript{4} divided the IoT into five layers namely:

1. Perception layer that includes sensors, RFID etc.
2. Network layer that deals with various networking technologies
3. Middleware layer includes service management and information processing
4. Application layer that deals with various applications
5. Business layer that manages various applications.

3. Existing System Analysis in IoT

M. Paschov et al.\textsuperscript{3} provides thorough analysis of Internet of Things in health care applications. This study also gives insight into the cost spent in technology used for data communication and internet substantially proved to be one of the successful modes of communication. Study also evaluated various protocols like MQTT, REST, CoAP etc. that can be implemented for various applications. This analysis also compares other communication technologies like Bluetooth, Near Field Communication (NFC) and Radio Frequency Identification (RFID) but for distant communication these technologies are not proficient. Smart home technologies that can be employed in Internet of Things environment has been implemented by Kelly et al. Some of these systems use additional communication technologies like Bluetooth, Zigbee\textsuperscript{5} which in turn increases the hardware cost and also increases the latency in packet transmission. Home automation using Bluetooth in Internet of Things environment has been proposed by M. Collota et al.\textsuperscript{6}. A gateway approach for connecting IP-WSN in 6LoWPAN with the Internet is demonstrated by S. Hong et al.\textsuperscript{7}. Systems using IPv6 is not available everywhere and also additional compression techniques may increase the complexity of the system. In this work, a complete smart environmental condition monitoring system using IP-enabled device and web server is illustrated, utilizing the inbuilt Ethernet communication that supports IPv4, thus making this system a simpler and an efficient one to implement in variety of applications.

4. System Architecture

For a system to be deployed in Internet of Things environment the deployed device has to be IP-enabled and it has to be connected to the internet continuously. The important issue in designing a system to work in Internet of Things environment is that the protocol used at the higher layers has to be chosen in such a way that it supports Internetworking Protocol (IP), hence reuse of existing protocols like Hyper Text Transfer Protocol (HTTP)\textsuperscript{8} in the application layer will be effective because it is already in use and it is secure. Hence server running HTTP provides the necessary information to the remote client browser in the form of web page with dynamic updates each time the client checks in.

This system consists of a Thermistor, humidity and fire sensor connected to an IP-enabled embedded device, a WiFi router and a Server. The sensed data is communicated over the Ethernet of an embedded device in the form of packets. These data packets from the embedded device are routed to the server and it stores the values in the database. The sensed values that are stored in the database can be retrieved by the server software whenever it is requested. Server that handles the HTTP requests hosts a website and provides the data to the web client i.e. any remote computer with the internet connection, in the form of web page by retrieving the data stored in the database. Hence the real time data from the environment can be obtained from anywhere using this system shown in Figure 1.

This system consists of three modules i.e. data acquisition module that consists of thermistor, fire and humidity sensor, data processing and transmission module that comprises of Intel Galileo Gen 2 with inbuilt Ethernet and router and web interface module that consists of web server.

4.1 Data Acquisition Module

This module consists of thermistor used for sensing the real time temperature from the environment. Thermistor is made of material whose resistivity varies with the temperature. If the resistivity of the material used in thermistor decreases with the surge in temperature, then the thermistor has negative temperature coefficient. If the resistivity of the material increases with the surge in temperature, then the thermistor has positive temperature coefficient. The equation describing the relationship between the resistance and the temperature is given by

\[ \Delta R = X \Delta T \]  

Where \( \Delta R \) denotes change in resistance, \( X \) denotes temperature coefficient of resistance, \( \Delta T \) denotes change in temperature.
in temperature. Humidity sensor gauges the moisture content in the environment by the changes in the electrical capacitance or resistance. Fire sensor senses the generation of Ultra-violet and Infra-red rays, thereby it detects the occurrence of flame.

4.2 Data Processing and Transmission Module

The data processing module used in this system is an advanced embedded device i.e. Intel Galileo Gen 2 (system in package). This device is made of Intel Quark SoC X1000 32 bit Application processor, and it is made compatible to work with Arduino integrated development environment. It has various communication facilities like Ethernet, USB, UART etc. This device is powered by 5V DC supply.

Sensors are connected to the input/output pins of an embedded device. These changes in analog values are converted into digital values by analog to digital converter that is inherent in that device. These digital values are converted into frames called datagrams (data packets) before it is transmitted over the Ethernet. This conversion is termed as encapsulation. This encapsulated frame comprises of information regarding the source and destination device and error checking mechanism. The encapsulated format of the data packet is shown in Figure 2.

First field in the Ethernet frame consists of Preamble bits that signal the device receiving the frame to synchronize its time with the source. This field permits the receiving device to avert few bits at the start of the frame. Start Frame Delimiter (SFD) indicates the starting point of the frame. Destination and Source address denotes the physical address of the destination and source devices. Source address is unicast and the destination address can be either unicast or broadcast or multicast. The field Length denotes the total number of bits in the MAC frame. Data field contains the original information that has to be transmitted to the upper layers. Cyclic Redundancy Check (CRC) comprises of error checking codes used for error controlling mechanism.

4.3 Web Interface Module

These data packets are routed by the router to the server in the network. Server running ASP.NET framework receives these data packets through socket communication. These data packets are stored in the database. These

<table>
<thead>
<tr>
<th>Preamble</th>
<th>SFD</th>
<th>Destination address</th>
<th>Source address</th>
<th>Length</th>
<th>Data</th>
<th>CRC</th>
</tr>
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Figure 1. Block representation.
sensor data are retrieved from the database by the server and presented to the client's web browser in the form of web page through the website hosted by the server. The advantage of using HTTP is that it supports IP without any modifications or adaptations. Remote monitoring of temperature is made more efficient using web server, since it provides temperature data to multiple clients at the same time accessing from various places thus fulfilling the vision of Internet of Things. The socket layer communication between the client and server is shown in Figure 3.

![Figure 3. Socket interface.](image)

Data packet communication begins with an IP-enabled device forwarding the data packets to the destination server. IP-enabled embedded device that operates in all five layers communicates the sensor data using Telnet over the Ethernet to the server through router. The router that operates in three layers namely physical, data link and network layer forwards the data packets to the server in the network. Server operates in all five layers and it aids in presenting the data stored in the database to the remote client in the form of webpage. The application layer in the client's system i.e. web browser helps in accessing the website. The flow of data packets at various layers is illustrated in Figure 4.

The received data packets can be observed using command line interface. IP-enabled embedded device uses Telnet protocol to communicate to the system that acts as a server, receives the data packets and store it in the database. The received data packets observed using command line interface is shown in Figure 5.

![Figure 4. Flow of Data packets between the devices.](image)

![Figure 5. Data packets reception.](image)

5. Experimental Results

Temperature monitoring system shown in Figure 6 is tested effectively in real time environment. This system proves to be efficient in real time monitoring of environmental parameters using IP-enabled smart device.
Figure 6. Complete system depiction.

The results are displayed in the form of a webpage to the remote client as shown in Figure 7. This webpage can be accessed from any part of the world with an internet connection thereby achieving the vision of Internet of Things. Since this system utilizes smart and compact embedded device acting as a sensor node, it can be well suited for diverse applications of remote monitoring.

Figure 7. Webpage display in client’s web browser.

6. Experimental Result Analysis

Figure 8. Packet reception analysis.

The above shown graph in Figure 8 shows the comparison of the amount of packets received at the Telnet client’s system along with the time it takes to receive the data.
packets. Time taken to receive the packets varies with the number of hops the data packets have to travel before reaching the destination device. The above analysis shows the loss percentage is very minimum hence making this system more reliable one to work in the Internet of Things environment.

7. Conclusion and Future Work

The implemented environmental monitoring system in the Internet of Things environment utilizes an advanced embedded device with Ethernet resource. This system also provides remote monitoring of parameters on the fly. This system can be successfully employed in various real time applications. Further enhancements can be made in this system by providing an actuator control to the device with the data being feedback to the system, hence whenever a threshold value is exceeded, actuator can be operated remotely.

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9. References