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A LOW POWER CONSUMPTION AND HIGH PENETRATION IOT SYSTEM

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Abstract. *This paper proposed and implemented an IoT system with low power consumption and high penetration. Users can get the information of environment from the remote side and control electrical equipment with the learnable IrDa controller. The main structure is a wireless sensor network based on Sub-1G lots of sensor nodes, IrDa circuit and meter circuit. The results of penetration experiment and transmission distance experiment show that Sub-1G is suitable for the connect layer of IoT. The system integration testing also indicates the reliability and stability. Finally, the system could be applied in many occasion barriers and big area environment.*
Keywords: IoT, Sub-1G, Sensor, IrDa

1. **Introduction.** As the Internet-of-Things (IoT) becomes more and more popular, many wireless communication technologies are considered as the connect layer, such as Bluetooth, ZigBee and Sub-1G. Most of the environment sensors for smart home network are built with Bluetooth wireless devices or ZigBee wireless devices [1-6], and the wireless devices are used to transmit sensing information to control unit. [6] proposed a Sub-1G wireless sensor network, the 8051 micro control unit (MCU) is used to collect the sensing information, and then these data will be sent to remote users via GSM protocol. [7] proposed a smart control system based on the technologies of Internet of Things, and the system set up a radio frequency 433MHz wireless sensor and actuator network (WSAN). The wireless router transits data frames with the central controller through IEEE 802.11 b/n/g Wi-Fi interface, and then user can manage all appliances. [8] proposed a sensor node with TI CC1150 using a channel in the 433MHz ISM band to achieve better propagation in forest environment and longer range; then a gateway was used to collect, process, and forward to an Internet-connected server. The field data received from the sensor nodes via GPRS module had long range communication capabilities to upload the deployment data to the application server. According to the references above, most architectures used in present wireless sensor networks are similar, but the differences are in the connect layer.

Sub-1G has stronger penetration and longer transmission distance than the other 2.4GHz spectrum protocol such as Bluetooth and ZigBee [9-11]. [9] discussed the differences between the protocols what is in the same IEEE 802.11 standard but different transmission frequencies. Sub-1G characteristic is operating in the frequency range from 865Hz to 915Hz which is less interfered with other signal. [10] mentioned that low frequency (1GHz) is less interfered than high frequency (2.4GHz or 5GHz). [12] discussed present IEEE 802.11ah standard being drafted for Sub-1G and compared with 2.4G/5G transmission ranges. The conclusion showed that in the same transmission power condition, transmitted efficiency in 900MHz is better than in 2.4GHz. [13] focused on improving energy efficiency in IoT, and evaluated the energy efficiency and latency of three operating modes.

In this paper, Sub-1G is selected to be the connect layer of the proposed system for wireless sensor network, and all the network nodes are connected in star topology. Then, Universal Asynchronous Receiver/Transmitter (UART) protocol which is based on RS-485 is used to communicate with the bridge on a person computer (PC), and a user-interface application program is used to show the variation of environmental parameter. The improvements of this study in this paper are: a Sub-1G to PC bridge based on industrial communication standard RS-485 is proposed, a learnable IrDa remote control is proposed and implemented in the system for smart home application, and detail penetration and distance experiments show the proposed system is suitable for the connection layer of IoT.

The study motivation and current research situation are described in this section. And, the proposed system architecture will be introduced in second section. The proposed hardware included the circuits and components will be detailed in following section. Next, the experiments are defined and the experimental results will show the proposed system workable. Finally, the conclusion discusses the advantage and application field of the proposed system.

2. System Architecture.

This paper proposed an IoT system; users can get the information of environment from the remote interface and control electrical equipment with the learnable Infrared Data Association (IrDA) controller. And the system includes a PC, a bridge, an IrDa driver, meter and sensor nodes. The data acquired command sent from the PC application program to the bridge via UART. When the bridge gets a command from PC, it transmits the command to sensor node to trigger environment data sampling by Sub-1G. The system architecture diagram is shown in Figure 1. The details will be described in this section.

2.1. Sensor.

Each node connects to several optional sensors: such as temperature, humidity, CO_2-concentrations, dust-concentrations sensor, and node internal supply voltage supervisor (SVS), which are also shown in Figure 1. When node receives trigger command from the bridge via Sub-1G, the sensors are triggered to sample. Then, the node will collect sensing information from sensors via build-in peripheral such as serial communication interface (SCI), and Analog-to-Digital Converter (ADC). And this information will be returned to bridge and sent back to the PC application program.

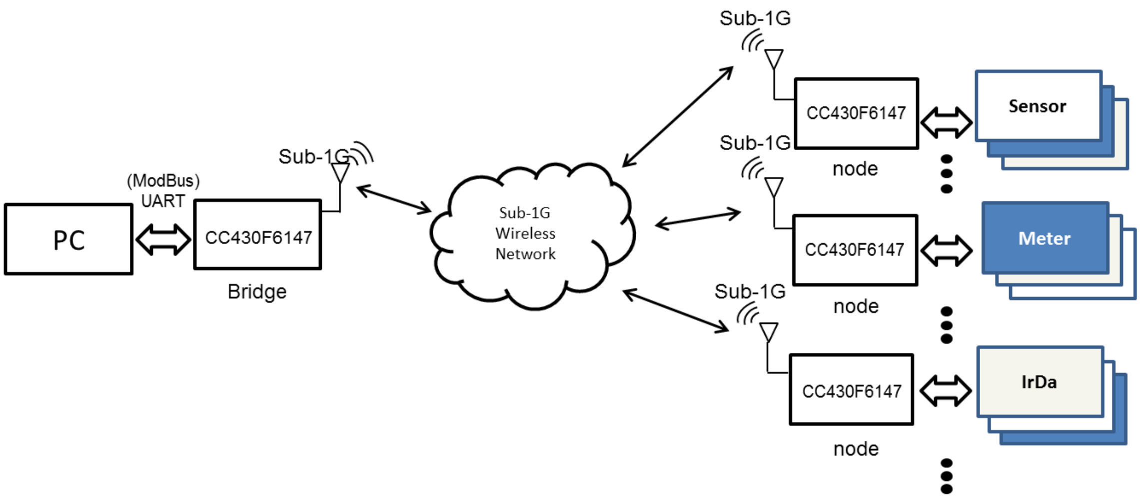

FIGURE 1. System architecture diagram

2.2. **Meter.** A meter block is used to perform smart meter function and monitor the power consumption. The Root Mean Square (R.M.S) values of grid current and voltage will be calculated and sent back to application program via Sub-1G. User can know condition for external power consumption of monitor environment. When meter detects external power consumption over standard, user can control node to do relative action in time in order to save consumption.

2.3. **Bridge.** As mentioned above, the bridge is used to be the interface between each node and the PC. The bridge communicates to PC by RS485 and UART, and to nodes by Sub-1G. When bridge gets commands from a PC, it encapsulates commands into Sub-1G packets format, then transmits it to node.

2.4. **IrDa.** The IrDa function and hardware is built-in to the sensor node to control appliances. The IrDa function includes learning and control: the former is used to analyze and learn the remote control commands, and the latter is used to repeat the IrDa command in remote site. When the environment measurement value is over a threshold, the application program will automatically control appliances based on user setting.

3. **Hardware Architecture.** As mentioned above, the proposed connect layer of IoT is based on Sub-1G; the TI CC430F6147 is used to be the sensor and communication controller. The other hardware and the connection with controller are described as follows.

3.1. **Sensors.** Environmental sensor node architecture proposed in this paper is shown in Figure 2: environmental sensors are connected to sensor node control, TI CC430F6147. The sensors are BH1750FVI for illuminance; SHT21 for temperature and humidity; T100A for CO_2; GP2Y1010AU0F for dust. The communication details are: BH1750FVI and SHT21 by the I2C, T100A by SCI, GP2Y1010AU0F by Pulse-Width Modulation (PWM) and ADC. And the DIP switches are connected to the input or output (I/O) input pin of CC430F6147 for setting Node ID and system spectrum.

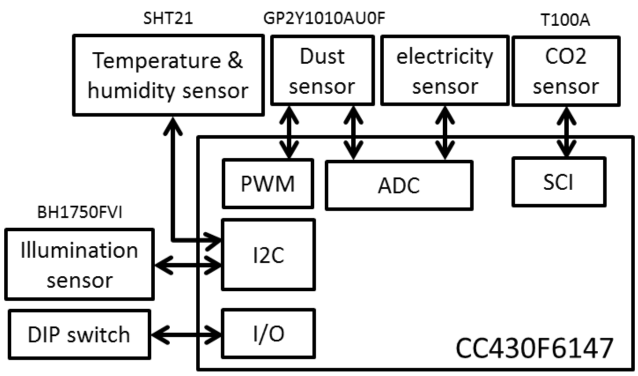

Figure 2. Hardware architectures of node

3.2. **IrDa.** The IrDa is used to perform remote control for appliances. When the environment parameter is over or under some threshold, system has to control remotely some suitable appliances for safety or comfort. However, due to the fact that Internet connected appliances are not popular, the IrDa circuit is adopted in sensor node. The IrDa subset also includes learning function, which is implemented by controller build-in capture peripheral. And build-in PWM peripheral is used to reconstruct the IrDa remote control signal for appliances on remote site. The block diagram is shown in Figure 3.

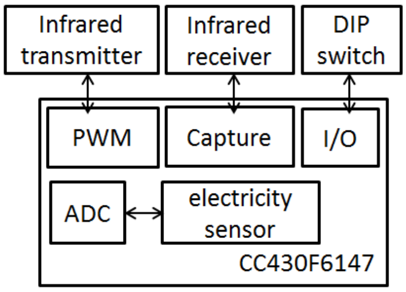

FIGURE 3. Hardware architectures of IrDa

3.3. **Meter.** To support smart meter function, power detecting circuit is also implemented in sensor node to detect voltage and current of grid. The AC voltage is divided by a voltage divider in preceding circuit, and then, an amplifier circuit is used to perform a two-pole low-pass filter function and level shifter for ADC input range of a controller. In other hand, an integrated circuit (IC) ACS712 is used to convert the current into voltage signal which is suitable for ADC range.

4. **Experiment.** The experiments include penetration experiment, transmission distance experiment, and the system integration test. The details will be discussed in this section.

4.1. **Penetration.** The penetration experiment is used to verify that Sub-1G is suitable for the connect layer of IoT. The experiment environment is set in a four-story building and each floor is 4 meters high. A fixed receiver, bridge, is set in top floor, and a transmitter, sensor node, is set in different floors. Every location, 100 data packages are sent from the transmitter in different transmitting power, and receiver will measure the received signal strength indication (RSSI). Figure 4 illustrates the RSSI in different floors and under different transmitting power conditions, from MAX, to −30dBm. However, data packages lost will occur when the RSSI is under −98dBm in experience. So, the experimental results show that the penetration of Sub-1G is suitable for connect layer of IoT in house. Moreover, the power consumption is only about 20mA when transmitting power is set to 0dBm.

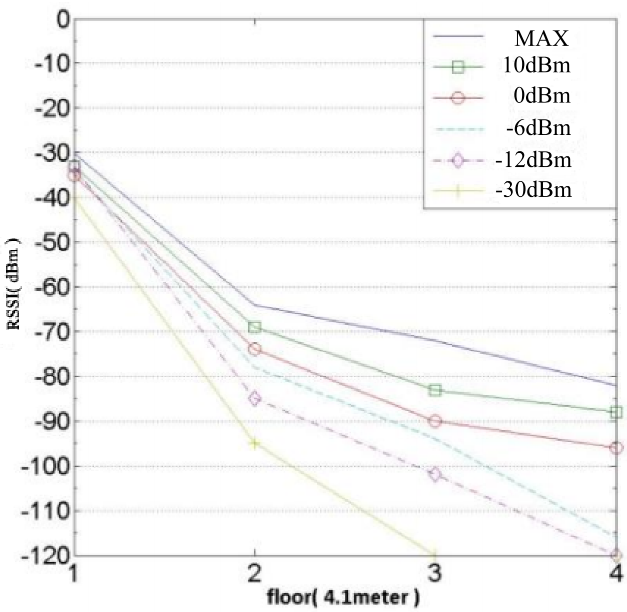

FIGURE 4. The results of penetration experiment

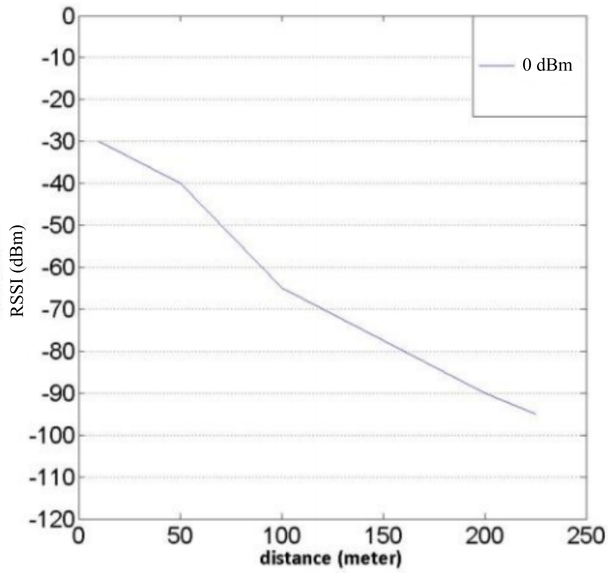

Figure 5. The results of distance experiment

The transmission distance experiment is set in open space, a playground of campus. Again, a receiver is fixed in the side of the playground; and a transmitter power is set to 0dBm, then it will send the data from different distance. Then, RSSI value is the average RSSI of 100 packages. The experimental results are shown in Figure 5. In open space, the transmission distance is over 225 meters; this results show that Sub-1G is suitable for IoT connect layer, again.

4.2. **Environment monitor.** Above measurement confirmed that Sub-1G has high penetration properties and it is suitable for IoT. In integrated system test, the sensor nodes run in long term. Figure 6 and Figure 7 are measurement data trends, and they show temperature and carbon dioxide concentration, respectively. Note, the peak in Figure 7 is caused by engineer's breath, which is used to confirm the sensor working well. This experimental results show the proposed IoT system works well in long term.

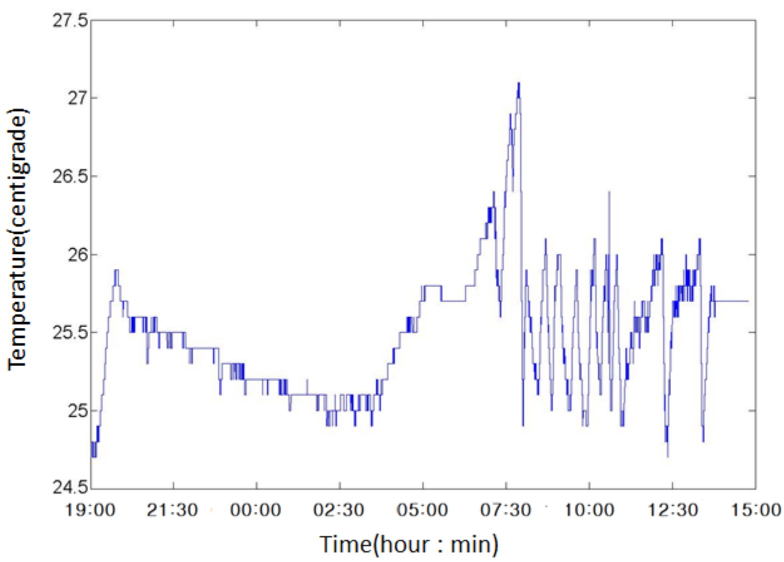

Figure 6. The concentrations of temperature graph

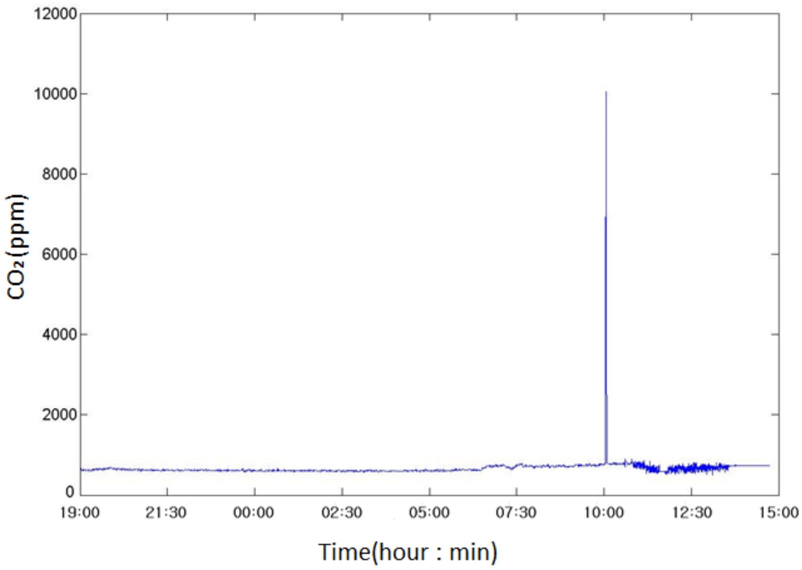

FIGURE 7. The concentrations of CO_2 graph

5. **Conclusion.** This paper proposed and implemented an environment monitor IoT system, in which connect layer is based on Sub-1G communication and protocol. The advantages of Sub-1G are low power consumption and high penetration. The system structure is discussed in this paper. And the experimental results show that the Sub-1G IoT system can penetrate the whole 4-floor building, and the transmitting distance is more than 200 meters, when the transmitting power is set to 0dBm. The experimental results also show system runs well in long term. Based on above advantages and experimental results, the proposed Sub-1G IoT system could be applied in many occasion barriers and big area environment. In the future, some research topics should be paid attention to: To reduce the power consumption of the Sub-1G IoT system, a dynamic auto tuning technology of a RF power amplifier based on RSSI should be considered to be developed. And, for the IoT system construction, the Sub-1G to Ethernet router could be implemented.

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