Heterogeneous IoT platform in Network Architecture

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Abstract: Heterogeneous Internet of Things (HetIoT) is an emerging research field that has strong potential to transform both our understanding of fundamental computer science principles and our future living.

This paper proposes a four-layer HetIoT architecture consisting of sensing, networking, cloud computing, and applications. This paper also suggests several potential solutions to address the challenges facing future HetIoT, including data integration and processing in large-scale HetIoT.

Keywords: IoT, heterogeneous networks, virtual reality, sensors.

I. INTRODUCTION

In recent years, researchers have designed and developed various hardware and software platforms associated with IoT, which have been widely applied in the areas of both industry and daily life. In these applications, Heterogeneous IoT (HetIoT) has involved various network architectures, including WSN, Wi-Fi, MCN (3G/4G/LTE/5G), WMN, and Vehicular Network. These heterogeneous network units employ RFID, sensors and other smart terminals to get the comprehensive sensing information anytime, anywhere. They can connect to cloud server by Internet or satellites, and reliably transmit urgent events and data in real time to a remote monitoring center for processing (Qiu, 2018).

With increasing deployment of wireless smart devices, self-organization and survivability of networks have become particularly important. According to Bone and Cluster (Theoleyre & Valois 2008), self-organizing architectures can improve the robustness of network. Besides, some researchers proposed various routing protocols to increase network survivability, such as BP, ISOS, etc. The coexistence of various heterogeneous network units limits channel resource efficiency, which attracts researchers' attention (Kim&Suh, 2011).

Researchers contributed to solving urgent problems, such as safety protection, robustness and big data transmission in large-scale IoT. This survey's goal is dedicated to discussing the heterogeneity and relationship among WSN, Wi-Fi networks, cellular networks, and vehicular networks.

HetIoT will build a smart world for intelligent industry and modern lifestyle in the future. Relaying on broad application areas, HetIoT will be widely integrated into our production and lives.

Many emerging technologies are based on the four-layer architecture, such as virtual reality, precision industry control, smart cities and intelligent transportation, etc. These techniques can provide the convenient and better life for citizens.

II. THE APPLICATIONS OF HETIOT

IoT is a complex system with multiple heterogeneous networks (Qiu &Chen, 2016). We will discuss a four-layer future HetIoT architecture as shown in Fig.1, which includes applicationslayer, cloud computing layer, networking layer, and sensinglayer. The heterogeneity and interoperability of the four-layeris better than previously published architectures for IoT. Everylayer of four-layer architecture has independent function andscalability. The sensing data collected from various sensorsare stored at cloud servers through efficient heterogeneousnetworking units. The heterogeneous networking units consistof many different network architectures. Due to improvementsin hardware design of sensors and optimization of network topology, HetIoT has been applied in daily life and industry.

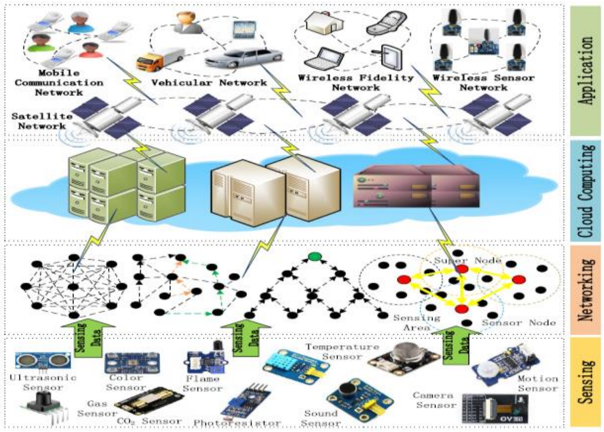

Fig. 1. Future HetIoT Architecture.

HetIoT has been applied in many fields and promotesthe integration of science and technology (fig. 2).

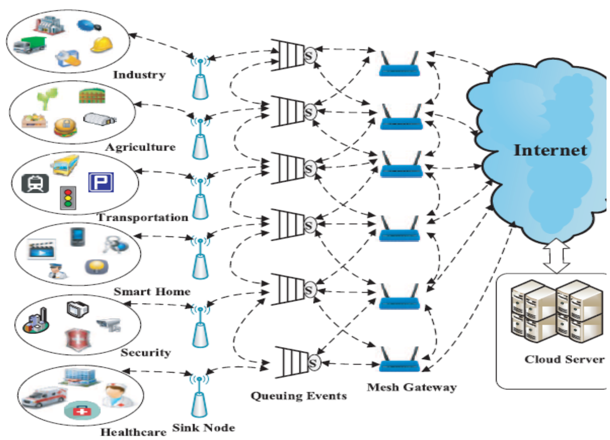

Fig. 2. Applications of IoT.

Smart Industrial HetIoT

Various smart devices have been employed in industrial production. In supply chain management, HetIoT applications have been applied to raw materials purchasing, inventory, sale and other areas in enterprises, which improves supply chain efficiency and reduces costs by optimizing the supply chain management system. The sensing and decision-making technology can provide better decision support for enterprises in supply chain network system (Li& Cheng 2013). In process optimization, HetIoT applications have improved the level of production line process monitoring, real-time parameter acquisition, production equipment monitoring and monitoring of material consumption.

Smart Agricultural HetIoT

Agricultural IoT products automatically turn on or off the specified devices in real-time based on sensed data, such as green house temperature, soil conditions, CO_2 concentration, humidity and light signals, leaf humidity, and other environ-mental parameters. Most of precision agricultural systems are WSNs, and energy consumption is a challenge for sensing area without power supply (Patota, 2016). Besides, topology construction is another research direction, which can improve the robust-ness against cyber-attacks.

Smart Home

Smart home refers to an efficient family matter management system utilizing various technologies such as integrated wiring, network communication, security defense, automatic control, audio, and video. The management system improves home safety, convenience, comfort, artistry and achieves eco-friendly living environment. Smart devices connect with each other by Wi-Fi networks that consist of remote wireless data networks (i.e., 3G/4G/LTE/5G) and short-range wireless connection networks (i.e., Bluetooth, infrared, RFID).

Security System

The security system can effectively monitor internal and external environment by using cameras. The surveillance sites include important sectors, facilities, and public spaces. Such system typically supports image authentication and image recognition. For example, Yuan et al. (Yuan&Yang, 2016) deployed a camera imaging device based on3D vision technology on the top of cars to monitor vehicles' safety. The security system supports internal probe defense, border protection detection and detection of the critical situation. For example, Sanquist et al. (Sanquist, 2008) designed radiation port monitors (RPM) against human issues for homeland security threat systems. The RPM integrates the radiation spectrum of goods with the signal of commodities data and improves the ability of system detection alarm to reduce the probability of false positive.

Smart Healthcare of HetIoT

IoT technology has penetrated into many fields of health-care , ranging from patient vital sign monitoring , torehabilitation exercises monitoring and guidance (Zhao & Feng, 2011), to individual's daily activity tracking and surgeryrooms . Healthcare has promoted the develop-ment of wearable smart devices, and opened up a newdirection of mobile health. Nowadays, smart phones, smartwatches, smart bracelets, head mounted smart equipment andother wearable devices detect people's heart rate, blood pressure, sleep state, and activities.

HetIoT systems based proposed three layers:

- ✧ Theory and Modeling: Future HetIoT will be a large-scale integrated system, which consists of various algorithms and models.
- ✧ Methodology and Strategy: Based on above-mentioned theories, we may use greedy principle, optimal path, heterogeneous topology, queueing method, transmission strategy, routing protocols, robustness optimization safety and privacy mechanisms to optimize, model, analyze, and enhance large-scale HetIoT.
- ✧ Design and Applications: In practice, key technology such as hardware design, data collecting, hard deployment, programming, and simulations are more important.

Heterogeneous Network Architecture for HetIoT: HetIoT is a complex system that consists of many heterogeneous network elements (HNEs). Designing a rational heterogeneous topology structure so that all heterogeneous network elements can be coordinated for communication and each heterogeneous network can maximize its efficiency is an important future challenge that researchers need to address (Poorter &. Moerman, 2011).

Researchers Leu and Chen, have proposed applying some traditional modeling methods (Leu & Chen, 2014) to guide the networking problems of large-scale HNEs, for example, Queueing Networks, Petri Net, State Machine and Complex Networks etc. These modeling methods can solve the single network architecture issues in HetIoT, and effectively optimize the internal node and network efficiency of a single network element.

Therefore, researcher normalize different types of data for large-scale HNEs in HetIoT, although the efficiency of the network is significantly affected. When the network size and load reach a certain level, the congestion of HetIoT will happen, even causing a chain-style collapse among networking nodes, which will lead to the paralysis of the entire network. In recent years, Software Defined Networks (SDN) (Qin & Denker, 2014), have been proposed to implement different data transfer between HNEs. SDN separates data communication from control layer, which makes network management more centralized and compatible. SDN can enhance virtualization and heterogeneity for HetIoT, but its technology is not mature, and standardization is not high.

Large-Scale Smart Self-Organizing Sensor Networks for HetIoT: HetIoT integrates a large number of distributed network nodes that form a network through self organizing routing protocols and robustness optimization methods (Qiu, 2016) and then collaborates on data communication to ensure that data can be sent to the destination node or the control center. When the scale of the network is small, the network load and the number of network links are small, and the transmission efficiency is high. However, the existing self-organizing routing protocols and optimal path strategies are not suitable for large-scale sensor networks whose robustness capacity is poor. Therefore, how to make these large-scale, distributed nodes for efficient self-organizing is a serious challenge to study.

Safety and Trustworthiness of HetIoT: Research is rare on the integration of HNEs. However, the goal of HetIoT research should be to achieve multi-network integration. In order to prevent local data theft or tampering, which would cause global damages to HetIoT, researchers are trying various modeling methods, such as Complex Networks, State Machine, Cryptography and Petri Net, to minimize data damages (Hashim& Munasinghe, 2010)..

Smart Hardware Design for HetIoT: With the increasing development of business HetIoT, lot of hardware networking components have been developed (Chi & Yan, 2014), such as wireless fidelity module, RFID module, the infrared module, Bluetooth module, etc. Those hardware components meet challenging demands of applications in data collecting, smart sensing, monitoring, safety, and trustiness.

Big Data Collecting and Processing of HetIoT: One of the challenges we are facing in large-scale HetIoT is how to process big data timely and effectively, particularly sensing data from different HNEs. Thus, on the one hand, balancing the relationship between the each HNE so that real-time data trans-mission can be effectively guaranteed, needs to be solved for largescale HetIoT. On the other hand, when massive data have been collected in HetIoT, processing the data efficiently so that HNEs can avoid data generated backlog queue needs to be studied.

III. HIGH-LEVEL GOALS AND PROVIDED SERVICES

The design and implementation of IoT platforms has been a popular research topic in recent years.

The pilot use case for our new IoT platform involves the control and monitoring of air-conditioning devices. The main goals from an end-user perspective are:

- lowering the electricity consumption,

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- increasing the level of comfort in the rooms and
- facilitating the work of the support teams through automation.

The proposed IoT platform is composed of a wireless radio network functioning on 868 MHz or alternatively on 433 MHz, a GPRS/3G/4G connection to the Internet, which may be replaced by a LAN or Wi-Fi connection, and a control center for data gathering, intelligent analysis and management (fig. 3).

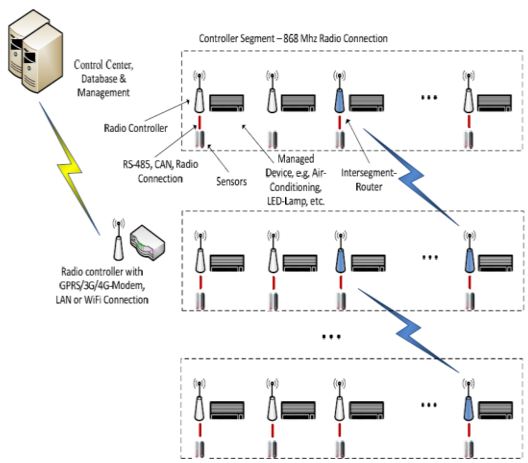

Fig. 3. Platform architecture

The wireless radio communication within the IoT platform is implemented using the LORA technology on the free 868/433 MHz radio frequency bands. The same type of connectivity is used for the sensors connected to the end nodes (JAN & NANDA, 2017).

Through the Internet connection, the IoT network connects to the control center and transmits and obtains information. The radio controller that implements the Internet connection may also play other roles such as controlling an air-conditioning device.

From a technical view point, the IoT network consists of two types of controller-radio controllers with extensible functions and sensors with wired or radio connectivity. The radio controllers are implemented using 32-bit RISC-microcontrollers of the series STM32Fx. They have onboard 3.3V, 5V, 10V and galvanically isolated 5V power supplies. The radio connectivity is implemented through a Semtech SX1276 LORA radio module on 868 MHz or 433 MHz. Among the provided communication interfaces are: RS232, RS485, UART, I2C, SPI, USB, isolated CAN, 4 analog inputs, 2 analog outputs.

In this way, the radio controller can communicate with various electronic devices such as GPRS-Modems, sensors or computers. There is support for a real-time clock and EEPROM for configuration options and up to 5 relays switching up to 10A loads at 250VAC/30VDC for actuator control. The sensors are smaller and less powerful microcontrollers based on the series STM32F0 or STM32L0. The temperature and humidity is measured by sensor chips such as MCP9701 and SHT21.

The control center that the IoT network connects uses open-source server software. The operating system is a Linux flavor (Ubuntu Server). As DBMS we use MySQL/MariaDB at the moment. Firebird is also supported as an option. The web server for user access is Apache in combination with PHP (HAO & CHEN,2017).

The communication protocol offers a unified way of transmitting and receiving data both through local and remote connections independently of the physical implementation of the connection. It supports addressing, routing, encryption, integrity checking via checksums and retransmission of lost data packets.

The radio controller consists of the function blocks shown in fig. 4.

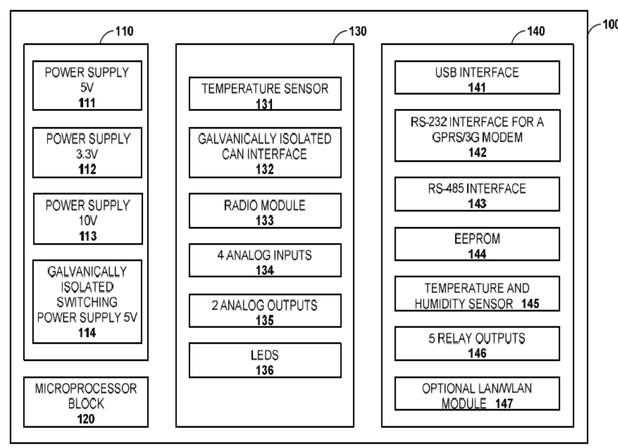

Fig. 4. Functional blocks of the radio controller

The physical implementation of the radio controller (100) consists of two printed-circuit boards (PCB) attached to each other via two multi-pin connectors. The first board is a base board which contains the power supply block (110), the microprocessor block (120) and the integrated peripheral block (130). The second board is an extending board housing the extended peripheral block (140). The boards are situated directly next to each other and they are mounted on a plastic PCB enclosure designed for DIN-rail mounting. Fig. 5 illustrate the physical appearance of the radio controller.

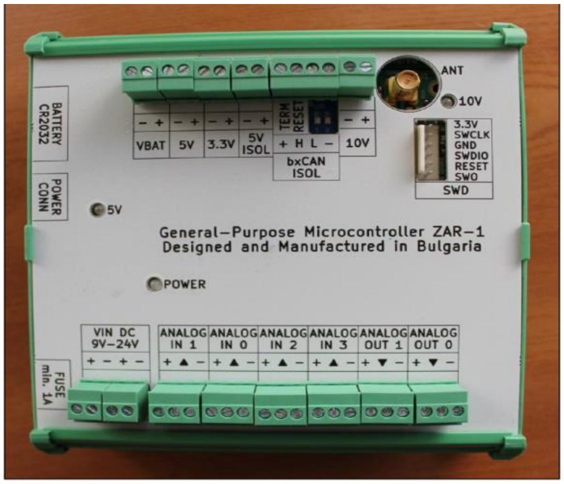

Fig. 5. Fully populated base board of the radio controller mounted in the DIN-rail enclosure .

Design and implementation of the sensors (fig.6**).**

The sensors are designed to measure the temperature and humidity of the environment around them. They may communicate to the main radio controllers either by wire (RS-485) or by radio (LORA). The connection to the printed-circuit board (PCB) is implemented through a standard terminal that is wired to one of the analog inputs of the microprocessor (KRYLOVSKIY & JAHN),

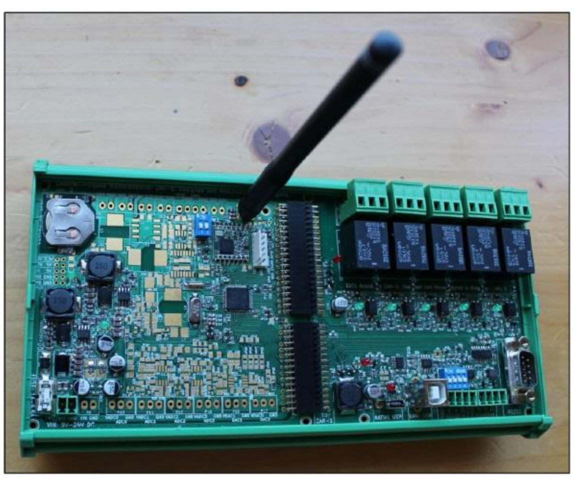

Fig. 6. Partially populated base board together with an extending board mounted in the DIN-rail enclosure

Through the unified communication protocol, sensor data can be transmitted through the radio network and passed to the control center over the Internet connection. The sensor controller can be placed in dry or wet indoor rooms as well as in outdoor spaces to gather, process and transmit temperature and humidity data at regular intervals.

Experimental results. In this project used the IoT radio network in a pilot implementation to control some air-conditioning devices.

The network coverage of the LORA radio technology within the commercial buildings has proved to be excellent.

The GPRS communication between the IoT radio network and the control center has been relatively reliable with a few cases of connectivity loss for short durations. The radio controller that implements the GPRS connectivity tracks such cases when they arise and as soon as the Internet connectivity is resumed, the connection to the control center is reestablished. The security of the radio network is on a good level.

This solution has good scaling potential and should remain responsive even when multiple radio networks transmit data to the control center at the same time.

IV. CONCLUSION

Future HetIoT will be based on sensor technology, hybrid networks, cloud computing and storage, and big data analysis to construct smart cities and intelligent sensing. All heterogeneous objects will be independently addressable to achieve interoperability.

The IoT platform proposed proves to be working well in commercial environments. radio communication (LORA) handled in a unified way above the physical layer of the network connection. This heterogeneous communication environment adapts well to the particular needs of the application and makes possible the reliable control of the devices and regular sensor data gathering.

The Internet-based control center provides possibility for smart sensor data analysis and versatile remote control of the devices connected to the IoT platform. The controllers of our own design can be modified if the application requirements change which ensures that other devices can be integrated into the

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existing radio network providing for better environmental control and in result-cost savings and increased user comfort.

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