The Applications Of WiFi-based Wireless Sensor Network In Internet Of Things And Smart Grid

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***Abstract*-The Internet of Things(IoT) and Smart Grid are of great importance in promoting and guiding development of information technology and economic. At Present, the application of the IoT develops rapidly, but due to the special requirements of some applications, the existing technology can not meet them very good. Much research work is doing to build IoT. WiFi-based Wireless Sensor Network(WSN) has the features of high bandwidth and rate, non-line-transmission ability, large-scale data collection and high cost-effective, and it has the capability of video monitoring, which can not be realized with ZigBee. The research on WiFi-based WSN and its application has high practical significance to the development of the Internet of Things and Smart Grid. Based on the current research work of applications in the Internet of Things and the characteristics of WiFi-based WSN, this paper discusses the application of WiFi-based WSN in Internet of Things, which includes Smart Grid, Smart Agriculture and Intelligent environment protection.**

Keywords-WiFi-based WSN; Internet of Things; Smart Grid; Application

I. INTRODUCTION

Internet of Things(IoT) refers to the networked interconnection of everyday objects. It is described as a self-configuring wireless network of sensors whose purpose would be to interconnect all things. It connects with the wireless network through the interface by the electronic tag (RFID), sensors, two-dimensional codes on objects. Through IoT communication between people and objects can be realized. Internet of Things has three basic characteristics: appreciable, internet connective and intelligent [1]. Internet of Things has four elements: information collection, two-way transmission, treatment and feedback control.

In 2005, the International Telecommunication Union (ITU) formally put forward the concept of Internet of Things [2]. The report notes that ubiquitous things communication era is coming. The report also drew up a blueprint for the Internet of Things era: When a driver operates wrong, the car will automatically alarm; Briefcase will remind the owner not forgetting something; clothes will inform the washing machine about the color and temperature required and so on. The application of IoT has been foreseen, such as security, intelligence library and so on. In the future, with the uniform standards and practical protocol, a super network including everything in the world might be constructed, which can change the world dramatically.

As an important part of Internet of Things, from the time when the smart grid concept was put forward, it has been highly valued by governments. Smart Grid is new kind of intelligent power system realized with information, communication, the computer control technology and the existing transmission/distribution power infrastructure. Smart Grid can improve energy efficiency, reduce environmental impact, improve the safety and reliability of electricity supply, and reduce the electricity transmission of grid [3-4].

II. THE STATUS OF SMART GRID

At present, most countries have realized the importance of developing Internet of Things and Smart Grid, and have put forward their own Smart Grid program according to their national conditions and economic development.

A. Smart Grids Transformation in the United States

In 2006, IBM has proposed a "Smart Grid" solution working with global professional research organizations and power companies. This solution was regarded as "the central nerve system" of the power system. Through the use of sensors, meters, digital controls, and analysis tools, the power company can automatically monitor the grid, optimize grid performance, prevent power outages, faster restore power supply, and the management of consumers to the power use can also be refined to any networked device.

In recent years, in order to revitalize the economy and reduce pollution, the United States Government proposed the integrated schemes of green energy and green environment. The Smart Grid is one of the important plans. In the economic stimulus plan, there is about 45 billion dollars used in Smart Grid investment and regional demonstration projects. Smart Grid uses digital technologies to collect, exchange, process data and improve the efficiency and reliability of the grid system. Advocates of Smart Grid try to make customers to believe that the Smart Grid can help customers to reduce their power costs.

B. Development of Smart Grid in Japan

Referring the United States' Smart Grid, according to their own national conditions, Japan government is going to build

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their Smart Grid to ensure the stabilization of power system. After consulting with power companies, the Japanese government plans to begin large-scale Smart Grid construction test in the island. They examine the large-scale use of solar power to find how to uniformly control the surplus power and frequency fluctuations, as well as batteries.

C. European Smart Grid Construction Practice

At present, Britain, France, Italy and other countries develop and promote the Smart Grid fleetly. Italy has realized grid intelligent firstly in local power. In early 2009, EU make it clear that wind power generated in the North Sea and the Atlantic and the Solar Energy generated in Southern Europe and North Africa should be integrated into the European power grid to develop renewable energy large-scale and quickly. European Smart Grid technology includes four aspects: power grid assets, power grid operation, demand-side measurement and power generation and storage [5-6].

D. the Smart Grid plan of the State Grid Corporation of China

May 2009, the State Grid Corporation of China announced the first Smart Grid plan: Building a strong Smart Grid which uses UHV grids as the backbone and bases on the coordinated development of all levels power grids. The Smart Grid is innovative and has the features of informationalization, automatization and interaction.

The State Grid Corporation also proposed the development of the three stages of Internet of Things: the information collection stage, collaborative awareness stage and extensive polymerization stage. The Corporation made a full deployment on the special chip of Internet of Things, application system development, standards, information security, wireless broadband communications, software platform, testing technology and experimental techniques aiming to gain a number of breakthroughs in core technologies on Internet of Things application in power system and get a lot of innovative achievement in the next three years, with which many research centers and industrialization bases in Smart Grid technology research and application of Internet of Things would be build in China[7].

III. THE WIFI-BASED WIRELESS SENSOR NETWORK

Because of its low cost and opening stack, ZigBee[8-10] is widely used in wireless sensor networks. Improving and Expand on the IEEE 802.15.4 standards, ZigBee is a kind of short-range, low complexity, low power and low-rate wireless sensor technology, which is improved and expand on the standard IEEE 802.15.4. But ZigBee also has its own limitations, such as the amount and rate of data transmission is not high, the transmission distance is limited, little and no non-line-transmission capacity and capacity to cross the barrier is weak.

With the evolution of wireless and SoC technology, many kinds of WiFi wireless sensor SoC chips for low power applications have been developed and accompany with it a new kind Wireless Sensor Network, named WiFi-based Wireless Sensor Network, came into reality[11-15]. WiFi-based Wireless Sensor Network consists of low power consumption nodes distributed in the detection area, sink nodes and network that managers build by the methods of self-organization. WiFi-based WSN is the combination of WiFi wireless mesh network and WSNs, and it has both the features of traditional WiFi network, network-centered, and WSN, data-centered. The power consumption of WiFi sensor nodes is so low that one AA battery is enough for 5 to 10 years [11].

Comparing with other Zigbee wireless sensor network technologies, WiFi wireless sensor network has the following significant advantages:

A. High Bandwidth

With WiFi technology data transfer rate can reach 2MKbps, the latest 802.11n can reach 300Mbps data transfer rate and about 100M to 150Mbps throughput. But Zigbee's data transmission rate is only 10-250Kbps. So WiFi transmission more efficient, less delay, better real-time, and it can without complex scheduling algorithm to solve the congestion problem.

B. Non-line-of-sight Transmission

WiFi has some non-line-of-sight(NLOS) transmission capacity. It can communicate through one load-bearing wall. Zigbee has no NLOS transmission capacity and it is weak in data transmission through the barrier. The transmission quality will drop when there is countercheck, even only a little, which is fatal to the application of needing high reliability such as Automatic Meter Reading.

C. Large Coverage Area

WiFi radio waves have broader coverage. Zigbee radio waves have lower coverage, its transmission distance is usually in 10-75 meters range, and the data transmission through the load-bearing walls are not effective; but the transmission range of WiFi can reach 300 m outdoor at least and about nearly 100m indoor barriers. Not only can it be used in home, but also in entire high-rise buildings.

D. Cost-effective

At present, WiFi network has been built in many intelligent buildings in Large and medium cities. Significant hardware cost can be saved if wireless sensor network is built on the basis of the existing WiFi network resources. In addition to that, interoperability with other Zigbee devices need not to be taken into account, which means shorter development cycle and lower project costs. With the continuous improvement of SOC technology and a large scale application, WiFi sensor nodes will be further decline in price. In the near future, WiFi might replace Zigbee wireless sensor network in some degree.

E. Easy Expansion

Each WiFi sensor node (may be a smart meter with WiFi capabilities) can support about 100 wireless connections. From the perspective of the developing of digital home in the future, WiFi sensor nodes such as smart meters (or meter reading terminal) can communicate with the home appliances without rewiring. In addition to Automatic Meter Reading, it can also

realize IPTV, security control, telemedicine and information appliances, which will benefit to realize digital home.

F. Strong Robustness

As WiFi-based sensor network use wireless mesh topology, there are usually more than one path available between the nodes, which significantly improves the reliability of the network. Comparing with the Zigbee, WiFi is more mature and it is more reliable to treat the network handling and to recover the faulty. WiFi technology also has both the advantage of architecture supports and quick installation.

G. Small Disturbance of Links

In the single-channel network environment, because of the shared channel competition, the two nodes of concurrent transmission is not permit in adjacent areas, resulting in multi-hop connection bandwidth dropped significantly when in signal-channel. To solve this problem, the node of WiFi wireless mesh network with a unique multi-interface multi-channel configuration, the wireless link in the adjacent area use a different orthogonal channels to reduce interference between the RF signals, and this make system capacity larger.

In summary, using WiFi-based WSN to make a variety of applications of Internet of things (such as Automatic Meter Reading) has many advantages, so the research on WiFi-based WSN technology and its applications, have far-reaching significance to develop the current world Internet of Things and the Smart Grid.

IV. THE APPLICATIONS OF WIFI-BASED WSN IN INTERNET OF THINGS AND SMART GRID

The Internet of Things is widely used. It can be used in intelligent transportation, environmental protection, public safety, intelligence testing, personal health and other fields, almost all applications in all aspects of human production and life. Experts predict that after the Internet of Things make the full application in the future that its business volume will be 30 times the scale of current and it will become a very large scale market. It can be seen in the real world that the Internet of Things have some preliminary applications, such as in logistics management, distribution, safety traceability of food, digital substation, smart home, digital oil field, intelligent greenhouse monitoring, intelligent transportation, public safety monitoring and so on. Currently, the Asian Games Organizing Committee has applied it to the food traceability management system in the Asian Games in 2010 to provide safe food for the majority of players and guests from various countries. Pudong International Airport set an electronic fence by sensor network buried in the ground outside the fence at the airport. When people or animals come to it, the system will automatically send identification signals and make out the precise position[16].

Now the applications of the Internet of Things are developing rapidly. For many reasons the existing technologies can not meet all the requirements of Internet of Things. New technologies are researching to resolve the above problem. Current research work and practical applications of WSN are mostly based on Zigbee and standard 802.15.4, which will be further improved in the transmission bandwidth, transmission rate and non-line-transmission capacity, especially in relation to video monitoring, large-scale data collection and transmission applications.

WiFi-based WSN can be good complement in the video monitoring that ZigBee has not. WiFi has high bandwidth, high rate, NLOF transmission ability, large-scale data collection and application of more cost-effective. Therefore, the research of WiFi-based WSN and its application is of great significance to develop the Internet of Things and Smart Grid in the world.

A. Application of Smart Grid

The applications in the Smart Grid are divided into smart power generation, intelligent transmission and substation and intelligent power use. Data collection is the key to intelligentize power grid. Realization of intelligent power grid makes it possible to get the information of the intelligent power grid completely and in time. The control of the grid information needs perfect communication lines and enough terminal information, and it can ensure the security and stability of data transmission, improve the reliability of data exchange and provide accurate information in time for the intelligent application. Smart Grid may use more devices, including a variety of intelligent sensors, control components and electrical equipment, which require higher digitization degree of power grid and better data collection, transmission, storage and utilization in the process of power generation, transmission, substation and distribution. Using a variety of information collection technologies to collect information of power use and device status and get the equipment running status make it possible to get the information of equipment failure in time, which can ensure the equipment operate correctly[17].

Some of the information collection technologies are based on Power Line Carrier Communication, some are based on fiber network, some are based on cable transmission, and others are based on wireless transmission. Because networks and users are various, especially in power using side, there are no network transmission ways that can meet the demands of all kinds of users. Suitable methods should be selected according to different demands. For wireless communication can be installed fast and need no line, it can be used in areas where network infrastructure are not so developed or can not be developed, such as old town, mountain areas and vast rural areas. Therefore, the research work on wireless sensor network applications in the smart grid is useful complement to cable transmission.

For the features of the low-cost and low power consumption in user managing and Meter Reading, Zigbee is often used in Automatic Meter Reading. But Zigbee has limitations too, such as low capacity of NLOS transmission, which is fatal to meter data collection in thousands of families of high-rise apartment-style. And more, its transmission rate is too low to meet the demands of the new generation of Automatic Meter Reading system in large scale of data real-time transmission and control.

Comparing with Zigbee-based WSN, WiFi-based WSN has better NLOS transmission capability and can be used to transmit through the load-bearing walls. It is more suitable for thousands of families meter reading transmission in high-rise

apartment-style. More, its transmission rate is faster and its bandwidth is higher, so it is more suitable for the new generation Internet of Things-based Automatic Meter Reading system, which has large scale of real-time data. In addition, WiFi is securer and WiFi-based WSN has lower power consumption comparing with Zigbee. Therefore, WiFi sensor network is more suitable to build new generation Automatic Meter Reading system facing to Internet of Things. With the increasing of production, the product cost of WiFi-base WSN will decrease soon. With the continuous development of SOC technology, the power consumption of WiFi sensor chip will be further reduced and it will be more suitable for Automatic Meter Reading or other applications which need low power consumption.

B. Application in the Intelligent Environment Protection

Environmental protection is an important long-term strategy of national development, and at the same time intelligent protection is an important application of Internet of Things. In intelligent environmental protection, the massive environmental data including water data, air data, regional environment data, nature protection data and other data, should be collected accurately by sensors and transmitted to Server to be treated and analyzed by software. Environmental protection measures should be taken by the analyzed data[18]. The intelligent environmental protection includes intelligent environmental monitoring, intelligent public facilities monitoring, intelligent city pipeline monitoring, intelligent sewage treatment monitoring, intelligent parks control and so on.

The current smart networks of environmental protection are mainly realized by cable private network, GPRS, GPS and other network implementation. The advantages of cable private network are high transmission speed and safety, and its disadvantages are high cost and dependence on cable, which result the inapplicability in wide range of environmental monitoring. Network with GPRS and GPS can use the existing wireless communication network and satellite to transmit data in wide range without pre-construction cost to build the network, but it has disadvantages too. Its data transfer rate is low and not perfectly real-time, so it is difficult to realize real-time video surveillance. The operation cost and maintenance fee is high too.

Technology of Internet of Things can be used in all sewage treatment facilities when water sewage plant based on IoT(Internet of Things) is built. The cost of IoT may account to 10% of total investment of a sewage plants. By the water quality data and water quantity data collecting from sewage treatment units and operation status data collecting from sewage treatment facilities, managers can control and monitor the water sewage facilities in real time, which can ensure the safe and efficient operation of the water sewage plant. Now technologies of Internet of Things have been used in sewage plants. For example, Zunyi 40,000t Urban Sewage Plant was started to build in November 2009. Suzhou University of Science and Technology established the Internet of things-based open wastewater treatment laboratory in November 2009 [19]. If the real-time images of key areas can be watched in office, the control and management effect of the plant will be better. This is difficult to realize with Zigbee-based WSN and GPRS, but it is available with WiFi-based WSN, which have higher transmission rate and bandwidth.

Technology of Internet of Things can be used in management of sanitation operation vehicles too. Sanitation operation includes garbage collection, waste transport, road sweeping and watering, road cleaning, stool treatment and so on. Sanitation operation vehicles can be better scheduled and arranged in emergency by GPS system and terminal side devices installing on the vehicles and the GPS system can benefit the supervision in sanitation operation[20]. If the operation images can be transmitted to the control center, managers can assess the sanitation work in real time. Its realization relies on WiFi-based WSN, which has high transmission rate and bandwidth.

C. Application of Precision Agriculture

In modern agriculture, technologies of IoT is often used in real-time information collection, such as temperature, humidity, wind, air station, rainfall, soil moisture, soil compaction, soil conductivity, pH value, soil nitrogen and other soil information. With the information farmers can make scientific decision [21]. With the development of the intelligent agriculture and precision agriculture, communications networks, intelligent sensing chips, mobile technologies such as embedded systems applications in agriculture have gradually become a research hotspot [22].

The IoT applications in agriculture are mainly used in intelligent control of cultivation environment, agricultural products safety and environmental information monitoring. For example, Chenzhou tobacco greenhouse intelligent monitoring, Ningbo intelligent monitoring of viticulture and Jinzhou agricultural greenhouse have all used IoT and realized planting at home. All the applications use sensors to collect data and transmit data through local area networks and wide area wireless communications network.

It may be better if remote diagnosis of diseases and insect pests can be realized. When the images of diseases or insect pests are transmitted to the server, treatment proposals can be given automatically. Its realization requires that WiFi-based WSN has low power consumption and it can be powered in crop fields easily.

V. CONCLUSION

Maybe all objects around us can be connected into Internet of Things and their demands are various, so there are no such kinds of technology that can suit all WiFi applications. New technologies and applications on WiFi are the hotspots of current research work. WiFi-based wireless sensor network is such a new kind of technology. Compared to traditional WSN based on Zigbee, it has the advantages of high bandwidth, fast transmission rate, long transmission distance and NLOS transmission ability. It can play a better role in some applications, especially in video monitoring requiring data transition and good real-time.

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