

# Gateway System of a Kind of Intelligent Home

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## Abstract

As the important application of Internet of things technology, intelligent home system becomes the research focus at home and abroad. This paper does design on home gateway system of intelligent home through combining with embedded technology, computer network technology and wireless sensor network technology. Utilizing CC2530 Chip of TI Company, it finishes the design of ZigBee networking module. Through using S3C6410 Chip and running embedded Linux System, it realizes protocol conversion program, completes design of telecommunication module and achieves connection of home gateway with Internet. Test results indicate that the designed home gateway system meets requirements of system design, achieves the anticipated design targets and keeps good practical value.

Key words: INTERNET OF THINGS, INTELLIGENT HOME, HOME GATEWAY, ZIGBEE TECHNOLOGY

## 1. Introduction

On the basis of family residence, intelligent home system utilizes computer technology, communication technology and control technology to realize integration and monitoring on relevant household facilities, thus leading automated, safe, effective and personalized intelligent dwelling environment to come into being[1]. With the development of Internet, requirements of people on intelligent home system have developed into Internet-based remote access and control from traditional local monitoring. As short-range communication protocol represented by ZigBee and TCP/IP are incompatible, one of the focuses in intelligent home research field is how to bring short-range communication network in the family access to Internet thus allowing users to do remote monitoring on household environment and facilities through Internet [2. 3].

Occident keeps staying in the leading position in not only definition of intelligent home standard but also development of system software and hardware. In recent years some American large corporations

including Microsoft, IBM and Motorola successively occupy forefront of intelligent home development force, launching some famous systems such as smart home [4], door of residence [5], etc. Asian countries are unwilling to lag behind, led by Japan and Korea which keep developed electronic technologies and chase hard. At present, representative overseas intelligent home systems are X-10 System of the U.S. [6], 8X System of Singapore and EIB System of Germany [7]. X10 System applies power line carrier technology to realize the transmissions of data and control signal. Its advantage is utilizing the existing 220V power line in the family and requiring no extra wiring. The centralized process mode and bus structure of 8X System increase its extendibility. EIB System of Germany achieves intelligent control function in the way of central control which needs to embed bus in the beginning of construction and requires much for engineering.

Comparing with those of foreign countries, intelligent home industry of our country is still in a preliminary stage. Most corporations do secondary

development on their mature intelligent home systems, occupying small proportion in innovation and core technology. Some corporations unwilling to lag behind also launch their own products including “e family” of Haier and “e-home” of Tsinghua Tongfang. E-family uses computer to be control center and directly controls appliances with network functions. Keeping simple structure, this system demands much on household appliances and cannot do intelligent control on traditional appliances, which leads it to be greatly constrained in the aspect of promotion. Following EIB System standard, e-home does design according to situations of Chinese families. It integrates security, automation and information through utilizing embedded software and hardware design, thus keeping functions of automatic meter reading, wireless remote control, video monitoring, humidity monitoring and regulation, surfing the Internet, etc. In the aspect of modular function design, it has caught up with and surpassed the Occident.

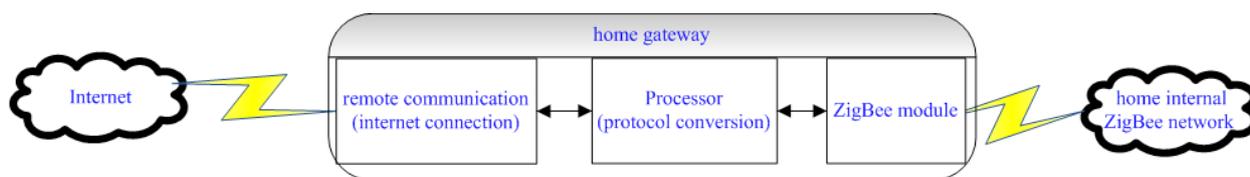
Taking a panoramic view of the situation, communication mode of domestic intelligent home system is still restricted although some successful cases of intelligent home system has appeared. Most of them are still utilizing wire-format link in which construction is difficult, price is high and it is difficult for aesthetic degree to satisfy requirements. Wireless interconnection mode is mainly composed of Bluetooth, Infrared and WiFi. These technologies can never meet market requirements because of their shortcomings covering cost, security, extendability, network coverage degree, etc. As an emerging short-range communication technology, the current popular ZigBee has good advantages in aspects of reliability,

security and signal covering range. Meanwhile extendability of wireless LAN established by it is also high.

### 2. Overall Design of Home Gateway System

Home gateway serves as server in the system, being responsible for listening to and dealing with connection request from the client. There is usually more than one user. Gateway server needs to do management on accesses of multiple users, preserve their operating records, receive operating instructions from users on the Internet and send orders to central controller in home internal network after analyzing and dealing with them. Operating results and data of intelligent home facilities would also be fed back to corresponding users’ upper computer programs to be shown through gateway. When users quit, gateway also takes charge of cutting off current connections. Therefore establishment of home gateway helps improve security of the whole system in which intranet protocol and extranet protocol are entirely independent. Changes of internal and external network communication protocols have no influences on other modules in the whole system, which provides convenience for developing extensions of system, helps set different permissions for different users to do authentication and guarantees that intelligent facilities in the intranet would not be illegally accessed and operated.

This design utilizes ZigBee wireless short-range communication technology to establish home internal network. Home gateway in this design has three functions which are ZigBee networking, protocol conversion and remote communication. Fig.1 shows structure diagram of home gateway system.



**Figure 1** Structure Diagram of Home Gateway System

(1) ZigBee networking. As network coordinator in home internal ZigBee network [8], ZigBee module in home gateway is in charge of establishing ZigBee network, managing facilities in ZigBee network, realizing automatic accession of ZigBee nodes, deleting nodes outside of ZigBee network and achieving internal routing function of it. Network address of each module in home internal ZigBee network is distributed by coordinator. When positions of modules change or coordinator restarts, their network addresses also change. Therefore mappings of net-

work addresses and physical addresses of facilities inside of home gateway need preserving thus guaranteeing accurate transmission of data. Home gateway in this design uses comparison table of network address and MAC address to finish conversion between physical address and network address.

(2) Protocol conversion. Home gateway exists in the connecting position of Internet and ZigBee network, being responsible for their communication. As protocols of Ethernet data format and ZigBee data format are different, protocol conversion should be

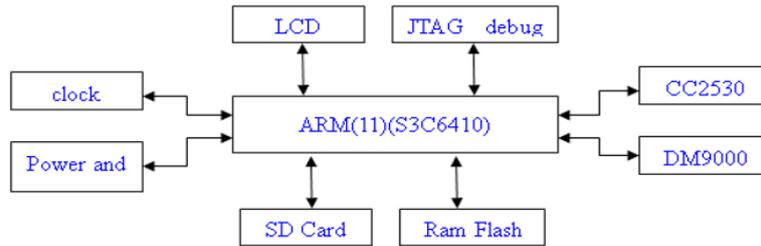
done between them to ensure their normal communication. This communication mode is to solve the problem that home internal IP address could not be found in extranet after it is distributed by network operator through DHCP.

(3) Remote communication. Connection between home gateway system and Ethernet is needed for the purpose of realizing remote control on facilities in appliance network. Communication mode between home gateway and remote control client in this design

is utilizing extranet server transmission, which is for solving the problem.

### 3. Designs and Realization of Home Gateway Hardware System

Hardware system design is mainly divided into two parts. One is design and realization of hardware of data processing system. The other is design and realization of hardware of ZigBee wireless network management system. Fig.2 is structure diagram of home gateway hardware.

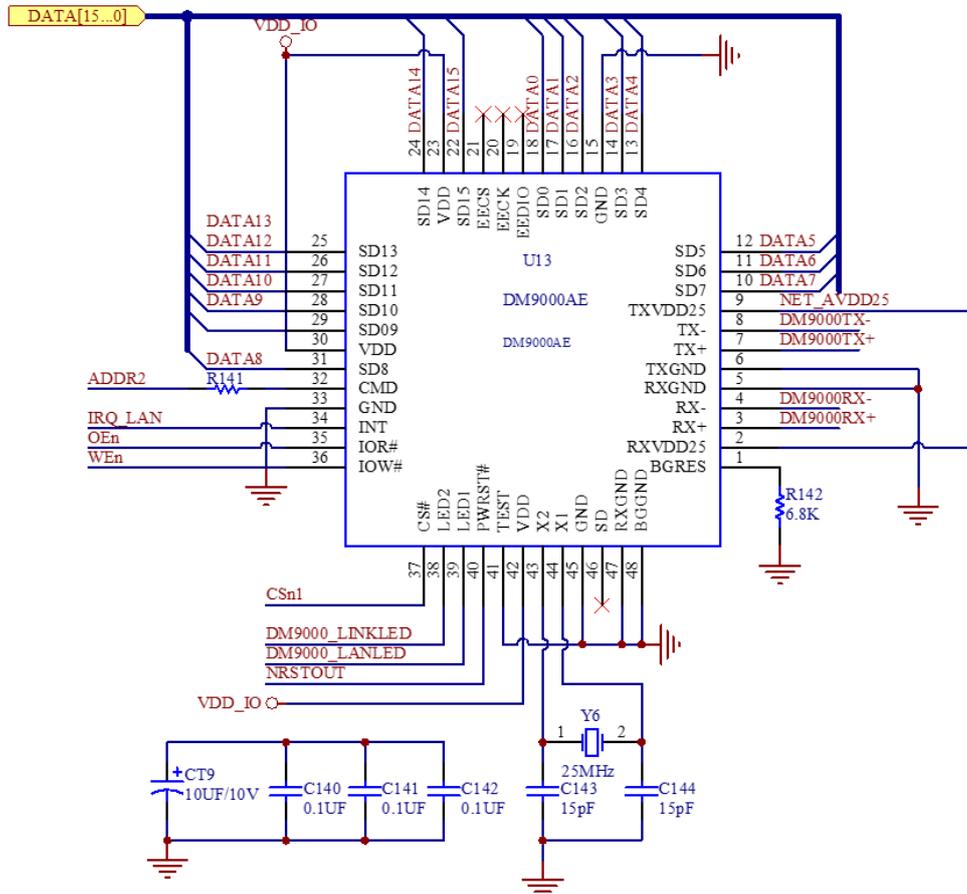


**Figure 2.** Structure Diagram of Home Gateway Hardware

Data processing system whose hardware uses S3C6410 finishes protocol conversion and remote communication of home gateway, designs essential peripheral circuits including RAM, FLASH, clock and power for server so as to guarantee its data processing ability and designs DM9000 Ethernet module

circuit to realize remote communication.

ZigBee wireless network management system whose hardware utilizes ZigBee Chip CC2530 finishes ZigBee networking of home gateway and designs circuits of antenna, clock, power and serial for chip to realize ZigBee networking.



**Figure 3.** DM9000AE Circuit Diagram



dule CC2530. In the design, SP3232EEA Chip converts serial signals of two UART Interfaces to RS232 levels. It is also externally connected with DB9 Interface thus providing convenience for its connection with other devices. Fig.5 is the circuit diagram of S3C6410 Serial.

**3.3. Realization of CC2530 Serial Circuit**

In the design of home gateway system, S3C6410 communicates with CC2530 through serial in which serial circuit needs designing for CC2530. The serial circuit designed for this time is seen in Fig.6 and derived through DB9 Interface.

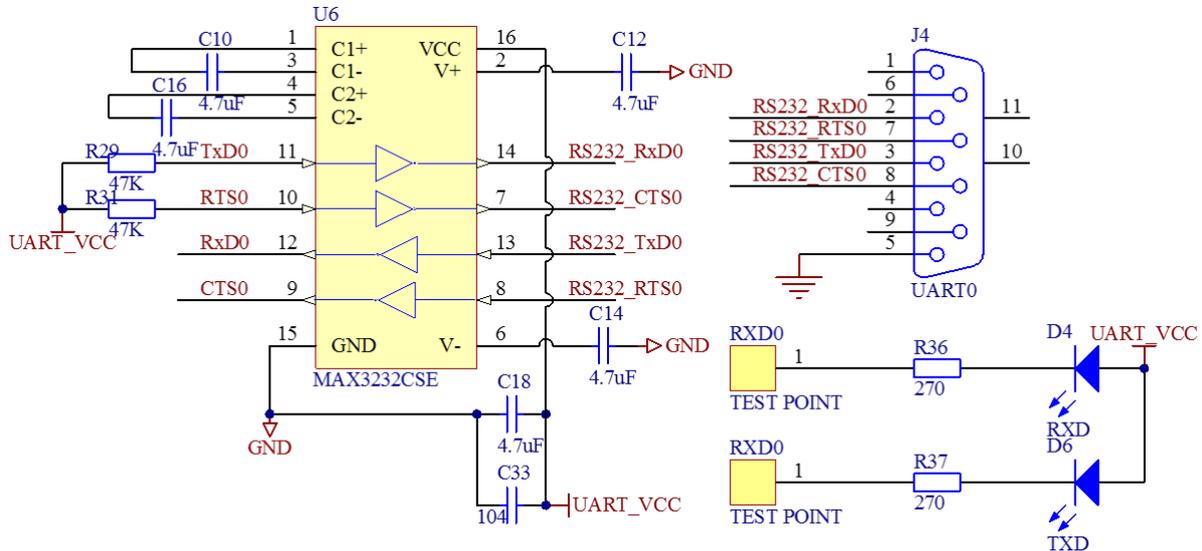


Figure 6. Circuit Diagram of CC2530 Serial

CC2530 Module supports multiple serials. As home gateway system only needs single serial, just one serial is designed this time. This serial design uses P0.2, P0.3, P0.4 and P0.5 Interfaces of CC2530 Module and utilizes MAX3232CSE to serve as serial circuit chip.

**3.4. Realization of CC2530 JTAG Circuit**

CC2530 has its special debugging interface through which programs could be downloaded and debugged in CC2530 and functions of break-point and single-step debug would be set. This design uses P2.1 of CC2530 to act as debugging data line and P2.2 as clock line which are derived through 10 pins of side-by-side interfaces thus extending system functions.

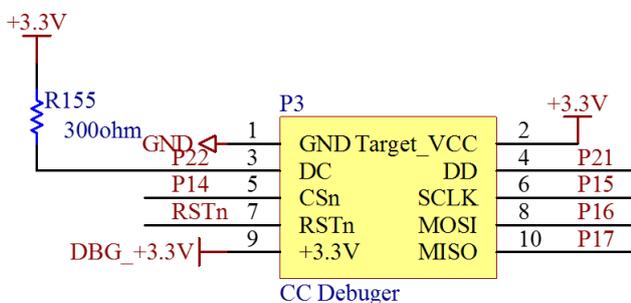


Figure 7. CC2530 JTAG Circuit Diagram

**4. Designs and Realization of Home Gateway Software System**

Suitable software system needs designing for ho-

me gateway after its hardware system is done for the sake of ensuring normal operation of the whole system. According to its three functions, software design of this time is also separated into three parts including ZigBee networking, protocol conversion and remote communication program.

**4.1. Design of ZigBee Networking Program**

This part mainly finishes ZigBee networking [9] and does management on network. After facilities successfully establish network, other facilities would be allowed to join if they applied for accession. Then data sent by them would be unpacked and analyzed. Network address and MAC address information of facilities transmitted by terminal node would be stored in address database of coordinator. It would be utilized as network address for searching nodes when coordinator did uni-cast transmission on terminal node facility. Temperature and voltage information would be transmitted to protocol conversion module through serial and done with further processing.

Realization of program in this part consists of two modules. They are device initialization and wait event handling module and ZigBee network event handling module.

Device initialization [10] and wait event handling module mainly finishes a series of initialization operation after device is electrified. Then it selects one ID to establish network and then switches to event handler to wait for event trigger of ZigBee net-

work or serial. If there was event trigger, it would shift to relevant event handler. If there was no event trigger, it would keep waiting. Fig.8 shows the flow diagram of its realization.

ZigBee network event handling [11] module mainly does analysis on events in the network. If it is information that devices ask for accession, they would be allowed. If it is other data, it would be unpacked and analyzed to determine whether it is address information sent by ZigBee node devices or temperature and voltage information needing transmitting to protocol conversion module. If it is temperature and voltage information, it would be transmitted to protocol conversion module for further processing. If it is address information of node devices, it would be stored in relevant data structure [12] for utilization when coordinator does uni-cast transmission on node devices. Fig.9 shows the process of its realization.

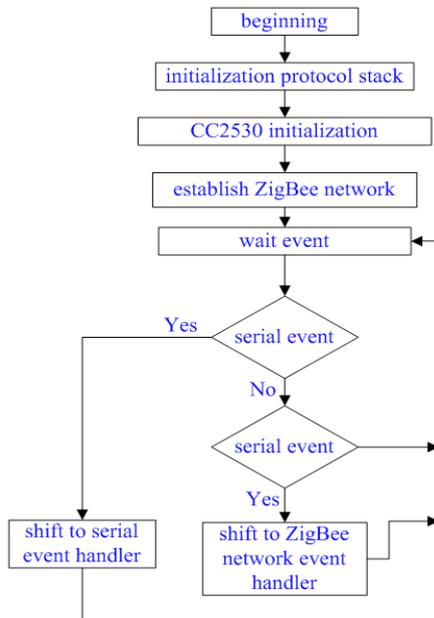


Figure 8. Flow Diagram of CC2530 Device Initialization Wait Event Handling Module

4.2. Design of Protocol Conversion Program

The main function of protocol conversion module is to finish the conversion of ZigBee network data format and Ethernet data format. Therefore realization of this part may include two modules in the aspect of program design. One is ZigBee network data converting to Ethernet data module. The other is Ethernet data converting to ZigBee network data module.

ZigBee network data converting to Ethernet data module finishes the data format conversion from ZigBee network to Ethernet. Fig.10 is the flow of its realization. Data of ZigBee network received by protocol conversion module is actually transmitted by

CC2530 through serial. It is to say that the data is transmitted from serial.

Ethernet data converting to ZigBee network data module finishes the data format conversion from Ethernet to ZigBee network. Fig.11 shows the flow of its realization. Data of Ethernet received by ZigBee network is transmitted by Ethernet. Through protocol conversion, it is sent to serial and finally reaches ZigBee network.

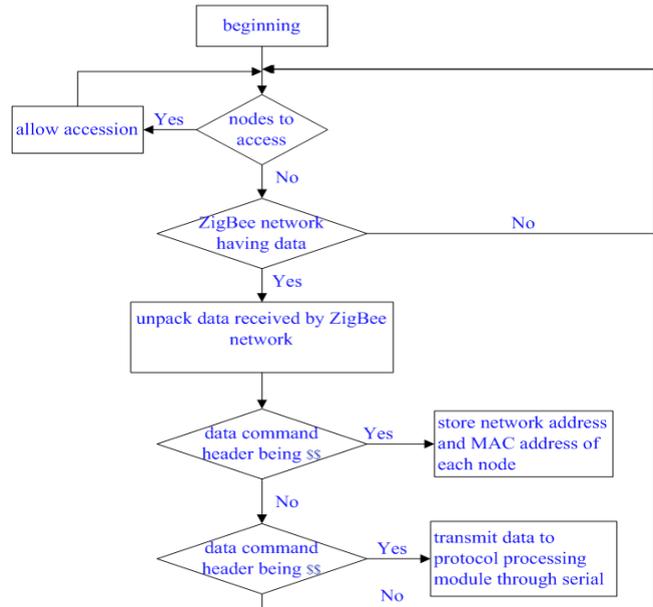


Figure 9. Flow Diagram of ZigBee Network Event Handling Module

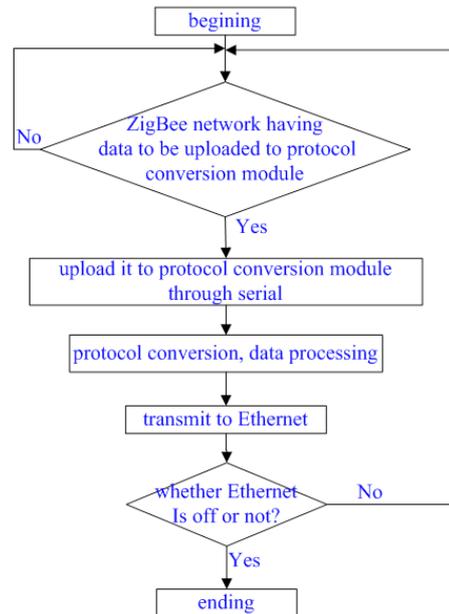


Figure 10. Flow Diagram of ZigBee Network Data Converting to Ethernet Data Module

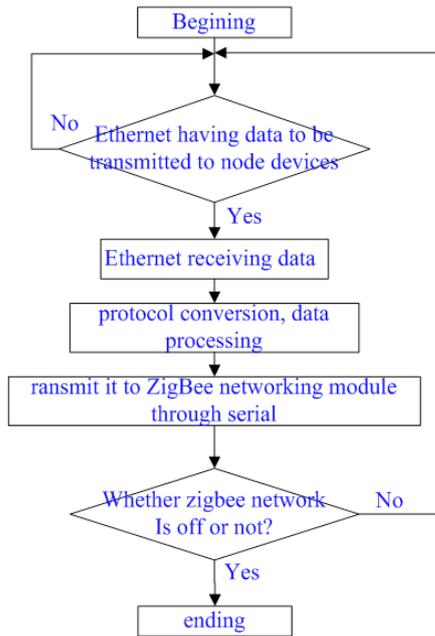


Figure 11. Flow Diagram of Ethernet Data Converting to ZigBee Network Data Module

**4.3. Realization of Remote Communication Program**

The main function of this program is realizing Internet connection of home gateway and maintaining this connection. It is simple to connect to Internet. Serving as Client of C/S, home gateway directly initiates connection to Server. As extranet server transmits data in the utilized communication architecture, gateway needs to regularly send a short message to extranet server to explain its online situation and report its IP address to maintain this Internet connection. Therefore realization of this program includes two modules which are connecting to Internet module and maintaining Internet connection module.

Connecting to Internet module realizes Internet connection of home gateway in which TCP connection is initiated to target IP address and connection is established with server’s permission. Fig.12 expresses its realization flow.

Maintaining Internet connection module realizes Internet connection of home gateway in which home gateway needs to regularly notify its online conditions and changes of IP address so that extranet server could always find its home gateway.Fig.13 shows its realization flow.

This module maintains Internet connection through utilizing a timer to regularly send online messages.

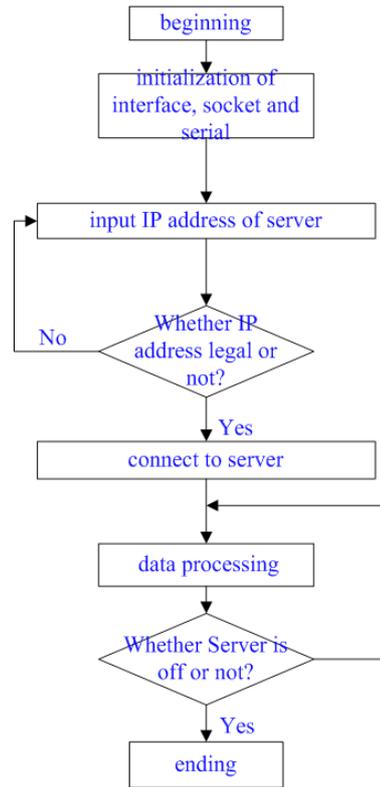


Figure 12. Flow Diagram of Establishing Internet Connection Module

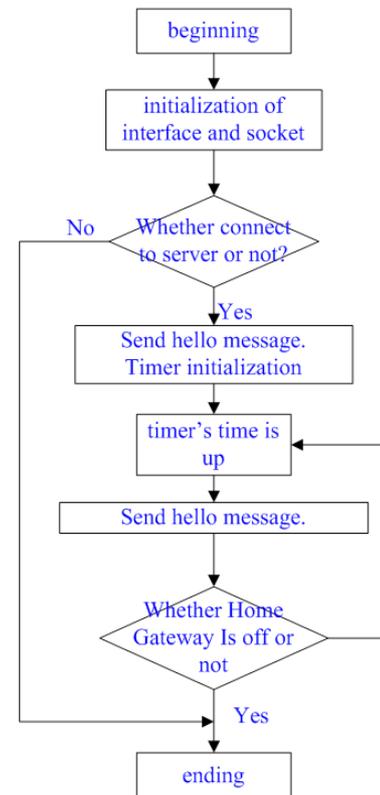


Figure13. Flow Diagram of Maintaining Internet Connection Module

**5. Conclusions**

Utilizing ARM Technology, ZigBee Wireless Net-

work Technology and Computer Network Technology which use unified wireless protocol and different control protocols, this paper establishes an intelligent home network composed of various terminal devices. On the basis of existing intelligent home system solutions, it proposes the combination of S3C6410 Processor and ZigBee Wireless Technology. These help realize remote and real-time monitoring and management on household appliances in intelligent home system. It is the true Internet of things.

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