U¹-Chip: Wireless Communication Module for Fast Service Discovery

Yuichi Taguchi, Shunsuke Saruwatari, Hiroyuki Morikawa, Tomonori Aoyama
The University of Tokyo
7–3–1 Hongo, Bunkyo-ku,
Tokyo, 113–8656, Japan
+81 3 5841 6710
{yuichi, saru, mori, aoyama}@mlab.t.u-tokyo.ac.jp

Mikio Hasegawa, Masugi Inoue
National Institute of Information and Communications Technology
3–4 Hikarino-oka, Yokosuka,
Kanagawa, 239–0847, Japan
+81 468 47 5063
{mikio, inoue}@nict.go.jp

ABSTRACT

This paper describes a framework for location-based service discovery using U¹-Chip, which is a wireless communication module specialized in fast device discovery and burst data communication. These features are enabled by using different frequency channels and media access control (MAC) protocols between discovery stage and communication stage. We show some application examples of the U¹-Chip, and then present prototype implementation and evaluation.

Keywords

wireless communication module, service discovery, location-based service

INTRODUCTION

In ubiquitous computing environment, many small smart devices provide various services anywhere, and we can enjoy services at anytime with a mobile terminal device like a PDA. To get connectivity easily and rapidly with them, low-power short-range wireless communications have become a key technology. Therefore the Bluetooth and ZigBee have been developed as wireless personal area networks (WPANs) until now.

However, they are targeted at a continuous communication forming a personal area network and are not always suited to practical services. There are many services completed within a short and burst communication of several Kbytes data, for example, acquiring available information from surroundings, or getting control of devices around the user. We call these services “instant services”. It is important for instant services to discover services rapidly and transmit data in bursts.

To realize these communications, we have developed a low-power and low-cost wireless communication module called U¹-Chip. The U¹-Chip uses very low-rate channel for reducing power consumption. However, using different frequency channels and MAC protocols between discovery stage and communication stage, it can accomplish both fast device discovery and burst data communication.

IMPLEMENTATION

We have developed the U¹-Chip prototype shown in Figure 1. It consists of an H8S microcontroller from Renesas and a CC1020 RF transceiver from Chipcon. The size of prototype is 3 cm × 3 cm.

Figure 2 shows a message sequence chart of the U¹-Chip. A master is a device requesting service discoveries (usually a user terminal device) and a slave is a device providing a service. At discovery stage, the adaptive tree walk protocol[1] is used in control channel to associate with slaves rapidly. At communication stage, a master and a slave occupy one data channel, and transmit data in bursts with carrier sense multiple access (CSMA) protocol.

For these communications, we designed a protocol stack shown in Figure 3 and implemented it on the U¹-Chip prototype. The details of each layer are described in the following sections.

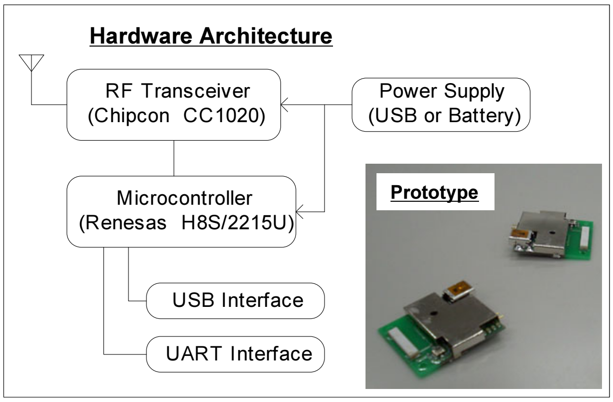

Figure 1: Overview of the U¹-Chip

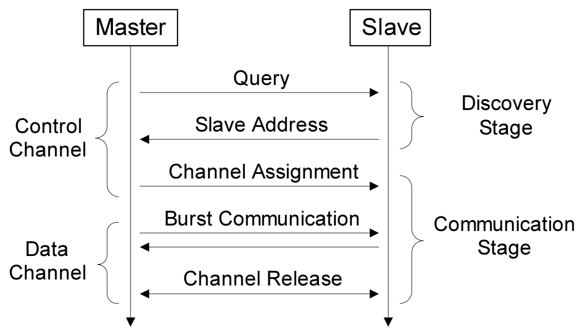

Figure 2: Message sequence chart

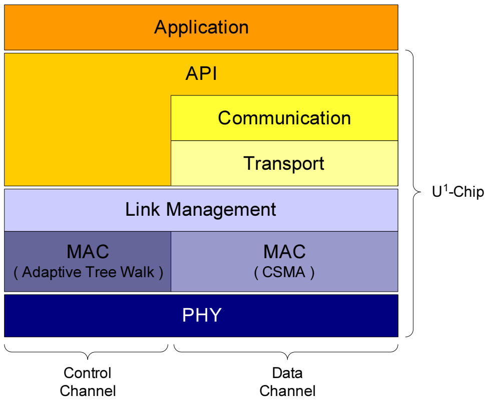

Figure 3: Protocol stack

Table 1: Physical layer specifications

Frequency band	429.25 – 429.7375 MHz
Number of channels	40 channels
Modulation	FSK
Raw data rate	4800 bps
Range	10 m

Physical Layer

The physical layer specifications of the U[1]-Chip prototype are shown in Table 1. A master only discovers physically near slaves because of the limitation of radio range. Thus location-based services are provided for the user.

MAC Layer

The prototype has 40 frequency channels. One of them is a control channel, and the rest are data channels. We use different MAC protocols in each channel: the adaptive tree walk protocol in control channel, and CSMA protocol in data channels.

The adaptive tree walk protocol uses a tree algorithm for channel arbitration. It is effective at discovery stage because it acts as a contention protocol to provide low delay when the number of slaves is small, but it acts as a collision-free protocol to provide good channel efficiency when the number of slaves is large. We use a quadtree composed of tree IDs of slaves. A tree ID consists of a service class of 2 bytes and an address of 8 bytes. The service class represents a category of service provided by the slave, and the address is a unique identifier for each U[1]-Chip.

The protocol works as follows: First, a master sends a query packet for all slaves. The slaves receiving this packet send a reply packet at different timings depending on their first 2 bits of tree ID, i.e. reply packets are sent to the master in 4 different time slots after the query packet. If there is 0 or 1 reply packet in a slot, the master can receive the packet successfully. But if there are more packets, a collision occurs. In this case, there are many slaves having the same tree ID prefix, therefore the master continues to send a query packet for this group of slaves recursively until discovering all slaves.

On the other hand, CSMA protocol is used in data channel for burst data communication. ACK packet is used to raise reliability of communication.

Link Management Layer

At the beginning of the communication stage, this layer looks for an available data channel with carrier sense and assigns it to a slave. This data channel is released when a communication is finished.

Transport Layer

In data channels, datagrams are divided into 1 Kbytes segments for reducing the risk of data loss. Fragmentation and reassembly are implemented in this layer.

Communication Layer

The U[1]-Chip uses request / response communication protocol like HTTP at the communication stage. This layer provides application programming interface (API) to use this protocol for application layer.

EVALUATION

As a preliminary evaluation, we measured the discovery time in both experiment and simulation. Figure 4 shows the time that a master spent for discovering all slaves at 4800 bps. In experiment, the tree IDs of slaves were fixed. In simulation, we assigned random tree ID to slaves at each simulation, and computed the average and the standard deviation of the discovery time for 300 times.

The experimental result is mostly contained within the range of standard deviation of the simulation although the discovery time depends on the distribution of the tree IDs of slaves. The master can discover about 5 slaves within a second at 4800 bps.

CONCLUSIONS AND FUTURE WORK

In this paper, we have designed and developed the U[1]-Chip that is a low-power and low-cost wireless communication module for fast device discovery and burst data communication. We have measured the device discovery time and presented that we can accomplish fast device discovery in spite of low data rate. Currently we are developing practical applications of the U[1]-Chip.

REFERENCES

[1] Capetanakis, J. I. Tree Algorithms for Packet Broadcast Channels. *IEEE Transactions on Information Theory*, vol. IT-25, no. 5, Sept. 1979, pp. 505–515.

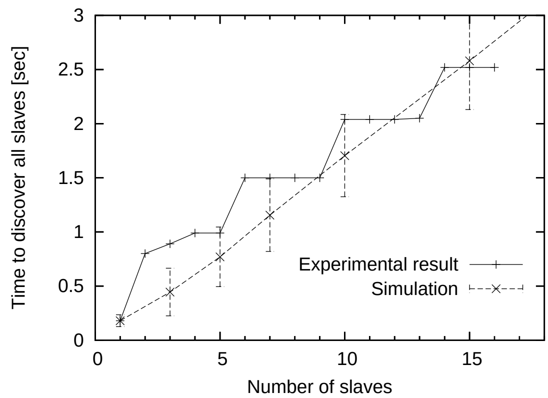

Figure 4: Evaluation of the discovery time