Proposal for a Seamless Connection Method for Remotely Located Bluetooth Devices

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***Abstract*—In view of the recent development of short-range wireless communication technologies, popularization of home automation is being anticipated. Hereafter, it is expected that the desire of manipulating short-range wireless communication devices located at home from the outdoors will increase. However, there exists a constraint of the reachable range of communication for such devices, and it is not possible to directly manipulate them from a remote location from home. In this paper, we propose a method to get connection with a remotely located Bluetooth device, by forwarding command and other messages exchanged between the hardware and software of Bluetooth device via the Internet. Based on this method, it is possible for a user to have seamless connection, by using ordinary Bluetooth applications, without the necessity of being conscious of the location of Bluetooth devices.**

I. INTRODUCTION

It is expected that home apparatuses are more and more computerized and that home appliances equipped with short-range wireless communication devices including Bluetooth are widely spread, in proportion to the development of information home appliances and information terminals in future. If it is or becomes feasible for users to manipulate home appliances by a device such as smartphone at home, it is necessarily thought that there arises a desire of manipulating appliances located at home from the outdoors as well. However, since such appliances have a limited reachable rage of communication, it is not possible to directly manipulate them from a remote location.

As a means of connecting with a Bluetooth device located in remote place, various different methods have been proposed thus far, such as methods using PUCC (P2P Universal Computing Consortium) [1], UbiGate using SIP [2], and UbiPAN [3]. However, these methods have certain specific problems; e.g. some of them require users to carry a gateway, some of them need to set a special server on the Internet, and some of them require users to differentiate connection methods or applications, depending on the location of the operating terminal or devices to be connected.

In this paper, we propose a method to connect with a remotely located Bluetooth device, by forwarding commands and messages which are exchanged between hardware and software in the Bluetooth terminal via the Internet. Based on this method, users are able to get connection with Bluetooth devices at home from the outdoors by means of ordinary Bluetooth applications, by performing the same operation as that performed at home, without the necessity of being conscious of the position of Bluetooth devices.

II. OUR PROPOSED METHOD

A. Overview

We propose in this paper a new connecting method that has solved above-mentioned problems. Our proposed method is realized based on the following basic policies.

- User can make a connection to Bluetooth devices always with the same operation, regardless of user's own location or the location of the Bluetooth device to be connected.
- Applications used by the user are ordinary Bluetooth applications that have no special functions.
- Users do not need to carry any other devices than the operating terminal. As the operating terminal, smartphone is mainly assumed, and that can be connected to the Internet.
- Any modification required in connecting with remotely located Bluetooth devices should be applied to user's operating terminal and home terminal only. That is to say, no special server is required on the Internet.

Fig. 1 shows the system configuration. In this paper, we call the Bluetooth device that exists at home and that is subject to connection as "RD" (Remote Device), and the operating terminal in the outdoors as "CD" (Control Device). As CD cannot make Bluetooth communication with RD directly, a gateway to relay communication (hereafter "BGW", Bluetooth Gateway) is set in the network at home. To BGW, one Bluetooth interface and one IP interface such as Ethernet or Wi-Fi are equipped. In our proposed method, Host Controller Interface (HCI) messages[1] exchanged between CD's "HOST"

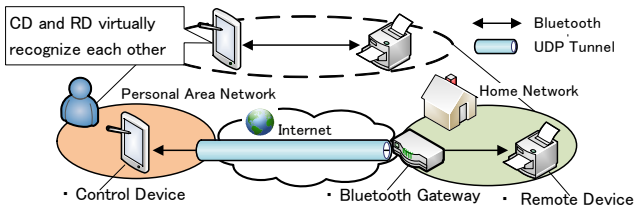

Fig. 1. System configuration.

[1]In this paper, HCI Commands, HCI Events and HCI Data are collectively called in this way.

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TABLE I
COMPARISON WITH RELATED WORKS.

	Using PUCC	UbiGate	UbiPAN	Proposal method
Differentiated use of applications	×Yes	×Yes	◯No	◯No
Dedicated application	×Necessary	×Necessary	◯Not necessary	◯Not necessary
Necessity of carrying a gateway	◯Not necessary	◯Not necessary	×Necessary	◯Not necessary
Setting of a special server	×Necessary	◯Not necessary	×Necessary	◯Not necessary
Implementation of function to device	◯Not necessary	◯Not necessary	◯Not necessary	×Necessary

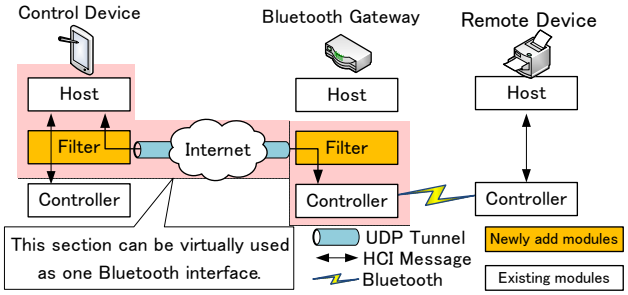

Fig. 2. Mechanism to usage the Bluetooth interface of Gateway as my own.

and "Controller" are forwarded to BGW through the Internet. Where, "Host" and "Controller" are the upper layer composed of software and the lower layer composed of hardware in Bluetooth stack respectively. BGW makes connection with RD at home, depending on the content of the HCI messages. Through this process, CD can handle the Bluetooth interface of BGW as if it were its own interface, and recognizes as if RD in a remote location existed in the vicinity.

B. Tunnel Establishment and Hooking of HCI Message

HCI message cannot go through on the Internet as they are. Thus, we make it possible to forward HCI message via the Internet, by establishing a UDP tunnel between CD and BGW and encapsulating it.

As indicated in Fig. 2, in our proposed method, HCI message exchanged between Host and Controller of CD is hooked so that it is forwarded to BGW via the Internet. Hooked data are forwarded to BGW through the IP tunnel established just before this process. BGW makes a connection with RD at home, according to the content of the HCI message received. In this way, in our proposed method, HCI message can be exchanged as if CD and BGW together functions as one Bluetooth device.

III. EVALUATION

We conducted an operational verification of our proposed method, by actually implementing the functions of forwarding HCI messages to Linux PC. We were able to confirm that HCI messages can be smoothly transmitted between two Linux PCs, which are remotely positioned with each other, on IP networks.

TABLE I shows the comparison between the above-mentioned related research/studies and our proposed method. In our proposed method, we are able to get connection with RD even from the outdoors by the same operation conducted at home, by treating the BGW set at home as CD's Bluetooth interface. On that occasion, users can start communication using ordinary Bluetooth applications all the time, without the necessity of being conscious of the location of CD and RD. Because smartphone is mainly assumed as CD, users can get connection with Bluetooth devices at home anytime and from anywhere without being constrained by the connection location. In addition, CD is able to make Bluetooth communication with RD via BGW, with the addition of a new function to CD. Thus, it is not necessary to relay communication by setting a special server on the Internet. Besides, users do not need to carry any other devices than CD.

In our proposed method, we need to apply some modification to the kernel of the operating terminal in the outdoors. Thus, it is the condition for our method that the terminal is operated by Linux kernel and further that a kernel module can be added. In the meantime, as the Bluetooth Stack in Android is the same as that in Linux, it is possible to apply our proposed method to Android smartphones.

IV. CONCLUSION

In this paper, we have proposed a method to make communication between two short-range wireless communication devices located remotely with each other, by sending/receiving control messages exchanged between the software and hardware of a short-range wireless communication device via the Internet. Based on our proposed method, a user can get connection with Bluetooth devices by always using ordinary Bluetooth applications, without the necessity of being conscious of the user's location or the location of the Bluetooth devices. Hereafter, we are going to complete implementation of our method to Linux kernel and perform an evaluation regarding the throughput of Bluetooth communication and the impact on delays in communication by our proposed method.

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