블루투스 스캐터넷을 이용한 물체 인식 시스템에 관한 연구
A study on the identification system of an object using Bluetooth Scatternets

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ABSTRACT

There has been much interest in the Bluetooth technology since it could enable users to connect to a wide range of computing and telecommunication devices without the need to carry or connect cables. It delivers opportunities for rapid, ad-hoc connections, and in the future, could possibly enable automatic, unconscious, connections between devices. In this paper, we discussed a scatternet formation protocol for Bluetooth-based ad hoc networks and proposed the identification system of an object using Bluetooth Scatternets. Over the past few years, several studies have been made on the identification of an object by several RF(Radio Frequency) systems. But there are still some problems, the interference of signals as an example, for the identification of an object. The critical question is how to identify an object precisely without the interference of signals. This paper is an investigation of the Scatternet formation protocol for Bluetooth-based ad hoc networks and the identification system of an object using Bluetooth Scatternets composed of multiple Piconets.

I. INTRODUCTION

Recently Bluetooth has become an attractive technology in wireless communications fields. It supports connection-oriented and connectionless links and is thus suitable for both voice and data communications. The Bluetooth system supports both point-to-point and point-to-multipoint connections. Several Piconets can be established and linked ad hoc, where each Piconet is identified by a different frequency hopping sequence. Bluetooth is likely to become another important platform for ad hoc networking, so ad hoc networking over Bluetooth can lead to many useful applications. Up to now, Bluetooth defines a simple network topology (Piconet) that only supports a limited number of devices and requires all devices to be in a range. However, support of the more demanding multi-hop ad hoc network topologies (so-called scatternets) is not specified in detail yet. Therefore, support for so-called "Scatternets" which are multi-hop networks comprising multiple Piconets is a challenging subject of current research. In this paper, we proposed the identification systems of an object using Bluetooth Scatternet.

This paper is structured as follows. Section 2 gives a short summary of the Bluetooth technology as the background information of an system. Section 3 proposes an railway system using Bluetooth Scatternets as the system model. Section 4 illustrates the communication inter Piconets in a Scatternet by implementing a basic protocol stack and Scatternets. Finally, section 5 presents our conclusions and describes future work.

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II. BLUETOOTH

A. Bluetooth Overview

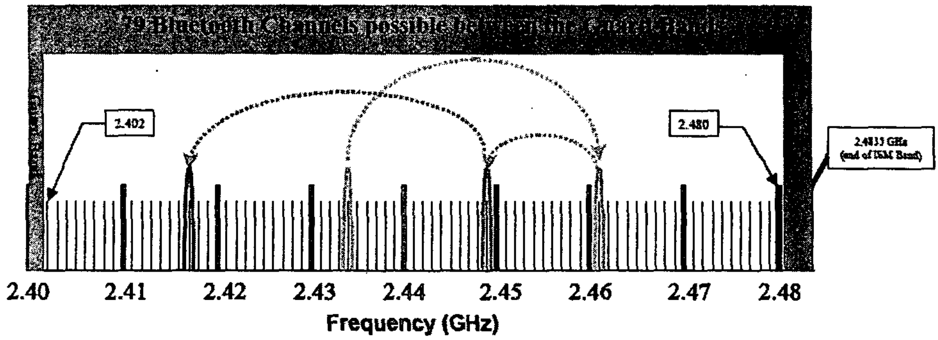
The Bluetooth technology is a Radio Frequency (RF) specification for short-range, point-to-point and point-to-multipoint voice and data transfer. The technology represents an opportunity for the industry to deliver wireless solutions that are ubiquitous across a broad range of devices. Comparing to IEEE 802.11b wireless LAN, Bluetooth has the advantages of multiple channels. Naturally, Bluetooth can be thought as communication media in ad hoc networks The gross data rate is 1Mb/s, but the actual data rates are 432Kbps for full duplex transmission, 721/56kbps for asymmetric transmission. A Time-Division Duplex (TDD) is used for full-duplex transmission. Bluetooth wireless technolgy is designed to be as secure as a wire with up to 128-bit public/private key authentication. The encryption strength can be very robust which is good for establishing a secure link. Also, Designed to operate in a noisy radio frequency environment, the Bluetooth radio uses a fast acknowledgement and frequency hopping spread spectrum (FHSS) scheme to make the link robust. The basic technical data of Bluetooth is presented in Table 1.

[Table 1] Bluetooth technical data.

Function	Performance
Spectrum	2.4 GHz ISM band
Transmission Power	1 mW / 2.5 mW / 100 mW
Modulation	2-GFSK
Range	10 ~ 100 m (dependent on Power Class)
Supported Stations	Up to 8 devices per piconet
Speech-Codes	LogPCM, CVSD
Frequency Hopping	Up to 1600 hops/s 79(23) Hopping-Channel (1 Mhz)
Services	Speech(3x64 kBit/s) Data (DL:721 kBit/s, UL:58 kBit/s or 433 kBit/s DL/UL)

B. Frequency Hopping

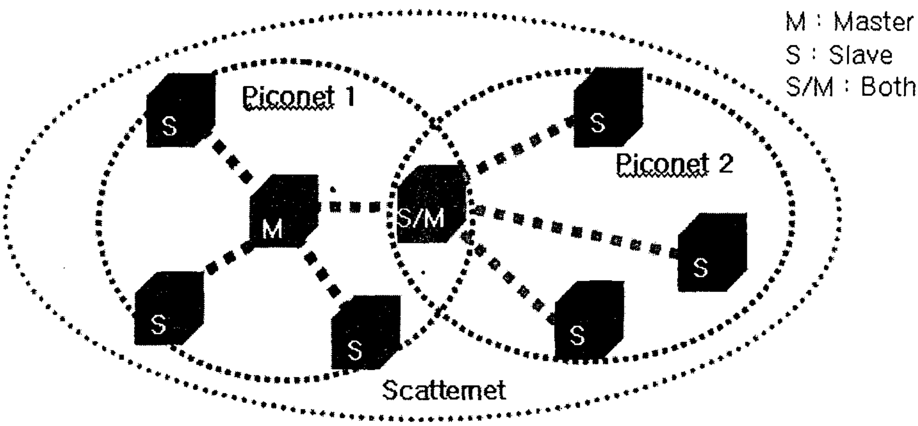
Bluetooth wireless technology uses the frequency-hopping version of spread spectrum, which entails the transmitter's jumping from one frequency to the next at a specific hop rate in accordance with a pseudo-random code sequence. The order of frequencies selected by the transmitter is taken from a predetermined set as dictated by the code sequence. Since only the intended receiver is aware of the transmitter's hopping pattern, only that receiver can make sense of the data being transmitted. The Bluetooth device hops at a rate of 1600 hops per second, pseudo-randomly selecting a single 1 MHz channel for operation. The channel selection is made regardless of other occupants in the band. The Bluetooth power is spread, making the entire ISM band experience the same average interference power from the Bluetooth device. This spreading allows Bluetooth to mitigate the effects of fading as well as interference. Although direct sequence offers the higher data rate, frequency-hopping spread spectrum is more resistant to interference and is preferable in environments with electromechanical noise and more stringent security requirements.



[Figure 2] Shows how a Bluetooth device operates in the ISM band over time.

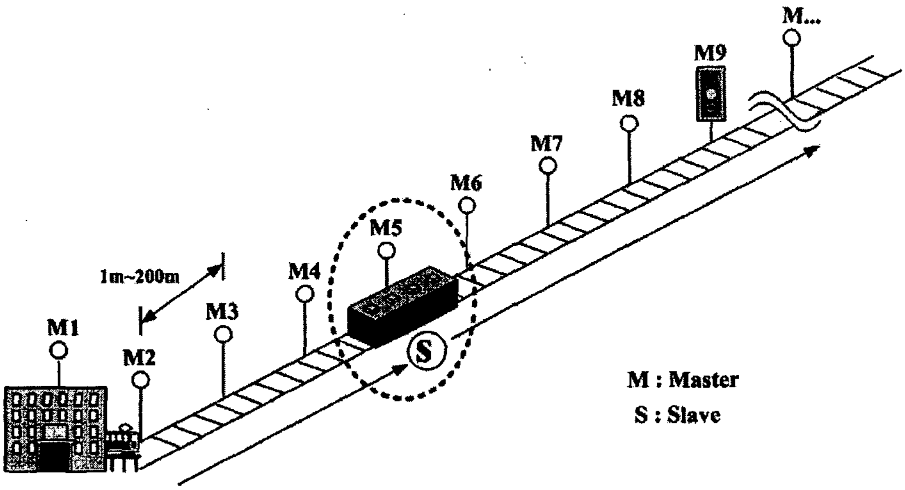
C. Scatternet

A collection of Slave devices operating together with one common Master is referred to as a Piconet. All devices on a Piconet follow the frequency hopping sequence and timing of the Master. The Slaves in a Piconet only have links to the Master; there are no direct links between Slaves in a Piconet.The specification limits the number of Slaves in a Piconet to seven(except a Master), with each Slave only communicating with the shared Master. However, a larger coverage area or a greater number of network members of more than one Piconet. When a deviceis present in more than one Piconet, it must time-share, spending a few slots on one Piconet and a few slots on the other. Figure is a Scatternet where one device is a Slave in one Piconet and a Master in another. On the right is a Scatternet where one device is a Slave in two. It is not possible to have a device which is a Master of two different Piconets, since all Slaves in a Piconet are synchronized to the Master's hop sequence. By definition, all devices with the same Master must be on the same Piconet. If there is a collision on a particular channel, those packets will be lost and subsequently retransmitted, or if voice, ignored. So, the more Piconets in an area, the more retransmissions will be needed, causing data rates to fall.



[Figure 3] A scatternet.

III. SYSTEM MODEL



[Figure 4] The identification system of an object in a railway.

This figure shows that the identification system of an object has applied to an railway system. As the figure indicates, the system consists of two parts that one is several Masters which were installed in railway as the identifying devices and the other is an Slave as an moving train. Thus, each master could be considered as a form of an Piconet and a group of masters could be regarded as Scatternet in the system applied. The distance between masters was determined from 1m to 200m as we need. Take the identification system on a railway for example. For moving a train, each Piconet where a master is hopping at a rate of 1600 hops per second (pseudo-randomly selecting a single 1 MHz channel for operation) identifies the train which is moving as a Slave. If a Master5 identifies the Slave as a train, the master5 transmits its signal to the other masters through Scatternet. So, the station as a Master1 will know where the train is moving on railway and the signal lamp as a Master9 will be operated in advance even if there is a breakdown in cables connected to the signal lamp system. It is easy to know precisely without interference of signals where the train is locating by the inter Piconets' communication. Because the asynchronous channel can support an asymmetric link with maximally 721 kbit/s in either and FHSS(Frequency Hopping Spread Spectrum) allows Bluetooth to mitigate the effects of fading as well as interference. Although DSSS(Direct Sequence Spread Spectrum)offers the higher data rate, frequency-hopping spread spectrum is more resistant to interference and is preferable in environments with electromechanical noise and more stringent security requirements. The interference in Bluetooth wireless communication should increase with the increasing number of piconets. This is so because Bluetooth communication uses a frequency hopping system that hops randomly from among a total 79 frequencies. As the number of piconets increase, the probability that two frequencies in adjacent piconets are the same increases. This leads to packet collisions requiring retransmission. But the number of Piconets is not important in the system applied since there is only one master and one slave device in a Piconet.

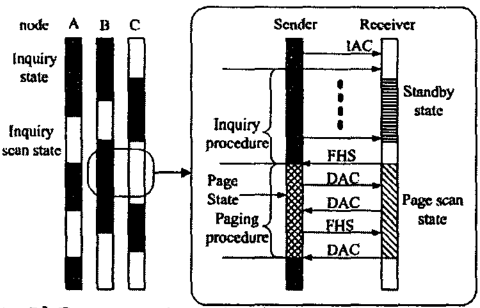
IV. SYSTEM SET UP AND EXPERIMENT

A. Conditions and Goal

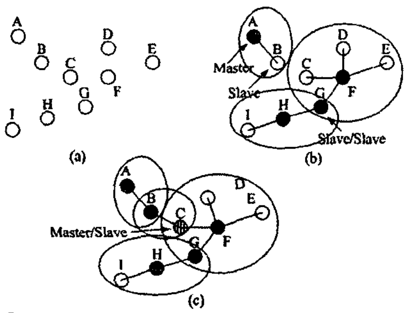
We assume following two conditions for Scatternet structure. (1):A node can belong to up to two Piconets. (2):Two Piconets share one node at most. The condition (1) not only prevents too much inter-piconet traffic load on particularbridges, but also reduces the overhead for channel switching among many Piconets. The condition (2) gives Piconets a chance to connect many other Piconets. It is also useful to simplify routing in the Scatternet. Our goal is to construct and maintain a high connectivity Scatternet under the conditions (1) and (2).

B. A Scatternet Operation Protocol

The Scatternet operation protocol consists of neighbor discovery protocol, Scatternet formation protocol and Scatternet adjustment protocol. In the neighbor discovery protocol, each node discovers its neighbor nodes alternating inquiry state and inquiry scan state. Scatternet formation protocol contains two phases, Piconet formation and disconnection detection. In the Piconet formation phase, a node buildsa Piconet based on the information acquired by the neighbor discovery protocol. The disconnection detection phase is for making additional Piconets and increasing the Scatternet connectivity. After a Scatternet was constructed, the Scatternet is adjusted for coping with movement of nodes by the Scatternet adjustment protocol. The details of the protocols are described below.



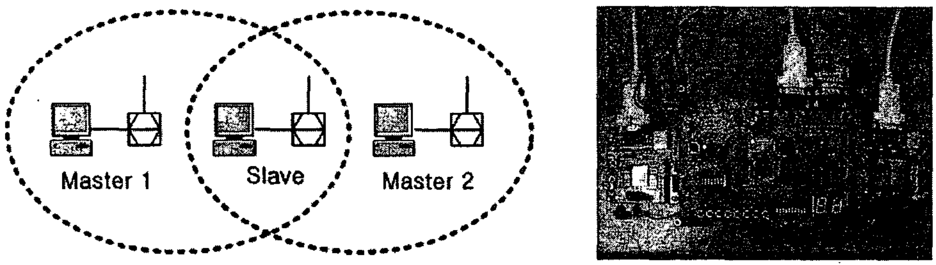
[Fig 5] Each node's action in the neighbor discovery protocol.



[Fig 6] (a) discovery phase (b) piconet formation phase (c) disconnection detection phase.

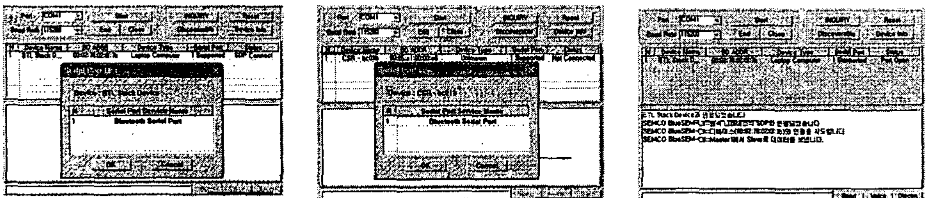
Each node alternates its state between inquiry state and inquiry scan state. Two nodes in opposite states can discover each other through inquiry procedure and paging procedure. Alternating state is independent of the two procedure. When a node starts the neighbor discovery protocol, it sets a neighbor discovery timer with the value T. The node continues the neighbor discovery process until the timer is expired. If the timer is expired, the node enters the piconet formation phase of the scatternet formation protocol. In the process of piconet formation, it is necessary to fulfill the conditions (1) and (2) of A. When two nodes become master-slave relationship, the master asks whether the slave belong to other Piconet. If so, the master gets the addresses of the master already has the bridge to the connected piconet, it rejects the node being its slave. This fulfills the condition (2) of A. Moreover, when a node belong to two piconets, it is in connection state and isn't paged from any nodes. This fulfills the condition (1) of A. For example. the network in [Figure 6] is formed to that in [Figure 6] (b) after piconet formation phase. When a master which starts the disconnection detection will get the address of the slave's neighbor from each slave. Moreover, if the slave belongs to other piconet, the master gets the master and slaves' addresses of the connected piconet. Then the master detects the slaves' neighbor nodes that do not belong to the connected piconet (disconnected nodes). The master selects the minimum slaves that cover all the disconnected nodes, and instructs those slaves to go into piconet formation phase. At this time, (2) of A is satisfied by not including a bridge in the selected slaves. For example the network in [Figure 6] is set to that in [Figure 6] after disconnection detection phase. If the scatternet adjustment protocol is applied, each node sets an adjustment start timer with the value T when it starts the scatternet formation protocol. When the timer is expired, a node starts the scatternet adjustment protocol.

C. System Design and Simulation



[Figure 7] The designed system composed of two masters and one Slave.

Having clarified the objectives of the experiment, I will now explain the procedure. We have used to the three devices equipped with Bluetooth Module to prevent too much inter-piconet load on particular and to reduce the overhead for channel switching among multiple Piconets. [Figure 7] indicates that the experiment system is consisted of two masters and one slave device. Each bluetooth module is connected with RS-232 cable to an controller. In order to be able to the properties of our approach, a Bluetooth simulation has been developed as a MFC program. [Figure 8] shows that the Bluetooth devices take the form of Piconet and communcate one another in the Scatternet. In Bluetooth environments, before a connection can be established, a somewhat involved procedure of device discovery must be performed before packets start flowing on the wireless links between the master and slave devices and vice-versa. The device discovery includes inquiry and paging procedures.



[Figure 8] The formation of Two Piconets and communication.

V. CONCLUSIONS AND FUTURE WORK

We propose a scatternet operation protocol for Bluetooth ad hoc networks. It assumes that many Bluetooth devices are distributed in an area. In this area, nodes are moving arbitrarily, and some nodes may not be able to communicate each other directly. This protocol is composed of the neighbor discovery protocol, the scatternet formation protocol and disconnection detection protocol. In this paper, we designed the identification system of an object in an railway using Bluetooth Scatternet and demonstrated how to identify an object in an Scatternet system by implementing an scatternet operation protocol and systems. As the simulation program indicates, each master device formed a Piconet with a Slave device and the Slave data between them communicates each other through a Scatternet. In conclusion, I would like to state the following points. The identification system of an object using Bluetooth scatternet has a wide application because the notable features of it are more resistant to interference and are preferable in environments with electromechanical noise and more stringent security requirements.

The Bluetooth technology enables the design of low-power, small-sized, and low-cost radios that can be embedded in a wide range of future products which will eventually lead towards ubiquitous connectivity. Future work is to examine routing suited to the Scatternet structure and performance of data transmission on the constructed Scatternet. Moreover, we will study more complex scatternet topologies using realistic. When designing the scatternet operation protocol, resistance against interference was already taken into account. However, its behavior under interference conditions and the appropriate amount and density of packet slots, which is needed to achieve sufficient resilience against interference, still needs to be clarified.

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