Performance Evaluation of Traffic in a Interfering Wireless LANs Environment for Bluetooth and IEEE 802.11

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Outline

- Performance evaluation for of Wireless-LAN (WaveLAN) system with simultaneous multiplex access

- Influence on system performance with movement of mobile terminal

- Interference of WLAN and Bluetooth in a Closed Space

- Interference measurement and performance evaluation of Bluetooth and WLAN with single channel

- Interference measurement and performance evaluation of Bluetooth and WLAN with multiple channels

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1. Evaluation for Communication Performance of the Wireless-LAN System (WaveLAN)

(1) To measure the communication performance by changing communication conditions (fixation, fall back) and the number of terminals

(2) To show how the system performance change with interference of the electric wave by the reflective wave from the wall of a classroom by changing the distance between the access point and terminals

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Experiment system

- The actual experiment system consists both hardware apparatus and software
- Simultaneous Multiplex Access (One Access Point and a Maximum of 15 Mobile Terminals)


Wired LAN
Wireless LAN Access Point
Server
Mobile Laptop PCs with a WLAN PC Card
Class Room
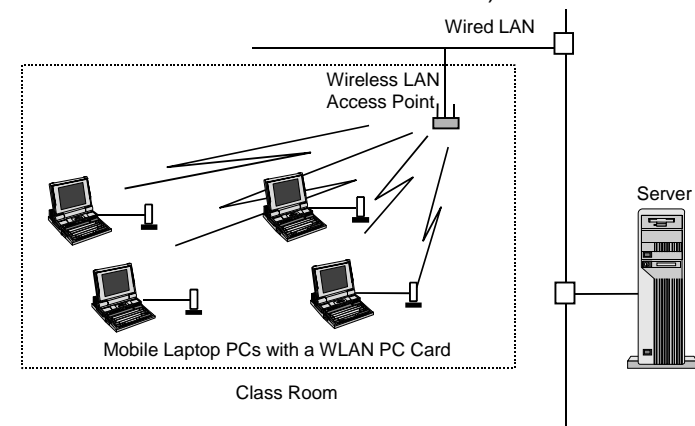
Structure of WLAN used in the experiment

Attribute	Typical value
Standard	IEEE802.11
Frequency Band	2.4GHz
Transmission Rate	8Mbps
Transmission Method	DSSS
Protocol	CSMA/CA

Experimental system

|	Server	Mobile Computer
Machine	Mitsubishi FT-8000	Sharp Mebius
CPU	Pentium Pro 200MHz X 4	Celeron 300MHz
Main Memory	256Mbytes	64Mbytes

- Communication speed: Maximum of 8 Mbps with changing in four stages of 8Mbps, 5Mbps, 2Mbps, and 1Mbps
- Connected to wire LAN by 100BASE-TX

Performance for Simultaneous Multiplex Access
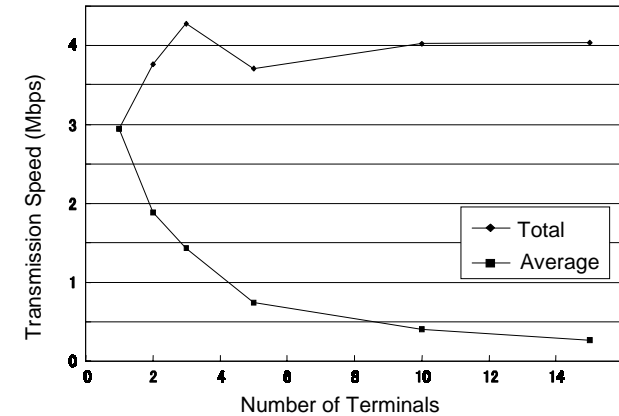
The number of terminals vs. transmission speed

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2. Influence on System Performance with Movement of Mobile Terminal
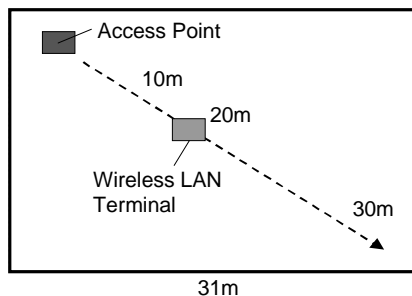
- The transmission speed in distance between a terminal and the access point is measured
- System performance change with Interference of the reflective wave from the wall etc. by change of distance between a terminal and the access point is clarified

- System performance is compared with distances 5m, 15m, 25m, and 30m
- Transmission speed falls when distances from the access point are 10m and 20m
- This is since the access point is installed in the indoor corner and it is measured on the room diagonal line, the transmission performance was affected by interference
- The transmission performance does not decrease so much by the distance change, even if the distance between the access point and a terminal is 30m

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3. Interference of WLAN and Bluetooth in a Closed Space

- Today, personal computers are often communicating with each other by means of the standard IEEE 802.11 wireless LAN systems

- For example: in Konan University, about 150 IEEE 802.11 based access points (NCR WavePOINT-II) have already been installed and portable personal computers each with an IEEE 802.11b based PC-card (NCR WaveLAN IEEE Turbo) are used commonly

- ``Bluetooth'' (IEEE 802.15) that uses the same 2.4GHz radio wave (ISM) band is recently emerging as a standard

- The present wireless-LAN systems will be used simultaneously with Bluetooth products in the future

One system may interfere with others

Evaluation and Analysis

● The number of simultaneous access terminals increases, the mean transmission speed per terminal decreases

● Total throughput peak in case the number of simultaneous access terminals is 3 is about 4.3 Mbps, but total throughput peak in case the number of terminal is 1 were about 3.3 Mbps

● Simultaneous access by two or more terminals can increase total throughput

● If the number of simultaneous access terminals increases further, throughput will decrease with transmission speed being slight

● The numbers of simultaneous access terminals are 10 and 15, the mean transmission speeds per terminal are 126Kbps and 85Kbps, respectively, and each total throughput is 1.3Mbps weakness

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Interference measurement and performance evaluation of Bluetooth and WLAN with single and multiple channels

Function of the apparatus equipment

(1) Mobile terminal
    The wireless interfaces of Wireless LAN and Bluetooth are mounted, respectively, and it is used for transmission and reception of data. (a) In Bluetooth use case, one kind form of the transmission between terminals is used. But (2) in WLAN use case, two kinds of transmissions between terminals and the transmission between WLAN base station and terminals are used

(2) The server for WLAN terminals opposite
    As a partner of a mobile terminal which performs data transmissions using a WLAN interface, the server is used via WLAN base station equipment

(3) WLAN base station equipment
    As mobile terminals which performs data transmissions using a WLAN interface, it is used for the use of those other than terminals opposite data communications. It connects with a server via HUB


Specification of WLAN Communication System	
Item	**Specification**
Spectrum diffusion system	Direct sequence spectrum diffusion system (DSSS)
Radio Frequency	2.412~2.484GHz
Transmission speed	A maximum of 11 Mbps
Access control method	Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA)

Communication system specification of FMV-JW281	
Item	**Specification**
Communication system	Bluetooth Ver.1.0B
Spectrum diffusion system	Frequency hopping spectrum diffusion system (FHSS)
Radio frequency	2.402~2.480GHz
The maximum communication speed	About 720 Kbps (in asymmetrical communication) About 430 Kbps (in symmetrical communication)
Communication distance	About 100m of prospect

4. Interference measurement and performance evaluation of Bluetooth and WLAN with single channel

Operating
Pana0005 (Bluetooth)

Data Transmission

**Pana0074 (WLAN)** → **Pana0027 (WLAN)**

Distance:3m
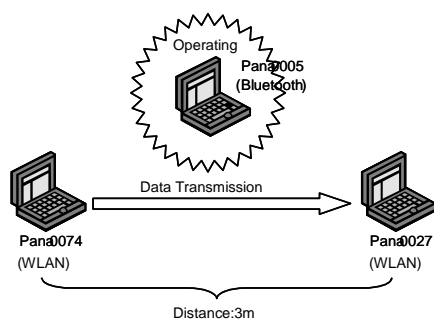
- ●Interference measurement of Bluetooth and WLAN for one channel system
- ● WLAN data transmission state is fixed
- ● To change various operation states of Bluetooth side
- ● Measure how interference arises and how both throughputs change
- ● One channel for WLAN is used

Procedure of the Experiment

- ● First turn on a terminal of Bluetooth, but the terminal does not link with other terminals and does not transmit data to other terminals
- ● Throughput is computed from the time required when carrying out data transmissions from one side to another side between the WLAN terminals
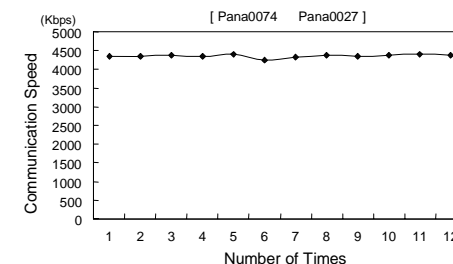

Evaluation and analysis

Result for the 1st set

(Kbps) [Pana0074   Pana0027]
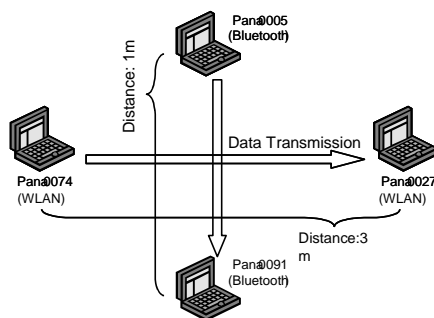Communication Speed — Number of Times
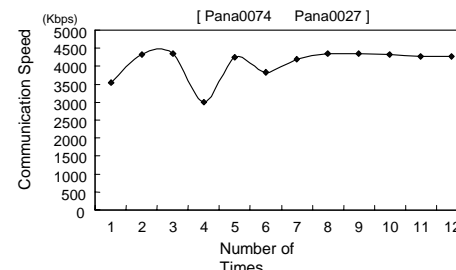
- ●The depression of the throughput of the 1st set is seen according to a unknown factor. But the throughput can be obtained in 4300Kbps level in almost time

Result for the 2nd set

(Kbps) [Pana0074   Pana0027]
Communication Speed — Number of Times

- ● The throughput of the 2nd set is obtained in 4300Kbps level in almost all times. The stability of system is very high

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Bluetooth data communications (communication ways crossing)

Pana0005 (Bluetooth)

Distance: 1m

Pana0074 (WLAN)   Data Transmission   **Pana0027 (WLAN)**

Distance:3 m

Pana0091 (Bluetooth)

- ● Each throughput of WLAN and Bluetooth is computed when data communications are carried out from one side to another side between Bluetooth terminals and between WLAN terminals, respectively

Procedure of the Experiment

- ● The 1st set: the transmissions of Bluetooth and WLAN sides are started simultaneously. The transmission of WLAN side is completed when the transmission number of Bluetooth side is just the 6th time
- ● The 2nd set: the transmission of Bluetooth side starts firstly. At the end of the 2nd transmission of Bluetooth side, the transmission of WLAN side is started and the transmission of WLAN side is is completed when the transmission number of Bluetooth side is just the 7th time


Evaluation and analysis

Measurement Data for the 1st Experiment Set

(Kbps)   (Kbps)
Communication Speed
WirelessLAN
BlueTooth
Frequency of Copies in Bluetooth Side
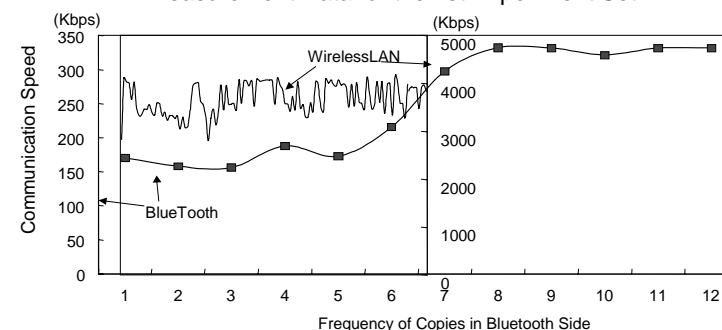
- ● Bluetooth side is influenced by the beginning of the transmission of WLAN, and the throughput decreases to the half grade of that when no load
- ● The throughput of Bluetooth side does not change when the transmission of WLAN side completed

Measurement Data for the 2nd Experiment Set

(Kbps) / (Kbps)
Communication Speed
Frequency of Copies in Bluetooth Side
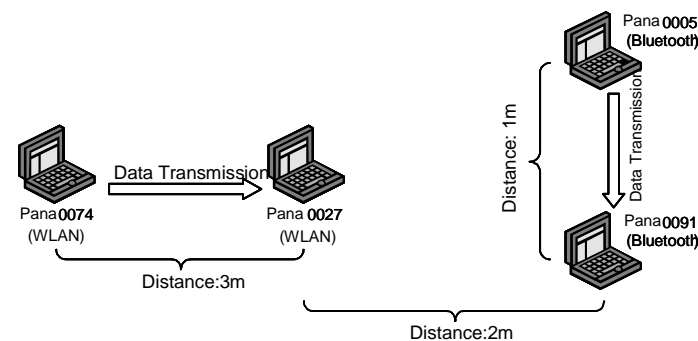WirelessLAN
BlueTooth
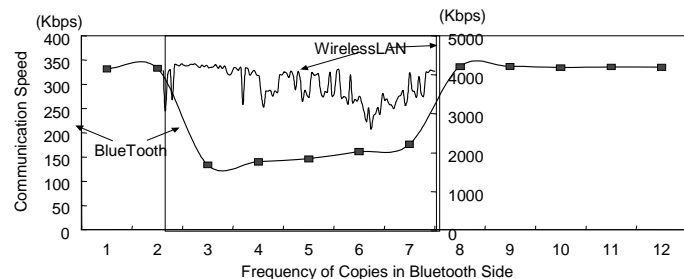
- The throughput of Bluetooth side falls in a half grade when the data transmission of Bluetooth side is with the transmission of WLAN together
- The throughput does not change as in the 1st set when the transmission of WLAN side does not occur

From results of the 1st and the 2nd set

- If it sees from Bluetooth side, the signal of WLAN side will be visible as noise and the throughput of Bluetooth side falls to half
- If it sees from WLAN side, the signal of Bluetooth side will be visible as noise, the throughput of WLAN side will fall from 4.3MKbps to 3.7MKbps, but not so much as that of Bluetooth side
- At WLAN, the throughput does not necessarily fall uniformly in the whole competition period, sometimes the throughput falls greatly
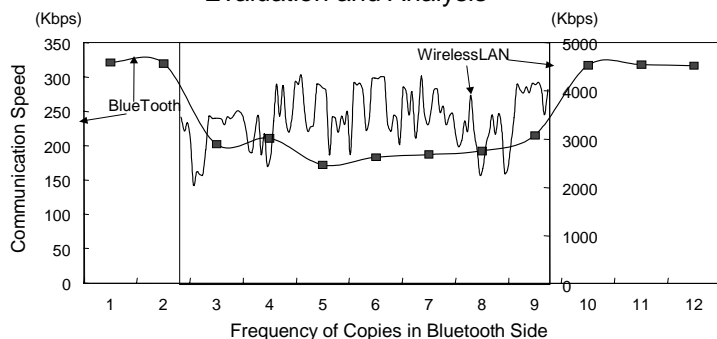

Bluetooth data communications (distant communication way)

Pana 0005 (Bluetooth)
Pana 0091 (Bluetooth)
Distance: 1m
Data Transmission
Pana 0074 (WLAN)
Data Transmission
Pana 0027 (WLAN)
Distance:3m
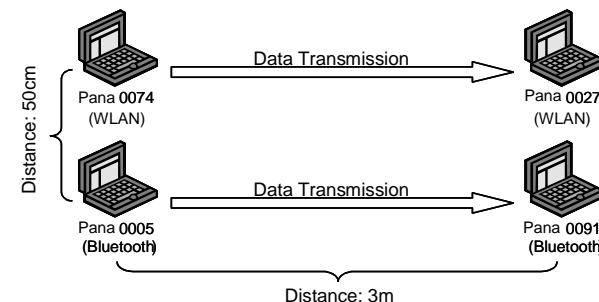Distance:2m

Procedure of the Experiment

- Bluetooth side started data transmissions previously and at the beginning of the 3rd transmission of Bluetooth side, data transmissions of WLAN side start
- Before the end of the 9th transmission of Bluetooth side, the transmission of WLAN side ends
- Each throughput is computed

Evaluation and Analysis

(Kbps) / (Kbps)
Communication Speed
Frequency of Copies in Bluetooth Side
WirelessLAN
BlueTooth

- The throughput of Bluetooth side falls in a half grade within the data transmission period of WLAN side

- The throughput does not change when the transmission of WLAN side does not occur

- Comparing with data communication of Bluetooth in the case that communication ways cross, we can conclude that the crossing does not influence on the system performance
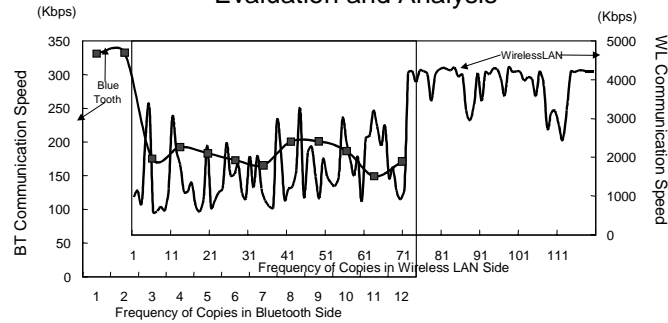

Bluetooth data communications (when communication way parallel and different interfaces do not approach very much)

Distance: 50cm
Data Transmission
Pana 0074 (WLAN)
Pana 0027 (WLAN)
Data Transmission
Pana 0005 (Bluetooth)
Pana 0091 (Bluetooth)
Distance: 3m
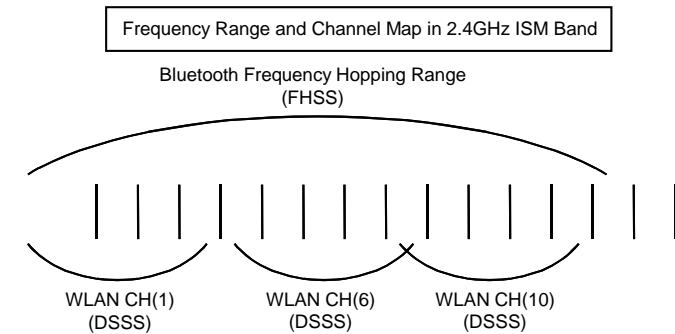
Procedure of the Experiment

- Bluetooth side started data transmissions previously and at the beginning of the 3rd transmission of Bluetooth side, data transmissions of WLAN side start
- At the end of the 71th transmission of WLAN side, the transmission of Bluetooth side ends
- Each throughput is computed when communication way parallel, but the distance between different interfaces is not so close

Evaluation and Analysis

- The throughput of Bluetooth side falls in a half grade within the data transmission period of WLAN side as the case of the distant communication way
- But the throughput of WLAN side changed more violently then that the case of the distant communication way
- The greatest factor to look signals of Bluetooth and WLAN which send the different electric wave mutually as noise is not in what position relation such as cross intersection, but in how the mutual distance of the terminals (interface cards) is near. The mutual distance of the terminals in this case is the nearest (50cm). In all previous cases, the distances are about 1.5m

5. Interference measurement and performance evaluation of Bluetooth and WLAN with multiple channels

Frequency Range and Channel Map in 2.4GHz ISM Band

Number of WLAN channels is set to 3 to let interference occur over all frequency range in Bluetooth side.
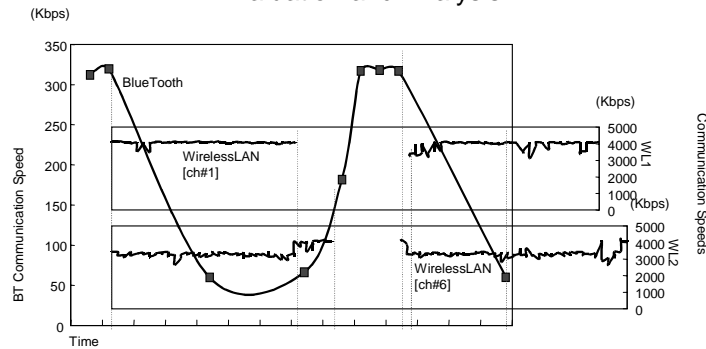
Bluetooth and Two WLAN Channels
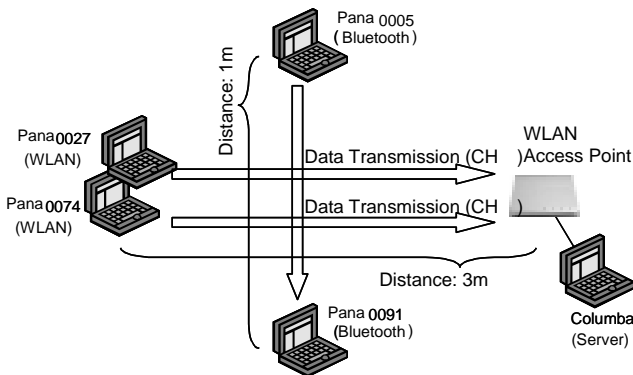
- It carries out data transmissions from one side to another side between two Bluetooth terminals
- The data transmissions of WLAN are carried out using two channels (the 1st channel (CH(1)) and the 6th channel (CH(6)) at the same time
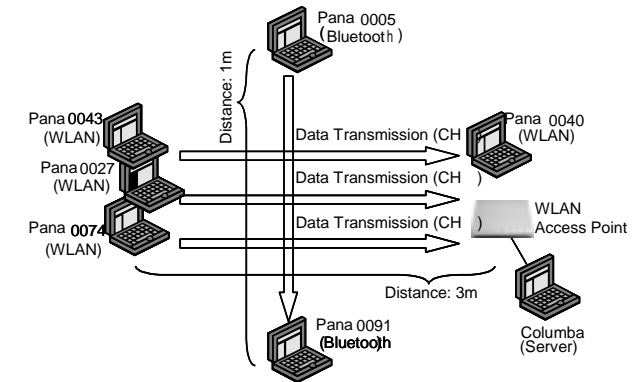- Each throughput is computed

Procedure of the Experiment

Bluetooth side started data transmissions previously and at the end of the 2nd transmission of Bluetooth side, CH(1) and CH(6) of WLAN start data transmissions (the 1st heat) simultaneously

At the end of the 4th transmission of Bluetooth side, the 1st heat of CH(1) ends

At the end of the 5th transmission of Bluetooth side, the 1st heat of CH(6) ends

At the end of the 8th transmission of Bluetooth side, the 2nd heats of CH(1) and CH(6) start at the same time

At the end of the 11th transmission of Bluetooth side, the 2st heats of CH(1) and CH(6) end

At the end of the 9th transmission of Bluetooth side, the 2st heat of CH(10) ends

End of the experiment

Slide 1 (top-left)

Evaluation and Analysis

(Kbps) — BT Communication Speed axis: 350, 300, 250, 200, 150, 100, 50, 0
Time
BlueTooth
WirelessLAN [ch#1]
WirelessLAN [ch#6]
(Kbps) Communication Speeds WL1: 5000, 4000, 3000, 2000, 1000, 0
(Kbps) WL2: 5000, 4000, 3000, 2000, 1000, 0

- When the data transmission of WLAN side begins, throughput of Bluetooth side fell suddenly. While three wireless LAN is carrying out simultaneous operation, throughput of Bluetooth side becomes 40Kbps

- It is further less than about 60 Kbps of the case with simultaneous operation of two WLAN channels. It is because in this case, over all frequency band used for Bluetooth side was influenced. This is considered that the communication becomes more difficult

Slide 2 (top-right)

Bluetooth and Three WLAN Channels

Pana 0005 （Bluetoot ）
Distance: 1m
Pana 0043 (WLAN)
Pana 0027 (WLAN)
Pana 0074 (WLAN)
Data Transmission (CH
Data Transmission (CH
Data Transmission (CH
Pana 0040 (WLAN)
WLAN Access Point
Distance: 3m
Pana 0091 (Bluetooth)
Columba (Server)

- It carries out data transmissions from one side to another side between two Bluetooth terminals
- The data transmissions of WLAN are carried out using three channels (the 1st channel (CH(1)), the 6th channel (CH(6)) and the 10th channel (CH(10))) at the same time
- Each throughput is computed

Slide 3 (bottom-left)

Procedure of the Experiment

Bluetooth side started data transmissions previously and at the end of the 2nd transmission of Bluetooth side, CH(1), CH(6), and CH(10) of WLAN start data transmissions (the 1st heat)

At the end of the 5th transmission of Bluetooth side, the 1st heat of CH(1) ends

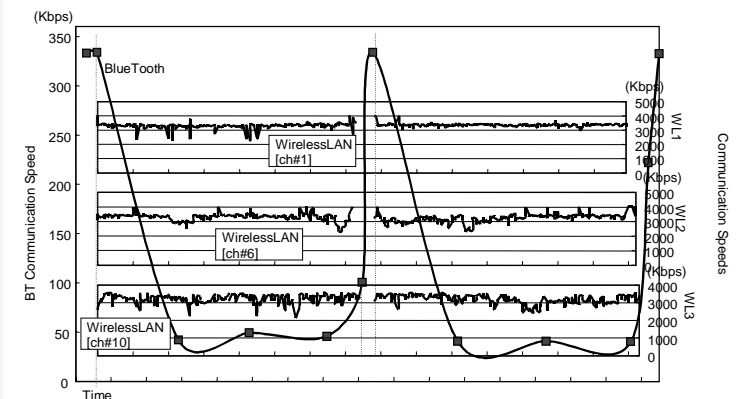The 1st heats of CH(6) and CH(10) end at the beginning of the 6th transmission of Bluetooth side

At the end of the 8th transmission of Bluetooth side, the 2nd heats of CH(1), CH(6) and CH(10) start at the same time

At the end of the 11th transmission of Bluetooth side, the 2st heats of CH(1) and CH(6) end

At the end of the 12th transmission of Bluetooth side, the 2st heat of CH(10) ends

End of the experiment

Slide 4 (bottom-right)

Evaluation and Analysis

(Kbps) — BT Communication Speed axis: 350, 300, 250, 200, 150, 100, 50, 0
Time
BlueTooth
WirelessLAN [ch#1]
WirelessLAN [ch#6]
WirelessLAN [ch#10]
(Kbps) Communication Speeds WL1: 5000, 4000, 3000, 2000, 1000, 0
(Kbps) WL2: 5000, 4000, 3000, 2000, 1000, 0
(Kbps) WL3: 4000, 3000, 2000, 1000, 0

- When the data transmission of WLAN side begins, throughput of Bluetooth side fell suddenly. While three wireless LAN is carrying out simultaneous operation, throughput of Bluetooth side becomes 40Kbps

- It is further less than about 60 Kbps of the case with simultaneous operation of two WLAN channels. It is because in this case, over all frequency band used for Bluetooth side was influenced. This is considered that the communication becomes more difficult

● The throughput is computed from the time required of each time data transmissions

Average throughput (Kbps) of WLAN		
	Heat 1	Heat 2
Channel (1)	3300	3561
Channel (6)	3217	3594
Channel (10)	3289	3237

● A difference characteristic among the WLAN channels was not observed. But the communication speed of WLAN side fell to 3.4Mbps

● Bluetooth is said that It is strong FHSS method in a noise. But it is influenced by WLAN over all hopping frequency band. In this case, the data communication is not possible hardly

The points for effect and result

● When the different interfaces simultaneously use over the same frequency band, interference surely occurs, the throughput falls violently. Therefore, it is better to avoid using Bluetooth and WLAN simultaneously in the same environment

● When it must be used simultaneously, Bluetooth mounting terminals and WLAN mounting terminals should use in the separate distance. The standard of distance is required 1m at the lowest

● When distance adjoins, the direction of WLAN has a large throughput fall degree. Since it will fall violently from 4.3M to 110Kbps, while Bluetooth usually falls only in the half grade from 320Kbps to 130Kbps at the same time. The terminal of WLAN becomes as it is torn off from WLAN system

● In order to secure communication with Bluetooth, it should avoid the place where WLAN is employed with multiple channels. Since Bluetooth use FHSS transmission method, if some frequency band of 2.4GHz is not taken up, a certain amount of communication is possible

● In order to guarantee many WLAN terminals to communication simultaneously with multiple channels, since a possible frequency band will be mostly occupied by WLAN. If a WLAN terminal and Bluetooth terminal are used simultaneously in such a place, throughput of Bluetooth terminal side will fall violently

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