Development of PAN (Personal Area Network) for Mobile Robot using Bluetooth Transceiver

S. H. Choo[1], Shamsudin H.M.Amin[1], N. Fisal[1], C. F. Yeong[1], J. Abu Bakar[2]
[1]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM,
Johor Darul Takzim, Malaysia
[2]Ericsson Sdn. Bhd., Wisma Ericsson, Jln SS7/19, Kelang Jaya
47301, Petaling Jaya, Selangor Darul Ehsan, Malaysia
e-mail: ober78@hotmail.com

Abstract- In recent years, wireless applications using Radio Frequency (RF) have been rapidly evolving in personal computing and communications devices. Bluetooth Technology was created to replace the cables used on mobile devices. Bluetooth is an open specification and encompasses a simple low-cost, low power solution for integration into devices. This research work aim was to provide a PAN (Personal Area Network) for computer based mobile robot that will support real-time control of four mobile robots from a host mobile robot. With ad hoc topology, mobile robots may request and establish a connection when it is within the range or terminated the connection when it leaves the area. A system contained of both hardware and software will be designed to enable the robots to participate in Multi-Agent Robotics System (MARS). Computer based mobile robot provide operating system that enabled development of wireless connection via IP address.

Keywords
Bluetooth Technology, Real time control, Multi Agent Robotics System, Personal Area Network.

I. INTRODUCTION

Upon entering the 21st century, wireless facilities for personal and commercial applications are becoming more desirable and, thanks to advances in wireless technology, also more attainable. Bluetooth is a wireless communication standard aimed at removing the need for cables between a wide range of electronic devices such as PCs, PDAs, and mobile phones [4]. How about wireless mobile robots application? If a fast network radio link is implemented, a whole new world of possibilities is opened in the research of robotics control and AI research works, sending real time image and information. Robots could communicate through obstacles or even through walls. There are a lot of on-going and completed projects on wireless mobile robot control. With wireless communication, mobile robots can connect to other mobile robots and PC. Thus, mobile robot can be controlled wirelessly via a computer or even constructing a MARS (Multi-Agent Robotics System).Infrared Data Association (IrDA) is another form of cheap wireless technology but requires a line-of-sight connection to establish communication in a shorter range of 1m [5]. This is not practical for an autonomous mobile robot. Due to these factors, this project tries to develop a Personal Area Network (PAN) for mobile robots which provide ad hoc networking, full duplex and bi-directional wireless communication. A host mobile robot will establish wireless connection with four mobile robots to form a mobile robots PAN. With ad hoc topology, mobile robots may request and establish a connection when it is within the range or terminate the connection when it leaves the area. These provide a simple communication between devices in close surrounding to form PAN. Implementing IP address on Bluetooth protocol will open a new world for mobile robot. With IP address, mobile robots can connect and communication in ad hoc network and can be improve for embedded IP or mobile IP. The new networks move to a packed-based mode of communication, allow high peak bandwidth, direct IP access, short response times and capability for users to stay permanently online [8]. A system comprising of both hardware and software will be designed to enable the robots to participate in Multi-Agent Robotics System (MARS). Ericsson Bluetooth Application and Starter kits and Motorola 71000 Bluetooth Development kit will be use as Bluetooth Transceiver.

II. BLUETOOTH TECHNOLOGY

A. Introduction

Bluetooth's primary function is to replace cables. It's a technology built around short-range radio links between mobile PCs, mobile phones and other portable devices. The technology promises to eliminate the confusion of cables, connectors and protocols confounding communications between today's high tech products.

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Fig. 1. Picture of Harald Bluetooth

In [Bluetooth revealed, 2000] the author describes the technology as '*Bluetooth refers to an open specification for a technology to enable shortrange wireless voice and data communications anywhere in the world*'. This implies several points that are keys to its understanding:

Open specification:
The Bluetooth Special Interest Group (SIG) has produced a specification for Bluetooth wireless communication that is publicly available and royalty free.

Short-range wireless:
Today, much of the communication takes place over cables. There are a wide variety of connectors with many combinations of shapes, sizes and number of pins; these cables can become quite burdensome to users. With Bluetooth technology, these devices can communicate without wires over air using radio waves to transmit and receive data. Bluetooth wireless technology is specifically designed for short-range (nominally 10 meters) communications; one result of this design is very low power consumption, making the technology well suited for use with small, handheld devices that typically are powered by batteries.

Voice and data:
Voice is now commonly transmitted and stored in digital formats. Bluetooth wireless communication makes provisions for both voice and data, and thus it is an ideal technology for enabling all sorts of devices to communicate using either or both of these content types.

Anywhere in the world:
Many forms of wireless communications are regulated in many parts of the world; radio frequency spectrum usage often requires a license with strict transmission power obligations. Bluetooth wireless communications operate within a chosen frequency spectrum that is unlicensed throughout the world (2.4 GHz). Thus, devices that employ Bluetooth wireless communication can be used unmodified, no matter where a person might be.

B. History

Bluetooth was invented in 1994 by L. M. Ericsson in Sweden. Japp Haartsen [13] is one of the co-inventors to Bluetooth; he says that the technology came about almost by accident. The original intention was to make a wireless connection between something like an earphone and a cordless headset and the mobile phone. When they realized that they could tap into a low radio frequency that required no licensing and was available to anyone in the world that wanted it, Hartseen and his colleagues at Ericsson began to experiment with different computer chips. They developed small radio chips that made wireless connection between devices containing them. To encourage adoption of Bluetooth and with hope of developing a global standard, Ericsson decided to give the specification for the technology away for free. When the technique was out there, The Bluetooth Special Interest Group (SIG) was formed. The members were Toshiba, IBM, Ericsson, Nokia and Intel. Today SIG have over 1200 company members. *Harald Blåtand* was King of Denmark from approximately A.D.940 to 985. During his reign King Harald is reported to have united Denmark and Norway and to have brought Christianity to Scandinavia. The word "Blåtand" translates to "Blue Tooth."

C. Bluetooth Protocol Stack

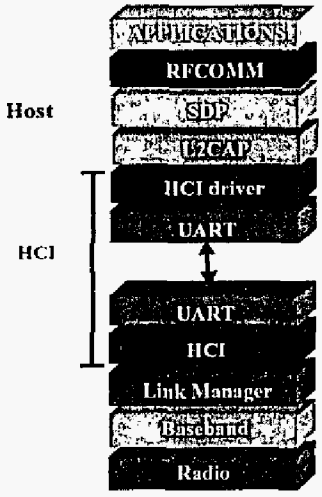


Fig. 2. Bluetooth Protocol Stack

The Bluetooth Specification is open [9], which makes it possible for vendors to freely implement their own (proprietary) or commonly used application protocols on the top of the Bluetooth-specific protocols. There are four basic parts to any Bluetooth system: a radio (RF) that receives and transmits data and voice, a baseband or link control unit that processes the transmitted or received data, link management software that manages the transmission and supporting application software [14].

The baseband layer forms the data link layer, which means that this layer either constructs packets to be sent over the physical layer or it receives packets from that layer. The baseband layer also takes care of packet acknowledgements, packet retransmissions and flow control. The baseband layer is physically implemented in the link controller, which is closely connected to the radio circuits. The link controller can be fed with audio data, which it passes on, in packets, for the RF (Radio) layer to transmit.

On top of the baseband layer the LM (Link Manager) protocol is situated, which forms the network layer of the protocol stack. This layer allows higher protocols on the protocol stack to invoke link set up, security and control commands. In order to execute these commands peer LMs send PDU (Protocol Data Units) to each other, containing link set up, security or control information. LM PDUs, received from the baseband, are filtered out by the LM on the receiver side and are not propagated to higher layers [14].

All layers up to the LM protocol layer are implemented in Bluetooth hardware. Higher protocols find their implementation in software running on a Bluetooth host. To be able to access all the SAPs (Service Access Points) of the LM protocol and to be able to exchange data with the baseband layer, the HCI (Host Controller Interface) protocol is used to provide an interface between the Bluetooth hardware and a host, using a physical connection between them. This can either be a USB, a RS-232 or an UART connection.

The L2CAP (Logical Link Control and Adaptation Protocol) is the transport layer of the protocol stack. This protocol supports higher-level protocol multiplexing, packet segmentation and reassembly [22].

The session layer can contain many different protocols. For instance, TCP/IP packets can be sent with Bluetooth and with RFCOMM a serial communication port can be simulated on a PC. It is possible for many more protocols to send their packets over Bluetooth.

The 2.4 GHz frequency is shared by other types of equipment, microwave ovens, wireless local area networks (LANs), industrial, security and medical applications. As a result, at first blush, interference with Bluetooth devices might seem extremely likely. However, the Bluetooth specification has solved this problem by employing what is called spectrum spreading, in which the Bluetooth radio hops among different frequencies very quickly. There are 79 hops starting at 2.402 GHz and stopping at 2.480 GHz, each of which is displaced by 1 MHz. Bluetooth avoids interference by hop-ping around these 79 frequencies 1,600 times per second. If the transmission encounters interference it waits 1/1600th of a second (625 μsec) for the next frequency hop and retransmits on a new frequency. Frequency hopping also provides data security because two packets of data are never sent over the same frequency consecutively and the changing frequencies are unpredictable [14].

D. Personal Area Network

Personal Area Network (PAN) is a network which allows electronic devices within a few meters of each other to communicate and synchronize information. The leading force in PANs is Bluetooth, a short-range radio technology which simplifies communication between different devices. It is based on the idea that a single chip fitted into electronic devices and buildings allows communication between them without wires. Already computer devices are being sold with Bluetooth preinstalled. This means that someone using a Bluetooth enabled laptop will be able to walk into a Bluetooth enabled building and immediately pick up access to its computer network. Some American airports are already experimenting with Bluetooth to provide laptop users in the departure lounge with access to the Internet. The only drawbacks to Bluetooth, compared with a wireless LAN, are its slower data rate and a range of only 10 meters - however, there are plans to extend this to a range of 100 meters [1].

Piconet and Scatternet

If Bluetooth devices are being connected to each other when they are brought together, then they will form, what is called, a piconet. Up to eight devices can be active in a piconet, one device will act as master, while the other devices will act as slaves. It is possible for a master to also be a slave in another piconet or for a slave to be connected to multiple masters. In this way piconets are combined to form a scatternet, see figure 3.

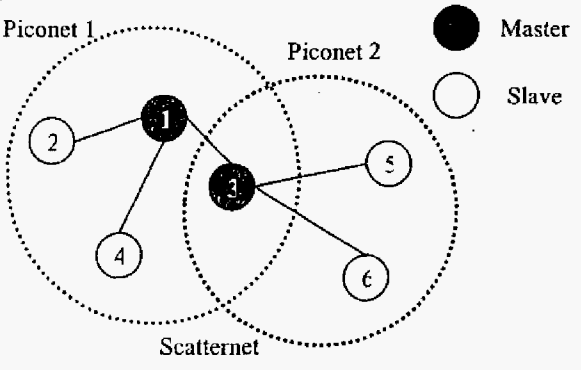


Fig. 3. Bluetooth devices forming a scatternet out of two piconets.

A Bluetooth device can undertake two actions to become an active member of a piconet. The device can start a page-scan procedures, this will seek for a packet

with paging information sent by another device. If the device is paged it will send back a response packet and after that a connection will be established, with the device becoming a slave in the piconet. The other more direct way of making a connection is to page another device. If a connection is established, then the paging device automatically becomes the master of the piconet. Before paging can take place it is necessary for the paging device to know the specific Bluetooth device address (BD_ADDR) of the device being paged. Prior to paging an inquiry procedure can be started, this will wait for other devices in inquiry scan mode to send back inquiry response messages containing, among other values, their Bluetooth device addresses [6].

With a fast radio link, a whole new world of possibilities is opened in the robotics research area. Sending real time image, robots could communicate through obstacles or even through wall.

III. RELATED WORKS

Various works have been done to develop Bluetooth enabled mobile robots. Radio Controlled Robot Car [6] was developed by two Electrical Engineering master students from the University of Karlskrona/Ronneby, which was completed in July 2000. The objective of their project was to create a point-to-point connection between a robot car and a PC both equipped with Bluetooth Starter Kits. The PC ran a program that sent steering (acceleration/braking) information to the robot car, which received the data and controlled its stepper motors accordingly. Two Ericsson Bluetooth Starter Kits were used as communication devices. The host in the Robot Car was a Digital Signal Processor (DSP) sitting on a development board. The use of a DSP card made this project less relevant to this research work where laptops and PCs are used. Student from University of Skovde, Sweden and De Montfort University, UK has developed Bluetooth Enabled mobile robots [2] [3]. They have designed and implemented a Bluetooth radio based station for Khepera robots. They intend to develop a wireless network system for the robots research work where robots can be controlled real time from a host computer wirelessly. They have successfully formed a Bluetooth piconet which have a master (PC host) and four mobile robots. Although piconet have been successfully developed, but communication between each Khepara robots and PC was not achieved in the HCI layer to test due to the Cstack [11] did not support this functionality. There were no problems to get the different connection handles for the two robots and to connect both of them. The problem was, that the stack allowed only the latest connection to be active, and no other connections were allowed at the same time. This was probably due to a stacks that was not fully developed yet. Another feature that was not supported by the Cstack, was the BT device baud rate setting. Bluetooth technology was not developed for mobile robots, but also sensors. Wireless I/O Unit using Bluetooth has been developed by a master student project from Lund Institute of Technology, Sweden [7]. A general circuit board that uses Bluetooth for wireless communication was constructed. The platform can easily be connected to almost any electrical device, e.g. carports, door locks, or sensors and actuators in industrial processes. Two development kits from Sigma Teleca were used in the development of the Bluetooth protocol stack. The stack was developed separately for the host computer and the embedded circuit board. Further on, the development kits used in the project had only point-to-point operability. To show that the circuit board works, they have implement it on a toy car and a joystick [7]. The signal from joystick will be transmit to PC, after processing the signal, PC send it to toy car via BT transceiver.

IV. PROJECT DISCRIPTION

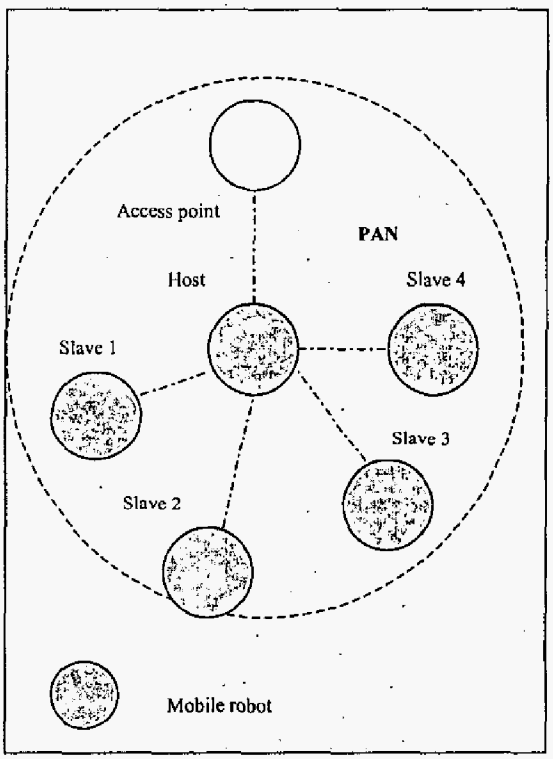


Fig. 4. Host Mobile Robot forming PAN

A. Overview

PAN for mobile robots will open new research area for mobile robots. As figure 4 show, a host mobile robot will establish Bluetooth wireless link between the mobile robots within the range which is the piconet or PAN. Meanwhile it will also connect to access point where this will enable it to access to wired network such as LAN. The host mobile robot will be requesting

for the connection and other slaves mobile robots will wait for connection request. Ad hoc networking is important because mobility of mobile robots, it should be easily be added to or removed from the network. Sending data wirelessly such as position of each mobile robot, real time image and also sensors readings will be possible after the PAN have been form. The host mobile must have the capability to manage the network, process the data, make decision and transmit control signal to slave robots. Beside managing the mobile robot PAN, the host mobile robot have the capability to establish wireless link to access point which allow connection to LAN.

Most research works provide point to point connection between PC and robot. Although they have successfully establish network for four mobile robots, but communication between each robots and PC was not successful. As result, Cstack is not suitable to development work.

To provide a Bluetooth enable mobile robot, communication between Bluetooth host (PC) and Bluetooth controller (Bluetooth transceiver) must be archive first. Bluetooth define it own protocol such as HCI, L2CAP, RFCOMM and SDP. A software stack must be develop to provide communication between host and transceiver. HCI is the lowest layer that provides this function. Most research works develop this layer to achieve the interfacing. A Bluetooth transceiver must be connected to PC via either USB or serial port, then a software stack can start the initializing the transceiver. To establish a Bluetooth wireless link, at least two Bluetooth devices is required. After all the initializing process has been successfully done, a Bluetooth device can start the inquiry process which will find other Bluetooth devices within the range. If there is one, it could ask for connection establishment (as master), and if other Bluetooth devices agree with the request, they will establish a Bluetooth wireless link. Data and voice communication will be possible on wards.

Point to point wireless communication via Bluetooth transceiver has been successfully develops with sending steering information and sensors reading from Handy Board between PC. HCI stack was implemented on Handy Board which acts as brain for mobile robot. The board receives ACL data from Bluetooth transceiver, extract and process the data. It also handle the sensor reading which put it in ACL packet format and send it to Bluetooth transceiver. During the navigation of the mobile robot, user from the PC was able to understand the surroundings of the robot after receiving sensors reading from the mobile robot. Thus, it enables a fast real time application and reaction.

B. PC Based mobile robot

Most mobile robot provides embedded system where no operating system is presented. To provide more complex algorithm, sending image and IP addressing, a PC based mobile robot is required. A basic PC based mobile robot has been built in past few months, it is completely finish with hardware. A laptop as the controller will provide OS environment for IP application, and more complex algorithm(porgramme) can be develop for handling Bluetooth stack, Bluetooth Piconet flow control and mobile robot control. The mobile robot was built in three layer, ground layer consist of wheels, motors, batteries and motor driver circuit; 2nd layer provide space for hardware interfacing (these include Bluetooth transceiver and computer interfacing, sensor and driver circuitry); meanwhile 3rd layer hold the laptop. Embedded PC (PC 104) is consider to replace a laptop to provide an OS.

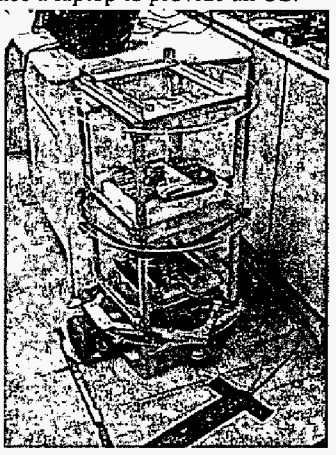
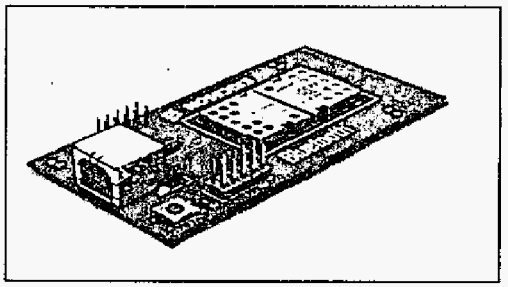


Figure 5. PC based mobile robots

C. Bluetooth Transceiver



The Bluetooth Application Tool Kit [12] is a platform, consists of a circuit board, which can easily be connected to the host computer with a UART or USB connection, which ensures ease of use and full Bluetooth data transfer speed. The tool kit has been developed by Ericsson and enables students in higher education to understand both the theory and applications of Bluetooth short-range radio communication. This kit has been use for most of the previous works.

D. Connection via IP

Developing IP address on Bluetooth will open a new world for mobile robot. With IP address, mobile robots can connect and communication in ad hoc network and can be improve for embedded IP and mobile IP. The new networks move to a packed-based mode of communication, allow high peak bandwidth, direct IP access, short response times and capability for users to stay permanently online [8]. These protocols were designed to be robust, surviving high network error rates and supporting transparent adaptive routing in case network nodes or lines were lost [10]. As IP v6 has been developed rapidly nowadays, this can be a plat form for the development. To implement IP address on Bluetooth Protocol Stack for enable connection and communication, studies on Bluetooth and IP protocol must be carry out.

E. Achievement

The author has finish building one unit of PC based mobile robot which will provide OS for IP addressing, various programming language and basic functions of mobile robot. Besides that, HCI have been successfully developed on Handy Board for interfacing with Bluetooth transceiver. Sending image through Bluetooth Transceiver from PC based mobile robot to PC has also been successfully tested.

F. Current work

Trying to establish Piconet for PC within range and further more communication among all the PCs. Studies on IP protocol must be carry out in order to implement IP on Bluetooth protocol stack.

V. CONCLUSION

The aim of this research is to provide a PAN for mobile robot. Wireless networking for mobile robots is a challenging work. The network need to manage up to seven slave communicate simultaneously to provide good performance. PAN for mobile robot will open a whole new world of possibilities in robotics research area. Research can be done for sending real time image, real time control, further more Multi-Agent Robotics Systems. Bluetooth technology is a good choice because it is low cost, low power radio based cable replacement technology. By year 2005, more than 2000 million products will be Bluetooth enabled. With embedded IP, PAN of mobile robot can be easily connected to other network such as LAN, WAN or Internet. User can control or observer the mobile robot. Research can be done to develop the application for home security, house keeping and office security.

VI. ACKNOWLEDGEMENT

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