# Embedded Bluetooth Data Acquisition System based on ARM for Unmanned Underwater Vehicle (UUV)

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**ABSTRACT:**
The Bluetooth is an open wireless technology which revolutionized the connectivity by providing freedom from wired connections. It is a cable replacement technology that has changed the face of connectivity between the communicating systems. The usage of cables in the industrial field especially in the application of autonomous systems becomes more cumbersome and any fault in the connections may lead to a total system failure. This paper presents an abstract model of Embedded Bluetooth Data Acquisition system which was designed using the ARM processor (S3C2440) as an embedded target and Bluetooth device which is connected to the ARM processor through a RS-232 serial port. In our implementation the ARM processor which acts as the Central Dta Acquisition System is used as the controlling system that controls the Bluetooth device connected to it and acquires the data from the different subsystems of a UUV.
***Keywords:***
*Bluetooth data acquisition, wireless networks,*
*Embedded systems on ARM.*

## 1. INTRODUCTION:

Bluetooth technology is a short-range wireless communications technology. It has developed rapidly in recent years. Data acquisition which based on sensor technology, signal detection and processing, computer science technology has formed an integrated application of technology. Modern industrial controlling and data acquisition system has stepped into embedded system module from traditional circuit and microcomputer module. Embedded systems play an irreplaceable role in industrial control and data acquisition & transmission system. In response to the complexity of the cable, the occurrence of accidents and completing the task without cables in industrial field, an Embedded Bluetooth Data Acquisition System based on S3C2440 and Bluetooth chip called BlueLINK was constructed to reduce cable connection. It has some advantages, such as portability, reliability, function and application, and so on.

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## 2. DATA ACQUISITION SYSTEM:

### A. The Functionality of the Data Acquisition Module:

The total functionality of the data acquisition module is such that it has to collect the information from the different subsystems of the Unmanned Underwater Vehicle into the Central Data Acquisition System for further processing and storage. This functionality is achieved by using the Bluetooth modules one at each of the subsystem and the CDAS. The CDAS sends the control commands to the subsystems to send the information collected by them to the CDAS at a timely manner. The CDAS repeats this function periodically and then the data received and processed by the CDAS is transmitted to the PC. The PC will display and dispose the data. The Bluetooth wireless data acquisition module is the most important part of this data acquisition system. An Embedded system using the ARM processor S3C2440 [2] is programmed to control the Bluetooth module. The total module can be powered up by a simple battery setup and it can also be programmed to automatically accomplish the data acquisition. The ARM processor module sends the commands to the Bluetooth chip connected to it which in turn collects the data from the respective subsystems and transfers to the ARM processor module. This data is then transferred by other means to the PC where it is displayed.
The following figure shows an overview of the project.

### B. Bluetooth Overview

Bluetooth is a low-power, low-cost and short-range wireless communication technology in the 2.4 GHz ISM (Industrial, Scientific and Medical) RF band. Bluetooth uses FHSS (Frequency Hopping Spread Spectrum) scheme with hoping rate of 1,600 hops per second to minimize the effects of signal interference. The transmission range is 10 meters and can be extended up to 100 meters by providing a power amplifier [1]. Bluetooth can offer a speed up to I Mbps.

To identify the identity of a Bluetooth device, each Bluetooth device has a 48-bit BD (Bluetooth Device) address [6], which has the same length as the MAC (Media Access Control) address of IEEE 802.x family [1]. Communication between Bluetooth devices follows a strict master-slave scheme. Each master device can have up to 7 active slaves and forms a so-called piconet. Between each master-slave pair, two different links can be provided [8]. One is the SCO (Synchronous Connection Oriented) and the other is the ACL (Asynchronous Connectionless Link) link. The SCO link is typically used for voice communication [7] and ACL link is used for data communication. For ACL links, a slave can transmit packets only after the master sends a packet addressed to it. Note that, slaves cannot transmit packets directly, i.e., the communication between slaves must go through the master Bluetooth device indirectly.

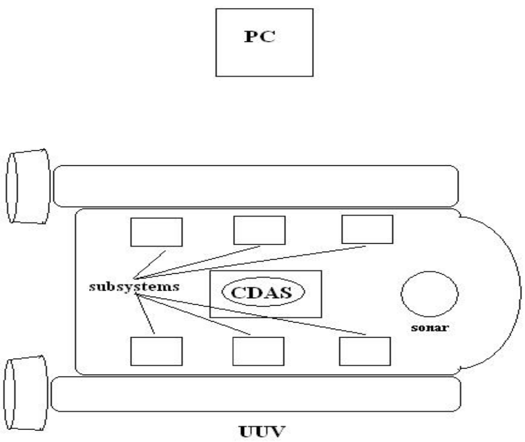



Figure1: Overview of the project

*Bluetooth Specification:*

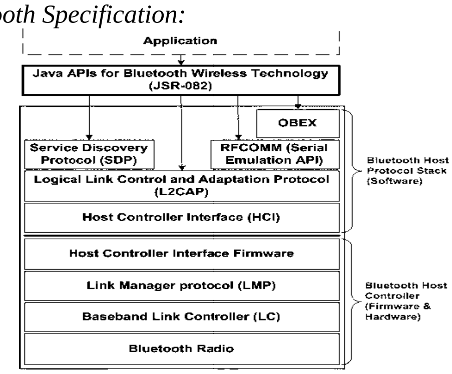



Figure 2: Bluetooth Protocol Stack

The above figure shows the Bluetooth protocol stack. The RF (Radio Frequency) defines the physical characteristics of the RF link, e.g., channel arrangement, permissible transmit power levels, and receiver sensitivity level. The base band specification defines the device discovery, link formation, and synchronous and synchronous communication with peer host. To provide a reliable wireless link, fast ARQ (Automatic Repeat Request), CRC (Cyclic Redundancy Check) and FEC (Forward Error Correction) are combined with the frequency-hopping scheme [9] in Base band to detect and resolve packet errors or lose during transmission.

**Radio Layer -**It is present at the base of the stack. It specifies the physical characteristics of the transmitter and the receiver. Radio module is responsible for the modulation and demodulation

**Base Band Layer-**It synchronizes the links between BTH devices. It properly formats the data to and from the radio layer.

**Link Control Layer-** It is responsible for the establishing and configuring links between the BTH devices. It also carries the link manager commands

**Bluetooth Supports Two Kinds of Links -** Asynchronous Connectionless (ACL) links for data transmission Synchronous Connection oriented (SCO) links for audio/voice transmission.

**Link Manager-**The link manager protocol is responsible for the link set up between BTH devices. It translates the host controller interface commands that it receives into base band level operations. It also responsible for security functions like and authentication and encryption by generating, exchanging and checking of link and encryption keys. It controls the power modes and duty cycles of the Bluetooth devices.

**Host Controller Interface (HCI)-**It is the boundary between lower and upper layers of the BTH stack. HCI supports the BTH systems that are implemented across two separate processors. Ex. BTH on a computer uses two processors. Blue tooth module implements lower layer. Blue tooth host implants upper layers Some BTH devices contain both upper and lower layers on a single processor, which do not require HCI.

**Logical Link And Adaptation Protocol Layer (L2CAP)-**It is responsible for establishing connection across existing ACL links or request an ACL link if one does not already exist. It plays a central role in communication between the upper and lower layers. It provides connection oriented and connectionless data services to the upper layer protocols by its multiplexing capability, segmentation and reassemble operation, and group abstractions. A single ACL link is enough for communication because of its multiplexing capability. It supports only ACL link, it is not defined for SCO links.

**Service Discovery Protocol Layer (SDP)-**Discovery services are crucial part of the Bluetooth framework. It defines actions for both servers and clients. A single BTH device can acts as both server and client. A SDP client communicates with SDP server using a reserved channel on a L2CAP link. When client finds desired service it requests a separate connection to use the service and a dedicated channel is used for communication.

**RFCOMM-** It is a serial line emulation protocol and is based on ETSI07.10 (European telecommunication standardization institute) specification. It emulates RS-232 control and data signals over Bluetooth base band, providing both transport capabilities for upper layers services (ex. OBEX) that use serial line as transport mechanism.
**OBEX Protocol-** It is a session protocol developed by infrared data association (IrDA) to exchange objects in a simple and spontaneous manner. Along with the grammar for the OBEX devices to communicate it also provides a model to represent objects and operations. In addition it also defines a folder-listing object, which is used to browse the contents of a folder on remote devices.
**The Application Oriented Protocols-**Cable replacement protocol: RF COMM. Telephony control protocol 1: TCS binary, AT- commands. Adopted protocol: PPP, UDP/TCP/IP, OBEX, WAP, vCard, vCal, WAE.

*ACL Link Packet Structure:*
The communication the subsystems and the Central Data Acquisition System occurs using the ACL links of the Bluetooth protocol and the general packet structure [10] can be shown as in figure 3.

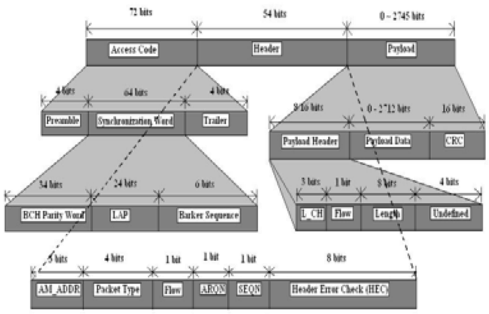


Figure 3: ACL link packet structure

As seen in the above figure, the communication between the subsystems to the CDAS is done through the ACL link between them. It is the protocol that a slave device cannot respond unless and until it receives a packet addressed to it in an ACL link. For a packet to be broadcast to all the subsystems, the Active Member address in the ACL packet sent from the CDAS should be all 0s. Therefore in the same way it wants to communicate with a particular device, it must assign the AM_ADDR field to that slaves Active member address so that only that slave responds and the others do not. This feature is availed in this project which enables the CDAS to make each subsystem respond individually.

## C. Design and Implementation:

This part of the project consists of two phases of which the first phase consists of designing the program or the code which controls the embedded system i.e. the ARM processor and also allows the ARM processor to control the Bluetooth device connected to it. The second phase consists of deploying the so developed program into the embedded system and running it. Here the Mini 2440 which is complete developed solution using S3C2440 from Samsung is used as the embedded kit. The S3C2440 contains the ARM 9 processor [2] in it. This module runs on Windows CE operating system. For designing the program for the embedded system, here Visual Basic .Net is used as the programming language. The program for controlling the Bluetooth device using the ARM processor is developed in the Visual Studio Environment which incorporates the visual basic compiler [5]. This code so developed is deployed into the embedded system using the Active sync through the USB cable. Here the Active sync is special software which converts the code into the ARM processor understandable format. This can be shown in the following figure.

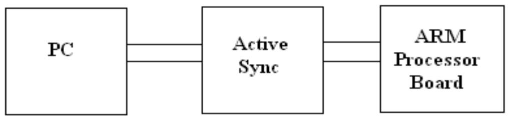



Figure 4: Development and Deployment of the Program to the ARM processor Board.

Implementation:
Once the code has been deployed into the ARM processor board, it runs automatically on the board. So before the deployment, the Bluetooth device must be connected to the ARM processor board through the serial port. The deployed code runs on the ARM processor [3] board and the code will enable two timers on the ARM processor Board one for 100ms (Timer 2) and the other for 10ms (Timer 1) such that the two timers start concurrently and timer 1 repeats itself for every 10ms and the timer 2 repeats itself for every 100ms. The ACL links of the Bluetooth devices are used for establishing the data acquisition system.

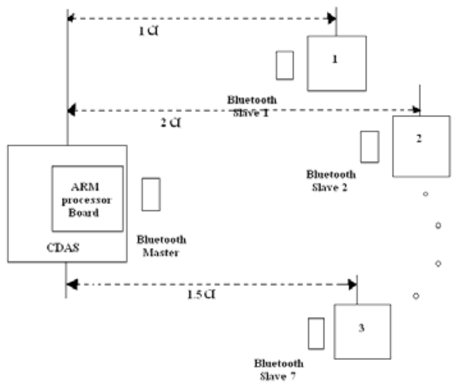



Figure 5: Implementation of Bluetooth Data Acquisition system.

As shown in the fig.3, the Bluetooth device connected to the ARM processor is made as the master of the piconet and the other Bluetooth devices connected to the subsystems of the UUV become the slaves. The communication between the master and the slave is only through ACL links [4] where the slave is allowed to transmit only after it receives a packet from master.

The subsystems are numbered as 1 to 7 and are placed at a distance which is a multiple of a parameter α (0.5m) from the CDAS as shown in the above figure. Firstly the master sends a data d1 as a broadcast packet to all the subsystems to packetize the data that is available with them to send. Then after each 10ms the master sends data d2 to d8 one for each of the 7 supported subsystems. Now as the subsystems receive this data, they respond with the data they posses, within the 10ms frame time. Thus the data acquisition system is established using the wireless medium such as Bluetooth.

## 3. PERFORMANCE EVALUATION

The embedded Bluetooth data acquisition system is evaluated based on the simulation parameters which are stated below. The simulation environment consists of a total of 7 slaves, i.e. the maximum number of slaves a Bluetooth device of version 2.1 can accommodate in a piconet. The slaves are scattered around the master (the CDAS is the master device in this data acquisition model) at random distances each separated by some α where α is the multiplication factor of the distance of the slave from the master. In this way all the slaves are separated from the master at a maximum distance of 3 meters.

The observed parameters and the simulation parameters are listed below:

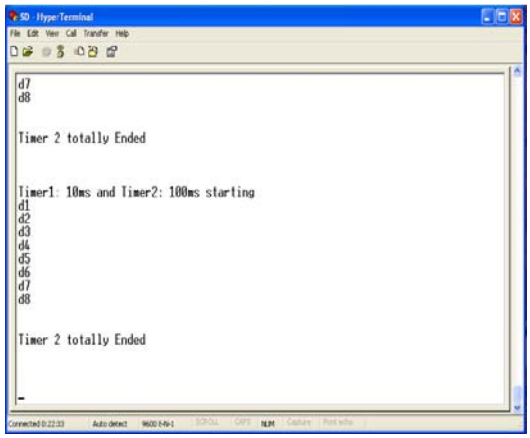
| Parameter | Value |
|---|---|
| Number of slave devices used | 7, each one controlled with a specific data |
| Distance factor α | 0.5meters |
| Maximum distance at which devices are placed from CDAS | 3 meters |
| Data rate attained | 2.0 Mbps |
| Data rate attained in previous model | 1.1 Mbps |
| Min data rate required | 1.2 Mbps |

As seen from the above results, the minimum required amount of data rate for the efficient functionality of the underwater vehicle is 1.2Mbps. The previous model could provide a data rate nearly enough for the vehicle communications, but at the cost of complexity. The proposed model is highly secure compared to the previous model and provides much better data rates than required and also simplifies the role of data acquisition system.

## 4. RESULTS AND CONCLUSION

A wide application and potential development of embedded system has become hotspots in the 21st century. The development of embedded system has injected new life into traditional measurement and control system. The system has achieved the design of Bluetooth data collector successfully by debugging of the hardware and software. This method of designing and implementing the Data Acquisition System using the Bluetooth medium achieves a maximum of 1.9Mbps of data rate against required 1.2Mbps.

The controlling data sent by the ARM processor for the data acquisition cannot be shown exactly as it will be received by different subsystems but for convenience of understanding the data is represented by considering a standalone PC to be all the subsystems and the data is received in the HyperTerminal through all the Bluetooth devices.




This is a new method of implementation of the Bluetooth as a medium for data acquisition system and this can be extended by using newer versions of Bluetooth for other under water vessels.

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