An Internet Based Wireless Analysis Tool Employing Bluetooth

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Abstract

With the expected deployment of Bluetooth devices in the next five years, it is imperative that managers of Bluetooth networks have a way to collect and analyze the usage patterns of their networks. Currently, Bluetooth networks simply operate without any effort by a central unit or operator. However, there are limitations, namely the finite capability for connections between each other. Our product enters the picture by yielding the information necessary to make judgments on network needs. We introduce the Bluetooth Diagnostic Interface (BDI).

The BDI utilizes network information available from the Bluetooth modules to ascertain and communicate piconet status to a website. The network manager can gather information on a certain master or slave by asking for its ID string in a query box on the website. This provides the ability to efficiently match supply of Bluetooth units with the demand as well as match the transmitted information with the needs of the user by analyzing their tendencies. The possibilities are endless.

To be prepared for increased Bluetooth network traffic there has to be a quick and easy means to monitor traffic trends and load. Our BDI elegantly offers this network monitoring functionality though the convenience of the Internet.

I. Introduction

Bluetooth is a wireless communication standard/system operating in the 2.45 GHz ISM band with 79 frequency channels. Bluetooth uses low-power and low-cost units employing frequency hopping to make the system more robust. Devices exist in a dynamic master-slave relationship. There is only one master in every piconet (a piconet is a Bluetooth network). Upon entry to a piconet, the slave adjusts its clock to sync with the master's and the master then determines the hopping sequence. These units can have a nominal 10 meter range or an extended 100 meter range when amplified.

Figure 1 provides an example of the basic connectivity between devices for our proposed solution. It shows a slave connecting to multiple masters in separate piconets. The server will communicate with users, via the Internet, to transmit the acquired information. The server will get this information from the network connections with the masters. The masters are also connected to the slave units via the 2.4 GHz wireless Bluetooth connection.

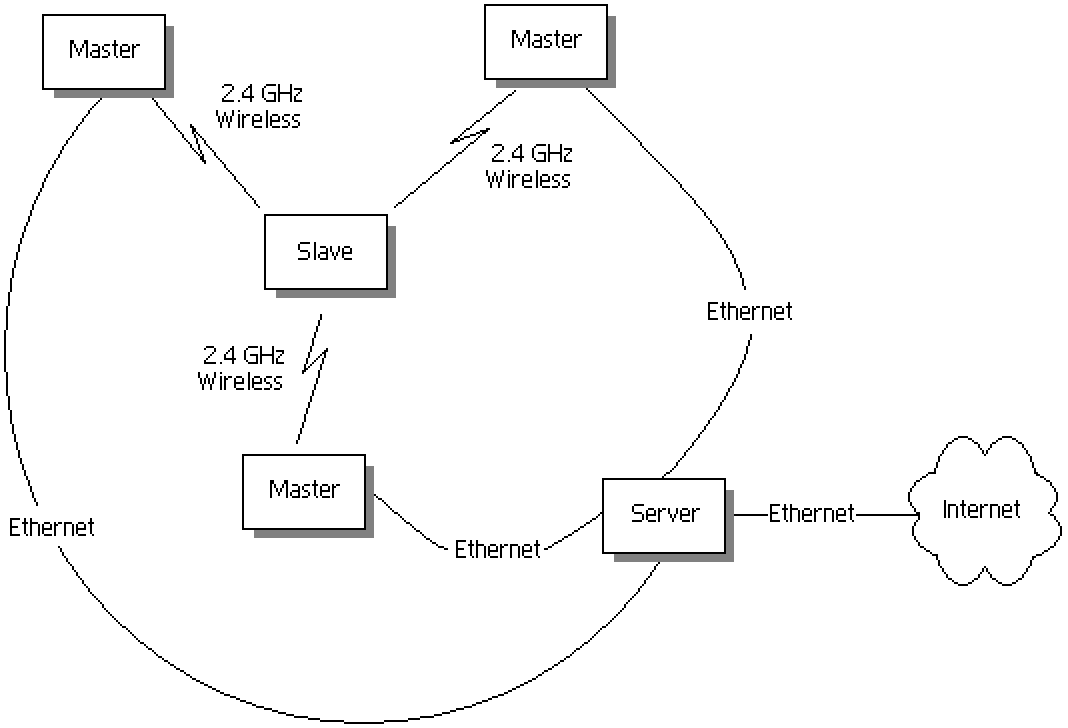


Figure 1: Device Orientation with Wireline and Wireless Interconnects

II. Literature Review

Kalia, *et. al*. discuss the efficient practices for increasing the Bluetooth capacity which pertinent to our project [1]. These span from the modes of operation for slaves in a piconet to how to best manipulate these modes to achieve 255 slaves per single master in a piconet to the intricacies of parking and unparking slaves. Since our project stems from the premise of tracking how many slaves are in a particular piconet at a time (and channeling information accordingly), these are areas of interest to our task at hand.

The premise of their discussion is that by manipulating between active and parked modes, the number of slaves participating in a piconet can be increased from 7 active slaves at a time to 255 slaves. In our project, we need to be able to count the number of active slaves in a piconet, and reading this mode is essential.

In all, this article is not only good for understanding of how slaves park or unpark, but also for future reference when attempting to expand the scope of this project to apply to more than 7 active slaves in a piconet. Our algorithms will have to be slightly modified to match the PUQP algorithm presented in this article, to reflect an accurate count of the number of slaves in a piconet.

Haartsen [2]. provides a prospective on the history of Bluetooth technology's and current tradeoff with past radio systems. Bluetooth is the codename for a technology for small factor, low cost, short-range radio links, built into a 9 x 9 mm microchip. Bluetooth technology allows for the replacement of many propriety cables that connect one device to another using one universal short-range universal link. In the past many ad hoc systems provided a few networks within the units in range. Bluetooth technology delivers piconets that are able to overlap within a given area forming scatternets.

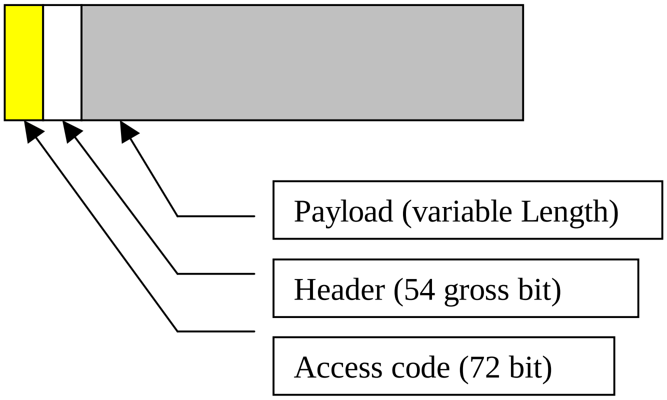


Figure 2. Packet Layout for Transmitting Information

Bluetooth transmits its information in a packet format as shown above, in Figure 2. The access code (AC) includes the identity of the piconet master. The AC aids in distinguishing a master in multiple piconets. This prevents packets from being accepted by slaves from other piconets within a scatternet.

Different transmission levels demonstrate the different modes of the slave units. In an idle mode the unit only scans a little over 10ms every T seconds. The duty cycle is very low in each case. In the park mode the duty cycle can be reduced even further. Only when a piconet is established can a park mode be initiated. A slave unit in park mode only listens to the access code at a very low duty cycle. The sniff mode is another low powered mode whereby the slave unit does not scan every master-to-slave slot within a piconet.

This seems to be a major hurdle in the progress of launching Bluetooth products in the market [3]. Two of the major problems we faced are also dealing with interoperability. The two problems are listed below:

1. *Master-to-Master connection*: One master always tried to establish a M/S connection with the other Master. It would not realize that the other was also a master and to break the connection with it. This resulted in double counting of slaves in a scatternet.

2. *Breaking the active connection of a Slave*: The Link Manager kept a slave in a piconet despite the slave deciding to be in only one. This meant that since the Master had a valid connection with the slave still, it would count it in its list of users. This also resulted in double counting of slaves in a scatternet.

We encountered the above difficulties of not being able to force the devices interact the way we wanted them to. In other words, we could not terminate connections between Bluetooth units when we didn't want them connected.

III. Problem Description and Specifications

The BDI utilizes three Bluetooth modules [4] to simulate its wireless connectivity. The three modules were required to simulate the Master / Slave relationship. The three modules establish a piconet. Within the piconet one unit acts as a master and the others assume connection as slaves. The BDI does not interfere with a Bluetooth unit's ability to establish a connection for sending data between the master and slaves. Utilizing a Web User Interface, the BDI is able to keep track of the number of users within its piconet. With a combination of HTML and VBScript, the BDI parses a text file to display the number of users connected to a master. The text file is created by the master and contains information on the master / slave identification string and the total number of users. For our device to function correctly it was able to do the following:

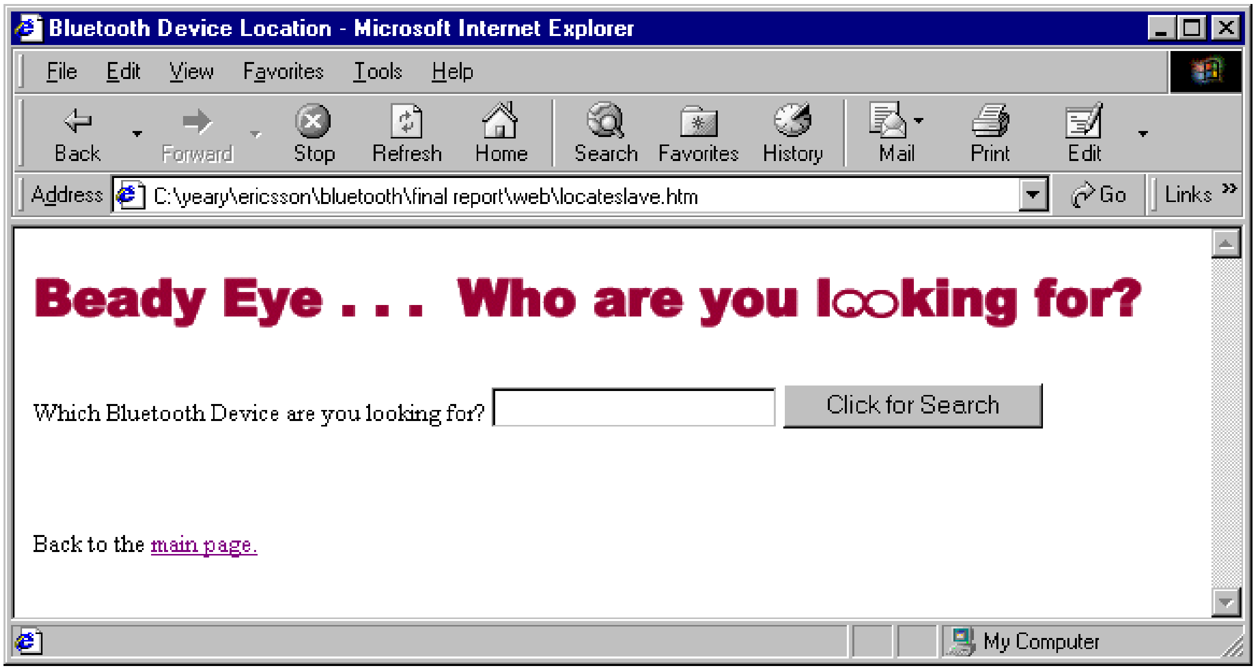
- Individually identify Bluetooth units
- Determine unit connection status
- Track a slave across a scatternet
- Communicate all data to a server
- Display in a user friendly manner
- Post data to the internet

IV. Solution and Results

First, a successful connection between a Master and a Slave needed to be established. This posed to be the first obstacle to overcome, and it worked very well. In fact, we have shown that the algorithms used go on to successfully implement connections between a Master and multiple Slaves. This was further tested by successfully sending data between the Master and Slaves. Moreover, until connectivity was successfully accomplished, we could not test nor fully implement any other feature.

After connectivity was established, we implemented the counting and tracking of multiple Slaves in a piconet. We first attempted to show tracking of one user, and this was readily accomplished. The algorithm we developed was such that additional users were tracked without modification to our code that tracked one Slave. This allowed for future testing of other capabilities for the project.

With multiple users being tracked, we began the implementation of posting BDI data to the Internet. As depicted in Figure 3 below, we developed a web front-end, which made easy access to any outside user. It allows someone to search for a device by address and see if it is currently in a piconet. If so, it returns the address of the Master that it belongs to. Also, it allows searching out a Master by address, whereby it returns the number of Slaves in its piconet, followed by the ability to list all Slave addresses in the piconet. The front-end utilizes time-stamps to reflect when the state of a piconet has been reported. The web design is intelligent enough to consider if the device is found at all and reports accordingly.



C:\yeary\ericsson\bluetooth\final report\web\locateslave.htm

Beady Eye . . . Who are you looking for?

Which Bluetooth Device are you looking for?

Back to the main page.

Figure 3: Similar to an inquisitive soul with a beady eye, this figure depicts our Bluetooth Diagnostic Interface (BDI) web browser interface.

After this proved successful, we turned our attention to looping the entire algorithm. This made the application “automatically” update the lists of current users. After attempting to use the Bluetooth native timers, we eventually turned to a simple loop, leaving the timer additions to future implementations.

The last part that was implemented was the attempt to split the code into separate Master and Slave programs. This would allow us to simply start one program or the other to specify a device as Master or Slave. Ideally, this would also eventually lead to performance improvement and the ability to solve Master-to-Master connectivity problems, as well as Slave-tracking across multiple

Masters. We believe our algorithm will successfully solve these problems if its implementation can be realized. As for now, it does make for clearer distinction between the devices, and it retained its abilities from all the prior accomplishments.

V. Conclusions: Three Primary Items of the Experiment

1. Master to Master connection: One master always tried to establish a M/S connection with the other Master. It would not realize that the other was also a master and to therefore break the connection with it. This resulted in double-counting of slaves in a scatternet.

2. Breaking the active connection of a Slave: The Link Manager kept a slave in a piconet despite the slave deciding to be in only one. This meant that since the master still had a valid connection with the slave, it would count it in its list of users. This also resulted in double-counting of slaves in a scatternet. Figure 4 illustrates the master/slave connectivity of concluding remarks 1 & 2.

   Note that with proper handling, Master A and Master B should only detect two slaves each making a total of four slaves. This leads to an analytical report of two masters, each with two slaves - a total of 6 devices altogether. However, as a result of the Master-Master problem (where each master detects the other as a slave in its network), each one will report three (2 slaves + 1 other master). In addition, without the slaves breaking their connections appropriately, slaves 2 & 3 will each appear in the other network as well. This means Master A will now report a total of 4 slaves (slaves 1 and 2 accurately, slave 3 because of connection, and Master B because it can't detect the difference). Master B will also report 4 slaves (slaves 2,3,4 and master A). This would lead to the inaccurate analysis of 2 masters, each with 4 slaves, or a total of 10 devices.

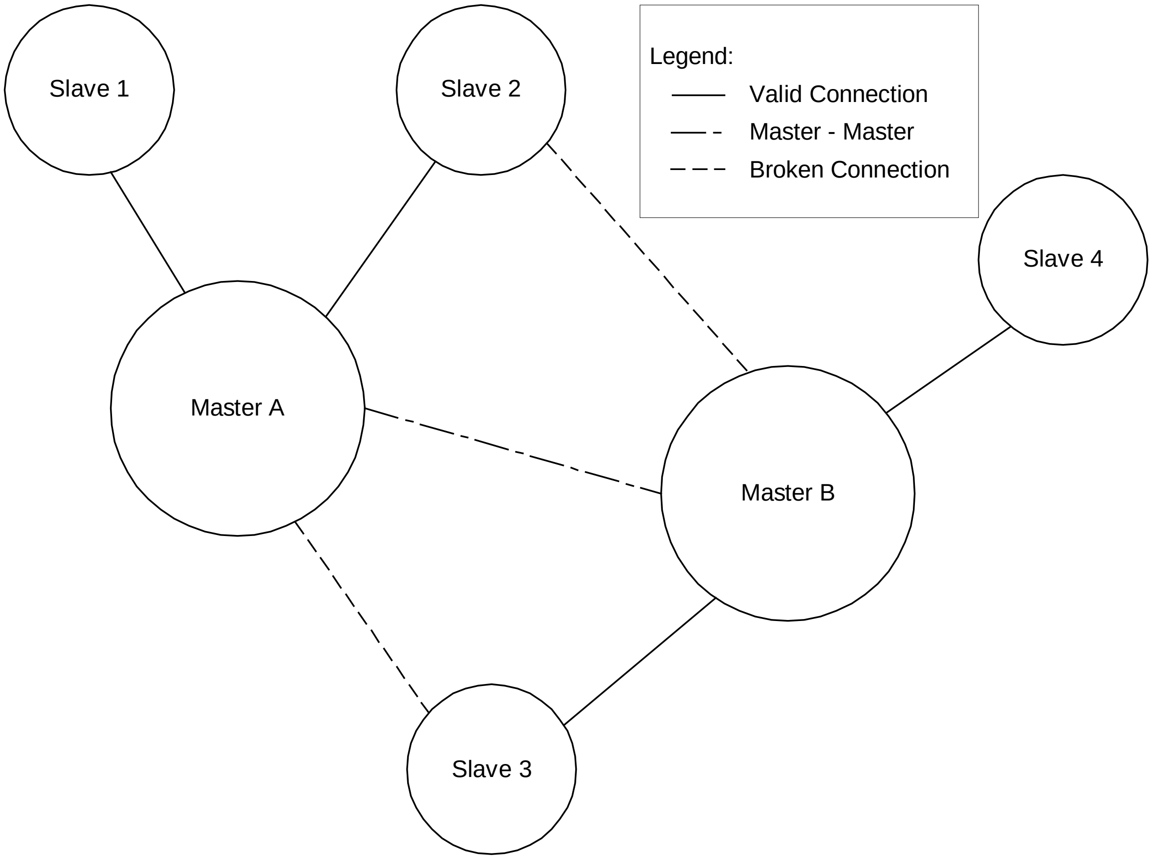


Figure 4. Connectivity Problems Illustrating Items 1 & 2

3. Efficiency: The algorithms developed for the operation of the BDI ended up being very slow when implemented. The time required for a master to read all slaves in its piconet could take up to 30 seconds, even for a very small number of slaves. Compound this with the time to break connections where necessary, decipher the difference between masters and slaves, and push data, report, and loop, and the entire process could take up to two minutes. This is not a realistic solution. The algorithm finally chosen for its possibility of successfully solving problems 1 & 2 proceeded as depicted by Figures 5 and 6.

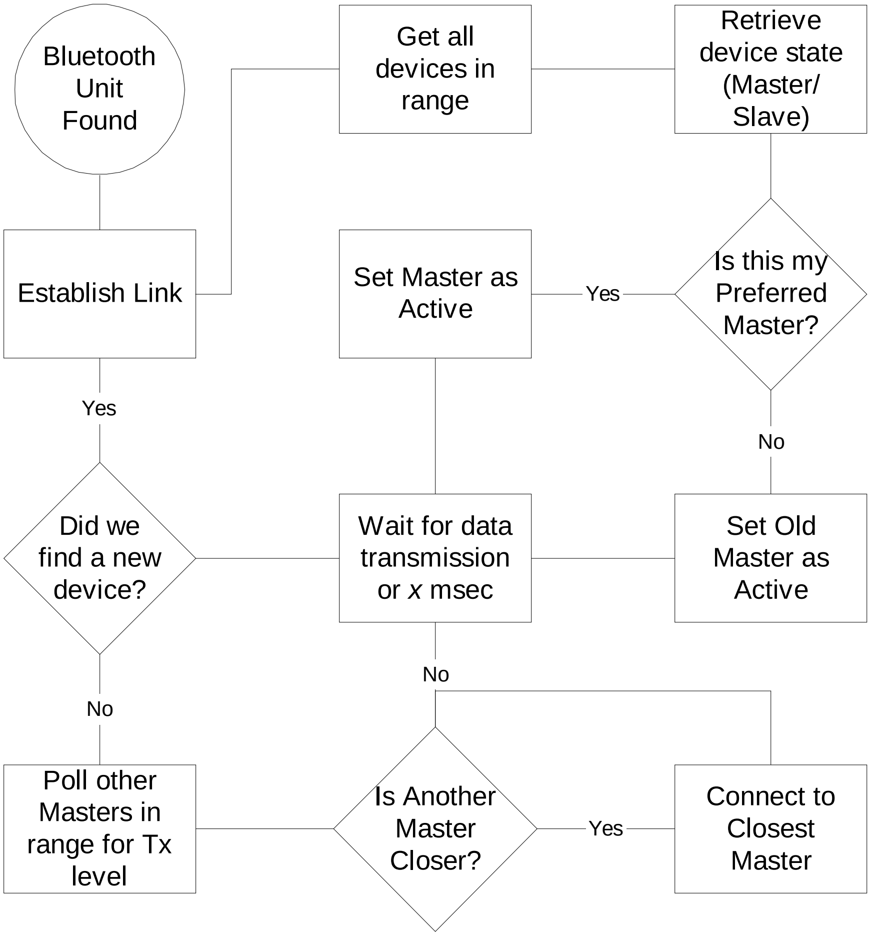


Figure 5. Slave's Logic Block Diagram

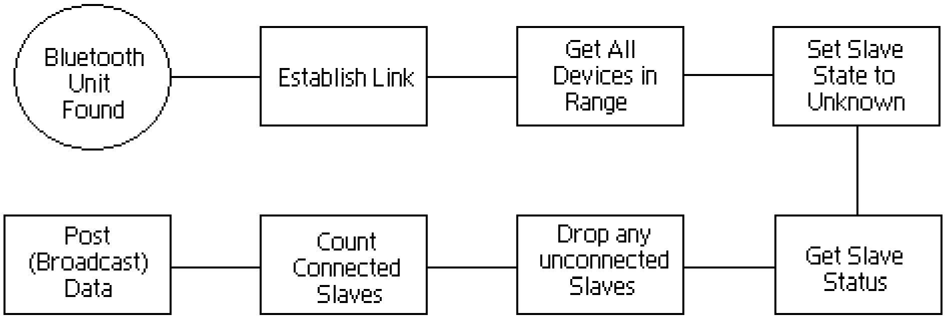


Figure 6. Master 's Logic Block Diagram

VI. Summary

The Bluetooth Diagnostic Interface (BDI) was designed to fill the needs of network managers for the monitoring of a Bluetooth scatternet. The BDI will utilize the network information available from the Bluetooth modules to ascertain and communicate network status. The BDI will give network managers the ability to track the connections in a Bluetooth scatternet. It will also indicate the active piconet that a module is in, and its connection history.

VII. Directory of terms:

Master Unit – A device in a piconet whose clock and hopping sequence are used to synchronize all other devices.

Parked Mode – Only a slave device in a piconet can be parked. A parked device is not active in the piconet and only listens for an activation packet at specified intervals.

Piconet – A collection of devices connected together in an ad hoc connection using Bluetooth technology. A piconet starts with two connected devices and may grow up to eight active connected devices. In establishing a piconet, one unit will act as a master and the other(s) as slave(s).

Scatternet – Multiple independent piconets combined together.

Server – In the context of this project, the server is the device that collects, analyzes, and publishes the network information.

Slave Unit –All devices in a piconet that are not a master.

Sniffing – Passively collecting network data and communications without interfering with the operations of the network.

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Bibliography

1. Kalia M.; Garg, S.; Shorey, R., "Efficient Policies for Increasing Capacity in Bluetooth: An Indoor Pico-Cellular Wireless System," *Vehicular Technology Conference Proceedings*, vol. 2, pp. 907-911, 2000.
2. Jaap Haartsen, " The Bluetooth Radio System," *IEEE Personal Communications*, pp. 28-36, February 2000.
3. Ron Schneiderman, "Bluetooth's Slow Dawn," *IEEE Spectrum*, vol. 37**,** no. 11, November 2000.
4. Ericsson Inc., "Bluetooth Application & Training Tool Kit," 2000.

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Mark Yeary received his B.S. (honors), M.S. and Ph.D. from the Department of Electrical Engineering at Texas A&M University, College Station, Texas, in 1992, 1994, and 1999, respectively. In the past, Mark served as teaching assistant with the Department of Electrical Engineering, and received an ``outstanding teaching assistant" award from the IEEE local student chapter for two years in a row. He also received a second place prize from the IEEE local chapter for his entry in graduate student paper contest. In the past as a student of Texas A&M University, Mark was a charter member and officer of the Engineering Scholars Program and has also been a recipient of the Dean's Outstanding Student Award. Dr. Yeary was also an NSF/FIE 98 New Faculty Fellow. Dr. Yeary has worked for IBM as a member of a microprocessor development team. In the past, he has also written numerous lines of HTML code as a website administrator for a department on campus. He is currently a member of the Digital Signal Processing Laboratory and a lecturer in the Department of Electrical Engineering at Texas A&M University. He is a member of Tau Beta Pi and Eta Kappa Nu. He is interested in both analog and digital signal processing, adaptive filters, interdisciplinary projects, and VLSI implementations of signal processing systems.

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