Chapter 1
The Interactive Video Data Services System

1.1 Introduction

The consumer market has been ever expanding. Part of the reason for this is due to the advertising that accompanies most products. From the time when products were advertised over the air through a radio channel to the added visual dimension of television today, technology has come a long way. Consumers could not only hear about, but also see how the product they were interested in. With more technological innovations came the tele-shopping networks. These networks offered the consumers a choice of placing orders for products over the telephone while the advertisement was still being aired. The variety and classes of products advertised on the tele-shopping networks have been increasing as well. Easily affordable household items, like kitchenware or jewelry, were now offered to the consumer at the convenience of a phone call. The interested consumers would place an order for a product advertised on television by dialing the telephone number that was displayed as part of the commercial. Upon calling in, and getting connected through an operator, the consumer could then purchase the product via a credit card or any other offered means of payment.

The advertisements aired on the television follow a general format. The product is first introduced and its uses are mentioned. Some customers are shown using the product and talking about how they feel about the product. Finally, the price of the product is announced. Then a telephone number and payment options are displayed prompting the consumers to call in and place their orders. Live operators are usually standing by waiting for the consumers to call and purchase the products advertised. As time progressed, the price of the product dropped to draw more consumer attention. This price keeps rocketing downwards till it hits a lower limit. This is, typically, when most consumers call in.

Some limitations with this system are easy to see. Since the number of telephone lines are normally constant and few, customers are put on hold when all the lines are busy. If there is an increased call volume, some customers get a busy tone without even going on hold. If a customer is willing to pay a higher price for the product, he/she should have a higher priority on the calling list. This does not happen, however. There are also other possible issues due to the nature of the telephone network like cross talk, interference, noisy lines, privacy, cost of adding more telephone lines at the vendor end etc.

Ideally, what is needed is a faster system with a fewer complications. Also the ideal system should be less dependent on the method of communication (wired, wireless etc.). From the customers’ viewpoint, the user-interface should be easy to use, there should be no waiting time, connection problems, busy tones, and placing an order for a product should be as simple as pressing a button. The system should be smart enough to know what product the customer needs when he presses a button, for example. The customer should be given the choice of making his/her purchase a higher priority over another customer's order. Naturally, this choice would come
with a higher price to the customer. This system should be fairly inexpensive, simple to implement, use and should have a good flexibility as to its medium of transmission - either through telephone networks, the Internet, cellular networks or other higher bandwidth networks. It should also be very reliable, modular, safe and robust.

A system with the above objectives was researched and developed by the faculty and students of The Electrical and Computer Engineering Department of Virginia Tech. This system was called the Interactive Video Data Services (IVDS) system.

1.2 The IVDS system

The project sponsor, Fernando Morales, approached The Center for Wireless Telecommunication at Virginia Tech with a concept to develop the IVDS system. The IVDS system was built with the above goals in mind. This system could be used even for ordering products on normal commercials (that were not aired on the tele-shopping networks). It was designed from various sub-components that were integrated to complete the system (Figure 1.1). These sub-systems were:

1. **The User Control**: The user control consisted of an audio link and a wireless transmitter. The audio link was a mechanism that would send an encrypted audio message in the television broadcast. This was needed in order to make the system smart and automatically recognize the product that the customer had chosen to purchase. This encrypted message was an audio signal within the main broadcast signal. This audible signal would contain information regarding the product being advertised. Since this embedded audio code could interfere with the audio portion of the broadcast that carried information to the customer, the audio code was designed to be in such a way as to have almost no impact on the audible signal heard by the system users. Additional information on the User Control subsystem evolution can be found in the theses of Henry J. Green [4] and John F. Tilki [5].

Next, a customer-initiated action was required that indicated the customer's need for the product (like a button press, for example). The radio frequency (RF) transmitter was designed for this purpose. The customer would then press a button on the transmitter when he/she intended to place an order. This prompted the transmitter to send a command signal out to a wireless receiver. The message sent out to the wireless receiver had a defined structure which included information about the product, the customer, etc.

To preserve the customer's privacy, the transmitter would transmit its data in an encoded format. This would make it difficult for decoders outside the IVDS system (used by hackers, for example) to understand the transmission. The transmission channel was designed as a one-way communication channel -- the receiver would not be capable of sending an acknowledgment back to the transmitter. There were bound to be message losses or corruption owing to the one-way nature of this channel. To guarantee that the message transmitted
made its way without corruption to the receiver required a retransmission strategy.

Figure 1.1: The Interactive Video Data Services (IVDS) system

The one-way communication channel and a retransmission strategy were researched, modeled and implemented by the group, as well. Information about the simulation and design of the one-way channel can be found in the thesis of Boris Davidson [6].

2. The Repeater Unit: The messages sent by the IVDS transmitter were picked up by a wireless receiver. This receiver was part of a repeater unit. The function of the repeater unit was to process the incoming IVDS messages (prioritizing, queuing, error checking etc.) and transmit fresh information over a wired or a wireless channel to the host system (at the vendor location). The data sent to the host system contained information about the time the message came in, the consumer and product codes, the geographical location of the repeater unit etc. The physical location of the repeater unit was needed to protect it from possible theft.

A team consisting of graduate students Steven Franks, Matt Kurtin, and supporting faculty commenced the hardware and software design for the repeater unit. After an initial prototype for the repeater unit was designed, Fernando Morales brought in Grayson Electronics® to manufacture the repeater unit modules. Grayson already had a similar hardware module that was called the Wireless Measurement Instrument™ (referred to as the WMI in
the rest of this thesis). The WMI™ consisted of four independent wireless receiver channels, a global positioning system (GPS) receiver, serial communication ports, handheld display/programmer unit, in-built kernel software and device driver software for the peripheral units, etc. The WMI™ system met the IVDS repeater unit's needs perfectly. The initial works on the repeater unit can be found in the thesis of Steven Franks [7].

The wireless receivers could receive messages at predetermined frequencies (around 900MHz). Attached decoder boards (one for each receiver) converted the wireless messages to digital signals that could be interpreted by the main processor on the WMI™. Custom software applications could be written on top of the in-built kernel software. Grayson® was using the kernel software primarily to test the throughput of the wireless channels.

3. **The Host:** The host system decoded the information sent by the repeater unit. This information was used by the vendor to ship the requested product to the appropriate customer. This completed the two-way transaction between the customer and the vendor.

1.3 **State of the technology**

At the time the IVDS system was being designed technologically there was a growth in the field of wireless communications and real-time operating systems. The method in which the system was implemented was at the time considered to be the state of the art. This led to the implementation of the communication channel between the User subsystem and the Repeater unit subsystem as a one-way wireless channel with a retransmission strategy. The Repeater unit subsystem was a real-time operating system with several microcontrollers talking to one another.

During the time this thesis was written, appliances that communicate with the Internet are not uncommon. Such appliances use microcontrollers that run off the direct crystal speed rather running off an internal hardware divide-by stage. Latest microprocessors can access large address spaces, support standardized networking protocols, have RISC architectures and instruction pipelines or queues to support faster processing. Though the IVDS system could have been implemented differently in the present age and time, the technology at the time the IVDS system was implemented was the state of the art.

1.4 **Thesis scope and research goals**

Since the WMI had embedded kernel software (in-built libraries, drivers, and other software modules that application software could be built upon), what was needed was application software that could be built on top of the kernel. This application software would invoke the in-built kernel functions as needed. The kernel had drivers for all of its peripheral devices such as the receiver decoder boards, the global positioning system (GPS) device, the serial ports etc. Therefore, the application software was a high level software that did not need to know how the internal peripherals were handled by the kernel.
Steven C. Franks initiated the work on the application software for the WMI™ [7]. The skeletal architecture was written using the C language. Software development tools were purchased from Microtek Research Incorporated™ (refer to Chapter 5 on tools used) for the application software. This software, upon completion, resided on the EEPROM devices on the WMI™. Franks developed the software to the point where incoming messages through the receiver-decoders were scanned in, checked for errors and displayed on a handheld display unit. This is where I was brought into the project.

The purpose of my work was to refine the existing software and expand it to the "next level." The software expansion consisted of message handling and processing (including queuing, modifying frame structure, and optionally displaying), and retransmitting messages through a CDPD modem via the serial link. These were the initial requirements for the application software. As the project evolved, the software architecture underwent some modification -- packet structures were changed, the software interrupt priorities were re-organized, internal message buffering was needed and GPS capability was required. Also, the project sponsor came up with a novel application for the IVDS system -- ordering products over the Internet. This required the retransmission medium to be the Internet.

In order to meet these goals, the kernel needed modification at some places to serve the application software better. These details are discussed in the thesis chapters that follow. This thesis is structured to walk the reader through the software development process and discuss the choices presented and those taken appropriately for the application software.

Chapter 2 discusses the Wireless Measurement Instrument™ in depth. This is needed to get a firm grasp on the on-board memory, the peripherals, how devices communicate internal to the WMI, the application software structure etc.

Chapter 3 talks about the state of the software when I came into the project, the analysis and modification of the application software henceforth. It also sets the stage for the retransmission medium over the Internet, which is discussed in Chapter 4.

Chapter 4 goes into a detailed discussion on the point-to-point-protocol (PPP) which is needed by any two given nodes to communicate over the Internet. It also addresses how much of the PPP was developed on the WMI™.

Chapter 5 goes over tricks and tips that were used while developing the application software. It also reviews the roadblocks and workarounds during code development, support tools, and suggestions for future software expansions.