UNIVERSITY OF WATERLOO

Faculty of Engineering

E&CE FOURTH YEAR DESIGN PROJECT DESIGN SIGN-OFF/AUDIT REPORT

4th year project group 2002.018

Wireless Ethernet LAN Adapter

This report is submitted as the design sign-off/audit report requirement for the E&CE-492A course. It has been written solely by us and has not been submitted for academic credit before at this or any other academic institution.

by

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GLOSSARY OF TERMS & ACRONYMS

Table 1 contains the definitions and acronyms used in this design specification document.

Table 1: Definitions and acronyms in Design Specification Document

Term	**Definition**
ARP	Address Resolution Protocol
BD	Buffer Descriptor
COM 1	Console Port
CP	Communication Processor
CPM	Communication Processor Module
DMA	Direct Memory Access
ECOS	Embedded Configurable Operating System
EDK	Embedded Development Kit
IP	Internet Protocol
ISR	Interrupt Service Routine
OS	Operating System
PC	Personal Computer
Rx	Receive
RxBD	Receive Buffer Descriptor
SMC	Serial Management Controller
SCC	Serial Communication Controller
SDMA	Serial DMA
Tx	Transmit
TxBD	Transmit Buffer Descriptor

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1.0 INTRODUCTION

This document describes the 4th year design project completion status at sign-off time. In the first section of this document, it describes the milestones achieved and missed at sign-off time. It also describes the modifications made to the original design and justification for the changes. In the second section of the document, it presents a design audit. This design audit contains the modified design specifications for the software design, which shows the good software design principles that have been followed. It also contains the test and verification data for the constructed prototype.

2.0 MILESTONES ACHIEVED AND MISSED

2.1 REASON FOR MISSING MILESTONES

One of the major obstacles encountered is the lack of detailed documentation to the Motorola board that used for the prototype design. On delivery of the board, there are three booklets that come with it. All three of them do not contain any documentation as to how to set up the different ports on the board. After performing some search on the Internet, we were able to find some sample code for another Motorola board, ADS860. Our board is MBX860, and the only similarity of the two boards is that both use the same processor, PPC860, whereas everything else differs between the two boards. Of the sample code that we downloaded, there is one file that contains the Ethernet port initialization steps. We have tried to use those steps by executing in the same order with the values set as appropriate for the MBX860 board. However, this proves to be unsuccessful. After which we have search on the Internet again, this time, we found the user manual for PPC860, the processing chip itself. The PPC860 documentation contains a section on Ethernet, and in it there is a 35-step initialization sequence of the Ethernet port [1]. We have matched the 35 steps with the initialization sequence we got for the ADS860 board and we found some differences between the two. Upon this discovery, we hope that the cause of our problem lies in the differences and thus we tried to use the 35-step initialization sequence. However, after the modifications have been made, we were still unable to perform normal communication between the PC and the Ethernet port of the Motorola board. With insufficient documentation, we do not see any clear path to establish communication between the Ethernet port and the PC. This led us to consider the option of loading an operating system onto the MBX860 board.

We found two alternatives, Embedded Red Hat Linux or Embedded Configurable Operating System (ECOS). We tried to install both of them, however, the installation for both OS is unsuccessful. We finally found the sample code of the ECOS driver for the Ethernet port [2]. There is a different set of initialization sequence from ECOS and when we modified our code to match that of ECOS, we are finally able to get Ethernet transmission to work.

We have encountered the same if not higher level of difficulties for setting up the serial communication. This is due to the fact that neither one of the two operating systems supports the Serial Port 2 which we need for the transceivers. There is a similar initialisation sequence in the user manual for PPC860, but like the Ethernet initialisation sequence, we were unsuccessful at initialisation the serial port. Without a schematic diagram of the MBX860 board, we have no idea how the different hardware components are related. It is through testing the ISA before we stumbled upon the method to access the Serial Port 1. Nevertheless, we are still unable to access the desired Serial Port 2.

We have contacted a Motorola representative about this lack of documentation problem. The cause is that the MBX860 board we are using is actually a production board, which Motorola sells to its customers, whom uses this board to develop products and sells to other companies. As a result, Motorola does not provide any sample code for initializing the ports. Whereas the ADS860 board is an evaluation board which Motorola uses as well, and thus the reason there are sample codes for the ADS860 board on Motorola website.

Under limited resources and support, we are still able to meet most of the milestones. The following section lists the milestones we have achieved and missed at sign-off time.

2.2 ETHERNET MODULE

2.2.1 MILESTONES ACHIEVED

For the Ethernet module, the Ethernet controller can be enabled to trigger interrupts and make the sending and receiving process fully interrupt-driven. Furthermore, the prototype is able to receive incoming Ethernet packets and transmit Ethernet packets from the Motorola board. To ensure 100% Ethernet compatibility with existing network, the interface of the prototype must be able to update the host's Address Resolution Protocol (ARP) table with its IP address. The Ethernet module was able to respond to ARP requests from the host and reply to PC with the updated hardware address.

2.2.2 MILESTONES MISSED

In the original design, the Ethernet adaptor was designed to update its own IP address with the IP address of the remote PC's IP address. This is necessary in order to achieve truly plug and play installation of the Ethernet adaptor. However, since setting up the interrupts and the Communication Processor Module (CPM) on the MBX860 turns out to be much more complicated than imagined, implementing the automatic IP-update feature in the design cannot be accomplished with insufficient time. For now, the remote PC's address is hard-coded in the software code. To change the IP, the software must be re-compile.

2.2.3 MODIFICATIONS AND JUSTIFICATIONS

2.2.3.1 BDS MODIFIED IN ETHERNET MODULE INSTEAD OF COPY MODULE

In the original design, the Ethernet Tx and Rx BDs are assumed to be directly accessible in the Copy Module's Assemble and Disassemble routines. With clear understanding of the CPM, it turns out that there are some special procedures that must be followed before gaining access to the BDs. Therefore, instead of modifying the BDs directly in the Copy module, the BDs have been made internal of the Ethernet module. The eth_send() and eth_recv() API functions have been implemented and perform the special procedures inside these functions. This maintains the software design's modularity and allows for easier debugging.

2.2.3.2 GENERATING ARP REPLY

An ARP reply module was not included in the original design for Ethernet module, but this turns out to be a very important feature in order to support 100% compatibility. If the prototype does not reply to ARP messages, the host PC will not associate remote PC's IP with the Motorola board's Ethernet hardware address. Therefore, the local PC will not send outgoing packets with the Motorola board's hardware address and the Motorola board will not accept the packets. Therefore, a generate ARP reply function was added to the Ethernet module in order to achieve Ethernet compatibility.

2.3 COPY MODULE

2.3.1 MILESTONES ACHIEVED

Assemble() was successfully called when serial data is received from the serial module. In addition, Disassemble() was successfully called when received Ethernet data from the Ethernet module.

2.3.2 MILESTONES MISSED

The requirements for the Copy module are satisfied at signoff time. However, additional testing will always yield more reliable and robust code.

2.3.3 MODIFICATIONS AND JUSTIFICATIONS

In the original design, the Copy module simply calls Assemble() and Disassemble() in a round-robin fashion and let the Assemble and Disassemble functions to determine whether data is available. In the current design, the Copy module will call the corresponding interface's API functions only when the data required by that function is available. This change is made to make the design more modular. Since the BDs are now kept internal to the interface modules and calling the corresponding API function will simply return a pointer to the internal buffer, the Assemble and Disassemble functions now simply copy the data from one buffer to the other buffer. The Copy module ensures the Assemble() and Disassemble() will be called only when there are valid data in the buffers, i.e. when the API functions does not return NULL.

2.3.4 DISASSEMBLE BLOCK OF THE COPY MODULE

2.3.4.1 MILESTONES ACHIEVED

The coding and the testing of the Disassemble block of the Copy module are completed. The function can successfully take a "controlled" packet from the PC and redirect it to the Console port (COM 1) of the Motorola Board. However, there are several modifications made since after the interim report.

2.3.4.2 MODIFICATIONS AND JUSTIFICATIONS

The most significant change is that the serial BD structure no longer exists. The reason for this is because a different method for the serial interface transmission was used. For further details of the justifications for the required changes in the serial interface, please refer to Section 2.4. Thus, instead of performing inspection of the ready data in the serial FIFO, all the code for the validation was moved into the serial interface. The reason for that is to keep the code as modular as possible, thus, the modification of the serial buffer should be left to the serial interface. The above decision greatly simplified the Disassemble block. The Copy module was made responsible to call functions in the Ethernet interface to check for incoming Ethernet data. In another word, when the Disassemble function is called by the Copy module, there must be data presents in the Ethernet receive buffer that is ready to be disassembled. This further simplified the Disassemble block and increased the modularity of the whole system.

It is decided upon to simplify the Disassemble Block due to the priority to have high code modularity. The Disassemble Block should only take received Ethernet data and transfer them into Serial transmit data. The accessing of the control bits, i.e. the empty flag, for the buffer should be left to the Serial interface. Also, the Copy module should perform the checking of the incoming Ethernet data and call Disassemble Block accordingly. Therefore, the validation procedure in the Copy module and the accessing of the control bits for the buffer are completely transparent to the Disassemble Block itself. This results in high code modularity.

2.3.5 ASSEMBLE BLOCK OF THE COPY MODULE

2.3.5.1 MILESTONES ACHIEVED

The coding and the testing of the Assemble block of the Copy module are completed. The function can successfully take a "controlled" packet from the COM 1 of the Motorola Board and redirect it to the PC. However, there are several modifications made since the interim report.

2.3.5.2 MODIFICATIONS AND JUSTIFICATIONS

In the original design, the Assemble function is responsible for keeping track of the states in which the Ethernet TxBDs and Serial RxBDs are. The idea behind this original design is so that the Copy Module is responsible for allocation of resources while the Ethernet and Serial modules act according to the orders from the Copy Module.

The responsibilities that the Assemble function of the original design has are as follows:

1. The Assemble function keeps track of the index of the serial RxBD that is currently being processed.
2. It checks which Ethernet RxBD is empty.
3. Responsible for finding free Ethernet Tx buffers by looping through the Ethernet TxBDs and checking the Ready bit of each one until found one with the status of Zero.
4. After data has been loaded into the Ethernet Tx Buffer, set the Ethernet's Ready bit to 1.

With the modified design, the above responsibilities are no longer performed by the Assemble function. Instead, the Copy Module calls functions provided by the Ethernet and Serial Modules that actually perform the above tasks. In addition, the original design uses redirection of Ethernet Tx pointers to point to the Serial Rx pointers while the new design performs actual copying of data from one buffer to another instead of using pointers. The main goal of these modifications is to keep the three modules as modularized as possible.

With the realization that the CPM must be gracefully stopped when the Status and Control bits of the BDs are to be changed, the responsible of modifying those bits and checking those bits to allocate resources must be shifted to the Ethernet and Serial modules as accordingly. For the Assemble function, this means it must relinquish the responsibility of checking the availability of the Ethernet Tx Buffers and the presence of Serial packets in the Serial Buffer. The advantage of shifting these responsibilities to the Copy Module is that when either Ethernet or Serial resource is not available, the Assemble function will not be performed. The new structure prevents the unnecessary idle time during looping inside the Assemble function and can move onto the Disassemble function. When Assemble function is called, it is ensured that the main task of assembling Serial packets into Ethernet packets is performed.

2.4 SERIAL INTERFACE

2.4.1 MILESTONES ACHIEVED

Successful receive and transmit data through the console port (COM1) of the Motorola Board was accomplished. When serial data is sent through the COM port of the PC to the console port of the Motorola Board, the serial interface can receive the data and transfer it to a designated buffer pool. Also, when data is put in the serial transmit buffer, the serial send function can transmit the data to the console port of the Motorola Board. All data in the serial transmit buffer is first converted into ASCII format before transmitting. Therefore, the display on the screen in the console port is the actual HEX data in the serial transmit buffer pool.

2.4.2 MODIFICATIONS AND JUSTIFICATIONS

Instead of having a chain of BDs pointing to a large buffer pool, it is decided upon to use two buffer pools. There is a serial transmit and a serial receive buffer. The size of either buffer is sufficient to hold an entire Ethernet packet of maximum size, which is 1520 byte. With single buffer pool implementation, there is no need to provide a BD structure since the same buffer pool can be reused due to the polling nature of the receive function.

Without the BD structure, there is no need to use the CPM. Therefore, CPM is only enabled in the Ethernet interface. In the receive function, it will receive the data from the serial FIFO by polling. The function will exit after it receives the entire EOS from the COM port of the PC. Since a cable is used as the transmission channel, the error in the channel is assumed to be zero. That is, the EOS will arrive to the receiver with no error.

As stated in the interim report, the intended method to access the COM2 of the

Motorola Board was to use the Serial Management Controller (SMC). But in this implementation, the serial output port has been switched to COM 1, which is the console port of the Motorola Board. Since COM1 of the Motorola Board is used, the maximum achievable transmission speed is 9600 baud. Accesses to the console port of the Motorola Board are done by directly controlling the ISA bus where the COM1 is connected. This unique method is necessary since the CPM is not initialized and the only way to get access to communication port is by direct access to the data bus that it is connected.

A single buffer pool is used for either transmit or receive is due to the fact that it is adequate and sufficient for a polling receive algorithm. For example, when the Copy Module decided to go into receive mode by waiting for incoming serial data, it blocks until the entire packet with the EOS. Before the Copy Module perform any further receiving of serial data, it will call the assemble function to transfer the incoming serial data to a ready to send Ethernet transmit packet. After that the Copy Module will set the empty flag for the serial receive buffer. As described, the buffer is used in a strictly sequential fashion and one such buffer is adequate.

Accordingly, the same reason applies to why only one serial transmit buffer is enough. The Copy Module copies all the data plus the EOS into the serial transmit buffer and call serial send function. The function will send all the data out to the console port of the Motorola Board before returning. After the data has been sent, the serial send function will set the empty bit of the serial transmit buffer to indicate that it is free for next use.

It was decided upon to use polling algorithm for data access in the serial interface. This is not the intended method for accessing data. Actually, data-polling algorithm is done earlier in the project implementation phase and is used for testing in the system integration phase. However, problems were encountered when tried to change the polling algorithm to a fully interrupt driven implementation. Documentation and procedures were followed and appropriate setups have been performed, however, it still failed. It is suspected that the interrupt from the Ethernet source and the ISA source conflicts each other. One such explanation might be due to the fact that the normal way of accessing the COM port was omitted. The normal way to access the COM port is through the use of serial channel provided in by the core processor. Due to the time limit of the project, it is decided upon to use the polling algorithm that has been proven working. The polling algorithm limits the performance of the system due to its block receive behaviour. The performance of the system would be increased if the interrupt driven implementation is used.

In the Motorola Board, there are two COM ports available to use. COM1 is used because it was discovered that that COM2 does not have a transceiver suitable for a RS-232 interface. Also, a better understanding of the functionality of the COM1 in the Motorola Board since it is proven working by the debug program for the board can make using COM1 an easier task. However, it is known that when using the console port for data transmission, connection to the only debug terminal has been lost. This will make the process of debugging the code a lot harder later on. Nevertheless, it was still decided to use COM1 because it seems to have a better chance of success using a working COM port instead of trying to work with a COM port that no documentations are available. Careful measures were taken to ensure the data is correct before preceded to remove the terminal that connects to the COM 1 port. For the actual verification and testing, please refer to section "Testing and Verification for Constructed Prototype" in this report.

Also, for the serial interface, the method to directly access the ISA bus that connects to the COM 1 port of the Motorola board was chosen instead of the SMC implementation. The SMC implementation is the safer and cleaner method for accessing the COM port in the Motorola Board. This is because all the interrupts are grouped together by the Serial Interface (SI) block before sending it to the core processor. This ensured that the interrupt are handled properly by priority. However, the initialisation instructions for the SMC stated in the user manual do not produce successful results, and proper configuration of the SMC or which registers value to set is unknown. Therefore, it is decided to access the ISA bus directly to get access to the COM 1 port.

2.5 WIRELESS TRANSCEIVERS

2.5.1 MILESTONES ACHIEVED

The wireless transceiver has been ordered and the test program provided along with the transceiver was used to verify its functionality. It is necessary to verify that the transceiver can only operate at simplex mode.

2.5.2 MILESTONES MISSED

The development of the wireless transceivers is one of the milestones that have been missed. Since the wireless transceivers are not considered as the main component of the project, the amount of time and manpower assigned to them are minimal. Also, when the transceiver was purchased, it claims that it is very easy to use or simply plug and play. However, in the testing of the transceivers, configuration procedures are needed in order to get a minimal error transmission. By running the test program that comes with the transceiver, the functionality of a simplex transmission is verified. However, in order to make it into half or full duplex, more components and development are needed [3]. This was completely unexpected and time has not been allocated for this purpose. It is strongly believed that making the transceivers functional will require a vase amount of time since care must been taken to avoid noise and distortion of signals when inserting additional circuits. Although getting the transceiver to work is important, many difficulties encountered during the development phase when working with another more vital part of the design, the Motorola Board, required the focus of the whole team and thus prevented putting more time into the transceiver. Thus, at the end, testing of the transceivers cannot be completed.

2.5.3 MODIFICATIONS AND JUSTIFICATIONS

The wireless transceiver needs additional circuitry to make it half-duplex. However, this modification has not been made yet. The transceiver can transmit data, but the bytes are shifted by half a byte. This behaviour does not occur when a NULL modem cable connection was used. Therefore, additional modifications to the code are required to compensate for this shift.

Table 2 summarizes the design milestones achieved and missed for this project.

Table 2: Design Project Milestones

Index	Start Date	End Date	Milestones	Group	Status
1	Oct 1, 2000	Oct 30, 2000	Initial research	All members	Completed
2	Nov1, 2000	Nov 31, 2000	Submit proposal and budget, find sponsors	All members	Completed
3	Dec 1, 2000	End of Dec 2000	Develop initial system design, finalize requirements and specifications	All members	Completed
4	Beginning of Jan 2001	End of Jan 2001	Decide on which FPGA and transceiver to use	All members	Decided to use Motorola board
5	Middle of Jan 2001	End of Jan 2001	Develop handshaking algorithm to avoid collisions on wireless channel	All members	No longer part of the customer requirement
6	Middle of Jan 2001	End of Jan 2001	Investigate possible encryption schemes	All members	No longer in customer requirement
7	Beginning of Feb 2001	End of Feb 2001	Develop algorithm for retrieving/sending contents between wireless transceiver and FPGA	All members	No longer in customer requirement
8	Beginning of Feb 2001	End of Feb 2001	Finalize design and order required components	All members	Ordered Motorola board and some sample National chips, transceiver not received yet.
9	May 01, 2001	May 5, 2001	Revise customer requirements (due week 2)	All members	Completed
10	April 20, 2001	May 7, 2001	Power up Motorola board and verify PC can communicate with debug console	All members	Completed

11	May 7, 2001	May 14, 2001	Verify PC can ping Ethernet port of Motorola board and investigate how to control the Ethernet port	Embedded PowerPC Software – Ethernet module	Completed
12	May 01, 2001	May 11, 2001	Obtain transceivers from school lab	Wireless Transceiver	Decided to order our own
13	May 7, 2001	May 11, 2001	Revise project milestones (due week 3)	All members	Completed
14	May 14, 2001	May 18, 2001	Write Functional specification, Verification Plan and Test Plan (due week 4)	All members	Completed
15	May 21, 2001	May 31, 2001	Investigate, test and verify wireless communication between transceivers	Wireless Transceiver	50% Completed
16	May 21,2001	June 8, 2001	Investigate how to retrieve contents received from Ethernet port on Motorola board and write algorithm to retrieve the content.	Embedded PowerPC Software – Ethernet module	Completed
17	May 21, 2001	May 27, 2001	Develop PC application to send/receive packets between PC and Ethernet controller; Verify packet contents	Embedded PowerPC Software – Ethernet module	Completed
18	May 21, 2001	May 27, 2001	Write Design Specification and project interim report (due week 5)	All members	Completed
19	May 28, 2001	June 1, 2001	Investigate how to access COM2 of the Motorola board in order to read/write to the transceiver	Embedded PowerPC Software – serial port module	Decided to use COM 1. Completed.
20	May 24, 2001	June 1, 2001	Request for the 2nd Motorola MBX Evaluation Board	Embedded PowerPC Software – Ethernet module	Completed
21	May 28, 2001	June 1, 2001	Order and receive a new transceiver from RF Digital	Wireless	Completed
22	May 28, 2001	June 8, 2001	Implement and test algorithm for reading and sending to transceiver	PC utility software	To do
23	June 1, 2001	June 15, 2001	Test transceiver for functionality	Wireless	50% Completed

24	June 5, 2001	June 15, 2001	Write programs in PC to disassemble and assemble packets	PC utility software	Completed
25	June 10, 2001	June 20, 2001	Write programs in PC to send and receive data in the serial port	PC utility software	Completed
26	June 10, 2001	June 17, 2001	Merge the different modules of the code together	All members	70% Completed
27	June 17, 2001	July 7, 2001	Testing of the entire system	All members	70% Completed
28	July 1, 2001	July 7, 2001	Target project completion date		To do
29	July 16, 2001	July 20, 2001	Project signoff (due week 12)	All members	To do
30	July 16, 2001	July 22, 2001	Design project abstract (due week 13)	All members	To do

3.0 DESIGN AUDIT

3.1 HIGH LEVEL DESIGN

The overall high-level design remains the same as the original design in the interim report with some minor modifications made to it. Please refer to Appendix D for the original design specification. In the new design, the Ethernet module, copy module, and serial module still act as the three main components of the design. To keep the modules more self-contained, thus making them have higher cohesion and lower coupling, the number of the buffers have been limited and various flags internal to the modules only are used and other modules can only access those buffers through API function calls. For example, the Tx and Rx BDs cannot be directly accessed by the Copy module; instead, the Copy module must call functions to obtain access to the Tx buffer or to set the BD empty bits.

Table 3 provides the modified module descriptions for the prototype design.

Table 3: Module descriptions

Module	Description
Serial_Interface	The Serial Block is used to transmit or receive data from the serial port. It consists of receive and sending API function which other modules can call. It also contains an internal Tx and Rx buffer pool which is used to hold data to be transmitted or received from serial port. To use these buffers, certain flags must be set, and API functions are provided to modify the flags.

Ethernet_Interface	The Ethernet ISR Block is used to transmit or receive data from the Ethernet interface. It contains buffers to hold data and it contains an interrupt ISR to service interrupts generated by events related to the Ethernet port. This module is also responsible for modifying Ethernet BDs. When new data is received from the Ethernet port, an interrupt will be generated after new data is copied to a buffer. External modules can access the data by calling API send or receive functions.
Copy_Block	The Copy Block is used to coordinate the data manipulation between the Ethernet port and the serial port. It will call the interface's receive functions alternately. If data from the Ethernet interface is ready, it will disassemble the packet into smaller serial port packet. For data coming in from the serial port stored in serial buffer, it will reassemble the packet into larger Ethernet port packet.
Initialization	The Initialization block is used to set up and initialize all global data structures. This part remains the same as the design specification in interim report.

3.1.1 TRANSMISSION OF DATA FROM ETHERNET TO SERIAL INTERFACE

The data flow from Ethernet to serial interface in the modified design is roughly the same as the one in interim report. The major change is that all sending and receiving tasks are done by API calls instead of directly accessing the BDs. Rather than directly checking the status flags modified by the ISR, the Copy module now must obtain the current status by the return value of the API function calls. The flags are kept internal inside the interface modules. The following Figure 1 shows the transmission of a packet from the Ethernet port to the Serial port.

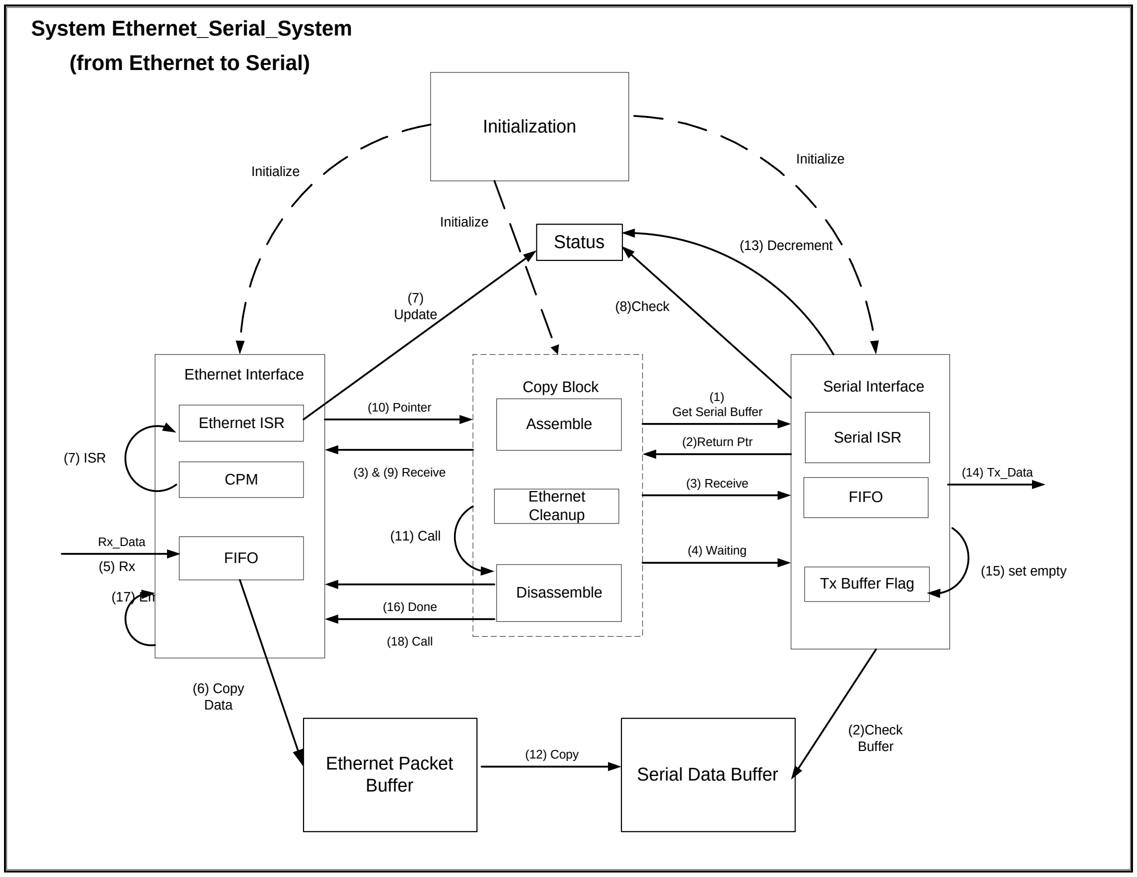


Figure 1: Transmission of a Packet from Ethernet to Serial port

The following sequence is used to process the data packet until it is transmitted out of the serial interface in the modified design:

1. Copy module gets a serial Tx buffer from serial module by calling ser_getTxBuffer.
2. In ser_getTxBuffer(), if the serial Tx buffer is not in use, it returns a pointer to Tx buffer and sets a flag to indicate the Tx buffer is now in use.
3. Copy module calls eth_recv(). If no packets are ready, then it quits and call ser_recv().
4. In the normal flow, the program will always be inside ser_recv(), waiting for a complete packet from serial interface until EOS is detected.
5. Data packet is received into the Ethernet receive FIFO queue.
6. CPM moves the data from the FIFO queue into the Ethernet receive buffer.

7. CPM generates an Ethernet interrupt to trigger Ethernet Receive ISR. The ISR increments the disassemble status variable to indicate that there is one more packet ready for disassemble.
8. The ser_recv() is constantly checking for the disassemble status variable. If disassemble variable is greater than zero, it immediately returns to copy module.
9. Copy module calls eth_recv() again.
10. eth_recv() detects the BD is not empty, so it returns a pointer to the contents of the Rx buffer and increment it's RxBD index to point to the next BD, which is the buffer that CPM will use when the next packet arrives.
11. Copy module received the pointer to the Ethernet Rx buffer containing the new packet. It calls the disassemble function.
12. The disassemble function copies the binary data to the serial Tx buffer, append "end of sequence" pattern and calls ser_send().
13. ser_send() converts binary data to ASCII data, decrements disassemble status variable to indicate the data packet stored in the buffer has been disassembled.
14. ser_send() sends data to serial port until the whole packet
15. ser_send() sets Tx buffer flag to be empty so that the Tx buffer can be re-used by next call. Ser_send() returns.
16. disassemble() calls eth_setRxBufferEmpty() to indicate it has finish using the current BD buffer.
17. eth_setRxBufferEmpty() sets the empty bit of the RxBD
18. disassemble() calls ser_getTxBuffer() again to get a pointer to the serial buffer to prepare for next transmission.

3.1.2 TRANSMISSION OF DATA FROM SERIAL TO ETHERNET INTERFACE

Figure 2 shows the different interactions of these components when a data packet comes in from the serial interface.

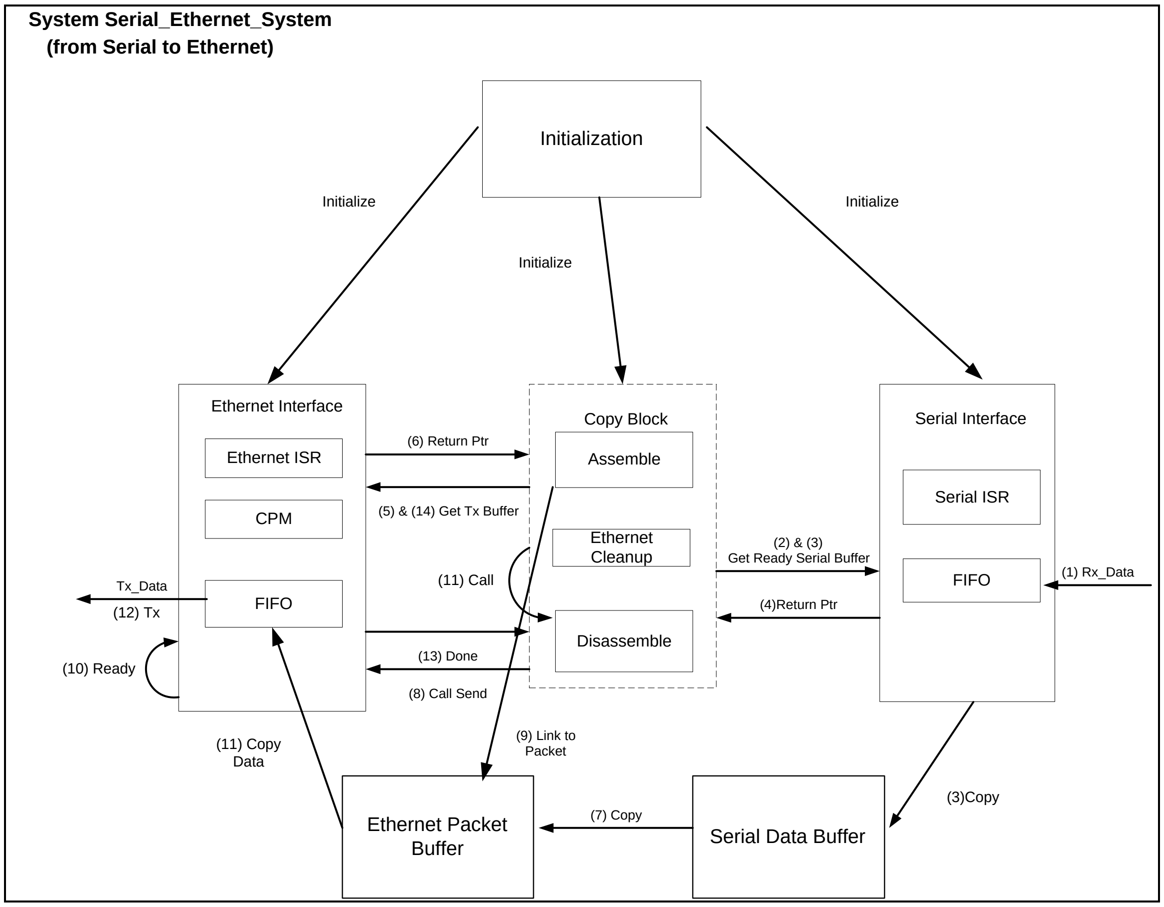


Figure 2: Transmission of a Packet from Serial to Ethernet Port

The following sequence happens to process the data packet until it is transmitted out of the Ethernet interface:

1. Data packet is received into the serial receive FIFO queue.
2. Copy module will usually be inside ser_recv().
3. ser_recv() polls the status bit in serial interface and copies to serial Rx buffer until

EOS is detected. At this point ser_recv() returns to Copy module.

4. Copy module receives a non-NULL pointer to serial Rx buffer. Therefore it will convert ASCII characters back to binary and calls Assemble function
5. Assemble function calls eth_getTxBuffer() to get a pointer to the next available Ethernet Tx buffer
6. eth_getTxBuffer() returns the next free Tx buffer and increments its own Tx buffer index. This is the buffer which CPM will be checking for ready bit.
7. Assemble function copies data from serial Rx buffer to Ethernet Tx buffer
8. The Assemble function calls eth_send() to send data.
9. The Assemble function will link the data in the serial RX BD into a packet.
10. eth_send() sets the ready bit of the Ethernet Tx BD to indicate to the CPM that the packet is ready for transmission.
11. The CPM will move the ready Ethernet TX BD's packet to the FIFO queue for transmission. The ready bit of the Ethernet TX BD will be automatically cleared by the CPM after the packet is moved to the FIFO queue.
12. The packet will get transmitted through the Ethernet interface.
13. eth_send() returns to Assemble() function. Assemble function now calls set_serRxBufferEmpty() to indicate to serial module that it has finished using the current Rx buffer.
14. eth_send calls eth_getTxBuffer() to get a new Ethernet Tx buffer to prepare for next transmission.

3.1.3 BLOCK DIAGRAM FOR THE COPY MODULE

Figure 3 shows the flow chart of the Copy Module. The Copy Module consists of five main functions: Disassemble, CopyToSerial, Assemble, CopyToEth, and Search.
When new data packets arrive from the Ethernet port, the disassemble function will partition the packets into smaller packets so that they can be handled by the serial interface.

After all the smaller partitions of an Ethernet packet are sent, it will call eth_setRxBufferEmpty() to set the empty bit of the Ethernet receive buffer. When new data arrive from the serial port, the assemble function will reassemble all the partitioned packets that the serial port has received back into an Ethernet packet. The Search function searches for the EOS pattern to indicate the end of an Ethernet packet. One serial receive may contain more than one Ethernet packet fragments. The Search function is used to distinguish between the last fragment of the current Ethernet packet and the first fragment of the next Ethernet packet. After the Ethernet packet is sent to PC, the Copy module will call ser_setRxBufferEmpty() to indicate to serial module that the current Rx buffer can be re-used for next reception of serial data.

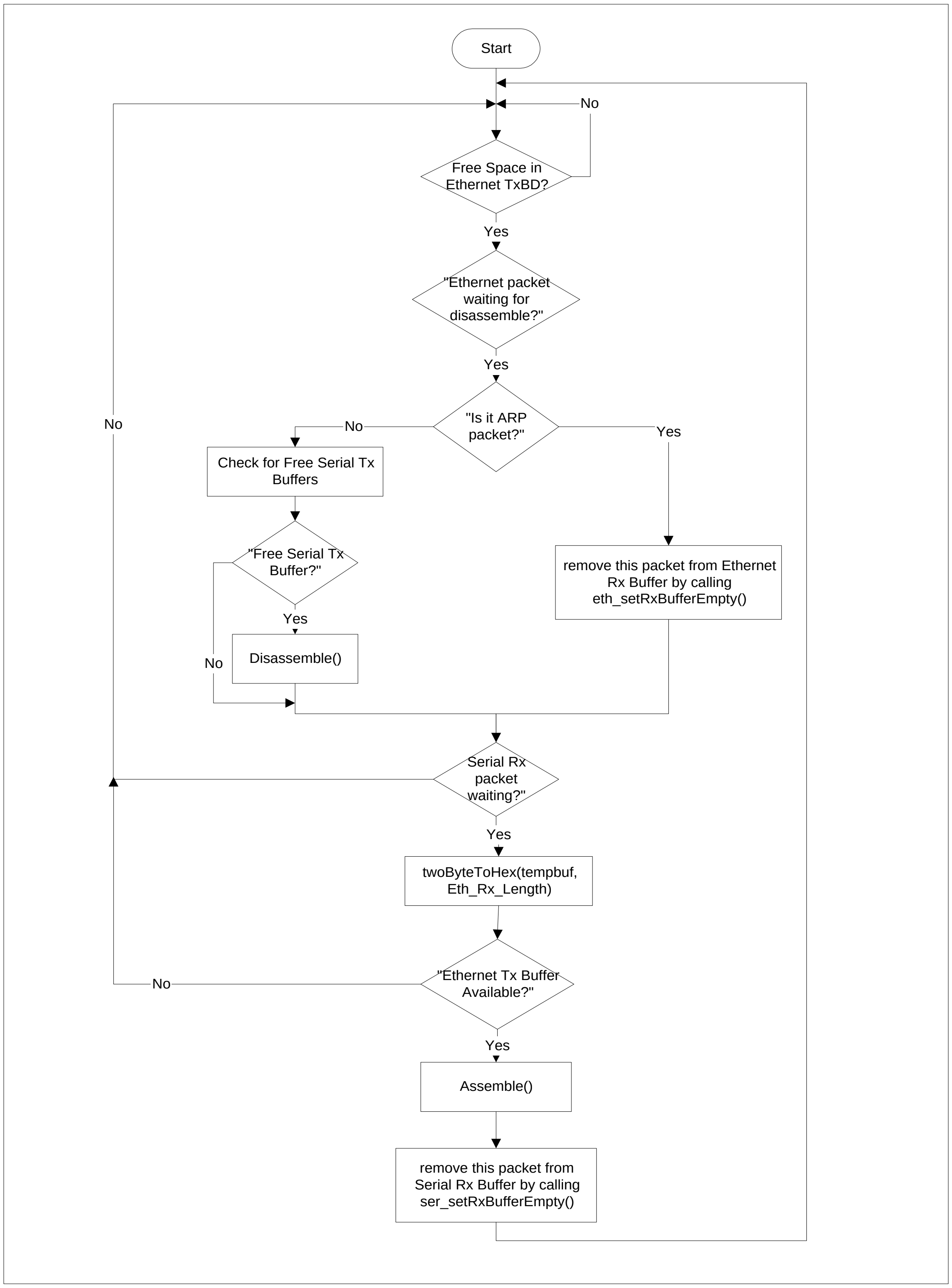

Start
No
Free Space in Ethernet TxBD?
Yes
"Ethernet packet waiting for disassemble?"
Yes
No
"Is it ARP packet?"
No
Yes
Check for Free Serial Tx Buffers
"Free Serial Tx Buffer?"
remove this packet from Ethernet Rx Buffer by calling eth_setRxBufferEmpty()
Yes
No
Disassemble()
Serial Rx packet waiting?"
Yes
twoByteToHex(tempbuf, Eth_Rx_Length)
No
"Ethernet Tx Buffer Available?"
Yes
Assemble()
remove this packet from Serial Rx Buffer by calling ser_setRxBufferEmpty()

Figure 3: Flow Chart for Copy Module

3.1.3.1 FLOW CHART FOR THE DISASSEMBLE FUNCTION

Figure 4 is the flow chart of the working Disassemble block of the Copy module.

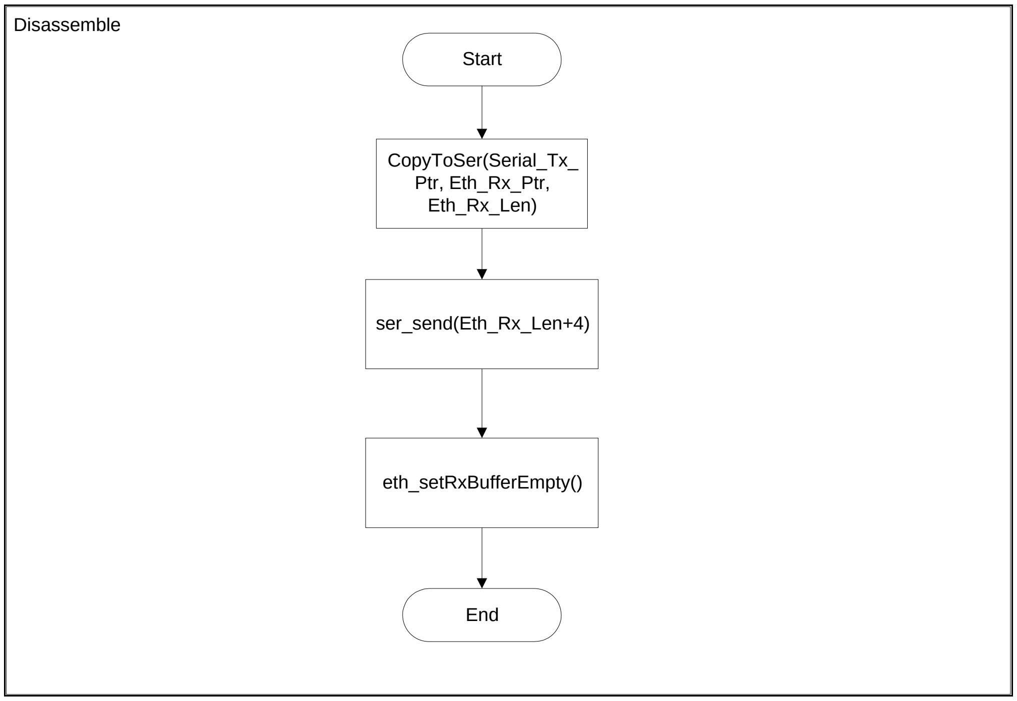


Figure 4: Flow Chart for Disassemble Function

As shown in Figure 4, the new Disassemble block simply copy the data from the Ethernet receive buffer to the serial transmit buffer. Then it will pad four byte of "End Of Sequence" (EOS) to indicate to the serial receive (at the other end) that the end of the Ethernet packet is reached. Therefore, the length passed into the function "ser_send" is increased by four to let the send function not only send the entire Ethernet packet, but also include the EOS bytes. After it finished sending the data, the Disassemble function will call "eth_setRxBufferEmpty" to set the Empty bit of the Ethernet Receive BD.Flow Chart for the Assemble Function.

3.1.3.2 FLOW CHART FOR THE ASSEMBLE FUNCTION

As shown in the following Figure 5, the Assemble function has been greatly simplified. The Assemble function no longer checks which Serial Rx Buffer contains data and which Ethernet Tx Buffer is empty. In addition, it does not have to wait for notification from the Ethernet Module that the Ethernet packet has actually been sent to the PC and that it is now empty and can be reused. The functionalities which the new Assemble function is responsible for are: to search for the "End of Sequence" in the Serial buffer, remove it and copy it over to the Ethernet buffer; if an Ethernet packet spans across more than one Serial buffer, then the Assemble function ensures the correct data and length of the Ethernet packet. After the whole packet has been copied to the Ethernet side, it will call the function, "ser_setRxBufferEmpty()" to notify the Serial Module that the Serial Buffer has been processed.

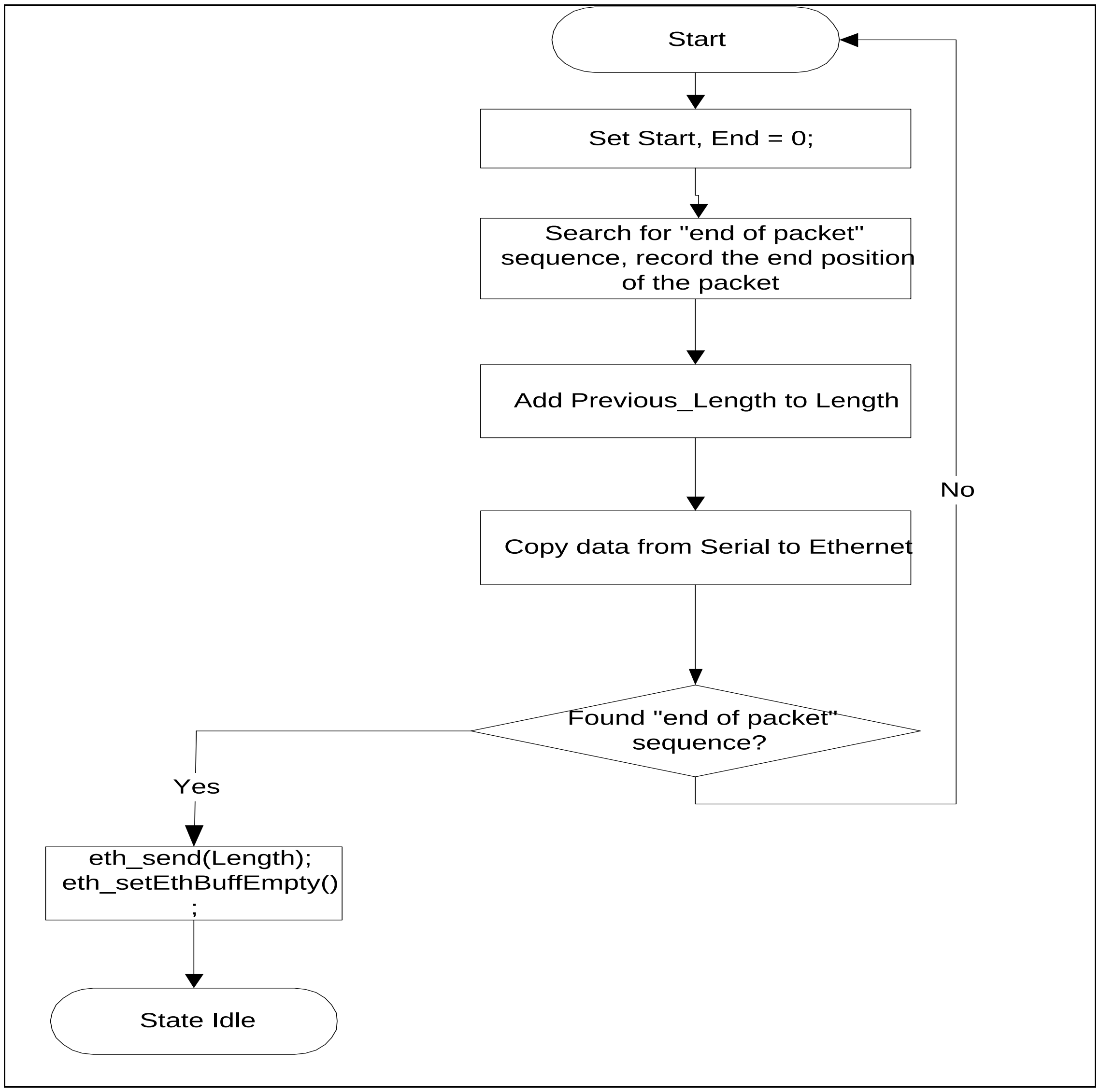

Start
Set Start, End = 0;
Search for "end of packet" sequence, record the end position of the packet
Add Previous_Length to Length
Copy data from Serial to Ethernet
Found "end of packet" sequence?
No
Yes
eth_send(Length); eth_setEthBuffEmpty();
State Idle

Figure 5: Flow Chart for Assemble Function

3.1.4 SYSTEM INITIATION

During startup of the WELA system, a script will be run to initialize the system. First, it will initialize the stack pointer and the interrupt vector table. After which the Ethernet Initialization sequence and Serial Initialization sequence will be ran. Lastly, the pointers used by the Copy Module will be initialized, the Rx interrupts will be enabled, and finally the GetLocalIP procedure will be executed before returning to the main routine.

3.1.5 ETHERNET INTERFACE

The Ethernet Interface module contains of four API functions and one interrupt routine. Eth_send() sends the data in the current Ethernet Tx buffer. Eth_recv() polls the empty bit of the current RxBD and returns the current Rx buffer if a new packet has arrived. Eth_setRxBufferEmpty() sets the current Rx BD's empty flag. Eth_getTxBuffer() gets the current Tx buffer if it is ready for use. The interrupt routine will be executed after a packet has been received from the computer into the Ethernet Interface. During the execution of this interrupt, the Copy Module will be notified that a new packet has been received and increment a counter that keep tracks of total number of packets stored in the Receive Buffer.

3.1.6 SERIAL INTERFACE

The serial Interface module contains four API functions. Ser_send() sends the data in the current serial Tx buffer. Ser_recv() polls the data ready bit of the current serial status register, and copy the current byte to receive buffer in main memory. It keeps copying new serial bytes to receive buffer until the EOS is detected. Eth_setRxBufferEmpty() sets the current Rx BD's empty flag. Eth_getTxBuffer() gets the current Tx buffer if it is ready for use. The interrupt routine will be executed after a packet has been received from the computer into the Ethernet Interface. During this interrupt routine, the Copy Module will be notified about the data length of this new set of serial data for the reconstruction of different sets of serial data into one complete packet.

3.1.7 GETLOCALIP PROCEDURE

This feature is not implemented yet at this point in time.

3.2 LOW LEVEL DESIGN

Table 4: Description of Local Variables used in Copy Module

Variable Name	Description
int RxPtrFound	Indicate if a free Ethernet Buffer is found..
int FoundARP	Indicate if the entry in Ethernet Buffer is ARP.
Char *Eth_Tx_Ptr`	Pointer to the current Ethernet Tx Buffer.
char *Eth_Rx_Ptr	Pointer to the current Ethernet Rx Buffer.
int Eth_Rx_Len	Length of the currently pointed to Ethernet Rx Buffer
Char *Serial_Tx_Ptr	Pointer to the current Serial Tx Buffer.
Char *Serial_Rx_Ptr	Pointer to the current Serial Rx Buffer.
Int End_Of_Sequence_Found	End of sequence found for the current packet
Int Previous_Length	Length of Ethernet Packet split into two Serial Buffers.

3.2.1 COPY MODULE

```
Module Main
{
 eth_int();
 loop until ( (Eth_Tx_Ptr = eth_getTxBuf()) != NULL )
 loop forever
 {
    if (!RxPtrFound)
    {
       /*    Check to see if there is an Ethernet Packet waiting for
             disassemble*/
       if ((Eth_Rx_Ptr = eth_recv(&Eth_Rx_Len)) != NULL)
       {
          RxPtrFound = TRUE;

          /* Search the current Ethernet Rx packet to see if it is an
              ARP message or not*/
                ARP_Init(&FoundARP, Eth_Rx_Ptr);
                if (FoundARP != TRUE)
                {
                   /* Check for a Free Serial Tx Buffer so that the
                      Ethernet Packet can be copied over*/
                   Serial_Tx_Ptr = ser_getTxBuf();
                   if (Serial_Tx_Ptr != NULL)
                   {
                      call Disassemble function;
                      RxPtrFound = FALSE;
                   }
                }
                else
                {
                   /* It is an ARP message, which has been replied
                   when ARP_Init() function was called*/
                   call eth_setRxBufferEmpty();
                   FoundARP = FALSE;
                   RxPtrFound = FALSE;
                }
             }
          }
          /* Check to see if a Serial Packet is waiting for assemble*/
          if ((Serial_Rx_Ptr = ser_recv(&Serial_Rx_Length)) != NULL)
          {
             /*Function twoByteToHex is used to convert ASCII into
             HEX*/
             call twoByteToHex(tempbuff, Serial_Rx_Ptr) function;
             Serial_Rx_Ptr = tempbuff;

             if (Eth_Tx_Ptr != NULL)
             {
                call Assemble() function;
                ser_setRxBufferEmpty();
                SerRxPtrFound = FALSE;
             }
          }
       }
       return 0;
    }
```

3.2.1.1 DISASSEMBLE BLOCK

```
Function Disassemble()
{
   CopyToSer(Serial_Tx_Ptr, Eth_Rx_Ptr, Eth_Rx_Len);
   //+4 for the four end of sequence bytes
    ser_send(Eth_Rx_Len+4);
    eth_setRxBufferEmpty();
}//End Disassemble
```

3.2.1.2 ASSEMBLE BLOCK

Table 5: Description of Local Variables used in Assemble Function

Variable Name	Description
int End	Indicate end position of the packet
int Start	Indicate start position of the packet
int Length	Indicate length of the packet

```
Function Assemble
```

```
{

    loop until ( (Previous_Length == 0 || Start == 0) && (Start <
    (Serial_Rx_Length -1)) )
    {
       Search(Start, End, End_Of_Sequence_Found, Serial_Rx_Length );
       Length = End - Start + 1;
       CopyToEth(Eth_Tx_Ptr+Previous_Length, Serial_Rx_Ptr + Start,
       Length);

       /*This condition is for the Ethernet Packet fits inside the
       Serial Buffer*/
       if (End_Of_Sequence_Found)
       {
          /* Notify Ethernet side that this packet is ready*/
          eth_send(Length + Previous_Length);

          Previous_Length = 0;
          End_Of_Sequence_Found = 0;
          Start = End + 5;     //End of sequence takes up 4 bytes
       }
        /* The Ethernet packet spans more than 1 Serial Buffer*/
       else if (!End_Of_Sequence_Found)
       {
          Previous_Length += Serial_Rx_Length - Start;
          ser_setRxBufferEmpty();
       }

       /* For cases when the Ethernet packet length is the same as the
       Serial Buffer size*/
       if (Start > (Serial_Rx_Length-1) )
       {
          ser_setRxBufferEmpty();
       }
    }
}
```

3.2.2 ETHERNET FUNCTIONS

3.2.2.1 ARP_INIT

```
void ARP_init
{
if received packet is ARP request packet
 {
 loop until get an Ethernet Tx Buffer
 Fill the Buffer with the ARP header and destination address
 call eth_send() to send out the packet
 set the Ethernet Rx Buffer to empty
 }
}
```

3.2.2.2 ETH_INIT

```
void eth_init
{
 initialize BD
 setup interrupt
 initialize SCC1
}
```

3.2.3 SERIAL FUNCTIONS

3.2.3.1 SER_SETRXBUFFEREMPTY FUNCTION

```
Function ser_setRxBufferEmpty
{
    /* This function just set the flag (ser_RxBufferPoolEmpty) to TRUE,
   if the flag (ser_RxBufferPoolEmpty) is FALSE*/
    if (!ser_RxBufferPoolEmpty)
        ser_RxBufferPoolEmpty = TRUE;
}
```

3.2.3.2 SER_GETTXBUF FUNCTION

```
Function ser_getTxBuf
{
 /* If the flag (ser_TxBufferPoolEmpty) is not empty,
    it means that the previous data has not been send yet.
    The user should call ser_send(int len) to send out the data
    At the end of that send function, the flag will be set to TRUE.*/

 if (!ser_TxBufferPoolEmpty)
     return NULL;

 /* If the flag (ser_TxBufferPoolEmpty) is empty,
    then return the address of the serial Tx Buffer Pool.
    It also set the flag (ser_TxBufferPoolEmpty) to FALSE,
    indicate that there will be data in the buffer that is not send.*/

    ser_TxBufferPoolEmpty = FALSE;
    return ser_TxBufferPool;
}
```

3.2.3.3 SER_SEND FUNCTION

Table 6: Descriptions of Local Variables used in ser_send Function

Variable Name	Description
int I	Counter
int j	Counter
char tempChar	Temporary storage of a char
char tempByteStr[3]	Temporary storage of a byte

```
Function ser_send(int len)
{

   /*    This function will ONLY run if the Buffer Pool is NOT empty,
   which means that there is some data in the buffer.*/

   if (!ser_TxBufferPoolEmpty)
   {
      for (i = 0; i < len; i++)
      {
         while (!(COM1->LSR & LSR_TX_EMPTY));
         tempChar = ser_TxBufferPool[i];
         oneByteToAscii(tempByteStr, &tempChar);
         // One Byte converted to 2 byte for sending ascii display.

         for (j = 0; j < 2; j++)
         {
            //spin if Tx holding register not empty
            while (!(COM1->LSR & LSR_TX_EMPTY));

           //send it out
            COM1->buf = tempByteStr[j];
         }
      }
      ser_TxBufferPoolEmpty = TRUE;
   }
}
```

Table 7: Description of Local Variables used in ser_recv Function

Variable Name	Description
int pktFlag	Indicate if a packet has been found
int I	Counter

```
Function ser_recv(int *len)
{

 // If the pool is not empty, then return NULL)
 // Means that the user forgot to call setSer_RxBufferEmpty() function
 if (!ser_RxBufferPoolEmpty)
```

```
    return NULL;

 // The serial receive buffer pool is empty.
 // This function will also receive the length of packet received thru
(len).
 while (i < BUFFER_SIZE &&  pktFlag == FALSE)
 {
       while (!(COM1->LSR & LSR_DATA_READY));
       ser_RxBufferPool[i] = COM1->buf;
       i++;
 }
 *len = i;
 ser_RxBufferPoolEmpty = FALSE;
 return ser_RxBufferPool;
}
```

3.2.4 ARP REPLY FUNCTION

Table 8: Description of Local Variables used in replyARP Function

Variable Name	Description
ARPPkt requestPkt	The ARP request packet received
ARPPkt replyPkt	The ARP reply packet generated

```
Function replyARP(const ARPPkt_t* requestPkt, ARPPkt_t* replyPkt)
{
   copy the local HW address to source field
   copy the original sender's HW address into the dest field
   set message type to ARP_REPLY
   copy source HW address into source field inside ARP header
   copy target HW address into dest field  inside ARP header
   copy target IP address into ARP header
}
```

4.0 PROTOTYPE TESTING AND VERIFICATION RESULTS

The testing results indicate the design can successfully transfer data from one interface to the other. Table 9 shows the basic essential customer requirements satisfied at this stage in time. Appendix I shows the demonstration results to faculty member Roger Sanderson.

Table 9: Functional Test and Verification Results

Test	Components tested	Test procedure	Result
ARP test	ARP reply feature, Ethernet transmit and receive	1. Verify PC's ARP table does not contain the entry for the local board. 2. Ping local board from PC. 3. Check ARP table of PC. It should contain entry which maps IP address with the board's hardware address.	Pass
Serial unit Test	Serial transmit and receive	1. Write a test program which echo received serial character. 2. Run the test program on board. Type characters to the console port. You should see the characters echo onto the screen.	Pass
Send Ethernet packets from PC	Ethernet receive, serial transmit, copy module's disassemble function.	1. Run our program on board. 2. Ping board from PC. 3. An ASCII version of the ping packets should show up on console port.	Pass
Send ASCII packet from console port	Ethernet transmit, serial receive, copy module's assemble function	1. Run program on board. 2. Run packet monitor program on PC. 3. Send pre-defined valid ASCII packet which represents textual version of a valid Ethernet packet 4. The PC's packet monitor program should show the same packet appearing at the Ethernet interface.	Pass

NULL modem connects two board's serial port together	All except transceivers	1. Connect one board's Ethernet port to PC A, one board Ethernet port to PC B. 2. Download our program to the two boards via console port. 3. Run program on the two boards, unplug from PC and connect the two board's serial port together using NULL modem. 4. Run network monitor program on PC B. 5. Ping from PC A. Packet monitor program on PC B should show PC A's ping packet.	Pass
Ethernet Stress test	Ethernet receive, serial transmit	1. Run program on board. 2. Run network monitor program on PC. 3. Ping board from PC continuously. 4. Packet data should display on console continuously.	Pass
Ethernet Stress test	Ethernet receive, serial transmit	1. Run program on board. 2. Run network monitor program on PC. 3. Ping board from PC continuously. 4. Packet data should display on console continuously.	Pass
Stress test	All except transceivers	1. Run program on board. 2. Run network monitor program on PC. 3. Ping board from PC. 4. At the same time, send ASCII packets to board. 5. Ping packet's content should show on console, while ASCII packets should show on network monitor program.	Fail. On examining the BD's content; it was shown that there are numerous collisions occurring.

Transceiver unit test	Transceiver communication	1. Connect transceiver A to PC A's console and connect transceiver B to PC B's console. 2. Type characters on PC A. The same characters should appear on PC B.	Fail. Some packet content received on PC B are shifted by half a byte but some packets are okay.
System integrated test.	All	1. Same setup as NULL modem test except use transceivers to connect to serial port instead of NULL modem cable. 2. PC A's ping packet content should show on PC B.	Fail. Since the transceiver fails its unit test.

As shown in the above Table 9, the basic functionality of the design is met. However, at the present time, total optimisation for the prototype has not been completed and thus, with the interest of the customers in mind, it is not wise to move onto full-scale manufacturing level deployment as of now. Nevertheless, if given more time to fully optimise and to perform extensive testing on the design, it can prove to be a successful product. The following lists the areas that should be improved before full-scale deployment.

1. The performance of the design can be increased significantly if the serial interface can be implemented to be fully interrupt-driven. The polling approach is inherently slow and there is a possibility that if the program does not poll fast enough, some serial bytes might be lost.

2. The current implementation makes use of COM1, the console port, instead of COM2. This is not the ideal port to use since access to any debugging messages is lost if a runtime error occurs. If any debug messages occur, the debug message's text will be treated as data embedded in the received serial data. This

will upset the operation of the program since the buffers will contain the debug message embedded with the actual data. In the final implementation of the project, COM2 should be used to transmit data instead of COM1.

3. The current implementation fails the stress test where many collisions occur. Therefore, the design must be improved to better handle error conditions in transmission and receptions.

4. The data are shifted by 4 bits when sending using transceiver. This may be due to the problem that there is 1 byte preamble before transmission. More time is needed to resolve this issue.

5. The transceiver pair received from the vendor only support simplex transmission. To support duplex operations, additional circuitry is required. This was not mentioned in the transceiver website when purchased was made and thus the required additional time was not allocated for building the extra circuitry.

6. The GetLocalIP feature is not implemented yet. This is necessary in order for the module to dynamically change its own IP address when plugging into different machines. The IP address is currently hard-coded and fixed at compile-time.

7. 100% TCP/IP compatibility is not achieved yet since Netscape will stop working when the network cable is removed and the prototype has been attached. The packet can arrives the destination successfully, but there are not responses from the other computer. It is suspected that there are some address fields in an IP packet require modification that is causing this problem.

It is strongly believed that given more time, the problem areas as stated above would be fixed before the final product demonstration in January 2002.

4.1 PLAN FOR IMPROVING THE NOT-YET PERFECT AREAS

A high priority should be given to make the serial transmission and reception fully interrupt-driven. More time is needed to investigate how to make CPM accept interrupts from the ISA bus controller. The priority assignments of the CPM interrupts must also be investigated so that both Ethernet and serial interrupts can be handled correctly.

The current design fails the stress test where collisions occur. This must be resolved before going for full-scale production. From the current knowledge of the CPM, it is known that when CPM senses an error when receiving, it will skip the current BD and proceed to next BD. Therefore, the current RxBD will contain the partially received packet and will never be emptied again. Therefore, the Ethernet ISR must be notified such that it will reset the empty bit when an error occurs.

It is also necessary to have the timer enabled in order to calculate the processing delay of the software code. The timer must be running on the board in order to obtain accurate measurement of the speed. More time is needed to enable the system timer on the Motorola so that it trigger an interrupt every certain second. A counter will be incremented each time the ISR is triggered. By reading the counter value change, the delay can be calculated from receiving a packet to sending to the other interface.

Finally, the GetLocalIP procedure needs to be implemented so that it automatically updates the local board's IP address. This can be done by pinging the local PC and retrieve the IP address of the local PC from the reply message. More research on IP protocol is needed.

5.0 REFERENCES

[1] Motorola Inc., "MPC8260 PowerQUICC II User's Manual". Motorola Inc., 1999.

[2] Red Hat Inc., "ECOS CVS," http://sources.redhat.com/ecos/ (current July 09, 1999)

[3] Linx Technologies, "HP Series-II Receiver Module Design Guide", Linx Technologies, 2000.

APPENDIX A: CUSTOMER REQUIREMENTS

The design of the WELA is fully based on the Customer Requirements. It is agreed with the customer of the WELA that it is to be 100% compatible with the existing Ethernet technology (IEEE 802.3). This is the first priority according to the customer. This requirement is especially important as it allows users to turn an existing configured, wired Ethernet network to a wireless Ethernet network without any additional capital spending expect for this device. To verify that the device is 100% compatible with Ethernet standard, the prototype will be attached to the Ethernet port and check for network functionality.

The second priority from the customer is cost. The customer only provides $400 for the construction of this prototype. Therefore, the components of the prototype of the WELA are mostly sponsored from other companies. However, the cost of the final product can be reduced significantly in mass production.

Another critical requirement from the customer is the transmission rate, which is the third priority. The ideal transmission rate should be as close to normal Ethernet speed, 10Mbps, as possible. However, due to the limited budget, a slower prototype is build to demonstrate the concept of the device. To conserve budget, it is agreed that a transceiver with a maximum transmission rate of 50kbps is used for this prototype. In addition, the maximum transfer rate of the serial port on the Motorola board used is 2.4Mbps. The logical processing of the code used also requires additional time. Upon completion of the prototype, if there is an interest in the device from the customer, the transmission rate can easily be improved by using faster transceiver, faster processor, and optimisation of codes.

The fourth, fifth, and sixth priorities from the customer are the transmission distance, the packet error rate and the transceiver output power respectively. The customer requires that the device can support a maximum distance of 25 meters under normal condition with a packet error rate of less than 2%. The customer stated that normal condition is one in which there are no obstacles between the two devices. As discussed with the customer, the transmission distance and the packet error rate can be improved by selecting faster transceiver that will have a stronger signal. For the transceiver output power, the customer requires the RF output power of the transceiver to be less than 1mW. A longer transmission distance can be achieved if the maximum output power requirement is relaxed. A 1W output power is limited due to regulations from Industry Canada.

The last priority is scalability. The customer requires that the WELA can support a Class C Ethernet network. Due to limitation of budget, it is agreed that a point-to-point prototype is built for proof of concept. To accommodate more network nodes, we advised the customer that a separate collision algorithm has to be implemented.

Table A-1: Summary of Customer Requirements

Priority	Requirement	Measurable
1	Compatibility with existing Ethernet network	100% compatible (no reconfiguration at terminals required)
2	Cost	Mostly sponsored
3	Speed (baud rate)	50kbps
4	Distance	25m
5	Packet Error Rate	2%
6	Maximum transceiver output power	1mW
7	Scalability	Point to point

APPENDIX B: PROJECT PLAN AND MILESTONES

B.1 PROJECT PLAN

Work distribution:

This project will be subdivided into several functional groups. Each group member will be responsible for working on his own area.

Table B- 1: Summary of Work Distribution

Group Name	Description of Responsibilities	Expected Design Challenges
Wireless transceiver group	*This group will be responsible for ensuring the pair of transceivers can communicate to each other and meets all RF requirements. Tasks include choosing a proper antenna and suitable ground plate, testing the wireless communication between the transceivers, and measuring the output power.* ***Ricky** and **E'Kong** will be responsible for this component of the project.*	♦ Interface the transceiver with the RS-232 port. ♦ Making sure that the voltage logic level is the same for the Motorola Board and the transceiver. ♦ Ensure transceivers can operate in full-duplex mode; if not, handshaking algorithms needed for half-duplex operations.

PC utility software group	*This group will be responsible for writing all the test programs on the PC side in order to test sending and receiving packets to the Ethernet port. These programs can be used not only to test the functionality of the prototype, but also for obtaining different statistics about the performance of our prototype. It can also provide useful information when debugging our embedded code running on the Motorola board. The group also needs to write programs to send pre-build packets to the serial port and to receive and display packet received from the serial port.* ***Tim** and **E'Kong** will be responsible for writing these Win32 based software.*	♦ Mastering Windows socket functions. ♦ Develop algorithm to calculating the speed of transmission accurately. ♦ Develop software to assemble and disassemble packets for display and transmission.
Embedded PowerPC software group– Ethernet module	*This group will be responsible for getting familiar with the use of the Ethernet port on the Motorola board. Writing software code to access packets with the Ethernet port and a buffer residing on the Motorola board. Main tasks include ensuring the PC and the board can communicate to each other, and write code to read and write packets from the Ethernet port.* ***Tim** and **Henry** will be responsible for writing the code for this component.*	♦ Minimizing the delay between receiving a packet and sending to the other interface. ♦ Partitioning packets into smaller size for serial transmission.
Embedded PowerPC software group – Serial port module	*This group will be responsible for getting familiar with the use of the serial port on the Motorola board and write software code to access the serial port. The serial port is the port to be connected to the data pins of the transceiver. Main task including writing code to read and write to the transceiver.* ***Ricky** and **Henry** will be responsible for this part of the project.*	♦ Minimizing the delay between reader a buffer and send to transceiver. ♦ Improving the error rate and implementing handshaking algorithms between transceivers. ♦ Assemble serial packets into bigger Ethernet packet.

B.2 PROJECT MILESTONES

Table B- 2: Design Project Milestones

Index	Start Date	End Date	Milestones	Group	Status
1	Oct 1, 2000	Oct 30, 2000	Initial research	All members	Completed
2	Nov1, 2000	Nov 31, 2000	Submit proposal and budget, find sponsors	All members	Completed
3	Dec 1, 2000	End of Dec 2000	Develop initial system design, finalize requirements and specifications	All members	Completed
4	Beginning of Jan 2001	End of Jan 2001	Decide on which FPGA and transceiver to use	All members	Decided to use Motorola board
5	Middle of Jan 2001	End of Jan 2001	Develop handshaking algorithm to avoid collisions on wireless channel	All members	No longer part of the customer requirement
6	Middle of Jan 2001	End of Jan 2001	Investigate possible encryption schemes	All members	No longer in customer requirement
7	Beginning of Feb 2001	End of Feb 2001	Develop algorithm for retrieving/sending contents between wireless transceiver and FPGA	All members	No longer in customer requirement
8	Beginning of Feb 2001	End of Feb 2001	Finalize design and order required components	All members	Ordered Motorola board and some sample National chips, transceiver not received yet.
9	May 01, 2001	May 5, 2001	Revise customer requirements (due week 2)	All members	Completed
10	April 20, 2001	May 7, 2001	Power up Motorola board and verify PC can communicate with debug console	All members	Completed
11	May 7, 2001	May 14, 2001	Verify PC can ping Ethernet port of Motorola board and investigate how to control the Ethernet port	Embedded PowerPC Software – Ethernet module	Completed
12	May 01, 2001	May 11, 2001	Obtain transceivers from school lab	Wireless Transceiver	Decided to order our own
13	May 7, 2001	May 11, 2001	Revise project milestones (due week 3)	All members	Completed

14	May 14, 2001	May 18, 2001	Write Functional specification, Verification Plan and Test Plan (due week 4)	All members	Completed
15	May 21, 2001	May 31, 2001	Investigate, test and verify wireless communication between transceivers	Wireless Transceiver	To do
16	May 21,2001	June 8, 2001	Investigate how to retrieve contents received from Ethernet port on Motorola board and write algorithm to retrieve the content.	Embedded PowerPC Software – Ethernet module	80% Completed
17	May 21, 2001	May 27, 2001	Develop PC application to send/receive packets between PC and Ethernet controller; Verify packet contents	Embedded PowerPC Software – Ethernet module	To do
18	May 21, 2001	May 27, 2001	Write Design Specification and project interim report (due week 5)	All members	Completed
19	May 28, 2001	June 1, 2001	Investigate how to access COM2 of the Motorola board in order to read/write to the transceiver	Embedded PowerPC Software – serial port module	To do
20	May 24, 2001	June 1, 2001	Request for the 2nd Motorola MBX Evaluation Board	Embedded PowerPC Software – Ethernet module	Pending
21	May 28, 2001	June 1, 2001	Order and receive a new transceiver from RF Digital	Wireless	Completed
22	May 28, 2001	June 8, 2001	Implement and test algorithm for reading and sending to transceiver	PC utility software	To do
23	June 1, 2001	June 15, 2001	Test transceiver for functionality	Wireless	50% Completed
24	May 28, 2001	June 8, 2001	Implement and test algorithm for reading and sending to transceiver	PC utility software	To do
25	June 5, 2001	June 15, 2001	Write programs in PC to disassemble and assemble packets	PC utility software	To do
26	June 10, 2001	June 20, 2001	Write programs in PC to send and receive data in the serial port	PC utility software	To do

27	June 10, 2001	June 17, 2001	Merge the different modules of the code together	All members	To do
28	June 17, 2001	July 7, 2001	Testing of the entire system	All members	To do
29	July 1, 2001	July 7, 2001	Target project completion date		To do
30	July 16, 2001	July 20, 2001	Project signoff (due week 12)	All members	To do
31	July 16, 2001	July 22, 2001	Design project abstract (due week 13)	All members	To do

B.3 EXPECTED/KNOWN REQUIREMENTS

Table B- 3: Expected or Known Requirements of the Project

Requirements	Needed	Comments
Lab Space	Microwave lab	We required using the **Microwave lab** to do measurement of the wireless transceiver. We have made arrangements with the associated about the use of the lab and permission has been granted.
Equipment	Power meter or spectrum analyzer	We need a **power meter** or **spectrum analyzer** to measure the RF output power of the transceiver to see if it satisfies the customer requirements. The equipment can be found in the Microwave lab.
	DC power supply	Also we need **two DC power supplies** to power up the two Motorola MBX Evaluation board. We have acquired one power supply and will request the second one from the Lab technician once we get the second Evaluation board.
	Transceiver	We have ordered a pair of **transceivers** from RF Digital Corporation. The cost of the transceiver will be taken from the budget allocated for the budget.
	Motorola MBX Evaluation Board	We need two **MBX Evaluation Boards** for the implementation of the design project. The board will serve as the prototypes. We currently got one of the board and now urgently requesting for the second board.

Software	Embedded Development Kit (EDK)	The **EDK** is needed because it is an essential tools to compile and assemble the code that is executed by the Motorola MBX Evaluation Board. We have already download and installed the development kit.
Budget	$600	We got allocated $400 for this project. However, due to the fact that we cannot get the transceiver from the lab technician that have previously promised us, we have to use budget to buy it ourselves. This results in an over-budgeted situation and we are currently trying to request for addition funding to cover the extra cost.
Special needs	None	None

APPENDIX C: FUNCTIONAL SPECIFICATIONS

To achieve 100% Ethernet compatibility, the Wireless Ethernet LAN Adapter will have a RJ45 jack that plugs into the RJ45 port of the Ethernet card. This will be a seamless process that requires only plugging the device into the Ethernet port and the network will function properly. The Motorola MBX860 Evaluation Board has been chosen for the demonstration of our concept.

For complete transparency to the host PCs in transport layer and above, each local board must be able to act like the remote PC as if the PCs are directly connected to each other. Therefore, each local board must be set to have the remote PC's IP address to "trick" the local PC that it is directly connected to the remote PC. This IP configuration must be done before the board can start transmitting real packets from PCs. The device must also be able to discard or ask host to retransmit the packet when an invalid address (checksum error) is received from the host PC. The conceptual representation of the design of the WELA is shown in Figure C-1.

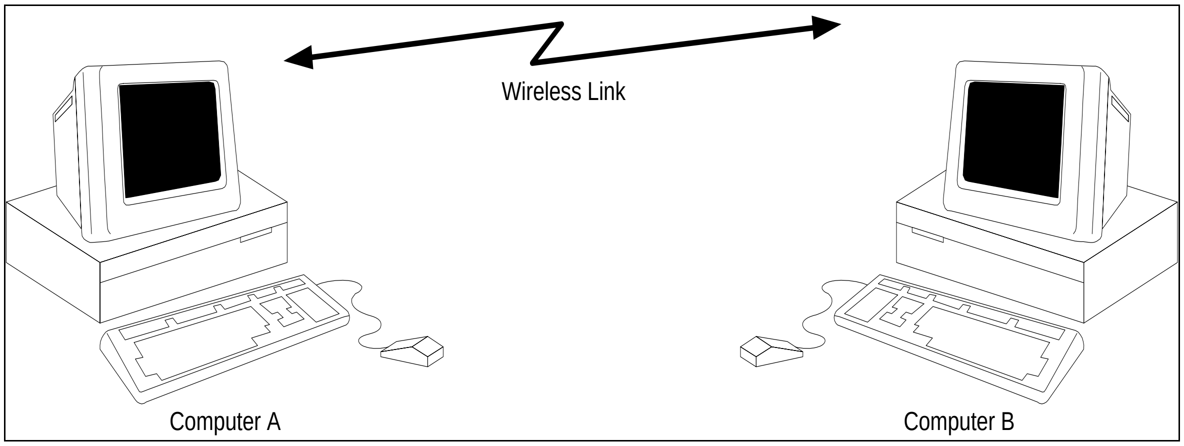


Figure C- 1: Overall System Architecture

The ideal transmission rate of the adapter should be as closed to the normal Ethernet speed, 10Mbps, as possible. Therefore, the software running on the device must be able to receive packet and sending it to the remote PC with a delay of less than 1/10Mbps, which translates to 0.1μs/bit. However, due to the limitation of budget, a transceiver with a transmission rate of 50kbps is used and thus the adapter provides a maximum transmission rate of 50kbps. In addition, the serial port of the Motorola board is used to connect to the transceiver, thus also limit the transmission rate. Other faster interfaces such as the parallel port or the PCMCIA slot could have been used instead; however, in order to use these interfaces to improve the speed to 10Mbps, additional interfacing circuitry is required. Since the transceiver can support only up to 50kbps, it is decided that using the serial port of the Motorola board is sufficient and logical to prove the concept. By using a higher transmission rate transceiver and the parallel port of the Motorola board, the adapter transmission rate can be increased to approach the speed of 1Mbps, if the software code is capable of processing at such high speed.

Since the transceivers are much slower than the Ethernet port, there is a possibility that the Ethernet buffer of the board will be full. The board must be able to stop receiving new packets from PC when the local Ethernet buffer is full in order to avoid overwriting any untransmitted useful data. Also, the device should be able to split a large Ethernet packet into smaller packets for serial transceiver transmission.

The WELA requires a supply power of 12V and the output power limit is set to 1mW. The adapter supports a packet error rate of less than 2%. The low output power requirement of the adapter as well as the required packet error rate limits the transmission distance to a maximum of 25m. If a greater output power limit is permitted, then the distance can be increased. In addition, the adapter will support a point-to-point network instead of a small network due to the limitation of the budget.

Table C- 1: Function Specifications of the WELA

Processor		
Microprocessor	MPC860EN	
Clock Frequency	50MHz	
Performance	52/62 MIPS estimated	
Power Requirements (board only)		
Supply Power	3V, 5V, 12V	
Total Consumption:	17 watts typical	
+5V ±5%:	2.6 amps typical	
+3.3V ±10%:	1.0 amps typical	
Environmental		
	Operating	**Non-Operating**
Temperature	0°C to +70°C	-40°C to + 85°C
Humidity	10% to 80%	10% to 90%
Vibration	2 Gs RMS 20–2000 Hz random	6 Gs RMS, 20-2000 Hz random
Input/Output Ports	RJ45 Ethernet input, Wireless medium	
Transceiver		
Rate	50kbps	
Distance	25m	
Supply Power	12V	
Output Power	1mW	
Ethernet Network Compatibility		
Transmission Rate	50kbps	
IP Address	Automatically configured to remote PC's address	
Error Detection	Header error detection	

Busy Signals	Automatically generate collision signals when local buffer is full

APPENDIX D: DESIGN SPECIFICATIONS

D.1 OVERVIEW

The WELA system consists of both hardware and software components. Our hardware components consist of the Motorola MBX860 Evaluation board and transceivers. The Motorola board has an Ethernet port and a serial port. The main design of the project is to write efficient software code to interface between the Ethernet port and serial port. A top level system diagram of the WELA system is shown in Figure D- 1.

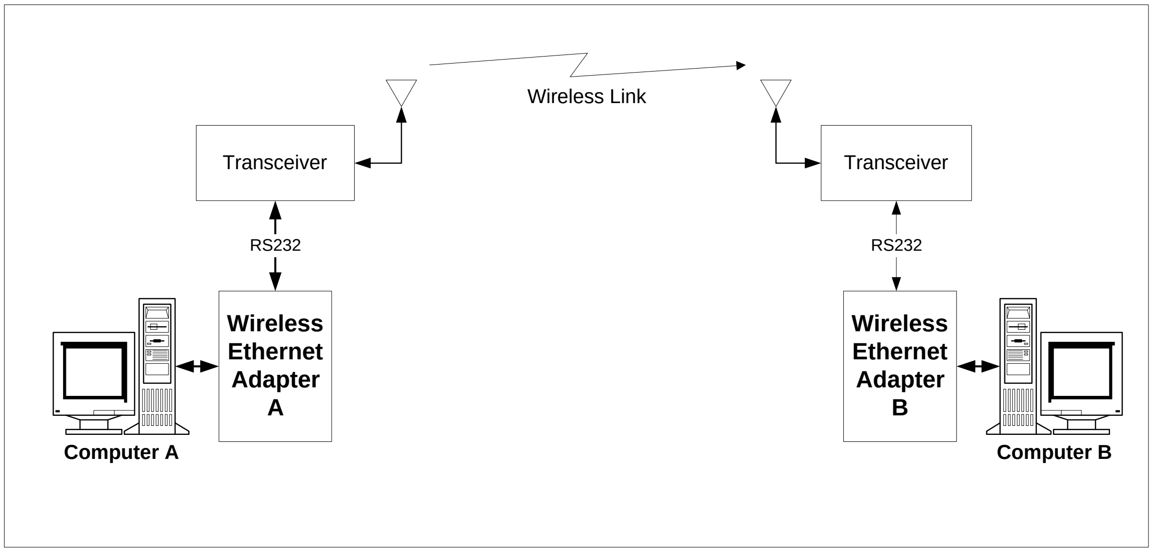


Figure D- 1: Top Level System Diagram

All port data transfers on the Motorola board are coordinated by the Communication Processor Module (CPM) hardware inside the PowerPC 860 chip. The CPM is responsible for copying the data received from the port's FIFO to the system's main memory using DMA transfer. The CPM allows newly received port data to be copied to the system's main memory without interrupting the CPU. Because of that, by the time the software detects that new data has arrived, the new data is already sitting in the main memory. On the other hand, when transmitting data to the port, the CPM is responsible for copying the data from the main memory to the port's output FIFO. A significant portion of the software design has to do with interfacing with the CPM hardware efficiently.

D.2 HIGH-LEVEL DESIGN

D.2.1 DESIGN APPROACH

The WELA system contains four main modules: Copy Module, Ethernet Interface, Serial Interface, and Initialization. Therefore, a modular design approach is used. Figure D- 2 provides a top-level structure illustration of the system.

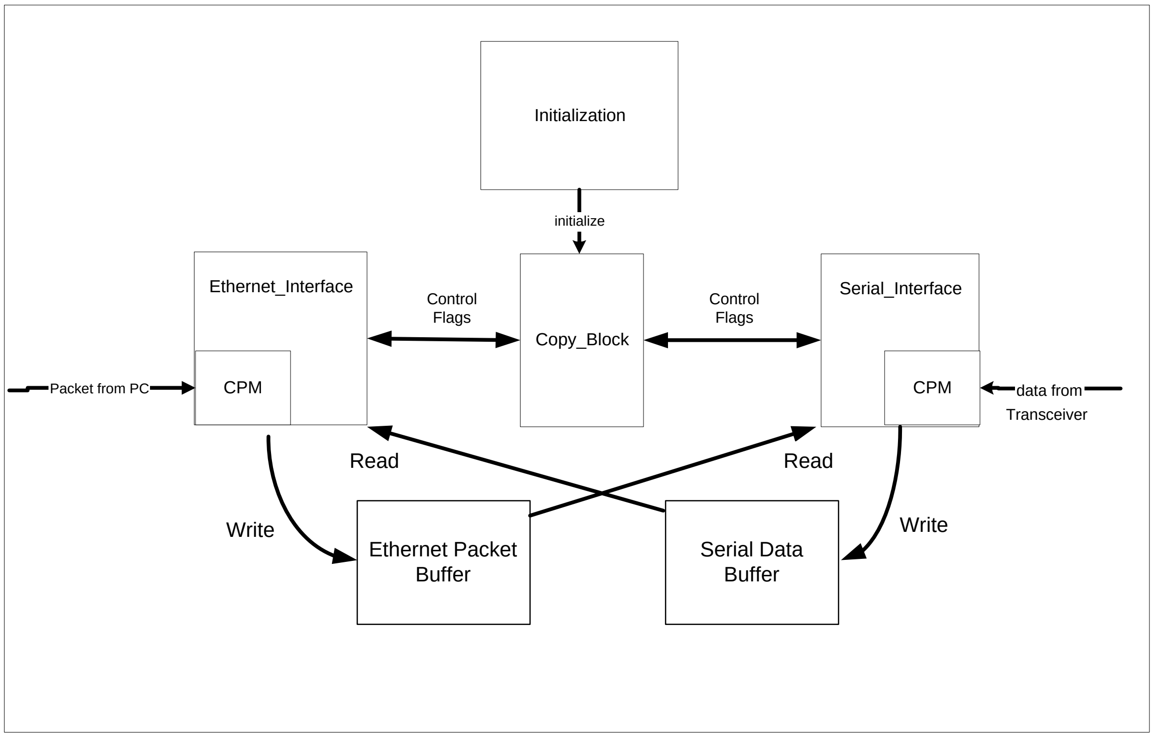


Figure D- 2: Top Level Structure Diagram

The Copy Module is subdivided into modules and the modules will be further divided into functions and procedures. These are illustrated in the process structure charts in the following sections. In designing the modules, a top-down approach is chosen. It is because a top-down approach is suitable for group discussions and it gives a clear analysis of the functionality of the whole WELA system. However, in the implementation of the WELA system, a bottom up approach will be used because facilitates debugging and testing of the programmed code separately. Also, it allows a better work division among the group members. The modules should be able to be tested individually and then combined together to form the whole WELA system.

D.2.2 SYSTEM EVENT DIAGRAM

Figure D- 3 is the system event diagram, which shows the logical sequence of events that happens when Computer A wants to send a packet to Computer B. During a normal transmission, the packet arrives the Ethernet interface of the adapter. The Ethernet packet is partitioned into smaller data chunks and put into the serial transmit interface. The smaller data chunk leaves the serial interface and is sent through the wireless transceiver. Then the serial interface notifies the Ethernet interface that the serial interface is ready to transmit the next data chunk. Adapter A keeps sending those partitioned data chunks until the entire Ethernet packet has been transmitted. On the remote side, when Adapter B's transceiver receives the data from adapter A's transceiver, the data is first put into a local buffer by the CPM. It keeps receiving packets until the entire Ethernet packet has been received. Then, the Ethernet interface of Adapter B checks if the header of the received Ethernet packet is valid. If it is valid, the packet is sent to Computer B and this means the transmission is done.

In the event that the Ethernet buffer is full when computer A tries to send a packet to Ethernet adapter, the Ethernet interface will send a busy signal to Computer A. Computer A will then retry after a certain timeout.

In the event that the local serial buffer is full, the Ethernet interface will wait until the serial buffer is ready again. Note that even if the serial buffer is full, the Ethernet interface can still accept packets from local computer until the Ethernet buffer is full. The computer will be notified when the Ethernet buffer can accept packets again and the normal sequence will once again be executed.

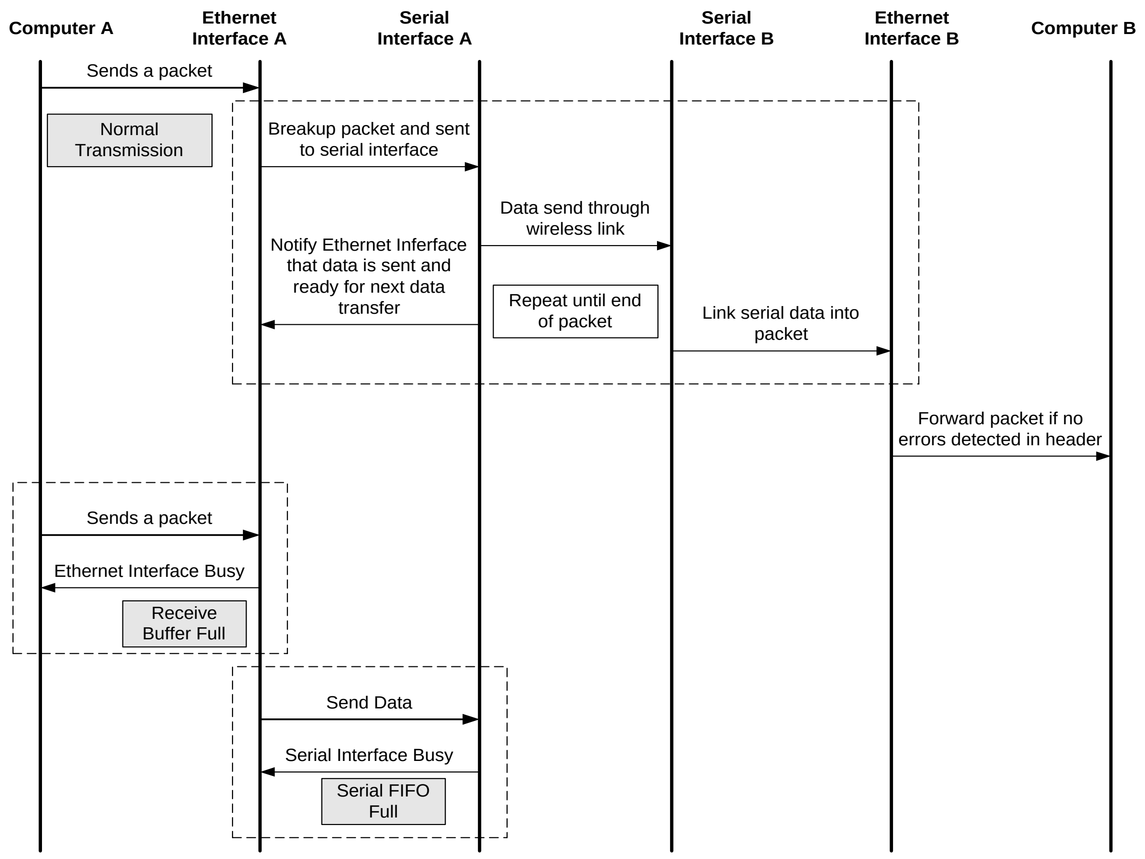

Computer A
Ethernet Interface A
Serial Interface A
Serial Interface B
Ethernet Interface B
Computer B
Sends a packet
Normal Transmission
Breakup packet and sent to serial interface
Data send through wireless link
Notify Ethernet Inferface that data is sent and ready for next data transfer
Repeat until end of packet
Link serial data into packet
Forward packet if no errors detected in header
Sends a packet
Ethernet Interface Busy
Receive Buffer Full
Send Data
Serial Interface Busy
Serial FIFO Full

Figure D- 3: System Event Diagram

Table D-1 provides a description for each of the modules of the system.

Table D- 1: Module Description

Module	Description
Serial_Interface	The Serial ISR Block is used to service interrupts generated by events related to the serial port. Whenever new data is received from the serial port, an interrupt will be generated after the new data is copied to a buffer.
Ethernet_Interface	The Ethernet ISR Block is used to service interrupts generated by events related to the Ethernet port. When new data is received from the Ethernet port, an interrupt will be generated after new data is copied to a buffer.

Copy_Block	The Copy Block is used to coordinate the data manipulation between the Ethernet port and the serial port. For data coming in from the Ethernet port stored in Ethernet BD, it will disassemble the packet into smaller serial port packet. For data coming in from the serial port stored in serial buffer, it will reassemble the packet into larger Ethernet port packet.
Initialization	The Initialization block is used to set up and initialize all global data structures.

D.2.3 TRANSMISSION OF DATA FROM ETHERNET TO SERIAL INTERFACE

Figure D- 4 shows the different interactions of the components listed in Table D-1 when a data packet comes in from the Ethernet interface.

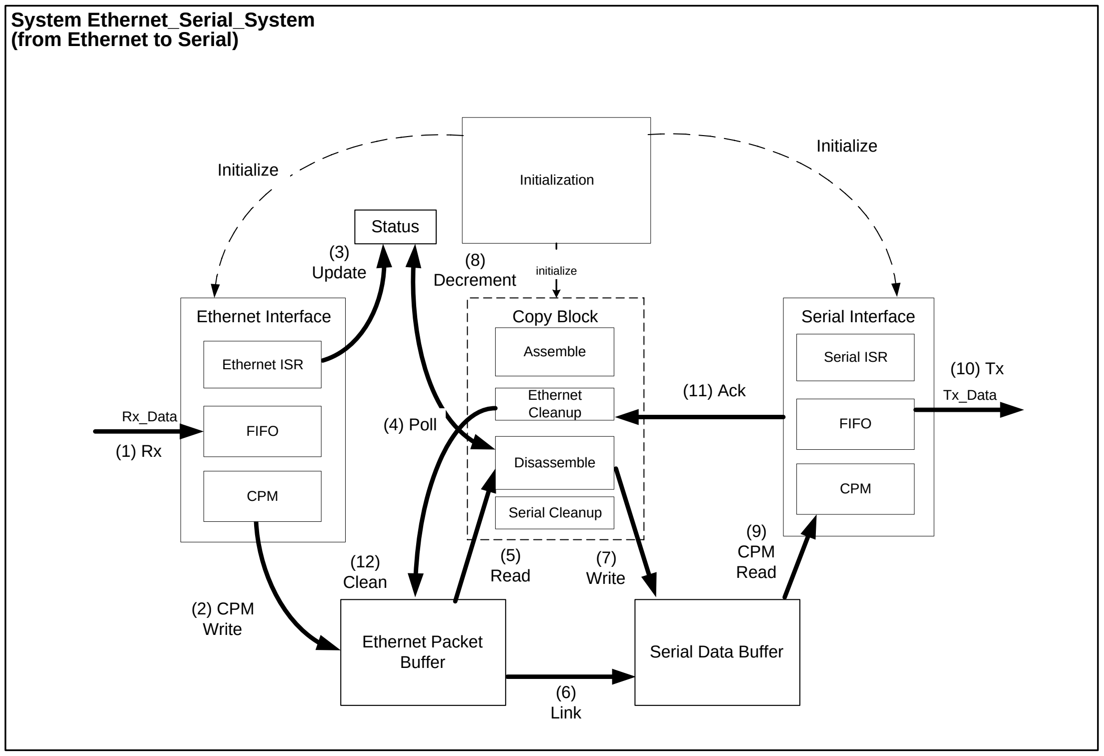


Figure D- 4: Transmission of a Packet from Ethernet to Serial port

The following sequence happens to process the data packet until it is transmitted out of the serial interface:

1. Data packet is received into the receive FIFO queue.
2. CPM moves the data from the FIFO queue into the Ethernet receive buffer.
3. CPM generates an Ethernet interrupt to trigger Ethernet Receive ISR. The ISR increments the disassemble status variable to indicate that there is one more packet ready for disassemble.
4. The copy module is constantly checking for the disassemble status variable.
5. When the status variable indicates that there is unprocessed packet, the disassemble function will attempt to locate the unprocessed packet (buffers are process based on a FIFO scheme). This is done by checking the BD that is pointed by the Current_Unprocessed_Ethernet_RX_Ptr of the Ethernet RX BD table. Once the unprocessed packet is located, the disassemble function reads in the packet length and the starting location in the memory.
6. The disassemble function calculates the amount of serial TX BDs needed to transmit the Ethernet packet. It will setup the serial TX BDs to point to each segment in the packet for serial transmission. Also, a serial TX BD will be pointed to the "End of Packet Sequence" after the Ethernet buffer is fully disassembled.
7. The disassemble function will set the Ready Bit of the serial TX BDs associated with the Ethernet packet to 1 for CPM processing.
8. Disassemble function decrements disassemble status variable to indicate the data packet stored in the buffer has been disassembled.
9. Move Current_Unprocessed_Ethernet_RX_Ptr to the next BD in the Ethernet RX BD table. CPM is constantly monitoring the empty bits of the serial Transmit BD, when it finds BDs that have ready bits set to 1, it processes the buffer by copying the data in the buffer to the serial Transmit FIFO queue. After the BD is processed, the ready bit of the BD is set to 0. The serial interface hardware sends out data in the serial Transmit FIFO queue.
10. After CPM processes a serial TX BD that is pointed to the "End of Sequence", it generates a serial interrupt to trigger serial Transmit ISR.

11. The ISR will acknowledge the Ethernet Cleanup routine.
12. The Ethernet Cleanup routine will free up the buffer that holds the sent packet.

D.2.4 TRANSMISSION OF DATA FROM SERIAL TO ETHERNET INTERFACE

Figure D- 5 shows the different interactions of these components when a data packet comes in from the serial interface.

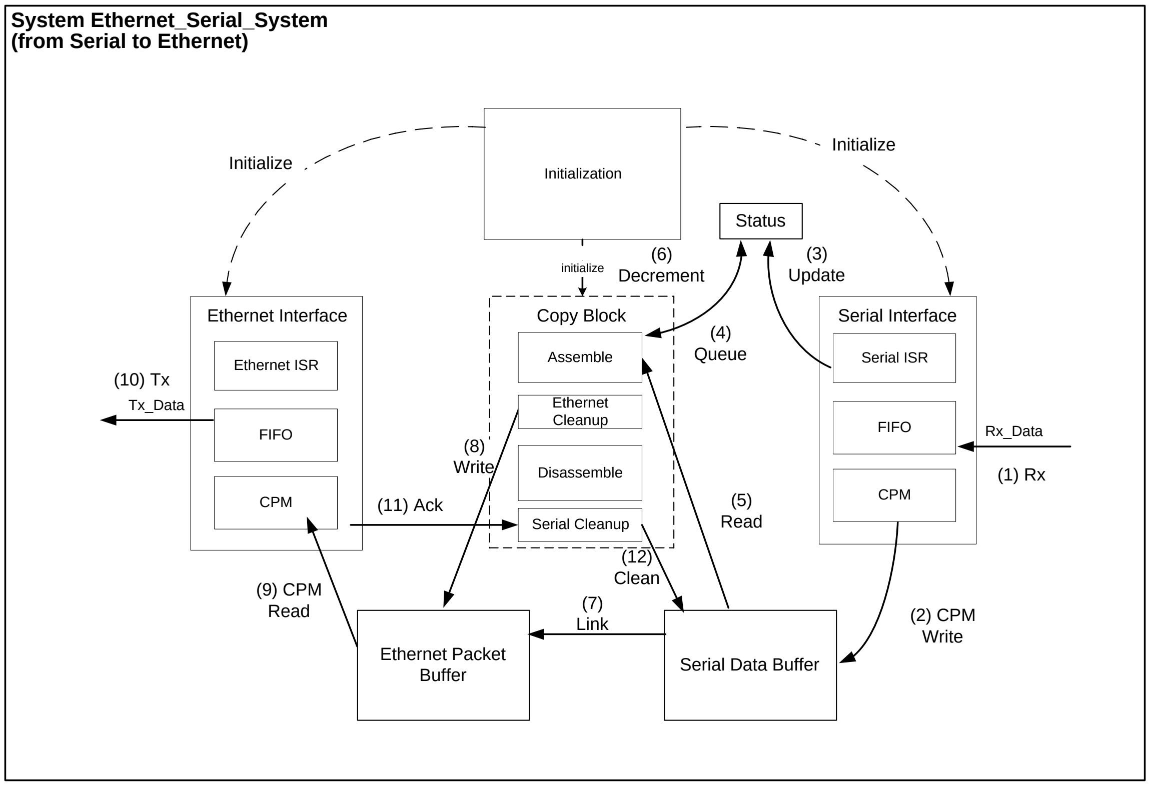


Figure D- 5: Tranmission of a Packet from Serial port to Ethernet

The following sequence happens to process the data packet until it is transmitted out of the Ethernet interface:

1. Data packet is received into the serial receive FIFO queue.
2. CPM moves the data from the FIFO queue into the serial data buffer.

3. CPM generates a serial interrupt to trigger serial Receive ISR. The ISR increments the assemble status variable to indicate that there is one more packet ready for assemble.
4. The copy module is constantly checking for the assemble status variable.
5. When the status variable indicates that there is an unprocessed data, the assemble function will attempt to locate the unprocessed data (buffers are process based on a FIFO scheme). This is done by checking the BD that is pointed by the Current_Unprocessed_Serial_RX_Ptr of the Serial RX BD table. The assemble function reads in the data length and the starting location of the data.
6. The Assemble function decrements assemble status variable to indicate the data packet stored in the buffer has been assembled.
7. The Assemble function will link the data in the serial RX BD into a packet.
8. After CPM processes a serial RX BD that contains the "End of Packet Sequence", it sets the Ready Bit of the Ethernet TX BD to indicate to the CPM that the packet is ready for transmission.
9. The CPM will move the ready Ethernet TX BD's packet to the FIFO queue for transmission. The ready bit of the Ethernet TX BD will be automatically cleared by the CPM after the packet is moved to the FIFO queue.
10. The packet will get transmitted through the Ethernet interface.
11. After the packet is transmitted, the TX ISR will run to acknowledge the Serial Cleanup routine.
12. The serial Cleanup routine will free up the buffer that holds the sent packet.

D.2.5 BLOCK DIAGRAM FOR THE COPY MODULE

The following Figure D- 6 shows the modular diagram of the Copy Module. The Copy Module consists of four functions: Disassemble, Assemble, Ethernet TxBD Cleanup, and Serial TxBD Cleanup.

When new data packets arrive from the Ethernet port, the disassemble function will partition the packets into smaller packets so that they can be handled by the serial interface. After all the smaller partitions of an Ethernet packet are sent, an ISR will notify the Ethernet RxBD Cleanup function to mark the Empty Status Bit of the BD for the Ethernet packet to 1. The value of 1 in the Empty Status Bits indicates that the BD is available for use. When new data arrive from the serial port, the assemble function will reassemble all the partitioned packets that the serial port has received back into an Ethernet packet. After the Ethernet packet is sent to PC, an ISR will notify the Serial RxBD Cleanup function to mark the Empty Status Bit of the Serial BDs that are used to reconstruct the Ethernet packet to 1.

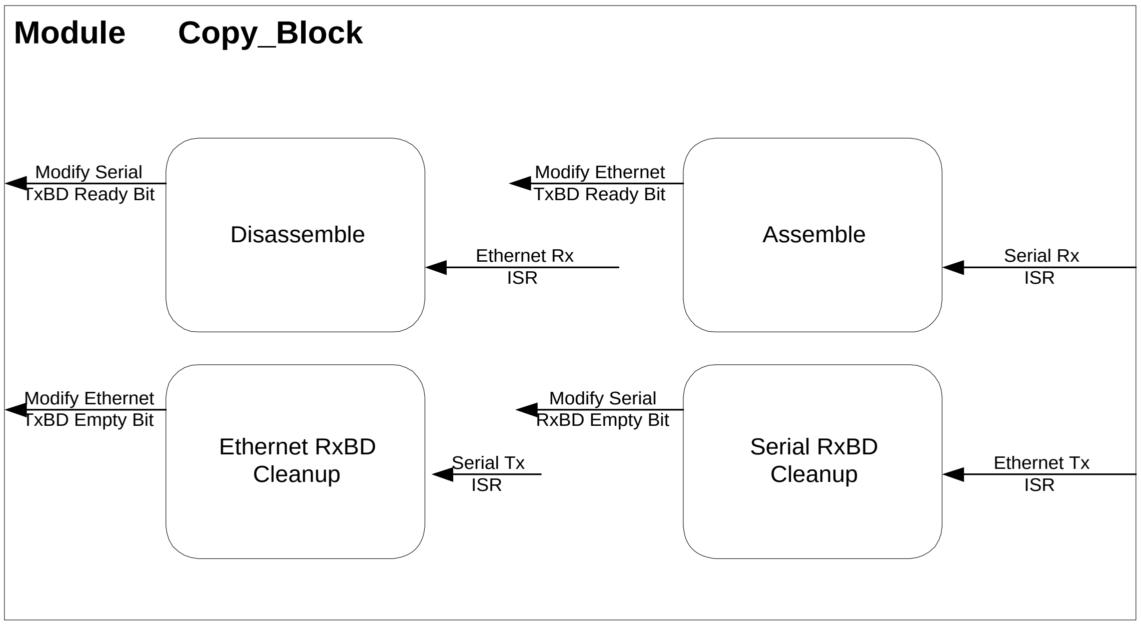
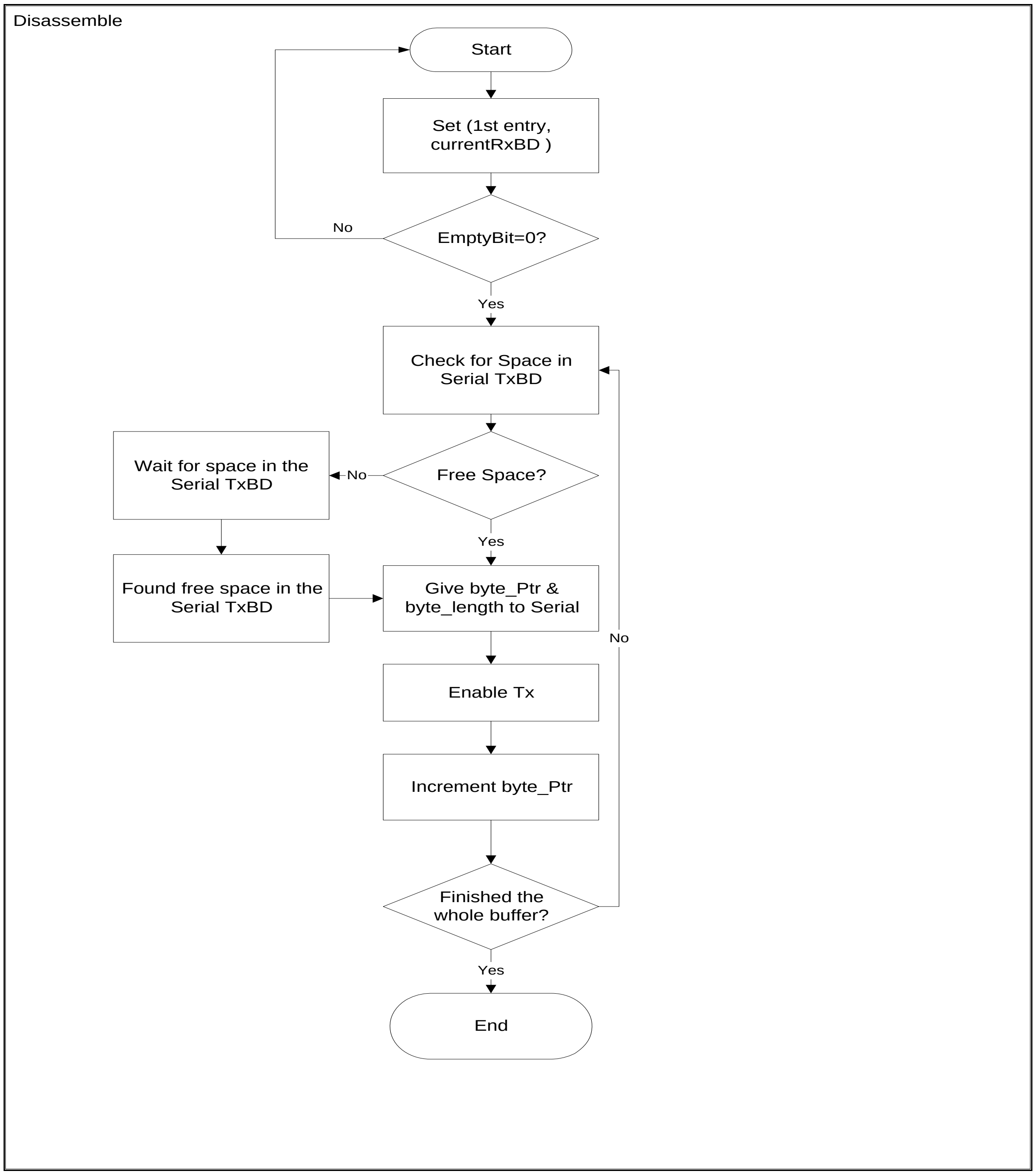


Figure D- 6: Block Diagram for Copy Module

D.2.5.1 Flow Chart for the Disassemble Function

Figure D- 7 shows the flow chart for the disassemble function that is part of the copy module.



Disassemble
Start
Set (1st entry, currentRxBD)
EmptyBit=0?
No
Yes
Check for Space in Serial TxBD
Free Space?
No
Wait for space in the Serial TxBD
Found free space in the Serial TxBD
Yes
Give byte_Ptr & byte_length to Serial
Enable Tx
Increment byte_Ptr
Finished the whole buffer?
No
Yes
End

Figure D- 7: Flow Chart for Disassemble Function

D.2.5.2 Flow Chart for the Assemble Function

Figure D- 8 shows the flow chart for the assemble function in the copy routine.

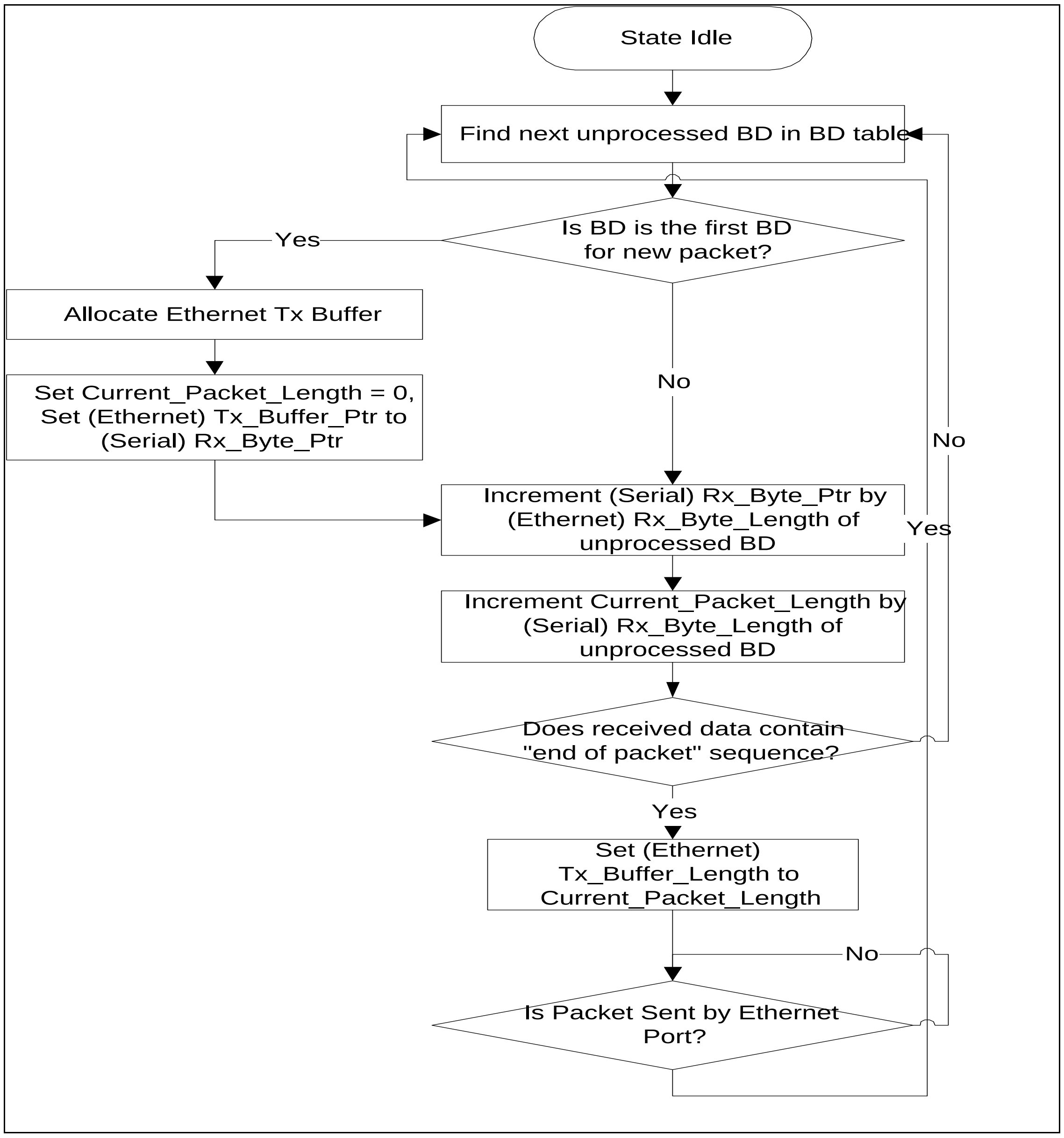

State Idle
Find next unprocessed BD in BD table
Is BD is the first BD for new packet?
Yes
Allocate Ethernet Tx Buffer
Set Current_Packet_Length = 0, Set (Ethernet) Tx_Buffer_Ptr to (Serial) Rx_Byte_Ptr
No
No
Increment (Serial) Rx_Byte_Ptr by (Ethernet) Rx_Byte_Length of unprocessed BD
Yes
Increment Current_Packet_Length by (Serial) Rx_Byte_Length of unprocessed BD
Does received data contain "end of packet" sequence?
Yes
Set (Ethernet) Tx_Buffer_Length to Current_Packet_Length
No
Is Packet Sent by Ethernet Port?

Figure D- 8: Data Flow Diagram for Assemble Function

D.2.6 SYSTEM INITIATION

During startup of the WELA system, a script will be run to initialize the system. First, it will initialize the stack pointer and the interrupt vector table. After which the Ethernet Initialization sequence and Serial Initialization sequence will be ran. Lastly, the pointers used by the Copy Module will be initialized, the Rx interrupts will be enabled, and finally the GetLocalIP procedure will be executed before returning to the main routine.

D.2.7 ETHERNET INTERFACE

The Ethernet Interface module contains one interrupt routine that is executed under one condition. The interrupt routine will be executed after a packet has been received from the computer into the Ethernet Interface. During the execution of this interrupt, the Copy Module will be notified that a new packet has been received and increment a counter that keep tracks of total number of packets stored in the Receive Buffer.

D.2.8 SERIAL INTERFACE

For the Serial Interface module, there is one interrupt routine that will be executed under one condition. For the interrupt routine, it is executed after a set of serial data has been received from the serial interface. During this interrupt routine, the Copy Module will be notified about the data length of this new set of serial data for the reconstruction of different sets of serial data into one complete packet.

D.2.9 GETLOCALIP PROCEDURE

During the final stage of system initialization, the GetLocalIP procedure will be executed. This procedure is executed for the exchange of IPs between the two wireless Ethernet adapters. At this stage of system initialization, the two wireless Ethernet adapters have been powered up and communication links can be established with their attached computer. The wireless Ethernet adapters will first request the IP of their associated computer. The associated computer broadcasts its IP through the reply message it sends to the wireless Ethernet adapter. After both the wireless Ethernet adapter A and B have received the IP of their associated computer, they will send each other a message to exchange this information. After this exchange of information, the two Ethernet adapters will then configure their own IP address to be that of the computer they are not attached to. This procedure is illustrated in the following Figure D- 9.

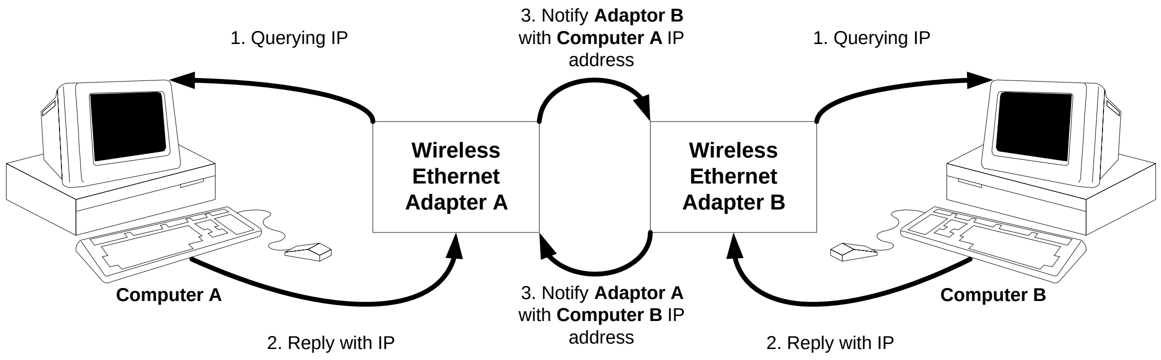

1. Querying IP
3. Notify **Adaptor B** with **Computer A** IP address
1. Querying IP
Wireless Ethernet Adapter A
Wireless Ethernet Adapter B
Computer A
Computer B
3. Notify **Adaptor A** with **Computer B** IP address
2. Reply with IP
2. Reply with IP

Figure D- 9: GetLocalIP Procedure Diagram

D.3 LOW-LEVEL DESIGN

D.3.1 GLOBAL STRUCTURES

In the following Table D-2, the description of the global variables used for the WELA system is explained.

Table D- 2: Description of Global Variables

Variable Name	Description
int Unassemble	The total number of received serial buffers that have not been processed.
int Disassemble	The total number of received Ethernet buffers that have not been processed.
int EthernetTx_Buffer_Ptr	The pointer to the currently processing Ethernet transmit buffer.
int EthernetRx_Buffer_Ptr	The pointer to the currently processing Ethernet receive buffer.
int SerialTx_Byte_Ptr	The pointer to the currently processing serial transmit buffer.
int SerialRx_Byte_Ptr	The pointer to the currently processing serial receive buffer.
int Current_Unprocessed_Serial_Rx_Ptr	The pointer to the first unprocessed serial RX BD
int Current_Unprocessed_Ethernet_Rx_Ptr	The pointer to the first unprocessed Ethernet RX BD.
int First_Disassembled_Unsent_Ethernet_RX_*BD*_Ptr	The pointer to the first disassembled but unsent Ethernet RX BD.
int First_Assembled_Unsent_Serial_RX_BD_Ptr	The pointer to the first assembled but unsent serial RX BD.

D.3.1.1 Description of Buffer Structure

Before introducing other global structures, the structure of a buffer is described first. It is due to the fact that the Buffer Structure is an extremely important component of the WELA. The data is stored in buffer and each buffer is referenced by a buffer descriptor (BD). Each BD is 8 bytes long. Two bytes are used as control bits. Two bytes are used to store the data length. Four bytes are used to store the address of the memory location of the buffer. Figure D- 10 provides a representation of the buffer.

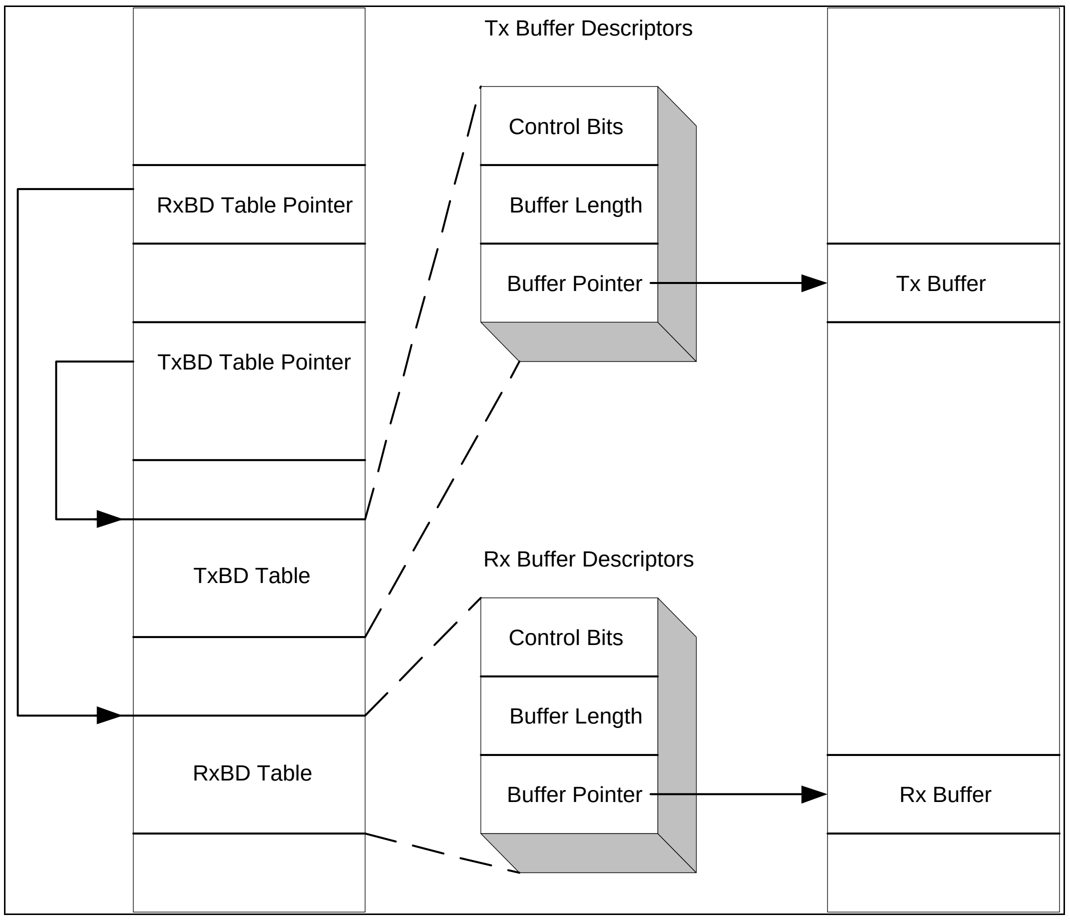


Figure D- 10: Buffer Structure

D.3.1.2 Addition data structure

Transmit Buffer Descriptor:

```
typedef struct Tx_BD_t
{

   /* Control Bits */
      bool  ready;      /* flag to indicate data ready for
                        transmission.
                        0 = buffer does not contain data need to be
                        transmitted, can be used to store new
                        transmission data
                        1 = buffer contains data need to be
                        transmitted */

   bool wrap;      /* flag to indicate last BD in Tx_BD table
                     0 = buffer is not the last BD
                     1 = buffer is the last BD */
    bool interrupt;  /* flag to indicate interrupt generated after BD
                     is processed
                     0 = no interrupt generated
                     1 = interrupt generated */

/* Data Length Bits */
    int data_length;  /* 16 bits to indicate the length of data in
                     buffer pointed by BD */

/* Buffer Pointer Bits */
    int Tx_buffer_high_ptr; /* 16 bits to indicate the higher order
                           bits of starting address of the
                           data in buffer pointed by BD */

    int Tx_buffer_low_ptr;  /* 16 bits to indicate the lower order
                           bits of starting address of the data in
                           buffer pointed by BD*/

}  Tx_BD
```

Receive Buffer Descriptor:

```
typedef struct Rx_BD_t
{

/* Control Bits */
bool  empty; /* flag to indicate new data received
                  0 = buffer is not empty, contain new data that has
                  not been processed
                  1 = buffer is empty, can be used to store new
                  received data */
bool wrap;   /* flag to indicate last BD in Rx_BD table
                0 = buffer is not the last BD
                1 = buffer is the last BD */

    bool interrupt;   /* flag to indicate interrupt generated after BD
                      is processed
                      0 = no interrupt generated
                      1 = interrupt generated */

    bool framing_error;  /* flag to indicate framing error has been
                         received
                         0 = no framing error current buffer
                         1 = framing error is received for one
                         character which is located in the last byte
                         of the buffer, a new Rx buffer is used to
                         store subsequent data.*/

    bool parity_error;   /* flag to indicate parity error has been
                         receive
                         0 = no parity error in current buffer
                         1 = parity error is received for one
                         character which is located in the last byte
                         of the buffer, a new Rx buffer is used to
                         store subsequent data. */
bool overrun;   /* flag to indicate overrun
                   0 = no overrun occurred in current buffer
                   1 = receive overrun occurred in data reception */

    bool carrier_detect_lost   /* flag to indicate carrier detect lost
                               0 = no carrier detect lost
                               1 = carrier detect signal is negated in
                               data reception */

/* Data Length Bits */
    int data_length;  /* 16 bits to indicate the length of data in
                      buffer pointed by BD */

/* Buffer Pointer Bits */
    int Tx_buffer_high_ptr; /* 16 bits to indicate the higher order
                            bits of starting address of the
                            data in buffer pointed by BD */

    int Tx_buffer_low_ptr;  /* 16 bits to indicate the lower order
                            bits of starting address of the data in
                            buffer pointed by BD*/
}  Rx_BD
```

D.3.2 SYSTEM INITIALIZATION

Constants are used during initialization. Table D-3 provides the description of these constants.

Table D- 3: Description of Constants used during System Initialization

Constant	Description
TX_BD_TABLE_PTR	This is a value to indicate the starting memory location of the transmit buffer descriptor.
MAX_TX_BD_SIZE	This is a value to indicate the number of transmit buffer descriptors.
RX_BD_TABLE_PTR	This is a value to indicate the starting memory location of the receive buffer descriptor.
MAX_RX_BD_SIZE	This is a value to indicate the number of receive buffer descriptors for the Serial Interface.

The following is the system initialization code:

```
/* Begin System Initialization */
Initialization stack pointer;
Initialization interrupt vector table;
Execute Ethernet Initialization Routine;
Execute Serial Initialization Routine;
Initialize pointers used by main Copy Routine;
Enable Rx interrupts;
Execute GetLocalIP procedure;
/* End of System Initialization */


/* Ethernet Initialization */
Initialize the SCC to be used in Ethernet mode;
Initialize SDMA configuration register;
Initialize RxBD;


/* Initializes all BD in RxBD*/
for i = 0 to max_number_of_BD_in_RxBD_table
{
          empty bit = 1;
          Set buffer pointers to point to the correct receive buffer;
          currentRxBD = first entry;
}

/* Initializes all BD in TxBD */
```

```
for i = 0 to max_number_of_BD_in_TxBD_table
{
          ready bit = 0;
          Set buffer pointers to point to the correct transmit buffer;
          currentTxBD = first entry;
}

Initialize various Ethernet registers;
Set port to receive all packets regardless of the address
(promiscuous mode);
Set port’s RxBD pointer to point to first entry in RxBD table;
Set port’s TxBD pointer to point to first entry in TxBD table;
Initialize Ethernet’s maximum frame size register;
Clear any pending Ethernet events;

/* Serial Initialization */

Enable the SCC for UART mode;
Configure transmit clock rate, parity, and stop bit;
Initialize DMA configure register;
Create list of RxBD and TxBD;

/* Initializes all RxBD in RxBD_List */
for I = 0 to max_number_RxBD_in_RxBD_List
{
          empty bit = 1;
          buffer size = 16 bytes;
          buffer pointer = buffer location;
}

Mark the last RxBD in the list;
Initialize RBASE register to point to first RxBD;
Initialize currentRxBD = RBASE;

/* Initializes all TxBD in TxBD_List */
for I = 0 to max_number_TxBD_in_TxBD_List
{
          ready bit = 0;
          buffer size = 16 bytes;
          buffer pointer = buffer location;
}

Mark the last TxBD in the list;
Initialize TBASE register to point to first TxBD;
Initialize currentTxBD = TBASE;

Clear all previous event in the SCCE2 event register;


/* After Initialization, get localhost IP */

Procedure GetLocalIP
begin
```

```
            Send a broadcast packet;
            Wait for localhost to reply until timeout;
            Retrieve localhost's IP address from content;
            Send IP address to serial port, along with a special
            sequence that this is a special packet for configuration IP
            only;

            /* for serial retrieve routine */
            If (special IP packet)
               Retrieve remote PC's IP from received data;
               Program remote PC's IP into local board's IP;
            else
               Normal retrieve routine;
            endif
  end
```

D.3.3 MODULE DESCRIPTIONS

D.3.3.1 Local data Variables

Table D- 4: Description of Local Variables used during Copy Module

Variable Name	Description
int SerialRxBDindex	The pointed entry in the Serial Receive BD table.
int SerialTxBDindex	The pointed entry in the Serial Transmit BD table.
bool Found_free_serial_TxBD	Flag to indicate that a free Serial Transmit BD buffer is found.
int Current_Packet_Length	The data length of the current packet.
int Ethernet_RxBDindex	The pointed entry in the Ethernet Receive BD table.
int Ethernet_TxBDindex	The pointed entry in the Ethernet Transmit BD table.
bool Found_free_ethernet_TxBD	Flag to indicate that a free Ethernet Transmit buffer is found.

D.3.3.2 Module Pseudocode

Module Main

```
Module Main
{
  Initialise();
  Loop forever
  {
    if (Disassemble > 0)
      call Disassemble function;
    if (Unassemble > 0)
      call Assemble function;
  }
}
```

Function Assemble

```
   Function Assemble
   {
        found = false;
        repeat
          if (SerialRxBDindex == Max_SerialRxBD_Size)
           SerialRxBDindex = 0;
              else
               SerialRxBDindex++;

             /* Find next unprocessed BD in Serial RxBD table;
                It is guaranteed that there will be at least 1 not
                Empty entry else this function won't be called.
             */
             if (SerialRxBD[SerialRxBDindex].Empty == 0)
             {
               Found_free_serial_RxBD = true;
               (Serial) Rx_Byte_Ptr =
                   SerialRxBD[SerialRxBDindex].Buffer_Ptr;
           (Serial) Rx_Byte_Length =
               SerialRxBD[SerialRxBDindex].Length;
             }
          until (Found_free_serial_RxBD);

       if (BD is the first BD for new packet)
       {
      /* find an empty Ethernet Tx slot to store the serial data
                If there are not free Tx slot, this will loop forever.
                Meanwhile, the CPM will keep processing data in
                background and update the BD.  Hopefully, there will be
                an empty slot eventually.
             */
           found_free_ethernet_TxDB = false;
        Repeat
           if (Ethernet_TxBDindex == Max_Ethernet_TxBD_Size)
             Ethernet_TxBDindex = 0;
           else
             Ethernet_TxBDindex++;

           If (EthernetTxBD[Ethernet_TxBDindex].Ready == 0)
              Found_free_ethernet_TxDB = true;
        Until (found_free_ethernet_TxDB);

         Current_Packet_Length = 0;
         (Ethernet) Tx_Buffer_Ptr = (Serial) Rx_Byte_Ptr;
       }
       else if (received data contain "end of packet" sequence)
      {
           EthernetTxBD[Ethernet_TxBDindex].Length =
              Current_Packet_Length;
           (Serial) Rx_Byte_Ptr+= (Serial) Rx_Byte_Length of
              unprocessed BD;
              /* setting the ready bit will automatically cause the CPM
              to send the buffer in background */
         PacketReady++;
         EthernetTxBD[Ethernet_TxBDindex].Ready = 1;
          }
       else
       {
            Current_Packet_Length +=
                (Serial) Rx_Byte_Length of unprocessed BD;
        (Serial) Rx_Byte_Ptr+= (Serial) Rx_Byte_Length of
                unprocessed BD;
        }
    Unassemble--;
       }
```

Function Disassemble

```
Function Disassemble
{
     found = false;
     repeat
      if (Ethernet_RxBDindex == Max_Ethernet_RxBD_Size)
        Ethernet_RxBDindex = 0;
      else
       Ethernet_RxBDindex++;

        /* Find next unprocessed BD in Ethernet RxBD table;
               It is guaranteed that there will be at least 1
               Non-empty entry else this function won't be called.
             */
        if (EthernetRxBD[Ethernet_RxBDindex].Empty == 0)
        {
          (Ethernet) Rx_Buffer_Ptr =
             EthernetRxBD[Ethernet_Rx_BDindex].Buffer_Ptr;
          (Ethernet) Rx_Buffer_Length =
             EthernetRxBD[Ethernet_Rx_BDindex].Length;
          found = true;
        }
     until (found);
     found_free_serial_TxDB = false;
    /* find an empty serial Tx slot to store the serial data
             If there are not free Tx slot, this will loop forever.
             Meanwhile, the CPM will keep processing data in
             background and update the BD.  Hopefully, there will be
             an empty slot eventually.
          */
     Repeat
        if (Serial_TxBDindex == Max_Serial_RxBD_Size)
          Serial_TxBDindex = 0;
```

```
   else
     Serial_TxBDindex++;

   If (SerialTxBD[Serial_TxBDindex].Ready == 0)
      Found_free_serial_TxDB = true;
Until (found_free_serial_TxDB);

Current_Tx_Byte_Length = (Ethernet) Rx_Buffer_Length;
SerialTxBD[Serial_TxBDindex].Tx_Byte_Ptr =
       (Ethernet) Rx_Buffer_Ptr;

While (Current_Tx_Byte_Length > 0)
{
  if (Current_Tx_Byte_Length > Max_Serial_BD_Data_Length)
  {
    SerialTxBD[Serial_TxBDindex].Tx_Byte_Length =
           Max_Serial_BD_Data_Length;
    Current_Tx_Byte_Length=- Max_Serial_BD_Data_Length;
    (Ethernet) Rx_Buffer_Ptr =+ Max_Serial_BD_Data_Length;
  SerialTxBD[Serial_TXBDindex].Ready = 1;
  }
  else
  {
    SerialTxBD[Serial_TxBDindex].Tx_Byte_Length =
           Current_Tx_Byte_Length;
    Current_Tx_Byte_Length  = 0;
    (Ethernet) Rx_Buffer_Ptr =+ Current_Tx_Byte_Length;
  SerialTxBD[Serial_TXBDindex].Ready = 1;

  // Getting another BD for the End of Sequence
  // data packet
        Repeat
      if (Serial_TxBDindex == Max_Serial_RxBD_Size)
      Serial_TxBDindex = 0;
     else
         Serial_TxBDindex++;

     If (SerialTxBD[Serial_TxBDindex].Ready == 0)
       Found_free_serial_TxDB = true;
    Until (found_free_serial_TxDB);


        SerialTxBD[Serial_TxBDindex].Tx_Byte_Length =
          EndOfPacketSequenceLength;
  SerialTxBD[Serial_TxBDindex].Tx_Byte_Ptr =
          (Ethernet) Rx_Buffer_Ptr;
  SerialTxBD[Serial_TXBDindex].Ready = 1;
  // Increment the global variable indicating
  // that 1 more data is ready for transmit
  DataReady++;
  // Enable the Serial interrupt so that
  // when the CPM move the end of packet
  // sequence, it will fire the Serial ISR.
```

```
            SerialTxBD[Serial_TXBDindex].Interrupt = 1;
         }
      Disassemble--;
        }
      }
```

Function Ethernet_RX_BD_Cleanup

```
Function Ethernet_RX_BD_Cleanup
{
  /* Run After interrupt from Serial Transmit ISR */
  First_Disassembled_Unsent_Ethernet_RX_BD_Ptr.Empty = 1;
  First_Disassembled_Unsent_Ethernet_RX_BD_Ptr += Size_of_BD;
}
```

Function Serial_RX_BD_Cleanup

```
Function Serial_RX_BD_Cleanup
{
  /* Run after unterrupt from Ethernet Transmit ISR */
  while (*ptr <> End_Of_Packet)
  {
      First_Assembled_Unsent_Serial_RX_BD_Ptr.Empty = 1;
      First_Assembled_Unsent_Serial_Rx_BD_Ptr += 8;
   }
     }
```

Module Serial_Receive_ISR_Block

```
Module Serial_Receive_ISR_Block
{
  /* Run After received a buffer from transceiver */
  Save registers
  Unassemble++;
  Pop registers
}
```

Module Serial_Transmit_ISR_Block

```
Module Serial_Transmit_ISR_Block
{
  /* Run After received a buffer from transceiver */
  Save registers
  Call EthernetRxBD cleanup;
  Pop registers
}
```

Module Ethernet_Receive_ISR_Block

```
Module Ethernet_Receive_ISR_Block
{
  /* Run After received a buffer from PC */
  Save registers
```

```
    Disassemble++;
    Pop registers;
  }
```

Module Ethernet_Transmit_ISR_Block

```
  Module Ethernet_Transmit_ISR_Block
  {
    /* Run After send a buffer to PC */
    Save registers
    Call SerialRxBD cleanup;
    Pop registers;

}
```

APPENDIX E: VERIFICATION PLAN

E.1 PERFORMANCE MEASUREMENTS

Due to the unexpected delays in getting the various parts of the CPM controller timer working, we are unable to use the Motorola board's internal timers to record the time between receiving the first piece data from one interface and the time just before the same piece of data leave the other interface. For now, we can only assure that our device can at least transmit and receive at 9600bps because we are able to send and receive at such rate through the serial port without any problems. We can also assure that our software code can support fully duplex operations of the Ethernet and serial interfaces.

If we had more time, we should be able to trigger the CPM timer to work correctly by setting the correct bits and enable the corresponding interrupts. When Ethernet ISR is triggered because of a receive interrupt, the timer is enabled. Then, when the data is just about to be sent to serial port (by either setting the TxReady bit in polling mode or TxReady bit in BD if using CPM), we can record the time and calculate the time elapsed. This will give a more accurate measurement of the pure delay incurred due to the processing delay of our software code.

E.2 FUNCTIONALITY TESTS

E.2.1 ETHERNET MODULE

The unit testing of the Ethernet module is accomplished by writing a PC packet monitor program that monitor all traffic on the PC Ethernet interface. The monitor program puts the PC's Ethernet interface into promiscuous mode so that any valid packets that appears on the Ethernet signal will be printed on screen. The outgoing packets from PC and incoming packets to PC are printed on screen. The raw data content is verified.

To test the ARP reply feature of our design, Our PC will be sending valid ping packets to the Motorola board. Initially, we verify that the PC does not contain an entry for the IP address we are pinging. Then when the PC first pings the IP address, it will first sends a broadcast packet which contains an ARP request. The PC's ARP table is then checked to ensure it contains an entry which associate the Motorola board's hardware address with that IP we're pinging to. This procedure tests both the ARP reply feature and the Ethernet sending and receiving components.

E.2.2 SERIAL MODULE

The unit testing of the serial module is accomplished by sending a string from the PC to the Motorola board's console interface. Either using the "cat" Linux command or directly typing to the console port can do this. The test program, running on the Motorola board, will call the ser_recv function and call the ser_send function to echo the characters back to the screen. This procedure tests the serial sending and receiving components. Our design passes this test when we use polling for the serial port COM1 but it fails when using interrupts for the serial port.

E.2.3 ASSEMBLE MODULE

The unit testing of the copy module is accomplished by predefining some dummy buffers which simulate the buffer pools of the Ethernet and serial interfaces. The dummy serial Rx buffers are filled with some pre-defined patterns and the test program ensures that fragments of serial data can be assembled back into a complete Ethernet packet and copied into the Ethernet Tx buffer. The memory contents of the dummy Ethernet Tx buffer is then examined to verify it contains valid data.

E.2.4 DISASSEMBLE MODULE

Disassemble can be tested in a similar way as the Assemble module. Pre-defined data are loaded into the Ethernet Rx buffer and the dummy serial Tx buffer contents are verified to contain correct disassembled fragments of the original Ethernet packet.

E.2.5 COPY MODULE

The testing of the copy module is in fact the integration test of our entire software design. First, run the PC network monitor on the PC. Then, ping the Motorola board from the PC and the packet content should show up on the serial console's screen. At the same time, we can send pre-defined packet data from the PC's serial port to the Motorola board. The same packet content should appear at the PC network monitor.

To verify the serial data are transferred correctly, we need to convert data input and output to console screen to a human readable format. Our data packet received from the Ethernet port are first converted to ASCII code before it actually got sent to screen.

Similarly, the code we downloaded to the console are in ASCII format for easier debugging.

APPENDIX F: TEST PLAN FOR THE CONSTRUCTED DESIGN PROTOTYPE

This section explains how the performance specifications can be measured.

To ensure 100% compatibility with existing Ethernet network, the following will be performed.

1. Remove existing Ethernet cable on Computer A and Computer B, connect the WELA to the Ethernet port on each computer.
2. Leave all networking settings unchanged.
3. Computer A pings Computer B.
4. Transfer a text file from Computer A to Computer B.
5. Connect Computer A to the Internet, Computer B access the Internet using Internet connection provided by Computer A (assuming Computer A has been configured as a proxy server).

If items 3 to 5 do not generate any errors, Ethernet network compatibility is met.

The verification of the transmission rate and the transmission distance can be performed together after the prototype WELA is successfully verified to be compatible with Ethernet network. To ensure a transmission speed of 50kbps and a distance of 25 meters can be achieved, the following will be performed.

1. Move Computer A and Computer B 25 meters apart.
2. Setup Ethernet connection between Computer A and Computer B using the prototypes.
3. Run a program that will send a stream of data from Computer A to Computer B. and Computer B sends the same information back to the Computer A. The time for WELA A to send the data from Computer A to WELA B and WELA B to send the data back to WELA A will be measured. Two complete transfers are in this time frame. The transmission rate can be found by dividing the number of bits in the data by the time required for one transfer.

4. Repeat step three 100 trials and take the average.

The bit error rate can be verified after ensuring Ethernet network compatibility, the transmission rate, and the transmission distance requirements are met. The following will be performed.

1. Move Computer A and Computer B 25 meters apart.
2. Setup Ethernet connection between Computer A and Computer B using the prototypes.
3. Run a program that will send a stream of data from Computer A to Computer B. Computer B will have another program running to count the number of data bits that are incorrect. The bit error rate is the total incorrect data bits divided by total data bits received.
4. Repeat step three 100 trials and take the average.

The packet error rate can be verified after the Ethernet network compatibility, the transmission rate and the transmission distance requirements are met. To ensure packet error rate of 2%, the following will be performed.

1. Move Computer A and Computer B 25 meters apart.
2. Setup Ethernet connection between Computer A and Computer B using the prototypes.
3. Run a program that will send a stream of data from Computer A to Computer B. Computer B will have another program running to check the checksum of the packet. If the checksum is incorrect, then the data in the received packet has error.
4. Repeat step three 100 trials and take the average.

The transceiver output power can be verified in the E&CE Microwave Lab. The following will be performed.

1. Setup Ethernet connection between Computer A and Computer B using the prototypes.
2. Run a program that will send a steam of data from Computer A to Computer B. Record the power indicated on the power meter.

F.1 PRELIMINARY VERIFICATION DATASHEET

Preliminary Verification for Max Software Speed

Instruction type	%	ticks/instruction	period (ns)	delay (ns)
load/store single	30%	7	60	126
load/store multiple	10%	23	60	138
add	16%	1	25	4
mult	4%	3	25	3
comp	20%	1	25	5
branch hit	10%	4	25	10
branch miss	10%	2	25	5
Total	**100%**			**291**

Total delay = total # of Instructions * Average delay/ instruction
Max baud rate = Total delay/transfer * # of bits/transfer

# of Instructions	Total delay/transfer (ns)	Maximum baud rate* (kbps)
20	5820	5498.281787
30	8730	3665.521191
40	11640	2749.140893
50	14550	2199.312715
60	17460	1832.760596
70	20370	1570.937653
100	29100	1099.656357
200	58200	549.8281787

*Assuming 32-bit per data transfer

APPENDIX G: VERIFICATION PLAN FOR THE PAPER DESIGN

G.1 OVERVIEW

This section discusses how the design will be verified to satisfy all the performance specifications before the prototype is created.

To verify that the module is 100% compatible and fully plug and play, it is necessary to ensure that the PC does not have to change the packet's destination IP address in order to use our module to send the packet instead of using the original cable. Also, when receiving a packet from the remote end, the source IP address should not change so that the local PC will think that the packet comes from the remote PC directly. The modules should be completely invisible to the host PCs.

The transmission rate of the transceiver and the processing speed of the processor on the evaluation board limit the transmission rate of the design. Each constraint must be verified independently. Both the evaluation board and the transceiver should be capable of operating at 10Mps in order to achieve an overall transmission rate of 10Mps for the adapter. However, as discussed in the functional requirement, the transceiver selected for this project has a maximum transmission rate of 50kbps due to the limited budget. We first need to verify that the evaluation board can operate at a rate of 10Mps, regardless of the transceiver used. We also have to verify that the transceiver can operate at a rate of 50kbps.

The way to verify that the evaluation board can operate at a rate of 10Mps is by estimating the delay between receiving a packet from PC and sending the packet to the transceiver. From the user manuals, the overhead of the processing instructions can be estimated. It is impossible to achieve 10Mbps if there is a high delay such as busy wait, in the code. We can also verify the maximum rate of the port we have chosen to use by reading the relevant documentation. If the port we have chosen to use has an upper bound rate that is lower than 10Mbps, then there is no way we can achieve the desired 10Mbps.

There are two major delays in the system. The first delay is the delay in copying from the interfaces to the system main memory. The Communication Processor Module (CPM) hardware utilization also needs to be verified to be less than 100% to make sure that the CPM has enough time to handle incoming data coming from the different ports. The second delay is the delay introduced by the software running in the processor's core.

G.2 ETHERNET AND SERIAL INTERFACE DELAYS

The CPM is a single shared resource used by all of the serial channels, including the Ethernet and Serial interface. It handles low-level protocol processing tasks and manages DMA for all of them.

Managing DMA for the Ethernet interface is a significant portion of the CPM processing. The worst-case scenario transfer rates are given for each port from the user manual. The maximum bit rate states the fastest rate that the Motorola board claims that it can transfer data for each port in the worst case.

G.3 COMMUNICATIONS PROCESSOR MODULE (CPM) UTILIZATION

The Ethernet and serial interface delays gives the maximum transfer rate for each port assuming all other ports are idle. However, when the CPM module itself needs to serve multiple ports concurrently, the CPM will not be able to process data at the port's maximum speed, even if each port is capable of a faster transfer rate. Therefore, the maximum speed an interface can operate at is also dependent on the CPM's data processing speed. CPM utilization represents the amount of time that the CPM is busy. It is an analysis of whether the CPM hardware is able to transfer data at the specified rates. If the CPM utilization is over 100%, that means that even the software running inside core introduces zero delays in the data path, the stated transfer rate is still not possible since the hardware simply cannot transfer data from the port to the memory using DMA at such high speed. In the following formula, the Ethernet transfer rate is the desired bit transfer rate, which is 10Mbps as stated in the customer requirement. The serial transfer rate is the transceiver baud rate, which is 50kbps. The maximum Ethernet and serial rates are the maximum rate at which the CPM can transfer data between the port and the main memory via DMA transfers. Therefore, the utilization of each port is given by the actual bit rate of the port divided by the theoretical maximum rate, and the total CPM usage is given by the sum of the utilization of each port. In our case, only the Ethernet and the serial port are used. The maximum rates are constants that are defined in the MPC860 user manuals.

$$\text{CPM utilization} = \sum_{i=1}^{N} \frac{\mathit{Serial\ Rate}_i}{\mathit{Maximum\ Serial\ Rate}_i}$$

$$= \frac{\mathit{Ethernet\ Rate}}{\mathit{Maximum\ Ethernet\ Rate}} + \frac{\mathit{Serial\ Rate}}{\mathit{Maximum\ Serial\ Rate}}$$

If the CPM utilization is higher than 100%, that means that the stated transfer rate is not possible because the CPM would not have enough time to process the incoming data. Therefore, we need to verify that the CPM utilization for our design is less than 100%.

G.4 SOFTWARE DELAYS

The software delay is the delay introduced in executing the code in the datapath from the instance a packet is received from Ethernet port to the instance the packet is sent to the remote PC. Each different type of instruction has a different latency and they are stated in the MPC860 user manual. One can estimate the total delay in the datapath by estimating the composition of each instruction type encountered in the datapath, multiplied by the estimated total number of instructions in the datapath. The total delay is the estimated delay in transferring one 32-bit word of data.

$$\text{Total Delay/DataTransfer} = Total\#ofInstructionsInDatapath \times \sum_{i=1}^{N} LatencyforInstructionType_i \times \%InstructionType_i$$

$$\text{Maximum Transfer Rate} = \frac{1}{TotalDelay/DataTransfer} \times 32bit/datatransfer$$

G.5 TRANSCEIVER

The only way to verify that the transceiver can operate at a rate of 50kbps is to check the specification on the datasheet of the transceiver.

The transmission distance depends on the transceiver used in the design. The transceiver must be verified that it is operational at a distance of 25 meters apart. The exact approach used in the verification of the transmission rate of the transceiver can be used. That is, check the specification of the datasheet of the transceiver.

APPENDIX H: PROTOTYPE TEST/MEASUREMENT DATA

A continuous stream of packets is sent to Ethernet port. After processing, the packets are outputted to the console port. The WELA is able to accept data at 0.1 second packets. This equates to 10 packets per second. Every packet that was sent are 102 bytes long. Thus, 1020 bytes of information are sent per second, or 8160 bits per second. However, there is a loss of about 1 packet for every 20 packets sent. This equates to an packet error rate of about 5%.

The console port is capable of transmitting data at 9600 bits per second. The figure we got is slight lower than this due to the internal processing.

APPENDIX I: DESIGN AUDIT PROTOTYPE DEMO