

XMODEM/YMODEM PROTOCOL REFERENCE

A compendium of documents describing the

XMODEM and YMODEM

File Transfer Protocols

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Please distribute as widely as possible.

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1. Tower Of Babel

A "YMODEM Tower of Babel" has descended on the microcomputing community bringing with it confusion, frustration, bloated phone bills, and wasted man hours. Sadly, I (Chuck Forsberg) am partly to blame for this mess.

As author of the early 1980s batch and 1k XMODEM extensions, I assumed readers of earlier versions of this document would implement as much of the YMODEM protocol as their programming skills and computing environments would permit. This proved a rather naive assumption as programmers motivated by competitive pressure implemented as little of YMODEM as possible. Some have taken whatever parts of YMODEM that appealed to them, applied them to MODEM7 Batch, Telink, XMODEM or whatever, and called the result YMODEM.

Jeff Garbers (Crosstalk package development director) said it all: "With protocols in the public domain, anyone who wants to dink around with them can go ahead."¹

Documents containing altered examples derived from YMODEM.DOC have added to the confusion. In one instance, the heading in YMODEM.DOC's Figure 1 has mutated from "1024 byte Packets" to "YMODEM/CRC File Transfer Protocol". None of the XMODEM and YMODEM examples shown in one document were correct.

To put an end to this confusion, we must make "perfectly clear" what YMODEM stands for, as Ward Christensen defined it in his 1985 coining of the term.

To the majority of you who read, understood, and respected Ward's definition of YMODEM, I apologize for the inconvenience.

1.1 Definitions

ARC ARC is a program that compresses one or more files into an archive and extracts files from such archives.

XMODEM refers to the file transfer etiquette introduced by Ward Christensen's 1977 MODEM.ASM program. The name XMODEM comes from Keith Petersen's XMODEM.ASM program, an adaptation of MODEM.ASM for Remote CP/M (RCPM) systems. It's also called the MODEM or MODEM2 protocol. Some who are unaware of MODEM7's unusual batch file mode call it MODEM7. Other aliases include "CP/M Users' Group" and "TERM II FTP 3". The name XMODEM caught on partly because it is distinctive and partly because of media interest in bulletin board and RCPM systems where it was accessed with an "XMODEM" command. This protocol is supported by every serious communications program because of its universality, simplicity, and reasonable performance.

XMODEM/CRC replaces XMODEM's 1 byte checksum with a two byte Cyclical Redundancy

¹. Page C/12, PC-WEEK July 12, 1987

Check (CRC-16), giving modern error detection protection.

XMODEM-1k Refers to the XMODEM/CRC protocol with 1024 byte data blocks.

YMODEM Refers to the XMODEM/CRC (optional 1k blocks) protocol with batch transmission as described below.

True YMODEM(TM) In an attempt to sort out the YMODEM Tower of Babel, Omen Technology has trademarked the term True YMODEM(TM) to represent the complete YMODEM protocol described in this document, including pathname, length, and modification date transmitted in block 0. Please contact Omen Technology about certifying programs for True YMODEM(TM) compliance.

ZMODEM uses familiar XMODEM/CRC and YMODEM technology in a new protocol that provides reliability, throughput, file management, and user amenities appropriate to contemporary data communications.

ZOO Like ARC, ZOO is a program that compresses one or more files into a "zoo archive". ZOO supports many different operating systems including Unix and VMS.

2. YMODEM Minimum Requirements

All programs claiming to support YMODEM must meet the following minimum requirements:

- ✓ **The sending program shall send the pathname (file name) in block 0.**
- ✓ **The pathname shall be a null terminated ASCII string as described below.**
- ✓ **The receiving program shall use this pathname for the received file name, unless explicitly overridden.**
- ✓ **The sending program shall use CRC-16 in response to a "C" pathname nak, otherwise use 8 bit checksum.**
- ✓ **The receiving program must accept any mixture of 128 and 1024 byte blocks it receives.**
- ✓ **The sending program must not change the length of an unacknowledged block.**
- ✓ **At the end of each file, the sending program shall send EOT up to ten times until it receives an ACK character. (This is part of the XMODEM spec.)**
- ✓ **The end of a transfer session shall be signified by a null (empty) pathname.**

Programs not meeting all of these requirements are not YMODEM compatible.

Meeting the minimum requirements does not guarantee reliable file transfers under stress.

3. Why YMODEM?

Since its development half a decade ago, the Ward Christensen modem protocol has enabled a wide variety of computer systems to interchange data. There is hardly a communications program that doesn't at least claim to support this protocol.

Recent advances in computing, modems and networking have revealed a number of weaknesses in the original protocol:

- ✓ The short block length caused throughput to suffer when used with timesharing systems, packet switched networks, satellite circuits, and buffered (error correcting) modems.
- ✓ The 8 bit arithmetic checksum and other aspects allowed line impairments to interfere with dependable, accurate transfers.
- ✓ Only one file could be sent per command. The file name had to be given twice, first to the sending program and then again to the receiving program.
- ✓ The transmitted file could accumulate as many as 127 extraneous bytes.
- ✓ The modification date of the file was lost.
- ✓ A number of other protocols have been developed over the years, but none have displaced XMODEM to date:
- ✓ Lack of public domain documentation and example programs have kept proprietary protocols such as Blast, Relay, and others tightly bound to the fortunes of their suppliers.
- ✓ Complexity discourages the widespread application of BISYNC, SDLC, HDLC, X.25, and X.PC protocols.
- ✓ Performance compromises and complexity have limited the popularity of the Kermit protocol, which was developed to allow file transfers in environments hostile to XMODEM.

The XMODEM protocol extensions and YMODEM Batch address some of these weaknesses while maintaining most of XMODEM's simplicity. YMODEM is supported by the public domain programs YAM (CP/M), YAM(CP/M-86), YAM(CCPM-86), IMP (CP/M), KMD (CP/M), rz/sz (Unix, Xenix, VMS, Berkeley Unix, Venix, Xenix, Coherent, IDRIS, Regulus). Commercial implementations include MIRROR, and Professional-YAM.¹ Communications programs supporting these extensions have been in use since 1981.

The 1k block length (XMODEM-1k) described below may be used in conjunction with YMODEM Batch Protocol, or with single file transfers identical to the XMODEM/CRC protocol except for minimal changes to support 1k blocks.

Another extension is the YMODEM-g protocol. YMODEM-g provides maximum throughput when used with end to end error correcting media, such as X.PC and error correcting modems, including 9600 bps units by TeleBit, U.S.Robotics, Hayes, Electronic Vaults, Data Race, and

¹ Available for IBM PC,XT,AT, Unix and Xenix

others.

To complete this tome, edited versions of Ward Christensen's original protocol document and John Byrns's CRC-16 document are included for reference.

References to the MODEM or MODEM7 protocol have been changed to XMODEM to accommodate the vernacular. In Australia, it is properly called the Christensen Protocol.

3.1 Some Messages from the Pioneer

#: 130940 S0/Communications 25-Apr-85 18:38:47

Sb: my protocol

Fm: Ward Christensen 76703,302 ¹

To: all

Be aware the article² DID quote me correctly in terms of the phrases like "not robust", etc. It was a quick hack I threw together, very unplanned (like everything I do), to satisfy a personal need to communicate with "some other" people.

ONLY the fact that it was done in 8/77, and that I put it in the public domain immediately, made it become the standard that it is.

I think its time for me to

(1) document it; (people call me and say "my product is going to include it - what can I 'reference'", or "I'm writing a paper on it, what do I put in the bibliography") and

(2) propose an "incremental extension" to it, which might take "exactly" the form of Chuck Forsberg's YAM protocol. He wrote YAM in C for CP/M and put it in the public domain, and wrote a batch protocol for Unix³ called rb and sb (receive batch, send batch), which was basically XMODEM with

(a) a record 0 containing filename date time and size

(b) a 1K block size option

(c) CRC-16.

He did some clever programming to detect false ACK or EOT, but basically left them the same.

People who suggest I make SIGNIFICANT changes to the protocol, such as "full duplex", "multiple outstanding blocks", "multiple destinations", etc etc don't understand that the incredible simplicity of the protocol is one of the reasons it survived to this day in as many machines and programs as it may be found in!

¹ Edited for typesetting appearance

² Infoworld April 29 p. 16

³ VAX/VMS versions of these programs are also available.

Consider the PC-NET group back in '77 or so - documenting to beat the band - THEY had a protocol, but it was "extremely complex", because it tried to be "all things to all people" - i.e. send binary files on a 7-bit system, etc. I was not that "benevolent". I (emphasize > I <) had an 8-bit UART, so "my protocol was an 8-bit protocol", and I would just say "sorry" to people who were held back by 7-bit limitations. ...

Block size: Chuck Forsberg created an extension of my protocol, called YAM, which is also supported via his public domain programs for UNIX called rb and sb - receive batch and send batch. They cleverly send a "block 0" which contains the filename, date, time, and size.

Unfortunately, its UNIX style, and is a bit weird¹ - octal numbers, etc.

BUT, it is a nice way to overcome the kludgy "echo the chars of the name" introduced with MODEM7. Further, chuck uses CRC-16 and optional 1K blocks. Thus the record 0, 1K, and CRC, make it a "pretty slick new protocol" which is not significantly different from my own.

Also, there is a catchy name - YMODEM. That means to some that it is the "next thing after XMODEM", and to others that it is the Y(am)MODEM protocol. I don't want to emphasize that too much - out of fear that other mfgs might think it is a "competitive" protocol, rather than an "unaffiliated" protocol. Chuck is currently selling a much-enhanced version of his CP/M-80 C program YAM, calling it Professional Yam, and its for the PC - I'm using it right now. VERY slick! 32K capture buffer, script, scrolling, previously captured text search, plus built-in commands for just about everything - directory (sorted every which way), XMODEM, YMODEM, KERMIT, and ASCII file upload/download, etc. You can program it to "behave" with most any system - for example when trying a number for CIS it detects the "busy" string back from the modem and substitutes a diff phone # into the dialing string and branches back to try it.

¹ The file length, time, and file mode are optional. The pathname and file length may be sent alone if desired.

4. XMODEM Protocol Enhancements

This chapter discusses the protocol extensions to Ward Christensen's 1982 XMODEM protocol description document.

The original document recommends the user be asked whether to continue trying or abort after 10 retries. Most programs no longer ask the operator whether he wishes to keep retrying. Virtually all correctable errors are corrected within the first few retransmissions. If the line is so bad that ten attempts are insufficient, there is a significant danger of undetected errors. If the connection is that bad, it's better to redial for a better connection, or mail a floppy disk.

4.1 Graceful Abort

The YAM and Professional-YAM X/YMODEM routines recognize a sequence of two consecutive CAN (Hex 18) characters without modem errors (overrun, framing, etc.) as a transfer abort command. This sequence is recognized when is waiting for the beginning of a block or for an acknowledgement to a block that has been sent. The check for two consecutive CAN characters reduces the number of transfers aborted by line hits. YAM sends eight CAN characters when it aborts an XMODEM, YMODEM, or ZMODEM protocol file transfer. Pro-YAM then sends eight backspaces to delete the CAN characters from the remote's keyboard input buffer, in case the remote had already aborted the transfer and was awaiting a keyboarded command.

4.2 CRC-16 Option

The XMODEM protocol uses an optional two character CRC-16 instead of the one character arithmetic checksum used by the original protocol and by most commercial implementations. CRC-16 guarantees detection of all single and double bit errors, all errors with an odd number of error bits, all burst errors of length 16 or less, 99.9969% of all 17-bit error bursts, and 99.9984 per cent of all possible longer error bursts. By contrast, a double bit error, or a burst error of 9 bits or more can sneak past the XMODEM protocol arithmetic checksum.

The XMODEM/CRC protocol is similar to the XMODEM protocol, except that the receiver specifies CRC-16 by sending C (Hex 43) instead of NAK when requesting the FIRST block. A two byte CRC is sent in place of the one byte arithmetic checksum.

YAM's c option to the r command enables CRC-16 in single file reception, corresponding to the original implementation in the MODEM7 series programs. This remains the default because many commercial communications programs and bulletin board systems still do not support CRC-16, especially those written in Basic or Pascal.

XMODEM protocol with CRC is accurate provided both sender and receiver Enhancements both report a successful transmission. The protocol is robust in the presence of characters lost by buffer overloading on timesharing systems.

The single character ACK/NAK responses generated by the receiving program adapt well to split speed modems, where the reverse channel is limited to ten per cent or less of the main channel's speed.

XMODEM and YMODEM are half duplex protocols which do not attempt to transmit information and control signals in both directions at the same time. This avoids buffer overrun problems that have been reported by users attempting to exploit full duplex asynchronous file transfer protocols such as Blast.

Professional-YAM adds several proprietary logic enhancements to XMODEM's error detection and recovery. These compatible enhancements eliminate most of the bad file transfers other programs make when using the XMODEM protocol under less than ideal conditions.

4.3 XMODEM-1k 1024 Byte Block

Disappointing throughput downloading from Unix with YMODEM¹ lead to the development of 1024 byte blocks in 1982. 1024 byte blocks reduce the effect of delays from timesharing systems, modems, and packet switched networks on throughput by 87.5 per cent in addition to decreasing XMODEM's per byte overhead 3 per cent on long files.

The choice to use 1024 byte blocks is expressed to the sending program on its command line or selection menu.² 1024 byte blocks improve throughput in many applications, but some environments cannot accept 1024 byte bursts, especially minicomputers running 19.2kb ports.

An STX (02) replaces the SOH (01) at the beginning of the transmitted block to notify the receiver of the longer block length. The transmitted block contains 1024 bytes of data. The receiver should be able to accept any mixture of 128 and 1024 byte blocks. The block number (in the second and third bytes of the block) is incremented by one for each block regardless of the block length.

The sender must not change between 128 and 1024 byte block lengths if it has not received a valid ACK for the current block. Failure to observe this restriction allows transmission errors to pass undetected.

If 1024 byte blocks are being used, it is possible for a file to "grow" up to the next multiple of 1024 bytes. This does not waste disk space if the allocation granularity is 1k or greater. With YMODEM batch transmission, the optional file length transmitted in the file name block allows the receiver to discard the padding, preserving the exact file length and contents.

1024 byte blocks may be used with batch file transmission or with single file transmission. CRC-16 should be used with the k option to preserve data integrity over phone lines. If a program wishes to enforce this recommendation, it should cancel the transfer, then issue an informative diagnostic message if the receiver requests checksum instead of CRC-16.

Under no circumstances may a sending program use CRC-16 unless the receiver commands CRC-16.

¹ The name hadn't been coined yet, but the protocol was the same.

² See "KMD/IMP Exceptions to YMODEM" below.

Figure 1 XMODEM-1k Blocks

SENDER	RECEIVER
"foo.bar open x.x minutes"	"s -k foo.bar"
	C
STX 01 FE Data[1024] CRC CRC	
	ACK
STX 02 FD Data[1024] CRC CRC	
	ACK
STX 03 FC Data[1000] CPMEOF[24] CRC CRC	
	ACK
EOT	
	ACK

Figure 2 Mixed 1024 and 128 byte Blocks

SENDER	RECEIVER
"foo.bar open x.x minutes"	"s -k foo.bar"
	C
STX 01 FE Data[1024] CRC CRC	
	ACK
STX 02 FD Data[1024] CRC CRC	
	ACK
SOH 03 FC Data[128] CRC CRC	
	ACK
SOH 04 FB Data[100] CPMEOF[28] CRC CRC	
	ACK
EOT	
	ACK

5. YMODEM Batch File Transmission

The YMODEM Batch protocol is an extension to the XMODEM/CRC protocol that allows 0 or more files to be transmitted with a single command. (Zero files may be sent if none of the requested files is accessible.) The design approach of the YMODEM Batch protocol is to use the normal routines for sending and receiving XMODEM blocks in a layered fashion similar to packet switching methods.

Why was it necessary to design a new batch protocol when one already existed in MODEM7?¹ The batch file mode used by MODEM7 is unsuitable because it does not permit full pathnames, file length, file date, or other attribute information to be transmitted. Such a restrictive design, hastily implemented with only CP/M in mind, would not have permitted extensions to current areas of personal computing such as Unix, DOS, and object oriented systems. In addition, the MODEM7 batch file mode is somewhat susceptible to transmission impairments.

As in the case of single a file transfer, the receiver initiates batch file transmission by sending a "C" character (for CRC-16).

The sender opens the first file and sends block number 0 with the following information.²

Only the pathname (file name) part is required for batch transfers.

To maintain upwards compatibility, all unused bytes in block 0 must be set to null.

Pathname The pathname (conventionally, the file name) is sent as a null terminated ASCII string. This is the filename format used by the handle oriented MSDOS(TM) functions and C library fopen functions. An assembly language example follows:

```
DB 'foo.bar',0
```

No spaces are included in the pathname. Normally only the file name stem (no directory prefix) is transmitted unless the sender has selected YAM's f option to send the full pathname. The source drive (A:, B:, etc.) is not sent.

Filename Considerations:

- ✓ File names are forced to lower case unless the sending system supports upper/lower case file names. This is a convenience for users of systems (such as Unix) which store filenames in upper and lower case.
- ✓ The receiver should accommodate file names in lower and upper case.
- ✓ When transmitting files between different operating systems, file names must be acceptable to both the sender and receiving operating systems.

¹ The MODEM7 batch protocol transmitted CP/M FCB bytes f1...f8 and t1...t3 one character at a time. The receiver echoed these bytes as received, one at a time.

² Only the data part of the block is described here.

If directories are included, they are delimited by /; i.e., "subdir/foo" is acceptable, "subdir\foo" is not.

Length The file length and each of the succeeding fields are optional.¹

The length field is stored in the block as a decimal string counting the number of data bytes in the file. The file length does not include any CPMEOF (^Z) or other garbage characters used to pad the last block.

If the file being transmitted is growing during transmission, the length field should be set to at least the final expected file length, or not sent.

The receiver stores the specified number of characters, discarding any padding added by the sender to fill up the last block.

Modification Date The mod date is optional, and the filename and length may be sent without requiring the mod date to be sent.

Iff the modification date is sent, a single space separates the modification date from the file length.

The mod date is sent as an octal number giving the time the contents of the file were last changed, measured in seconds from Jan 1 1970 Universal Coordinated Time (GMT). A date of 0 implies the modification date is unknown and should be left as the date the file is received.

This standard format was chosen to eliminate ambiguities arising from transfers between different time zones.

Mode Iff the file mode is sent, a single space separates the file mode from the modification date. The file mode is stored as an octal string. Unless the file originated from a Unix system, the file mode is set to 0. rb(1) checks the file mode for the 0x8000 bit which indicates a Unix type regular file. Files with the 0x8000 bit set are assumed to have been sent from another Unix (or similar) system which uses the same file conventions. Such files are not translated in any way.

Serial Number Iff the serial number is sent, a single space separates the serial number from the file mode. The serial number of the transmitting program is stored as an octal string. Programs which do not have a serial number should omit this field, or set it to 0.

The receiver's use of this field is optional.

Other Fields YMODEM was designed to allow additional header fields to be added as above without creating compatibility problems with older YMODEM programs. Please contact Omen Technology if other fields are needed for special application requirements.

The rest of the block is set to nulls. This is essential to preserve upward compatibility.²

If the filename block is received with a CRC or other error, a retransmission is requested. After the filename block has been received, it is ACK'ed if the write open is successful. If the file cannot be

¹ Fields may not be skipped.

² If, perchance, this information extends beyond 128 bytes (possible with Unix 4.2 BSD extended file names), the block should be sent as a 1k block as described above.

opened for writing, the receiver cancels the transfer with CAN characters as described above.

The receiver then initiates transfer of the file contents according to the standard XMODEM/CRC protocol.

After the file contents have been transmitted, the receiver again asks for the next pathname.

Transmission of a null pathname terminates batch file transmission.

Note that transmission of no files is not necessarily an error. This is possible if none of the files requested of the sender could be opened for reading.

The YMODEM receiver requests CRC-16 by default.

The Unix programs sz(1) and rz(1) included in the source code file RZSZ.ZOO should answer other questions about YMODEM batch protocol.

Figure 3 YMODEM Batch Transmission Session

SENDER	RECEIVER
	"sb foo.*<CR>"
"sending in batch mode etc."	
	C (command:rb)
SOH 00 FF foo.c NUL[123] CRC CRC	
	ACK
	C
SOH 01 FE Data[128] CRC CRC	
	ACK
SOH 03 FC Data[128] CRC CRC	
	ACK
SOH 04 FB Data[100] CPMEOF[28] CRC CRC	
	ACK
EOT	
	NAK
EOT	
	ACK
	C
SOH 00 FF NUL[128] CRC CRC	
	ACK

Figure 4 YMODEM Batch Transmission Session-1k Blocks

SENDER	RECEIVER
	"sb foo.*<CR>"
"sending in batch mode etc."	
	C (command:rb)
SOH 00 FF foo.c NUL[123] CRC CRC	
	ACK
STX 02 FD Data[1024] CRC CRC	
	ACK
SOH 03 FC Data[128] CRC CRC	
	ACK
SOH 04 FB Data[100] CPMEOF[28] CRC CRC	
	ACK
EOT	
	NAK
EOT	
	ACK
	C
SOH 00 FF NUL[128] CRC CRC	
	ACK

Figure 5 YMODEM Filename block transmitted by sz

```

-rw-r--r--      6347   Jun 17 1984 20:34   bbcsched.txt

0  0100FF62 62637363 6865642E 74787400 |...bbcsched.txt.|
10 36333437 20333331 34373432 35313320 |6347 3314742513 |
20 31303036 34340000 00000000 00000000 |100644.....|
30 00000000 00000000 00000000 00000000
40 00000000 00000000 00000000 00000000
50 00000000 00000000 00000000 00000000
60 00000000 00000000 00000000 00000000
70 00000000 00000000 00000000 00000000
80 000000CA 56

```

Figure 6 YMODEM Header Information and Features

Program	Length	Date	Mode	S/N	1k-Blk	YMODEM-g
Unix rz/sz	yes	yes	yes	no	yes	sb only
VMS rb/sb	yes	no	no	no	yes	no
Pro-YAM	yes	yes	no	yes	yes	yes
CP/M YAM	no	no	no	no	yes	no
KMD/IMP	?	no	no	no	yes	no

5.1 KMD/IMP Exceptions to YMODEM

KMD and IMP use a "CK" character sequence emitted by the receiver to trigger the use of 1024 byte blocks as an alternative to specifying this option to the sending program. Although this two character sequence works well on single process micros in direct communication, timesharing systems and packet switched networks can separate the successive characters by several seconds, rendering this method unreliable.

Sending programs may detect the CK sequence if the operating environment does not preclude reliable implementation.

Instead of the standard YMODEM file length, KMD and IMP transmit the CP/M record count in the last two bytes of the header block.

6. YMODEM-g File Transmission

Developing technology is providing phone line data transmission at ever higher speeds using very specialized techniques. These high speed modems, as well as session protocols such as X.PC, provide high speed, nearly error free communications at the expense of considerably increased delay time.

This delay time is moderate compared to human interactions, but it cripples the throughput of most error correcting protocols.

The g option to YMODEM has proven effective under these circumstances. The g option is driven by the receiver, which initiates the batch transfer by transmitting a G instead of C. When the sender recognizes the G, it bypasses the usual wait for an ACK to each transmitted block, sending succeeding blocks at full speed, subject to XOFF/XON or other flow control exerted by the medium.

The sender expects an initial G to initiate the transmission of a particular file, and also expects an ACK on the EOT sent at the end of each file. This synchronization allows the receiver time to open and close files as necessary.

If an error is detected in a YMODEM-g transfer, the receiver aborts the transfer with the multiple CAN abort sequence. The ZMODEM protocol should be used in applications that require both streaming throughput and error recovery.

Figure 7 YMODEM-g Transmission Session

SENDER	RECEIVER
	"sb foo.*<CR>"
"sending in batch mode etc."	
	G (command:rb -g)
SOH 00 FF foo.c NUL[123] CRC CRC	
	G
SOH 01 FE Data[128] CRC CRC	
STX 02 FD Data[1024] CRC CRC	
SOH 03 FC Data[128] CRC CRC	
SOH 04 FB Data[100] CPMEOF[28] CRC CRC	
EOT	
	ACK
	G
SOH 00 FF NUL[128] CRC CRC	

7. XMODEM Protocol Overview

8/9/82 by Ward Christensen.

I will maintain a master copy of this. Please pass on changes or suggestions via CBBS/Chicago at (312) 545-8086, CBBS/CPMUG (312) 849-1132 or by voice at (312) 849-6279.

7.1 Definitions

<soh> 01H

<eot> 04H

<ack> 06H

<nak> 15H

<can> 18H

<C> 43H

7.2 Transmission Medium Level Protocol

Asynchronous, 8 data bits, no parity, one stop bit.

The protocol imposes no restrictions on the contents of the data being transmitted. No control characters are looked for in the 128-byte data messages. Absolutely any kind of data may be sent - binary, ASCII, etc. The protocol has not formally been adopted to a 7-bit environment for the transmission of ASCII-only (or unpacked-hex) data, although it could be simply by having both ends agree to AND the protocol-dependent data with 7F hex before validating it. I specifically am referring to the checksum, and the block numbers and their ones- complement.

Those wishing to maintain compatibility of the CP/M file structure, i.e. to allow modemming ASCII files to or from CP/M systems should follow this data format:

- ✓ ASCII tabs used (09H); tabs set every 8.
- ✓ Lines terminated by CR/LF (0DH 0AH)
- ✓ End-of-file indicated by ^Z, 1AH. (one or more)
- ✓ Data is variable length, i.e. should be considered a continuous stream of data bytes, broken into 128-byte chunks purely for the purpose of transmission.
- ✓ A CP/M "peculiarity": If the data ends exactly on a 128-byte boundary, i.e. CR in 127, and LF in 128, a subsequent sector containing the ^Z EOF character(s) is optional, but is preferred. Some utilities or user programs still do not handle EOF without ^Zs.
- ✓ The last block sent is no different from others, i.e. there is no "short block".

Figure 8 XMODEM Message Block Level Protocol

Each block of the transfer looks like:

<SOH><blk #><255-blk #><--128 data bytes--><cksum>

in which:

<SOH> = 01 hex

<blk #> = binary number, starts at 01 increments by 1,
and wraps 0FFH to 00H (not to 01)

<255-blk #> = blk # after going thru 8080 "CMA" instr, i.e.
each bit complemented in the 8-bit block number.
Formally, this is the "ones complement".

<cksum> = the sum of the data bytes only. Toss any carry.

7.3 File Level Protocol

7.3.1 Common_to_Both_Sender_and_Receiver

All errors are retried 10 times. For versions running with an operator (i.e. NOT with XMODEM), a message is typed after 10 errors asking the operator whether to "retry or quit".

Some versions of the protocol use <can>, ASCII ^X, to cancel transmission. This was never adopted as a standard, as having a single "abort" character makes the transmission susceptible to false termination due to an <ack> <nak> or <soh> being corrupted into a <can> and aborting transmission.

The protocol may be considered "receiver driven", that is, the sender need not automatically re-transmit, although it does in the current implementations.

7.3.2 Receive_Program_Considerations

The receiver has a 10-second timeout. It sends a <nak> every time it times out. The receiver's first timeout, which sends a <nak>, signals the transmitter to start. Optionally, the receiver could send a <nak> immediately, in case the sender was ready. This would save the initial 10 second timeout. However, the receiver MUST continue to timeout every 10 seconds in case the sender wasn't ready. Once into a receiving a block, the receiver goes into a one-second timeout for each character and the checksum. If the receiver wishes to <nak> a block for any reason (invalid header, timeout receiving data), it must wait for the line to clear. See "programming tips" for ideas

Synchronizing: If a valid block number is received, it will be: 1) the expected one, in which case everything is fine; or 2) a repeat of the previously received block. This should be considered OK, and only indicates that the receivers <ack> got glitched, and the sender retransmitted; 3) any other

block number indicates a fatal loss of synchronization, such as the rare case of the sender getting a line-glitch that looked like an <ack>. Abort the transmission, sending a <can>.

7.3.3 Sending_program_considerations

While waiting for transmission to begin, the sender has only a single very long timeout, say one minute. In the current protocol, the sender has a 10 second timeout before retrying. I suggest NOT doing this, and letting the protocol be completely receiver-driven. This will be compatible with existing programs.

When the sender has no more data, it sends an <eot>, and awaits an <ack>, resending the <eot> if it doesn't get one. Again, the protocol could be receiver-driven, with the sender only having the high-level 1-minute timeout to abort.

Here is a sample of the data flow, sending a 3-block message. It includes the two most common line hits - a garbaged block, and an <ack> reply getting garbaged. <xx> represents the checksum byte.

Figure 9 Data flow including Error Recovery

SENDER		RECEIVER
		times out after 10 seconds,
	<---	<nak>
<soh> 01 FE -data- <xx>	--->	
	<---	ack
<soh> 02 FD -data- xx	--->	(data gets line hit)
	<---	<nak>
<soh> 02 FD -data- xx	--->	
	<---	<ack>
<soh> 03 FC -data- xx	--->	
(ack gets garbaged)	<---	<ack>
<soh> 03 FC -data- xx	--->	
	<---	<ack>
<eot>	--->	
	<---	<anything except ack>
<eot>	--->	
	<---	<ack>
(finished)		

7.4 Programming Tips

+ The character-receive subroutine should be called with a parameter specifying the number of seconds to wait. The receiver should first call it with a time of 10, then <nak> and try again, 10 times.

After receiving the <soh>, the receiver should call the character receive subroutine with a 1-second timeout, for the remainder of the message and the <cksum>. Since they are sent as a continuous stream, timing out of this implies a serious like glitch that caused, say, 127 characters to be seen instead of 128.

+ When the receiver wishes to <nak>, it should call a "PURGE" subroutine, to wait for the line to clear. Recall the sender tosses any characters in its UART buffer immediately upon completing sending a block, to ensure no glitches were mis- interpreted.

The most common technique is for "PURGE" to call the character receive subroutine, specifying a 1-second timeout,¹ and looping back to PURGE until a timeout occurs. The <nak> is then sent, ensuring the other end will see it.

+ You may wish to add code recommended by John Mahr to your character receive routine - to set an error flag if the UART shows framing error, or overrun. This will help catch a few more glitches - the most common of which is a hit in the high bits of the byte in two consecutive bytes. The <cksum> comes out OK since counting in 1-byte produces the same result of adding 80H + 80H as with adding 00H + 00H.

¹ These times should be adjusted for use with timesharing systems.

8. XMODEM/CRC Overview

Original 1/13/85 by John Byrns -- CRC option.

Please pass on any reports of errors in this document or suggestions for improvement to me via Ward's/CBBS at (312) 849-1132, or by voice at (312) 885-1105.

The CRC used in the Modem Protocol is an alternate form of block check which provides more robust error detection than the original checksum. Andrew S. Tanenbaum says in his book, *Computer Networks*, that the CRCCCITT used by the Modem Protocol will detect all single and double bit errors, all errors with an odd number of bits, all burst errors of length 16 or less, 99.997% of 17-bit error bursts, and 99.998% of 18-bit and longer bursts.¹

The changes to the Modem Protocol to replace the checksum with the CRC are straight forward. If that were all that we did we would not be able to communicate between a program using the old checksum protocol and one using the new CRC protocol. An initial handshake was added to solve this problem. The handshake allows a receiving program with CRC capability to determine whether the sending program supports the CRC option, and to switch it to CRC mode if it does. This handshake is designed so that it will work properly with programs which implement only the original protocol. A description of this handshake is presented in section 10.

Figure 10 Message Block Level Protocol, CRC mode

Each block of the transfer in CRC mode looks like:

<SOH><blk #><255-blk #><--128 data bytes--><CRC hi><CRC lo>

in which:

<SOH> = 01 hex

<blk #> = binary number, starts at 01 increments by 1, and
wraps 0FFH to 00H (not to 01)

<255-blk #> = ones complement of blk #.

<CRC hi> = byte containing the 8 hi order coefficients of the CRC.

<CRC lo> = byte containing the 8 lo order coefficients of the CRC.

¹ This reliability figure is misleading because XMODEM's critical supervisory functions are not protected by this CRC.

8.1 CRC Calculation

8.1.1 Formal Definition

To calculate the 16 bit CRC the message bits are considered to be the coefficients of a polynomial. This message polynomial is first multiplied by X^{16} and then divided by the generator polynomial ($X^{16} + X^{12} + X^5 + 1$) using modulo two arithmetic. The remainder left after the division is the desired CRC. Since a message block in the Modem Protocol is 128 bytes or 1024 bits, the message polynomial will be of order X^{1023} . The hi order bit of the first byte of the message block is the coefficient of X^{1023} in the message polynomial. The lo order bit of the last byte of the message block is the coefficient of X^0 in the message polynomial.

Figure 11 Example of CRC Calculation written in C

The following XMODEM crc routine is taken from "rbsb.c". Please refer to the source code for these programs (contained in RZSZ.ZOO) for usage. A fast table driven version is also included in this file.

```
/* update CRC */
unsigned short
updcrc(c, crc)
register c;
register unsigned crc;
{
    register count;
    for (count=8; --count>=0;) {
        if (crc & 0x8000) {
            crc <<= 1;
            crc += (((c<<=1) & 0400) != 0);
            crc ^= 0x1021;
        }
        else {
            crc <<= 1;
            crc += (((c<<=1) & 0400) != 0);
        }
    }
    return crc;
}
```


8.2 CRC File Level Protocol Changes

8.2.1 Common_to_Both_Sender_and_Receiver

The only change to the File Level Protocol for the CRC option is the initial handshake which is used to determine if both the sending and the receiving programs support the CRC mode. All Modem Programs should support the checksum mode for compatibility with older versions. A receiving program that wishes to receive in CRC mode implements the mode setting handshake by sending a <C> in place of the initial <nak>. If the sending program supports CRC mode it will recognize the <C> and will set itself into CRC mode, and respond by sending the first block as if a <nak> had been received. If the sending program does not support CRC mode it will not respond to the <C> at all. After the receiver has sent the <C> it will wait up to 3 seconds for the <soh> that starts the first block. If it receives a <soh> within 3 seconds it will assume the sender supports CRC mode and will proceed with the file exchange in CRC mode. If no <soh> is received within 3 seconds the receiver will switch to checksum mode, send a <nak>, and proceed in checksum mode. If the receiver wishes to use checksum mode it should send an initial <nak> and the sending program should respond to the <nak> as defined in the original Modem Protocol. After the mode has been set by the initial <C> or <nak> the protocol follows the original Modem Protocol and is identical whether the checksum or CRC is being used.

8.2.2 Receive_Program_Considerations

There are at least 4 things that can go wrong with the mode setting handshake.

1. the initial <C> can be garbled or lost.
2. the initial <soh> can be garbled.
3. the initial <C> can be changed to a <nak>.
4. the initial <nak> from a receiver which wants to receive in checksum can be changed to a <C>.

The first problem can be solved if the receiver sends a second <C> after it times out the first time. This process can be repeated several times. It must not be repeated too many times before sending a <nak> and switching to checksum mode or a sending program without CRC support may time out and abort. Repeating the <C> will also fix the second problem if the sending program cooperates by responding as if a <nak> were received instead of ignoring the extra <C>.

It is possible to fix problems 3 and 4 but probably not worth the trouble since they will occur very infrequently. They could be fixed by switching modes in either the sending or the receiving program after a large number of successive <nak>s. This solution would risk other problems however.

8.2.3 Sending_Program_Considerations

The sending program should start in the checksum mode. This will insure compatibility with checksum only receiving programs. Anytime a <C> is received before the first <nak> or <ack> the sending program should set itself into CRC mode and respond as if a <nak> were received. The sender should respond to additional <C>s as if they were <nak>s until the first <ack> is received. This will assist the receiving program in determining the correct mode when the <soh> is lost or garbled. After the first <ack> is received the sending program should ignore <C>s.

8.3 Data Flow Examples with CRC Option

Here is a data flow example for the case where the receiver requests transmission in the CRC mode but the sender does not support the CRC option. This example also includes various transmission errors. <xx> represents the checksum byte.

Figure 12 Data Flow: Receiver has CRC Option, Sender Doesn't

SENDER		RECEIVER
	<---	<C>
		timers out after 3 seconds
	<---	<C>
		timers out after 3 seconds
	<---	<C>
		timers out after 3 seconds
	<---	<C>
		timers out after 3 seconds
	<---	<nak>
<soh> 01 FE -data- <xx>	--->	
	<---	<ack>
<soh> 02 FD -data- <xx>	--->	(data gets line hit)
	<---	<nak>
<soh> 02 FD -data- <xx>	--->	
	<---	<ack>
<soh> 03 FC -data- <xx>	--->	
<ack gets garbaged>	<---	<ack>
		timers out after 10 seconds
	<---	<nak>
<soh> 03 FC -data- <xx>	--->	
	<---	<ack>
<eot>	--->	
	<---	<ack>

Here is a data flow example for the case where the receiver requests transmission in the CRC mode and the sender supports the CRC option. This example also includes various transmission errors. <xxxx> represents the 2 CRC bytes.

Figure 13 Receiver and Sender Both have CRC Option

SENDER		RECEIVER
	<---	<C>
<soh> 01 FE -data- <xxxxxx>	--->	
	<---	<ack>
<soh> 02 FD -data- <xxxxxx>	--->	(data gets line hit)
	<---	<nak>
<soh> 02 FD -data- <xxxxxx>	--->	
	<---	<ack>
<soh> 03 FC -data- <xxxxxx>	--->	
<ack gets garbaged>	<---	<ack>
		timers out after 10 seconds
	<---	<nak>
<soh> 03 FC -data- <xx>	--->	
	<---	<ack>
<eot>	--->	
	<---	<ack>

9. More Information

Please contact Omen Technology for troff source files and typeset copies of this document.

9.1 TeleGodzilla Bulletin Board

More information may be obtained by calling TeleGodzilla at 503-621-3746. Speed detection is automatic for 300, 1200, and 2400 bps. TrailBlazer modem users may issue the TeleGodzilla trailblazer command to switch to 19200 bps once they have logged in.

Interesting files include RZSZ.ZOO, YZMODEM.ZOO, ZCOMMEXE.ARC, ZCOMMDOC.ARC, and ZCOMMHELP.ARC.

9.2 Unix UUCP Access

UUCP sites can obtain the current version of this file with

```
uucp omen!/u/caf/public/ymodem.doc /tmp
```

A continually updated list of available files is stored in /usr/spool/uucppublic/FILES. When retrieving these files with uucp, remember that the destination directory on your system must be writeable by anyone, or the UUCP transfer will fail.

The following L.sys line calls TeleGodzilla (Pro-YAM in host operation). TeleGodzilla determines the incoming speed automatically.

In response to "Name Please:" uucico gives the Pro-YAM "link" command as a user name. The password (Giznoid) controls access to the Xenix system connected to the IBM PC's other serial port. Communications between Pro-YAM and Xenix use 9600 bps; YAM converts this to the caller's speed.

Finally, the calling uucico logs in as uucp.

```
omen Any ACU 2400 1-503-621-3746 se:--se: link ord: Giznoid in:--in: uucp
```

10. Revisions

8-03-87 Revised for clarity.

5-31-1987 emphasizes minimum requirements for YMODEM, and updates information on accessing files.

9-11-1986 clarifies nomenclature and some minor points.

The April 15 1986 edition clarifies some points concerning CRC calculations and spaces in the header.

11. YMODEM Programs

ZCOMM, A shareware little brother to Professional-YAM, is available as **ZCOMMEXE.ARC** on TeleGodzilla and other bulletin board systems. **ZCOMM** may be used to test **YMODEM** and **ZMODEM** implementations.

Unix programs supporting **YMODEM** are available on TeleGodzilla in **RZSZ.ZOO**. This **ZOO** archive includes a **ZCOMM/Pro-YAM/PowerCom** script **ZUPL.T** to upload a bootstrap program **MINIRB.C**, compile it, and then upload the rest of the files using the compiled **MINIRB**. Most Unix like systems are supported, including **V7**, **Xenix**, **Sys III**, **4.2 BSD**, **SYS V**, **Idris**, **Coherent**, and **Regulus**.

A version for **VAX-VMS** is available in **VRBSB.SHQ**.

Irv Hoff has added 1k blocks and basic **YMODEM** batch transfers to the **KMD** and **IMP** series programs, which replace the **XMODEM** and **MODEM7/MDM7xx** series respectively. Overlays are available for a wide variety of **CP/M** systems.

Questions about Professional-YAM communications software may be directed to:

Chuck Forsberg
Omen Technology Inc
17505-V Sauvie Island Road
Portland Oregon 97231
VOICE: 503-621-3406 :VOICE
Modem: 503-621-3746 Speed: 2400,1200,300
Usenet: ...!tektronix!reed!omen!caf
CompuServe: 70007,2304
GEnie: CAF

Unlike **ZMODEM** and **Kermit**, **XMODEM** and **YMODEM** place obstacles in the path of a reliable high performance implementation, evidenced by poor reliability under stress of the industry leaders' **XMODEM** and **YMODEM** programs. **Omen Technology** provides consulting and other services to those wishing to implement **XMODEM**, **YMODEM**, and **ZMODEM** with state of the art features and reliability.