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XMODEM/YMODEM PROTOCOL REFERENCE

A compendium of documents describing the

XMODEM and YMODEM

File Transfer Protocols

This document was formatted 10-14-88.

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(May 6, 1944 – September 24, 2015 -- RIP)

This document was corrected 9-16-2021.

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provided the text is not altered (appologies, Craig).

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, some self styled rewriter of history

altered the heading in YMODEM.DOC's Figure 1 from "1024 byte Packets" to

"YMODEM/CRC File Transfer Protocol". None of the XMODEM and YMODEM

examples shown in that 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

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1. Page C/12, PC-WEEK July 12, 1987

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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 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. In a nutshell, YMODEM means

BATCH.

YMODEM-g Refers to the streaming YMODEM variation 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.

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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.

For those who are too lazy to read the entire document:

+ Unless specifically requested, only the file name portion is

sent.

+ No drive letter is sent.

+ Systems that do not distinguish between upper and lower case

letters in filenames shall send the pathname in lower case only.

+ The receiving program shall use this pathname for the received file

name, unless explicitly overridden.

+ When the receiving program receives this block and successfully

opened the output file, it shall acknowledge this block with an ACK

character and then proceed with a normal XMODEM file transfer

beginning with a "C" or NAK tranmsitted by the receiver.

+ 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 within each file it receives. Sending programs may

arbitrarily switch between 1024 and 128 byte blocks.

+ 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, this pathname block shall be acknowledged the same as other

pathname blocks.

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

and shall not be described as supporting YMODEM.

Meeting these MINIMUM requirements does not guarantee reliable file

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transfers under stress. Particular attention is called to XMODEM's single

character supervisory messages that are easily corrupted by transmission

errors.

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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.

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

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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 batch

transfers with 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 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 [2]

To: all

Be aware the article[3] 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.

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

2. Edited for typesetting appearance

3. Infoworld April 29 p. 16

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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 Unix[4] 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!

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 weird[5] - 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

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

5. The file length, time, and file mode are optional. The pathname and

file length may be sent alone if desired.

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protocol. I don't want to emphasize that too much - out of fear that

other mfgrs 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.

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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

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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 YMODEM[1] 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

3 per cent overhead (block number, CRC, etc.).

Some environments cannot accept 1024 byte bursts, including some networks

and minicomputer ports. The longer block length should be an option.

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.

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

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

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

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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.

Figure 1. XMODEM-1k Blocks

SENDER RECEIVER

"sx -k foo.bar"

"foo.bar open x.x minutes"

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

"sx -k foo.bar"

"foo.bar open x.x minutes"

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

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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:

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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.

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+ 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.

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.[3]

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.

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3. Fields may not be skipped.

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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.[4]

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

opened for writing, the receiver cancels the transfer with CAN characters

as described above.

The receiver then initiates transfer of the file contents with a "C"

character, according to the standard XMODEM/CRC protocol.

After the file contents and XMODEM EOT have been transmitted and

acknowledged, 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.

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4. 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.

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Most YMODEM receivers request 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 (1 file)

SENDER RECEIVER

(command: "sb foo.\*<CR>")

"sending in batch mode etc."

C (command: ”rb<CR>")

SOH 00 FF foo.c NUL[123] CRC CRC

ACK

C

SOH 01 FE Data[128] CRC CRC

ACK

SOH 02 FD Data[128] CRC CRC

ACK

SOH 03 FC Data[100] CPMEOF[28] CRC CRC

ACK

EOT

NAK

EOT

ACK

C

SOH 00 FF NUL[128] CRC CRC

ACK

Figure 7. YMODEM Header Information and Features

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| 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. This two character sequence generally

works well on single process micros in direct communication, provided the

programs rigorously adhere to all the XMODEM recommendations included

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Figure 4. YMODEM Batch Transmission Session (2 files)

SENDER RECEIVER

(command: "sb foo.c baz.c<CR>")

"sending in batch mode etc."

C (command: ”rb<CR>")

SOH 00 FF foo.c NUL[123] CRC CRC

ACK

C

SOH 01 FE Data[128] CRC CRC

ACK

SOH 02 FD Data[128] CRC CRC

ACK

SOH 03 FC Data[100] CPMEOF[28] CRC CRC

ACK

EOT

NAK

EOT

ACK

C

SOH 00 FF baz.c NUL[123] CRC CRC

ACK

C

SOH 01 FE Data[100] CPMEOF[28] CRC CRC

ACK

EOT

NAK

EOT

ACK

C

SOH 00 FF NUL[128] CRC CRC

ACK

Figure 5. YMODEM Batch Transmission Session-1k Blocks

SENDER RECEIVER

(command: "sb -k foo.\*<CR>")

"sending in batch mode etc."

C (command: ”rb<CR>")

SOH 00 FF foo.c NUL[123] CRC CRC

ACK

C

STX 01 FE Data[1024] CRC CRC

ACK

SOH 02 FD Data[128] CRC CRC

ACK

SOH 03 FC Data[100] CPMEOF[28] CRC CRC

ACK

EOT

NAK

EOT

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ACK

C

SOH 00 FF NUL[128] CRC CRC

ACK

Figure 6. YMODEM Filename block transmitted by sz

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

00 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

herein. Programs with marginal XMODEM implementations do not fare so

well. Timesharing systems and packet switched networks can separate the

successive characters, rendering this method unreliable.

Sending programs may detect the CK sequence if the operating enviornment

does not preclude reliable implementation.

Instead of the standard YMODEM file length in decimal, 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 inital 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

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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 8. YMODEM-g Transmission Session

SENDER RECEIVER

(command: "sb foo.\*<CR>")

"sending in batch mode etc..."

G (command: ”rb -g<CR>")

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

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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.

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+ The last block sent is no different from others, i.e. there is no

"short block".

Figure 9. 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 re-

transmitted; 3) any other block number indicates a fatal loss of

synchronization, such as the rare case of the sender getting a line-glitch

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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 10. 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.

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+ 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.

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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 CRC-

CCITT 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 11. 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.

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. This reliability figure is misleading because XMODEM's critical

supervisory functions are not protected by this CRC.

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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 12. 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

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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.

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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 13. Data Flow: Receiver has CRC Option, Sender Doesn't

SENDER RECEIVER

<--- <C>

times out after 3 seconds,

<--- <C>

times out after 3 seconds,

<--- <C>

times out after 3 seconds,

<--- <C>

times 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>

times 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.

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Figure 14. Receiver and Sender Both have CRC Option

SENDER RECEIVER

<--- <C>

<soh> 01 FE -data- <xxxx> --->

<--- <ack>

<soh> 02 FD -data- <xxxx> ---> (data gets line hit)

<--- <nak>

<soh> 02 FD -data- <xxxx> --->

<--- <ack>

<soh> 03 FC -data- <xxxx> --->

(ack gets garbaged) <--- <ack>

times out after 10 seconds,

<--- <nak>

<soh> 03 FC -data- <xxxx> --->

<--- <ack>

<eot> --->

<--- <ack>

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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 1200, 2400 and 19200(Telebit PEP) bps.

TrailBlazer modem users may issue the TeleGodzilla trailblazer command to

swith to 19200 bps once they have logged in.

Interesting files include RZSZ.ZOO (C source code), YZMODEM.ZOO (Official

XMODEM, YMODEM, and ZMODEM protocol descriptions), ZCOMMEXE.ARC,

ZCOMMDOC.ARC, and ZCOMMHLP.ARC (PC-DOS shareware comm program with XMODEM,

True YMODEM(TM), ZMODEM, Kermit Sliding Windows, Telink, MODEM7 Batch,

script language, etc.).

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

6-18-88 Further revised for clarity. Corrected block numbering in two

examples.

10-27-87 Optional fields added for number of files remaining to be sent

and total number of bytes remaining to be sent.

10-18-87 Flow control discussion added to 1024 byte block descritpion,

minor revisions for clarity per user comments.

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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 amd 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: 19200(Telebit PEP),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.

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