International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Optimization of the HDLC I-Frame Structure and IIASA Data Communication Network

Masunaga, Y.

IIASA Research Memorandum
February 1976

RM-76-7

OPTIMIZATION OF THE HDLC I-FRAME STRUCTURE AND IIASA DATA COMMUNICATION NETWORK

Yoshifumi Masunaga

February 1976

PREFACE

IIASA adopted the HDLC protocol, proposed by ISO in 1974, as its data link protocol for the data communication network. Some optimization problems arose because of the open-ended characteristics of the HDLC protocol. This paper gives a solution to the most fundamental and also indispensible optimization problem of determining the optimal HDLC Information frame structure (finding out the optimal length of the information part of the HDLC Information frame) for the IIASA computer network under the assumption of the typical NRM and HDX usage of the HDLC protocol and the basic usage of data communication network that is file transfer.

ABSTRACT

This memorandum presents a solution to one of the most basic optimization problems which arose from the adoption of the HDLC (High level Data Link Control) procedure in the IIASA data communication network data link control protocol. Strictly, the problem discussed here is finding out the optimal HDLC Information-frame structure in order to maximize the throughput, so that the solution states the optimal length of the information part of the Information-frame is 5, 16, 57, 190, 610 and 1800 bytes corresponding to the line quality of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, and 10^{-7} in bit error probability, where the HDLC half duplex normal response mode and the case of file-transfer are assumed. Some other related results and remarks are also given in this memorandum.

I. INTRODUCTION

In 1974, ISO proposed HDLC (High Level Data Link Control) as a standardized international link control protocol for data transmission [1]. IIASA has planned its own international computer network and adopted HDLC as the data communication link protocol [5,6].

As it is known, HDLC has flexibility in usage, so that the network designer can extract an appropriate subset of HDLC protocols in order to realize his idea, and still examine some optimization problems arising from that usage. IIASA now intends to use a public switched telephone line as the physical data transmission line for its data communication network, and accordingly the following fundamental form is assumed:-

1. Line speed 1,200 bps;
2. Asynchronous communication;
3. Half duplex communication.

In order to support this communication form, the NRM (Normal Response Mode) and HDX (Half DupleX) usage of HDLC were deduced with some optimization problems to be solved.

I think that such optimization problems are generally divided into two categories:

1. Optimization from physical stand point of view
2. Optimization from procedural stand point of view

For example, an optimization problem for determining optimal length of the information part of HDLC I-frame (Information frame) in order to maximize throughput of the network refers to category one, and for determining an optimal error recovery procedure using HDLC commands/responses in the same sense refers to category two.

This paper discusses the first problem assuming the most typical NRM and HDX usage of HDLC protocols and the most fundamental and basic usage of the data communication network, i.e. file transfer.

II. FUNDAMENTAL SCHEME

A. Assumptions of Link and Commands/Responses

Let us assume that the DTE (Data Terminal Equipment) designated S (source station) wants to transfer (very large amounts of) data to DTE designated D (destination station) and S acts as a primary station (as shown in Figure 1).

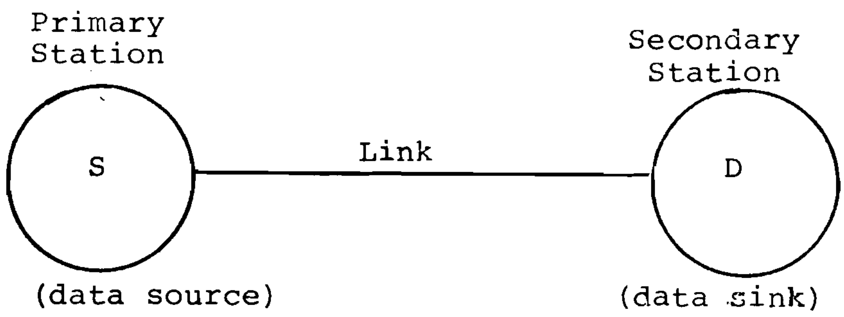


Figure 1. Linking Scheme.

Also, let us assume that a subset of HDLC procedures which will support communication consists of the following commands and responses (as listed in Table 1).

Table 1. Set of Commands and Responses.

	Commands	Responses
Information Transfer Format	I-Information	I-Information
Supervisory Format	RR (Receive Ready) RNR (Receive Not Ready)	RR RNR
Unnumbered Format	SNRM (Set Normal Response Mode) DISC (Disconnect)	UA (Unnumbered Acknowledgment) CMDR (Command Reject)

B. Control Flow

Next let us show the scheme of control flow. Because S is responsible for the organization of data flow it must take action to establish a link between S and D. Figure 2 shows a typical control flow of data transmission from S to D and in this case no error happens during data transmission.

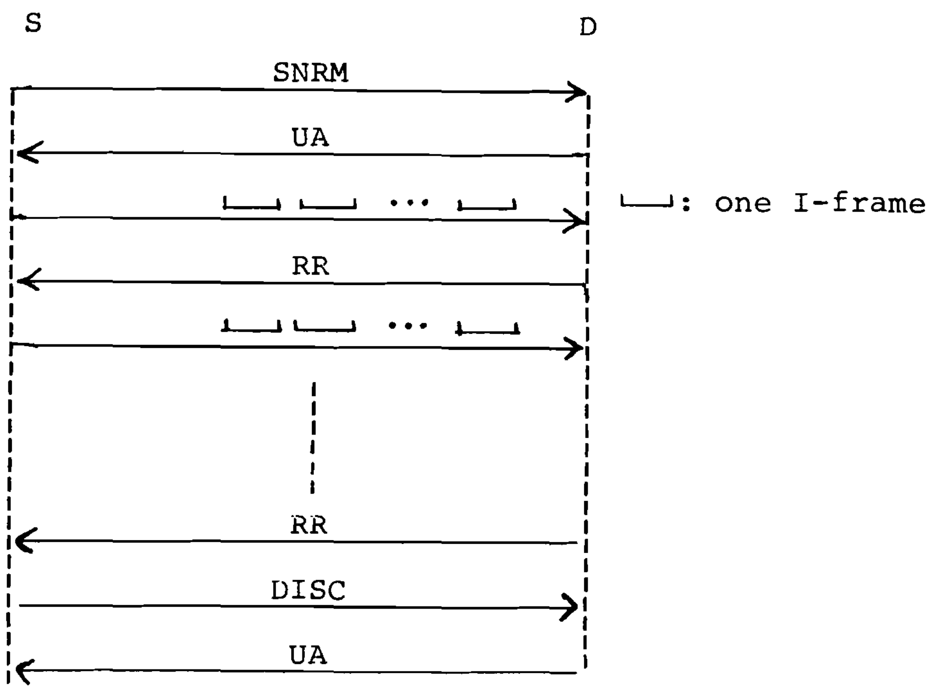


Figure 2. Typical Control Flow for one way file transfer.

C. Error Recovery Procedure

Here we shall examine an error recovery procedure.

Because our HDLC subset does not include supervisory format commands/responses such as REJ (REJect) or SREJ (Selective REJect), we must use Poll/Final bit error recovery procedure. As it is known HDLC error recovery procedure is effected by means of a "numbering scheme" which is cyclic within a modulus specified in the standard, and measured in terms of frames, and the modulus are equal to 8 for unextended control field which is also our usage.

Let us illustrate the case when the transmission error happens on the I-frame:

The source station can send at most 7 I-frames in sequence with the final bit equal to 0 for the zero-th through fifth I-frame and the final bit equal to 1 for the last sixth I-frame in order to indicate the end of the frame sequence.

Here, we shall assume that the error happened on the i-th I-frame ($0 \leq i \leq 6$) and no error happened on the j-th I-frame for $\forall j, j < i$ (if no error happened, set $i = 7$) then the Poll/Final bit error recovery procedure urges the destination station to acknowledge the source station by sending RR response with the receive sequence number $N(R) = i$ and Poll bit set equal to 1. After receiving RR response, the source station again begins to transmit at most seven I-frames in sequence whose top I-frame is numbered i and so on. Figure 3 illustrates the typical Poll/Final bit error recovery in our file transfer case.

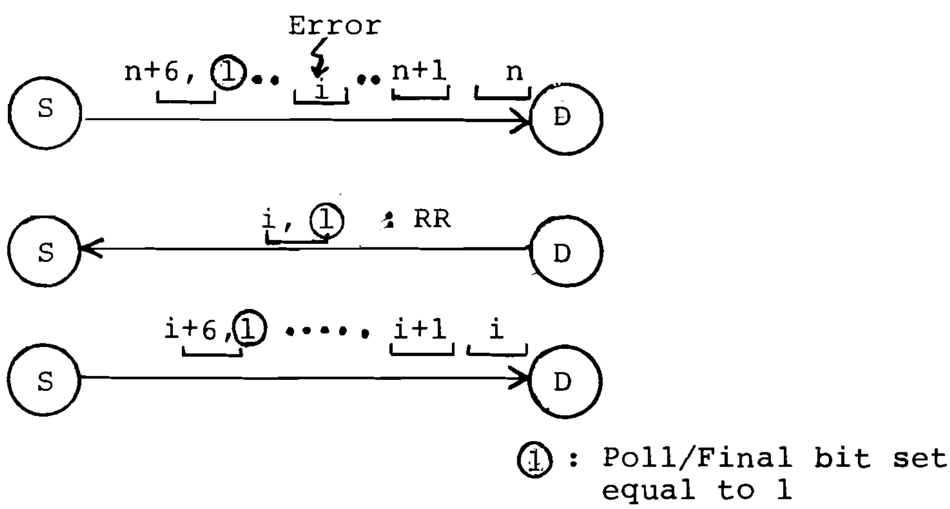


Figure 3. Poll/Final Bit Error Recovery.

D. Modem Polarity Switching Time

Modems need time to switch their polarity: The modem can receive data when it is in the receiving state, and it can send data when it is in the sending state, but it takes time to switch its state from receiving to sending, or from sending to receiving. In another term, it is a time for doing CLEAR to SEND, for example, in this paper it is denoted by d_m and is supposed to be 250 ms.

So the typical time flow is illustrated as follows:

1. Firstly, it takes t_s seconds to transmit data from the source station to the destination station;
2. Secondly it takes d_m seconds for the destination station to switch its modem polarity to CLEAR to SEND. (Within $t_s + d_m$ seconds the source station has switched its modem polarity to the receiving state.)
3. Thirdly, it takes t_d seconds to transmit acknowledgment information from the destination station to the source station, etc.

III. OPTIMAL I-FRAME STRUCTURE

A. Frame Structure

In this section we shall outline the structure of I-frames S-frames and U-frames. Firstly, the structure of I-frame is shown in Figure 4.

F	A	C	I	FCS	F

F : Flag of one byte length with bit pattern 01111110
A : Address part of one byte length
C : Control part of one byte length
FCS: Frame check sequence of two bytes length
I : Information part of arbitrary length

Figure 4. I-Frame Structure.

The structure of S-frame and U-frame are just the same as that of I-frame without the I-part.

B. Frame Error Probability

One of the most remarkable assumptions in our approach is that the system designer is only informed about the bit error probability for the quality of line and nothing more. This assumption seems quite natural: Hereafter, we shall use the following notation:

P_b = bit error probability
$\bar{P}_b = 1 - P_b$ = probability for a bit transmitted correctly
P_f = Frame error probability
$\bar{P}_f = 1 - P_f$ = probability for a frame transmitted correctly
L_i = byte length of information part of the I-frame.
$L_i = 0$ for S- and U- frames.

Then $\bar{P}_f$ is defined as follows: Where one start bit and one stop bit, which precedes and follows each byte respectively are assumed for synchronization

$$\bar{P}_f = (\bar{P}_b)^{10\cdot(6+L_i)} \quad .$$

C. File Transfer

One of the most typical, fundamental uses of a data communication network could be (one-way) file transfer, i.e. the source station wants to transfer (a large amount of) files to the destination station. The source station only receives data and does not want to send data except acknowledgements.

So the assumptions are summarized as follows:-

1. There is an infinite length queue of equally sized I-frames at the source station;
2. The destination station does not want to send data to the source station only acknowledgement;
3. The modulus of the HDLC numbering scheme is eight, and the source station always sends seven I-frames in sequence to the destination station;
4. The destination station acknowledges error condition using RR response.

D. $P_0, P_1, \ldots, P_7$

In order to induce a formula which expresses the average amount of data transmitted correctly from the source station to the destination station, let us introduce probabilities P_0, $P_1, \ldots, P_7$ as follows:

P_0 : Probability of occurrence of error in the first frame of the frame sequence. In this case the destination station cannot get any data from the source station.

P_i : Probability of occurrence of error in the (i + 1)th frame in the frame sequence, but not in any frame transmitted before. So the station D receives i-times unit of information from the station S, where unit information means data packed in one I-frame.

P_7 : Probability of occurrence of no error in any frame in the frame sequence. So the station D receives total 7 units of information from the station S.

E. Calculations of $P_0, P_1, \ldots, P_7$.

$$P_0 = P_f \cdot \overline{P}_f^{\,6} + P_f \cdot \binom{6}{1} \cdot P_f \cdot \overline{P}_f^{\,5} + \ldots + P_f \cdot \binom{6}{i} \cdot P_f^{\,i} \cdot (\overline{P}_f)^{6-i} + \ldots + P_f \cdot P_f^{\,6}$$

$$P_j = \overline{P}_f^{\,j} \cdot P_f \cdot \overline{P}_f^{\,(7-j-1)} + \ldots + \overline{P}_f^{\,j} \cdot P_f \cdot \binom{7-j-1}{i} \cdot P_f^{\,i} \cdot \overline{P}_f^{\,(7-j-1-i)} + \ldots + \overline{P}_f^{\,j} \cdot P_f \cdot P_f^{\,(7-j-1)}$$

$$P_7 = \overline{P}_f^{\,7} \quad .$$

These equations are reduced to the following using the next well known equation:

$$\binom{n}{0} P^0 \cdot q^n + \binom{n}{1} P^1 \cdot q^{n-1} + \ldots + \binom{n}{i} P^i \cdot q^{n-i} + \ldots + \binom{n}{n} P^n \cdot q^0 = 1$$

where

$$P + q = 1 \quad .$$

Then P_0, P_1, ..., P_7 is expressed as follows:

$$P_0 = P_f$$

$$P_1 = \overline{P}_f \cdot P_f$$

$$P_2 = \overline{P}_f^{\,2} \cdot P_f$$

$$P_3 = \overline{P}_f^{\,3} \cdot P_f$$

$$P_4 = \overline{P}_f^{\,4} \cdot P_f$$

$$P_5 = \overline{P}_f^{\,5} \cdot P_f$$

$$P_6 = \overline{P}_f^{\,6} \cdot P_f$$

$$P_7 = \overline{P}_f^{\,7} \quad .$$

As it is easily checked:

$$\sum_{i=0}^{7} P_i = 1 \quad .$$

F. Calculation of the Amount of Information Transmitted Correctly Within a Second

Here we shall derive an asymptotic equation which will show the amount of information transmitted correctly within a second:

1. Firstly, it takes t_s seconds to transmit 7 I-frames from the source to the destination in sequence,

Where t_s is given by:

$$t_s = 7 \cdot [10 \cdot (6 + L_i)]/S_1 \quad ,$$

where

L_i : byte length of the information part of I-frame

S_l : line speed in bits per second.

Within a t_s seconds the destination station will get the I_1 amount of correct information from the source

where

$$I_1 = 0 \cdot P_0 + \hat{e} \cdot P_1 + \ldots + 7 \cdot \hat{e} \cdot P_7 \quad ,$$

where

$\hat{e}$ is an amount of information packed in an I-frame, and is given by

$$\hat{e} = 8 \cdot L_i \quad \text{(bits)}.$$

2. After receiving 7 I-frames in sequence from the source, it takes d_m seconds for the destination station to change its modem polarity and after d_m seconds the destination station will send the acknowledgement response RR with error information to the source. Here it is assumed that the source is able to change the polarity of its modem before receiving the acknowledgement from the destination. In the following calculation, it is also assumed that no transmission error occurs in sending back the acknowledgement from the destination to the source.

   The source station takes also d_m seconds to change the modem status from receiving to sending, and

$t_d = 60/S_1$ seconds are taken to transmit an acknowledement from the destination to the source, so it takes $2 \cdot d_m + t_d$ seconds more before the source station begins to transmit 7 I-frames in sequence again according to the error information from the destination sent by using RR response.

Afterall, the total of I_2 amount of correct information shall be sent from the source to the destination within $t_s + t_u$ seconds,

where

$$t_u = 2 \cdot d_m + t_d + t_s$$

and I_2 is given by

$$I_2 = \sum_{i_1=0}^{7} \sum_{i_2=0}^{7} P_{i_1} \cdot P_{i_2} \cdot (i_1 + i_2) \cdot \hat{e} \quad .$$

Let us continue our discussions, then, after n-times the amount of I_n data shall be sent correctly to the destination within $t_s + (n - 1) \cdot t_u$ seconds,

Where I_n is given by

$$I_n = \sum_{i_1=0}^{7} \cdots \sum_{i_n=0}^{7} P_{i_1} \cdot P_{i_2} \cdots P_{i_n} \cdot (i_1 + i_2 + \cdots + i_n) \cdot \hat{e} \quad .$$

So, the amount of $I_n/[t_s + (n - 1) \cdot t_u]$ data shall be transmitted correctly to the destination within one second by that time.

Then the expected amount of data correctly transmitted within one second shall be defined as follows:

$$I = \lim_{n \to \infty} \frac{I_n}{t_s + (n-1) \cdot t_u} .$$

Now, the maximization problem which should be discussed in this section is to find the L_i which maximizes I.

G. <u>Finding Out the Optimal Length of Information Part</u>

At first, we shall discuss the recursive behavior of I_n in order to get a more simplified expression of I.

$$I_1 = 0 . P_0 + \hat{e} \cdot P_1 + \ldots + 7 \cdot \hat{e} \cdot P_7 = \sum_{i=0}^{7} P_i \cdot i \cdot \hat{e} .$$

$$I_n = \sum_{i_1=0}^{7} \ldots \sum_{i_n=0}^{7} P_{i_1} \ldots . P_{i_n} (i_1 + \ldots + i_n) \cdot \hat{e}$$

$$= \sum_{i_1=0}^{7} \ldots . \sum_{i_{n-1}=0} \Big\{ P_{i_1} \ldots P_{i_{n-1}} \cdot P_0 \cdot (i_1 + \ldots + i_{n-1} + 0) \cdot \hat{e}$$

$$+ P_{i_1} \ldots \cdot P_{i_{n-1}} \cdot P_1 \cdot (i_1 + \ldots + i_{n-1} + 1) \cdot \hat{e}$$

$$+ \ldots$$

$$+ P_{i_1} \ldots . P_{i_{n-1}} \cdot P_7 \cdot (i_1 + \ldots + i_{n-1} + 7) \cdot \hat{e} \Big\}$$

$$= I_{n-1} + \sum_{i_1=0}^{7} \cdots \sum_{i_{n-1}=0}^{7} P_{i_1} \cdots P_{i_{n-1}} \cdot P_0 \cdot 0 \cdot \hat{e}$$

$$+ \sum_{i_1=0}^{7} \cdots \sum_{i_{n-1}=0}^{7} P_{i_1} \cdots P_{i_{n-1}} \cdot P_1 \cdot 1 \cdot \hat{e}$$

$$+ \ldots$$

$$+ \sum_{i_1=0}^{7} \cdots \sum_{i_{n-1}=0}^{7} P_{i_1} \cdots\cdots P_{i_{n-1}} \cdot P_7 \cdot 7 \cdot \hat{e}$$

$$= I_{n-1} + P_0 \cdot 0 \cdot \hat{e} + P_1 \cdot 1 \cdot \hat{e} + \ldots + P_7 \cdot 7 \cdot \hat{e}$$

$$= I_{n-1} + I_1 \quad \text{for } n \geq 2 \quad .$$

So, the following eauation is obtained

$$I_n = n \cdot I_1 \quad ,$$

where

$$I_1 = \sum_{i=0}^{7} P_i \cdot i \cdot \hat{e} \quad .$$

Afterall, I is reduced as follows

$$I = \lim_{n \to \infty} \frac{I_n}{t_s + (n-1) \cdot t_u}$$

$$= \lim_{n \to \infty} \frac{n \cdot I_1}{t_s + (n-1) \cdot t_u}$$

$$= \lim_{n \to \infty} \frac{I_1}{\frac{t_s}{n} + (1 - \frac{1}{n}) \cdot t_u}$$

$$= \frac{I_1}{t_u} \quad .$$

Here we shall show the results under the assumption listed below

(a) Bit error probability

$P_b = 10^{-2}$, 10^{-3} , 10^{-4} , 10^{-5} , 10^{-6} , 10^{-7} .

(b) Line speed

$S_1 = 1200$, bits per second.

(c) Modem's polarity switching time

$d_m = 250$ ms.

Notice that by "utility of line capacity" we mean $(I/S_1) \cdot 100\%$.

Table 2. Optimal Length of the Information Part.

P_b	Optimal Length of Information Part	Amount of information transmitted in a second*	Utility of Line Capacity
10^{-2}	5 (bytes)	16.6 (bits/sec)	1.38%
10^{-3}	16	223	18.6
10^{-4}	57	592	49.3
10^{-5}	190	822	68.5
10^{-6}	610	913	76.1
10^{-7}	1800	944	78.7

$S_1 = 1200$ bps

$d_m = 250$ ms

*As the reader can see, this does not include I-frame overhead consisting of flags, address and control part and FCS.

The next two figures show the relationships between the amount of information transmitted in a second and byte length of information part, and the relationship between the optional length of the information part and bit error probability.

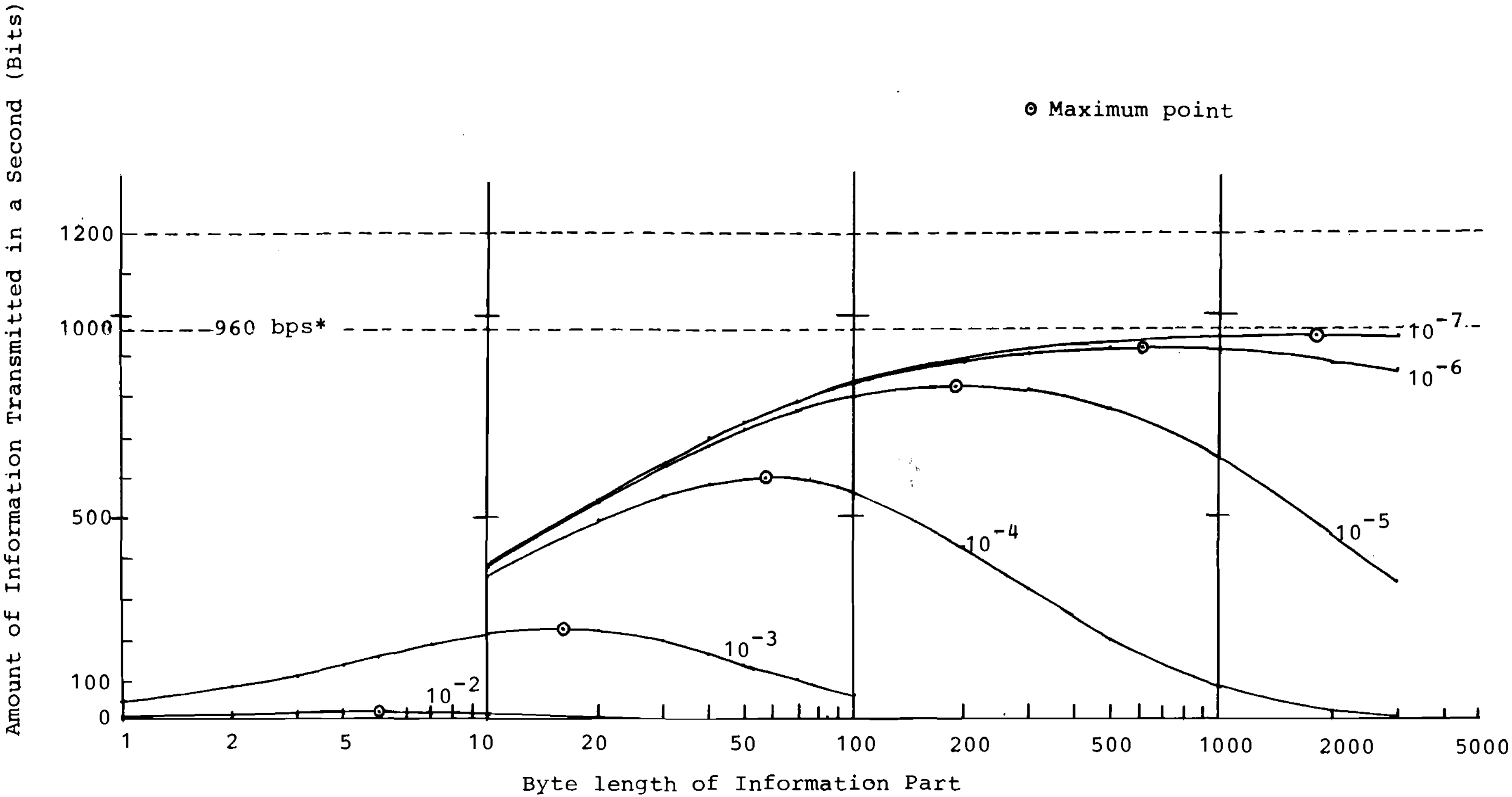


Figure 5. <u>Relation between the Amount of Information Transmitted in a Second and the Byte length of the Information Part, where</u> S_1 = 1200 bps <u>and</u> d_m = 250 ms.

*Theoretical Maximum

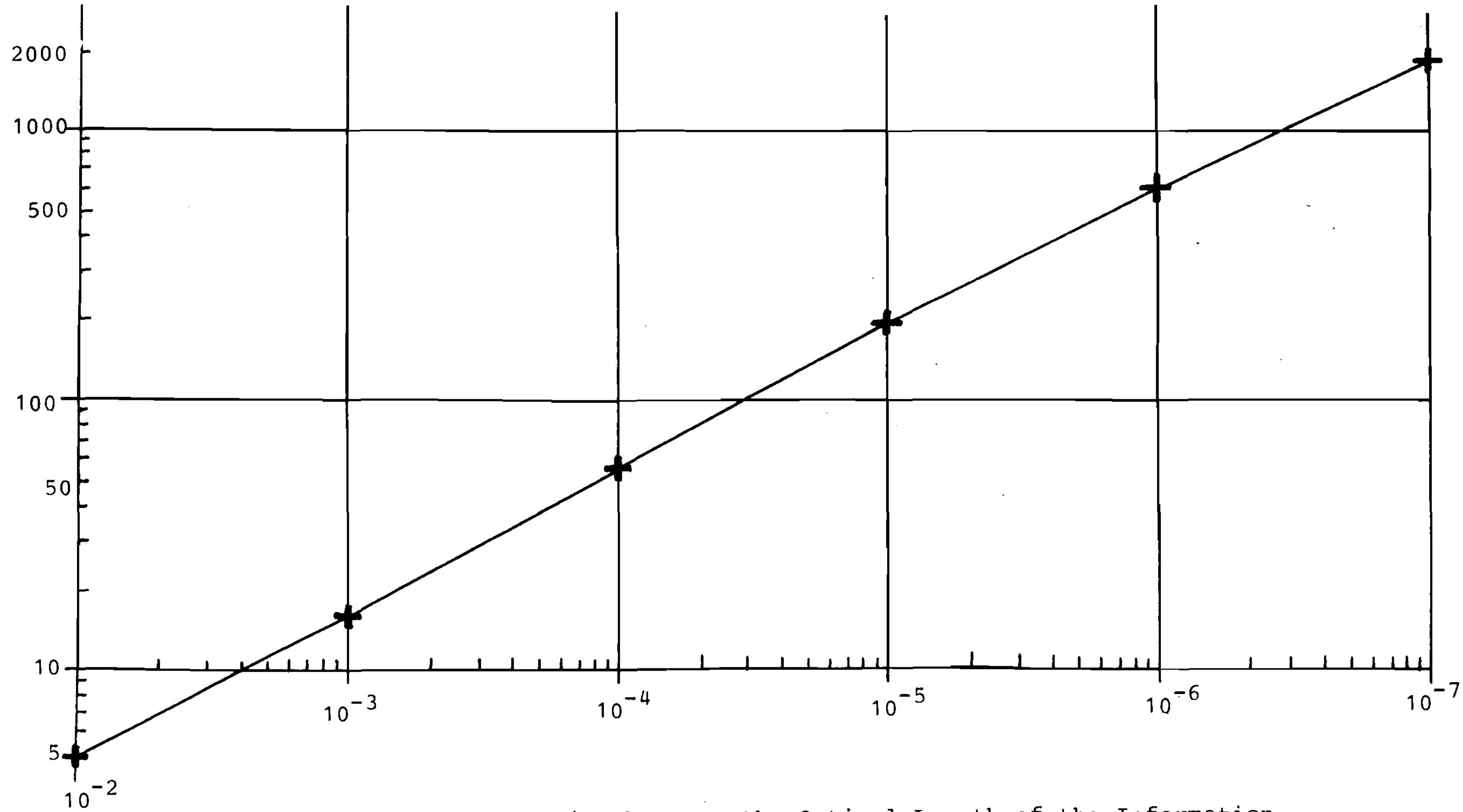


Figure 6. <u>Relation between the Optimal Length of the Information Part in Bytes and the Bit Error Probability, where S_1 = 1200 bps and d_m = 250 ms.</u>

H. Remarkable Results

As the reader can see, the remarkable facts are the following:

1. When the bit error probability is high (for examples $P_b = 10^{-2}$, 10^{-3} or 10^{-4}), the amounts of information transmitted correctly are extremely reduced. In other words, one must retransmit one information frame again and again in order to transmit it correctly, as the precise number of retransmission times are calculated in the next chapter;

2. When the bit error probability is low (for examples $P_6 = 10^{-5}$, 10^{-6} or 10^{-7}), more than 800 bits of data are transmitted correctly within a second if one uses a line with the speed 1200 bps. In this case the line seems very reliable;

3. It should also be mentioned that in the case when the bit error probability lies between 10^{-4} and 10^{-5}, the amount of information transmitted correctly varies very sensitively corresponding to the change of bit error probability.

   To explain this phenonmena, it is very interesting to point out the following:

   Let us assume that the bit error probability of the line is 10^{-5} and therefore we designed I-frame with having 190 bytes lenth of information part. In that case, one can get the amount of 822 bits of correct information within a second. Now, let us assume that we unfortunately get a bad line with the bit error rate 10^{-4}. Then one can only get the amount of 437 bits of correct information transmitted within a second, which is 47% less than the expected amount, and which is also 27% less than the maximal amount of information received within a second in the case of the bit error probability equal to 10^{-4} which is 592 bits.

So one must be careful in designing the length of information part if the line quality is assumed to lie especially between 10^{-4} and 10^{-5} in bit error probability.

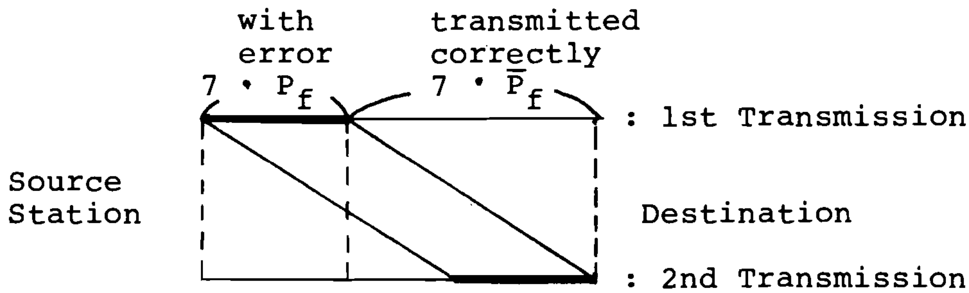
IV. AVERAGE NUMBER OF TOTAL TRANSMISSION TIMES

A. Introductory Remark

It might be very useful to know how many times it takes to transmit one information frame correctly from the source to the destination using the transmission procedure mentioned in III.C. This analysis automatically gives us the average time needed to transmit one information frame correctly to the destination.

B. Setting-Up Formula

If 7 I-frames with the length of information part equal to L_i were transmitted in sequence an average number of $7 \cdot \overline{P}_f$ frames in sequence would be received correctly at the destination. So, for the next transmission the remainder of $7 \cdot P_f$ frames should be retransmitted, and if $7 \cdot P_f \leq 7 \cdot \overline{P}_f$ is satisfied, then the remainder would be received correctly with the result that the destination station could receive the seven I-frames correctly in sequence by the second transmission. This is illustrated as follows:



If the condition $N \cdot P_f \leq 7 \cdot \overline{P}_f$ is not satisfied then the third transmission is required in order to transmit the first seven I-frames correctly to the destination, etc.

Now the average number of total transmission times needed to transmit seven I-frames correctly to the destination is given by n_0 such that:

n_0 is the integer n which satisfies the following two equations

$$\begin{cases} P_f - (n-2) \cdot \overline{P}_f > 0 \\ P_f - (n-1) \cdot \overline{P}_f \leqq 0 \end{cases} .$$

This equation can be reduced further

$$\frac{1}{\overline{P}_f} \leqq n < 1 + \frac{1}{\overline{P}_f} .$$

C. Results

Here, let us show the average number of total transmission times. The calculation is for the frames with optimal information-part length in the sense of III.G.

Table 3. Average Number of Total Transmission Times.

P_b	Average Number of Total Transmission Times	Optimal Information Part Length
10^{-2}	4 (4.22sec)*	5 byte
10^{-3}	2 (3.12sec)	16
10^{-4}	2 (7.90sec)	57
10^{-5}	2 (23.4sec)	190
10^{-6}	2 (72.4sec)	610
10^{-7}	2 (211.3sec)	1800

S_1 = 1200 bps

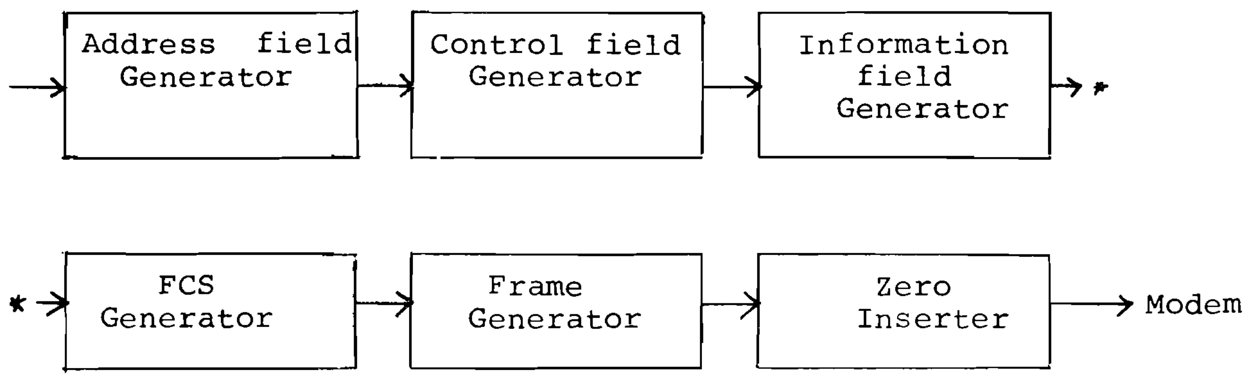
d_m = 250 ms

* :( ) denotes total second needed to transmit 7 I-frames correctly to the destination.

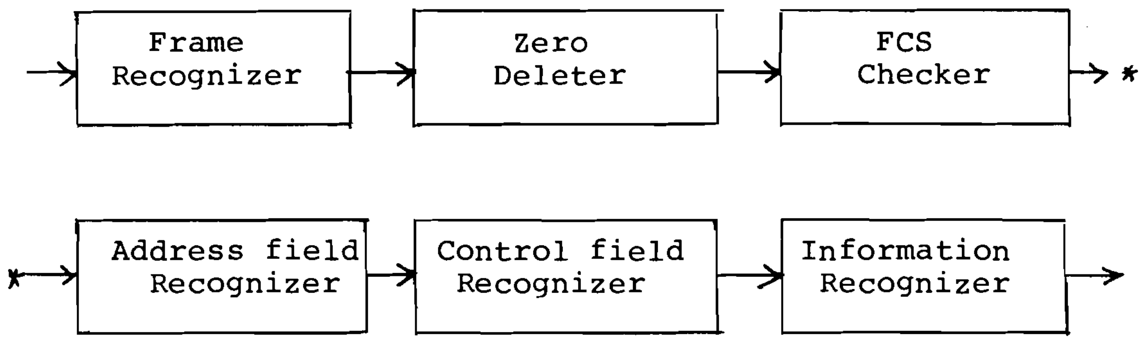
V. SOME IMPLEMENTATION PROBLEMS

A. Frame Driver and Receiver

In order to implement the HDLC (subset) we must, first of all, discuss how to generate and recognize frames. Figure 7 shows the frame driver and receiver, which have ability to generate and recognize frames:



FRAME DRIVER



FRAME RECEIVER

Figure 7. Frame Driver and Receiver.

B. Frame Control Program

In order to combine the frame driver and receiver, the supervisory program is necessary. Such a supervisory program controls information flow by giving the address information, control field bits properties such as N(S), N(R), S, M bits to the frame driver, and conversely by receiving the address information, control field bits properties and data from the frame receiver. Figure 8 shows a combination of supervisory programs, frame driver and frame receiver, which together we shall call Frame Control Program:

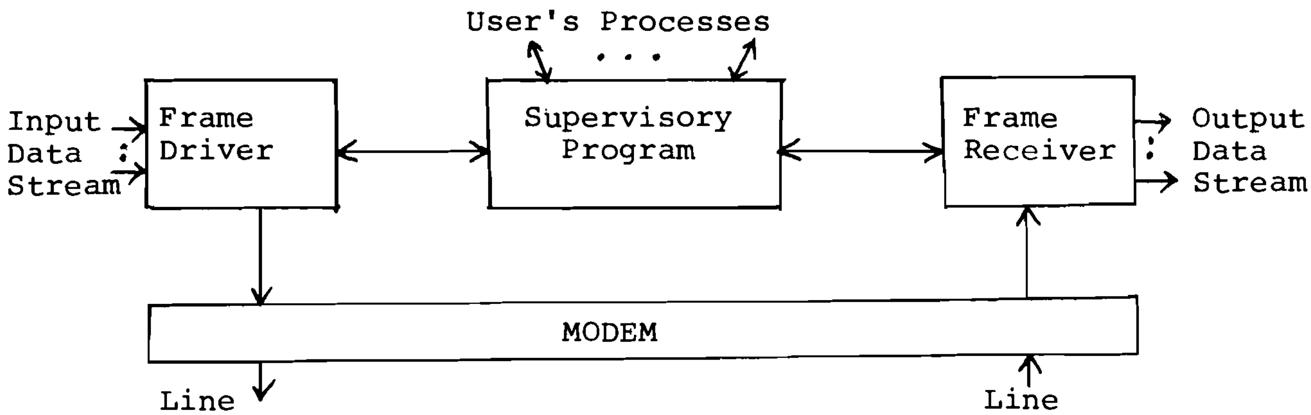


Figure 8. Frame Control Program.

It also seems natural for the station to prepare two kinds of frame control programs, one of which should be loaded when the station wants to act as the primary station, and the other should be loaded when the station wants to act as a secondary station. As shown in Table 1, the commands and responses have different characters. The first character will be represented by a P-frame control program, and the second character by a S-frame control program. If the program is not to be distinguished it will be referred to as frame control program.

C. Time Flow of Driver and Receiver

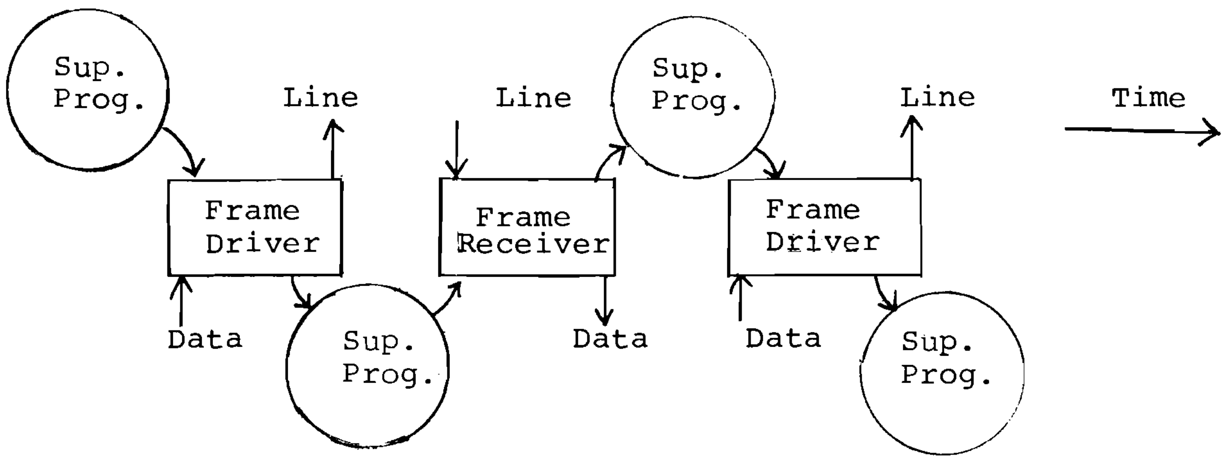


Figure 9. Time Flow.

Firstly, the supervisory program asks the frame driver to send S- or U-frame, or at most seven I-frames by giving address information, current N(R), N(S), S or M information, and the frame driver sends the appropriate frames. Secondly, the frame drivers sends N(S) information back to the supervisory program. Finally, the frame receiver is activated and passes the error information to the supervisory program, then the process returns to the initial stage.

VI. CONCLUDING REMARKS

Although this paper gives the solution to an optimization problem of a HDLC information structure there are a lot of other problems which should be solved in order to develop an efficient IIASA computer network.

The author would like to point out the following remarks:-

A. Lack of physical data on (telephone) line quality:

In this paper all discussions are based on the assumption that physical (telephone) line quality might lie between 10^{-2} to 10^{-7} error probability in one bit. As the reader can easily see, and as the author has also pointed out in section III.H., the optimal length of the information frame varies sensitively corresponding to the bit error probability. Consequently it appears that the network designer must know the real line quality in order to build an efficient computer network.

The author has another aspect for the necessity of having physical line quality [4], which reports that about one third of bit error happens in burst mode, i.e. at least two consequent bits are damaged, so the assumption of this paper that errors occur independently among bits seems to lack correctness in the strict sense, i.e. it is hopefully expected that the real error probability of one frame would be expected a little bit lower than the calculated one presented in this paper.

B. Relationship between the bit error probability and the line speed:

Generally speaking, there might be a relationship between the bit error probability and the line speed. Briefly speaking, it is expected that the error probability of one bit will increase as the line speed increases. But we have not yet any information about this, therefore, we could not establish a good extrapolation corresponding to the chabge of line speed.

Here the author would like to stress that the physical measurements on line quality is indespensible in order to build an efficient computer network.

C. File Transfer:

This paper deals with the case of one-way file transfer, but it is also expected to extend our discussion to the case of two-way file transfer. In the latter case it is expected that the optimal length of the information frame would be shorter than the result presented in this paper when the line quality is bad, but no significant change would occur when the line quality is good.

D. Timeout function:

In order to make discussions more strict and physical the timeout function should be taken into account. If the last I-frame of the I-frame sequence transmitted is damaged or missed, in general, there is no way to recognize the I-frame sequence, because the station can only recognize the end by identifying the Poll/Final bit in HDX, NRM usage. To avoid this the timeout function is attached usually to the primary station, i.e. the primary station will send the last I-frame sequence again after a certain period of time until the communication starts again.

In this paper it is assumed that the station can recognize the end of the I-frame sequence in any form, mainly because of the assumption that the station is always fully loaded with files to be transmitted.

E. Optimization problem from procedural stand point of view

As the author mentioned in section I, another type of optimization problem from procedural stand point of view should also be discussed. In the case of IIASA computer networking it should be stated as follows:-

Add SREJ (Selective REJect) command/response to the set of supervisory commands/responses (so the total set of supervisory commands/responses consists of RR, RNR and SREJ). Because the SREJ command/response is designed to request the retransmission of a single information frame following the detection of a sequence error rather than the retransmission of the information frame requested plus all additional information frames which may have been subsequently transmitted (the latter is exactly the case of this paper as mentioned in section II.B.), so more efficient frame error recovery procedure is expected by using SREJ command/response. The author also feels that it is necessary to examine this problem in order to build an efficient IIASA computer network.

REFERENCES

[1] High Level Data Link Control Procedures, Proposed Draft International Standard on Elements of Procedures. ISO/TC97/SC6/1005, May 1975.

[2] IBM Synchronous Data Link Control General Information, GA27-3093-O, IBM, 1974.

[3] Masunaga, Y. "The Local Computer Network in Tohoku District Japan," unpublished IIASA working paper.

[4] Yaegashi, J, Fujita, K. and Oizumi, J. "A Computer Network Using the Public Communication Network--A Study on the Transmission System," P-1, Technical Report of IECE of Japan, Vol. 75, No. 42, 1975 (in Japanese).

[5] Butrimenko, A, Sexton, J.H. and Dashko V. "Part III. IIASA Data Communication Network, unpublished IIASA working paper.

[6] Sexton, J.H. "Part IV. IIASA Data Communication Network Data Link Control Procedure and Part V. Optimization of the Frame Retransmission Mechanism," unpublished IIASA working paper.

[7] Roberts, L.C.T. and Wessler, B.D. "Computer Network Development to Achieve Resource Sharing," AFIPS SJCC, 1970.

[8] Frank, H., Kahn, R.E. and Kleinrock, L. "Computer Communication Network Design--Experience with Theory and Practice," AFIPS SJCC, 1972.

[9] Pouzin, L. "Presentation and Major Design Aspects of the CYCLADES Computer Network," SCH511, IRIA, 1973.