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IMPROVEMENTS IN ERROR IMMUNITY OF SYNCHRONOUS DIGITAL HIERARCHY (SDH) POINTERS

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I- Abstract

In this paper, a modified way to improve the immunity of the SDH pointers against communication errors is proposed. The compatibility between the current systems and those utilizing the proposed way is considered. A simulation program for a communication channel utilizing the SDH technique is developed. The simulation results for both the International Telecommunication Union Tele-communication standardization section (ITU-T) recommended way and the modified one are presented. The obtained result asserts that the proposed way is superior to the ITU-T recommended one. A mathematical derivation for the improvement factor of the probability to interpret an erroneous pointer in the SDH network utilizing the ITU-T recommendations and that utilizing the proposed way is carried out in both the steady state and at the beginning of new data.

II- Key Words

SDH, SONET, Improvements, Immunity, Pointers

III- Introduction

It is known that SDH and Synchronous Optical NETwork (SONET) will be widely deployed in access metropolitan and toll networks to transport both today's and tomorrow's services (e.g., high quality video, high resolution imaging, high speed data) [1]. Contrary to the existing asynchronous hierarchy (Plesiochronous Digital Hierarchy (PDH)), the advantage of the SDH/SONET format ease with which the signals can be manipulated (e.g. multiplexed, added, dropped and/or cross-connected). The SDH / SONET standard also eliminates the back-to-back

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intermediate interfaces that are required in today's PDH transmission networks. The higher level of integration possible with SDH/SONET leads to fewer components at transmission nodes and less susceptibility to failures and errors due to both intrinsic causes and maintenance activities [2]. Therefore, any additional improvements in the error performance of SDH/SONET networks will improve the superiority of the SDH/ SONET networks to the PDH ones. In SDH the administration unit (AU) pointer provides a method of allowing flexible and dynamic alignment of the virtual container (VC) within the AU frame. It means that the VC is allowed to "float" within the AU frame. Thus the pointer is able to accommodate differences not only in the phases of the VC and section overhead (SOH) but in the frame rates as well. Interpreting an erroneous pointer is very critical because all the received data in that frame will be erroneous data and will be lost. That is why ITU-T has proposed a good algorithm to improve the pointer immunity against the communications channel errors [3]. The pointer is composed from two bytes (16 bits) as shown in figure 1. NDF is enabled if a new pointer value is sent, otherwise it is disabled. In NDF, a single error can be easily detected and corrected.

N	N	N	N	S	S	I	D	I	D	I	D	I	D	I	D

← 10 bits pointer value →

N New data flag (NDF) I Increment
SS Administration unit type D Decrement

NDF is enabled when at least 3 out of 4 bits match "1001".
NDF is disabled when at least 3 out of 4 bits match "0110".

Negative justification (Invert 5 D-bits and accept majority vote).
Positive justification (Invert 5 I-bits and accept majority vote).

Figure 1 SDH administration pointer coding .

IV- ITU-T rules for interpreting the AU pointers:

The following summarizes the rules recommended by ITU-T for interpreting the AU pointers [3].

1) During normal operation, the pointer locates the start of the VC within the AU frame.
2) Any variation from the current pointer value is ignored unless a consistent new value is received three times consecutively or it is preceded by one of rules 3. 4 or 5.
3) If the majority of the I-bits of the pointer word are inverted, a positive justification operation is indicated. Subsequent pointer values shall be incremented by one.

4) If the majority of the D-bits of the pointer word are inverted, a negative justification operation is indicated. Subsequent pointer values shall be decremented by one.
5) If the NDF is set to 1001, then the coincident pointer value shall replace the current one at the offset indicated by the new pointer value regardless of the state of the receiver.

According to the above rules, we may divide the pointer interpretation into two time domains [4]. These are, when the pointer value is new (NDF is enabled) and when the pointer value is not new (NDF is disabled).

- **At new data**

$$P_{E-NEW-POINTER} = P_{ENEW}(3+\frac{P_{ep}}{1-P_{ep}}) \quad (1\text{-a})$$

where

$$P_{ENEW} = 1 - P_{CNEW}$$

is the probability to receive an erroneous pointer when the new data flag is enabled,

$$P_{CNEW} = (1-Q)^{10}$$

is the probability to receive a correct pointer when the new data flag is enabled,

$$P_{ep} = 1-(P_{CNDF} * P_{CNEW})^3 - P_{ENDF} * P_{CNEW}$$

is the probability of error propagation (in case if erroneous pointer is received),

$$P_{CNDF} = (1-Q)^3(1+3Q)$$

is the probability to receive a correct new data flag and

$$P_{ENDF} = Q^3(4-3Q)$$

is the probability to receive an erroneous new data flag.

At practical values of Q (Q <<1) we have

$$P_{E-NEW-POINTER} \approx 30Q \quad (1\text{-b})$$

In the steady state

$$P_{E-POINTER} = P_{ET}(3+\frac{P_{ep}}{1-P_{ep}}) \quad (2\text{-a})$$

where

$$P_{ET} = P_{EA} + 2P_{EB} + P_{ED}$$

is the probability to receive an erroneous pointer when the new data flag is disabled,

$$P_{EA} = 10Q^3(1-Q)^9(1+3Q)^3(1-Q^3)^9$$

is the probability to receive three successive erroneous pointers in each of which the same bit pattern is received,

$$P_{EB} = Q^3(1+3Q)(1-Q)^3(10-15Q-6Q^2)$$

is the probability to receive erroneous pointer due to erroneous increment decrement and

$$P_{ED} = Q^3(4-3Q)(1-(1-Q)^{10})$$

is the probability to receive erroneous pointer due to an erroneous enabled new data flag and at least one of the bits carrying the pointer value is erroneously received.

At practical values of Q (Q <<1) we have

$$P_{E-POINTER} \approx 90Q^3 \qquad \text{(2-b)}$$

From equation (1), it is clear that the probability to interpret an erroneous pointer at the beginning of new data is proportional to Q while in the steady state, and according to equation (2), that probability is proportional to Q^3. It is clear that, in the steady state, the pointer is strongly immunized against communication errors. This is a very good advantage of the ITU-T recommended way for interpreting the pointer. The disadvantages of these recommendations are the low immunity against errors at the beginning of new data. In the following section, a new way is proposed to improve the pointer immunity against communication errors specially at the beginning of new data.

V- The Proposed Way to Interpret Pointers in SDH

The idea of this way is to send the two bytes (H1 & H2) of the pointer in another two locations in the reserved areas in the SDH overhead. One of the two areas is exactly the same like the two bytes of the pointer while the second area is the inverted value of those two bytes. At the receiver, the inverted area is re-inverted and a voting is carried out. The majority value wins. Voting technique may be used to reduce the effect of communication channel errors if an important data is transmitted or if the communications channel is noisy.

If a receiver utilizing the new proposed way is receiving signals transmitted by an old transmitter (not utilizing the new proposed way), the majority will be determined by the value at the pointer located at the area defined by ITU-T since the values at the newly proposed locations will cancel each other (one location value is the inverted value of the second location). If a receiver utilizing the ITU-T recommended way is receiving signals transmitted by a transmitter utilizing the new proposed way, it will neglect the values in the two locations proposed in the new way. This means that compatibility between current systems and those utilizing the newly proposed way is guaranteed.

After voting, an erroneous bit is interpreted if two or three erroneous bits are received from the three transmitted bits.

If we have *k* bits, the probability to receive *j* erroneous bits from them is [5]:

$$P_{ejk} = \frac{k!}{j!\,(k-j)!} Q^j (1-Q)^{k-j}$$

where P_{ejk} is probability to have *j* erroneous bits from *k* bits.

$$P_{e23} = \frac{3!}{2!\,1!} Q^2 (1-Q)^1$$
$$= 3Q^2(1-Q)$$
$$P_{e33} = \frac{3!}{3!\,0!} Q^3 (1-Q)^0$$
$$= Q^3$$
$$P_e = 3Q^2(1-Q) + Q^3$$
$$= 3Q^2 - 2Q^3$$

Since Q << 1 then

$$P_e \approx 3Q^2 \qquad (3)$$

Replacing the bit error rate Q in equations (1) and (2) by P_e value (equation (3)), we can derive the probability to interpret an erroneous pointer in the proposed way.

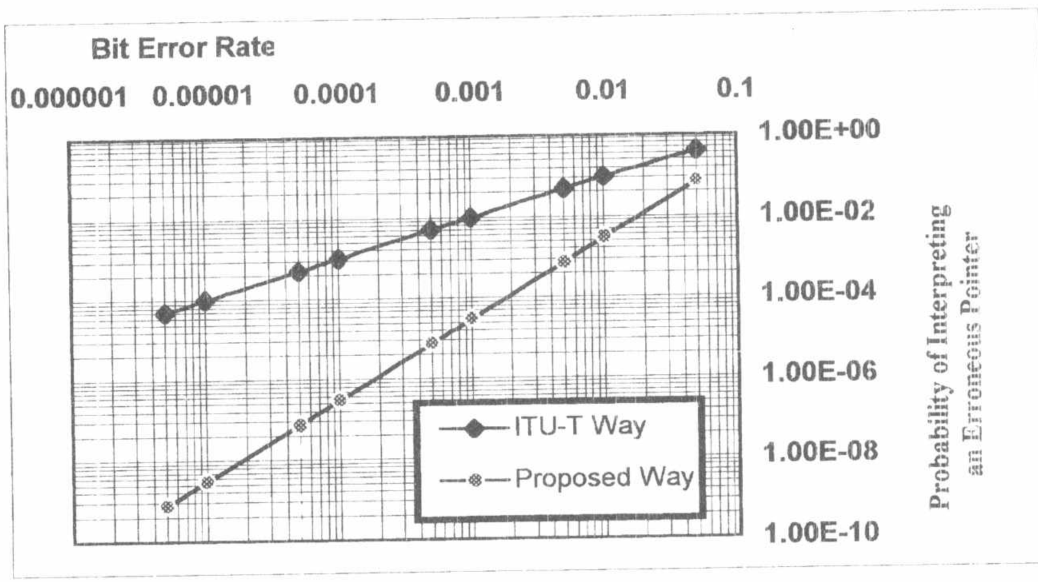

Figure 2. Probability of Interpreting an Erroneous Pointer New Frames (NDF Enabled).

At practical values of Q (Q <<1) we have

- At new data

$$P_{E-NEW-POINTER-P} \approx 90Q^2 \quad (4)$$

- In the steady state

$$P_{E-POINTER-P} \approx 2430Q^6 \quad (5)$$

Improvement factor:

- At new data

$$IPROVMENT-FACTOR = 30Q/90Q^2 = 1/3Q \quad (6)$$

- In the steady state

$$IPROVMENT-FACTOR = 90Q^3/2430Q^6 = 1/27Q^3 \quad (7)$$

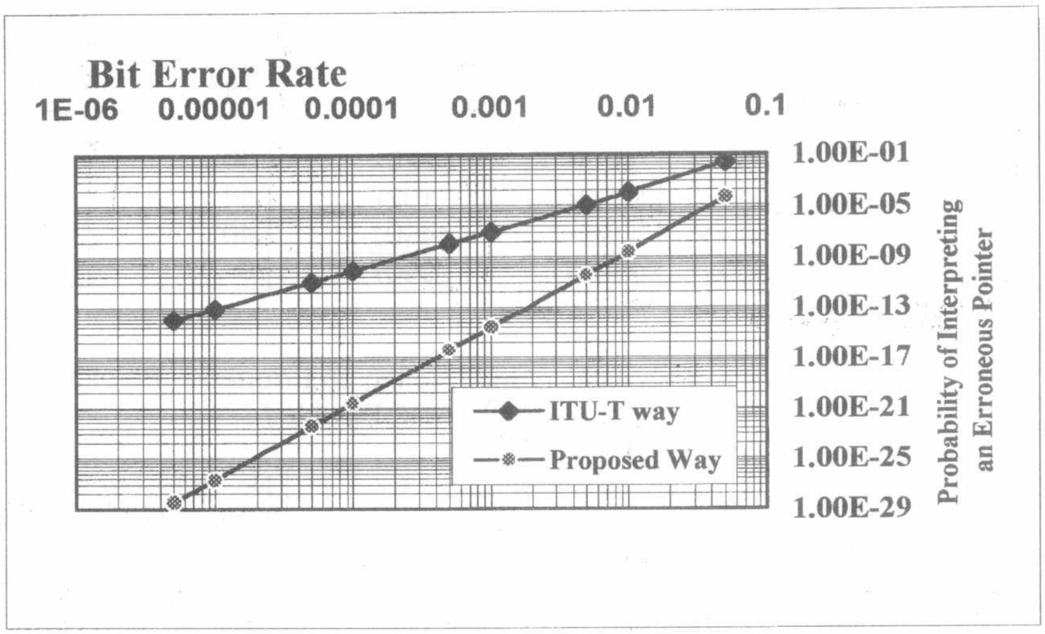

Figure 3. Probability of Interpreting an Erroneous Pointer Steady State (NDF Disabled).

VI- Simulator Program

A simulator program was written in FORTRAN to simulate a communication channel utilizing the SDH technique. The program is composed of several cascaded modules. Each module simulates a block of the simulated channel. At the transmitter, an additional module was added to encode the pointers as recommended in the new proposed way. The communication channel errors was simulated by a random error source using the random function generator built in the FORTRAN package. At the receiver, a statistical analysis on the received signal was done. The analysis results insured that the bit error rate at the receiver side is very close to what was given to the simulator. An additional block was added to interpret the pointers as described in the new proposed way. The simulator was used to compare the error immunity of SDH pointers in the ITU-T recommended way and the new proposed way. The comparison was done at different bit error rates. To reduce

Table 1. Probability of Interpreting an Erroneous Pointer
New Frames (NDF Enabled).

Bit Error Rate Q	No. of Transmitted Frames	No. of Erroneous Interpreted Pointers (ITU-T Recommendations)		No. of Erroneous Interpreted Pointers (Proposed Way)	
		Calculated	Simulated	Calculated	Simulated
0.1	10000	6513	4613	2626	2216
0.07	10000	5160	4860	1376	1356
0.03	20000	5252	5052	533	522
0.01	40000	3825	3785	120	129
0.007	100000	6784	6720	147	150
0.003	400000	11839	11939	108	102
0.001	1000000	9955	9920	30	30
0.0007	3000000	20934	21027	44	45
0.0003	15000000	44939	44901	40	39
0.0001	30000000	29987	29907	9	12

Table 2. Probability of Interpreting an Erroneous Pointer
Steady State (NDF Disabled).

Bit Error Rate Q	No. of Transmitte d Frames	No. of Erroneous Interpreted Pointers (ITU-T Recommendations)		No. of Erroneous Interpreted Pointers (Proposed Way)	
		Calculated	Simulated	Calculated	Simulated
0.10	10000	5023	3914	36	30
0.09	10000	3072	2560	18	17
0.08	20000	3580	3128	16	14
0.07	40000	3938	3592	14	12
0.06	100000	5064	4886	13	16
0.05	400000	9606	9118	16	15
0.04	1000000	10182	10023	10	9
0.03	4000000	14463	15230	7	6
0.02	20000000	18392	18114	3	3
0.01	20000000	2014	2021	0	0

the time losses in case of any unpredictable problem, the intermediate results and variables are recorded every one- percent of the processing cycle. Running the simulator on a Pentium 233 MMX computer, about 95 frames per second were processed. To reduce the duration of the processing cycle, high bit error rates were used during the simulation process. Five cycles were carried out and the average results are provided in Tables 1 and 2. The elapsed time was about 144 hours per one cycle.

VII- Conclusion

By comparing the output of the simulator program and the results of the analytical derived equations given in table 1, we notice that:

i- When the bit error rate is high ($Q = 0.1$ which is not practical), there is some deviations between the output of the simulator program and the results of the analytical derived equations. These deviations are due to the approximation we made during the derivation of the analytical equations which is valid only for $Q \ll 1$.

Ii- As the bit error rate decreases (becoming more practical), both the analytical calculated and the simulated results are very close to each other. This means that the analytical derived equations and the simulator program are correct at the practical values of bit error rates.

iii- The proposed way to increase error immunity of the pointer in SDH has strongly improved the error performance of the SDH pointer compared to the ITU-T recommended way.

VIII- References

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