PERFORMANCE OF THE ISDN USER-NETWORK INTERFACE FOR SIGNALLING AND PACKETIZED USER-DATA TRANSFER

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ABSTRACT

A central feature of the ISDN is the user-network interface which is for most applications the basic access (2B + D) carrying 2 x 64 kbps + 16 kbps on a conventional subscriber loop. The D-channel is mainly used for the transmission of signalling information controlling the use of the B-channels. As, however, the utilization of this channel by signalling data will be very low in the average of time, CCITT has specified low-rate packetized user-data as an additional type of information to be carried by the D-channel. For higher-rate packet switched data, transmission via the (circuit switched) B-channels to a packet handler within the ISDN will be used.

This paper will focus on the performance of the D-channel in terms of delay times for signalling influenced by user-data and throughput investigations for packetized user-data on D- and B-channels.

INTRODUCTION

The user-network interface of the ISDN is characterized by a number of B-channels for user-data transmission and a separate D-channel for the transfer of signalling information for the use of the B-channels.

For most applications the "Basic Access" will be used with 2 B-channels and 1 D-channel with 16 kbps. The B-channels provide a circuit switched connection between a Terminal Equipment (TE) and another TE, a server module of the network providing higher layer functions of the ISDN , or a packet handler. For packet switching purposes in the ISDN a B-channel is switched to a packet handler which transmits the packetized data into the packet switching subnetwork.

Transmission of signalling information via the D-channel happens in a frame-oriented manner. Due to the fact that this channel will have a very low utilization in the average of time it offers a good opportunity for using this channel also for low-rate packetized user-data (p-data), as e.g. interactive data transfer or teleaction information. The disadvantage of this approach is the fact that these data will affect the signalling performance which leads to higher system reaction times.

The aim of this paper is to give values for the system reaction times for signalling purposes and throughput measures for the transmission of packetized user-data on D- and B-channels.

SIGNALLING IN THE D-CHANNEL

The D-Channel Protocol

Layer 1 of the D-channel protocol specifies the interface at the S-bus. The access of the different TEs to the D-channel is controlled by a kind of carrier sense multiple access protocol with collision detection.

Layer 2 of the D-channel-protocol is based on the LAPB-procedure of X.25 (HDLC-ABM), adapted and extended to the new requirements of this point-to-multipoint configuration. For LAPs transmitting signalling information, the window size is limited by 1.

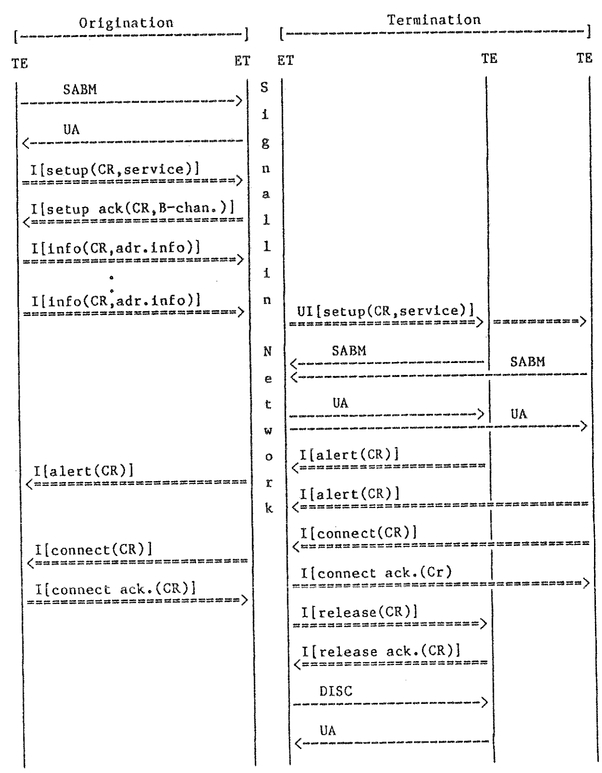

Figure 1: Signalling Scheme for Call Set Up (CR: Call Reference Number)

Contribution to ISS'87
March 15-21, 1987
Phoenix, Arizona USA

Layer 3 defines the signalling procedures between the TE and the Exchange Termination (ET) for controlling connections on a B-channel and for the use of service facilities. An example for the various signalling schemes is shown by Figure 1.

The originating TE first sets up a signalling link. To identify the adjoint call, every signalling message includes an arbitrarily chosen 'Call Reference Number' (CR). By a 'Setup' message, the desired service and facilities are indicated. The 'Setup Acknowledge' message assigns a B-channel, and with the following 'Info' messages all dialling informations are sent if they have not yet been sent within 'Setup'.

At the terminating TE, the incoming call is indicated by an unnumbered information frame (UI-Frame) with group address. All TEs, able to accept this call have to set up a logical link first. As in our example for a telephone call, all TEs are signalling that they are 'Alerting'. That TE accepting the call indicates this by sending a 'Connect' message. The exchange will acknowledge this to both TEs - originating TE and terminating TE. The other terminating TEs which have sent 'Alert' and did not get that call will be released and stop alerting. The signalling link to these TEs is now cleared down using the 'DISC'-frame. The logical links to and from the TEs which are involved in a connection are kept active until this connection is released.

Implementation Aspects

In order to obtain an economical realization of the user-network-interface a set of VLSI modules has been developed (ref.9) which leads to an implementation for public networks which is depicted in Figure 2.

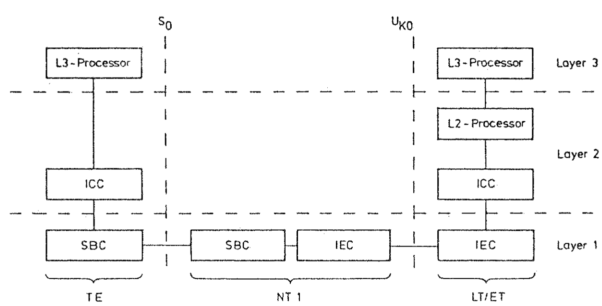

Figure 2: Implementation of the Basic Access using VLSI-Modules

ICC: ISDN Communications Controller
IEC: ISDN Echo Canceller
SBC: S-Bus Interface Circuit

For an economical realization of the ISDN access a combination of ICC and SBC on a single chip, the ISAC-S will be available.

For PBX purposes either an S-interface will be proviced directly by the ET without using the U-interface and thus omitting the NT1, or if the distance between TE and ET is too large for the S-bus to be used, an IBC (ISDN Burst Controller) will be provided instead of the IEC.

The ICC-module is able to handle the full LAPD function for one LAP within the data transfer phase. For the TE this is sufficient because in general only one LAP per TE has to be implemented. Because of the multiple-LAP capability in the ET there the ICC handles only the low-level LAP-functions like bit-insertion, framing, FCS-generation and -checking. The higher level LAP-functions like flow control and sequence control are achieved by means of software in the L2-processor due to the changing number of LAPs that have to be handled in parallel by the ET.

The layer 3 of TE and ET is handled by separate processors. In the ET the processors handling layers 2 and 3 are used by more than one subscriber line (typical values are 4 or 8 subscribers per pair of processors (ref.6))

The Simulation Model

On the left hand side of Figure 3 there is a number of TEs each containing one LAP-process for signalling information.

The channel access procedure, a kind of CSMA/CD protocol, has been depicted like a multiplexer ($MUX_1/DMUX_1$) as there are two mechanisms which guarantee that exactly one frame will be transmitted via the S-interface without delay. The first mechanism is the priority scheme which ensures the higher priority of signalling information compared to p-data and the fair scheduling of all connected terminals. The second one guarantees in the case of a collision that the terminal sending the first "zero-bit" will succeed and transmit its frame while the other one(s) will withdraw and try again later.

Each LAP has one input buffer and one output buffer connecting it to the $MUX_1/DMUX_1$. The LAPs are scheduled according to a cyclic polling strategy. The packet generator which generates a basic load of p-data will be scheduled with lower priority. The LAPs in the TEs are connected to the layer 3 process (L3) by a pair of buffers (L2-I, L2-O).

Layer 3 is running on a separate processor and is controlled by the L3 protocol. The buffers Rx-BLC (BLC = Broadcast Link Control) are used for the reception of UI-frames with group address (e.g. UI[setup]). The BLC processes have been included into L3.

The behaviour of the user of each TE is controlled by an environment simulator ES. Its behaviour is characterized by an alternation of service- and idle times for each connection.

On the right hand side of Figure 3 in the ET there are two processors, one for the L3 process and one for the L2 processes. These L2-processes are

- o LAP (as many as there are TEs connected)
- o PTX, the sending phase for p-data
- o PRX, the receiving phase for p-data
- o Busy, the phase representing the other user-network interfaces handled by the same L2 processor. The busy phase is scheduled after each L2-phase and its duration is a function of the previous phase.

The buffers connecting the L2-processor with the U-interface are scheduled in the same way as

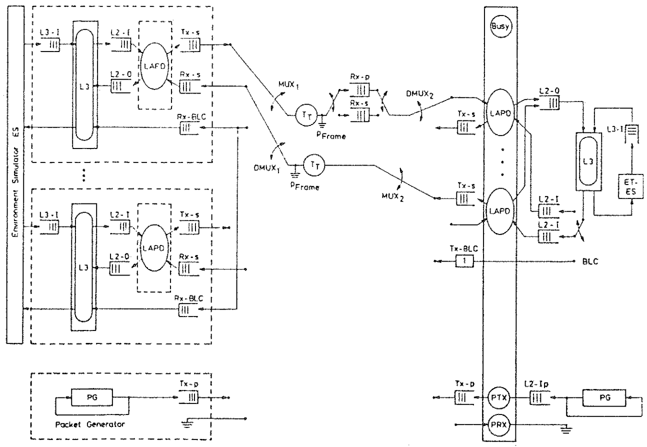

Figure 3: Simulation Model

described for the TEs. The priorities of LAPs, BLC and PTX are arranged in descending order. A separate low-priority input queue for p-data has been introduced to obtain shorter flow times for signalling data.

The channel is mapped by a phase representing the transmission time of a frame T_T and the probability of a frame to get lost because of a transmission error p_{Frame}.

A typical scenario for a connection establishment is shown by Figure 1. Considering this scenario and the frequency of call attempts on a single D-channel it is obvious that in the average of time the load by signalling information can nearly be neglected.

But the scenario also shows that each incoming setup message can cause a set of terminals having the same service features to respond by setting up a link and signalling "Alerting". While this happens, the channel and the processors, too, can represent a bottle-neck which increases the call delay considerably. An additional very strong influence will be caused by a basic load of p-data.

Simulation Results

Prior to the discussion of the results a few comments are necessary concerning the input parameters. In order to obtain a high number of relevant events within reasonable simulation time, we assumed some time values (e.g. the transmission time via the signalling network) to be lower than they would be in real applications. This has to be taken into account when the results are interpreted.

As we did only simulate the behaviour of one basic access we had to distinguish between the two directions of connection establishment (TE -> ET or outgoing call, and ET -> TE or incoming call). The main result which is of interest in the scope of this paper is the call delay which is the time between

- o Sending of the last I[info] and receiving of I[alert] by the originating TE in the case of a calling TE (we assumed the time composed of 2 * (transmission delay through the signalling network) + (call delay in the case of a calling ET) to be only 50 ms).
- o Sending of UI[setup] and receiving of the first I[alert] by the terminating ET in the case of a calling ET.

Figures 4 and 5 show the results versus the basic channel load by p-data. Confidence intervals are so small that it has not been worth including them in the figures.

Table 1 shows the input parameters which have been assumed for the simulation. (Values have been taken from (ref.6)).

The function of the busy phase is a worst case consideration for a number of 4 U-interfaces served by a single L2-processor in parallel.

To obtain the overall call delay, take the call delay for an outgoing call, subtract 50 ms, add 2 * estimated transmission delay via the signalling network, add the call delay for an incoming call.

For an example let us assume a 20% channel load by p-data on both subscriber lines. 8 terminating TEs may respond and the two-way mean transmission time via the signalling network may be 500ms.

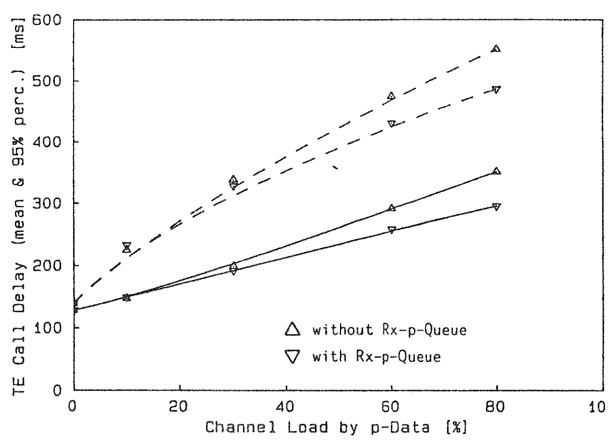

Figure 4: Call Delay for Outgoing Calls
(Solid Lines: Mean Value,
Dashed Lines: 95% perc.)

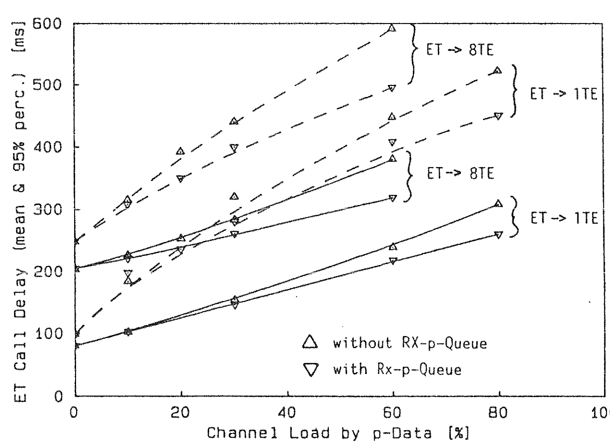

Figure 5: Call Delay for Incoming Calls
(Solid Lines: Mean Value,
Dashed Lines: 95% perc.)

Table 1: Input Parameters for the Simulation

DF*: Distribution Function Type
- M: Negative Exponential (Markovian)
- E_k: Erlangian Order k
- D: Deterministic

Parameter	DF*	Mean Value
Holding Times		
LAP (ET) TE calling	E_8	4.0 ms
ET calling	E_5	3.6 ms
LAP (TE) TE calling	E_9	3.5 ms
ET calling	E_8	2.6 ms
PRX (ET)	E_{12}	5.6 ms
PTX (ET)	E_{13}	8.4 ms
L3 (ET/TE)	D	3.0 ms
T_T	D	Frame length / 16kbps
Busy	3 * prev. phase + 0.5 ms	
Packetized Data		
packet length	M	800 bits
interarrival time	M	Parameter
Transmission Errors		
P_{Frame}	Resulting from independent bit errors of $P_{Bit} = 10^{-5}$	
Miscellaneous		
Length of I-frames	D	according to (ref.2)

We obtain 180ms - 50ms + 500ms + 230ms = 860ms for the mean call delay as seen from a calling terminal under the conditions assumed for the simulation if the Rx-p-queue is used.

Comparing the results for using a separate low-priority Rx-p-queue for p-data with the results for the approach where this queue is not used shows that for high p-data load a significant improvement in reaction times can be achieved if such a priority scheme is realized in a consequent manner.

PACKETIZED USER DATA ON THE ISDN-ACCESS

The ISDN-user-network interface also provides the use of packetized user-data according to recommendation X.25. Accessing the packet switching capability within the ISDN is possible either using the D-channel or a B-channel to the next packet handler within the network. See Rec. I.462 for a detailed description of the different integration scenarios.

The behaviour of a layer 2 (HDLC) link on both types of channels has been studied using a detailed simulation model. This model has been published in (ref.8), but it has been adapted to the D-channel specifications for the acknowledged multiple frame information transfer.

The performance has been measured in terms of the maximum throughput of error free layer 3 messages. For this purpose the input-buffers of the LAP-processors are assumed never being empty in this simulation. The throughput has been normalized by the data rate of the associated channel; 16 kbps on a D-channel, 64 kbps on a B-channel. Processing and propagation delay have been taken to be 2 msec.

The following figures depict the influence of the length of the I-field and of the single-bit error probability, resp. In all figures results are shown for the values of the window size of 1, 3 and 7.

Throughput vs. I-Field Length

D- and B-channels have been investigated assuming a bit error probability of 10^{-5}. In any case the maximum throughput of information has an upper bound given by the ratio of I-field length to total I-frame length. Each frame carries a fixed amount of overhead bits for flags, address, control and FCS-fields, in total 8 bytes. Hence, the throughput decreases for very short messages.

On both channels a window size of 1 (W = 1) leads to a simple handshake protocol with a poor performance behaviour due to the intervals during which a sender has to stop waiting for acknowledgements. Using W = 3 or W = 7 on the D-channel, the sender is able to send a continuous stream of frames without waiting for acknowledgement. Therefore, the results for W = 3 and W = 7 are identical, See Figure 6.

Figure 7 shows different results for W = 3 and W = 7 and very short I-fields on the B-channel. As pointed out for W = 1, the same effect reduces the performance on a link with W = 3 and I-fields shorter then 32 bytes. Here again we have to deal with the impact of a small window, which forces the sender to stop and to wait for the acknowledgements.

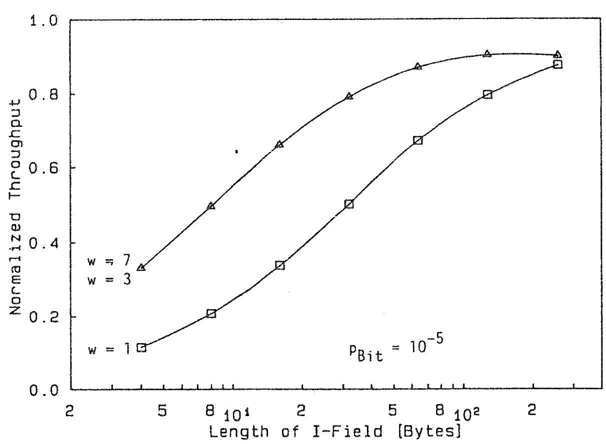

Figure 6: Throughput vs. Length of Info Field (D-channel, 16 kbps)

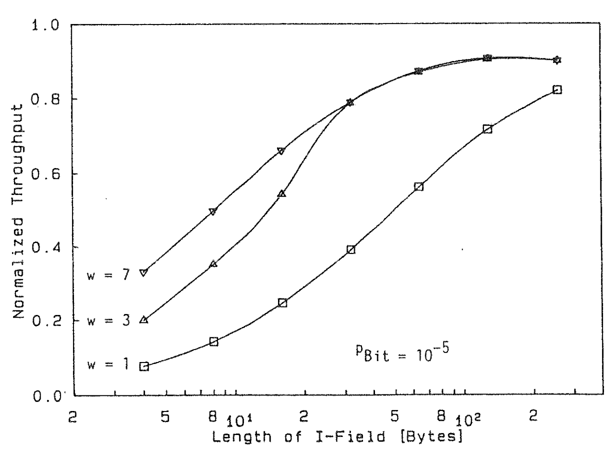

Figure 7: Throughput vs. Length of Info Field (B-channel, 64 kbps)

This behaviour, affecting the throughput of an HDLC-link does not occur if the following condition is fulfilled:

$$\frac{t_I}{t_L} > \frac{2}{W-2}$$

t_I = transmission time of an I-frame
t_L = propagation and processing delay
W = Window size ($W > 2$)

This rule of thumb allows a quick calculation of window-size and I-field length on a link with low frame error probability.

Throughput vs. Single Bit Error Probability

On both channels the I-field length is now fixed to 64 bytes per I-frame (Figures 8 and 9). For W = 3 and W = 7 the maximum throughput for both channels is nearly identical and can be calculated to be 0.89 * v if errors are neglected (v = bit transmission rate).

Using the LAP with W = 1 on a D-channel leads to a maximum throughput of 0.67 * 16 kbps and on a B-channel to 0.57 * 64 kbps. This can easily be explained because the time a sender has to wait for the acknowledgements is relatively smaller on the slower D-channel.

The curves on Figures 8 and 9 show that, under the circumstances mentioned above, up to a single-bit error probability of 10^{-4} the throughput will be sufficient for most applications.

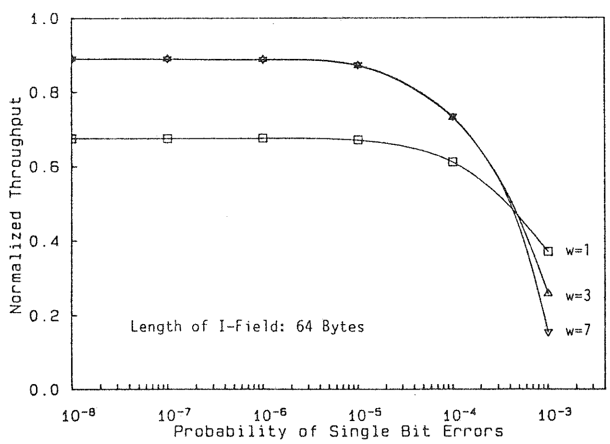

Figure 8: Throughput vs. Bit-Error Probability (D-channel, 16 kbps)

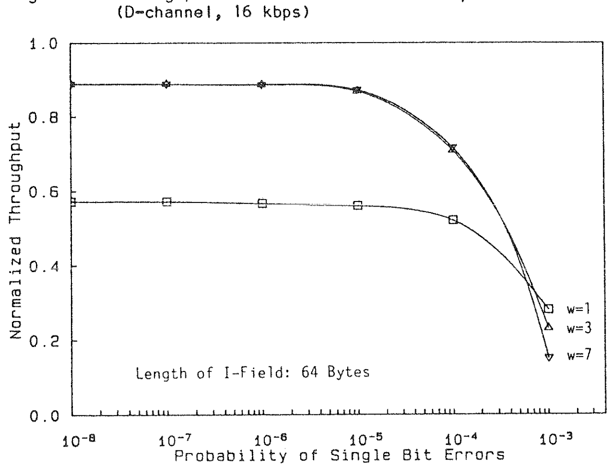

Figure 9: Throughput vs. Bit-Error Probability (B-channel, 64 kbps)

CONCLUSION

We have presented a simulation study of the ISDN user-network interface. The simulation model is based on an implementation using a VLSI-chip set. We obtained results for the call delay of incoming and outgoing calls under the assumption of a basic load of packetized user-data (p-data). All results depict improving performance under higher p-data load if an additional input queue in front of the ET for these data is used.

The performance of the packetized user-data transfer has been studied, too. An X.25 link (layer 2) has been simulated using either the D-channel or a B-channel to the next packet switching module within the ISDN. The maximum throughput for different packet lengths and bit-error probabilities with different values for the window-size confirms the parameter values chosen by CCITT.

ACKNOWLEDGEMENTS

We greatly acknowledge the fruitful discussions with W. Berner, W. Dyczmons and K. Zauner from Siemens AG during this project.

We wish to thank R. Stiefel and W. Schollenberger for their effort in the development and implementation of the D-channel-simulator.

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