INTERNATIONAL STANDARD

IEC 1142

First edition
1993-01

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Withdrawn

Data exchange for meter reading, tariff and load control – Local bus data exchange

Echange des données pour la lecture des compteurs, contrôle des tarifs et de la charge – Echange des données par bus en local

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* See web site address on title page.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

DATA EXCHANGE FOR METER READING, TARIFF AND LOAD CONTROL – LOCAL BUS DATA EXCHANGE

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by technical committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

This International Standard has been prepared by IEC Technical Committee No. 13: Equipment for electrical energy measurement and load control.

The text of this standard is based on the following standards:

DIS	Report on Voting
13(CO)1016	13(CO)1020

Full information on the voting for the approval of this standard can be found in the Voting Report indicated in the above table.

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INTRODUCTION

This International Standard has been established by working group 14: Data exchange for meter reading, tariff and load control of technical committee 13: Equipment for electrical energy measurement and load control.

The working group has the task of establishing standards, by reference to ISO Standards, necessary for data exchanges by different communication media, for remote reading, tariff and load control, consumer information.

The media can be either distribution line carrier (DLC), telephone (including ISDN), radio or other electrical or optical systems and they may be used for local or remote data exchanges.

Meter reading and programming may be performed manually by a meter reader, or supported by means of a local communication system, or automatically by means of a remote communication system. Manual meter reading means that the reader has access to the meter and reads each register, while "supported" reading implies the use of a communication system or a local bus system and a hand-held unit (HHU). Fully remote reading implies a remote communication system such as those involving distribution line carrier or telephone systems.

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DATA EXCHANGE FOR METER READING, TARIFF AND LOAD CONTROL – LOCAL BUS DATA EXCHANGE

1 General

1.1 *Scope and object*

This International Standard describes a method for local bus data exchange, where a number of tariff devices in a given area are connected by a dedicated bus; all of these tariff devices may then be read by connection of a hand-held unit to a central magnetic plug.

This standard presents hardware and protocol specifications for local systems, while specifications for a remote system falls within the scope of another standard.

Considering the fact that several systems are in practical use already, particular care was taken to maintain compatibility with existing systems and/or system components and their relevant protocols.

This standard is specific for local bus systems. In these systems, a hand-held unit also known as primary station or MASTER is connected to several tariff devices also known as secondary stations or SLAVES through a dedicated bus having a flexible structure.

The master is connected to the bus by a magnetic (inductive) plug. The bus itself is passive and all the tariff units – the number of which is limited – are electrically isolated from it.

The protocol is also based on OSI and uses four layers: PHYSICAL, DATA LINK, SESSION and APPLICATION.

The protocol permits the reading and programming of tariff devices. It allows for the detection and identification of so-called "forgotten" units that are not registered in the portable terminal's data base.

The protocol has been designed to be particularly suitable for the environment of electricity metering, especially as regards electrical isolation, and software security. While the protocol is well defined, its use and application are left to the user. The use of the local bus system for point to point communication is also left to the user.

1.2 *Normative references*

The following normative standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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ISO 7480: 1984, *Information processing - Start/stop transmission – Signal quality at DTE/DCE interfaces.*

ISO 7498: 1984, *Information processing systems – Open Systems Interconnection – Basic Reference Model.*

1.3 *Definitions*

address: Sequence of binary digits indicating the destination of a communication or set of data.

alternate: Transmission on a data circuit in either (half duplex) direction.

tariff device: Fixed data collection unit, normally linked or combined with an electricity meter.

call: Process consisting of sending signals to set up a link between stations.

baseband: Transmission of a signal at its original frequency band without undergoing any modulation.

baud: Unit of speed of modulation.

BCD: Abbreviation for "Binary Coded Decimal". Coding of a decimal figure between 0 and 9 using 4 bits.

bit: Acronym for binary digit.

buffer: Buffer memory.

bus: Wired system of communication connecting stations and permitting a single communication at a time.

flag: Symbol used to indicate the particular status of a data item or unit.

exchange: Set of several frames constituting the whole of a remote reading or programming transaction.

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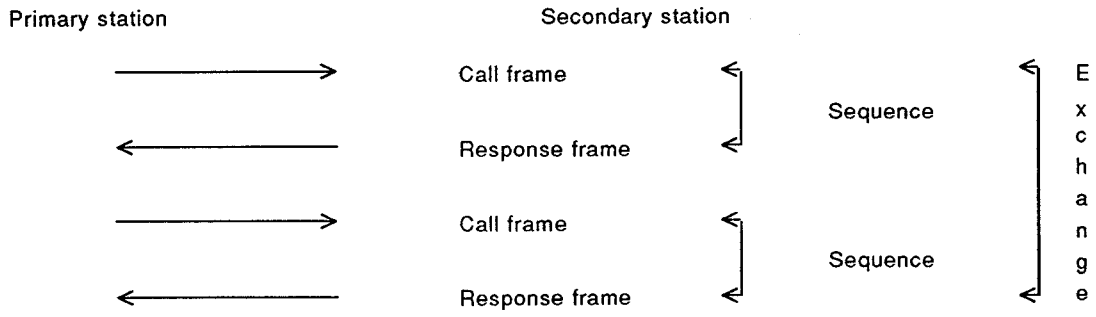

Organization of an exchange

remote data exchange: Data exchange between one or a group of tariff devices and a data concentrator via a communications network.

local data exchange: Data exchange between one or a group of tariff devices and a hand-held unit.

polling: Process consisting of inviting data stations to transmit one after the other.

selective calling: Process consisting of inviting one or more stations to receive.

polling list: List of data stations to be polled and the order in which they are to be polled.

byte: Set of 8 significant bits.

startover: Procedure by which a station attempts to solve conflict or error situations occurring during an exchange, by repeating the failed sequence.

protocol: Set of conventions required to make remote units co-operate in establishing and maintaining data exchanges.

(data) sink: Part of a terminal by which data is received from a data link.

sequence: Subset of an exchange, comprising call and response frames.

different sequences: Those not corresponding to a re-run procedure. The frames transmitted by the primary station are therefore different, either by way of their control field (as for remote programming), or by way of their TAB field (as in multiple remote readings).

identical sequences: Those corresponding to a re-run procedure. In the event of a first call failing, the frame transmitted by the primary station at the time of these sequences is therefore absolutely identical.

(data) source: Part of a terminal by which data is fed into a data link.

station: Set of functional units comprising a terminal, an ETCD and their connections.

primary station: Station having complete control of a link.

secondary station: Station responding to commands in accordance with a link procedure.

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synchronization: Function to enable processes to interact at a given moment in time.

hand-held unit (HHU): A portable equipment for transferring data to or from tariff devices, or electricity meters.

time out: Time lapse after which it is accepted that an expected event has not occurred.

frame: Transfer of a set of consecutive blocks forming a whole for the receiving station.

field (block): Functional subset of n bytes in a frame

1.4 *List of abbreviations or acronyms used*

AADP	Primary station address (table A)
AADS	Secondary station address (table A)
ACLE	Key (table A)
ADG	General ADdress
ADON	Data (table A)
ADP	Primary station ADdress
ADS	Secondary station ADdress
ADTP	Remote programming data (table A)
AG	Wake up call
ALEA	Random variable
ANA	Number of bytes in ADON field (table A)
ANAP	Preceding random number (table A)
ANECHAU	Number of bytes in table A for a unit exchange
APREC	Previous call
APSES	Synchronization flag between APPLICATION and SESSION
AR	Out and return characterizing the different sequences
ARJ	Authentication reject
ASO	Coding of cases of reply to a forgotten station call
ATAB	Type of data (table A)
ATYPE	Type of operation
AUT	Authentication command
BDON	Data (table B)
BERREUR	Error (table B)
BFEx	Standby window number x (table B)
BNA	Random number (table B)
BNDEROU	Number of bytes in diagnostic field on exchange run (table B)

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BNECHAU	Number of bytes in table B for a unit exchange
BNR	Number of bytes in BDON field (table B)
BNSEQI	Number of identical sequences (table B)
BTIMOUT	Error on TIME OUT (table B)
BTOB	Error flag on "chatterbox" time out (table B)
BTOCO	Error flag on communication time out (table B)
BTOE	Error flag on transmission time out (table B)
BTOL	Error flag on DATA LINK time out (table B)
CASO	Coding of cases of reply to a forgotten station call
CCITT	International Telegraph and Telephone Consultative Committee
COM	Command
CRC	Cyclic redundancy code
DASO	Forgotten station call flag
DAT	DATa command
DES	Data Encryption Standard
DIB	Drapeau d'Initialisation de Bus
DNA	Negative acknowledgment flag
DON	Data
DRJ	Data rejected
DSO	Forgotten station flag
DTP	Remote programming flag
DTR	Remote reading flag
ECH	ECHo command
EMP	Location
ENQ	ENQuiry
EOS	Last programming frame command
E/R	Transmission/reception
ER	Combination ERLI, ERSES
ERAP	APPLICATION error
ERLI	DATA LINK error
ERREUR	Protocol error
ERSES	SESSION error
ETCD	Data communication terminal equipment
ETTD	Data processing terminal equipment
FE	Transmission window
FINEMI	End of transmission
FINPHI	End of PHYSICAL
FR	Reception window
FROMEXT	Flag originating FROM EXTernal process
HF	High frequency

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HHU	Hand-held unit, also TSP
IASO	Standby window indicator for forgotten station calls
IB	Bus initialization command
ISO/OSI	Open Systems Interconnection
K	Key
LIPHI	Synchronization flag between DATA LINK and PHYSICAL
LISES	Synchronization flag between DATA LINK and SESSION
LON	Length
LSB	Least Significant Bit
LSUP	Number of bytes of data field
MSB	Most Significant Bit
N	Number
NAO	Random number for forgotten station response
NAx	Random number No. x
NAxK	Encrypted random number
NSEQD	Number of different sequences
NTR	Number of remote readings
PAG	Wake up call port
PAREP	Non-reply flag
PHILI	Synchronization flag between PHYSICAL and DATA LINK
REC	Remote programming command (RECord)
RECNU	Non-reception
RSO	Reply from forgotten stations
RxD	Data reception
SESAP	Synchronization flag between SESSION and APPLICATION
SESLI	Synchronization flag between SESSION and DATA LINK
TAB	Type of data (table)
TACEO	Cumulative time out between bytes
TACEOM	Maximum cumulative time out between bytes
TAG	Wake up call time
TAGM	Maximum wake up call time
TAO	No-byte time
TAOM	Maximum no-byte time
TA1O	Waiting time for first byte
TA1OM	Waiting time for first byte (maximum first byte time out)
TDP	Table of programming data
TE	Transmission time
TEMPO	Temporization
TFE	Time related to transmission window
TFR	Time related to reception window

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TIMAX	MAXimum TIme
TOB	"Chatterbox" time out
TOBM	Maximum "chatterbox" time out
TOCO	Communication time out
TOCOM	Maximum communication time out
TOE	Transmission time out
TOEM	Maximum transmission time out
TOL	DATA LINK time out
TOLM	Maximum DATA LINK time out
TP	Remote programming
TR	Remote reading
TRO	Forgotten station response time
TSP	Hand-held unit, also HHU
TxD	Data transmission
ZDT	Reading and programming data field

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2 Local bus data exchange – secondary station (SLAVE)

2.1 *Specification*

The local bus reading protocol is designed to send data over a physical medium between one or more units called secondary stations to a data input unit called a primary station or more commonly a hand-held terminal (HHT) or hand-held unit (HHU). The latter name will be used from now on.

The transmission medium is a job-oriented medium; in other words it is only for use with the data transactions specified in the present standard. Under no circumstances will it be developed towards distribution line carrier (DLC) or telephone type communications without the general principles set out herein being substantially reworked. However, all the general conventions (transmission direction, data coding, etc.) conform to current standardization.

2.1.1 *Functions of local bus reading*

Local bus reading allows communication with isolated units or units located on a common bus.

The protocol shall support several types of transaction:

* Remote data reading

The HHU gathers data contained in the units.

* Remote programming

The HHU sends data to a unit to change all or part of its characteristics or to clear the data.

For security reasons and to avoid fraud, every remote programming transaction shall be accompanied by a two-way authentication by DES type encryption (see annex B).

* Detection of forgotten units for deferred reading

Irrespective of the process used for remote reading of the stations on a bus, the protocol shall make provision for several units connected to a bus to be detected, even if they are unknown to the HHU and the higher levels (billing files prepared) so that data can be read from these units at a later stage. It is however specified that in a nominal case, the units on a bus are known to the HHU. Forgotten units are thus uncommon and shall not unduly complicate the simplicity of the principles employed under normal circumstances.

It is possible for a maximum of five units to be unknown to the HHU.

2.2 *General requirements*

2.2.1 *Type of unit and addressing*

The units connected to the bus may have different functions (e.g. electricity metering only, gas metering only or another function).

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The detection of forgotten units shall be capable of being selective so as to address only certain types of units connected to a bus out of all the units connected to the same bus.

Each unit connected to the bus is given a specific address. Every HHU is also given a functional address to differentiate several possible levels of access.

2.2.2 *Availability*

The physical connection of an HHU to a bus for the purpose of any of the above-mentioned transactions is only momentary; the protocol selected shall therefore provide for immediate availability of the bus after connection and a non prohibitive transaction time in respect of each individual unit and all the units on a bus.

2.2.3 *Compatibility*

The number of units connected to a bus may vary between 1 and 100 independently distributed over the physical transmission medium.

There may be different types of remote reading or programming units; the protocol shall be transparent to the type of unit up to application level. Some units may, among other things, understand and accept only one type of transaction (e.g. remote reading only). The protocol of these units shall in all cases be compatible with the protocol specified below and shall not generate any malfunctions.

It shall also be taken into account that certain types of units connected to the bus will be complex units containing this remote reading function among other things; it is therefore not possible for a unit to be permanently listening for the bus. The protocol shall therefore include a physical logging on function with the units before proceeding with the transaction.

The protocol used shall be capable of easy installation in the various types of unit without the cost becoming prohibitive. The size of program memory and data required to install the protocol shall therefore be as small as possible.

2.2.4 *Security*

The level of security and control brought into use is closely connected to the physical characteristics of the transmission medium. These characteristics are specified in clause 4.

2.2.5 *Scope for change*

According to knowledge as to current requirements in the field of local bus reading, the data to be transmitted is often not more than a few hundred bytes, it is transmitted in one block if possible, or in several blocks if the protocol requires so or if the length of the data exceeds the maximum permitted size for a block. In all cases, provision is made for a transaction which exceeds this nominal framework.

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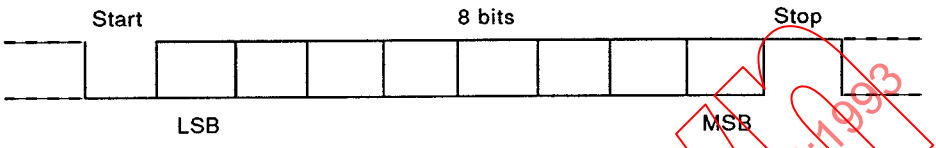
2.3 *Basic principles*

2.3.1 *Transmission mode*

Transmission mode is asynchronous. The transmitter transmits data independently of the receiver. However, the start and end of a word are framed by two signals conventionally called "start" and "stop".

A word consists of an 8-bit byte framed by a start bit and a stop bit.



Format of a word

Data is transmitted in series, the start bit is immediately followed by the LSB and terminates with the MSB.

This mode of transmission offers the advantage of simplicity and is particularly advantageous as regards producing economical hardware.

It should be stressed that this mode of transmission does not preclude the use of a more sophisticated higher level procedure (error detection, alternation management, etc.).

2.3.2 *Transmission speed*

Transmission speed is 1 200 bauds resulting in a bit time of 833 µs and 8,33 ms to transmit a byte framed by a start and stop bit.

In order to comply with CCITT baud rate recommendations, tolerance will be ± 1 %.

2.3.3 *Configuration organization*

The network is organized as a multipoint asymmetric bus: a single station can take the initiative to communicate (primary station (HHU)), and talk to any of the n stations connected to the bus (secondary stations).

The primary station can receive or transmit data (source or sink). Secondary stations can also receive or transmit data (source or sink) but only at the initiative of the master station.

The same physical transmission line is used to transmit and receive, but not simultaneously: the data link is half-duplex (alternate).

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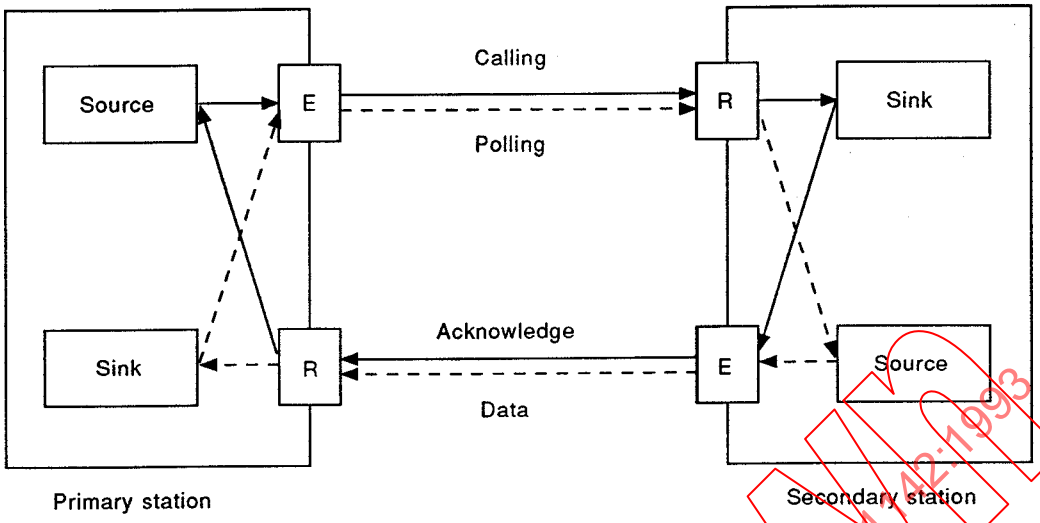
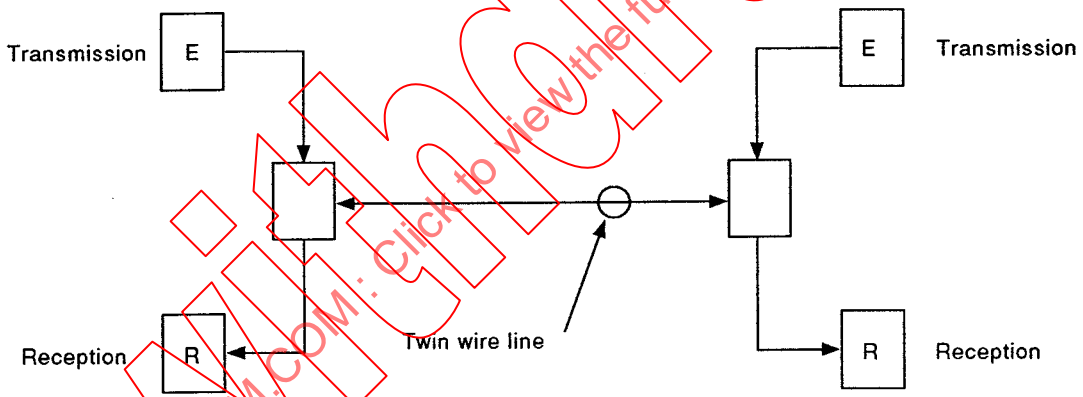


Organization of the link



Physical organization of the link

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The above diagrams only show a point to point link; a multipoint configuration can be obtained by connecting n secondary stations to the primary station shown.

2.3.4 *Network access*

The system consists of a multipoint bus at a physical level which becomes point to point at a higher level in the majority of cases.

Remote programming

With remote programming, the command function is given to the HHU which is then a data source; the primary station (HHU) invites the secondary station to receive the messages it has to send.

The link here is controlled by "selective" calling.

Remote reading

With remote reading, the command function is given to the HHU which is a data sink; the primary station (HHU) invites the secondary station to send a message.

The link here is controlled by "polling".

The "polling/selective" function is combined with an addressing system which enables a single secondary station to be selected from the n stations standing by on the bus.

In this operating mode, the system does not have to manage collisions as the calls and responses are perfectly deterministic.

Special case

A special case is the detection of forgotten stations after remotely reading a whole bus. This is fairly unusual as the maximum number of forgotten units on a bus cannot exceed five. An oversight can only occur if there is an error in initializing the address list for the bus contained in the HHU or if there is an error after amending the address list (polling/selective list).

The method of access used is thus by broadcasting with a response from the forgotten stations in random time slots, implying collision handling.

The co-existence of this broadcasting option with the polling/selective method implies uniform acknowledgment handling for compatibility between these two principles.

It should be noted that the broadcast method (with random access) could not be applied to the whole bus without significantly increasing the complexity of the protocol or without significantly increasing the remote reading or programming time, to such an extent that it becomes null and void.

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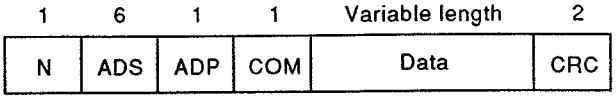
2.4 *General organization of frames and exchanges*

2.4.1 *Format of a frame*



11 bytes + Length of data field

A frame consists of six fields which can be grouped functionally.

2.4.1.1 *Check field*

N: number using 1 byte (binary) set by the transmitter to show the number of bytes in the frame sent.

CRC: Cyclic redundancy code using 2 bytes (binary) set by the transmitter and calculated for all (N–2) preceding bytes (see characteristics of the CRC used in annex A).

These control elements enable the receiver to verify that the frame has been transmitted error free.

2.4.1.2 *Address field*

ADS: Secondary station address using 6 bytes (coded in BCD – 2 digits per byte, see annex E).

The value of this address in decimal is between

$0 \leq ADS \leq 999999999999$ (12 digits)

In the HHU to secondary station direction, this field is completed by the HHU depending on the station(s) with which it wants to communicate.

In the secondary station to HHU direction, this field is completed via the system by the secondary station with its own internal address (placed in non-volatile memory when each unit is initialized).

NOTE - ADS value 0 is reserved as a general address. It is then called ADG.

ADP: Primary station address using 1 byte (coded in BCD - 2 digits per byte).

The values taken by this variable are between (in decimal) $0 \leq ADP \leq 99$

In the HHU to secondary station direction, this field is completed by the calling HHU which inserts its specific address or the general address (ADP = 0). In the opposite direction, if the secondary station answers, it replies with the ADP address(es) to which it has been programmed.

NOTE - The address ADP = 0 can be used to determine to which ADP the secondary station has been programmed to respond.

2.4.1.3 *Command field*

COM: command (coded in 1 byte) telling the receiver the type of action to be taken.

Commands which may be transmitted by the HHU

ENQ: Enquiry – remote reading

REC: Receive – remote programming

AUT: Authentication frame – remote programming

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IB: Initialize bus – reset forgotten station flags (DSO) of units connected to the bus for the purpose of calling the forgotten stations.

ASO: Forgotten station call.

Commands which may be transmitted by a secondary station

DAT: Positive response to polling – remote reading (ENQ)

DRJ: Negative response to polling
– remote reading (ENQ) if TAB(i) is unknown

– remote programming (AUT) if programming data is not accepted

ECH: Response to selection – remote programming (REC)

EOS: Final positive response after AUT command – remote programming.

ARJ: Final negative response after AUT command – remote programming.

RSO: Reply from forgotten station.

2.4.1.4 *Data field*

Variable length field depending on the frame in use and the type of data requested.

The data is partly application-unique and is therefore not covered by this standard. However, in remote reading, remote programming and calling forgotten stations, fixed fields (length and location in the frame) are used and all application shall take note of this so as to ensure system compatibility. The fields in question are an authentication field (ZA1, ZA2) for remote programming, a field to specify the type of data requested or transmitted (TAB) for remote reading and a field to give a list of the TAB(i) to sensitize the sought-after units in forgotten station calls.

2.4.1.5 *Length of frame*

In line with currently known and proposed future applications and bearing in mind the desired efficiency of the whole transmission, the maximum length of a frame is 128 bytes. Frames are of variable length. Only the data field can vary from 0 to 117 bytes (128 – 11).

However, the protocol provides for the transmission of several frames of data in succession if the maximum length cannot be adhered to.

2.4.2 *Principle of wake up call – physical opening of communication*

Before any exchange on the bus, the HHU at its own initiative sends a wake up call designed to alert the communications system of every unit connected to the bus. It should be noted that some of these multifunctional units may use all or part of the communications system for other applications and other links which have absolutely nothing to do with local bus reading.

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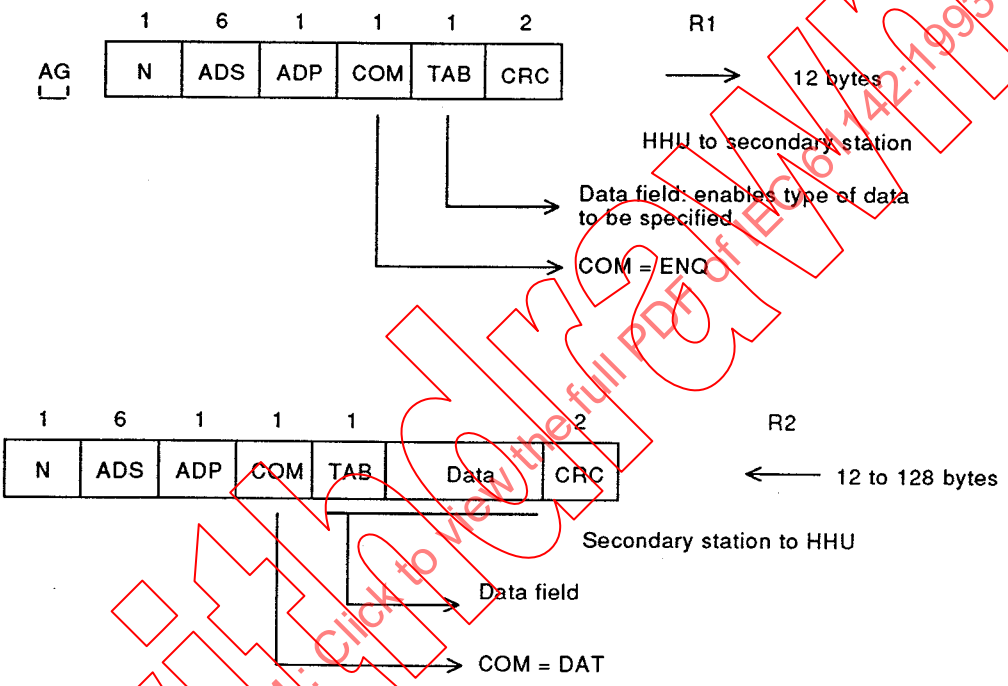
The wake up call consists of a specific sequence which is detailed in 2.6.2.

2.4.3 *Principle of detection of an end of frame*

A receiver detects an end of frame when no bytes are detected in the PHYSICAL layer (TAOM) for a given period of time. It then switches from receive mode to standby while it analyzes the frame received and prepares the response frame. When the response frame is ready, the station switches to transmit mode.

2.4.4 *Format of a remote reading exchange*

2.4.4.1 *Nominal example with error-free transmission*



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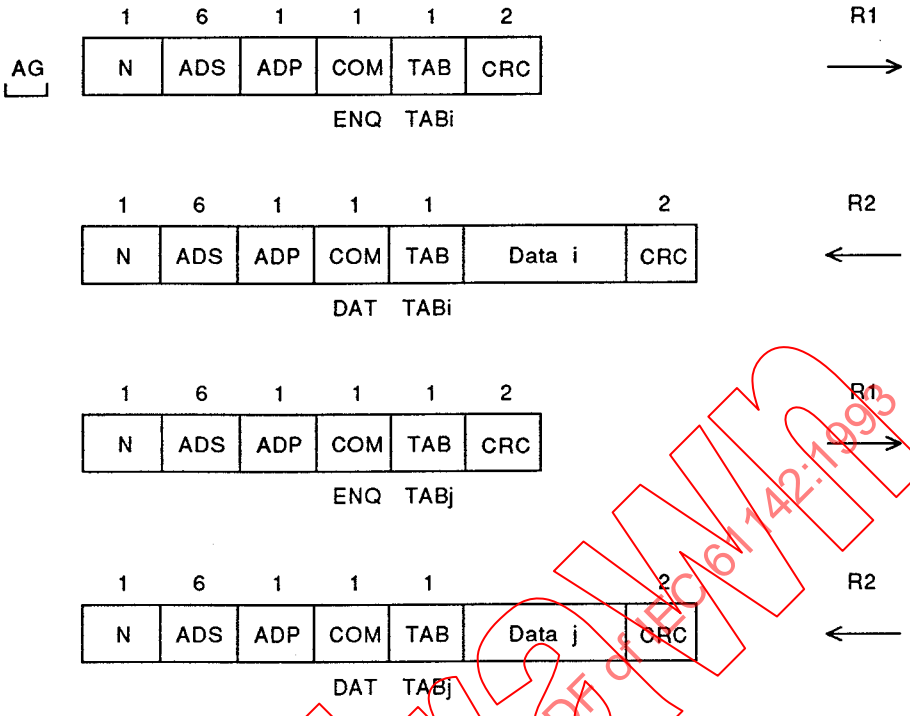
2.4.4.2 *Example of data transmission spread over several frames*

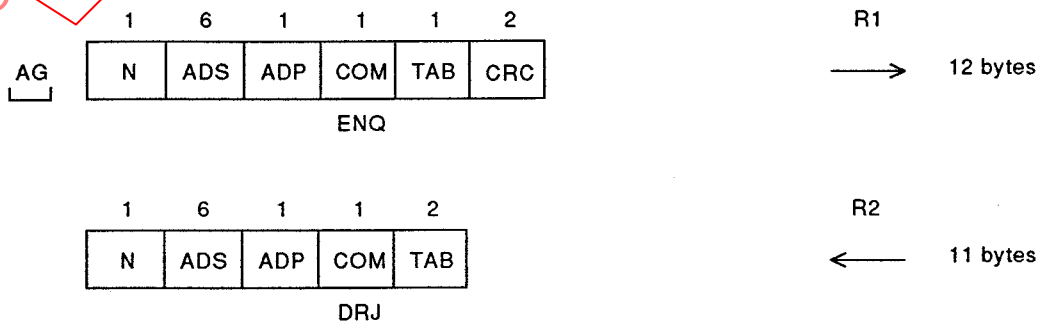


The HHU is able to read the data in succession according to the format of the exchange as specified above. A single wake up call is necessary at the beginning of the exchange.

The exchanges shall comply with the overall communication time and the frame and response time, details of which are given in 2.6.

The maximum number of TAB(i) generated during an exchange is five.

2.4.4.3 *Example of identifier TAB(i) unknown at the secondary station*



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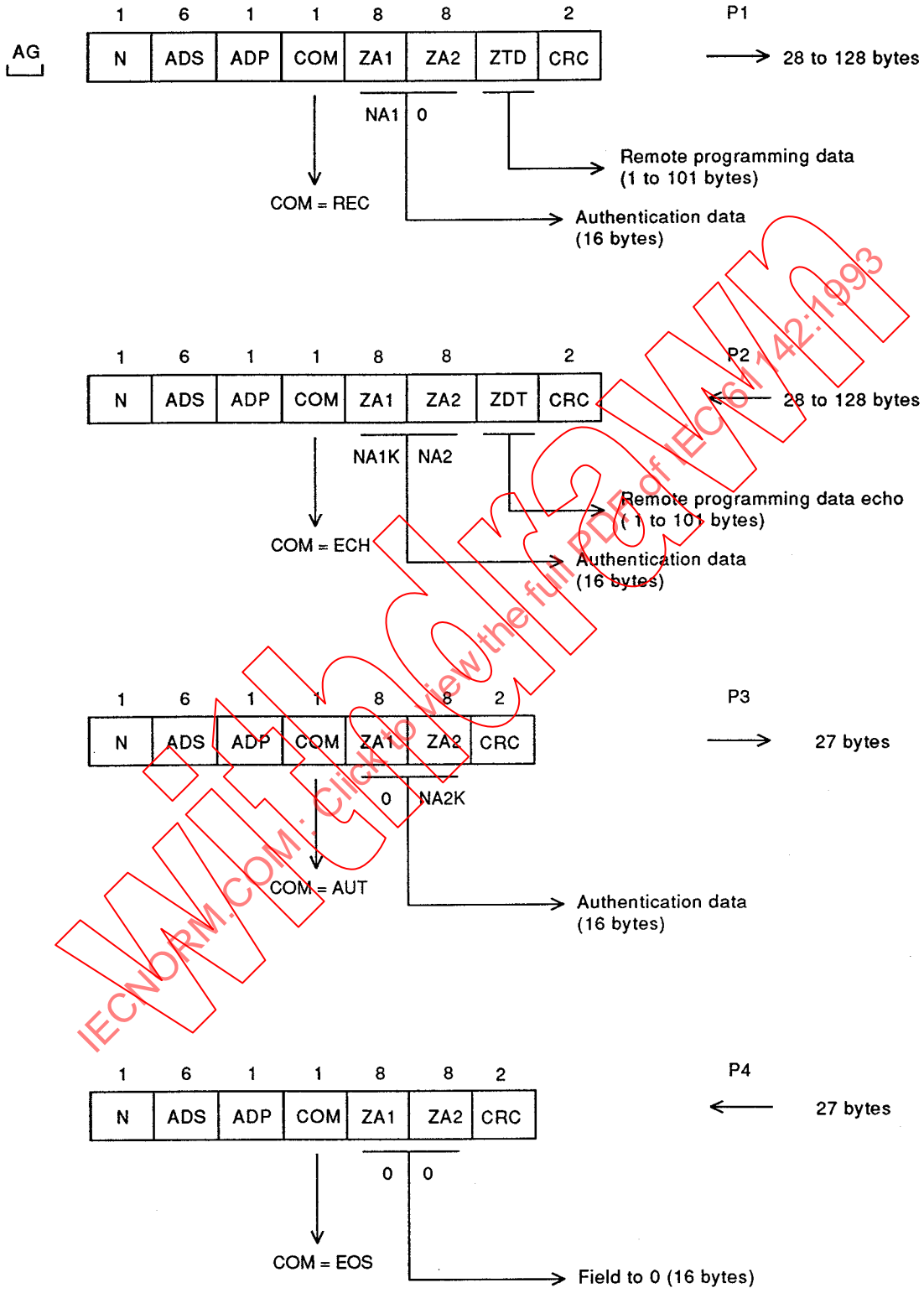
2.4.5 *Format of a remote programming exchange*

Example of error free transmission



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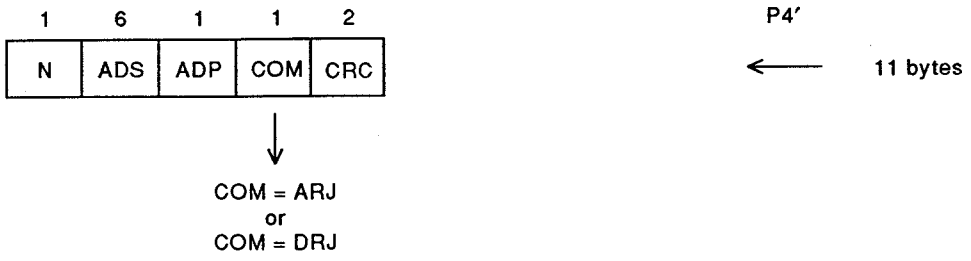
or



This exchange consists of four frames arranged in two successive return transmissions. In the data field, the first 16 bytes are reserved for authentication purposes. Details of authentication are given in 2.9.3.1. Henceforth, if the specification imposes two-directional authentication and the DES encryption system to be used, a minimum of three frames will be necessary to perform this function.

The first frame contains the remote programming data which is stored in the secondary station without being validated and echoed back on the following frame P2. Frame P3 is then transmitted to conclude two-directional authentication.

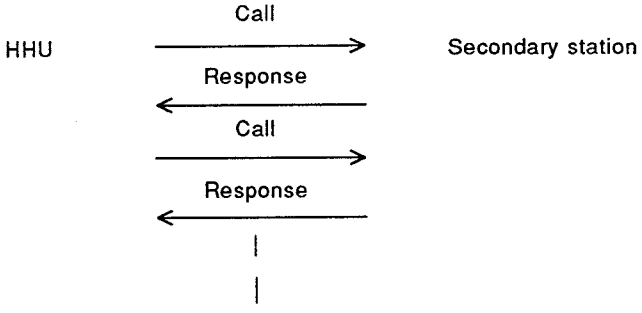
When the secondary station receives P3:

- if authentication is correct and if the remote programming data stored when P1 was sent is validated, a positive acknowledge (COM = EOS) frame P4 concluding the exchange is sent to the HHU;
- if authentication is incorrect or if the remote programming data is not validated, a negative acknowledge frame P4 is returned (COM = ARJ or COM = DRJ).

An ambiguity persists if P3 is received by the secondary station which then validates the data. If the frame P4 transmitted by this station is received in error, the HHU takes it that the data has not been accepted (even after several attempts to repeat P3 with no correct response). In this case, the remote programming exchange will be followed by a remote reading exchange to remove the ambiguity.

2.4.6 *Uniformity of remote reading / remote programming exchanges – Example of startover after error*

A properly conducted exchange consists of one or more call-response sequences with frames of identical format.



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For the primary station (HHU), a remote reading or remote programming type call shall be followed by a response considered as a positive acknowledge or as notification of an error in the type of data transmitted (no startover is provided for in this case).

Detecting an error from a secondary station associated with a poor transmission is translated into a no response which constitutes a negative acknowledge for the HHU. A startover is then attempted at the initiative of the HHU by repeating the call of the defaulting sequence.

An error detected on the response frame received by the HHU initiates the same startover procedure on the incorrect sequence.

Startovers are generated by the HHU. The maximum number of startovers is two. If the exchange is unsuccessful despite these attempts, the HHU halts the exchange with that station and signals a fault.

2.4.7 *End of exchange – physical disconnection*

The end of an exchange is detected by the secondary station if no further frame is received after a response frame (R2 or P4 type) within a period of time specified at the PHYSICAL level by time TA1OM (see 2.6.2.2). The detection of an end of exchange switches the communication system to standby and it may be used for other applications. No further exchange can then be carried out unless preceded by a wake up call sequence.

2.4.8 *Initializing the bus and calls to forgotten stations*

These two modes do not operate on a selective addressing with call-response principle, but on a broadcast with no response principle in the case of initializing the bus and possible responses in random time slots in the case of forgotten stations.

2.4.8.1 *Principle of reading a complete bus*

For the successive reading of a complete bus, the HHU can ascertain, after reading all the known units, that there are no more units which may have been forgotten and which do not appear in the HHU's files.

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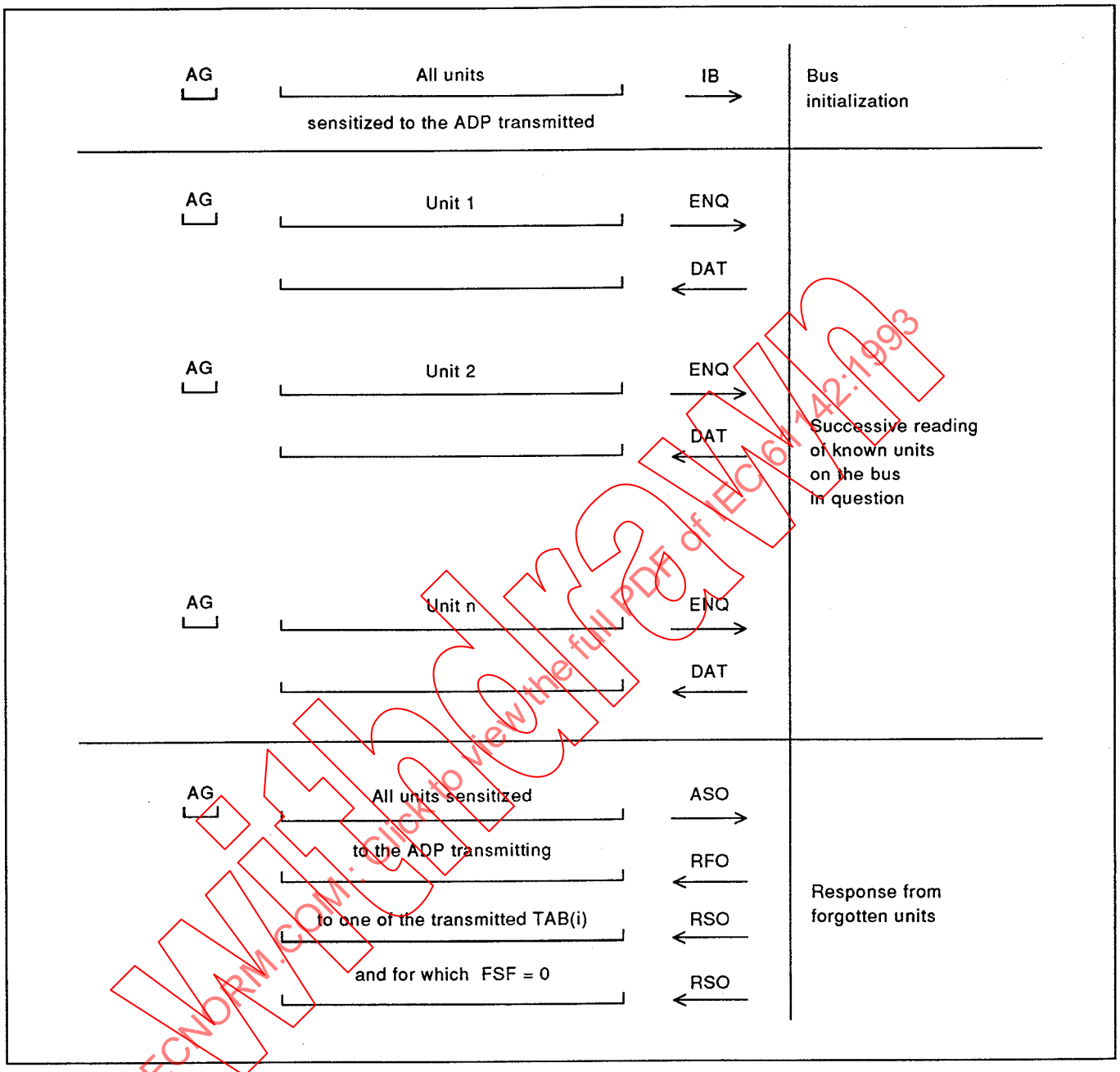
Schematic diagram of the sequence used



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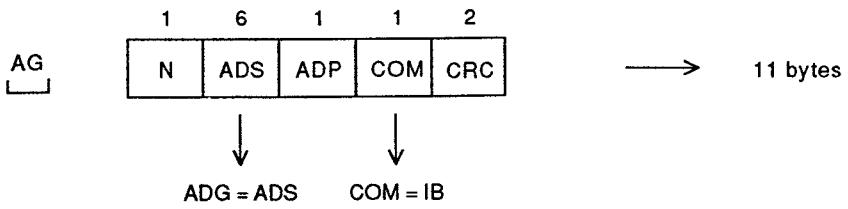
2.4.8.2 *Format of a bus initialization frame*



This frame has the same basic format as the others. The secondary station address field now serves to address all the units on the bus without exception and is called general address (value 0 over 12 digits). All units connected to the bus and acknowledging the ADP primary address are thus sensitized.

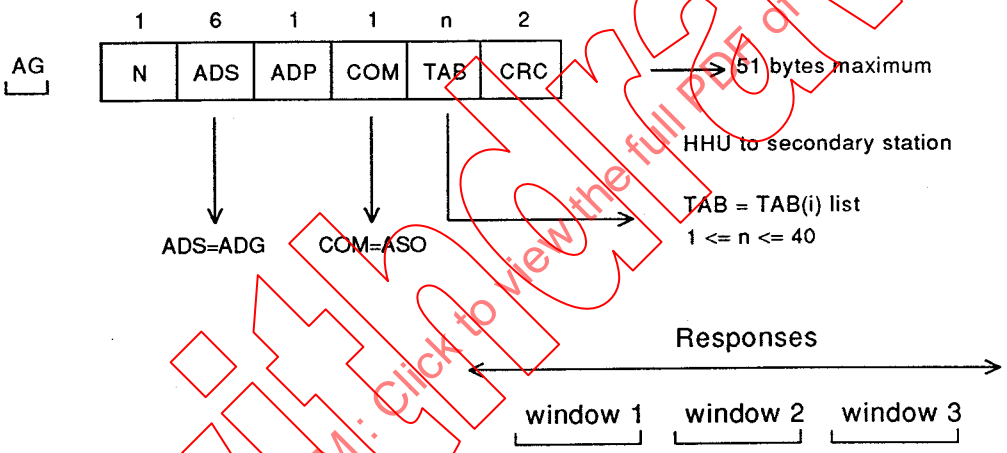
The action of the bus initialization command is to reset a flag in these units to zero (DSO: forgotten station flag).

After the initialization frame, any read unit receiving an R1 frame relating to it (by the presence of its specific address in the ADS field) shows its DSO (DSO = 1) if TAB is known and will then no longer be considered as a forgotten station.

The bus initialization command is never followed by a response.

2.4.8.3 *Format of a call to a forgotten station and the associated response*

At the end of a remote reading sequence, the HHU can search for "forgotten" units (max 5 in 100). This can only be effective if the preceding "Initialisation and successive reads" sequence is respected.



A forgotten station call, preceded by a wake up call, comprises the ADG general address in the secondary station address field. All the stations on the bus sensitized to the ADP of the received frame interpret the ASO command.

If the station's DSO flag is at zero and the ADP address is approved to authorize a response by the secondary station, the station is deemed to have been forgotten and responds to this call if it recognizes at least one of the TAB(i) in the list of its possible TAB(i).

If the station's DSO flag is activated (DSO = 1), the station does not respond and comes off standby for the bus.

This broadcast call implies that several responses may be sent to the HHU. In order to minimize collisions between response frames, each forgotten station has three time slots in which to respond. Each selects its slot at random; the random selection varies from one call to another, the length of the time slot is specified in accordance with the transmission time of a response.

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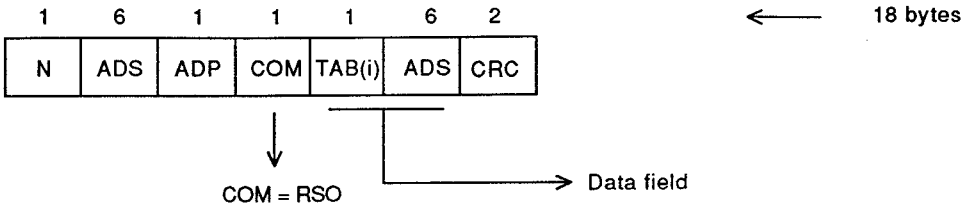

The response frame complies with the general frame format given above; the 7-byte data field contains the first TAB(i) recognized from the list sent in the ASO frame and the 6 bytes of the address of the forgotten unit which is responding.

The HHU opening three monitoring time windows, may be confronted with any of the following situations:

- no response to the three monitoring windows, the HHU knows that no unit has been forgotten on this bus.
- at least one response (no collision) to one of the windows, the HHU records the address of the forgotten unit and proceeds to read it in a subsequent exchange in order to remove it from the group of forgotten units.
- collision response to a window, the HHU cannot act on the response but it knows that there are forgotten units on the bus. It therefore proceeds with another forgotten station call on the assumption that the change in the random selection procedure will enable the responses to be transmitted without collision.

This transmission continues until all the forgotten units are read.

2.4.9 *Addressing – Opening and closing the link*

On reception of an exchange initiating frame, all units on the bus are standing by to store and interpret the frame. After authentication, which we shall assume is error free, the address is analyzed in order to turn the link into:

Nominal example

- a point to point connection by acknowledging a specific address (selective addressing) in the case of remote reading or remote programming.

All units not recognizing their specific address are "cut off" immediately after this frame (protocol cancelled).

Other examples

- A random access multipoint connection by acknowledging the general address in the case of a forgotten station call (multipoint connection limited to a maximum of 5 units);
- A non response multipoint connection in the case of bus initialization.

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2.5 *General organization of the protocol*

2.5.1 *Overview*

Protocols usually follow construction rules which give them a certain universality and allow them to be used in other systems. A reference model for Open Systems Interconnection (OSI) has been prepared; this architectural model opens up virtually unlimited possibilities and in particular an arbitrary number of layers.

Local bus reading does not require all the layers specified in this reference model, but the essence of four of them has been used to define an architecture in the application in question: PHYSICAL, DATA LINK, SESSION and APPLICATION layers.

The specification of this hierarchical, decentralized format shall:

- facilitate the design and construction of the protocol from existing basic elements, while minimizing installation costs;
- simplify its operation by offering formal rules;
- guarantee an acceptable system reliability, particularly through strict compartmentalization of the functions, thus avoiding error propagation;
- provide upgrade, expansion and maintenance facilities, thanks to its modular design;
- optimize performance.

The architecture thus presented specifies neither a hardware product nor a software product, but a hardware and software organizational concept with the advantage of a hierarchical structural.

2.5.2 *PHYSICAL layer*

This layer is intimately related to the hardware used; it specifies:

- the physical characteristics of the transmission medium;
- the characteristics of the connections between the DPTE (Processing Units) and the ETCD (Modems) as well as those of the interface connected to the bus;
- the way in which the physical making and breaking of the connection is performed;
- the half-duplex handling;
- the way in which the binary elements are represented (0, 1): link level, duration, code translation, etc.

2.5.3 *DATA LINK layer*

The purpose of this layer is to take the binary digits (grouped into bytes) supplied by the PHYSICAL layer and transform them into an error free link for the next layer.

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It includes:

- checking the frame by CRC, credibility check on the frame length and the content of certain fields;
- transformation of a multipoint physical connection into a point to point link connection by selective addressing.

Link errors will cause a no-response which, after a TOLM (link time out), will be taken as a no-acknowledge and processed as such by the HHU or the secondary station depending on the sequencing of the original frames.

2.5.4 *SESSION layer*

The SESSION layer processes the command in successive frames and introduces the APPLICATION data.

At this level, it is assumed that all the error detection problems associated with the DATA LINK layer have been resolved; the SESSION layer shall then interpret the action which is required of it (remote reading, remote meter programming, forgotten station call, bus initialization, etc.) introduce any data to be transmitted to the APPLICATION layer and initiate the response procedure by forwarding the field of data associated with the command to the lower layers.

2.5.5 *APPLICATION layer*

This is the highest level layer. Its job is to forward three types of data:

- authentication data in some cases to ensure that certain transactions are secure and not open to fraud;
- data specifying the nature of the requested information or the type of data in the following fields;
- pure data regarding the remote reading of a unit or remote programming data.

2.5.6 *Inter-layer interaction*

The progress of the protocol brings each layer into play in succession using synchronization flags.

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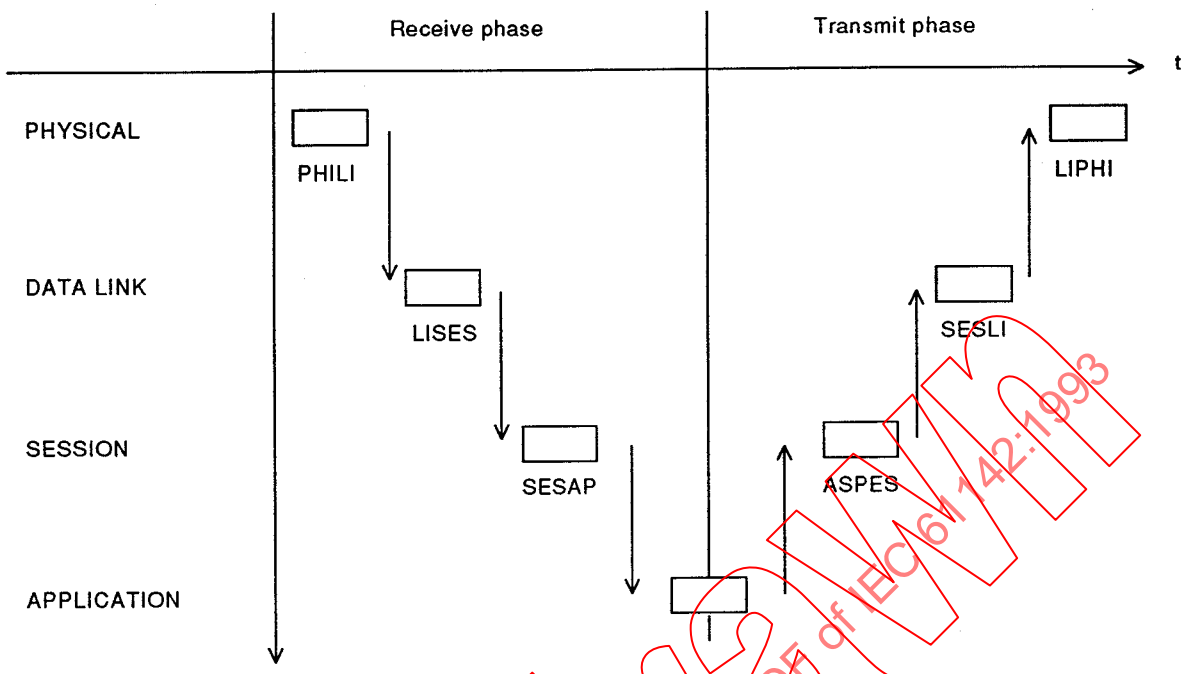

Nominal layer sequencing and synchronization over a "call-response" sequence

These "receive-transmit" stages follow one another depending on the exchange in progress.

A layer does not pass the synchronization flag to the next higher or lower layer until the task allotted to it has been completed.

Any error in the receive stage (on the secondary station side) is translated by signalling an error flag belonging to the layer in error (ERLI, ERSES flags), stopping progress through the layers and retransmitting synchronization flags to the lower layers to signal the fault.

Timing is controlled by the PHYSICAL layer so that the inhibiting of one layer does not cause irreversible situations.

Moving from one layer to another may be accompanied by the transmission of parameters and "data buffers" known for example by their memory location (address) and length (number of bytes); such knowledge may be implicit or explicit.

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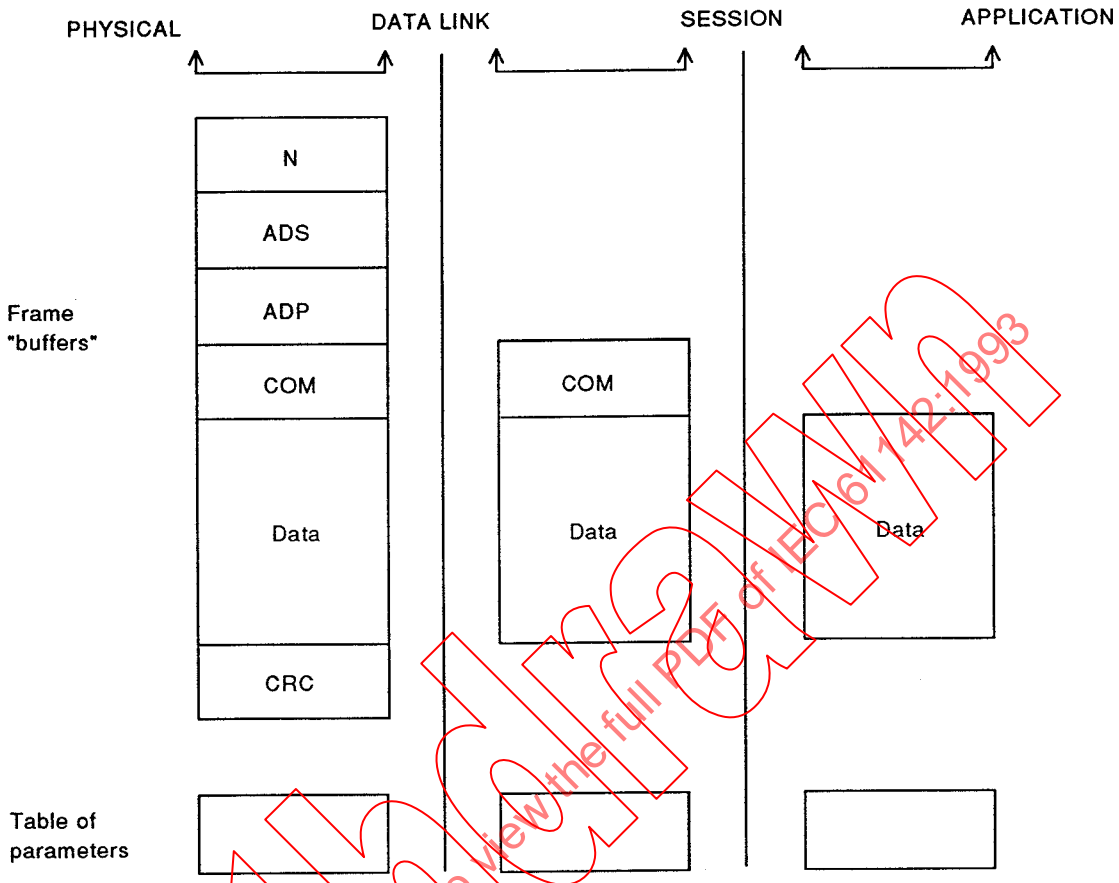
Example of transmitting a frame
with the associated buffers



As stated above, these tables may be sent directly from layer to layer or more simply by defining the addresses and lengths of all the component sub-tables.

The parameters are therefore in a known location and always consist of the same number from one layer to another.

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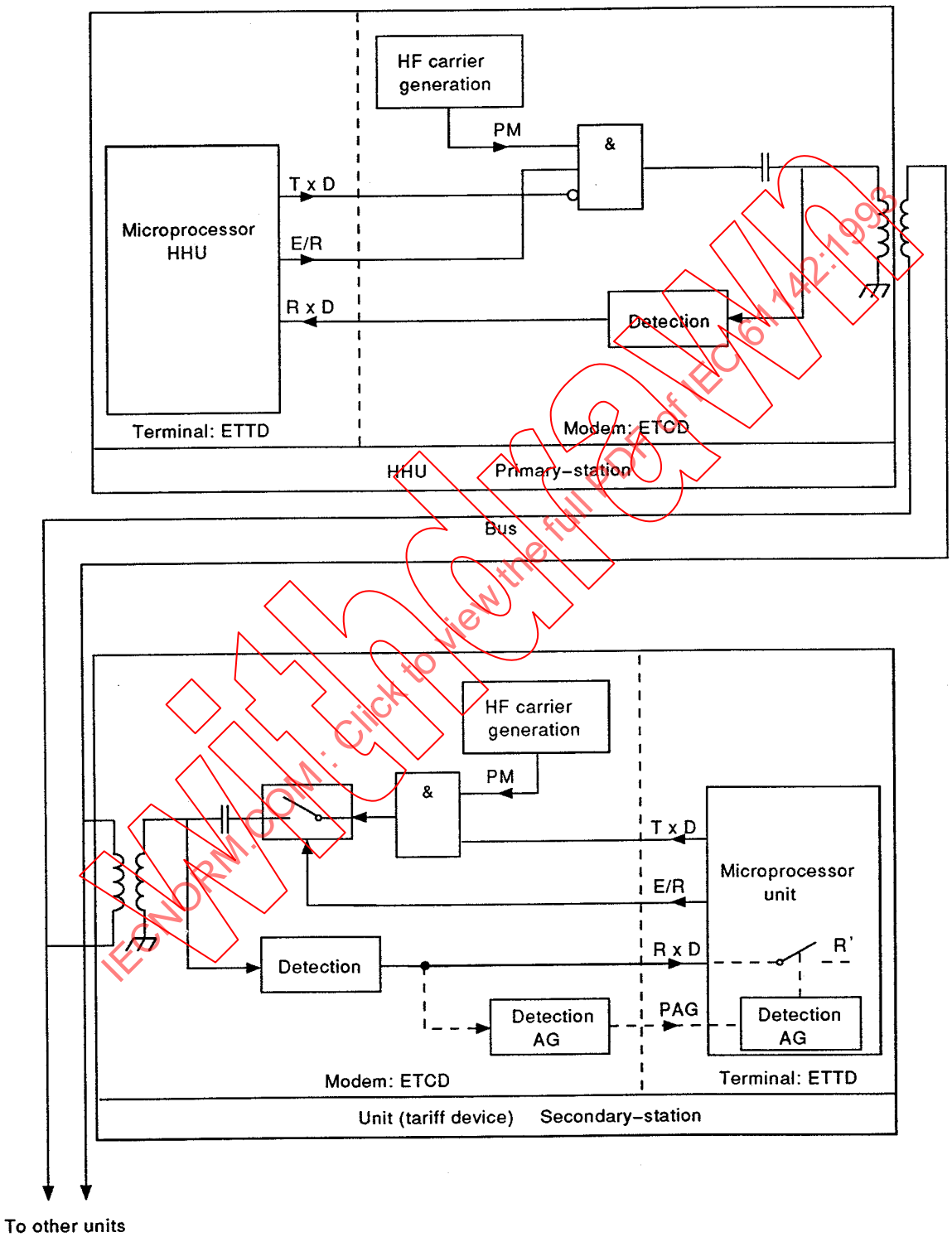
2.6 *PHYSICAL layer*

2.6.1 *Hardware overview – Schematic diagram of transceivers*



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The HF carrier is generated continuously; the TxD serial transmission output modulates the carrier. An outlet port on the ETTD's microprocessor allows the ETCD modem to be switched to transmit or receive. On standby the modem is switched to receive (by E/R) the gate is non pass; the envelope of the signal moving on the bus is therefore permanently available at the microprocessor's serial receive input (RxD). On transmit, the ETTD transmitter is intrinsically monitoring for the bus (by RxD), software locking enables the ETTD's serial port not to be validated on receive (the serial port does not work on Full Duplex).

On the primary station side, the system does not need to detect general calls.

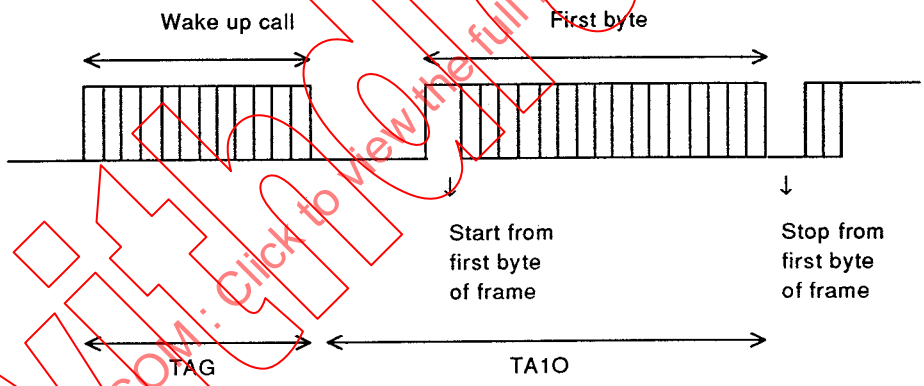
On the secondary station side, a software or hardware general call shall be detected.

A detailed description of the hardware components used in the modems and the characteristics of the communication medium is given in this standard (see clause 4).

2.6.2 *Characteristics of a wake up call*

A wake up call is a specific sequence whose job is to put the microprocessor's serial communication receive function on standby. This sequence consists of a continuous carrier for a nominal time of 100 ms (TAG).

2.6.2.1 *Representation on the bus*



TAGm = Minimum wake up call time = 50 ms
TAGM = Maximum wake up call time = 150 ms

2.6.2.2 *Principle of detection – Immunity to interference*

The end of a general call shall be followed by the first byte of the frame after a time out for the first byte, TA1O such that:

$$TA1Om \leq TA1O \leq TA1OM$$

where TA1Om = 30 ms
TA1OM = 160 ms

NOTE - From the end of the wake up call the secondary station has a maximum time of TA1Om to enter receive mode.

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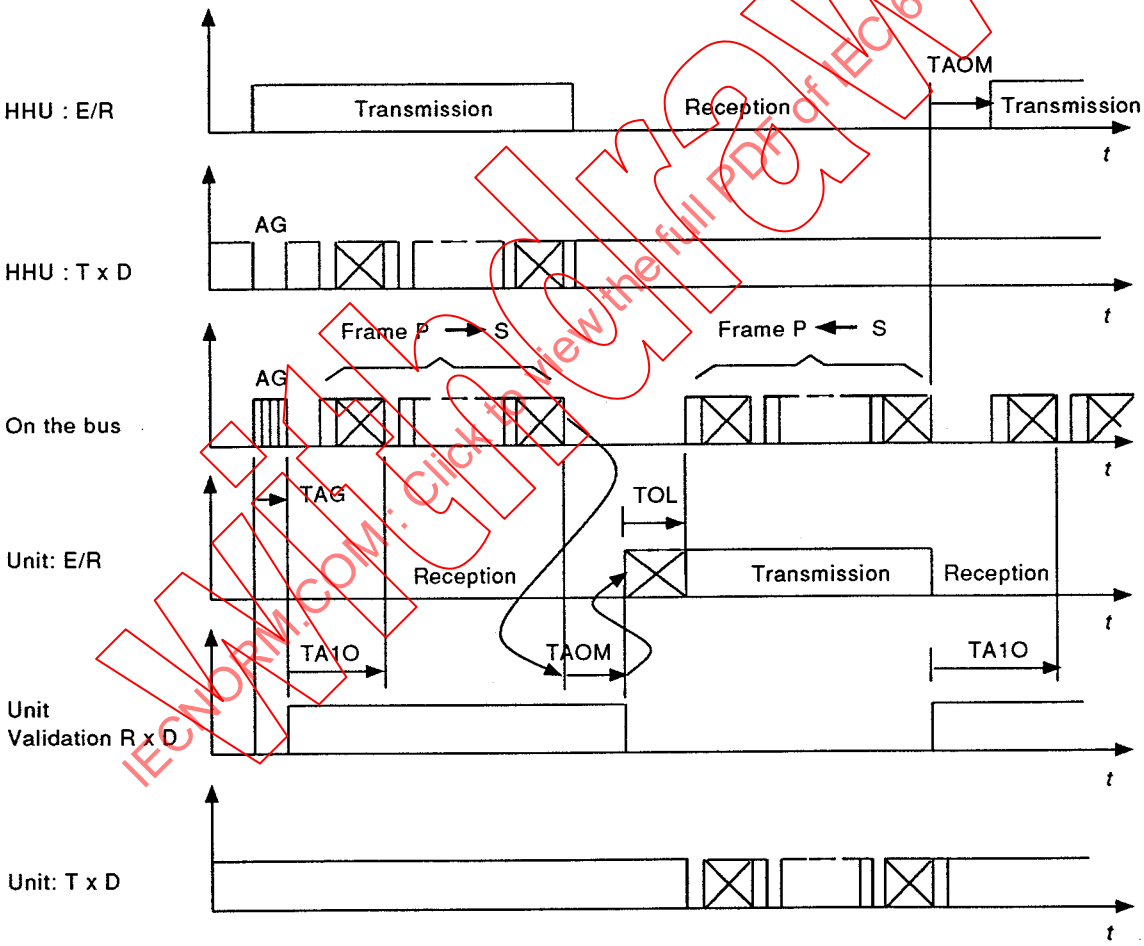
During the general call time, any interference interrupting the carrier for more than 100 µs reinitializes the general call detection parameters.

The presence of the carrier for between 50 and 150 ms without interference greater than 100 µs is therefore interpreted as a wake up call and "alerts" the secondary stations model to receive the bytes of the frame to follow.

2.6.3 *Characteristics of transmission/reception sequences*

In accordance with the schematic diagram given below, the characteristics of a transmit-receive sequence are as given below.

2.6.4 *Timing chart (nominal)*



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2.6.4.1 *Comments*

The transceiving levels on the bus are given in this standard (see clause 4).

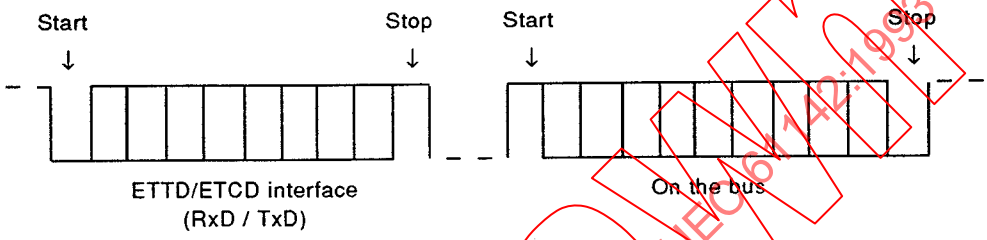
The first frame transmitted by the primary station is preceded by a general call nominally lasting 100 ms; this signal is generated by the serial transmission port used (TxD) and then modulates the frequency of the carrier.

The bytes in each frame, transmitted by the primary station or a secondary station, are transmitted in reverse logic:

level 1 logic from TxD or RxD = no carrier on the bus;

level 0 logic from TxD or RxD = carrier on the bus;

which translates into the following signals to transmit one byte:



After a frame and the stop of the last byte is transmitted, the bus will no longer contain a carrier; similarly, time outs between bytes will be translated by no carrier on the bus.

Receiving stops as soon as an end of frame is detected. The detection criterion is not receiving bytes for a given time TAOM = 40 ms (maximum absence of bytes time). Detection triggers the interpretation of the frame received and the associated actions handled at higher levels of the protocol. It disables serial reception logically. This detection criterion means that no similar sequence shall intervene in the transmission of a frame before it is completed. Furthermore, considerations as to the duration of exchanges mean that the maximum time for the sum of the time outs between the bytes in a frame shall be: TACEOM (maximum cumulative time out between bytes) = 30 ms. This parameter will be generated only by the transmitter and will not be checked on reception.

A modem may be switched to transmit as soon as an end of frame is detected (and reception stopped) or only when a frame starts to transmit. Both these facilities shall be possible and shall be totally transparent if the whole protocol is to work properly.

When an end of frame is detected in receive mode, the first byte of the frame shall be transmitted within the time required for the upper layers to process the information received and prepare the response frame. This time is called the "DATA LINK time out" (TOL) and its maximum value is TOLM = 100 ms. It does not include the transmission time for the first byte but only adds up the time until the start of the first byte transmitted.

The modem is switched from transmit to receive logically after the transmission of the stop of the last byte in the frame. This length is in fact known by the transmission software which determines the moment it is switched to receive.

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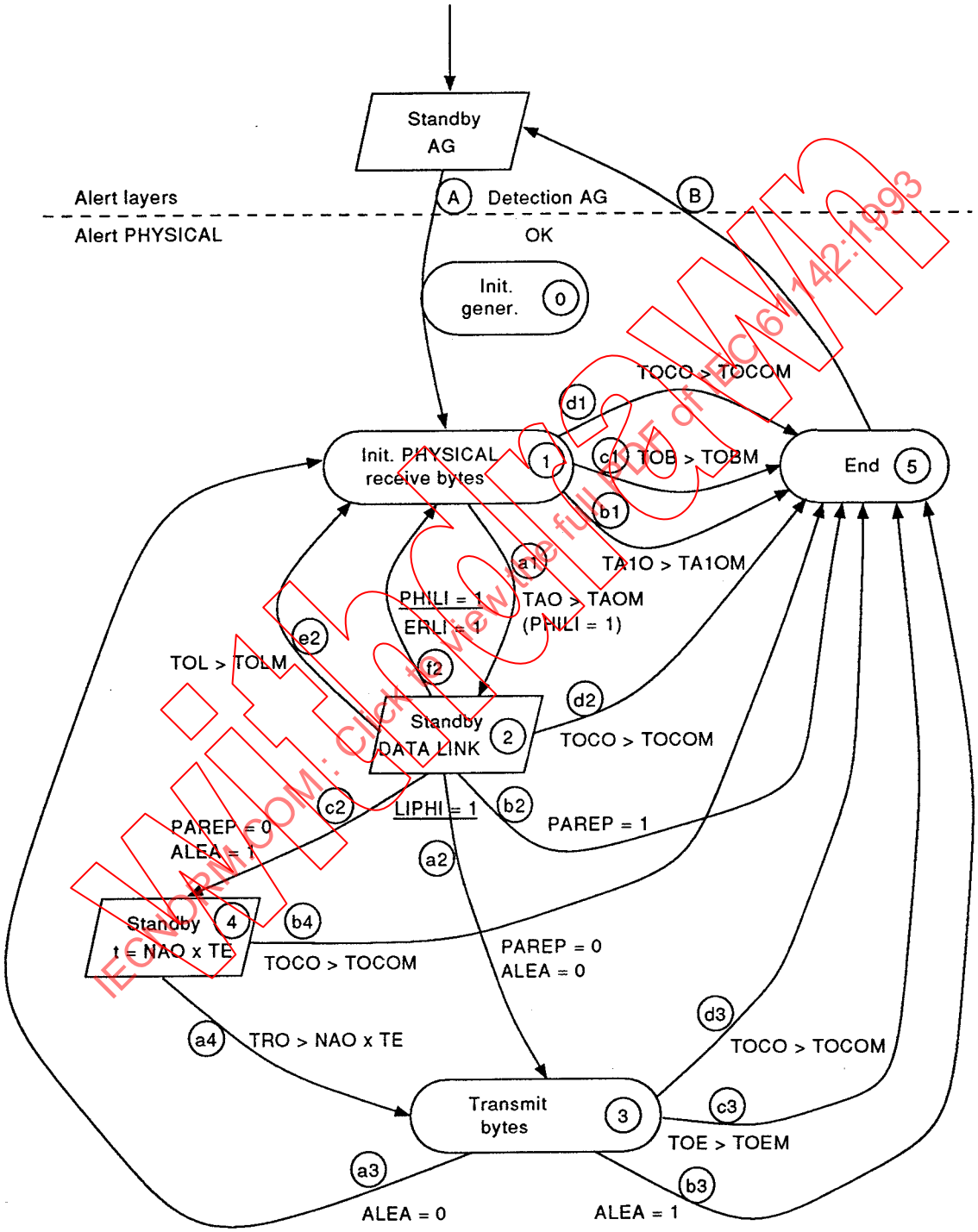
2.6.5 *States on the PHYSICAL layer*

2.6.5.1 Diagram of states on the PHYSICAL layer



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2.6.5.2 *Description of states on PHYSICAL layer*

** General principles*

All states are controlled at execution time level by "time outs" labelled TOXXX. By definition, a "time out" occurs in parallel with the execution of the actions of the corresponding state. They are reset whenever the state in question is reached, except for the communication time out, TOCO which controls the overall duration of an exchange and operates in parallel with all states from the "Receive bytes" state achieved by a "general call detection" event.

Time outs labelled TAXXX run in series with the execution of the actions of the state in question. They are reset and validated as soon as the action is completed.

The various timers are incremented by a clock, the frequency of which will be selected to comply with the timing operations specified in the application. The clock increments in parallel to the action of the PHYSICAL layer.

The PHYSICAL layer is alerted and synchronized if a general call is detected logically or physically, provided that the validation criteria of a general call are met.

However, depending on the type of application developed, it is possible to leave the PHYSICAL layer on permanent standby; start up will be activated only on a general call; this option depends on the application which shall be managed outside the local bus reading protocol.

The diagram and related explanations assume the PHYSICAL layer is completely switched off outside a local bus reading communication.

* *State 0*

General initialization of the protocol. All variables on all layers required for handling a complete exchange are initialized in this state. Start communications time out timer TOCO.

* *State 1*

Reinitialization of PHILI.

Receive bytes: each byte received is stored in a buffer which will be sent to upper layers for processing.

* *State 2*

LIPHI synchronization flag from DATA LINK put on standby.

* *State 3*

Transmit bytes: the upper layer has prepared a buffer or a set of buffers to be transmitted; their location and length are transmitted to PHYSICAL for this transmit state.

* *State 4*

Time lapse TRO = NAO x TE, NAO is a random value between 0 and 2 coming from the upper layers. The time TE is fixed. In this state, the modem is in receive mode. TE is fixed at 500 ms.

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* *State 5*

Closure of the physical connection, the PHYSICAL layer switches off all upper layers and itself logs off. All the layers of the protocol are thus deactivated.

2.6.5.3 *Description of PHYSICAL events*

A. The carrier has been detected for a time TAG between TAGm and TAGM; this information enables all the protocol layers to be put on standby and the PHYSICAL layer activated by coming to state 1 "receive bytes". This event is also associated with the overall initialization of the protocol and the initialization of time out TOCO.

a1. Exceeding the no bytes time TAO means that the end of reception of a frame can be assumed. This event then causes the DATA LINK layer to execute by changing the synchronization flag PHILI = 1.

This event is the standard exit from state 1 when no time out overrun has been detected and the exchange is not finished.

b1. Exceeding the time out for the first byte TA1O halts the protocol by moving to state 5. This event means that switching the modem to receive is not followed by the expected frame.

This is the event which indicates among other things that a restart has not occurred and the protocol can cut off (example of exist after transmission of the remote reading frame).

c1. Exceeding the "chatterbox" time out (TOB) enables reception to be cut off if it lasts longer than the transmission time for the maximum number of bytes comprising a frame (128 bytes) plus the cumulative time out between bytes (TACOM) and a 10 % safety margin to cover inaccuracies in time measurement.

$$TOBM = \left(\frac{127 \times 10^4}{1\,200} + TACEOM\right) \times 1{,}1^2 + TAOM$$

$$TOBM = 1\,360 \text{ ms}$$

TOB monitors a "chatterbox" HHU.

NOTE - This time check may be replaced by a check on the maximum number of bytes which can be transmitted on a frame, with equivalent effect.

d1. If the overall communication timer TOCO overruns, this causes a change to state 5. This timer is initialized once only during the overall initialization of the protocol.

a2 – b2 – c2 – f2.
Returning the upper layers to synchronization by LIPHI = 1, indicating that their actions are terminated, causes a move to state 1, 3, 4 or 5.

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These events are then differentiated depending on the state of the three parameters PAREP (no response), ALEA (random) and ERLI (DATA LINK error). PAREP tells the PHYSICAL layer to move to end of protocol state without transmitting a frame and without waiting for a startover.

PAREP is set by the upper layers when

– decoding an IB command (bus initialization);

– detecting an ADS address which is not that of the unit;

– an ASO command (forgotten station call) addresses a unit which has not been forgotten or is not concerned;

– detecting a primary address ADP unknown to the secondary station.

ALEA is located by the upper layers when an ASO command is detected, it tells the unit, whether it has been "forgotten" or not, that no startover is to be expected after the transmission of its response frame.

a2. Event LIPHI = 1 associated with state (PAREP = 0 and ALEA = 0), this is when a response is to be transmitted and a startover is expected.

b2. Event LIPHI = 1 associated with state (PAREP = 1) when no response is to be transmitted.

c2. Event LIPHI = 1 associated with state (PAREP = 0 and ALEA = 1) when a response is to be transmitted with a delay (state 4).

d2. Communication time out TOCO overrun.

e2. DATA LINK time out TOL overrun, which in fact controls the execution time of all upper layers after an end of frame has been detected and the associated synchronization PHILI = 1 has moved to synchronization feedback LIPHI = 1. It is associated with the reinitialization of all upper layers: DATA LINK reset to state 0, SESSION reset to state 0 and APPLICATION reset to state 0.

f2. Event LIPHI = 1 associated with ERLI = 1 (DATA LINK error) means that an error has been detected at an upper level. Under these states, the unit reverts to state 1 "receive bytes" to wait for a startover from the primary station.

a4. time out TRO = NAOxTE is reached and allows a move to state 3 for the transmission of a forgotten station response frame into one of the authorized time windows.

b4. Communication time out TOCO overrun.

a3. Exit after end of frame transmission where ALEA = 0 (the frame which has just been transmitted is not a response to a forgotten station call). The PHYSICAL layer reverts to state 1 to receive any subsequent frame.

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b3. Exit after end of frame transmission where ALEA = 1 (the frame transmitted is a response to a forgotten station call). The PHYSICAL layer knows that no startover or frame is expected. It can therefore switch to state 5 to disconnect.

The unit shall not revert to state 1 so as not to receive frames transmitted by other stations.

c3. The transmission time out (TOE) stops transmission if it lasts longer than TOEM.

$$TOEM = \left(\frac{128 \times 10^4}{1\,200} + TACEOM\right)$$

$$TOEM = 1\,100 \text{ ms}$$

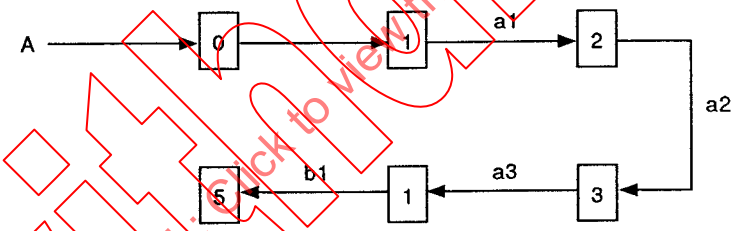
d3. Communication time out TOCO overrun.

NOTE - TOCO will be detected with a precision encompassing the maximum duration of a "call-response" sequence; it may therefore only be checked at the beginning of state 1.

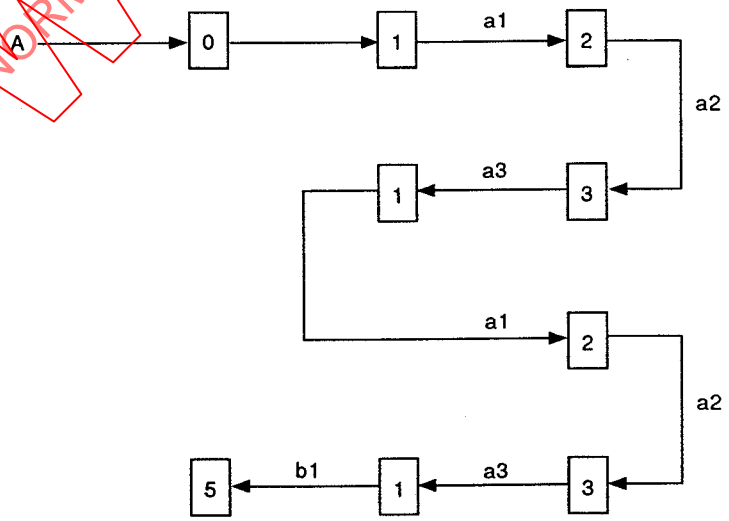
B. After switching off all the layers of the protocol, the PHYSICAL layer switches itself off.

2.6.5.4 *Diagram of several examples of states*

- Remote reading: nominal example



- Remote programming: nominal example



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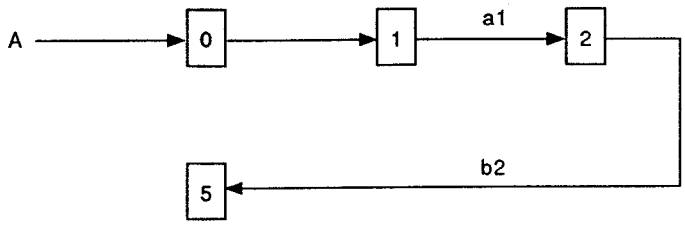
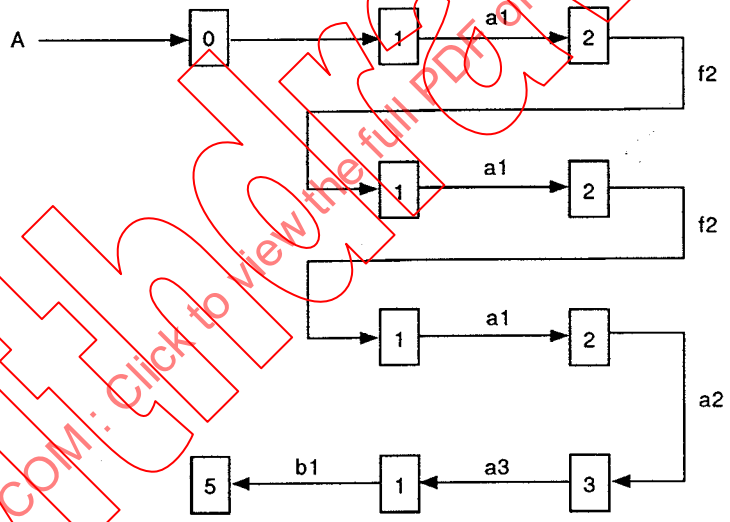
- Bus initialization: nominal example



This diagram is also applicable in the case of a forgotten station call addressing a non forgotten unit and in the case of remote reading or remote programming arousing a station whose address is not that of the primary call address ADP.

- Example of startovers followed by correct remote reading on an error detected by the secondary station in the upper layers



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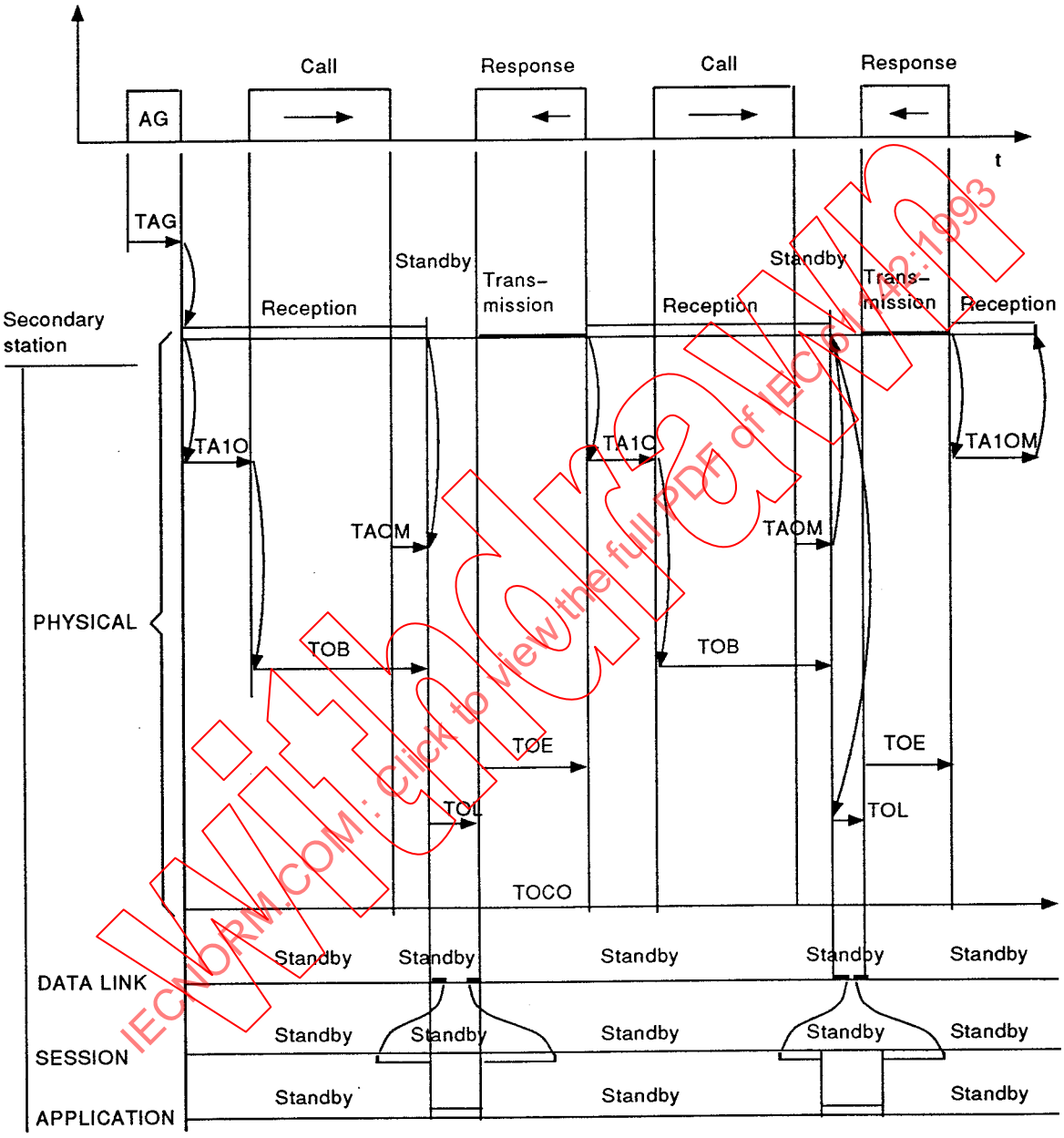
2.6.6 *Time division charts*

2.6.6.1 *Nominal example (as seen from secondary station)*



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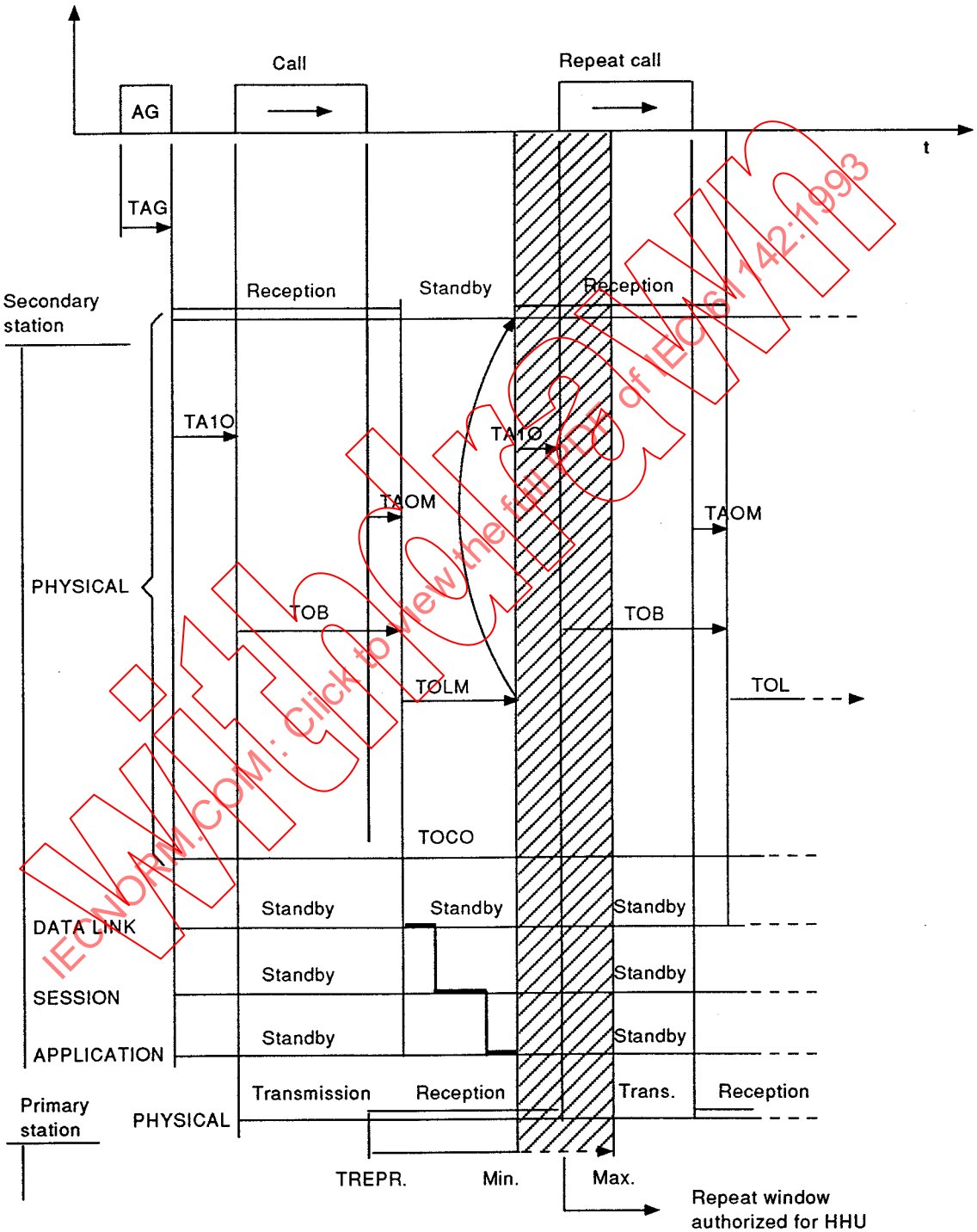
TAG	=	100 ms
TAOM	=	40 ms
TA1OM	=	160 ms
TOLM	=	100 ms
TACEOM	=	30 ms
TOCOM	=	15 s
TOEM	=	1 100 ms
TOBM	=	1 360 ms

2.6.6.2 *Example of error on reception (as seen from secondary station)*

Example corresponding to events e2 and f2 on the PHYSICAL layer diagram corresponding to an overrun of the DATA LINK time out or an error on the upper layers (ERLI = 1).

* *Example of event e2 (TOL > TOLM)*



Repeat call time of HHU after transmission

TREPRmin = TAOM + TOLM

TREPRmax = TAOM + TOLM + (TA1OM – duration of 1 byte)

Time seen from secondary station

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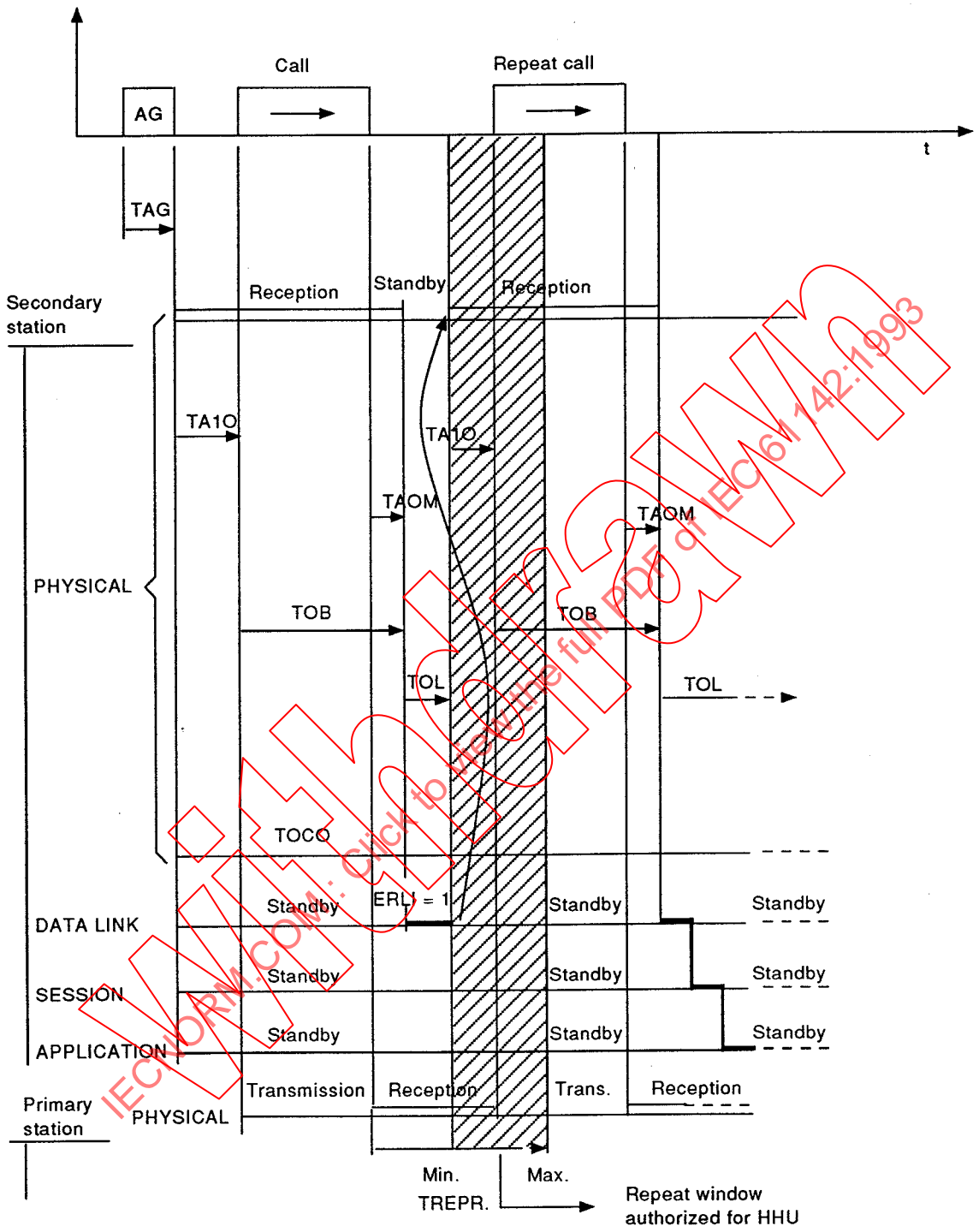
– *Example of event f2 (ERLI = 1)*



HHU startover time after transmission:

TREPRmin = TAOM + TOL with min TOL = 0
TREPRmin = TAOM
TREPRmax = TAOM + (TA1OM – duration of 1 byte)

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– By combining the above two examples, the startover time shall be between MAX (TREPRmin) ≤ TREPR ≤ min(TREPRmax)

TAOM + TOLM ≤ TREPR ≤ TAOM + TOL + (TA1OM – duration of 1 byte)

TAOM + TOLM ≤ TREPR ≤ TAOM + (TA1Om – duration of 1 byte)

160 ms ≤ TREPR ≤ 170 ms

It should be noted that according to the above inequation TA1OM cannot be less than TOLM.

If no expected response frame comes after a call frame is transmitted, the primary station shall carry out a startover in the time division window specified by TREPRmin and TREPR-max. The startover time (after having been reset to zero) is counted whenever the primary station switches to receive mode.

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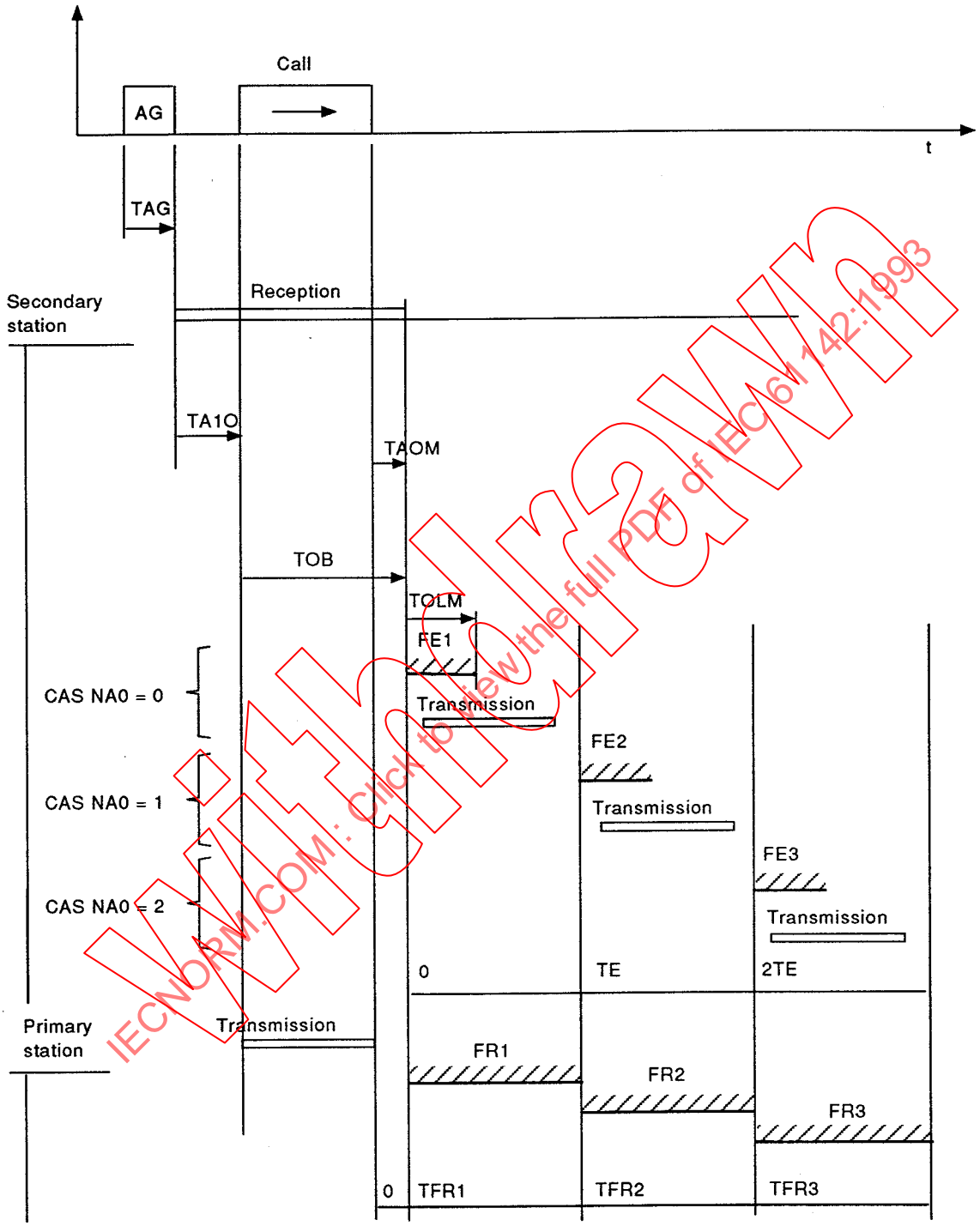
2.6.6.3 *Example of forgotten station call*



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After a forgotten station call, the station can respond in three time slots. The start of transmission of a frame takes place in window FE1, FE2 or FE3 if the random number NAO is 0, 1, or 2 respectively.

The digit time TE separating two windows FE is the maximum time a forgotten unit can need to respond, added to the maximum time a primary station can need to interpret and store the received frame.

If TRAMOU represents the transmission time for n bytes comprising a response frame, then TE shall be selected such that:

$$TE > \underbrace{TOLM + TRAMOU + TACEOM}_{\text{Secondary station}} + \underbrace{TAOM' + TOLM'}_{\text{Primary station}}$$

We assume that the HHU DATA LINK time out is equivalent to the unit DATA LINK time out. Similarly for the maximum no byte time (TAOM)

TOLM = TOLM′ = 100 ms
TAOM = TAOM′ = 40 ms
TACEOM = 30 ms

$$TRAMOU = NOCT \times \frac{10}{1\,200} \times 10^3 = \frac{18 \times 10^4}{1\,200} = 150 \text{ ms}$$

(NOCT = 18 for a forgotten unit response frame).

TE > 420 ms

With a digit time of 500 ms after transmission the primary station can specify three reception windows FR1, FR2 and FR3 with respectively:

TFR1 = 40 ms
TFR2 = 540 ms
TFR3 = 1 040 ms

These three windows are thus specified to be perfectly synchronized to the forgotten station reply in all cases which may arise.

In view of the theoretical possibility of having an ASO frame comprising 40 different TAB(i), the maximum overall duration of a forgotten station call is therefore:

$$T = TWUM + TA1OM + \left(\frac{(51 - 1) \times 10^4}{1\,200} + TACEOM\right) \times 1{,}01^2 + TAOM + 3TE$$

$$T = 150 + 160 + \left(\frac{50 \times 10^4}{1\,200} + 30\right) \times 1{,}02 + 40 + 1\,500$$

$$T = 2\,305 \text{ ms}$$

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NOTE - With an ASO frame comprising only one TAB(i), the maximum overall duration of a forgotten station call is 2 s.

2.6.6.4 *General comments and details of measurements*

All the times will be checked to ± 1 % precision (with a minimum of ± 10 ms precision).

It should be noted that the HHU general call time will be transmitted with ± 10 ms precision on either side of a nominal value of 100 ms.

The HHU shall leave enough time between two successive exchanges for the first called unit to switch off after the exchange involving it before calling the next unit (this time shall be greater than TA1OM).

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2.7 *DATA LINK layer*

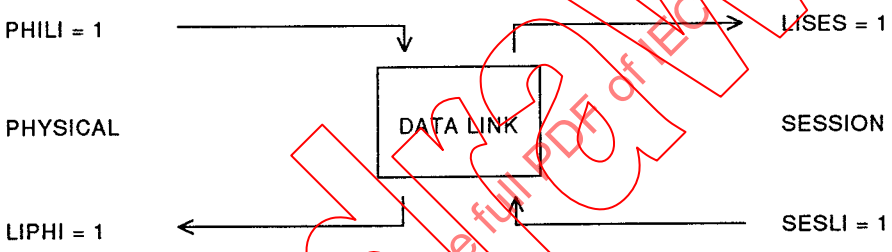
2.7.1 *Opening-closing of the DATA LINK*

As soon as it is activated, the DATA LINK layer is on standby for the synchronization flag (PHILI) transmitted by the lower layer (PHYSICAL).

A secondary station in receive mode analyzes the incoming frame before signalling the upper layer (SESSION) with a synchronization flag LISES that it can begin to carry out its actions.

The upper layer (SESSION) in return transmits a SESLI flag at the end of its work; this response corresponds to the transmission of all the information or "buffers" required to transmit a response frame.

A LIPHI flag is then transmitted to the lower layer (PHYSICAL) for the physical transmission of any response frame.



Disconnection can occur in any of the following four events, managed by the DATA LINK layer itself:

- erroneous syntax check (event b12)
- address received does not correspond to unit's specific address or general address (event b13)
- end of construction of response frame (event a15)
- SESSION feedback with ERSES error or PAREP flagged indicating that no response is to be transmitted (b14 and c14).

All disconnections reset the DATA LINK layer to PHYSICAL standby state.

The DATA LINK layer is only switched off by the PHYSICAL layer on a normal end of exchange or on one of the time outs running out.

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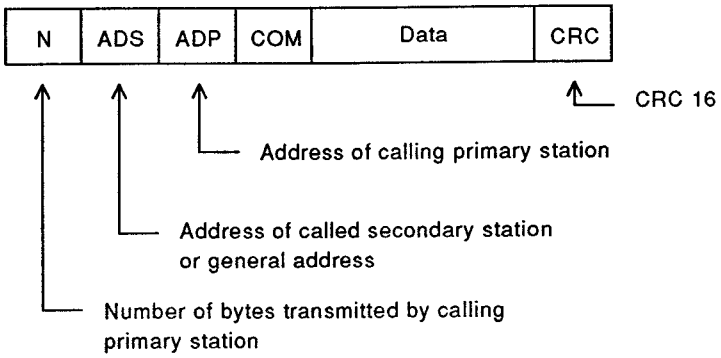
2.7.2 *Format of a received frame – Area of action of the DATA LINK*



2.7.2.1 *Syntax checks and transmission validity checks*

These checks include:

- CRC16 check on all bytes in the frame
- comparison of the contents of the first byte in the frame, representing the number of bytes transmitted by the primary station, with the number of bytes actually received by the secondary station;
- syntax and validity check on byte COM (1 <= COM <= 11 – see annex E);
- syntax and validity check on byte ADP (0 <= ADP <= 99 – see annex E).
- syntax and validity check on byte N test for N ≤ 128 (see annex E).

If any errors are detected by the secondary station during the checks, the DATA LINK layer disconnects and reverts to standby for PHYSICAL for any startover procedure.

If there are no errors, the DATA LINK layer carries out a check on the address field.

2.7.2.2 *ADS and ADP fields address check*

Depending on the action to be taken, the ADS field contains the general address recognized by all units ADS = ADG, or the specific address of one of the stations connected to the bus.

The ADP field contains the primary address to which the secondary station has been programmed to respond to or the general primary address (ADP = 0) which is recognized by all secondary stations.

When the secondary station recognizes both its ADP and its ADS, the DATA LINK layer remains connected and moves to standby for the upper SESSION layer after having sent it the synchronization flag LISES = 1.

Otherwise, the DATA LINK layer disconnects by going on standby for PHYSICAL having sent the synchronization flag LIPHI = 1 to the lower layer. The DATA LINK layer also calculates the length of the field intended for the upper layers and gives them its location.

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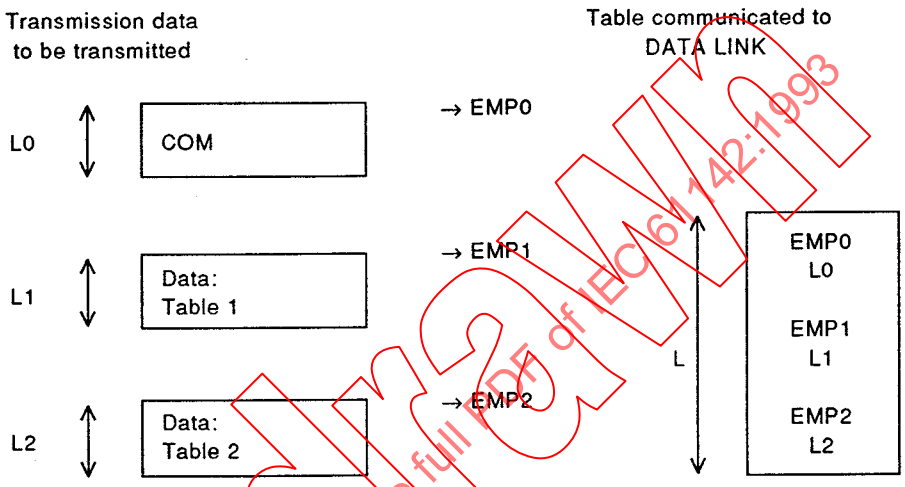
2.7.3 *Format of a transmitted frame – Area of action of DATA LINK*

In the upper layers return phase in respect of a transmission of bytes by a secondary station, the DATA LINK layer which was on standby for SESSION receives the synchronization flag SESLI = 1 together with a buffer or set of buffers. They are referenced by their start of field address and their length (number of bytes).

In order to minimize the number of parameters travelling between layers, it is possible to transmit only the length L of a table comprising all the start of field and length values.



After this synchronization feedback from the upper layers, the DATA LINK is instructed to insert fields ADS, ADP, N and CRC.

The primary address ADP is a copy of the specific ADP to which it has been programmed. The secondary station address ADS is the specific address of the answering secondary station.

Byte N is calculated from the length of the buffers to be transmitted which come from the upper layers as follows:

$$N = (L0 + L1 + L2) + \underbrace{L(ADS)}_{6\text{ bytes}} + \underbrace{L(ADP)}_{1\text{ byte}} + \underbrace{L(N)}_{1\text{ byte}} + \underbrace{L(CRC)}_{2\text{ bytes}}$$

$$N = (LSUP) + 10 \text{ bytes}$$

The response frame thus comprises a set of buffers. The physical transmission procedure searches for each of these buffers in turn, the location and length of which are known. The exact number of buffers is left to the initiative of the designer depending on the hardware capabilities and memory capacity he has at his disposal, provided that transmission times are adhered to.

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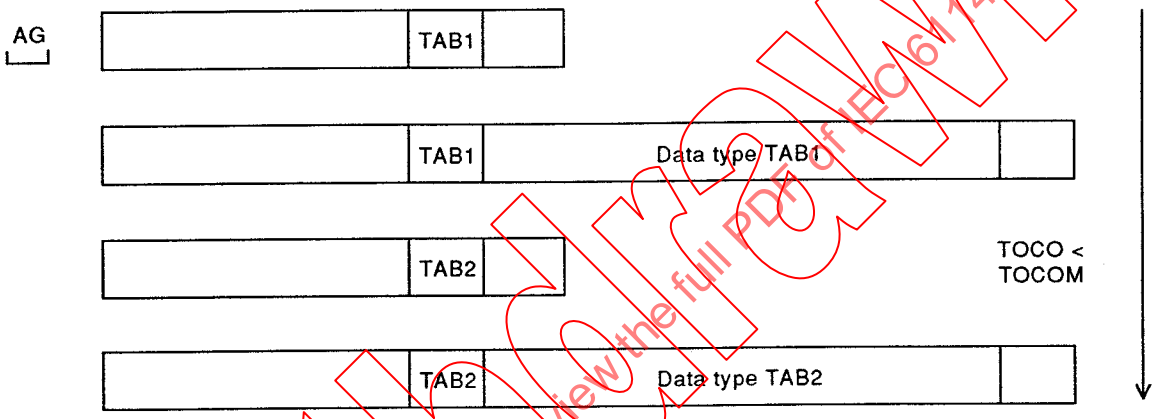
2.7.4 *Operation of sequence chaining*

After an error free "call-response" sequence, the secondary station's DATA LINK layer resets to standby for the PHYSICAL layer for a possible startover or the next frame.

Even in remote reading, the protocol enables data to be read from several successive "response" frames when the data exceeds the maximum length of a frame, without having to generate a further general call. *A priori,* it is the portable data input terminal which takes the initiative to take the reading in several "call response" sequences. The only limitation lies in the overall communication time which shall not exceed the communication time out TOCO.

* *Format of a remote reading over several sequences*



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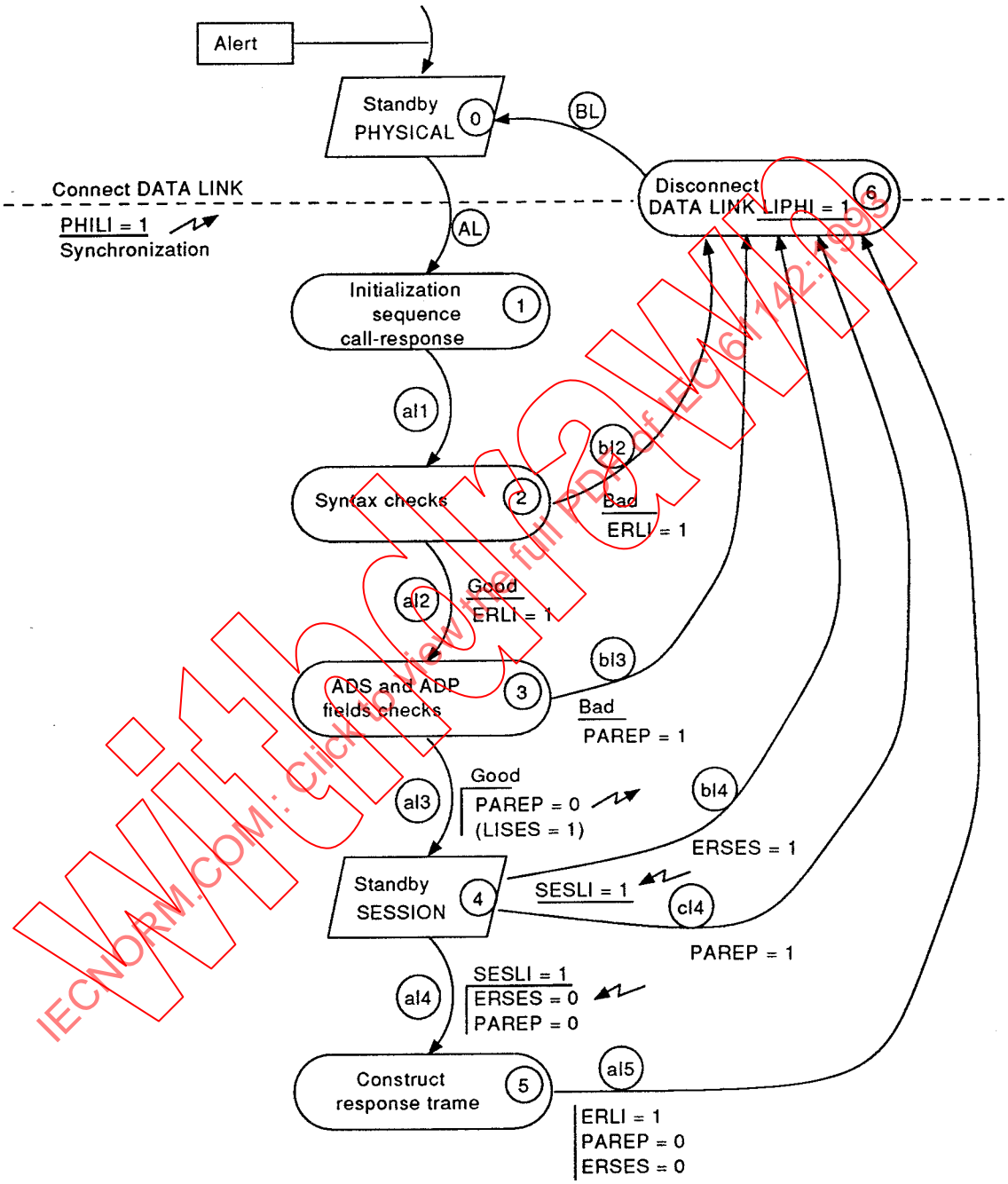
2.7.5 *States of the DATA LINK layer*

2.7.5.1 *Diagram of DATA LINK states*



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2.7.5.2 *Description of DATA LINK states*

This layer can only be switched off by the PHYSICAL layer.

* *State 0*

As soon as it is activated, the DATA LINK layer is on standby for the synchronization from PHYSICAL; exit from this standby state constitutes the connection of the DATA LINK layer commencing actual execution of the actions it has to perform.

Once its work is done the DATA LINK layer reverts to standby (disconnect).

* *State 1*

This state constitutes the initialization of the variables required for the proper running of a "call-response" sequence. The variables LIPHI, LISES, PAREP, and ERLI are reset to zero by the system at this level.

* *State 2*

Corresponds to syntax check and credibility check on the received frame (see 2.7.2.1).

An error in either of these checks causes the error flag ERLI = 1 to be set.

* *State 3*

Corresponds to the ADS and ADP address fields check (see 2.7.2.2). The presence of a specific address ADS or general address ADG in this field constitutes a correct check; otherwise a PAREP flag is set. Checking the ADP field is designed to approve stations for dialogue with certain types of small units. If the station recognizes its specific ADP or the general primary address (ADP = 0), the check is correct, otherwise the PAREP flag is set.

* *State 4*

Standby for feedback from SESLI synchronization flag from upper layer (SESSION).

* *State 5*

Construction of response frame (see 2.7.3).

* *State 6*

Disconnection of DATA LINK and synchronization moves to lower layer by LIPHI = 1.

2.7.5.3 *Description of DATA LINK events*

AL. Setting the synchronization flag PHILI = 1 connects the DATA LINK and permits access to state 1.

al1. Initialization complete, unconditional move to state 2.

al2. Various syntax checks carried out by state 2 are correct and exit from condition 2 with ERLI = 0 allows access to state 3.

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bl2. At least one error is detected in state 2 and transmitted by ERLI = 1. Synchronization flag LIPHI is then set to tell PHYSICAL that it can resume action. The PHYSICAL layer then uses the ERLI parameter to select its type of action (return to receive bytes for possible startover).

al3. Address field check is correct; exit from state 3 with PAREP = 0; synchronization flag LISES = 1 being set, the upper layer is then permitted to begin its work. The LINK layer is then set on standby for SESSION (state 4).

bl3. Address field is incorrect; exit from state 3 with PAREP = 1 to indicate to the lower PHYSICAL level, resynchronized by flag LIPHI = 1, that it need not respond to this call as it is intended for the standby unit and the PHYSICAL layer can disconnect definitively without waiting for any startovers.

al4. Setting the synchronization flag from SESSION (SESLI = 1) permits a move from state 4 to state 5 provided that ERSES = 0 and PAREP = 0.

bl4. Setting SESLI = 1 together with the transmission of an error from SESSION (ERSES = 1) permits a move to state 6 thus disconnecting the DATA LINK which will not transmit a response.

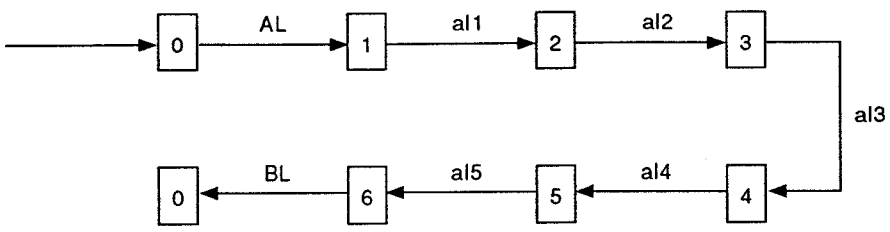
cl4. Setting SESLI to 1 together with PAREP = 1 indicating that no response is to be sent, moves control to state 6.

al5. Once the response frame is composed (see 2.7.3), DATA LINK moves the synchronization flag to PHYSICAL by LIPHI = 1. As parameters ERLI, ERSES and PAREP are at 0, the PHYSICAL layer will proceed to transmit the frame buffer (or buffers), thus transmitted.

BL. After the DATA LINK is disconnected and flag LIPHI = 1 sent, the DATA LINK layer reverts to standby for PHYSICAL.

2.7.5.4 *Diagram of several examples of states*

- Remote reading: nominal example



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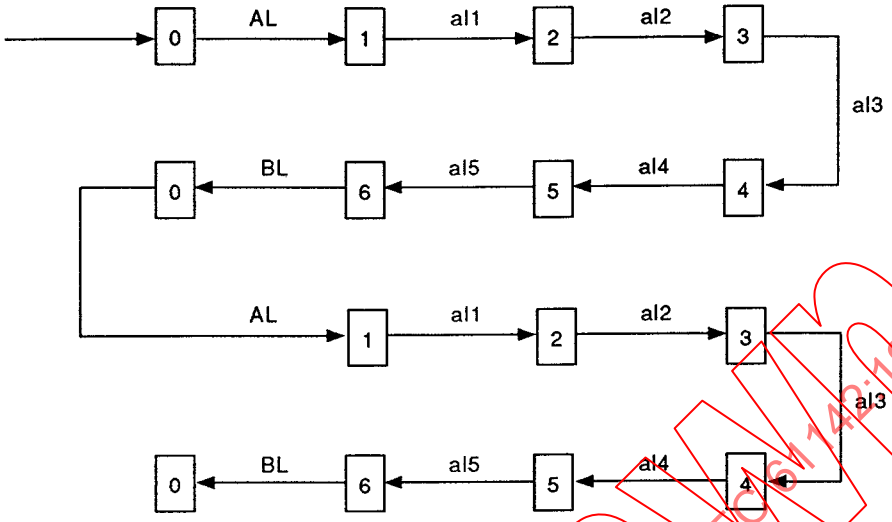
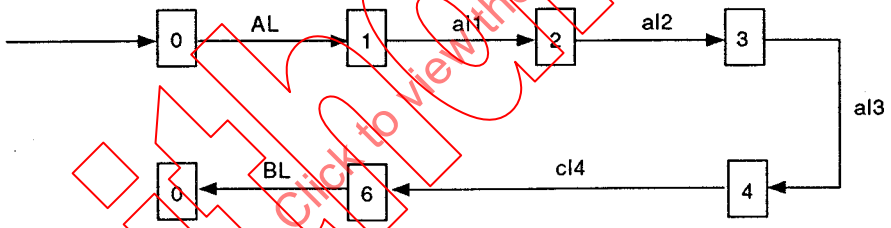
- Remote programming: nominal



- Bus initialization



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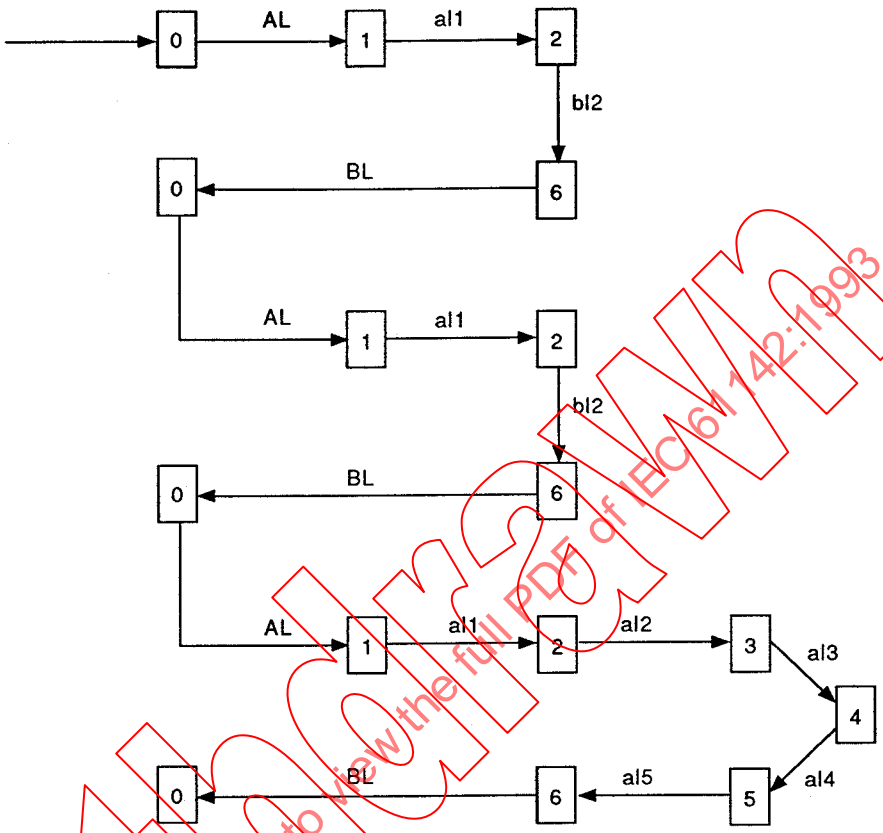
- Example of startovers after syntax check error (ERLI = 1) followed by correct remote reading on third attempt.



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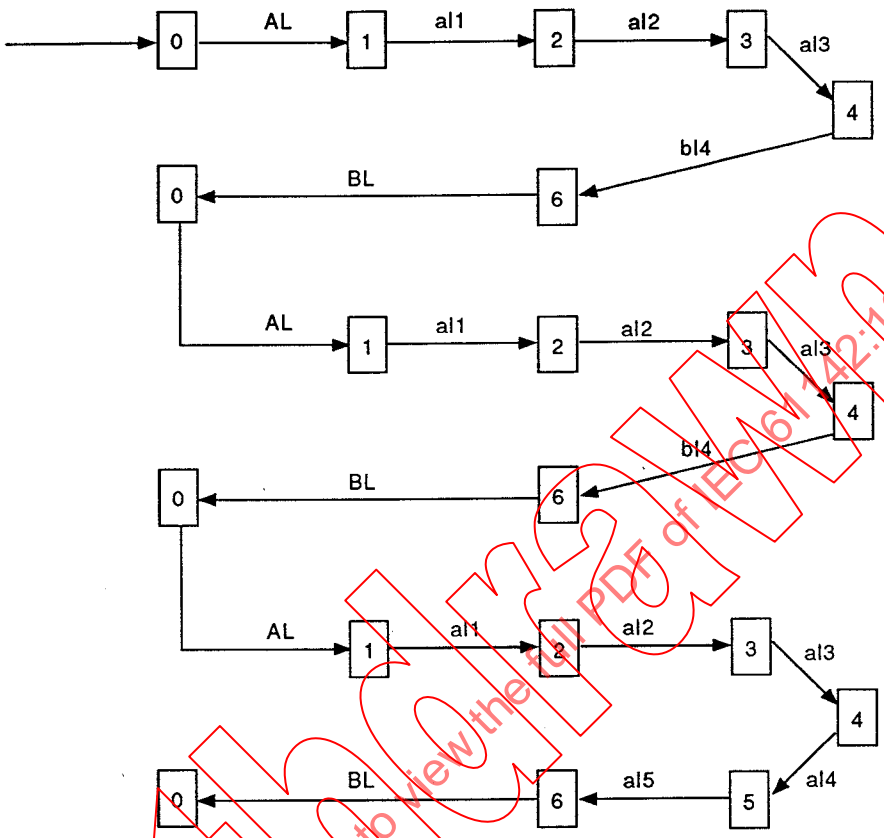
- Example of startovers after SESSION return error (ERSES = 1) followed by correct remote reading on third attempt



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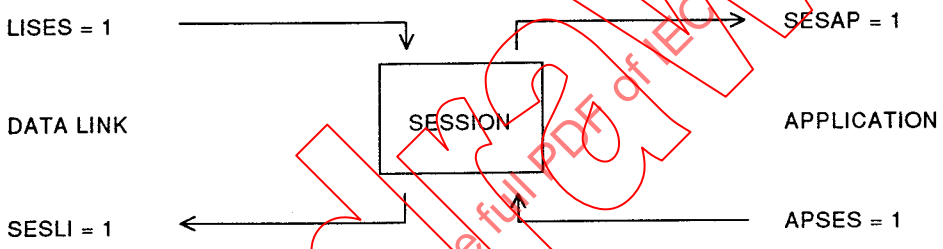
2.8 *SESSION layer*

2.8.1 *Opening and closing the SESSION*

As soon as it is alerted, SESSION goes to standby state for the synchronization flag LISES from the lower DATA LINK layer. This flag authorizes the performance of the actions associated with SESSION. When SESSION is synchronized by DATA LINK, it is implicit that the lower layers have performed their tasks without detecting errors or anomalies.

The main function of SESSION is to interpret the contents of the command field in the received frame in order to take the appropriate action and transmit the synchronization flag to APPLICATION. On return from APPLICATION, SESSION sets the command byte tailored to the response to be transmitted and synchronizes the execution of the lower DATA LINK layer.

SESSION disconnects when it sends the synchronization flag SESLI = 1 to the lower layer.



The SESSION layer is switched off only by the PHYSICAL layer on a normal end of exchange or expiry of one of the time outs.

2.8.2 *Command field in receive mode*

The possible commands on an initial call-response sequence are: ENQ (remote reading), REC (remote programming), IB (bus initialization), ASO (forgotten station call).

On the following sequences, depending on proper running and not the exchange, the commands may be:

ENQ (startover or remote reading over several sequences)
REC (startover in remote programming)
AUT (in remote programming only)

If ENQ has been recognized in an initial sequence, the following sequence, in the event of a startover, can only carry the same command. Otherwise, a SESSION error is detected.

Generally speaking, any abnormal chaining generates a SESSION error signalled by ERSES = 1. This error causes the progressive disconnection of the lower layers for a subsequent startover.

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2.8.3 *Command field in response mode*

Any call command received by a unit (see 2.8.2) is systematically associated with a response command (except for IB).

Service	Command field	
	Call	Response
Remote reading	ENQ	DAT or DRJ
Remote programming	REC AUT	ECH ECS or ARJ or DRJ
Bus initialization	IB	–
Forgotten station call	ASO	RSO

This response command is inserted into the descending buffer(s) returning from APPLICATION (APSES = 1) before the flag SESLI = 1 is transmitted to the lower DATA LINK layer.

If the identifier TAB(i) of an ENQ frame is unknown to the secondary station, if the remote programming data is not validated or if the authentication AUT of the primary station is not performed, APPLICATION sets the DNA flag (no acknowledge flag) indicating that a negative acknowledge frame comprising the DRJ (Data Reject) command or ARJ (Authentication Reject) command respectively has been transmitted:

- DNA = 1 means that a DRJ frame should be transmitted;
- DNA = 2 means that an ARJ frame should be transmitted.

2.8.4 *Possible examples of command interpretation*

To interpret commands, it is necessary to know whether it is the first or a subsequent sequence. The variable APREC (previous call) is assigned to this function. Four other flags reveal the command of the previous sequence.

DIB: Bus initialization flag

DASO: Forgotten station call flag

DTR: Remote reading flag

DTP: Remote programming flag

APREC is set to 1 on the following state:

If DIB or DASO or DTR or DTP = 1, then APREC = 1.

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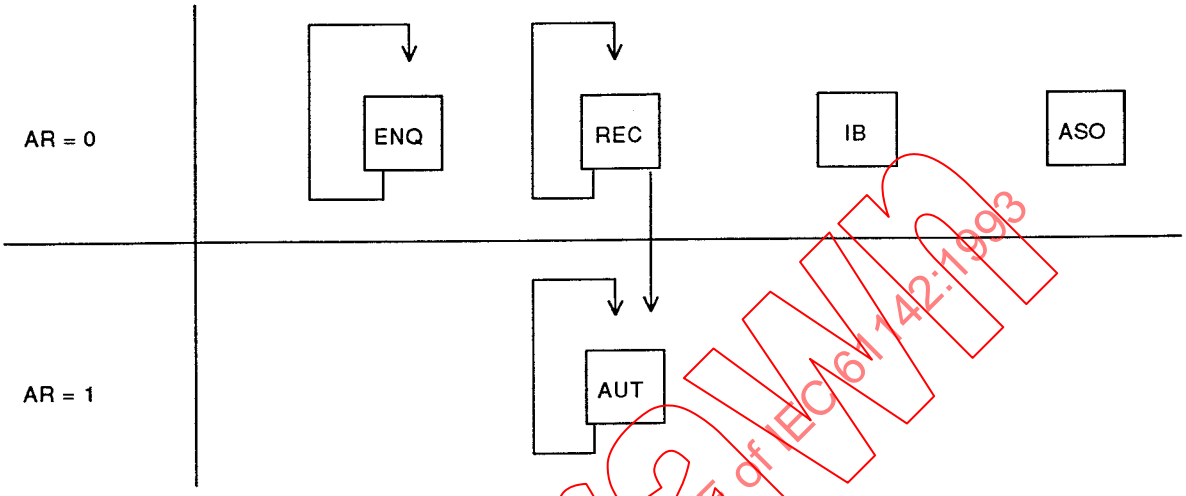
Another variable AR enables the progression of remote programming call-response sequences to be followed, as shown in the diagram under "command field in receive mode". This variable is transmitted to APPLICATION to enable it to know the sequence in progress.

Command field in receive mode:



All flags (DIB, DASO, DTR, DTP, APREC, AR and DNA) are reset to 0 on the overall initialization of the protocol and are never erased by the SESSION layer.

The variable DNA is set by the APPLICATION layer and is never erased by the SESSION layer.

The table of 2.10.2 indicates the layer set for each flag and the one which it uses.

All these variables enable a flowchart of the various command interpretation possibilities to be drawn up.

* *Flowchart of state 2*

If APREC = 0 (this is a first call-response sequence)

Then

* *If COM = ENQ* (this is a remote reading exchange)

Then

- Set DTR = 1 in remote reading mode
- Set APREC = 1 signalling that a first call has just been received
- Prepare COMmand byte in response mode: DAT (DRJ command will be substituted on return from APPLICATION if DNA = 1)
- Synchronize APPLICATION by SESAP = 1
- Standby for APPLICATION

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* *If COM = REC* (this is a remote programming exchange)

Then

- Set DTP = 1 in remote programming mode
- Set APREC = 1
- Prepare COMmand byte in response mode: ECH
- Synchronize APPLICATION by SESAP = 1
- Standby for APPLICATION

* *If COM = ASO* (this is a forgotten station call - no startover)

Then

- Set DASO = 1 in forgotten station call mode
- Set APREC = 1
- Prepare response byte COM = RSO
- Synchronize APPLICATION by SESAP = 1
- Standby for APPLICATION

* *If COM = IB* (this is a bus initialization - no startover and no response to be transmitted)

Then

- Set DIB = 1 in bus initialization mode
- Set APREC = 1
- Synchronize APPLICATION layer SESAP = 1
- Standby for APPLICATION

* *If COM <> (ENQ and REC and ASO and IB)*

Then (error)

- ERSES is set to 1 (to startover position without response)
- Synchronize DATA LINK by SESLI = 1
- Standby for DATA LINK

If APREC = 1 (this is not a first call-response sequence)

Then

* If COM = ENQ

Then if DTR = 1 and (DPT = DASO = DIB = 0)

Then (remote reading startover or request for new tables of data)

- Prepare response command byte: COM = DAT (DRJ will be substituted on return from APPLICATION if DNA = 1)
- Synchronize APPLICATION by SESAP = 1
- Standby for APPLICATION

Otherwise (incorrect chaining: error)

- Set ERSES = 1
- Synchronize DATA LINK by SESLI = 1
- Standby for DATA LINK

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* *If COM = REC*

Then if (DTP = 1 and AR = 0) and (DTR = DIB = DASO = 0)

Then (remote reading startover on first call-response sequence)

- Prepare response command byte: COM = ECH
- Synchronize APPLICATION by SESAP = 1
- Standby for APPLICATION

Otherwise (incorrect chaining: error)

- Set ERSES = 1
- Synchronize DATA LINK by SESLI = 1
- Standby for DATA LINK

* *If COM = AUT*

Then if DTP = 1 (DTR = DIB = DASO = 0)

Then (first AUT received)

- Prepare response command byte: COM = EOS (ARJ will be substituted on return from APPLICATION if DNA = 2 or DRJ if DNA = 1)
- Set call-response (AR = 1)
- Synchronize APPLICATION by SESAP = 1
- Standby for APPLICATION

Otherwise (startover on AUT: AR = 1)

Then if DNA = 2 (last AUT has had ARJ)

- Prepare response command byte COM = ARJ

Then if DNA = 1 (last AUT has had DRJ)

- Prepare response command byte COM = DRJ

Otherwise (last AUT has had EOS)

- Prepare response command byte COM = EOS
- Data field empty
- Synchronize DATA LINK by SESLI = 1
- Standby for DATA LINK

Otherwise (incorrect command chaining: error)

- Set ERSES = 1
- Synchronize DATA LINK by SESLI = 1
- Standby for DATA LINK

* *If COM <> (ENQ and REC and AUT)*

Then (error)

- ERSES is set to 1 (to startover position without response)
- Synchronize DATA LINK by SESLI = 1
- Standby for DATA LINK

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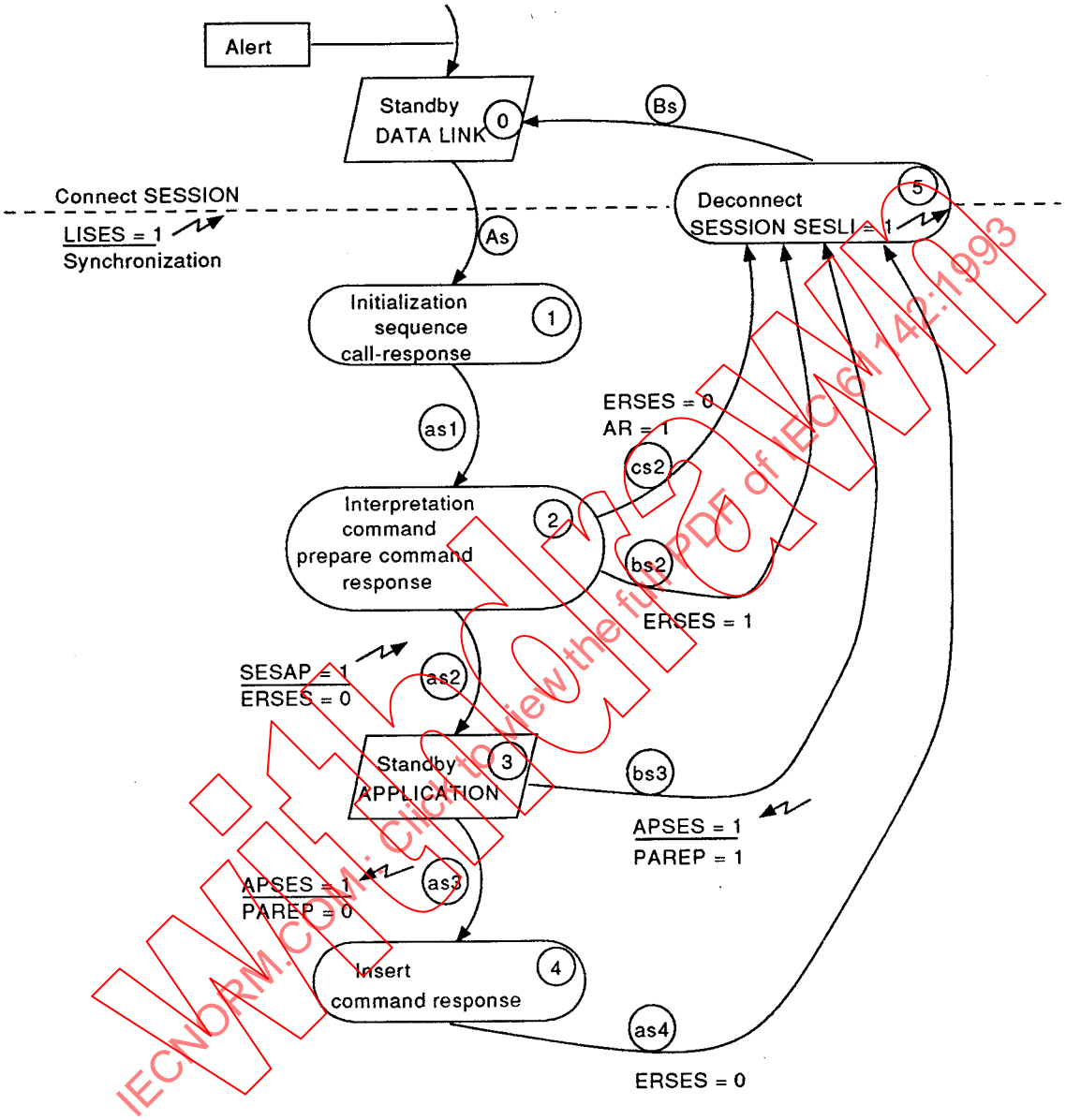
2.8.5 *States of the SESSION layer*

2.8.5.1 *Diagram of SESSION states*



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2.8.5.2 *Description of SESSION states*

This layer can only be switched off by PHYSICAL

* *State 0*

As soon as it is alerted, the SESSION layer puts itself on standby for the synchronization flag from DATA LINK.

* *State 1*

Initialization of the parameters SESLI, SESAP and ERSES which are needed for a call-response sequence.

* *State 2*

The command field is interpreted according to various parameters as mentioned in 2.8.4 above in order to specify the type of action to be taken.

In this state, the command response byte is also prepared for insertion in state 4.

* *State 3*

Standby for synchronization feedback from APPLICATION layer.

* *State 4*

Insertion of response command specified in state 2 and modified in DNA = 1 or DNA = 2.

* *State 5*

SESSION disconnects and synchronization moves to lower layer by SESLI = 1.

2.8.5.3 *Description of SESSION events*

As. Reception of the synchronization flag LISES = 1 from the lower DATA LINK layer enables state 0 to change to state 1.

as1. Unconditional move from state 1 to state 2.

as2–bs2–cs2. All three are different interpretations of the command; at the same time, the SESLI flag is set to return to lower DATA LINK and PHYSICAL levels in the event of an error or the SESAP flag is set to synchronize the upper APPLICATION layer. The command interpretation flowchart is given under 2.8.4 above.

as2. Command interpretation is correct for sequence in progress and previous sequences (ERSES = 0). SESLI flag synchronizing APPLICATION is set and SESSION moves to standby state 3.

bs2. Command interpretation is not for expected command (ERSES = 1). SESLI flag synchronizing the lower DATA LINK layer is set; SESSION disconnects (state 5).

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cs2. Response to startover on second call-response sequence from remote programming service: the same response as for the first call is sent.

as3. After standing by for APPLICATION (state 3), synchronization flag APSES feedback together with state PAREP = 0 enables the system to change to state 4.

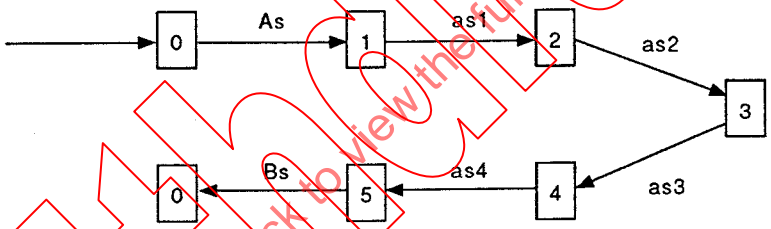
bs3. After standing by for APPLICATION (state 3), synchronization flag APSES feedback together with state PAREP = 1 (no response to be transmitted) indicates that SESSION shall disconnect (state 5).

as4. Unconditional change, after command insertion (state 4) to state 5 together with setting of synchronization flag for lower DATA LINK layer (SESLI = 1).

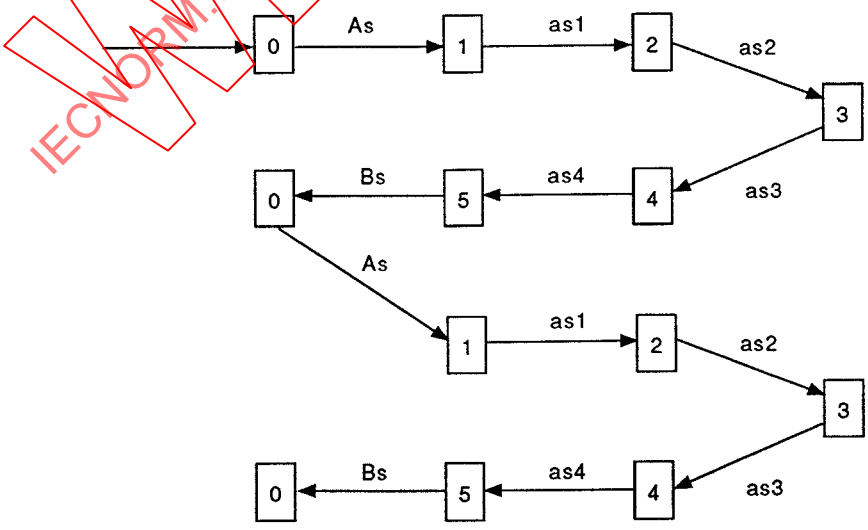
Bs. After disconnection and transmission of SESLI, return to DATA LINK standby state for next call-response sequence.

2.8.5.4 *Diagram of several examples of states*

- Remote reading: nominal example



- Remote programming: nominal example



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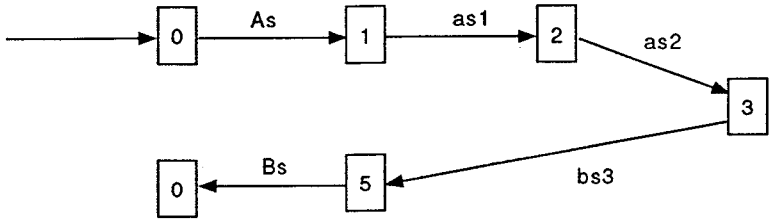
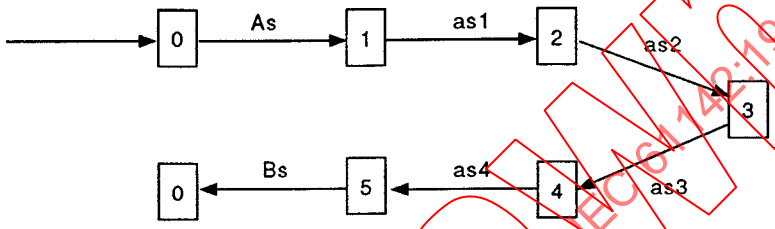
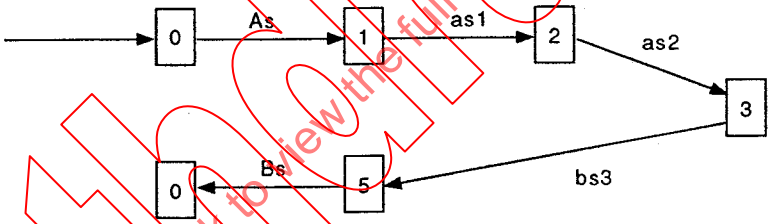
- Bus initialization



- Forgotten station call addressed to a forgotten station



- Forgotten station call addressed to a non-forgotten station



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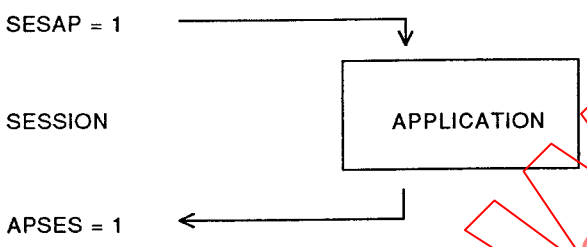
2.9 *APPLICATION layer*

2.9.1 *Opening-Closing*

After having been opened at the beginning of the protocol, the APPLICATION layer is set on standby for the synchronization flag from SESSION. If the lower layers perform their tasks correctly, the SESAP flag enables APPLICATION to be synchronized (connected) which commences with an initialization phase (state 1).

APPLICATION disconnects as soon as the flag for the lower SESSION layer is set.



The APPLICATION layer can only be switched off by the PHYSICAL layer.

2.9.2 *APPLICATION related action in remote reading mode*

A frame arriving at a secondary station includes 1 byte of TAB(i) data specifying the type of data to be read automatically. The match between the code of this TAB(i) byte and the related data table will be specified for each application.

If the TAB(i) is not known to the secondary station, APPLICATION sets flag DNA to 1 such that a negative acknowledge frame is retransmitted to the primary station.

2.9.3 *APPLICATION related action in remote programming mode*

The first 16 bytes of the data field are intended for authentication parameters.

2.9.3.1 *Principle of two-way authentication*

Authentication is carried out by an exchange of random numbers encrypted using a secret key peculiar to each unit (Ki). The random numbers are defined in 8 bytes (see annex D), they are encrypted in 8 bytes using an 8-byte key and the DES algorithm specified in annex B.

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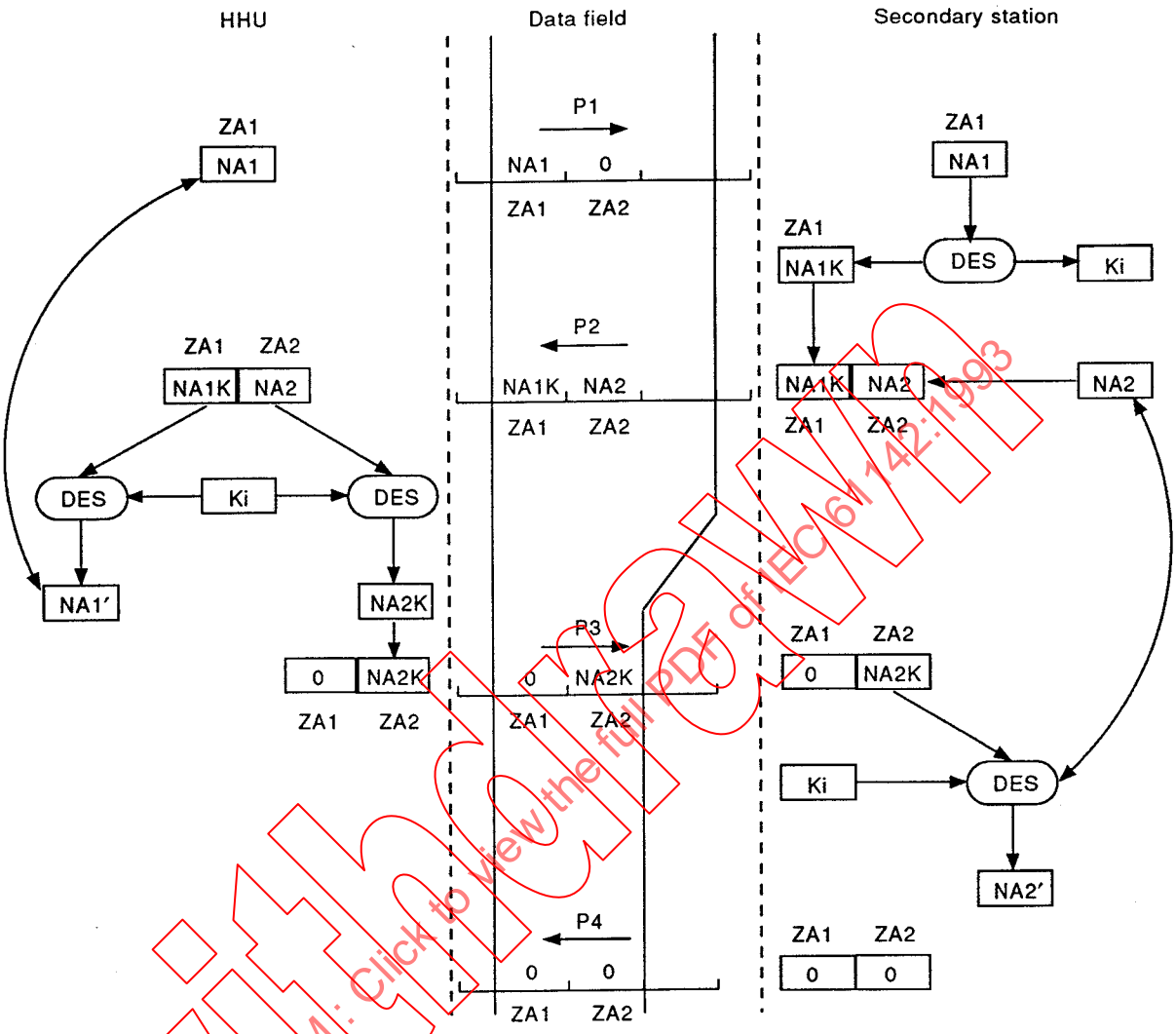
This two-way authentication is superimposed on frames P1, P2 and P3 as follows:



The Ki key is known to the HHU and the secondary station.

A random number NA1 is generated by the HHU and transmitted into the ZA1 field of frame P1; field ZA1 is empty.

On arrival at the secondary station field ZA1 is decrypted by the DES algorithm to obtain the encrypted random number NA1K.

Returning frame P2 contains this random number NA1K in field ZA1 and a random number NA2 generated by the secondary station in field ZA2

On reception of P2, the HHU decrypts field ZA1 using the DES algorithm and the Ki key. The resulting NA1′ is compared to NA1. If NA1′ = NA1, the HHU considers the called secondary station to be authenticated. Otherwise, the HHU considers that an impostor is attempting to speak on the line in place of the unit in question; it then aborts its remote programming exchange without a startover and logs an authentication failure.

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After correct authentication of the secondary station, the HHU encrypts the random number NA2 generated by the secondary station and transmits it into field ZA2 of P2. It obtains an encrypted number NA2K which it transmits on P3 into field ZA2; field ZA1 is at zero.

The secondary station decrypts field ZA2 using its Ki key and the DES algorithm; it thus obtains NA2′ which it compares to the previously generated random number NA2. If NA2 = NA2′, the secondary station considers the HHU to be authenticated. Otherwise, the secondary station's APPLICATION layer sets flag DNA to 2 such that a negative acknowledge frame is retransmitted to the primary station.

A frame P4 is transmitted by the secondary station to show that two-way authentication has been validated and that it has also been able to validate the remote programming data stored after frame P1.

The principle of this exchange therefore offers security against attempted fraudulent remote programming.

The principle of a remote programming exchange with authentication will be used whenever any data item in the called secondary station is changed (reset to 0, change in internal parameters, etc.). Consequently, remote reading never changes the data transmitted by the secondary station.

2.9.3.2 *Action related to the ZDT data field*

This field contains the remote programming data itself; it travels in frame P1 to be stored by the secondary station awaiting validation.

It is echoed on frame P2 by the secondary station. After verifying the authentication fields, the HHU verifies that the data echo matches the data transmitted on P1. If there is a mismatch, it repeats the defective sequence, in other words it repeats its P1 call with a different random number NA1.

On reception of frame P3, the secondary station verifies the authentication of the primary station. If this is positive, the previously stored data may be decoded and validated.

When the latter operation has been successfully completed, frame P4 with the EOS command is sent to the primary station to close the procedure.

If there is any decoding problem with the programming data, it is not validated and the secondary station's APPLICATION layer sets flag DNA to 1, such that a negative acknowledge frame is returned to the primary station.

2.9.3.3 *Description of the data field ZDT*

The data field ZDT comprises two sub-fields:

- the field TDP which relates to the programming data contained in the field DON (equivalent to TAB for the local bus reading);

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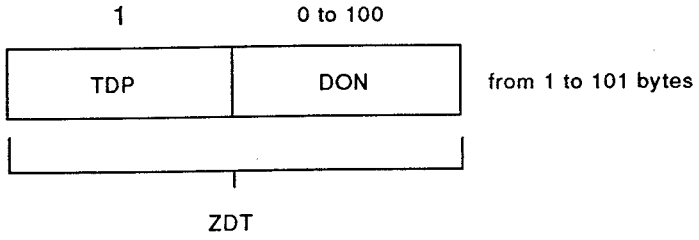
- the field DON



2.9.4 *Action relating to forgotten station calls*

In a forgotten station call, the mere fact of the DASO flag coming from the lower SESSION layer is enough to initiate the procedure related to this call, which is peculiar to the APPLICATION.

APPLICATION sets variable ALEA to indicate to the lower layers, particularly PHYSICAL, that it has to generate a response delay (TRO = NAO x TE). The random number NAO which specifies three possible delays is generated by the secondary station's APPLICATION layer (NAO = 0 or 1 or 2). For units on the same bus, random number generation will involve strings of different numbers from one unit to another. This generation will therefore be associated to a parameter peculiar to each unit, for example its address ADS(s) in combination with automatically readable consumption index (see annex C).

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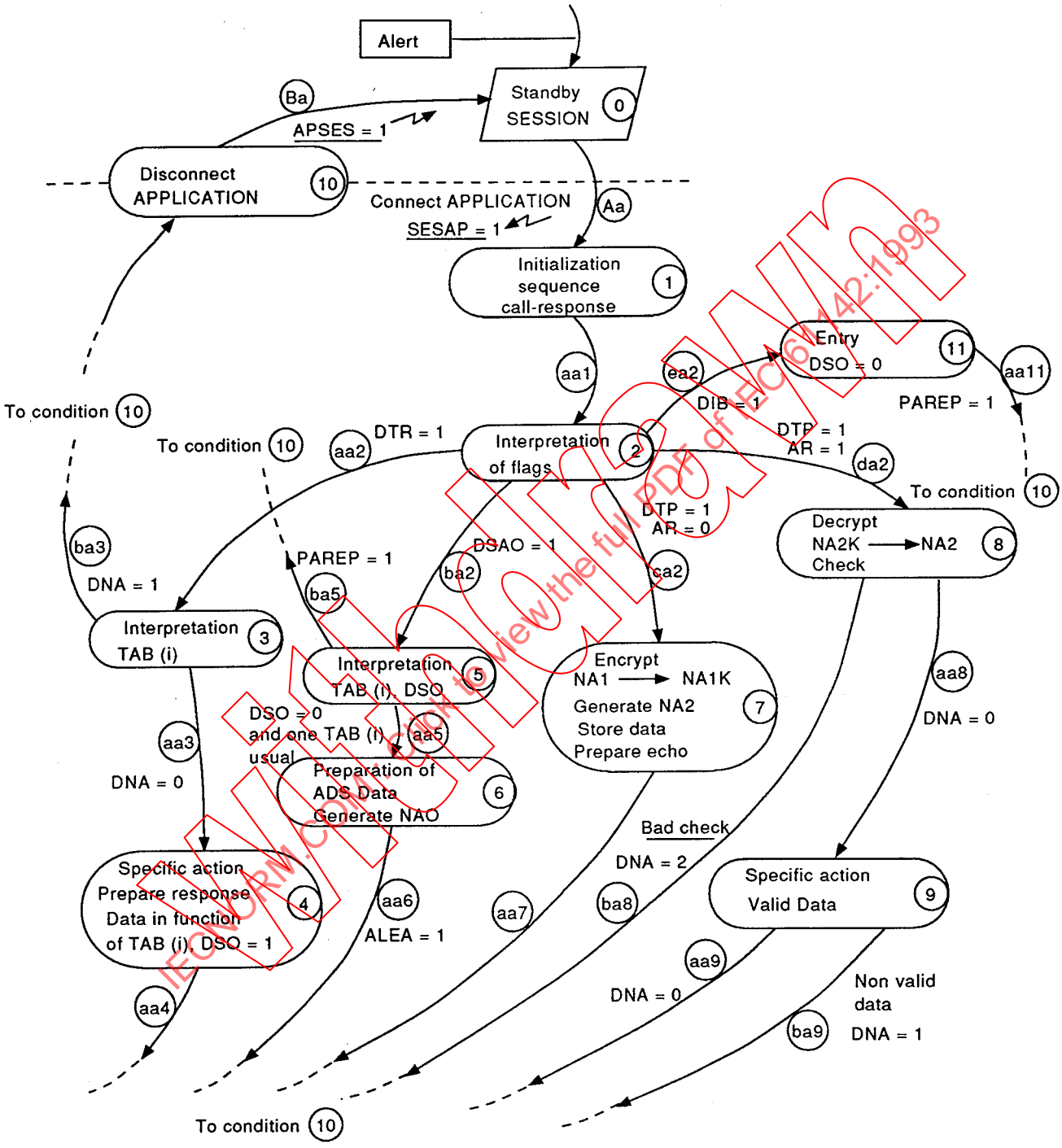
2.9.5 *APPLICATION layer states*

2.9.5.1 *Diagram of APPLICATION states*



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2.9.5.2 *Description of APPLICATION states*

This layer can be switched off only by PHYSICAL.

* *State 0*

Standby for SESSION. As soon as it is alerted, the APPLICATION layer puts itself on standby for synchronization from SESSION.

* *State 1*

Initialization of a call-response sequence. Each sequence begins by initializing certain parameters APSES and ALEA.

* *State 2*

Interpretation of flags indicating the type of command received, which enables a change to state 3, 5, 7, 8 or 11.

* *State 3*

Remote reading: the interpretation of the byte TAB(i) describing the type of data table to be read and the setting of flag DNA (DNA = 0 or DNA = 1).

* *State 4*

Remote reading: preparation of the response data table according to the TAB(i) received. Forgotten station flag set (DSO = 1).

* *State 5*

Forgotten station call: verification of the presence of a known TAB(i) and the resetting of DSO.

* *State 6*

Forgotten station call: preparation of the response by inserting the station's secondary address and the first known TAB(i) of the ASO frame in the data field, and generation of random number NAO using the principle described in annex C so that the response can be given in a random time slot. ALEA is set to 1.

* *State 7*

Remote programming: First sequence: the response data field receives the same random number NA1 which is encrypted using the DES algorithm in association with random number NA2. The response data field (ZDT) will also contain the echo of the received data.

* *State 8*

Remote programming: Second sequence: the data field contains the encrypted number NA2K which is decrypted and checked against NA2 sent in the first sequence. DNA is set to 2 if the test is incorrect.

* *State 9*

Remote programming: Second sequence: decoding of remote programming data and related job-oriented action. DNA is set to 1 if the test is incorrect.

* *State 10*

APPLICATION disconnects and synchronization passes to lower layer by APSES = 1.

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* *State 11*

Bus initialization. Initialization of forgotten station flag (DSO = 0). PAREP is set to 1.

2.9.5.3 *Description of events*

Aa. Reception of synchronization flag SESAP = 1 from the lower SESSION layer enables change from state 0 to state 1.

aa1. Unconditional change from initialization state 1 to state 2.

aa2. The flag sent by SESSION (DTR = 1) corresponds to a remote reading action.

ba2. The flag sent by SESSION (DASO = 1) corresponds to a forgotten station call action.

ca2. The flag sent by SESSION (DTP = 1) corresponds to a remote programming action, variable AR (AR = 0) indicates that this is the first remote programming sequence.

da2. The flag sent by SESSION (DTP = 1) corresponds to a remote programming action, variable AR (AR = 1) indicates that this is the second remote programming sequence.

ea2. The flag sent by SESSION (DIB = 1) corresponds to a bus initialization action.

aa3. DNA = 0 indicates that TAB(i) is known to the secondary station and that a DAT frame is to be transmitted.

ba3. DNA = 1 indicates that TAB(i) is wrong and that a negative acknowledge DRJ frame is to be transmitted.

aa4. Unconditional change from state 4 to state 10.

aa5. PAREP = 0 indicates that a response shall be made to this call. A secondary station has been forgotten (DSO = 0). The intersection between the list of TAB(i) received and that of the secondary station contains at least one TAB(i)

ba5. PAREP = 1 indicates that no response is to be made to this call
- either the secondary station has not been forgotten (FSF = 1)
- or the intersection between the list TAB(i) received in the ASO frame and that of the secondary station is empty.

aa6. Unconditional change to state 10. The variable ALEA in set (ALEA = 1) to indicate to the lower layers that this is a response which shall be generated in the window specified by the number NAO.

aa7. Unconditional change to state 10.

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aa8 DNA = 0 indicates that the check on NA2 is correct.

ba8. DNA = 2 indicates that the check on NA2 is wrong: a negative acknowledge ARJ frame shall be transmitted.

aa9. DNA = 0 indicates that programming data has been validated by the secondary station.

ba9. DNA = 1 indicates that the programming data is wrong and that it has not been validated by the secondary station: a negative acknowledge DRJ frame shall be transmitted.

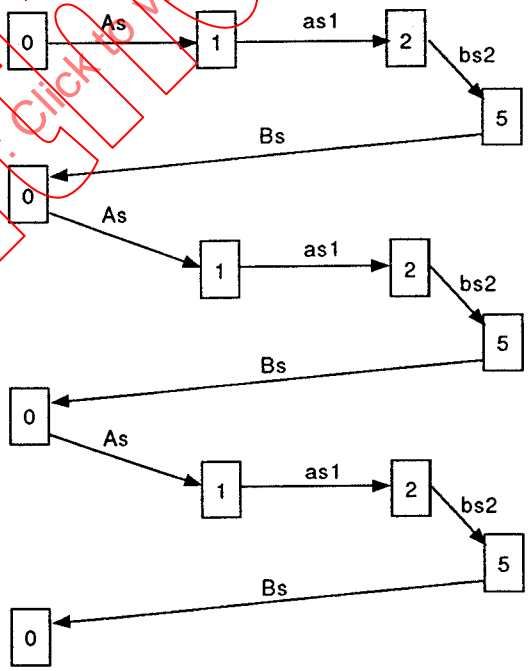
aa11. Unconditional change to state 10. The variable PAREP is set at 1 to indicate to the lower layers that no response is to be transmitted.

Ba. After disconnection and setting of APSES to 1, return to SESSION standby state for the next sequence.

2.9.5.4 *Possible simplification*

These states represent only the minimum action to be taken in respect of all the applications which use the local bus reading protocol. For remote reading only (without remote programming), they could be simplified.

In fact, for this type of application, the REC command received by a secondary station is regarded by SESSION as an error with the diagram of states related to SESSION:



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In this case, the APPLICATION layer is never synchronized and never encounters DTP = 1.

In the APPLICATION states diagram, all the states and actions related to DTP = 1 may therefore be removed without the overall compatibility of the simplified protocol being adversely affected.

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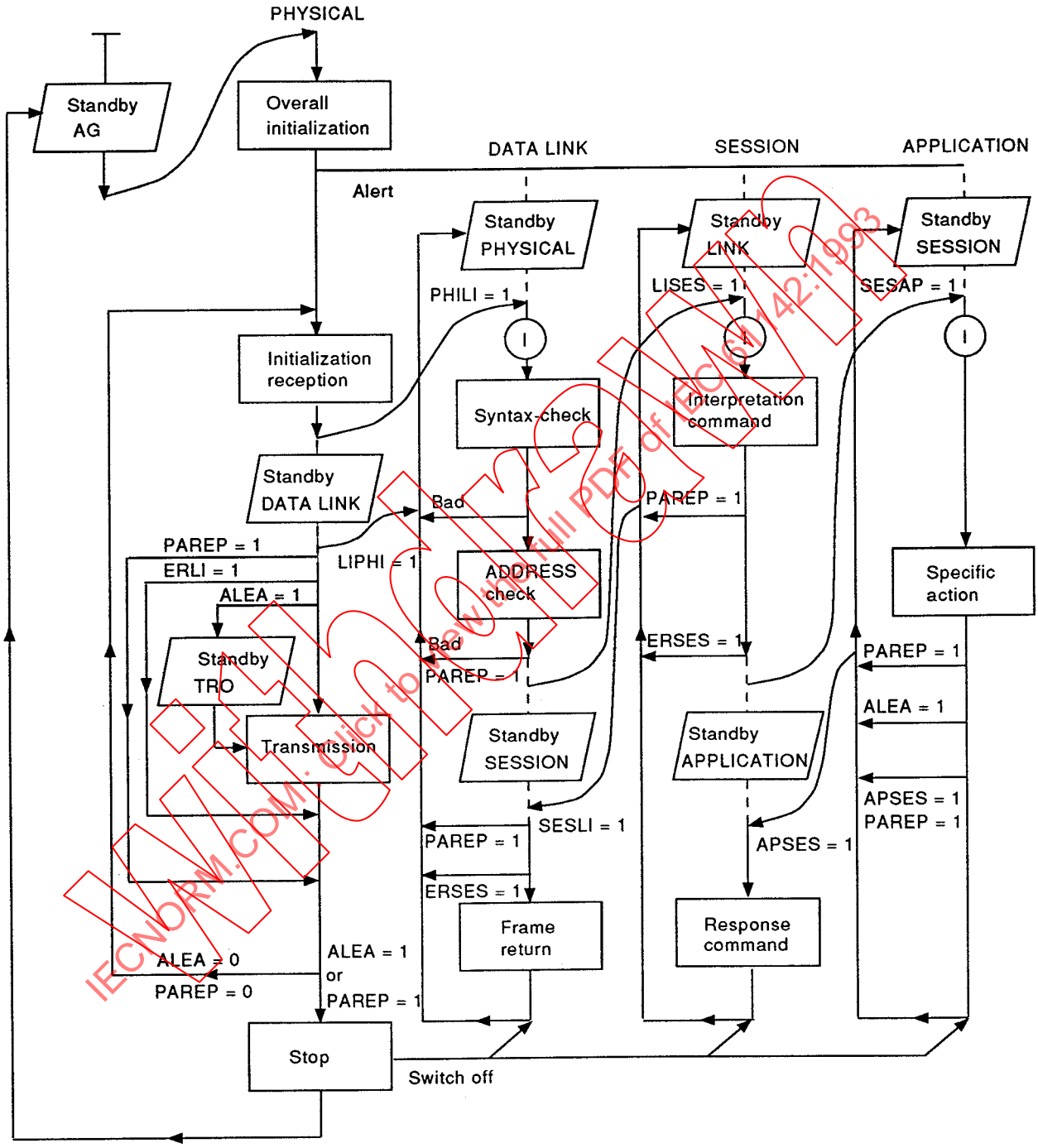
2.10 *Summary and inter-layer relationships*

2.10.1 *Simplified general diagram of states*



N.B.: Timeouts are not shown
ERSES = 1 → ERLI = 1

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2.10.2 *Synchronization flags and parameters*

Global initialization	PHILI / LIPHI / LISES / SESLI / SESAP / APSES = 0 DTR / DTP /DIB / DASO = 0 ALEA = 0 PAREP = 0 DNA = 0 AR = 0 APREC = 0 NAO = 0			
	PHYSICAL	DATA LINK	SESSION	APPLICATION
Initialization	PHILI = 0	LIPHI = 0 LISES = 0 ERLI = 0	SESLI = 0 SESAP = 0 ERSES = 0	APSES = 0 ALEA = 0
Synchronization flags and transmitted parameters	PHILI → Buffers (emp,lon)	LISES → Buffers (emp,lon)	SESAP → Buffers (emp,lon) DIB/DTR/DTP/DASO/AR	
Variable assigned in conditions and actions	PHILI (RA2)	LIPHI LISES PAREP ERLI	DIB/DTR/DTP DASO SESLI, SESAP LISES APREC ERSES AR	NAO APSES PAREP DSO ALEA DNA
Synchronization flags and transmitted parameters	LIPHI ← Buffers (emp,lon) PAREP ERLI NAO ALEA	SESLI ← Buffers (emp,lon) PAREP ERSES NAO ALEA	APSES ← Buffers (emp,lon) PAREP DNA NAO ALEA	

This table does not include time variable management.

NOTE - The error flags ERSES and ERLI which are transmitted layer by layer to the PHYSICAL layer are always accompanied by the same processing at this layer level.

In the previously presented operation, it is implicit that sending ERSES = 1 between SESSION and DATA LINK is accompanied by setting ERLI to 1 in DATA LINK.

For PHYSICAL, simply checking ERLI therefore enables the error free execution of all the upper layers to be known. Strictly speaking, it is possible to replace ERLI and ERSES by an overall parameter ER which can be set by either of the two upper layers (DATA LINK, SESSION) and checked by PHYSICAL. ER is then reset to zero when DATA LINK is initialized.

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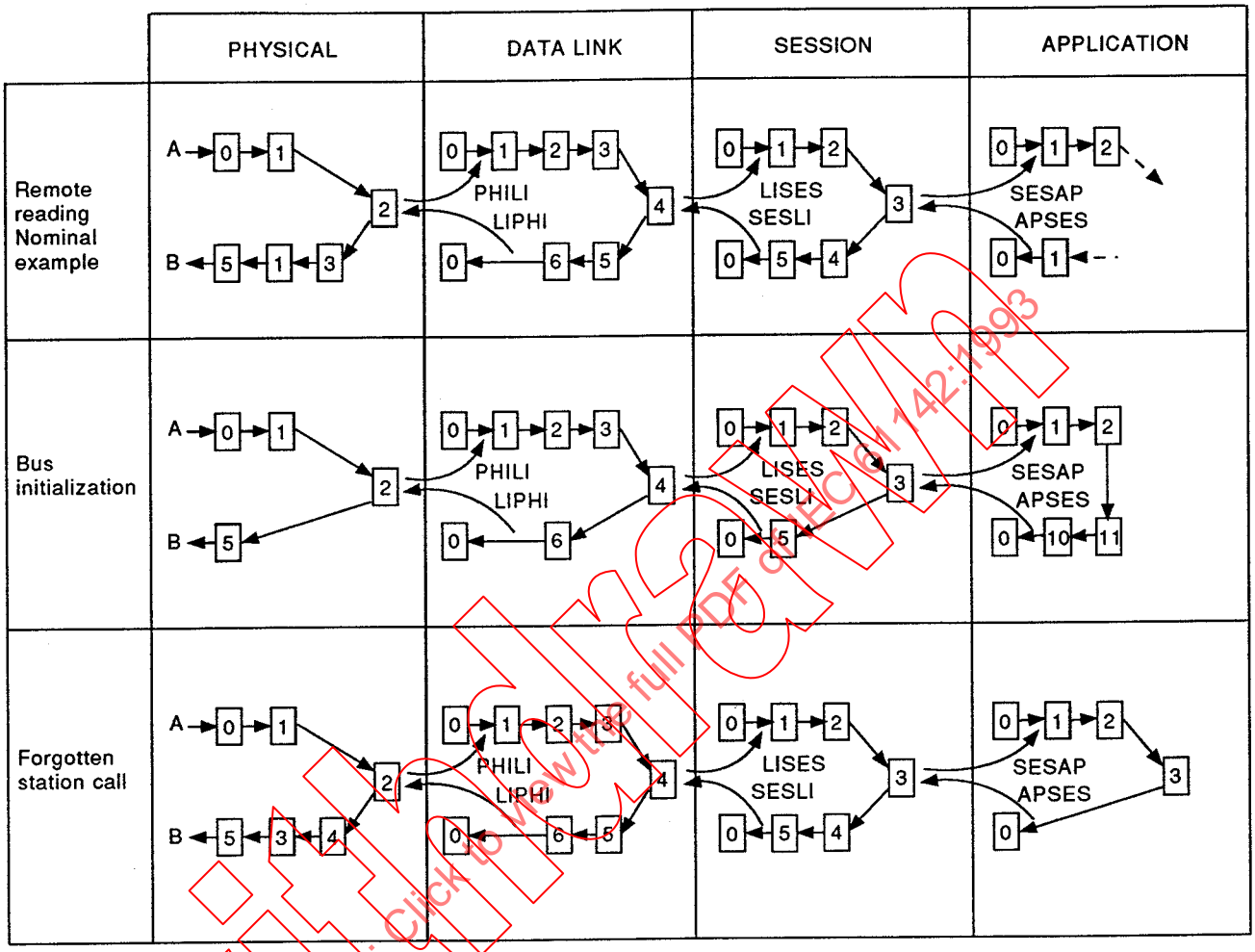
2.10.3 *Simplified general diagram covering a few examples*



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2.10.4 *General comments*

The purpose of the present standard is simply to define the protocol for the secondary stations (called secondary protocol). The primary station protocol is by nature complementary and can be inferred from the secondary protocol. Everything required to create it can be logically deduced from the points raised above.

Consequently, all diagrams, figures and explanations are to be interpreted with the secondary station protocol in mind.

2.10.5 *Development of the protocol*

The presentation of the various layers offers nothing more than a framework for development. A definitive development may group or explode certain states depending on the ease of programming, the language used and the architecture selected. In order to ensure compatibility of all developments around this protocol, it is essential that identical events produce identical effects and that the time constraints are adhered to.

As regards the method of programming, an initial approach may lead the designer to develop the protocol in a purely sequential logic on the assumption that each layer constitutes a sub-routine overlap. Another approach might produce a development linked to a multi-task monitor (or supervisor); in this case each layer would be considered as one task.

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3 Local bus data exchange – primary station (MASTER)

3.1 *Introduction*

This standard defines the rules to be followed for implementing a protocol seen from the perspective of the HHU. Reference is frequently made throughout the following pages to clause 2 of this standard, which specifies the functionalities of the protocol, the general organization of the frames and exchanges and various layers of a secondary station (queried unit).

Clause 3 of this standard is therefore set out as follows:

- firstly, 3.2 and 3.3 give general reminders together with additional information essential for understanding the system;
- next, 3.4 defines the principles of interfacing the protocol with a so-called external process, linked to the HHU. A brief description of the content of the data tables exchanged on activation and at the end of the protocol makes it possible to clarify the exchanges with the HHU;
- 3.5, 3.6, 3.7 and 3.8 present a description of the different layers making up the local bus reading protocol as regards the primary station;
- finally, 3.9 comprises a summary of the inter-relationship between the different protocol layers.

3.2 *General reminders*

3.2.1 *Functionalities of the protocol*

This protocol, intended for the relay of information between so-called secondary stations and a primary station, should be capable of maintaining three essential functions – the remote reading of information, remote programming and the detection of forgotten stations over a bus (see clause 2).

3.2.2 *Basic principles*

See 1.3 for definitions.

The general features relating to the exchange are described in clause 2.

The various points concerning the general organization of the frames and exchanges, the general structure of a frame and the definition of the various component blocks, as well as the detailed structure for each case of remote reading, remote programming and forgotten station call comply with the specifications given in clause 2.

3.2.3 *Protocol structure*

In order to fall in with the general rules governing the implementation and architecture of a protocol, the local bus reading has been ranked into four levels (PHYSICAL – DATA LINK – SESSION – APPLICATION).

Such an organisation proves advantageous in a number of ways, especially with respect to presentation and ability to understand the protocol system, thereby implying less complication as regards design, implementation and maintenance.

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The architecture presented here, however, is only an implementation framework for the primary station protocol. The fine details of this framework are only given in this document so as to better define the predicted functionalities for the working of the system.

In this respect, final implementation in accordance with the details mentioned, might arrange the automata states described below differently by grouping, dividing or modifying certain states. In order to provide the requisite compatibility between different implementations of the same protocol, however, it is essential that all the functions are perfectly executed, all the events described produce identical effects and that time-division constraints are respected.

Finally, it should also be made clear that presentation of the protocol in this document, even if based on a multitask architecture, should not exclude other programming principles, such as purely sequential ones, for example.

3.3 *Tables A received and B returned by the protocol*

Table A, available to the protocol at the beginning of its run, makes it possible to define unambiguously the basic operation (action) corresponding to an exchange to be made over the bus.

The table B sent back, constructed by the protocol and available at the end of its run, makes it possible to know the outcome of the basic operation.

The basic operations fall into four categories:

- bus initialization IB
- forgotten station call ASO
- remote reading of a secondary station TR
- remote programming of a secondary station TP

3.3.1 *Table A*

Total knowledge of the outcome of a basic operation is constituted by knowledge of the following parameters, which are necessary and adequate for managing the whole protocol:

- address of secondary station to be called AADS
- address of calling primary station AADP
- type of operation ATYPE
- data ADON

In order for this information to be processed more easily, additional parameters are linked to it for constructing table A:

- number of bytes in table A for a unit exchange ANECHAU
- number of bytes in ADON data field ANA

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3.3.2 *Table B*

Total knowledge of the outcome of a basic operation is constituted by knowledge of the following parameters:

- diagnostic on the running of the protocol
  - for each sequence (i)
- number of identical sequences — BNSEQI(i)
  - for each identical sequence (i, j)
- error due to time out — BTIMOUT(i,j)
- error in layers — BERREUR(i,j)
- data resulting from operation carried out — BDON

Table B is constructed from this information linked to additional parameters enabling easy processing:

- number of bytes in table B for a unit exchange — BNECHAU

  val (BNECHAU) = val (BNDEROU) + val (BNR) + 10
- number of bytes in diagnostic field — BNDEROU

  $$\text{val (BNDEROU)} = \sum_{1}^{n} li = 2 \times \sum_{1}^{n} (\text{val (BNSEQI(i))} + 1)$$
- number of bytes in BDON data field — BNR

3.3.3 *Organization of byte format tables*

The general organization of these tables is set out in the following pages.

In a field, the least significant bytes are at the top and the most significant at the bottom.

3	LSB
3	MSB

In order to make them transparent to any N° 5 CCITT code (7- or 8-element ISO code) for example, they are displayed in 30H to 3FH Hex code; the data bits are in the least significant 4-bit byte of each 8-bit byte.

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Example: N = 5 4 3 2 1 0 in decimal code

3	0	LSB = least significant byte
3	1	
3	2	
3	3	
3	4	
3	5	MSB = most significant byte

Coding of the AADS, AADP and ATYPE fields is derived from the coding factors of the blocks in the frame, mentioned in annex E.

The same applies for ATAB(i).

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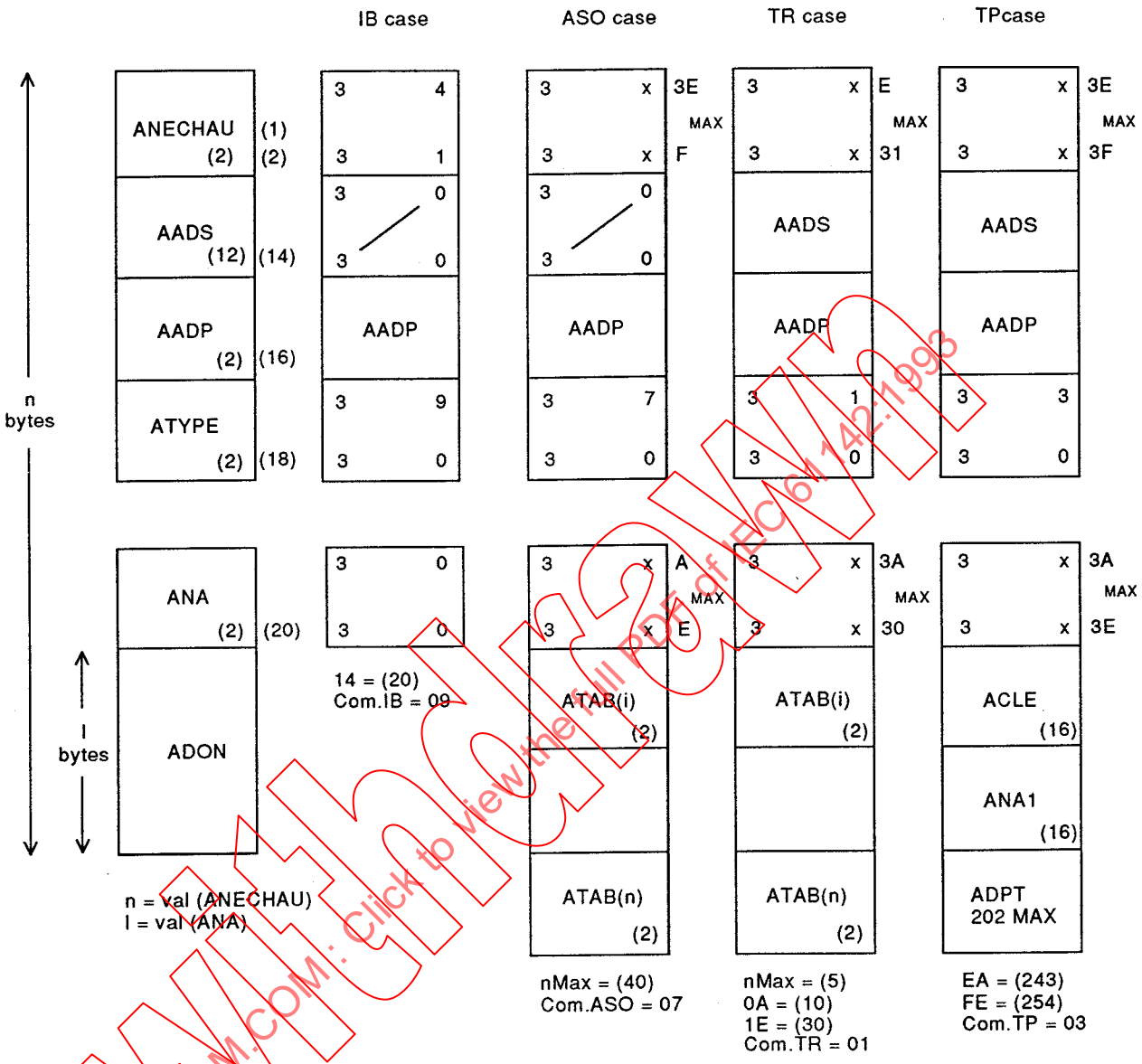
3.3.3.1 *Tables A*



NOTE – The bracketed values are decimal, the others are hexadecimal.

Detail of values taken by ANA and ANECHAU in remote reading

Remote reading in different run-return n sequences	(1)	(2)	(3)	(4)	(5)
ANA	3 2 3 0	3 4 3 0	3 6 3 0	3 8 3 0	3 A 3 0
ANECHAU	3 6 3 1	3 8 3 1	3 A 3 1	3 C 3 1	3 E 3 1

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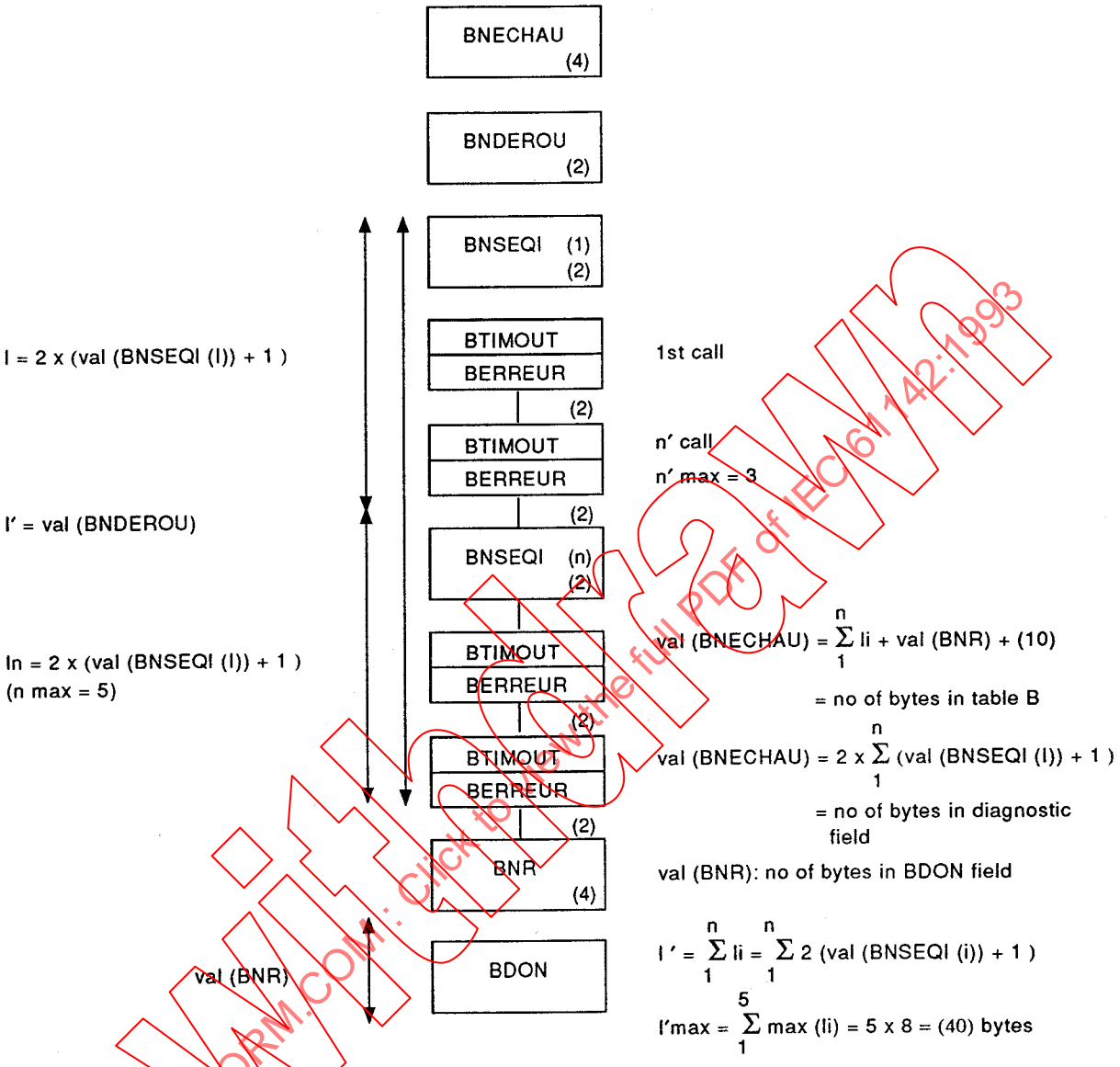
3.3.3.2 *Tables B*



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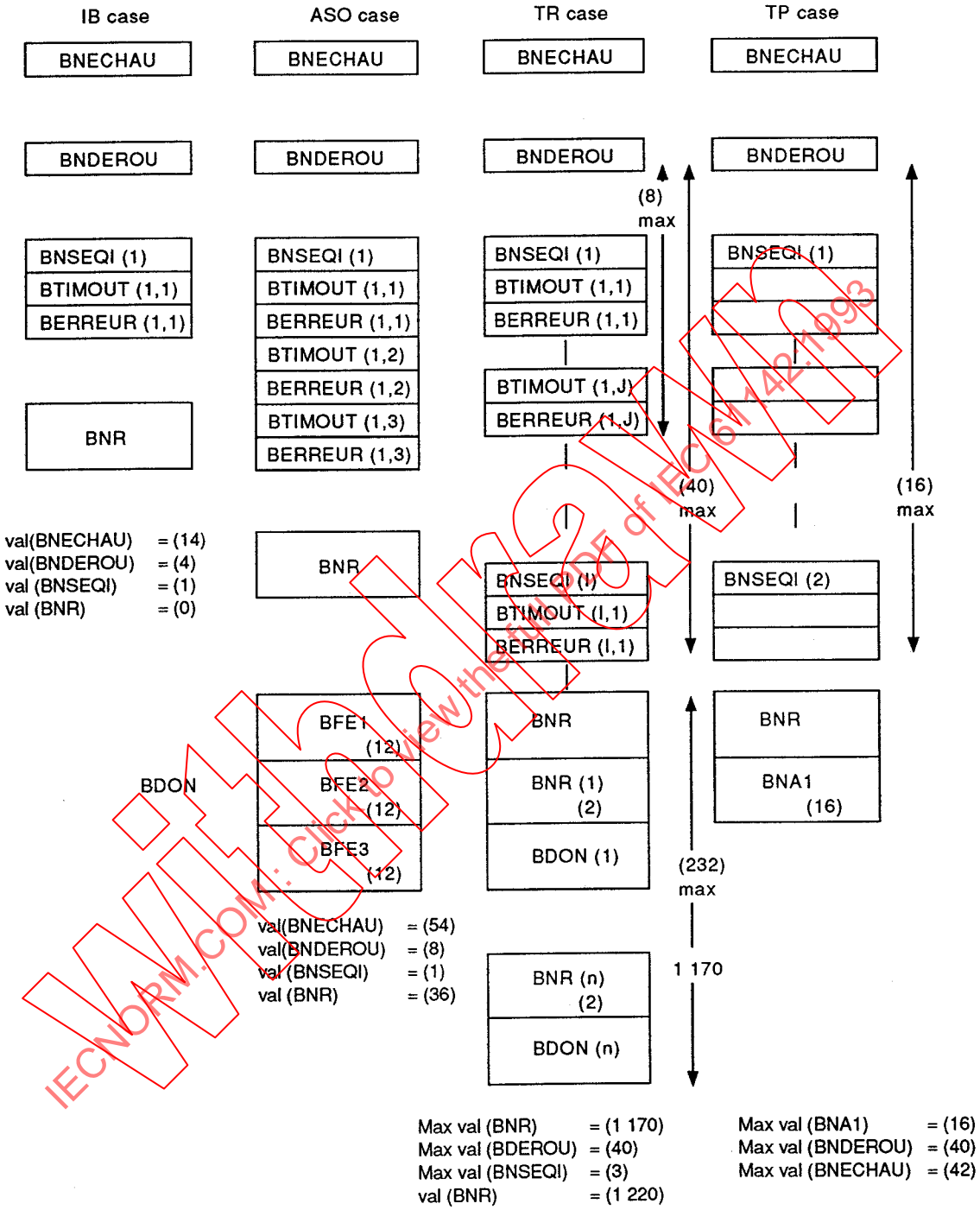
3.3.3.3 *Detail of tables B*



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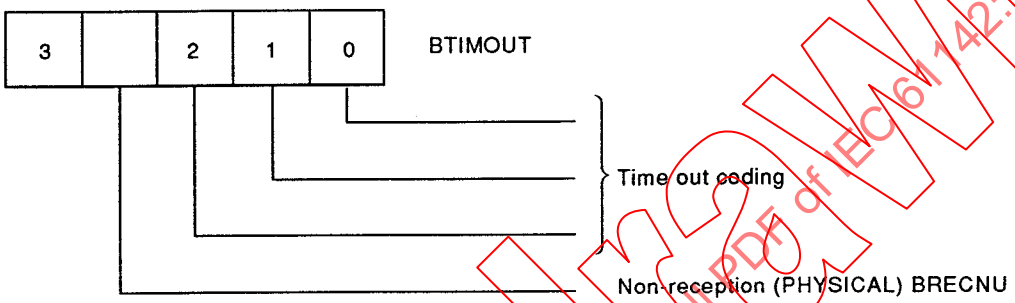
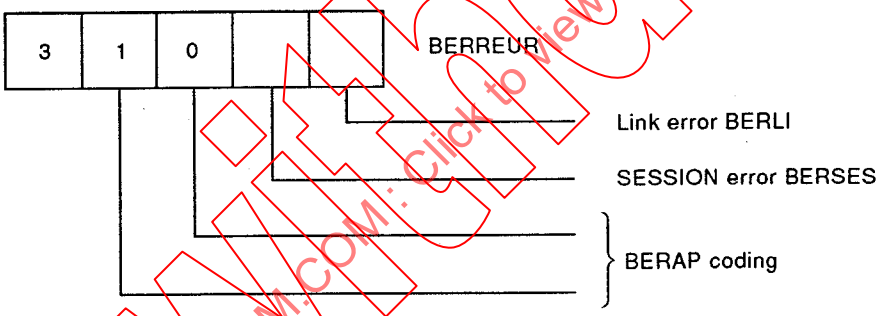
The bracketed values are decimal, the others are hexadecimal
I = indicator of different sequences
J = indicator of identical sequences

3.3.3.4 *Detail of BFEI window in ASO case*

Reply type	1	2	3
BFEI field	3 0 3 0	AADS	3 F 3 F

3.3.3.5 *Detail of BTIMOUT and BERREUR fields*





Detail of time out coding

2	1	0	Meaning
0	0	0	Time out not initiated
0	0	1	Transmission time out: TOCO′
0	1	0	Origination time out: TOE′
1	0	0	DATA LINK time out: TOL′
1	1	1	"Chatterbox" time out: TOB′

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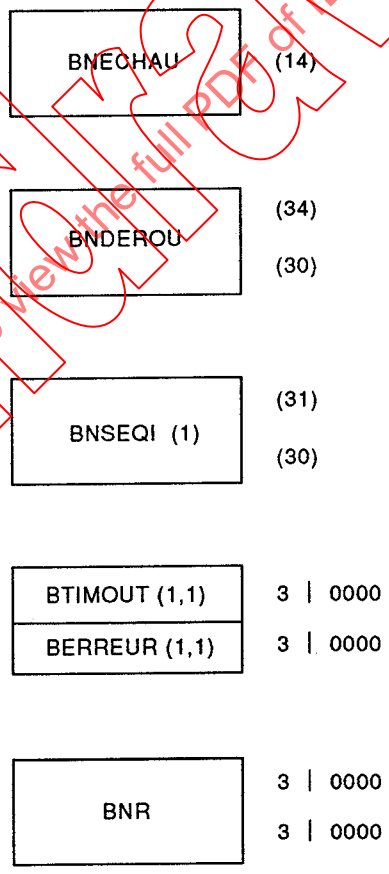
Detail of BERAP Coding

1	0	Meaning
0	0	No error
1	0	Rejected data (DNA = 1)
0	1	Rejected authentication (DNA = 2)
1	1	APPLICATION error (ERAP = 1)

3.3.3.6 *Initialization of table B*

In a case of overflow on a TOCO′, TOB′, TOE′ or TOL′ time out, the PHYSICAL layer is positioned in the BTIMOUT field corresponding to the sequence in progress, the overflow flag linked to this time out; the current sequence is known by means of the parameters I and J coming from APPLICATION.

Table B is initialized in the following way in order to prepare for a possible exchange cancellation in case of time out:



On each sequence, APPLICATION will update this table by setting a data field if the sequence is successful; if the sequence aborts after the authorized re-runs, the data field linked to this sequence will not appear.

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3.3.4 *Tables A and B linked to the initialization of the bus*

3.3.4.1 *Received table A*

Initialization of the bus is always carried out over a whole bus, consequently the AADS field corresponds to an address ADG = 0 so that all units concerned (ADP known) are affected by this action.

The ATYPE field, after truncation and concatenation into 1 byte corresponds to the command IB = 09H, which will be used by the protocol.

The ADON data field is empty and the number of bytes in the ADON table is therefore 0.

The primary station will provide its address in the AADP field, this field, after truncation and concatenation into 1 byte, corresponding to the ADP address used by the protocol.

The number of bytes in this table is 20 and constant.

3.3.4.2 *Returned table B*

In theory, initialization of the bus is not followed by replies on the part of the secondary station, the BDON field is therefore empty.

No re-run procedure is carried out on this operation, which infers the values contained in the BNSEQI(i) and BNDEROU fields.

The RECNU bit is at 1 on a normal exchange run, the number of bytes in table B is 14 and fixed.

3.3.5 *Tables A and B linked to the call of forgotten stations*

3.3.5.1 *Received table A*

A forgotten station call is sent to all or part of a bus depending on the content of the ATAB(i) and the set-up of the bus: it is broadcasted

After processing as in the previous paragraph, the ATAB(i) becomes TAB(i) bytes, which are directly inserted into a forgotten station call frame. The secondary stations reply if they recognize at least one TAB(i) in the list of their possible TAB(i), and if DSO = 0.

The content of the different fields is therefore deduced from these factors. The ATYPE field corresponds to the command ASO = 07H.

The AADS field corresponds to the general address (ADG = 0) in such a way that all the secondary stations set to react to the ADP will interpret this command.

The primary station will provide its address in the AADP field.

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3.3.5.2 *Returned table B*

The outcome of a forgotten station call operation is multiform. In fact, if no station is forgotten no station should reply. If stations are forgotten they reply in one of the three random time-division windows; the resulting table B should indicate what has occurred in each of these windows.

Type 1: no reply in origination window FEi: BFEi field will be at 0 (30H).

Type 2: comprehensible reply in window FEi, the BFEi field corresponding to this window contains the address of the replying station (ADS).

Type 3: incomprehensible reply in window, FEi, the field corresponding to this window contains FF...FF (3FH).

The three BFEi fields are each made up of 12 bytes, the BNR field therefore corresponding to coding of the number 36 (24H).

The BNSEQI(1) field corresponds to 1 as a forgotten station call is never followed by re-runs. A new forgotten station call will always be preceded by a wake up call as mentioned below.

After a correct exchange, the BTIMOUT byte and the BERREUR byte can take on different values depending on the type of reply:

- no reply;
- correct reply;
- reply collision.

Table B is always made up of 54 bytes (36H).

3.3.6 *Tables A and B linked to a remote reading*

3.3.6.1 *Received table A*

In a remote reading, an exchange can be made up of several sequences corresponding to successive remote readings with different data; this facility is offered by the protocol to enable the remote reading of data greater than 116 bytes (see details of this several-sequence remote reading operation in clause 2).

The maximum number of sequences is 5, which authorizes the remote reading of data up to 116 x 5 = 580 bytes coded on 1 160 bytes in table B.

In order to define the number and order of these successive sequences, table A includes in the ADON data field the ATAB(i) information corresponding to the type of data to be read at the time of each sequence. After processing the bytes TAB(i), the different ATAB(i) fields become directly inserted into the protocol frames. The secondary stations cannot, *a priori*, reply correctly to a remote reading one of whose TAB(i) over one of the sequences would result in a data field greater than 116 bytes. This fact shall thus be borne in mind for correspondence between TAB(i) and the associated data field. This correspondence is not dealt with here as it is closely linked to the various applications which can be carried out with this protocol.

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The different fields in table A are therefore AADS and AADP with ATYPE corresponding to the remote reading (TR: ENQ = 01H). The length of the ADON field varies by a minimum of 2 bytes to a maximum of 10 bytes, which infers the content of the ANA field. The total number of bytes in this table may therefore fluctuate between a minimum of 22 bytes for a one-sequence remote reading and 30 bytes for a five-sequence remote reading; the content of the ANECHAU field is deduced from these factors.

3.3.6.2 *Returned table B*

The data read in the various sequences are retrieved in the different BDON(i) fields. In order to give the protocol greater flexibility and not set the size of a data field linked to a particular TAB(i) once and for all, each BDON(i) field is preceded by 2 bytes specifying the size of this field which can contain up to 232 bytes. The maximum number coded in BNR therefore corresponds to the value 1 170 = 5 x (232 + 2) = 492H.

The BNSEQI(i) field contains a value from 1 to 3 according to the number of identical calls over the sequence in question (three calls maximum).

If a link has occurred with an error in each of the three call/reply sequences, the data relating to this link will not appear in table B, but the result of other links is nonetheless available if they have proceeded normally.

If an exchange has taken place with an error for a sequence and its two repeats, the data associated to this sequence does not appear in table B, but the result of any other sequence is still available if they have passed without error.

3.3.7 *Tables A and B linked to a remote programming*

3.3.7.1 *Received table A*

In remote programming, the requisite knowledge for the implementation of an exchange is made up of the usual AADS, AADP and ATYPE data, together with the encoding key, and the actual remote programming data.

The key comprises 64 bits in the protocol's exchange frames; it is 16-byte coded in table A; similarly, for the NA1 number.

Note: To provide key security it is recommended to transmit a coded version of the key specifications in table A to the primary stations interface.

The maximum length of the remote programming data is 202 bytes in table A (i.e. 101 actual bytes in the protocol). This value infers that of the ANA field corresponding to 234 bytes (202 + 16 + 16), i.e. EA in Hex, and that of the ANECHAU field corresponding to 254 bytes, i.e. FE in Hex.

3.3.7.2 *Returned table B*

The return table for a remote programming comprises a 16-byte data field corresponding to the random NA1 number generated in the exchange. Any error is notified in the BERREUR field.

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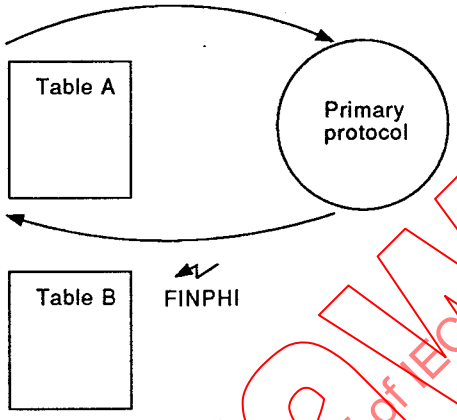
The BNR field contains the value 16 (10H) and the BNECHAU field, the value 12 (0CH).

3.4 *Activation of protocol and concatenation of exchanges*

3.4.1 *Activation*

The protocol of the HHU is activated by an external procedure which awaits return of the FINPHI variable before continuing to run its program.



In order to remove certain ambiguities which might come into play when a protocol is running, the HHU has always the role of the primary station, whatever the service provided may be.

3.4.2 *Remote programming concatenation*

Any remote programming exchange is followed by a remote reading exchange making it possible to check the coherence of the information programmed into the unit addressed and the HHU.

The remotely programmed data should be automatically readable in one or several sequences with the aid of one or several TAB(i).

In order to simplify management of the tables in the HHU when the remote reading and remote programming exchanges are to be carried out over the same bus, the HHU firstly implements all the remote reading exchanges (possibly linked to a forgotten station call procedure, as defined below), then the remote programming exchanges on the unit(s) concerned.

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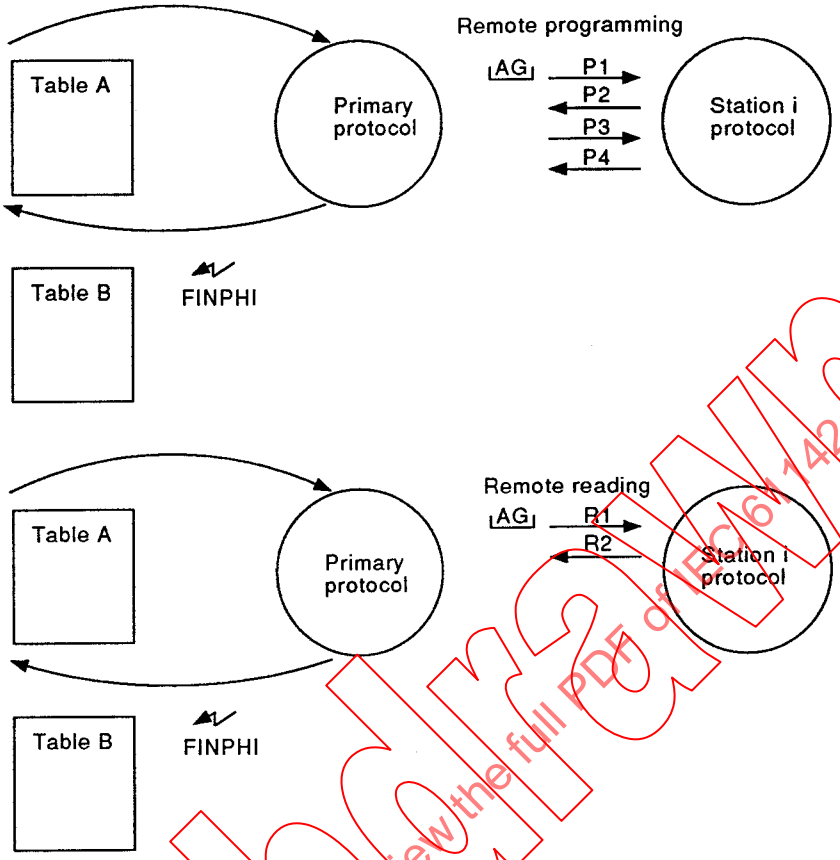

Remote programming concatenation

3.4.3 *Concatenation of all of forgotten stations*

In the case of a forgotten station call, if returned table B includes one or a number of comprehensible addresses in one of the three BFEi window fields, the HHU in the following exchanges will initiate reading of the identified forgotten units. If returned table B includes one or several window fields at FF...FFH, the HHU will renew the forgotten station call in the next exchange.

This concatenation is explained in the flowchart below; the forgotten station call ends when all the forgotten stations have been detected or when the forgotten station call number takes on a value which will be set by the HHU according to the anticipated likelihood of success.

At the end of this concatenation, the HHU will have available all the necessary information concerning the forgotten stations; among other things, it can define whether there are still any forgotten stations after the number of authorized exchanges.

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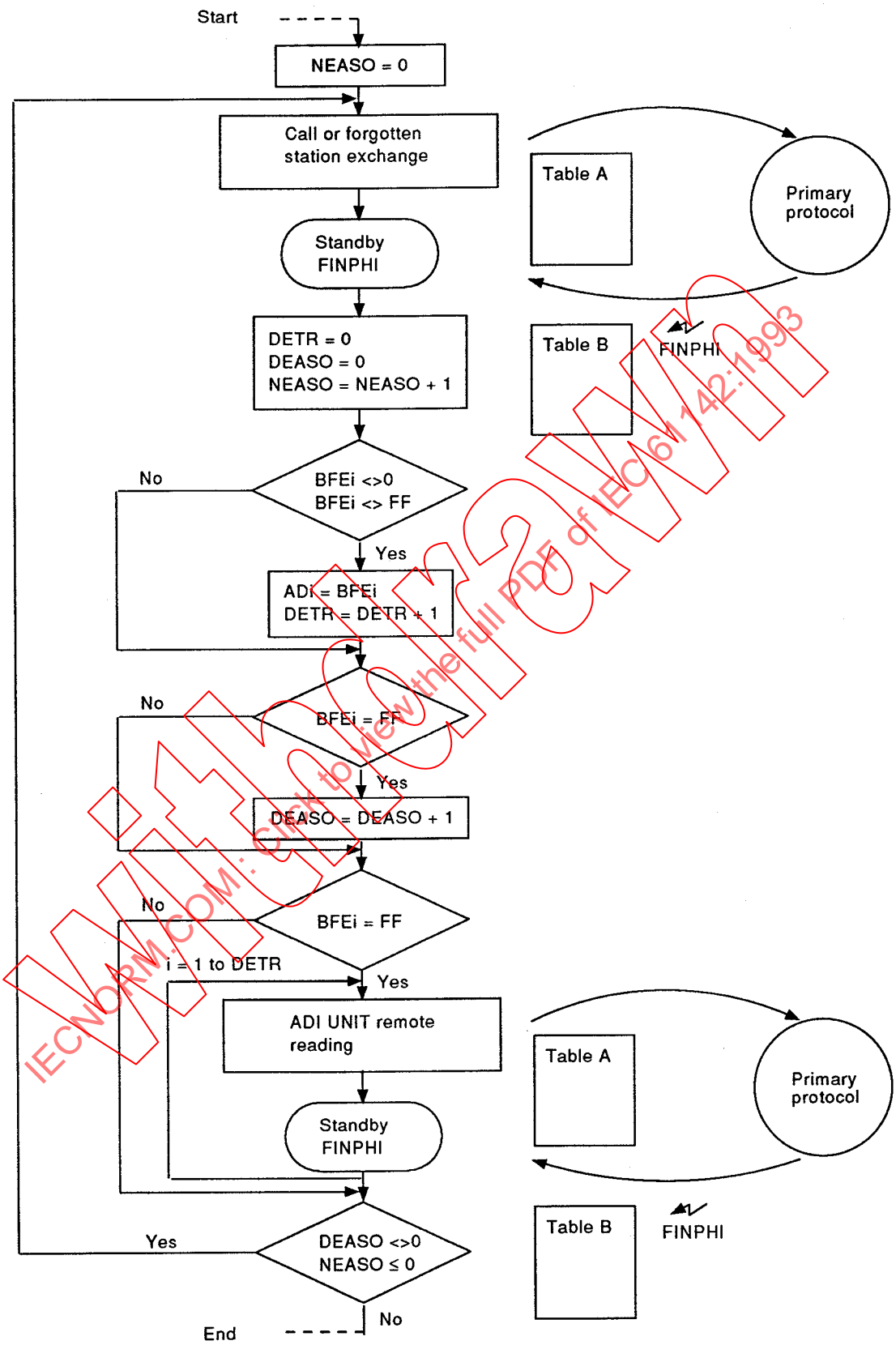
Flowchart of forgotten station call



DETR = Remote reading exchange flag
DEASO = Forgotten station call exchange flag
NEASO = Number of forgotten station call exchanges, set by the HHU.

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3.4.4 *Time separating two exchanges*

Taking account of the functional features of the protocol, a maximum time between two successive exchanges shall be specified in order to ensure that a secondary station's protocol is ended before resuming a new exchange. This time shall be greater than the time left by the secondary station for a possible re-run procedure, hence the minimum time between the end of the primary station's protocol and the start of that for the next exchange: 200 ms.

3.4.5 *Exchange time seen by the external process*

If the master protocol fails in such a way that there is no reply (return of table B and FINPHI flag) for a maximum period of 15 s (corresponding to the maximum TOCO′ transmission time out), the external process should regain the initiative to renew the same operation, i.e. reactivation of the protocol with the same table A.

Before this reactivation, the external process will reinitialize the layers of the protocol.

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3.5 *PHYSICAL layer*

3.5.1 *General*

The basic charts for the send/receive system in the primary station or secondary stations can be found in clause 2.

The PHYSICAL layer is activated by an event outside the initiative of the HHU, starting with a general initialization necessary for all layers of the protocol and an activation of the other layers of the protocol, i.e. DATA LINK, SESSION and APPLICATION.

At the time of an exchange, the primary station takes the initiative by generating a wake up call for a nominal period of 100 ms, details of which are given in clause 2.

The wake up call made, PHYSICAL awaits set-up of the frame by the higher layers according to the various parameters contained in table A; when the first frame to be transmitted over the bus is fully set up, PHYSICAL will receive a synchronization flag from the layer immediately above (DATA LINK) in order to start transmitting the frame in question. At the end of transmission, a 40 ms backoff – TEMPO (temporization) – is activated; this corresponds to the time that a secondary station takes to detect the end of a frame (by means of a TAOM time overflow). This standby is needed for primary/secondary synchronization in the case of forgotten station calls.

From this moment, the secondary station, if it replies, should take action within a shorter time than TA1OM′; the primary station thus goes into reception mode and waits a maximum TA1Om′ to receive the first byte.

Two cases may then occur. Either there is a reply within the allocated time, the primary station then storing the whole frame until a no-byte condition occurs to indicate the end of the frame (TAO′ ≥ TAOM′). Or there is no reply and the primary station then sets a RECNU variable to 1.

A non-reception condition (RECNU = 1) is accompanied by a synchronization transition to the higher layers (PHILI goes to 1) so that they can interpret whether the operation is correct.

After interpretation of the frame received (RECNU = 0), the higher layers will decide, according to the global context (value of variables), either to continue the exchange or to stop it. This end-of-exchange indicates to PHYSICAL that it should close the protocol: DATA LINK, SESSION and APPLICATION are cancelled. The running of the variable FINPHI to 1 indicates to the external process that it can regain the initiative in order to store and if necessary process the information from table B issuing from this exchange.

In the running of PHYSICAL, a specific case is set up by the forgotten station call. The origination of such a frame is followed by possible replies in three clearly defined time-division windows. An IASO variable, processed by the higher layers, is incremented according to the time-division windows in which one is working. A timer counter, activated a TAOM′ after origination of the frame, enables definition of the three time-division windows in tight synchronism with the secondary station emissions.

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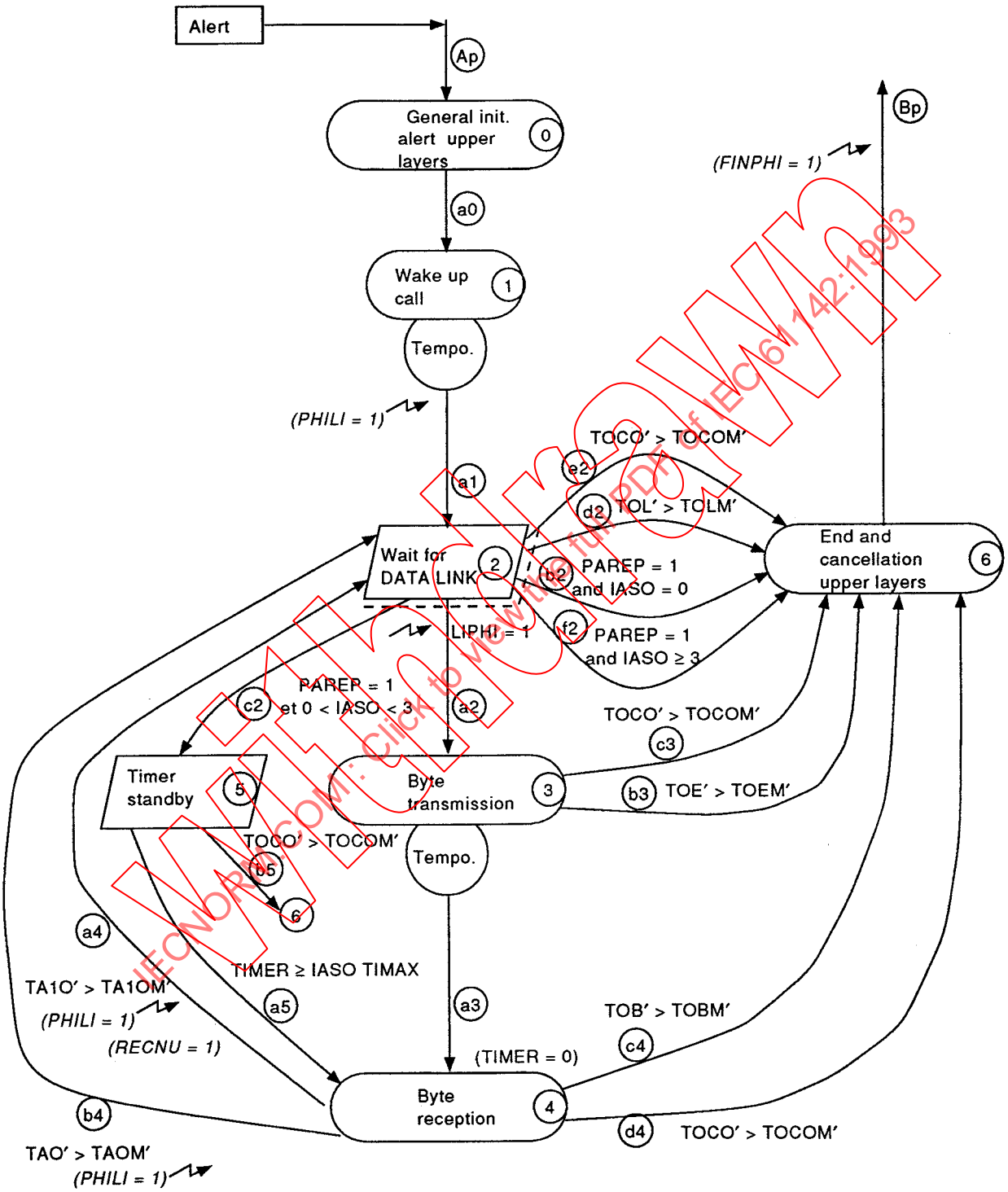
3.5.2 *States in PHYSICAL layer*

3.5.2.1 *State diagram*



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3.5.2.2 *Description of states*

General principles

The execution time for each state is controlled by a time called time out. Each time a state is accessed, its time out is reset and then incremented until this state is excited. Overflow of this time leads to an early exit from the state in question.

In order to control the total time of an exchange, a TOCO′ time counter is incremented as from the end of the wake up call if an overflow occurs during an exchange (TOCO′ > TOCOM′), it produces early exit from the state during which this overflow occurs.

This early exit, in the case of overflow by time out, is linked to the setting of an overflow flag in the BTIMOUT(i,j) field.

The TAXXX′ waiting times are also used for controlling the running of certain states. They do not correspond to time out and cannot replace them.

These different time counters are incremented by a clock whose period will be selected to meet the time measurement criterion defined below. This clock carries out the incrementations in parallel to the action of the PHYSICAL layer.

On initialization, parameters I and J are at 1 and table B is configured in a basic state; table B and parameters I and J are then gradually reset by APPLICATION after each sequence.

Details of this operation are given in the APPLICATION layer.

* *State 0*

General initialization of the protocol. Start communications time out timer TOCO. All variables of all layers and the synchronization flags necessary for management of an exchange are initialized.

The upper layers DATA LINK, SESSION and APPLICATION are put on alert.

* *State 1*

The PHYSICAL layer generates a wake up call (see 2.6.2).

When the wake up call time reaches the nominal value, a 40 ms backoff TEMPO is activated; this enables the secondary stations receiving the wake up call signal to validate this call.

Clause 2 specifies that the wake up call should be followed by the first byte in the frame after a minimum TA1Om of 30 ms. The backoff as regards the secondary station is therefore in keeping with this principle; it is set at a low value in order to minimize the total transmission time.

At the end of this backoff, the PHYSICAL layer, by setting of the PHILI synchronization flag, invites the DATA LINK higher layer to carry out its operation.

* *State 2*

Putting on standby of LIPHI synchronization flag originating from DATA LINK.

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* *State 3*

Sending of bytes: the upper layers formed a buffer or set of buffers for transmission; their location and length are sent to PHYSICAL so that it can carry out transmission of the bytes constituting the buffer(s).

This state is followed by a standby (TEMPO) of 40 ms, necessary for synchronization of the standby windows in case of a forgotten station call.

* *State 4*

Reception of bytes: the PHYSICAL layer puts the modem into reception state and stores the bytes received in a buffer which will be sent to the upper layers for processing.

In the event of a forgotten station call with IASO = 0 set by the APPLICATION layer, the timer counter, having been reset, will be activated; it allows measurement of the duration of the standby windows for the three possible replies.

* *State 5*

Event of a forgotten station call (0 < IASO < 3). This state makes it possible to await synchronization for the determination of the start of the second and third standby windows.

* *State 6*

End of PHYSICAL layer which cancels all the upper DATA LINK, SESSION and APPLICATION layers and sets itself to end of run after signalling to the external process via FINPHI that the protocol is ended.

3.5.2.3 *Description of occurrences*

Ap. Alert and activation of the PHYSICAL process by an external process.

a0. Unconditional transition from state 0 to state 1.

a1. After the wake up call and a 40 ms standby, unconditional transition from state 1 to state 2.

a2. LIPHI = 1 event (return of synchronization from DATA LINK) linked to PAREP = 0 variable. This case occurs when the upper layers want to send a frame: first frame in a new sequence, re-run in case of error on a remote reading or remote programming sequence.

b2. LIPHI = 1 event linked to PAREP = 1 and IASO = 0 variables indicate that there should not be any reply. This case corresponds to a normal bus, remote reading or remote programming initialization exit; or to an exit by error after the re-runs authorized in remote reading or remote programming.

c2. LIPHI 1 event linked to PAREP = 1 variable and IASO equal to value 1 or 2. It concerns a forgotten station call; IASO is incremented by the APPLICATION layers during the period corresponding to each window:
- at the beginning of the first window IASO = 0
- at the beginning of the second window IASO = 1
- at the beginning of the third window IASO = 2.

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d2. Overflow of TOL′ (TOL′ > TOLM′) indicates that the primary station protocol is running abnormally, the protocol should therefore be stopped.

f2. LIPHI = 1 event linked to PAREP = 1 and IASO ≥ 3 variables. This case corresponds to a normal forgotten station call exchange exit after the passing of the three standby windows (reported by IASO).

e2.c3.d4.b5. The transmission time out, initialized after the wake up call, is checked after each state 2, 3, 4 and 5; its overflow brings about the transition in state 6 corresponding to the stopping of the protocol.

a3. Normal exit from state 3 if the TOE′ and TOCO′ times out are not in overflow. A byte transmission is therefore systematically followed by the modem being put into reception mode.

b3. Overflow of TOE′ transmission time out which controls the transition in state 6 corresponding to the stopping of the protocol.

a4. The primary station does not receive any byte, which leads to overflow on the waiting time for the first byte (TA1O′ > TA1OM′). This event is linked to the setting of RECNU to 1 and to the setting of a synchronization flag sent to DATA LINK (PHILI = 1) before transition to state 2.

This event corresponds to a case of no reply from the secondary station; the working of the protocol is therefore erroneous if it involves a remote reading or remote programming exchange, but may correspond to a normal case if it concerns a forgotten station call or a bus initialization.

b4. The event TAO′ > TAOM′ indicates the end of reception of bytes. The synchronization flag is set (PHILI = 1) before transition to state 2.

c4. The overflow of the TOBM′ time out leads to the transition to state 6 corresponding to the end of the protocol.

a5. At the time of a forgotten station call, the three windows are controlled by a timer time; overflow on this timer (timer ≥ TIMAX if it concerns the second window or timer ≥ 2 x TIMAX if it concerns the third, with TIMAX = 500 ms) results in transition to reception state 4 for standby in the next time-division window.

Bp. State 6 is linked to cancelling of the protocol as a whole and the sending of a synchronization flag (FINPHI = 1) for management of the result of the exchange by an external process.

3.5.2.4 *State diagram showing a number of examples*

In these various cases, it is never envisaged that there will be an overflow on a time out.

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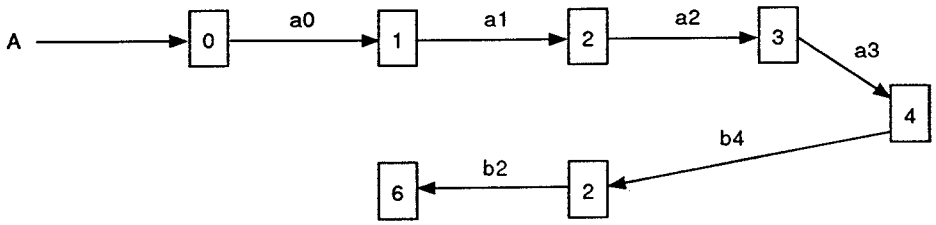
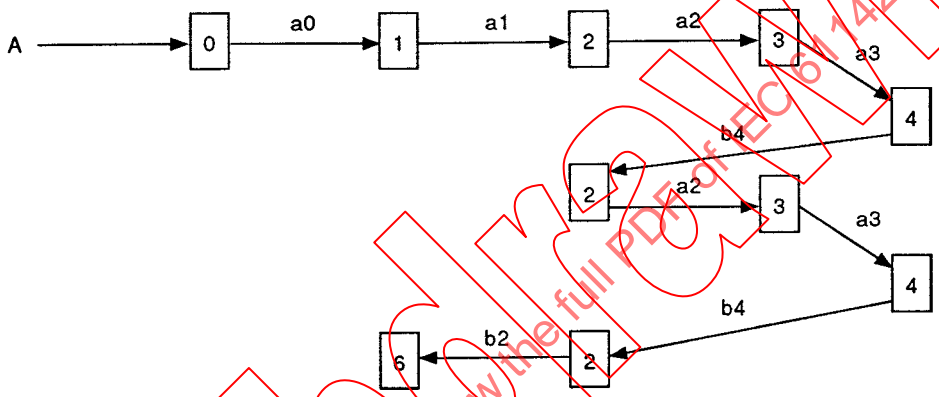
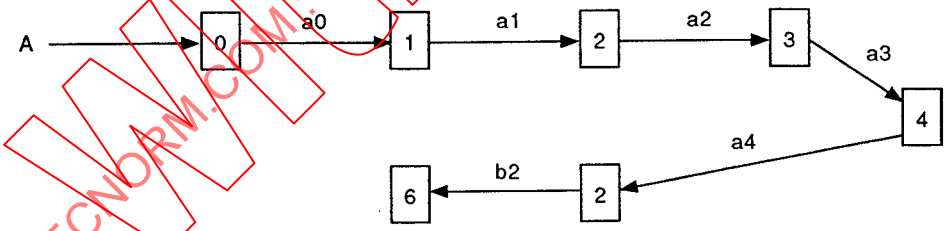
- *Remote reading: nominal case*



- *Remote programming: nominal case*



- *Bus initialization: nominal case*



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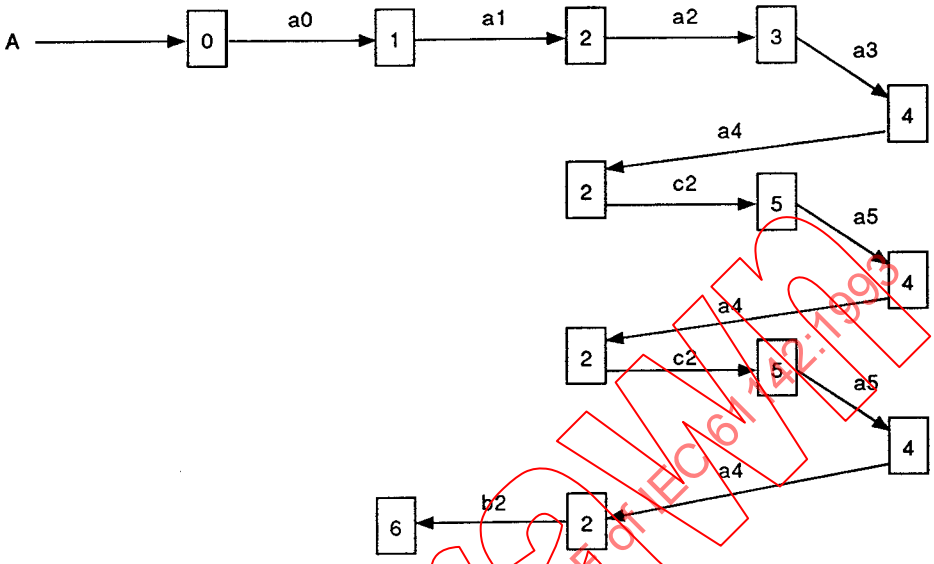
* Forgotten station call: case of reply in second window only



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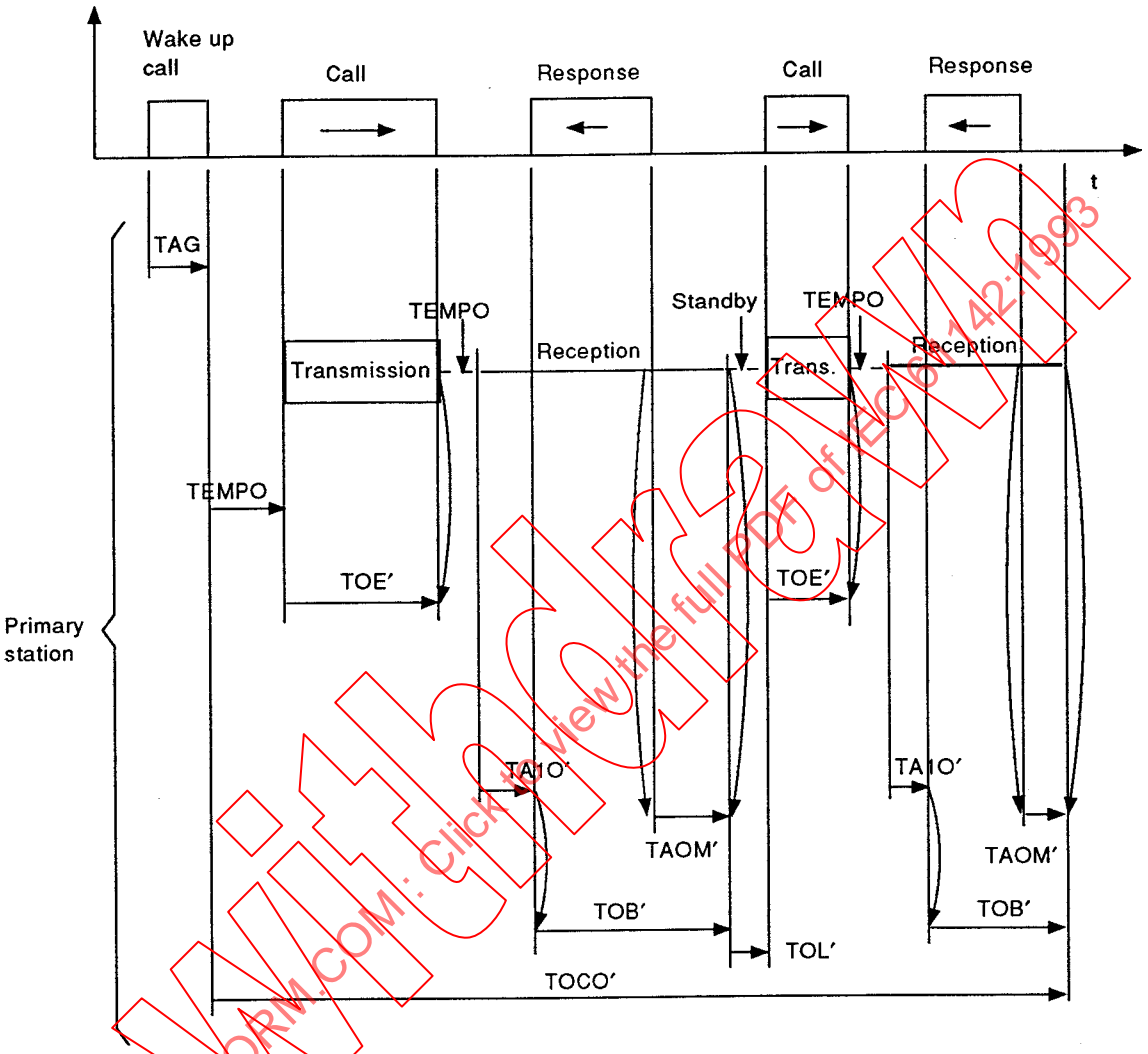
3.5.3 *Time-division charts*

3.5.3.1 *Nominal case* (seen by a primary station)



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TAG′ = 100 ms
TAOM′ = 40 ms
ZA1OM′ = 120 ms
TOLM′ = 100 ms
TOCOM′ = 15 s
TACEOM′ = 30 ms
TOEM′ = $(128 \times 10^4 / 1\,200) + TACEOM' = 1\,100$ ms
TOBM′ = $(127 \times 10^4 / 1\,200) \times (1{,}1)^2 + TAOM' = 1\,360$ ms
TEMPO = 40 ms

Remarks

The time chart should be compared with the one given in clause 2 (nominal case seen by a secondary station). The working of the primary station at the time-division level is just like the working of the secondary station.

The TACEOM′ time, which prevents too great a waiting time between the sending of two bytes, is managed by the transmitter which should verify this criterion, and will never be verified by the receiver.

3.5.3.2 *Other cases – Factors regarding accuracy of times*

The charts in the event of error after reception and forgotten station call are taken from the diagrams in clause 2.

All times are controlled to an accuracy of ± 1 % up to ± 10 ms.

The wake up call time as regards the primary station therefore falls between TAG′m = 90 ms and TAGM′ = 110 ms with respect to an absolute reference.

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3.6 *DATA LINK layer*

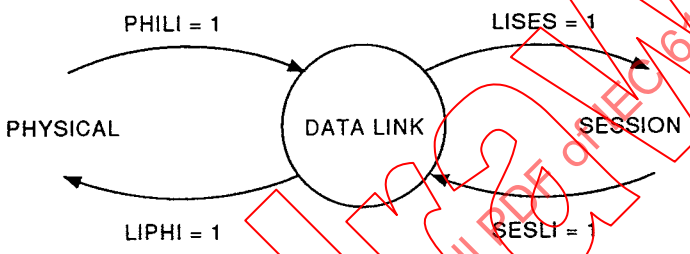
3.6.1 *General*

The DATA LINK layer is alerted by the PHYSICAL layer on activation of the latter. It is then on standby for the synchronization flag (PHILI) from PHYSICAL.

On reception of this flag, it carries out its operation before signalling to the upper layer (SESSION) by means of a synchronization flag LISES that it can begin running its operations.

It then puts itself in wait mode for the return of the synchronization flag from SESSION (SESLI) to carry out its operation before resynchronization PHYSICAL with LIPHI.

This synchronism can be represented as follows:



Disconnection (return on standby from PHYSICAL) can occur over various events which will be described in the state diagram.

The DATA LINK layer is only cancelled by the PHYSICAL layer at the normal end of an exchange or on overflow of one of the times out.

3.6.2 *DATA LINK action fields*

The action of DATA LINK for the primary station is fairly similar to that of DATA LINK for the secondary station (see clause 2).

The syntactic and transmission validity checks include on reception:

- syntactic check of byte N ($N \leq 128$);
- check by CRC 16;
- syntactic and validity checks on the control field (COM);
- syntactic and validity checks on the primary address field (ADP) and secondary address field (ADS);
- correspondence between the primary and secondary ADP and ADS addresses received in the frame with the data contained in table A (AADS and AADP fields). This check involves neither the case of AADS = 0 nor the case of AADP = 0.

On transmission, DATA LINK will receive from the upper layer a buffer corresponding to the data for transmission linked to the control field; it then makes up the full frame sent by PHYSICAL over the bus by inserting the bytes from the ADS and ADP fields which originate from table A and by calculating the number N put as a header and the CRC inserted at the end of a frame.

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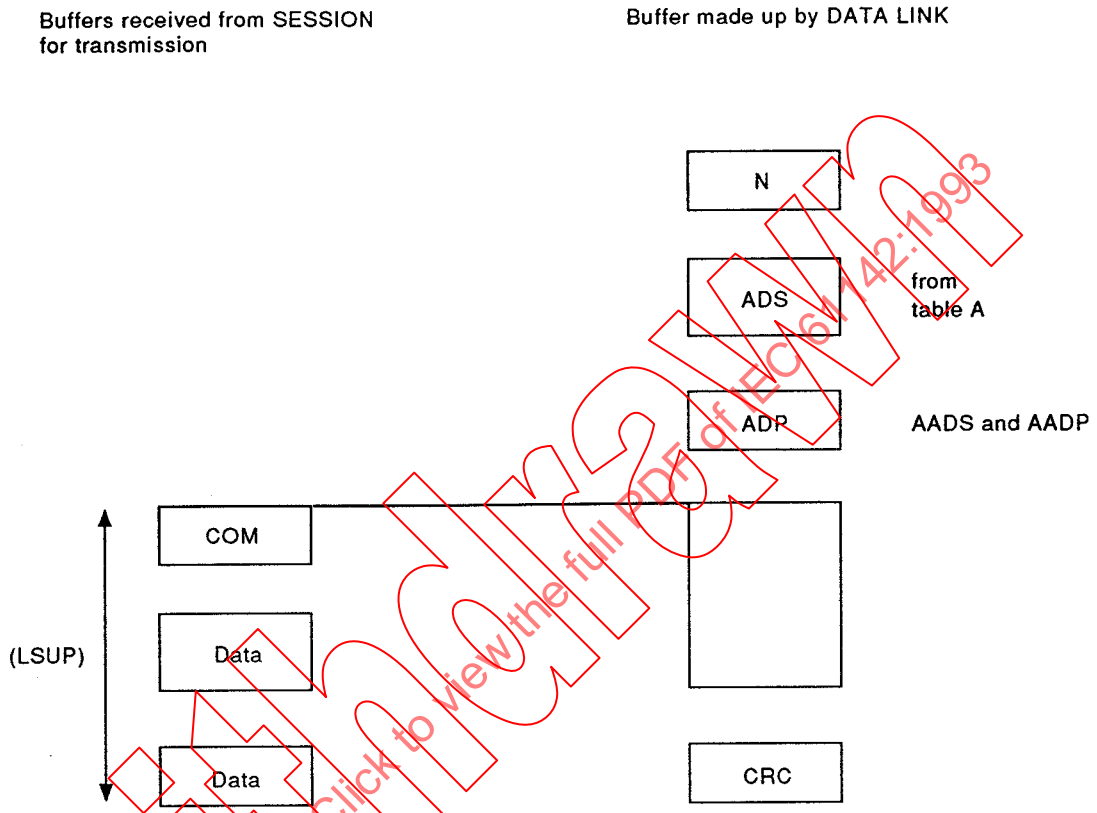
Value of number N

$$N = (LSUP) + L(ADS) + L(ADP) + L(N) + L(CRC)$$
$$6 \quad 1 \quad 1 \quad 2$$

$$N = (LSUP) + 10 \text{ bytes}$$



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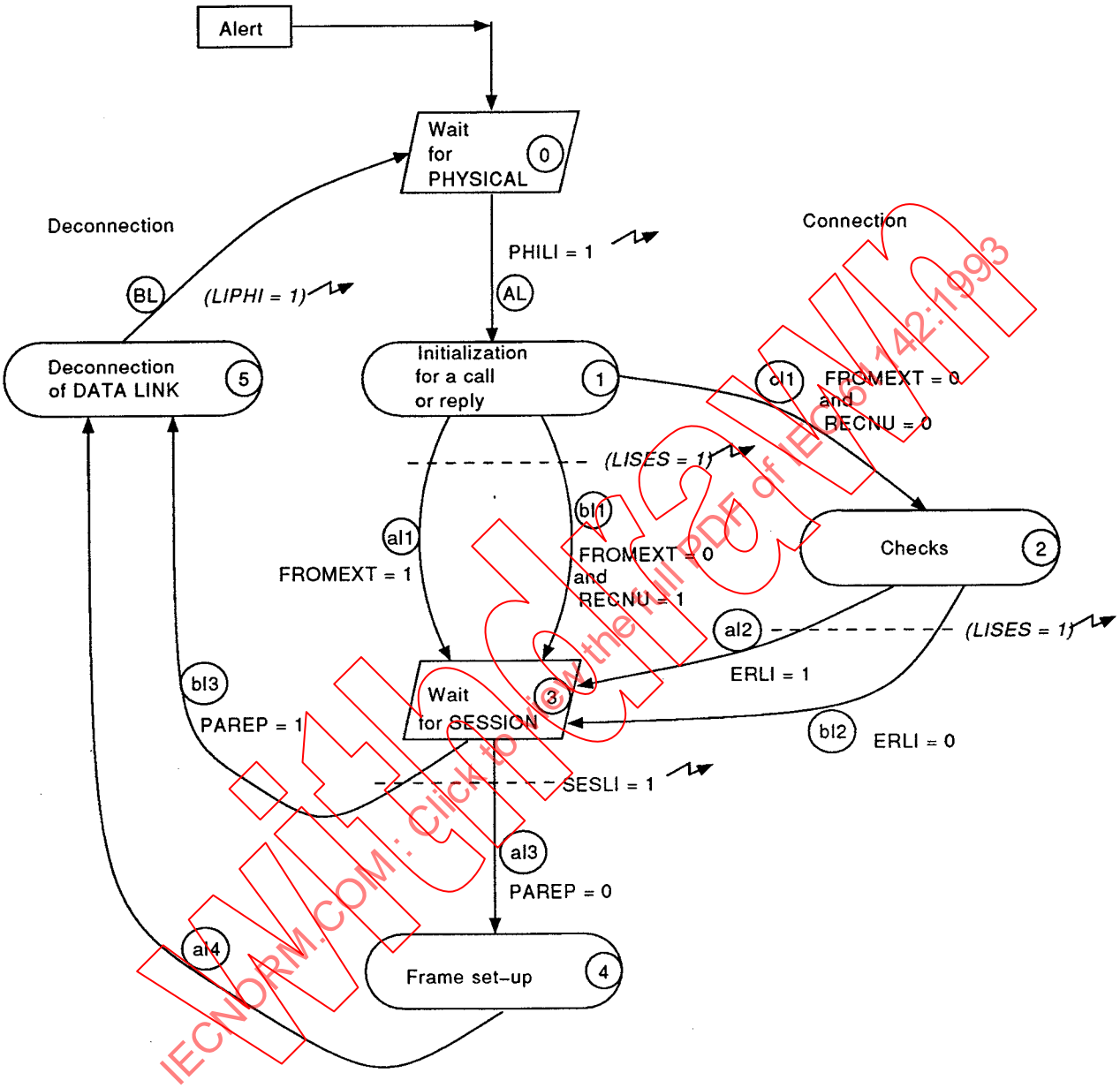
DATA LINK therefore receives from SESSION a buffer or set of buffers flagged by their field start address and their length.

In order to minimize the number of parameters passing between layers, it is possible to transmit just the length and location of a table covering the set of field start and length values.

This factor applies to all levels, including the present case involving the passing of buffers between SESSION and DATA LINK and the passing of buffers between DATA LINK and PHYSICAL.

3.6.3 *States in DATA LINK layer*

3.6.3.1 *State diagram*



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3.6.3.2 *Description of states*

* *State 0*

On being alerted, the DATA LINK layer places itself on standby for the PHYSICAL layer (synchronization flag PHILI = 1), the FROMEXT variable is 1 after the first passage through this state, it is at 0 for subsequent passages (set at 1 in the general initialization of the protocol).

* *State 1*

Call or reply initialization state. It includes the resetting of the variables required for running a sequence (LIPHI, LISES, PAREP and ERLI are reset).

* *State 2*

Syntactic and validity checks on a received frame. Check of ADS field (if ADS ≠ 0) and ADP field (if ADP ≠ 0). The specific operations corresponding to this state are described at the beginning of this clause. An error in one or other of these checks leads to the link error flag (ERLI = 1) being set.

The end of this state is accompanied by the setting of the synchronization flag (LISES = 1).

* *State 3*

Standby for return of synchronization flag SESLI from upper layer (SESSION).

* *State 4*

Set up of the frame by arranging the buffers received from SESSION as specified in 3.6.2.

* *State 5*

Disconnection of DATA LINK and synchronization transition to lower layer PHYSICAL by setting LIPHI.

3.6.3.3 *Description of occurrences*

AL. The setting of the PHILI flag causes DATA LINK to exit from state 0 for transition to state 1.

al1. After initialization, if this is the first time that the DATA LINK system is going into state 1 (FROMEXT = 1) DATA LINK will pass the synchronization flag to the SESSION layer so that the upper layers can prepare the frame for transmission.

bl1-cl1 If this is not the first time that the system is going into state 1, there has already been an initial frame transmitted (FROMEXT = 0).

bl1 If there was no reply as a result of the first transmission (RECNU = 1), the system is set to state 3 so that the upper layers can interpret this result.

cl1 A reply to this first call has been given (RECNU = 0), the system enters state 2 to check the received frame.

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al2. If at least one error appears in the set of checks made in state 2, the system will pass to state 3 with setting of the ERLI variable (ERLI = 1).

b12. If no error is detected in state 2, the system will pass to state 3 without setting the ERLI variable.

a13.-b13. Setting of the SESLI synchronization flag leads to exit from the SESSION wait state (state 3).

al3 Setting SESLI with PAREP = 0 indicates that transmission frame is required. The system enters state 4.

bl3 Setting SESLI with PAREP = 1 indicates no frame required. The system enters state 5.

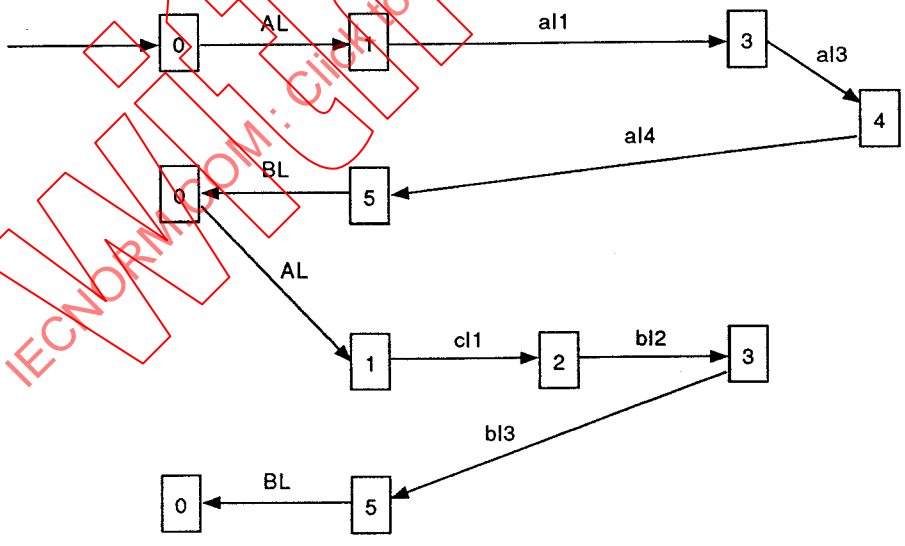
a14. When a frame has been made up, the system will unconditionally pass to state 5.

BL. Disconnection of DATA LINK is linked to PHYSICAL's transition to wait state 0 after setting of the LIPHI flag to enable synchronization of the PHYSICAL layer.

3.6.3.4 *State diagram showing a number of examples*

In these various cases, it is never envisaged that there will be an overflow by a time out in the PHYSICAL layer.

- Remote reading: nominal case



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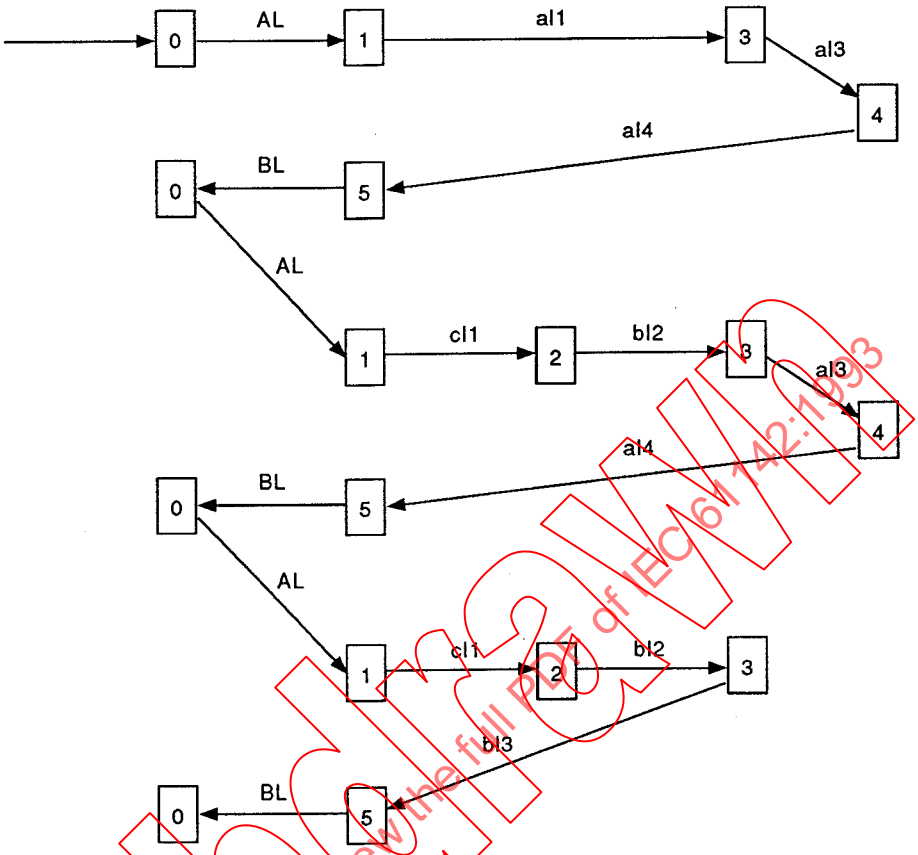
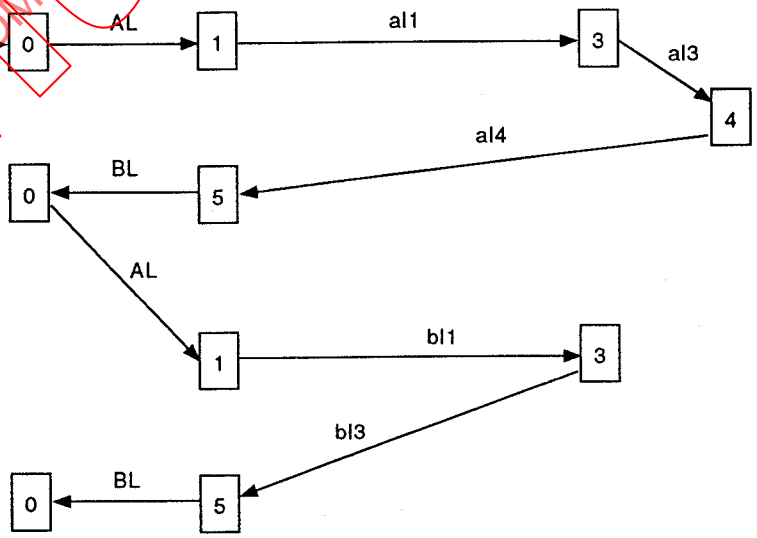
- Remote programming: nominal case



- Bus initialization: nominal case



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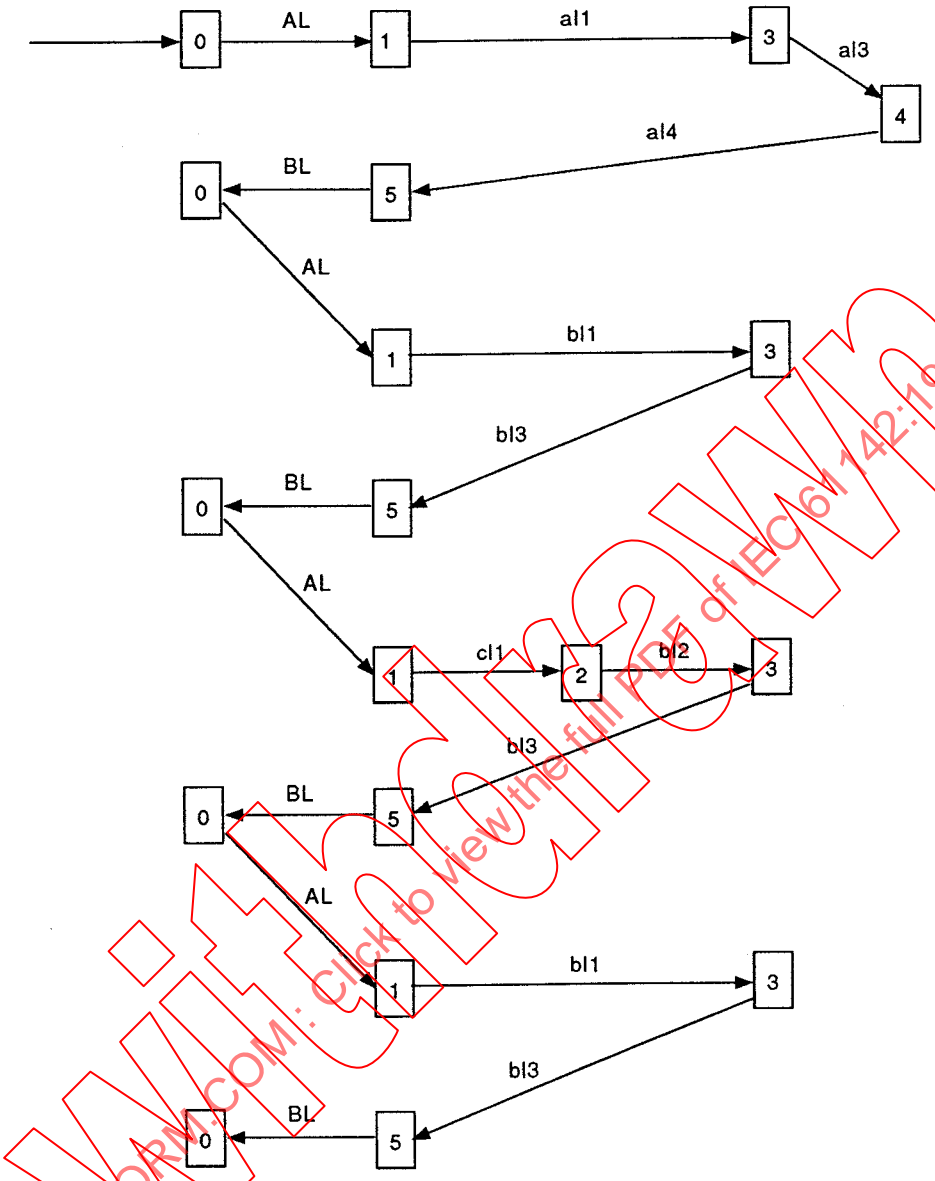
* Forgotten station call: one reply in second window only



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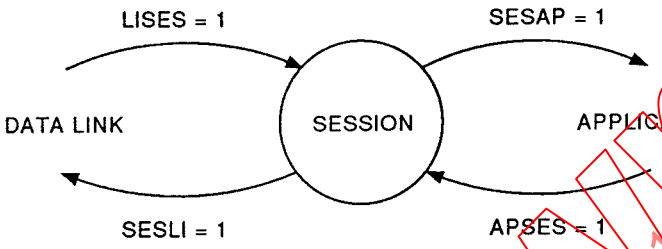
3.7 *SESSION layer*

3.7.1 *General*

The SESSION layer is alerted by the PHYSICAL layer at the start of the protocol. It is then on standby for the synchronization flag (LISES) from DATA LINK.

The synchronism of SESSION with the adjacent layers is represented as follows:



The SESSION layer is cancelled by the PHYSICAL layer only at the end of a normal exchange or on overflow of one of the times out.

SESSION's main function is to control and manage the concatenation of the commands in the successive frames.

On an initial sequence (FROMEXT = 1), the primary station prepares the first command to be sent over the bus according to the content of the ATYPE field in table A placed at the disposal of the external process.

Flags are set depending upon the command received (see 3.7.2) to communicate the required service to the APPLICATION layer.

The APPLICATION layer is then prompted to supply a possible data buffer which is increased by SESSION from the command field prepared earlier, before being submitted to the lower layers for transmission over the bus.

After this call, according to the type of action and protocol sequence, a reply frame is awaited from the secondary stations (case of remote reading, remote programming, reply in a forgotten station call window) and is interpreted. SESSION then verifies the succession without error of the commands for a correct concatenation of the frames and prepares a possible command for a subsequent sequence.

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Command concatenation table seen by a primary station

	Call	Reply
Remote reading	ENQ	DAT or DRJ
Remote programming	REC AUT	ECH EOS or ARJ or DRJ
Bus initialization	IB	/
Forgotten station call	ASO	RSO

If one of the reply frames does not reach the primary station, or arrives wrongly, a re-run procedure is implemented on the faulty sequence, except in the case of an ASO frame.

3.7.2 *Possible cases for the interpretation of commands*

An APREC (previous call) variable, making it possible to determine whether an initial sequence is involved, is needed for this interpretation. Four other flags make it possible to know the type of sequence made at the time of the previous call:

DTR = Remote reading flag

DTP = Remote programming flag

DASO = Forgotten station call flag

DIB = Bus initialization flag

These flags are set at the time of preparing the first command for the first frame of an exchange (see state 2 of the state diagram).

APREC is set to1 if DIB = 1 or DASO = 1 or DTP = 1 or DTR = 1.

A DNA variable is linked to the non-acknowledgment frames possibly received:

DNA = Non-acknowledgment flag indicating that a frame including the command DRJ (DNA = 1) or ARJ (DNA = 2) has been received.

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Algorithm of state 3

* *If* APREC = 0 (case of a first sequence)

Then APREC = 1

If COM = DAT (case of remote reading)

Then

if DTR = 1 (concatenation OK)

if DTR = 0 *then* ERSES = 1

If COM = DRJ (case of remote reading, identifying unknown TAB data)

Then

if DTR = 1 *then* DNA = 1

if DTR = 0 *then* ERSES = 1

if COM = ECH

Then

if DTP = 1 *then* COM = AUT (case of remote reading) (preparation COM 2nd sequence)

if DTP = 0 *then* ERSES = 1

If COM = RSO

Then

if DASO = 1 *then* CASO = 3 (case of forgotten station call; comprehensible reply)

APREC = 0

if DASO = 0 *then* ERSES = 1

if COM ≠ RSO

Then

if DASO = 1 *then* CASO = 2

ERSES = 1

APREC = 0

If COM ≠ DAT and COM ≠ ECH and COM ≠ RSO and COM ≠ DRJ

Then

ERSES = 1 (error in concatenation of commands other than in the above four instances).

* *If* APREC = 1 (case of a second sequence)

Then

If COM = DAT (case of a re-run in remote reading or call from another TAB table)

Then

if DTR = 1

then Nothing (concatenation correct)

if DTR = 0

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then ERSES = 1 (concatenation incorrect)

If COM = DRJ

Then

if DTR = 1 (case of a re-run in remote reading of call from unknown TAB)

then DNA = 1 (indication of unknown TAB)

if DTP = 1 and AR = 1 (case of refused programming data)

then DNA = 1 (indication of rejected data)

otherwise ERSES = 1 (concatenation incorrect)

If COM = ECH (case of a re-run in remote programming on the first sequence)

Then

if DTP = 1 and AR = 0

Then

if (DTR = 0 AND DASO = 0)

then COM = AUT (preparation command next sequence)

otherwise ERSES = 1 (concatenation incorrect)

if DTP = 0 or AR = 1

then ERSES = 1 (concatenation incorrect)

If COM = EOS (case of a re-run in remote programming on second sequence)

Then

if DTP = 1 and AR = 1

then Nothing

if DTP = 0 or AR = 0

then ERSES = 1 (concatenation incorrect)

If COM = ARJ (rejected authentication)

Then

if DTP = 1 and AR = 1

then DNA = 2 (indication rejected authentication)

if DTP = 0 or AR = 0

then ERSES = 1

If COM ≠ DAT and COM ≠ ECH and COM ≠ RSO and COM ≠ DRJ and COM ≠ ARJ and COM ≠ EOS

Then

ERSES = 1 (error in concatenation of commands other than in the above three instances)

NOTE - The protocol will never initiate any re-run procedure on a forgotten station call, no matter what the reply.

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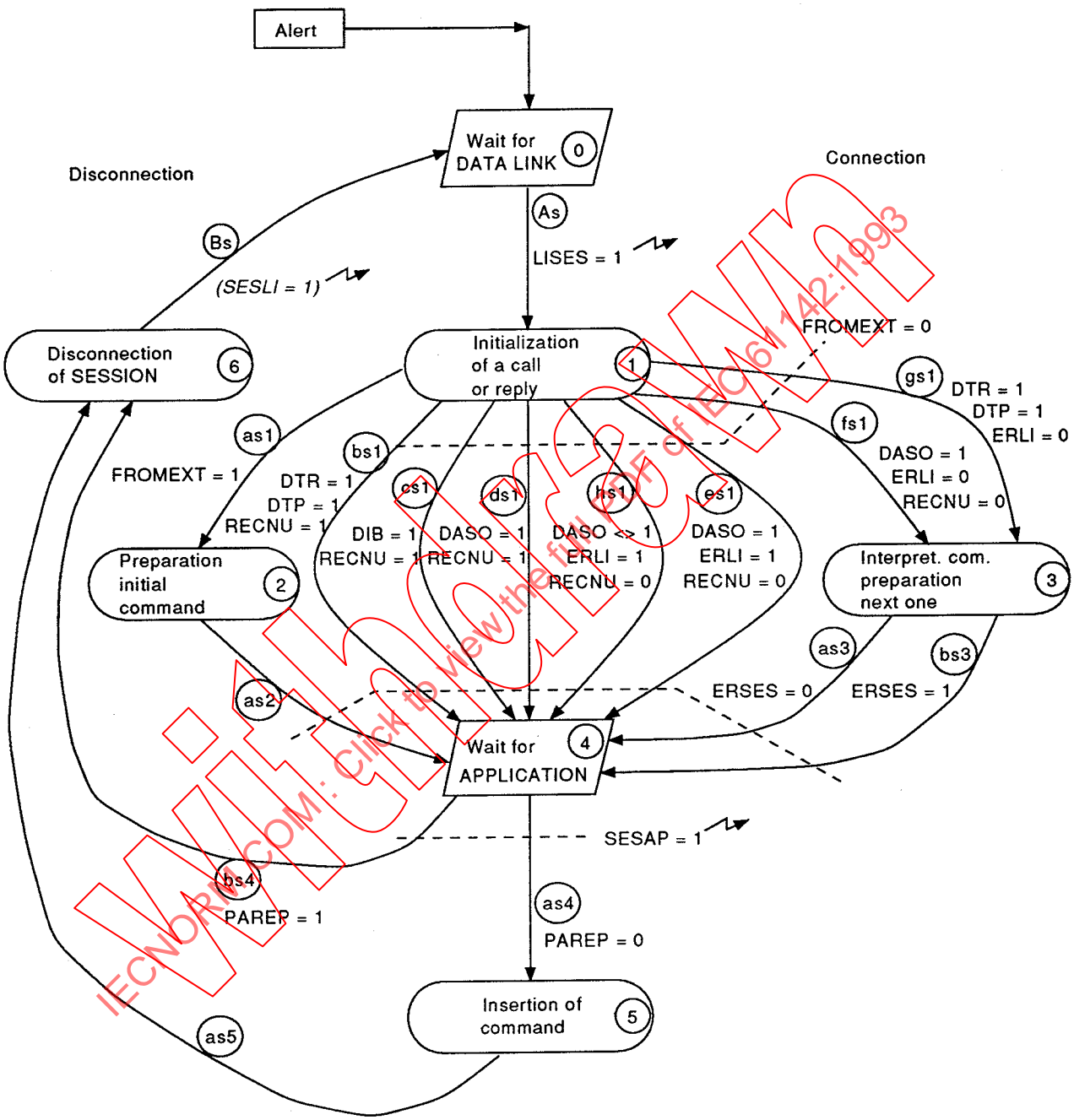
3.7.3 *States in SESSION layer*

3.7.3.1 *State diagram*



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3.7.3.2 *Description of states*

* *State 0*

Wait for synchronization flag LISES from lower layer DATA LINK.

* *State 1*

Initialization of a call or reply.

In this state, SESSION begins by defining two cases: if this is the first time that SESSION is connected at the time of an exchange (FROMEXT = 1), it shall prepare the initial command (transition to state 2)). If this is not the first time (FROMEXT = 0), flags DIB, DASO, DTR, DTP, RECNU AND ERLI shall be examined in order to decide which transition to carry out.

* *State 2*

Preparation of initial command.

SESSION will prepare the command byte for insertion into the first frame according to the content of the ATYPE field in table A. The flags (DTR, DTR, DIB, DASO) are set according to the initial command.

* *State 3*

Interpretation of the command and preparation of the next command in accordance with the algorithm shown earlier.

* *State 4*

Wait for return of synchronization from APPLICATION (APSES).

* *State 5*

Insertion of the command, prepared during states 2 and 3, into the buffer on return from APPLICATION. This command is modified if DTP = 1 and AR = 0 and COM = AUT and becomes COM = REC.

* *State 6*

Disconnection of SESSION accompanied by transition of synchronization to lower layer (SESLI = 1).

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3.7.3.3 *Description of occurrences*

As. reception of the synchronization flag LISES makes it possible to pass from DATA LINK wait state 0 to initialization state 1.

as1. This is the first time that SESSION has been connected during the exchange (FROMEXT = 1); this event causes the system to go into state 2 – preparation of initial command.

bs1. Case where FROMEXT = 0 and the exchange corresponds to a remote reading or a remote programming (DTR = 1 or DTP = 1) not linked to any reception on the sequence in question (RECNU = 1), a case of error is involved, and a re-run

procedure is then to be considered. This case of error is therefore linked to the setting of ERSES.

cs1. Case where FROMEXT = 0 and the bus initialization flag is set (DIB = 1). If, in addition, RECNU = 1 (non-reception), this is a case of normal bus initialization for which no reply should occur. ERSES remains at 0.

ds1. Case where FROMEXT = 0 and the forgotten station call flag is set (DASO = 1). If, in addition, there is non-reception (RECNU = 1), this involves a standby window where no secondary station has replied. There is therefore no need to interpret any command received, the system therefore goes into state 4 by setting the CASO = 0 variable. ERSES remains at 0.

es1. Case where FROMEXT = 0 and the forgotten station call flag is set (DASO = 1). If, in addition, there is an erroneous reply (RECNU = 0 and ERLI = 1), this involves a reply from a secondary station (with transmission error) or several secondary stations in the relevant standby window. As this reply is not comprehensible, the system will pass directly to state 4 by setting the CASO = 1 variable.

fs1. Case where FROMEXT = 0 and the forgotten station call flag is set to 1 (DASO = 1). If, in addition, there has been a comprehensible reply and no transmission error (RECNU = 0 and ERLI = 0), this involves a reply from a secondary station in the relevant standby window. The system then passes to state 3.

gs1. Case where FROMEXT = 0 and the DTR = 1 or DTP = 1 flags are linked to ERLI = 0; this involves non-erroneous return within a remote reading or a remote programming sequence.

hs1. Case where FROMEXT = 0 and ERLI = 1 and RECNU = 0 and DASO ≠ 1. This frame is incorrect and SESSION cannot interpret it. The system passes directly to state 4 on standby for APPLICATION.

as3. If there is no error in interpretation of the command, ERSES is not set.

bs3. If there is an error in interpretation of the command (concatenation error), ERSES is set.

as4. Return of synchronization coming from APPLICATION (APSES = 1), linked to the PAREP variable at 0 indicating that a new sequence is to be carried out.

bs4. Return of synchronization coming from APPLICATION (APSES = 1), linked to the PAREP variable at 1 indicating that a new sequence is not to be carried out. The system thus goes into disconnection (state 6).

as5. Unconditional transition of state 5 to state 6.

Bs. Disconnection of SESSION linked to the transition of the synchronization flag (SESLI = 1) to the lower layer DATA LINK.

NOTE - The CASO variable makes it possible to interpret the result of a forgotten station call for one of the standby windows.

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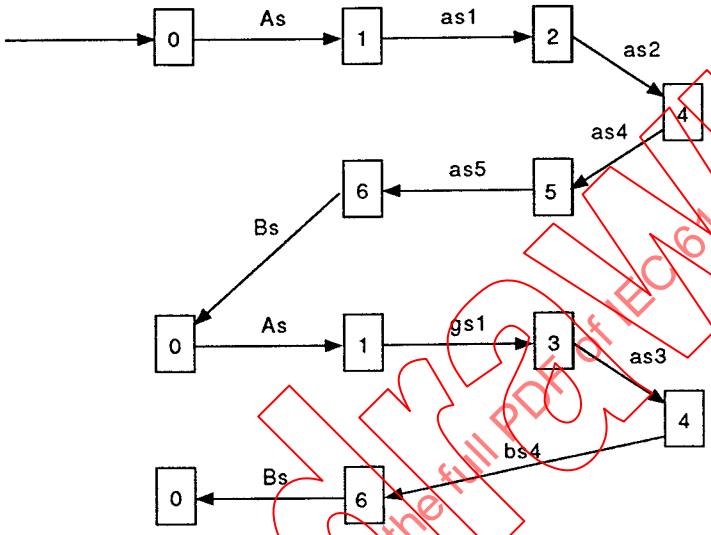
- CASO = 0: No reply in the window concerned (ds1).
- CASO = 1: Reply with DATA LINK error (es1).
- CASO = 2: Reply without DATA LINK error, but an error in SESSION (fs1 – bs3).
- CASO = 3: Reply without DATA LINK, SESSION error (fs1 – as3).

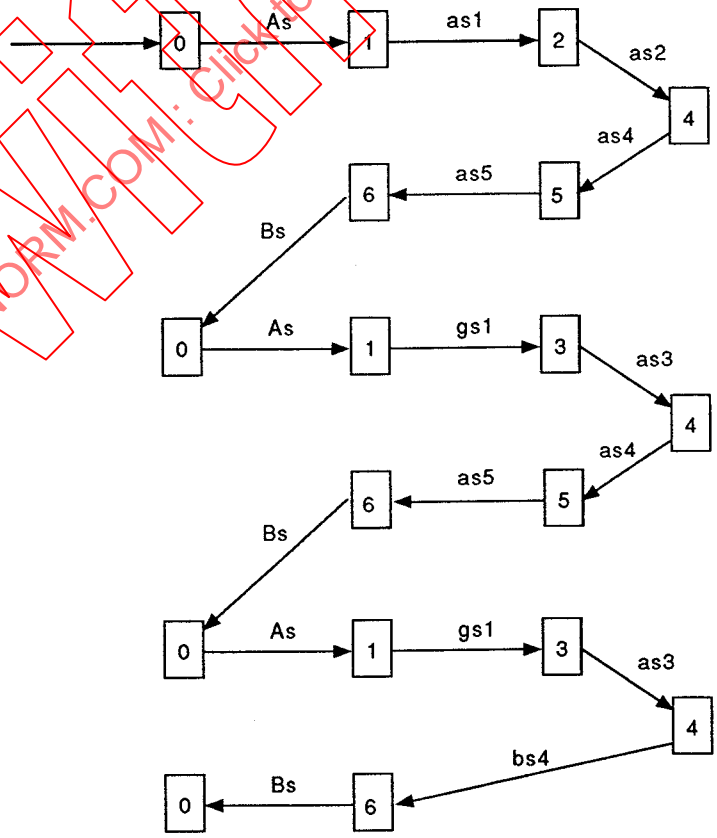
The value taken by CASO then enables APPLICATION to set up the relevant table B field (BFEi field).

3.7.3.4 *State diagram showing a number of examples*

- Remote reading: nominal case



- Remote programming: nominal case – Reply in second window



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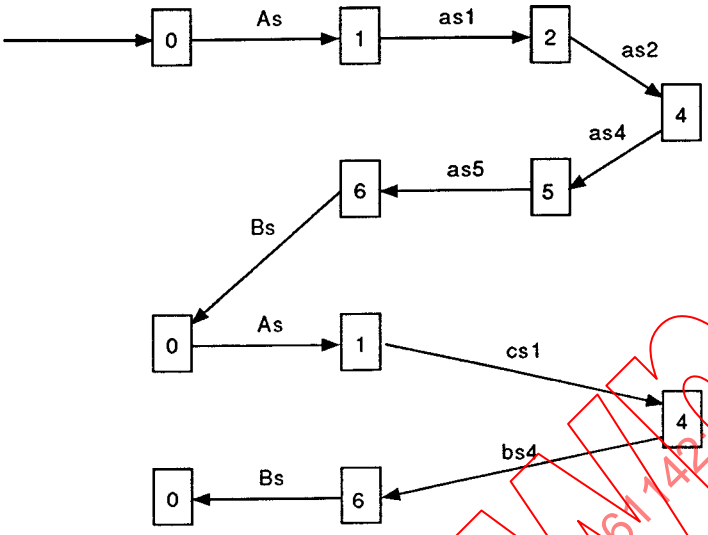
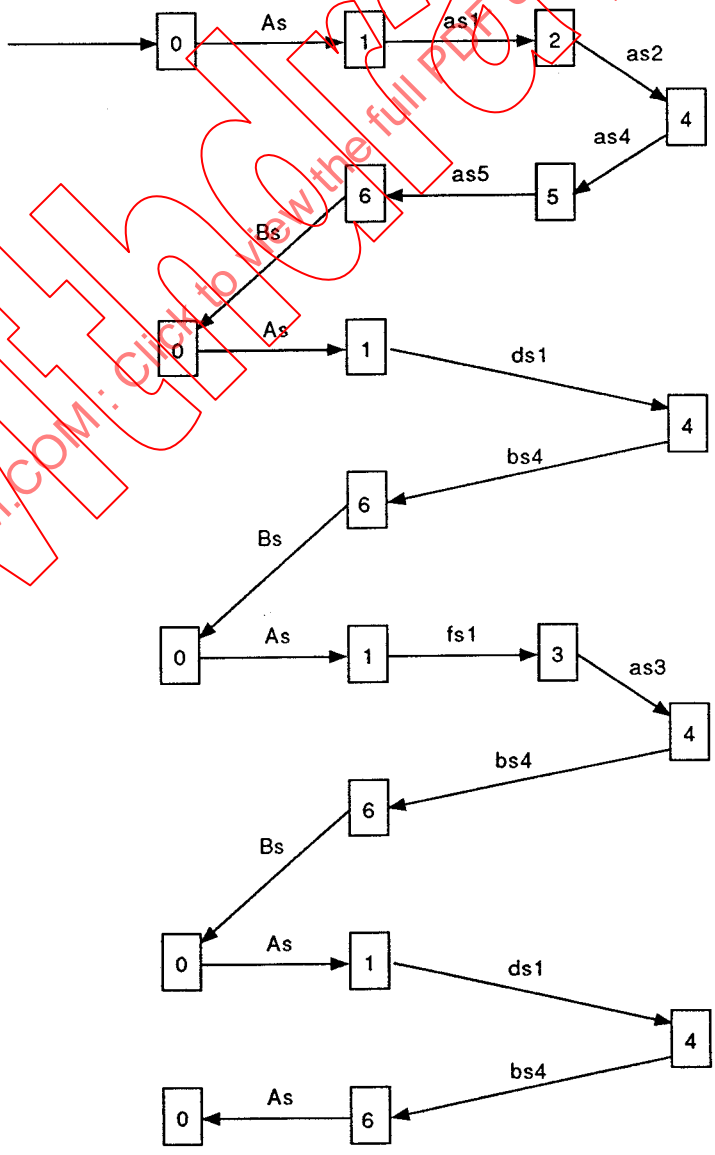
- Bus initialization: nominal case



- Forgotten station call: nominal case – Reply in the second window



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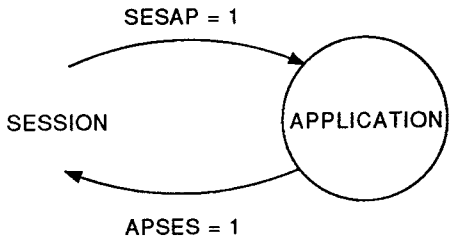
3.8 *APPLICATION layer*

3.8.1 *General*

The APPLICATION layer is alerted by the PHYSICAL layer at the start of the protocol. It then awaits the synchronization flag from SESSION (SESAP) to begin its operation.

Synchronism of the APPLICATION layer with the adjacent SESSION layer is represented as follows:



It is cancelled by the PHYSICAL layer only at the end of the protocol.

3.8.2 *Operations linked to APPLICATION*

The APPLICATION layer is responsible for management of the data field within the frames as a whole. In the origination phase, it fills this field depending on the type of exchange and sequence in progress; on reception, it interprets and processes this field.

According to the four possible types of exchange, table A resulting from the external process contains the necessary data for management of the data field of each frame.

For a forgotten station call, the first frame transmitted over the bus comprises one or several TAB(i) bytes in data field; they come from table A's ATAB(i) content and are inserted by APPLICATION.

For a remote reading exchange, the frames transmitted over the bus by the primary station include a TAB byte in data field; this comes from table A (ATAB). The number of sequences to be carried out in order to read all the data corresponding to the different TAB(i) is contained in table A's ANA field.

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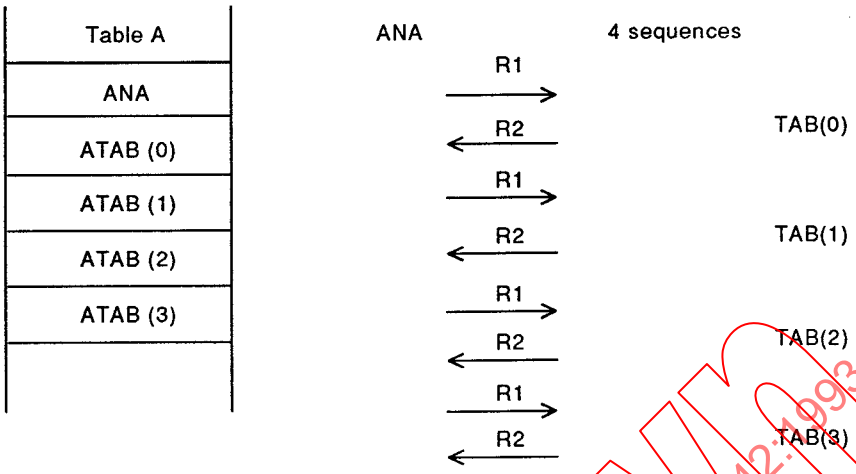
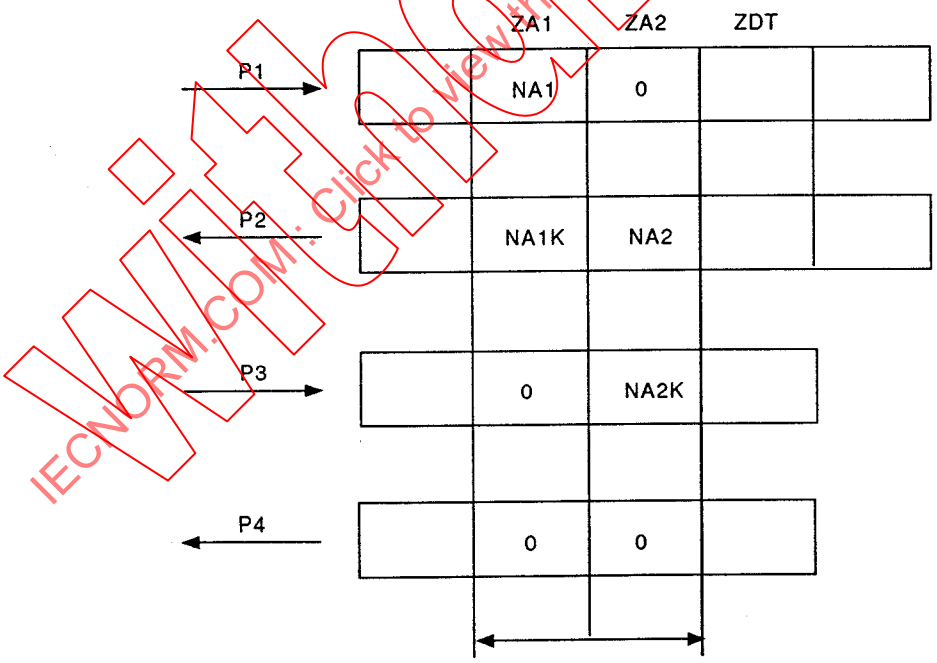


Example of remote reading in four sequences

In remote programming, the data sent to the relevant secondary station come from table A. In this type of exchange, an authentication procedure by encryption of random numbers with the aid of the K key (from table A) is implemented; this operation is explained in clause 2.



Field in frame processed by APPLICATION

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Annex D indicates the generation principle of the random number (NA1 for the primary station).

On initialization, the first random number in the string thus generated is obtained by a combination of the key and the remote programming data, linked to the coefficients of the generator polynomial R1 in accordance with the formula:

$$NA\ (1) = f\ ((K + (TP\ data)),\ R1)$$

The following random numbers are generated in the same way by replacing the K key by the preceding random number

$$NA\ (i) = f\ ((NA_{i-1}) + (TP\ data)),\ R1)$$

K:	64 bits
R1:	64 bits
TP Data:	64 bits
NA(i):	64 bits

The TP data come from the ADTP field, each byte being truncated so as to lose the least significant 4-bit byte, to a limit of 64 bits, or 16 bytes from the ADTP field. In the event of the ADTP field being less than 16 bytes, this field is wrapped round on itself until obtaining these 64 bits.

The APPLICATION layer also makes up table B on return to the external process.

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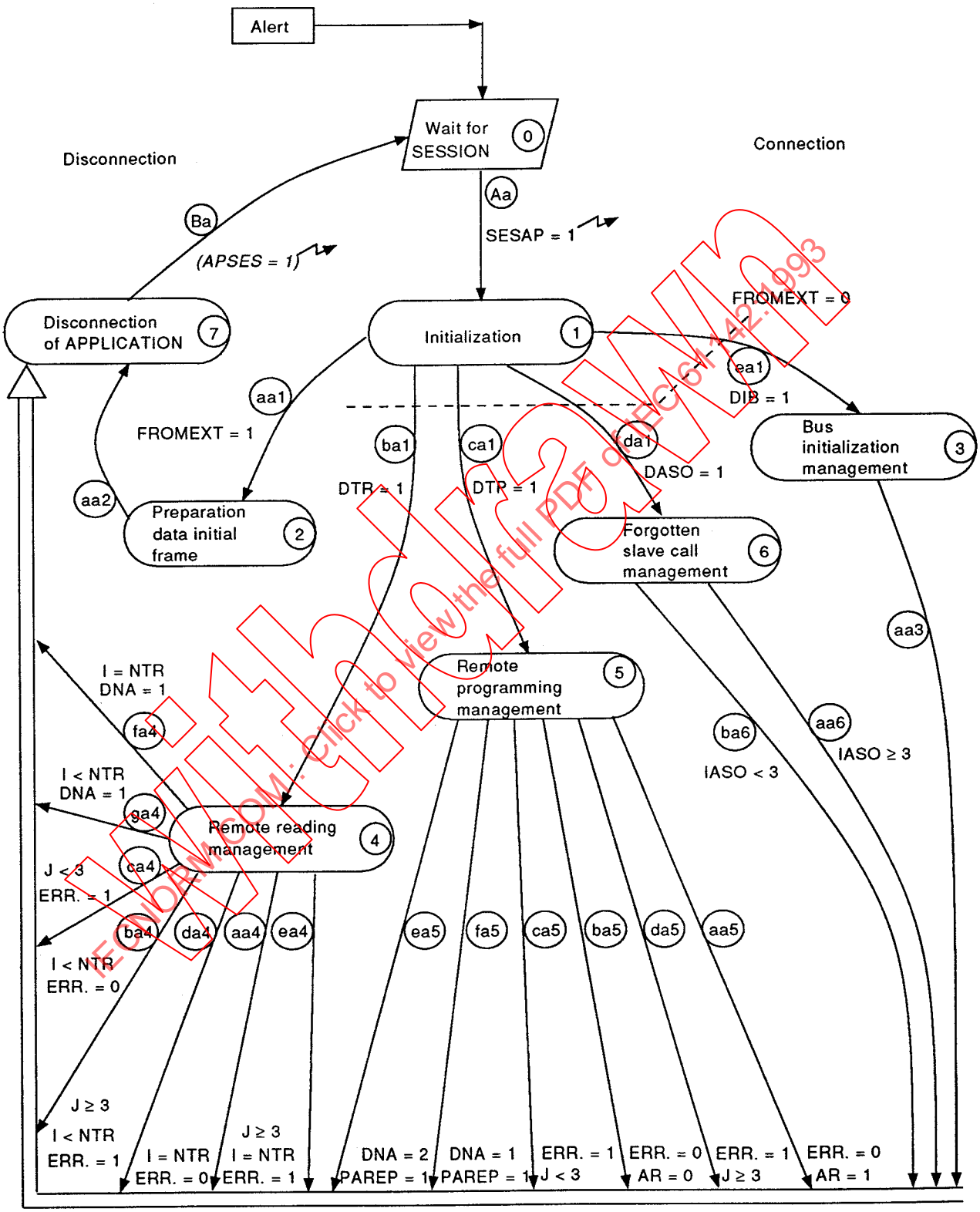
3.8.3 *States in APPLICATION layer*

3.8.3.1 *State diagram*



ERR. = ERROR

ERROR = 1 if (ERLI = 1 or ERSES = 1 or ERAP = 1)
ERROR = 0 if (ERLI = ERSES = ERAP = 0)

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3.8.3.2 *Description of states*

* *State 0*

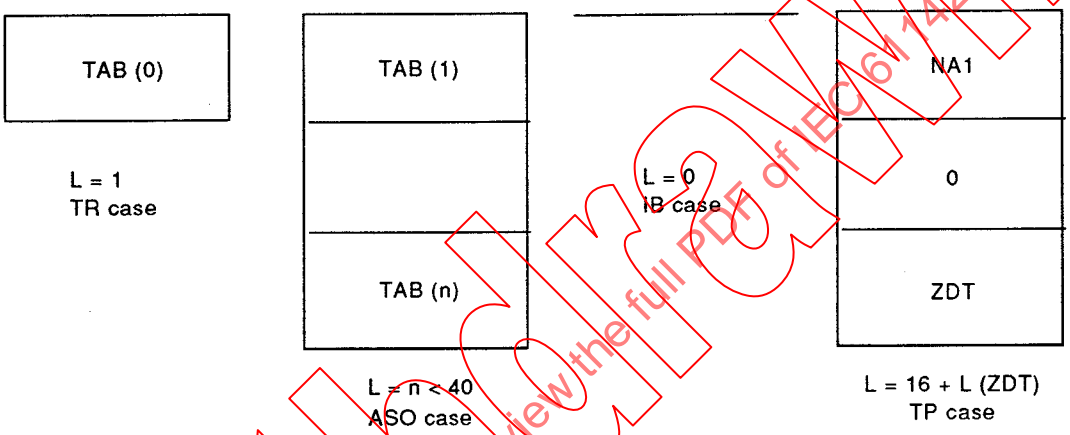
Standby for synchronization flag SESAP from lower layer SESSION.

* *State 1*

Initialization of variables necessary for management of the APPLICATION layer (resetting of APSES, ERAP).

* *State 2*

Set-up of the first frame comprising preparation of a buffer with application bytes and length L, according to the type of operation desired (hence DTR, DTP, DASO or DIB flags).



The data comes from table A sent to the protocol, the NA1 number in remote programming is obtained after computation between the preceding random number (contained in table A) and the data bytes linked to a generator polynomial (see previous pages and annex D).

This state also includes resetting of the FROMEXT variable.

* *State 3*

Management in the event of bus initialization with preparation of table B for sending to the external process (see description of table B content below).

At the end of this state, the PAREP variable is set, indicating the end of an exchange to the lower layers.

* *State 4*

Management in case of remote reading. The number of different sequences requested for this reading (NTR) is determined from the content of table A's ANA field.

So as to determine whether the exchange should continue in order to read other data, each transition in this state increments an I variable which is checked in relation to the number of NTR sequences requested.

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A variable J is incremented to check the number of re-runs for an identical sequence.

The PAREP variable (indicating the end of an exchange) is set when 1 = NTR and:

– DNA = 0 and ERAP = 0 and ERSES = 0 and ERLI = 0 and J < 3;

– DNA = 1 and ERAP = 0 and ERSES = 0 and ERLI = 0 and J < 3;

– DNA = 0 and (ERAP = 1 (TAB field of return frame R2 does not correspond to the TAB field in the outward bound frame R1) or ERSES = 1 or ERLI = 1) and J > 3.

A retransmission (identical sequence) is generated if DNA = 0 and J > 3 and (ERAP = 1 or ERSES = 1 or ERLI = 1).

A different sequence is generated if 1 < NTR and:

– ERAP = 0 and ERSES = 0 and ERLI = 0 or

– ERAP = 1 or ERSES = 1 or ERLI = 1 and J ≥ 3.

On each transition into this state, table B is reset according to the result of the sequence in progress.

* *State 5*

Management in case of remote programming.

- On the first sequence (variable I = 1):

If there is no SESSION or DATA LINK error (ERLI = ERSES = 0), the APPLICATION will proceed to decryption of NA1K. This decryption operation makes it possible to obtain a value NA1′ which is compared with the random number NA1 previously transmitted over frame P1; if the result is incorrect, the ERAP variable (APPLICATION error) is set, there is no retransmission PAREP = 1.

Similarly, the echoed data (in P2 ZDT field) are checked in relation to the data transmitted (in P1 ZDT field), if this check is erroneous, ERAP is set and a retransmission is authorized (PAREP = 0).

If no problem is detected on this first sequence (P1, P2), characterized by ERLI = 0 and ERSES = 0 and ERAP = 0, the system will prepare for the next sequence (P3, P4) by incrementing the I variable (I = 2); it also encrypts the content of the ZA2 field received in P2 in order to make up the P3 ZA2 field (Number NA2), so that the NA2K result is sent back over P3.

If a problem other than NA1′ ≠ NA1 occurs on the sequence (P1, P2), and if the number of three identical calls is not reached, the system will prepare to begin the same call again; it increments the J variable. If the three calls on this sequence are still erroneous, the exchange is stopped and the lower layers advised by means of transition of the PAREP parameter (PAREP = 1).

The AR variable remains at 0 to indicate that processing of the first sequence is involved.

- On the second sequence (variable I = 2):

If the DNA flag = 0 and if there is no SESSION or DATA LINK error, APPLICATION will confirm that the ZA1 and ZA2 fields are at 0, in accordance with the structure and content of the P4 frame (see clause 2). If the check is accurate, the ERAP variable will remain at 0 and the protocol considers the remote programming exchange as having been successful. If the check is inaccurate, the ERAP variable is set.

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If no error is detected on this sequence (P3, P4), characterized by ERLI = 0 and ERSES = 0 and ERAP = 0, the system will prepare to stop the exchange by setting the PAREP variable to 1.

If DNA = 1, the BERREUR table is completed (rejected data) and the system will prepare to stop the exchange by setting PAREP to 1.

If DNA = 2, the BERREUR table is completed (rejected authentication) and the system will prepare to stop the exchange by setting PAREP to 1.

If an error is detected on this sequence (P3, P4), and if the number of three identical calls is not reached, the system will prepare to begin the same call again by incrementing the J variable. If this value is reached, the exchange is stopped by transition of the variable PAREP = 1.

The AR variable is set (AR = 1) by the APPLICATION layer to inform SESSION to send the first AUT.

On each transition in this state, table B is updated again according to the sequence in progress.

* *State 6*

Management in case of forgotten station call.

Depending on the CASO variable sent by SESSION, APPLICATION knows which action to take with regard to the standby window in question.

For CASO = 0, no reply has taken place in the standby window concerned, APPLICATION therefore prepares the relevant information for table B (field at 00H).

For CASO = 1, an erroneous reply (ERLI = 1) has taken place in the window concerned. This may involve two units which have replied in the same standby window, the replies therefore being superimposed over the bus, making reception incomprehensible; or a unit which replied and whose transmission was disturbed. Whatever the case, APPLICATION knows there has been a reply which cannot be interpreted, and so prepares an item of information for table B (field at FFH).

For CASO = 2, a reply has taken place, the lower layers PHYSICAL and DATA LINK have not detected any error, but SESSION finds incoherency ininterpretation of the command returning from the secondary station (ERSES = 1), APPLICATION prepares an item of information for table B (FFH field) to indicate to it that there is an uninterpretable reply.

CASO = 3 involves a correct reply for DATA LINK and SESSION in the standby window concerned. APPLICATION then checks the content of the received TAB field in relation to the call content for the same field. If this check is accurate, APPLICATION transmits, for table B, the field corresponding to the address of the detected unit. If this check is inaccurate, ERAP is set and APPLICATION will prepare an item of information for table B (BFEi at field FFH) to indicate that there has been an unworkable reply in the standby window.

Each time that APPLICATION goes into this state (hence, at each standby window in the case of a forgotten station call), it increments the IASO variable which indicates in which standby window the system is located and enables the PHYSICAL layer to keep track of developments in the various time-division slices allocated to the windows.

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The PAREP variable is set at 1 as from the first transition to state 6. It indicates to the lower layers SESSION and DATA LINK that they do not have to carry out any frame set-up for transmission. In addition, as soon as IASO reaches value 3, the exchange is stopped by the PHYSICAL layer (event aa6).

On each transition into this state, table B is updated.

* *State 7*

Disconnection of APPLICATION and transition to lower layer by APSES = 1.

3.8.3.3 *Description of occurrences*

Aa. reception of the synchronization flag SESAP makes it possible to pass from SESSION wait state 0 to initialization state 1.

aa1. On the first transition (FROMEXT = 1), the system will pass from the initialization state to the initial frame set-up state (state 1 to 2).

ba1. After initialization, if DTR = 1, the system will pass to state 4 for management of a a remote reading sequence.

ca1. After initialization, if DTP = 1, the system will pass to state 5 for management of a remote programming sequence.

da1. After initialization, DASO at 1 will cause the system to pass from state 1 to state 6, for forgotten slave call management.

ea1. After initialization, DIB at 1 will cause the system to pass from state 1 to state 3, for bus initialization management.

aa2. Unconditional transition from state 2 to APPLICATION disconnection state 7.

aa4. Transition to state 7 at the end of a normal remote reading ERAP = ERSES = ERLI = 0 and I = NTR and DNA = 0.

The PAREP variable is set to 1.

ea4. Transition to state 7 with an error after three re-runs on the last sequence (ERAP = 1 or ERSES = 1 or ERLI = 1, and I = NTR and J ≥ 3 and DNA = 0).

The PAREP variable is set to 1.

da4. Transition to state 7 on an error after three re-runs over a sequence which is not the last, the system should continue to the next sequence (ERAP = 1 or ERSES = 1 or ERLI = 1, and I < NTR and J ≥ 3 and DNA = 0).

ba4. Non-error remote reading sequence (ERLI = ERSES = ERAP = 0) and DNA = 0, but the protocol should carry out other sequences (I < NTR).

ca4. Remote reading sequence with error ERLI = 1 or ERSES = 1 or ERAP = 1 and J < 3 and DNA = 0). In one sequence a re-run procedure to be considered since J < 3.

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fa4. Transition to state 7. This is the last sequence, the PAREP variable is set (I = NTR, DNA = 1, PAREP = 1).

ga4. Transition to state 7. A new different sequence is initialized (I < NTR, DNA = 1, PAREP = 0, I = I + 1, J = 1).

aa5. Transition to state 7 at the end of a normal remote programming (ERREUR = 0, AR = 1), the PAREP variable is set to 1.

ba5. Transition to state 7 after the first sequence (P1-P2) without error. The system is set for the second sequence (P3-P4). AR is set to 1.

ca5. Transition to state 7 with error (ERLI = 1 or ERSES = 1 or ERAP = 1) and DNA = 0 and a lower number than three calls on the sequence involved (P1-P2 or P3-P4). Consequently, the re-run procedure is carried out.

da5. Transition to state 7 with ERROR (ERLI = 1 or ERSES = 1 or ERAP = 1) and a number of calls equalling 3 over the sequence in question. The exchange is aborted, and the PAREP variable then set to 1.

ea5. Transition to state 7 with authentication error of the primary station by the secondary station (DNA = 2). The exchange is ended, and the PAREP variable is set to 1.

fa5. Transition to state 7 with rejection of remote programming data by the secondary station (DNA = 1). The exchange is ended, and the PAREP variable is set to 1.

ga5 Transition to state 7 with authentication of the secondary station (ERAP = 1 with NA1' ≠ NA1); no repeat is generated, PAREP is set to 1.

aa6. The three standby windows have passed (IASO ≥ 3). No re-run is carried out. The system passes to state 7 and the PAREP variable is set to 1.

ba6. Transition to state 7, the three standby windows have not passed (IASO < 3); the system shall therefore position itself for standby in the next window.

aa3. Unconditional transition to state 7 with setting of PAREP variable to 1.

Ba. Disconnection of APPLICATION linked to transition of the synchronization flag (APSES = 1) for the lower SESSION layer.

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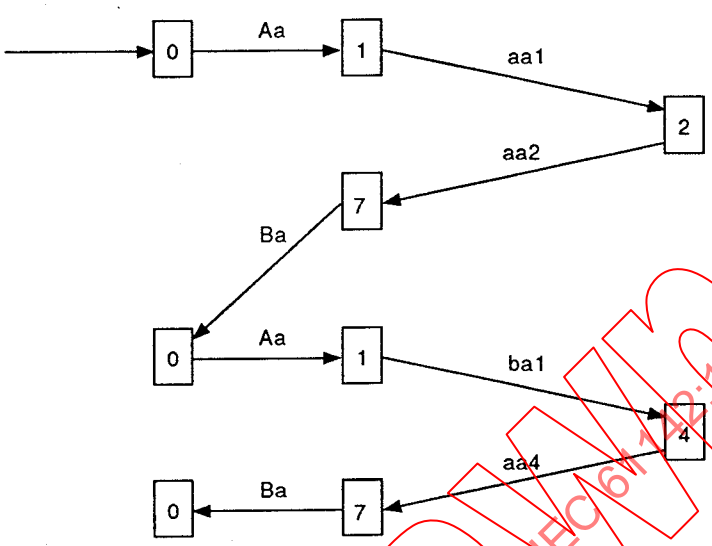
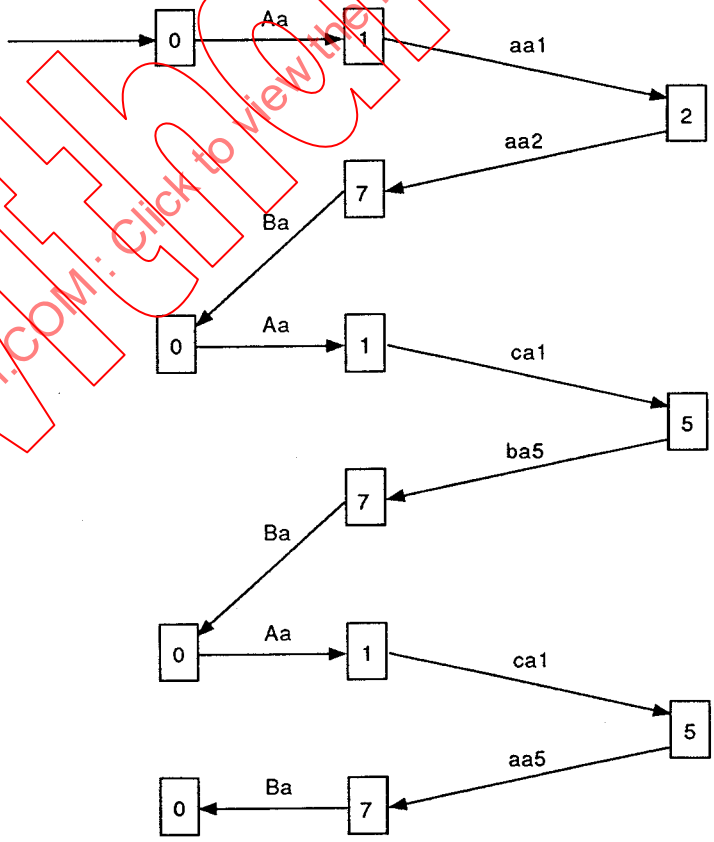
3.8.3.4 *State diagram showing a number of examples*

- Remote reading: nominal case



- Remote programming: nominal case



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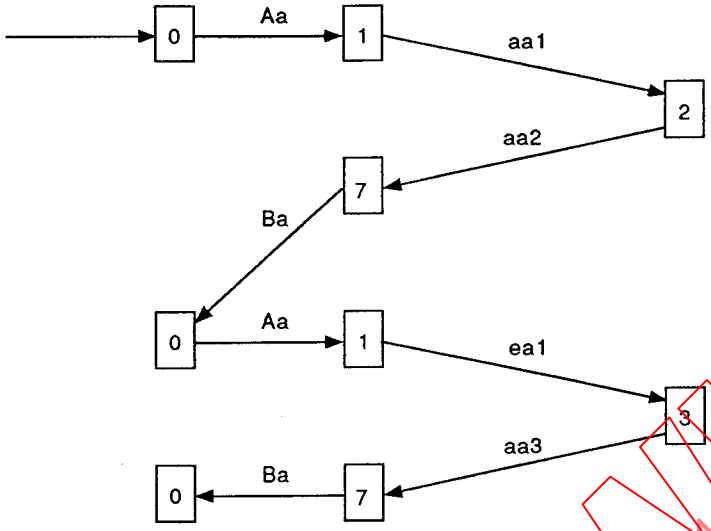
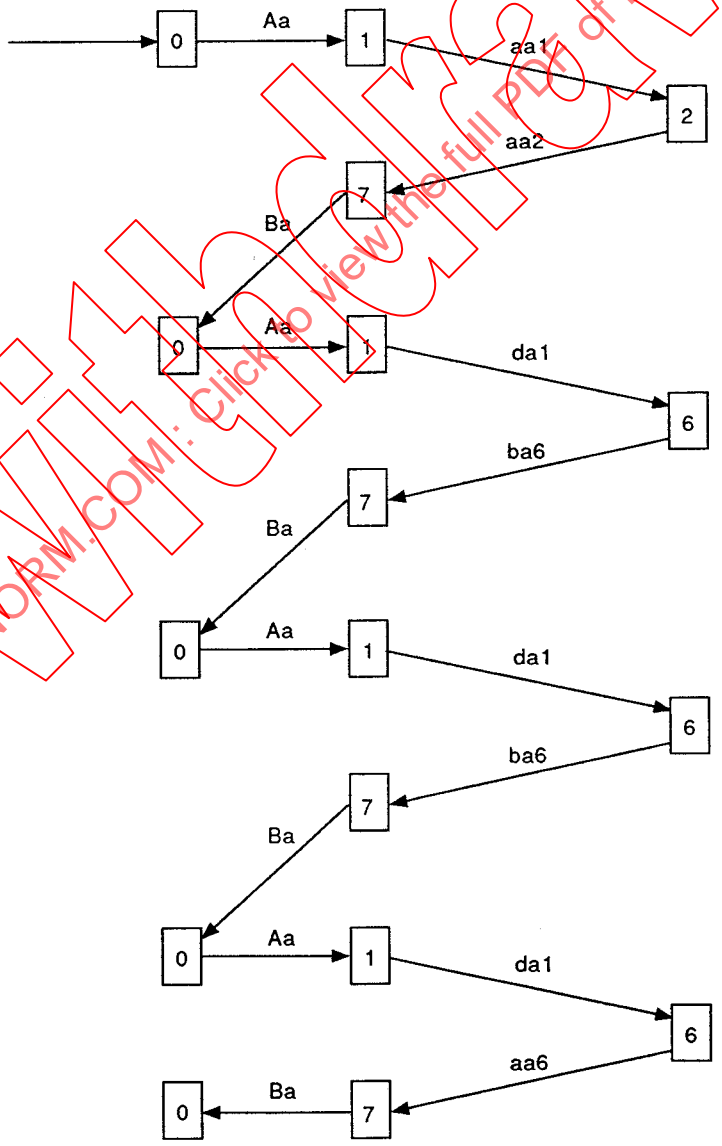
– Bus initialization



– Forgotten station call: reply in second standby window only



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3.8.4 *Set-up of table B*

3.8.4.1 *Case of forgotten station call*

On exit from state 6, the following operations are carried out to update table B:

* Exit at event ba6 or aa6
  - Setting of BERREUR (1,J) and BTIMOUT (1,J) depending on ERLI, ERSES, ERAP and RECNU for this sequence.
  - Result of the sequence stored in BDON with update of BNR.
  - Updating of BNECHAU field.
* The following additional operations are carried out on exit by event ba6 only.
  - Incrementation of J variable.
  - Incrementation of BNSEQI(1) content.
  - Creation of new BTIMOUT(1,J) and BERREUR(1,J) fields initialized at value 0.
  - Updating of BNDEROU and BNECHAU fields.

3.8.4.2 *Case of bus initialization*

On exit from state 3, table B is updated:

- Setting of BERREUR(I,1) an BTIMOUT (I,1)

3.8.4.3 *Case of remote reading*

On exit from state 4, table B is updated as follows:

* Exit at event ca4, da4 or ea4 (involving case of error in one of the layers).

da4. - Setting of BERREUR(I,J) and BTIMOUT(I,J)
  - Incrementation of I variable.
  - Creation of new BNSEQI(1), BTIMOUT(I,1) and BERREUR(I,1) fields, initialized respectively at 1, 0 and 0.
  - Updating of BNDEROU and BNECHAU.

ca4. - Setting of BERREUR(I,J) and BTIMOUT(I,J)
  - Incrementation of J variable.
  - Incrementation of BNSEQI(1) content.
  - Creation of new fields BTIMOUT(I,J) and BERREUR(I,J) initialized at value 0.
  - Updating of BNDEROU and BNECHAU fields.

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ea4. - Setting of BERREUR(I,J).

* Exit at event fa4 or ga4 (data table not known by secondary station)

fa4. - Setting of BERREUR(I,J).

ga4. - Setting of BERREUR(I,J).

- Incrementation of I variable.

- Creation of new BNSEQI(I), BTIMOUT(I,1) and BERREUR(I,1) fields, initialized respectively at 1, 0 and 0.

- Updating of BNDEROU and BNECHAU.

* Exit at event aa4 or ba4 (involving case without error in the layers)

aa4. - Setting of BERREUR(I,J).

- Result of the sequence stored in BDON(I) with update of BNR(I) and BNR.

- Updating of BNDEROU and BNECHAU fields.

* The following additional operations are carried out on exit at event ba4 only.

- Incrementation of I variable.

- Creation of new BNSEQI(I) field, with initial value at 1, and BTIMOUT(I,1) and BERREUR(J,1) fields, with initial value at 0.

- Updating of BNDEROU and BNECHAU fields.

3.8.4.4 *Case of remote programming*

On exit from state 5, table B is updated:

* Exit at event ca5 or da5 (case of error in the layers).

da5. - Setting of BERREUR(I,J) and BTIMOUT(I,J)

ca5. - Setting of BERREUR(I,J) and BTIMOUT(I,J)

- Incrementation of J variable.

- Incrementation of BNSEQI(I) content.

- Creation of new BTIMOUT(I,J) and BERREUR(I,J) fields, initialized at value 0.

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- Updating of BNDEROU and BNECHAU fields.

* Exit at event ea5 and ga5 (authentication rejected)

- Setting of BERREUR(I,J).

* Exit at event fa5 (rejected programming data)

fa5. - Setting of BERREUR(I,J).

* Exit at event aa5 or ba5 (no error in layers)

aa5. - Setting of BERREUR(I,J).

ba5 - Setting of BERREUR(I,J).

- Incrementation of I variable.

- Creation of new BNSEQI(I) field, with initial value at 1, and BTIMOUT(I,1) and BERREUR(I,1) fields, with initial value at 0.

- Updating of BNDEROU and BNECHAU fields.

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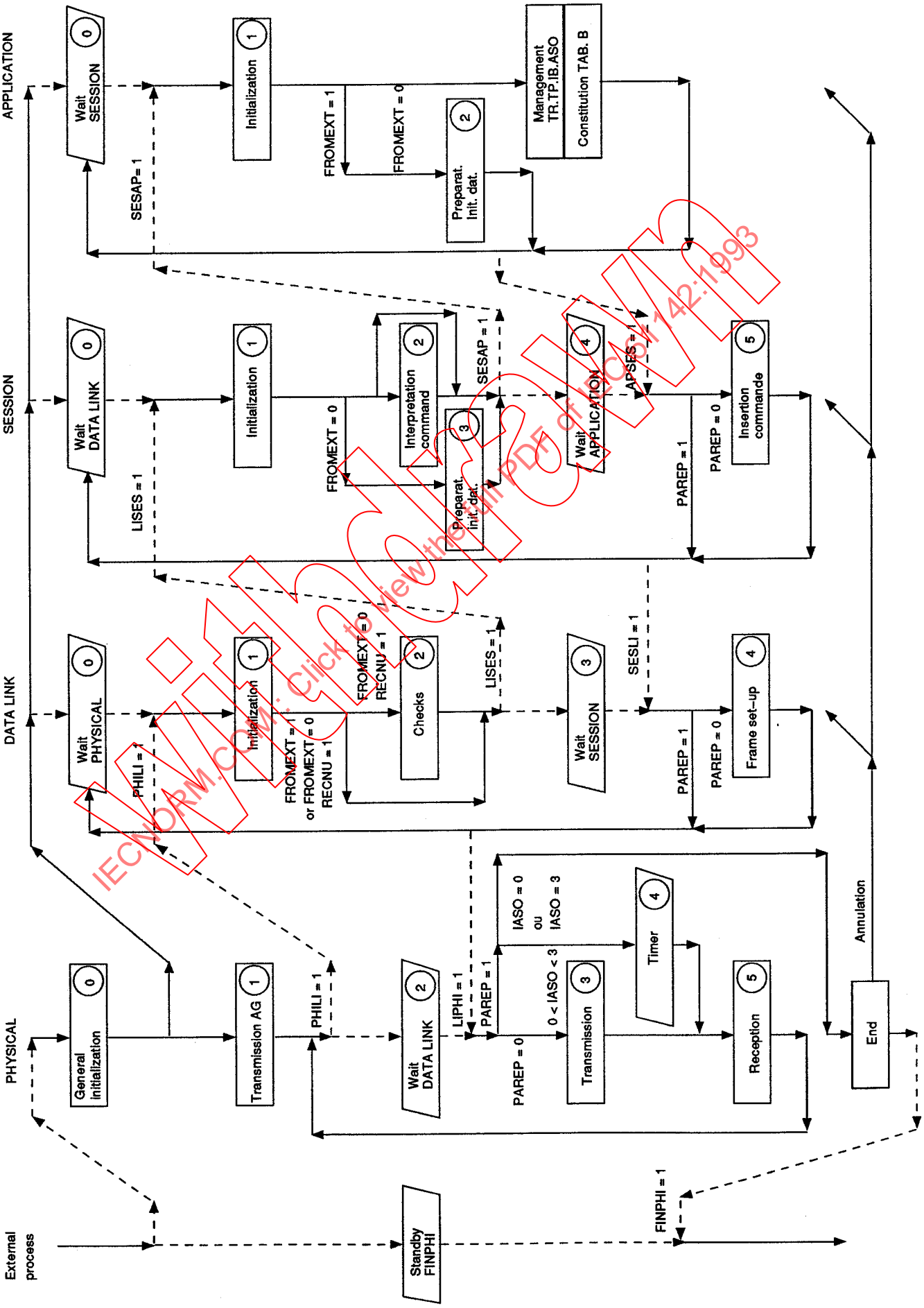
3.9 *Synopsis and inter-relationship between layers*

3.9.1 *Simplified general diagram of states*



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3.9.2 *Parameters and synchronization flags*

General initialization	PHILI = LIPHI = LISES = SESLI = SESAP = APSES = 0 DTR = DTP = DASO = DIB = 0 PAREP = AR = IASO = 0 RECNU = 0 APREC = 0		I = J = 1 FROMEXT = 1 Init table b	
	PHYSICAL	DATA LINK	SESSION	APPLICATION
Initialization of each level	PHILI = 0 RECNU = 0	LIPHI = LISES = 0 ERLI = 0 PAREP = 0	SESLI = SESAP = 0 ERSES = 0 DNA = 0	APSES = 0 ERAP = 0
Synchronization flags and parameters transmitted →	PHILI RECNU	LISES ERLI RECNU FROMEXT	SESAP DIB/DASO/DTR/DTP CASO/RECNU ERLI/ERSES DNA/FROMEXT	
Variables assigned in the different layers	RECNU PHILI	LIPHI/LISES ERLI	SESLI/SESAP ERSES DIB/DASO/ DTR/DTP APREC DNA CASO	APSES ERAP FROMEXT (RAZ) PAREP IASO Param.table B I / J AR
Synchronization flags and parameters transmitted ←	LIPHI PAREP IASO	SESLI PAREP IASO FROMEXT	APSES PAREP IASO FROMEXT AR	

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