Terminal Exchange Access System for NB-ISDN: 
Key Issues for a Traffic Reference Model

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A traffic reference model is introduced to dimension a Terminal Exchange Access System in a NB-ISDN environment. Firstly the model context and the functional patterns are described. Then the structure of the model is presented and the involved traffic variables and their relationships are defined. Finally an application procedure is presented.

1. INTRODUCTION

The most developed traffic characterization refers to the Plain Old Telephone Service: it is the result of years of theoretical and practical work, mainly consisting in the formulation of simplifying assumptions and in the verification of a satisfying effectiveness of the performance design and of the planning based upon them.

Well known examples of such hypotheses are: 1) the calls associated to different origin-destination pairs are independent; 2) the users (origins and destinations) can be considered as belonging to user classes (residential, small business, etc.) and the mean characterization of each class can be used as characterizing all its users; 3) the holding time distribution is independent on the inter-arrival time distribution and on the origin-destination pair: it is a morphological character of the telephone service; it can be approximated by a negative exponential distribution; 4) the inter-arrival time distribution is independent on the holding time; it depends only on the origin: it is therefore a planning character and can be approximated by a negative exponential distribution; 4) a complete metrics is provided by the mean value of the holding time and by an array containing, for each class, the number of subscribers belonging to the class and the associated mean value of the inter-arrival time.

In an ISDN context the characterization of each teleservice requires the same work, but the verification of the validity of the assumptions can be done only on the basis of different integration scenarios. In particular, the design requires a traffic characterization associated to the outlets (B and D channels) of the accesses (Basic, Primary and their multiplexes), whilst the forecasting can be done in terms of access inlets. The mapping of the forecastable demand on the demand required for the design represents a first integration scenario.

Furthermore, each teleservice must be characterized with reference to the attributes defining it.

Purpose of this paper is the formulation of a traffic reference model for the first design choices of an ISDN Terminal Exchange Access System, starting from the forecastable demand.

Previous characterizations of ISDN traffics ([1],[2],[3]) are based on a mapping of the inlets (terminals) on the outlets (channels) of the accesses. However their methodological approach does not take into account both the complexity of the attributes description of the services and the layered structure of the ISDN architecture.

These purposes can be reached by analyzing the sequence of the layer events (functional patterns) related to the user requests and to the deliveries of the layer functions involved in each communication instance.

Such an approach is adopted in this paper, where two functional patterns
(Call Patterns and Connection Patterns) are introduced, which consider only the events relevant for the traffic engineering up to layer 4. The statistical characterization of these patterns constitutes the required relationship between access inlets-outlets.

The context of the model is described in Sec. 2 and the functional patterns in Sec. 3. Sec. 4 presents the structure of the model, defining the variables and their relationships, while in Sec. 5 an application of the model is considered.

As far as the types of accesses are concerned, B and D channels will be only considered, by taking into account that the extension to other types of access channels (e.g. H0 and H12 channels) does not let any problem.

2 MODEL CONTEXT

A consistent and complete definition of services, service users and service providers has a key role in the characterization of the demand in an ISDN communication environment.

A companion paper [4] proposes a definition of service users and providers by referring to specific inter-layer boundaries of the ISDN architecture. In particular concepts as Application Users and Providers, Teleservice Users and Providers, Bearer Service Users and Providers are there defined as well as the concept of Communication Context.

A Multi-Service Communication Context, which is typical in an ISDN environment, can be associated to an user defined at the boundary environment/application. Such an user, called Final User, can select one or more applications, one or more teleservices, one or more bearer services.

The method of the attributes, recommended in CCITT I-series [5] is used in the model for the traffic characterization of the Final User demand: the values of the attributes of each service, provided within the Multi-Service Communication Context defining the Final User, constitute the basis of the characterization process.

The Final User demand is the effect of the direct requests of application and/or teleservice and/or bearer service and by the definition of the value of the attributes of the selected services (applications, teleservices or bearer services). The value of each attribute of a service can be defined either on a real time basis (per call basis) or on a provisional basis (per subscription basis). The value of each attribute can be defined: mandatory by the Final User (requested values), discretionary by the Service Provider (offered values) or as a result of a negotiation (negotiated values).

Significant examples of application attributes are: the list of the teleservices supporting the application; the list of the bearer services directly supporting the application (the bearer services offered in response to a teleservice request are not included) and the scheduling graph modeling the application in terms of teleservices. The list of teleservices or bearer services supporting an application can be formed selecting one or more of the available teleservices.

Teleservice is the generic name for one basic service only or for one basic service in addition to one or more supplementary services. Significant attributes of a teleservice are: the information media (voice/sound, data, texts, still images, moving images); the information handling processes (only information transfer, combining information retrieval, combining on-line information processes); the information bit-rate; the communication patterns (1-to-1, 1-to-N, N-to-N, broadcast); the symmetry (one way, two way balanced, two way unbalanced); the source/destinations combinations; etc.

Three main types of ISDN terminals can be distinguished: 1) a simple mono or multi-service terminal with human and communication interfaces; 2) an intelligent workstation with human and communication interfaces supported by dedicated processing and storage capabilities; 3) a common use service center (such as a data base for information retrieval) with communication interfaces supported by large scale intelligence and human services. Multiple ISDN terminal installation can be provided under a variety of teleservice access aggregates and in-house distribution schemes (Customer Premises Equipments).

Furthermore, a teleservice can be implemented by one or more bearer services classes, each formed by one or more bearer services as described in CCITT Rec. I.211 [5].

4.1A.3.2
3. FUNCTIONAL PATTERNS

The definition of the traffic variables requires the identification of all the significant events occurring during a call or a connection and resulting in a request (and, possibly, in an activation) of some access or network resources. These events can be described as points of a service delivery process.

Within a layered architecture, these events must be assigned to the layers and the mechanisms generating the layer $i$ events starting from the layer $i$, as well as the inverse mechanism must be taken into consideration. The events related to the layers 1, 2, 3 and 4 activities have been considered as a reference.

A generic Call Pattern and a generic Connection Pattern are proposed to model any teleservice and any bearer service.

3.1. Call Pattern

The choice of a teleservice can be made directly or through an application. In both cases the final effect of the choice is the generation of a Call Demand using an appropriate set of layers 7, 6 and 5 functionalities.

The provision of a teleservice involves a pool of layer 4 functionalities, that are requested by the upper layer to the layer 4 entities. In the following the set of these requests will be referred as a Call, while the sequence of specific events which occur as a consequence of the upper layer requests will be named Call Pattern.

A teleservice can give rise to various Call Patterns in dependence of the choice about the characteristic attributes of it.

A mix of teleservices can be modeled, from the traffic engineering point of view, by a mix of Call Patterns and by the statistical distribution of the traffic variables on it.

A mix of Call Patterns can be better modelled if each specific Call Pattern can be derived from one generic Call Pattern, simply giving specific values to some of the variables defined on it.

In an ISDN the most general Call Pattern correspond to a Multi-Point Call. Furthermore, the call instance generating it and any other occurring within it must be modelled through a generic Call Demand Sequence (CDS) taking into account the utilized Supplementary Services.

Fig. 1 gives an example of a CDS, when the automatic repetition Supplementary Service is available. A rather complex formula (but a very simple algorithm), taking into account all the possible events occurring in a generic CDS, allows the calculation of the time between the Call Demand event and the Closed Negotiation event. For sake of simplicity, the CDS is here modeled through this time.

![Fig. 1: Example of Pattern for a Multi-Point Call](image-url)
The model of a Multi-Point Call is now under study. Therefore, the paper confines itself to Point-to-Point Calls, for which Fig. 2 shows an example of a Call Pattern as a time diagram, in which two kinds of events can be identified: Final User dependent and Service Provider (or network) dependent events.

The Final User generates a Call, initiating a CDS with a Call Demand event activating the pertinent layer 4 functionalities.

The CDS can end with the following events: 1) abandon during the attempts sequence which aims to get the resources needed for the negotiation; 2) beginning of the negotiation which gives rise or to an Accepted Reservation event and corresponds to the conclusion of the negotiation phase with the teleservice provider or to a Rejected Reservation event (not considered in Fig. 2, which refers to a successful Call Sequence).

In the case of an Accepted Reservation the following events are defined: a) the Service Activation event, that arises when the Final User requires to use the service functionalities; b) the Service Delivery event, that occurs when the user plans to terminate all the service activities.

With respect of to frame of events, two other events, perceivable by the Final User but network dependent, must be defined: i) the Network Connection event that occurs when the network resources are provided to the layer 4 entities; ii) the Call Release event, that occurs when all the functionalities involved in the Call are released.

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**Fig. 2: Example of Call Pattern for a Point-to-Point Call.**

On the basis of the occurrence times of the previous events the following time intervals can be defined, as shown in Fig. 2:

- \( T_a \) is the Service Access time;
- \( T_p \) is the Service Provisioning time;
- \( T_d \) is the Service Delivery time;
- \( T_h \) is the Service Holding time.

Obviously the distributions of these times depend on the particular Call Pattern and/or the specific traffic sources.

It is to be observed that on demand calls are defined by the coincidence of the Accepted Reservation event with the Service Activation event and by the Service Delivery event moving to infinite time.
3.2. Connection Pattern

The choice of a bearer service arises directly or through a previous choice of a teleservice. In any case the effect of a bearer service selection is the establishment of a Connection.

The term Connection is here used to indicate a set of layer 3,2 and 1 functionalities, that are involved by the service requests addressed from layer 4 entities to the lower layers in correspondence with the Call Pattern progress. Therefore a Connection is the implementation of one or more bearer service classes: a specific access procedure and handling protocol for control or user information is an example of a specific connection architecture.

The sequence of events which occur as a response to layer 4 requests is described by the so called Connection Pattern. A bearer service can be implemented by various Connection Patterns in dependence on the definition of a value for the set of its attributes. For the same reason a Call Pattern can give rise to various Connection Patterns.

A mix of bearer services can be modelled, from the traffic engineering point of view, by a mix of Connection Patterns and by the statistical distributions of the traffic variables on it. The definition of a generic Connection Pattern helps in modelling bearer services mixes.

A Connection Pattern involves both the User and the Control Planes. Reference to the planes (Control plane, User plane, Management plane) cannot be avoided for Connection Patterns. The events must be assigned to the pertinent planes.

Fig. 3 shows the User plane component of a Connection Pattern describing a packet mode bearer service. This Connection Pattern involves several sequences of events, each of them related to a specific layer (3,2 or 1).

![Connection Pattern Diagram](image)

**Fig. 3:** Example of a Connection Pattern related to a Call Pattern during the Service holding time and describing a packet mode bearer service.

The holding time is splitted in a sequence of information spurts (info-spurts) and pauses. In this case the Connection Pattern can be characterized by some variables whose mean values will be denoted by:

- \( IC \) is the mean number of info-spurts per call
- \( PI \) is the mean number of packets per info-spurt;
- \( FP \) is the mean number of frames per packet;
- \( BF \) is the mean number of bits per frame,
where packets, frames and bits correspond to the data units of layer 3,2 and 1, respectively.

In the case of the circuit mode bearer service, the connection pattern structure assumes a simplified form because only the holding time is relevant.

The Control plane component (related to signalling and negotiation events) of a Connection Patterns can be characterized by specific variables, whose mean values are:

- $SP$ is the mean number of signalling packets per call;
- $SB$ is the mean number of bits per signalling packet;
- $NP$ is the mean number of negotiation packets per call;
- $NB$ is the mean number of bits per negotiation packet.

For these mean values the same dependence holds as outlined for the variables $IC, PI, FP$ and $BF$.

4. MODEL STRUCTURE AND DATA

In ISDN the load on access resources is a complex figure with several components which can be defined for each of the possible transfer modes (i.e. circuit and packet mode on B channel, packet and signalling mode on D channel), starting from the assumption that the possible traffic sources in an ISDN environment can be represented by standard aggregates of service terminals referred as Reference Customer Premises Equipment (RCPE).

4.1 Traffic sources characterization

According with the assumption stated above, we refer to a set $E$ of different RCPE types. A particular RCPE type $e$ comprises a pool $S(e)$ of teleservices available through the customer equipment. One of these teleservices, denoted by $s$, can be accessed by a number $K(s,e)$ of terminals that represent the independent traffic sources. For each RCPE type, we define the probability $P(e)$ to have the RCPE type $e$ in the set $E$.

The Final User population is assumed to be subdivided in classes characterized by homogeneous communication needs. The set of user classes and a single class are denoted by $U$ and $u$, respectively. For each user class, the probability $P(u)$ that a user belongs to the user class $u$ can be introduced.

The association between a RCPE type $e$ and a user class $u$ is defined by means of the conditional probability $P(e|u)$ that a user belonging to the class $u$ is equipped with the CPE type $e$.

If the probabilities $P(u)$ and $P(e|u)$ are known, the probability $P(e)$ can be easily evaluated:

$$P(e) = \sum_{u \in U} P(e|u)P(u) .$$

For each pair $(e,u)$ and for each teleservice $s$ characteristic of this pair, the value $rccd(s,e,u)$ is given. This value, which is a planning variable, is the mean number of $s$-teleservice call demands, evaluated in reference conditions per independent traffic source, for the user class $u$, equipped with the CPE type $e$.

The traffic inputs of the model can be identified with the different RCPE types. Therefore we need to have the values $rccd(s,e)$ of the reference conditions call demands, depending only on the RCPE type $e$ and the teleservice $s$. These values can be so obtained:

$$rccd(s,e) = \sum_{u \in U} rccd(s,e,u)P(u) - \sum_{u \in U} rccd(s,e,u)P(e)$$

4.1A.3.6
and can be computed by using the known data and the Eq.(1).

It is to be observed that in an ISDN the reference conditions describe a lot of elements to be taken into account. At least the breakdown of Call Patterns in Connection Patterns should be considered. Moreover the Busy Period Condition needs further study; in the following this reference period is denoted by $T_0$.

### 4.1 Traffic variables definition

The characterization of the offered load to an ISDN access system should be made by taking into account the layered architecture of this system and by defining, for each of the relevant layers, the appropriate traffic variables. By focusing on the network and system dimensioning aspects only, traffic variables related to layers 4, 3, 2 and 1 will be considered. They can be so defined.

- **For the layer 4**: RCCD are the Reference Conditions Call Demands, i.e. the mean number of call requests evaluated in reference conditions.

- **For the layers 3, 2 and 1**: $E_3$, $E_2$ and $E_1$ are the mean traffic intensities offered to the layers 3, 2 and 1, respectively; $PPS$, $FPS$ and $BPS$ are the mean numbers of packets, frames and bits per second, respectively, which are offered to the layer 3, 2 and 1 resources and averaged during a specific period; if this period coincides with the reference period $T_0$ the variables will be denoted with the letter $m$ (e.g. $PPSm$, $FPSm$, $BPSm$); when the period is the sum of the holding times of the specific layer during the reference period, the letter $p$ is used as a notation (e.g. $PPSp$, $FPSp$, $BPSp$).

These variables have to be evaluated for each of the information flows, which are to be handled by the ISDN access system, i.e. the flow on: 1) the B channel in circuit mode (Bc access); 2) the B channel in the packet mode (Bp access); 3) the D channel in the packet mode for user information (Ds access). In the case of Bc access, the variables $PPS$, $FPS$, $BPS$ are not significant, while the variables $E_3$, $E_2$, $E_1$ assume equals values because the layers 3, 2 and 1 can not be distinguished.

### 4.3 Call Pattern and Connection Pattern characterization

A **Call Pattern** is completely defined by the values assigned to the variables $T_a$, $T_p$, $T_d$, $T_h$ as defined in par. 3.1 and each teleservice can be associated to a set of Call Patterns, each of them corresponding to a significant set of attribute values.

In the following the argument $(d, s, e)$ will be used to denote the variables associated to the Call Pattern $d$ of the teleservice $s$ accessed through the RCPE type $e$ (pair $(s, e)$); moreover $D(s, e)$ is the set of Call Patterns associated to the pair $(s, e)$ and $P(d|s, e)$ is the probability to have the Call pattern $d$ in the set $D(s, e)$.

A **Connection Pattern** of the type considered in Fig.3 is completely identified by assigning the values of all the morphological variables $IC$, $PI$, $FP$, $BF$ as defined in par.3.2.

A Call Pattern, related to a particular teleservice, can be implemented by several Connection Patterns, each of them corresponding to a particular use of one or more bearer services. In the following the argument $(x, d, s, e)$ will be used to denote the variables associated to the Connection Pattern $x$, supporting the Call Pattern $d \in D(s, e)$. Moreover $X(d, s, e)$ is the set of the previous Connection Patterns and can, if considered in the User Plane be subdivided in the following three subsets:

- $X_{Bc}(d, s, e)$ is the set of $x \in X(d, s, e)$ using the Bc access;
- $X_{Bp}(d, s, e)$ is the set of $x \in X(d, s, e)$ using the Bp access;
- $X_{Dp}(d, s, e)$ is the set of $x \in X(d, s, e)$ using the Dp access.
The probability to have the connection pattern \( x \in X(d,s,e) \) will be denoted by \( P(x|d,s,e) \).

On the basis of the above definitions, the relationship between RCPE types, Teleservices, Call Patterns and Connection Patterns is shown in Fig. 4.

**Fig. 4: Relationships between RCPE types, Teleservices, Call Patterns and Connection Patterns.**

By assuming that the probabilities \( P(d|s,e) \) and \( P(x|d,s,e) \) are known, other significant probabilities characterizing the access inlets can be evaluated. For example we can express the probability \( P(Bp|s,e) \) that a call generated by the pair \((s,e)\) is handled by the \(Bp\) access:

\[
P(Bp|s,e) = \sum_{d \in D(s,e)} P(d|s,e) \sum_{x \in XBp(d,s,e)} P(x|d,s,e),
\]

while the mean holding time \( ETh(Bp,s,e) \) for the same calls can be evaluated by means of:

\[
ETh(Bp,s,e) = \sum_{d \in D(s,e)} ETh(d,s,e) P(d|s,e) \sum_{x \in XBp(d,s,e)} P(x|d,s,e),
\]

where \( ETh(d,s,e) \) is the mean holding time of the Call Pattern \( d \in D(s,e) \).

Moreover the mean number \( PPC(Bp,s,e) \) of packets per call, generated by the pair \((s,e)\) and handled by the \(Bp\) access is expressed by:

\[
PPC(Bp,s,e) = \sum_{d \in D(s,e)} P(d|s,e) \sum_{x \in XBp(d,s,e)} PPC(x,d,s,e) P(x,d,s,e),
\]

where

\[
PPC(x,d,s,e) = IC(x,d,s,e) PI(x,d,s,e).
\]

In a similar way the mean number of frames per call \( FPC(Bp,s,e) \) and the mean number of bits per call \( BPC(Bp,s,e) \) can be obtained, substituting to \( PPC(x,d,s,e) \) in Eq. (5) the following expressions:

\[
FPC(x,d,s,e) = PPC(x,d,s,e) FP(x,d,s,e),
\]

\[
BPC(x,d,s,e) = PPC(x,d,s,e) BF(x,d,s,e),
\]

respectively.
4.4 Traffic variables evaluation

For exemplifying the application of the model, some formulas will be here presented to characterize the load on the Bp access generated by the RCPE type \( e \). For the layer 4, we have

\[
RCCD(Bp,e) = \sum_{s \in S(e)} K(s,e) \ rccd(s,e) \ P(Bp,s,e),
\]

where the evaluation of \( P(Bp,s,e) \) can be performed by means of Eq.(3).

Moreover, for the layer 3, we obtain

\[
E3(Bp,e) = (1/To) \sum_{s \in S(e)} K(s,e) \ rccd(s,e) \ ETh(Bp,s,e),
\]

\[
PPSm(Bp,e) = (1/To) \sum_{s \in S(e)} K(s,e) \ rccd(s,e) \ FPC(Bp,s,e),
\]

\[
PPSp(Bp,e) = PPSm(Bp,e) / E3(Bp,e),
\]

where the Eqs.(4) and (5) must be used.

By assuming that each layer 2 connection (data link) supports only one layer 3 connection (virtual circuit), the load on the layer 2 resources is characterized by:

\[
E2(Bp,e) = E3(Bp,e),
\]

\[
PPSm(Bp,e) = (1/To) \sum_{s \in S(e)} K(s,e) \ rccd(s,e) \ FPC(Bp,s,e),
\]

\[
PPSp(Bp,e) = PPSm(Bp,e) / E2(Bp,e).
\]

Finally, about the load on the layer 1 resources, we obtain:

\[
E1(Bp,e) = 1 - \prod_{s \in S(e)} [1 - \frac{K(s,e) \ rccd(s,e) \ ETh(Bp,s,e)}{To}],
\]

\[
BPSm(Bp,e) = (1/To) \sum_{s \in S(e)} K(s,e) \ rccd(s,e) \ BPC(Bp,s,e),
\]

\[
BPSp(Bp,e) = BPSm(Bp,e) / E1(Bp,e).
\]

5 MODEL APPLICATION

The methodological approach described in the previous sections has been applied in characterizing the B and D channels populations in terms of partitions (classes) and in determining the penetration factors of each class (i.e. the percentage of B and D channels belonging to the considered class). The computation procedure is developed in six steps.

In the step 1, the identification of RCPE types (set \( E \)) and user classes (set \( U \)) is performed, together with the statistical characterization in terms of the probabilities \( P(u) \) and \( P(e|u) \); in particular, for each RCPE type \( e \) the set \( S(e) \) of the available teleservices should be identified.

Successively (step 2), for the RCPE type \( e \) and the user class \( u \) as defined in the first step, and for each teleservice \( s \), which is characteristic of the pair \( (e,u) \), the demand forecasting is made on ISDN traffic sources in terms of: 1) the number \( K(s,e) \) of independent traffic sources for the considered teleservice; 2) the mean number \( rccd(s,e,u) \) of reference conditions call demands per independent traffic source.
The step 3 is devoted, for each pair \((s,e)\), to the identification of the corresponding Call Patterns and their statistical characterization in terms of the probabilities \(P(d|s,e)\). Each Call Pattern \(d\) should include a distinction between requests to be handled on user or control planes and an evaluation of the associated morphological variables (see par.3.1).

In the step 4, for each triplet \((d,s,e)\), the corresponding Connection Patterns are identified together with their statistical characterization in terms of the probabilities \(P(x|d,s,e)\). Moreover, for each Connection Pattern, its allocation is provided on the access channels and a morphological description is made in terms of the pertinent traffic variables referring to user and control planes.

The following three steps take advantage of the results of the previous ones in order to statistically define some classes of the B and D channel in terms of the penetration factor of each class.

In particular, for each RCPE type, the computation is performed (step 4) of the traffic amount generated by access inlets and loading the resources at the first four layers of the user and control planes. The traffic should be characterized by the variables defined in par.4.2 and its evaluation will follow the guidelines exemplified in par.4.4.

Furthermore, for each RCPE type, the access outlets are dimensioned (step 5) in terms of B and D channels accessed through a basic or a primary arrangement.

The procedure is closed (step 6) with the statistical analysis of the sets of B and D channels (one set for each RCPE type) and the clustering of these sets in classes. For each class the penetration factor is computed by using the statistical description of RCPE types (step 1) and the dimensioning of the access outlets (step 5).

6 CONCLUSIONS

In the frame of the traffic model introduced in this paper, various items require further study.

In particular, two main questions have to be confronted with; namely reference is made to the definition of: 1) a generic Multi-Point Call and Connection Pattern; 2) specific models of the Control plane components in the generic Connection Pattern taking into account the specific protocols (e.g. Rec.Q.931).

Moreover, the reference conditions, extending the busy hour concept, should be specified in the definition of the planning and morphological variables.

For an extension of the model applicability and, in particular, for a complete characterization of the traffic processes occurring in all the layers of the ISDN architecture, further functional patterns related to layers 7,6 and 5 should be defined.

REFERENCES


