Open Interfaces between Digital Local Exchanges and Optical Access Networks for Narrowband and Broadband Services

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Abstract - **This paper provides a brief introduction to the open V5 interface supporting narrowband services and the VB5 interface specified for broadband services. These interfaces connect access networks to the local exchange and service nodes, respectively. Both types of interfaces have been defined and approved by ITU-T and ETSI.**

Keywords - **access network; local exchange; protocols; standards; service node; signalling; V5 Interface; VB5 Interface**

I. INTRODUCTION

With respect to the architecture of switched networks such as the PSTN or ISDN there is a clear tendency towards a reduced number of local exchanges, serving a larger number of subscribers. The local exchanges are supported by access networks which concentrate and transport traffic from the user to the exchange. This reduces the costs for operation and maintenance of the network. If the interface between the access network and the local exchange is standardised the network operator will have the possibility to connect access networks from different vendors to a local exchange. This is a very attractive advantage for network operators since the price per line will drop due to the vendor competition in the local loop. Driven by European network operators like Deutsche Telekom and British Telecom the European Telecommunications Standards Institute (ETSI) defined between 1991 and 1994 the so-called V5 interfaces between Local Exchanges (LEs) and Access Networks (ANs). An AN could be for example a Fibre In The Loop (FITL) system or a Digital Loop Carrier (DLC) system [1,2,3,12]. Today Deutsche Telekom has connected more than one million customers via V5-type interfaces. The V5 standards were adopted by ITU-T (International Telecommunication Union - Telecommunication Standardisation Sector).

For the support and operation of ANs, further standards for the open Q3 interfaces in the AN and LE have been defined by ETSI [4,5]. These management interfaces will be used to control operation, administration, provisioning and maintenance of ANs and LEs via the Telecommunications Management Network (TMN) [6].

Broadband services such as video on demand and new multimedia applications like teleteaching, teleworking, or teleconferencing require broadband infrastructures up to the customer premises. The access network (AN), which is the part between the User Network interface (UNI) and the service node (SN), is considered the key network element, since significant investment costs will be necessary, in particular, for the last few hundred meters towards the subscriber.

In order to determine the most cost-effective architecture and technology for the AN, a number of criteria have to be considered such as density and type of customer, or re-usability of installed infrastructure. The existing infrastructure has typically been designed for the support of narrowband on-demand services or broadband distribution services.

With respect to bandwidth fibre-to-the-home solutions offer maximum performance. Replacing existing copper wires by optical fibres is, however, for most applications not economic and currently only justified for high traffic business customers. New promising technologies or architectures like VDSL on twisted copper pairs or hybrid fibre coax architectures seem to provide attractive alternatives.

In order to allow for a fast introduction of broadband services, standardised interfaces are required between the AN and the SN. The interfaces should be flexible enough to support any existing service and, ideally, also future services. At the same time they should be independent of the architecture and technology that might be used in ANs.

This paper provides an overview of the basic requirements and principles adopted for V5 and VB5 interfaces, respectively.

Table 1 provides a list of abbreviations as used in the text.

II. OPTICAL ACCESS NETWORKS

Fig. 1 illustrates the functional model of the narrowband part for interactive services (based on 64 kbit/s) of a FITL system [7]. The system consists of an Optical Line Termination (OLT), typically located in the building of the LE, one or several Passive Optical Networks (PONs), and a number of Optical Network Units (ONUs).

The OLT provides open interfaces to the main network and to the TMN, and terminates the optical fibres of the PON. The OLT has to concentrate and groom the traffic from and to the ONUs, interpret signalling and control information conveyed via the V5 interface, and manage provisioning and maintenance operations. It is noted that OLTs could also be located at remote sites. In this case, transparent access to the LE could be provided e.g. by add drop multiplexers and SDH rings.

The PON physically connects the ONUs and the OLT and contains only passive optical components, such as splitters. In order to support the point-to-multipoint information transport, Time Division Multiplexing (TDM) and Time Division Multiple Access (TDMA) techniques are used. Traffic between user ports and the LE is typically not concentrated on the fibre. Concentration is performed, if required, in the OLT and on the V5.2 interface.

The ONUs terminate the optical fibre and provide the User Network Interface (UNI). Depending on the number of supported user ports and the location of an ONU, the configuration is called Fibre To The Home (FTTH), Fibre To The Building (FTTB) or Fibre To The Curb (FTTC).

Since mass deployment of OANs requires cost-effectiveness, compared to traditional copper distribution networks, complexity and intelligence of the FITL system, in particular of the ONU, should be limited to the minimum.

The OAN principally provides the transport facilities that connect customers to the main network, whereas the LE still remains fully responsible for all service-related aspects. Therefore, one of the main targets of the V5 specification was to minimise the call control functionality in the AN.

With the introduction of TMN, a number of operation, maintenance and provisioning functions, which were traditionally located in the LE, move into the AN or the operations system of the AN. In particular, fault and performance management of the user ports and lines are no longer controlled by the LE. This, however, requires co-ordination between AN and LE either via TMN or V5. For this purpose, two V5 control protocols were defined to cover all those operation, maintenance and provisioning functions, which directly affect service and, therefore, require immediate co-ordination via V5.

AN	Access Network
ATM	Asynchronous Transfer Mode
BA	Basic Access
BCC	Bearer Channel Connection
c-channel	communication channel
DLC	Digital Loop Carrier
EF	Envelope Function
ETS	European Telecommunications Standard
ETSI	European Telecommunications Standards Institute
FCS	Frame Check Sequence
FITL	Fibre In The Loop
FTTB	Fibre To The Building
FTTC	Fibre To The Curb
FTTH	Fibre To The Home
ISDN	Integrated Services Digital Network
ITU-T	International Telecommunication Union-Telecom. Standard. Sector
LAPD	Link Access Procedures on the D-channel
LAPV5	Link Access Procedures on the V5 interface
LC	Line Circuit
LE	Local Exchange
NNI	Network-Network Interface
OAN	Optical Access Network
OLT	Optical Line Termination
ONU	Optical Network Unit
OSI	Open Systems Interconnection
PON	Passive Optical Network
PRA	Primary Rate Access
PSTN	Public Switched Telephone Network
SDH	Synchronous Digital Hierarchy
SN	Service Node
TDM	Time Division Multiplex
TDMA	Time Division Multiple Access
TMN	Telecommunications Management Network
TSx	Time Slot x $(0 \leq x \leq 31)$
UNI	User-Network Interface
VC	Virtual Circuit
VP	Virtual Path

Table 1: *Abbreviations*

III. THE V5 INTERFACES

III.1 - Basic principles for V5 interfaces

The basic idea of an AN-LE configuration with standard V5 interface is to keep the full responsibility for all service-related aspects in the LE.

The AN provides only the transparent transport means between LE and customer. There is no call control in the AN, which should be kept as simple as possible. For the customer there should be no difference visible between being directly connected to the LE or being connected via an AN.

III.2-The Physical Layer

The V5 interfaces are based on interfaces at 2048 kbit/s in compliance with European Telecommunications Standards ETS 300 166/167 (corresponding to ITU-T Rec. G.703/G.704) [8,9]. This is to avoid major structural changes in existing LEs. V5.1 is a single 2048 kbit/s interface, whereas V5.2 may consist of one or up to sixteen 2048 kbit/s links, provisionable by the operator. Time slot 0 (TS0) of the 32 time slots of each 2048 kbit/s link is always used for frame alignment, error reporting and error performance monitoring using cyclic redundancy check procedures. In addition, in case of V5.2 links, TS0 is used to verify the correct physical connection of a 2048 kbit/s link.

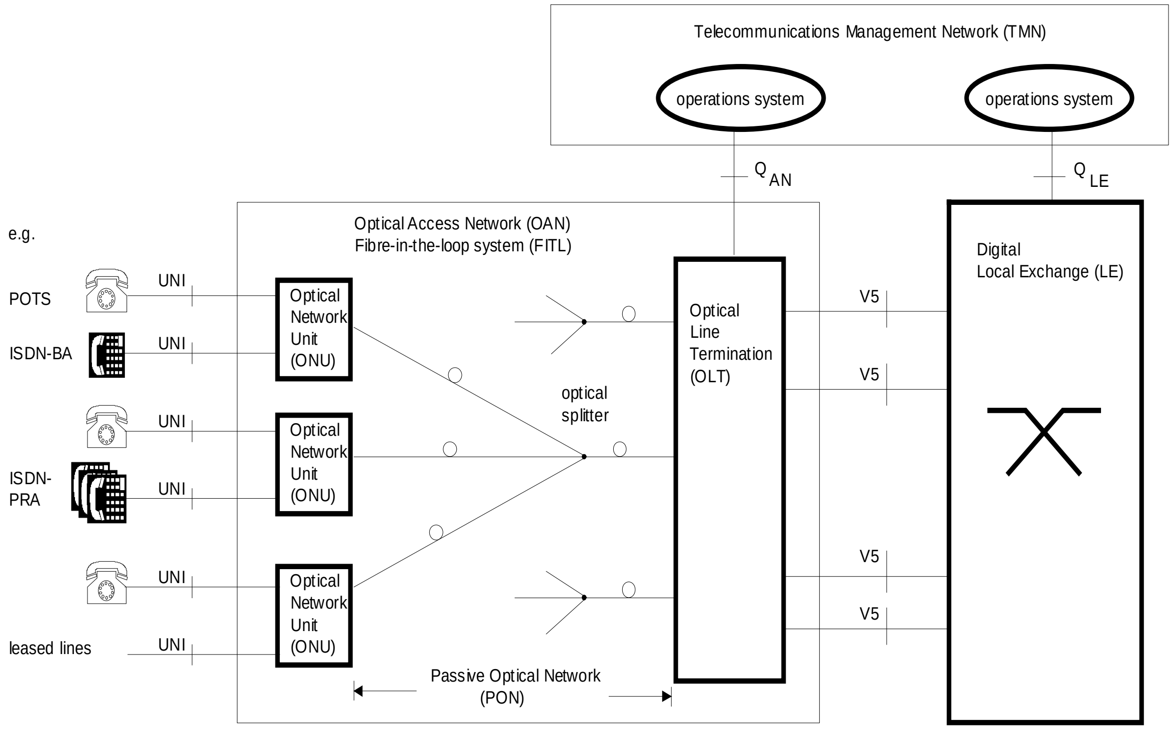


Figure 1. *Functional model of a Fibre in The Loop system.*

Up to three time slots (TS15, TS16, TS31) on each 2048 kbit/s link may be assigned as so-called communication channels (c-channels). C-channels carry PSTN signalling, ISDN-D-channel information, control information and, if required, the bearer channel connection protocol and the protection protocol. All 64 kbit/s time slots not provisioned as c-channels are available as PSTN or ISDN bearer channels or may carry analogue or digital leased lines.

V5.1 provides flexible, provisionable allocation of bearer channels to user ports. Since the allocation is not performed dynamically on a call by call basis, traffic concentration is not supported by the V5.1 interface. Thus, a maximum of 30 PSTN customers or 15 ISDN-BAs or any reasonable mixture may be connected via a single V5.1 interface. For customer accesses with low occupancies the V5.1 is therefore not very economic.

In order to provide concentration capability on a per-call-basis, a Bearer Channel Connection (BCC) protocol, which controls the dynamic allocation of all bearer channels, was specified for V5.2. A fully equipped V5.2 interface with sixteen 2048 kbit/s links could therefore support several thousand user ports. The V5 interface structures and concepts allow for upgrading V5.1 to V5.2.

III.3 - Protocol Principles and Multiplexing Structure

The specification of the various V5 protocols are based on the following principles:

- Message-based signalling and control information transfer are used to allow for easy incorporation of new features.
- Common signalling channels are defined for economic use of time slots.
- Message layouts and protocol procedures closely follow existing European Telecommunications Standards (ETSs) for the OSI data layer (layer 2, defined in ETS 300 125 [10] corresponding to ITU-T Rec. Q.921) and the OSI network layer (layer 3, ETS 300 102 [11], ITU-T Rec. Q.931).
- To minimise AN processing and complexity, ISDN-D-channel protocols are not terminated

in the AN at the network layer but are only frame relayed through the AN.

- To cover all National PSTN signalling systems and services, a mainly stimulus-based approach is adopted using a single data link (layer 2 connection) for all PSTN customers of a V5 interface. Once a signalling path for a certain user port is established, all analogue line signalling events, such as e.g. digits or meter pulses, are exchanged transparently via PSTN messages from the LE to the user port. **Fig. 2** illustrates the PSTN protocol architecture.
- Only a few service-affecting management messages are conveyed via V5 using the control or link control (only in case of V5.2) protocols. They provide the bi-directional information transfer required to control the operational status of individual user ports or 2048 kbit/s links, activation and deactivation of ISDN-BA lines, link identification and co-ordinated and synchronised re-provisioning. It is, however, assumed that the TMN has the main responsibility for the management and co-ordination of AN and LE.
- C-channels are protected against 2048 kbit/s link failures, if V5 consists of more than a single 2048 kbit/s link (only relevant for V5.2). A protection protocol, running on two 2048 kbit/s links in parallel, controls the switch-over of c-channels in case of a link failure. These two dedicated 2048 kbit/s links, carrying the protection protocol, are called primary link and secondary link.
- A common Bearer Channel Connection (BCC) protocol under control of the LE sets up connections on a per call basis in the V5.2 case.
- The message layout and multiplexing technique allows to flexibly mix different protocols on a c-channel or to separate them on several c-channels.
- In the V5.1 case, the control protocol is always allocated to TS16. All other protocols may be assigned to either TS16, TS15, or TS31.
- In the V5.2 case, the control and link control protocols, the BCC protocol and, if provisioned, the protection protocol are always kept together in TS16 of the primary 2048 kbit/s link of the V5.2 interface. All other protocols may be assigned to TS16, TS15, or TS31 of any 2048 kbit/s link of the V5.2 interface by provisioning. TS16 of the secondary 2048 kbit/s link also carries the protection protocol and is reserved as backup c-channel for TS16 of the primary link.

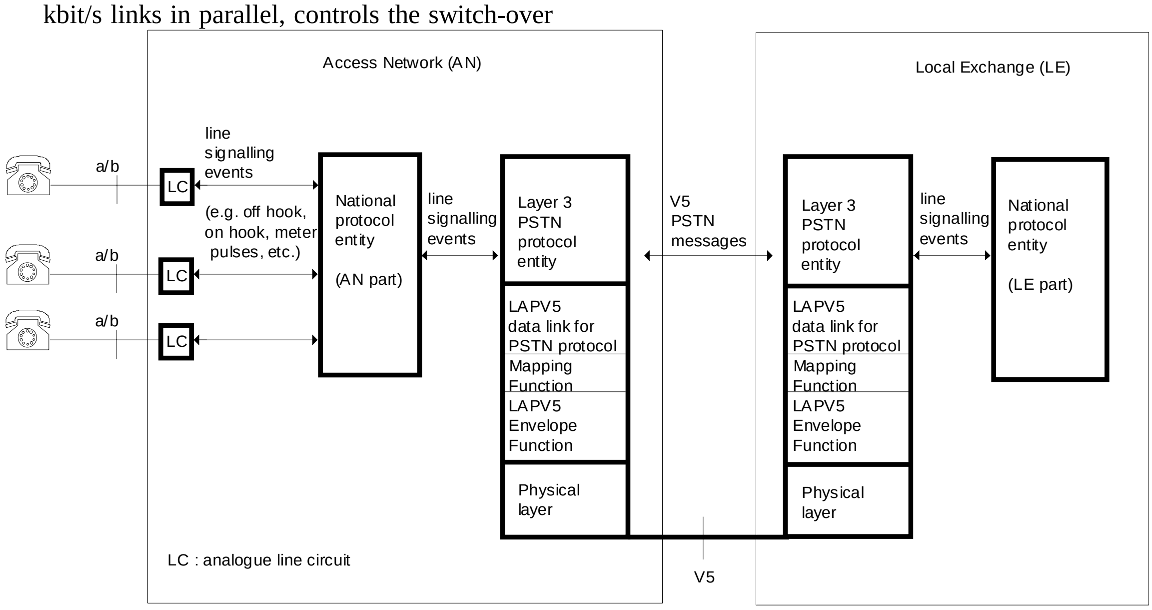


Figure 2. *Functional model for the PSTN protocol.*

In order to support full flexibility in multiplexing the different information streams into the c-channels, the data link layer (OSI layer 2) is divided into two sublayers. A mapping function performs the inter-sublayer communication within layer 2.

The protocol architecture of the V5 interface is shown in **Fig**. 3.

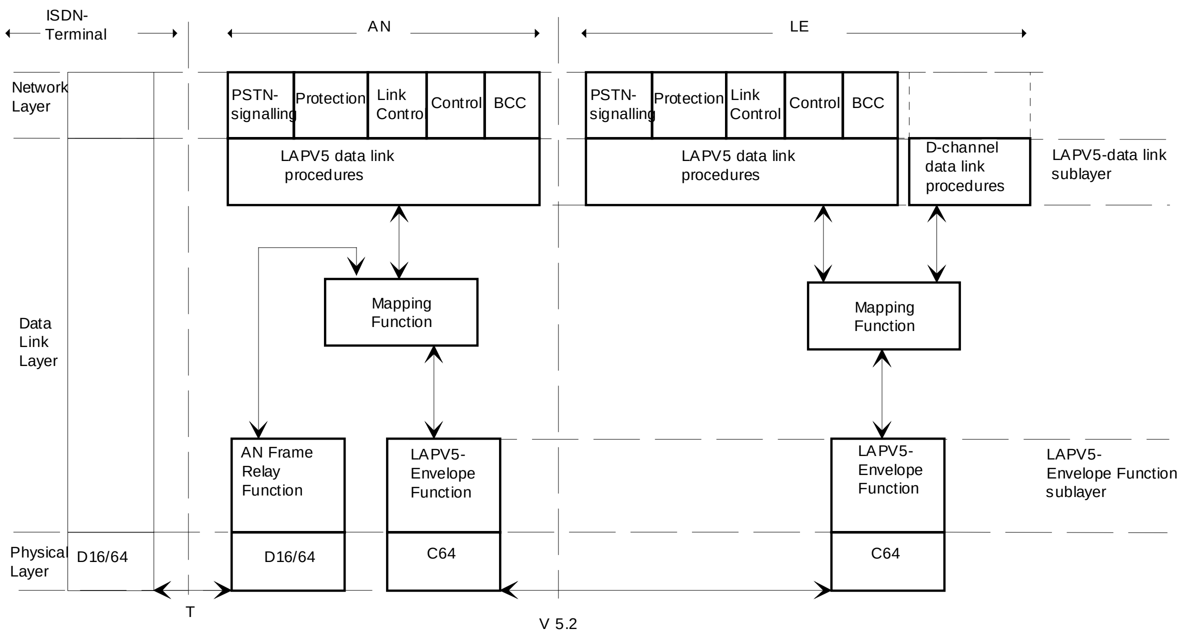


Figure 3. *V5 protocol architecture (BCC, protection, and link control protocols are only used for V5.2, D16 and D64 are the 16 kbit/s and 64 kbit/s D-channels for ISDN-Bas and ISDN-PRAs, respectively. C64 is the 64 kbit/s c-channel. D64 is only supported by V5.2).*

For each of the above mentioned V5 protocols a data link, called LAPV5 data link, is permanently established. The procedures specified for the LAPV5 data link are based on the Link Access Procedures on the D-channel (LAPD, ETS 300 125, ITU-T Rec. Q.921). Communication towards the network layer is performed via this data link sublayer.

IV. THE VB5 INTERFACES

IV.1 - Introduction

Even though currently most telecommunication services are still narrowband services mainly based on 64 kbit/s connections, it is expected that the demand for new broadband services such as video-on-demand, teleworking and teleshopping will soon increase significantly. These services require a broadband infrastructure, in particular, broadband access for the subscriber. It is anticipated that in the beginning independent narrowband and broadband access networks will co-exist, which could in future merge to one integrated access network for all types of services. To connect broadband/integrated access networks to broadband exchanges, which are typically called service node (SN), standardised interfaces are required. As a consequence standardisation bodies such as ETSI and ITU-T have defined the so-called VB5 interfaces. In the following general principles and requirements are proposed for those broadband VB5 interfaces.

IV..2 - Network Architecture

The media independent architecture of ANs is defined in a framework Recommendation of ITU-T [13]. **Figure 4** shows the boundaries of the AN.

For the definition of VB5 interfaces a clear functional split between AN and SN was considered [13]. The functionality of ANs is limited mainly to transport bearer capabilities. This implies e.g. that signalling is not interpreted in the AN. The SN provides access to the switched and permanent services. The SN is responsible for call and connection control, signalling, as well as access connection and resource handling.

As a general principle, all functions related to operation, administration, and maintenance are performed via the management interfaces Q3(AN) and Q3(SN). The necessary co-ordination and synchronisation between AN and SN concerning these functions is provided by the Telecommunications Management Network (TMN).

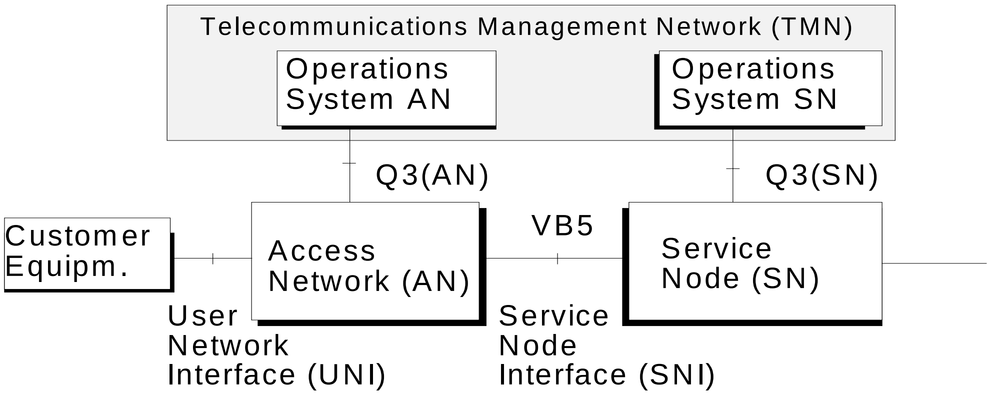


Figure 4. *General Architecture - Boundaries of an Access Network (AN)*

Currently, a large variety of architectures for ANs, using different physical media like optical fibres, unshielded twisted pair, coaxial cables, and radio, are discussed in various standardisation bodies, such as ETSI, ITU-T, ATM-Forum, and DAVIC.

Figure 5 shows the example of an ATM oriented Passive Optical Network (PON). The Service Node interface (SNI) has to support different services, e.g. analogue telephone services (PSTN), narrowband ISDN services (ISDN-BA, ISDN-PRA), broadband ISDN services (supported by B-ISDN UNI), and non-B-ISDN broadband services such as video on demand, broadcast services, and LAN interconnect functionality.

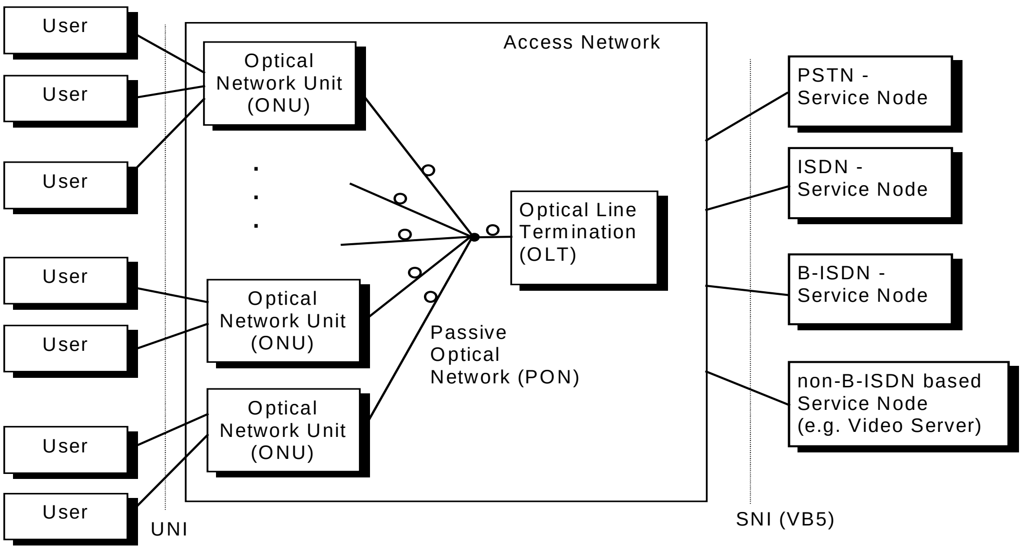


Figure 5. *Functional architecture of an ATM based passive optical access network*

IV. 3. Reference Model for VB5 Interfaces

The functional reference model for access arrangements using VB5 interfaces is shown in **Figure 6**. The main functional blocks in the AN are User port function (UPF), ATM connection function, Service port function (SPF), and AN system management. The VB5 related functional entities in the SN are Service port function (SPF) and SN system management.

The User port function provides user access to the network via the UNI. The UPF comprises for example the physical termination of the UNI, activation and deactivation of a UNI, maintenance of the UNI, and testing of a UNI. The natural access type is a B-ISDN access with a UNI according to ITU-T Recommendation I.432. However, also non-B-ISDN access types such as narrowband ISDN or PSTN access types or broadband non-B-ISDN accesses are supported by the VB5 concept. For these cases an adaptation function is required in the AN, in order to convert non-ATM information into the appropriate

ATM-format. In Figure 3 this is indicated by the ATM Adaptation function (AAF) for a so-called virtual user port.

The Service port functions (SPF) in the AN or SN, respectively, support the connection of both network elements via the VB5 interface.

The ATM connection function inside the AN provides the capability of cross connecting virtual paths (VP) or virtual channels (VC). The VB5.2 variant also permits switching of VCs at the ATM level under control of the SN. In order to control the VC switch in the AN by the SN a dedicated VB5.2 protocol will be specified.

The system management function in the AN or SN co-ordinates operation, provisioning and maintenance of the above mentioned functional entities. Whenever time-critical co-ordination between AN and SN is required this is performed through the VB5 interface. Non-time-critical co-ordination is done via the Telecommunications Management Network (TMN), i.e. via Q3(AN) and Q3(SN).

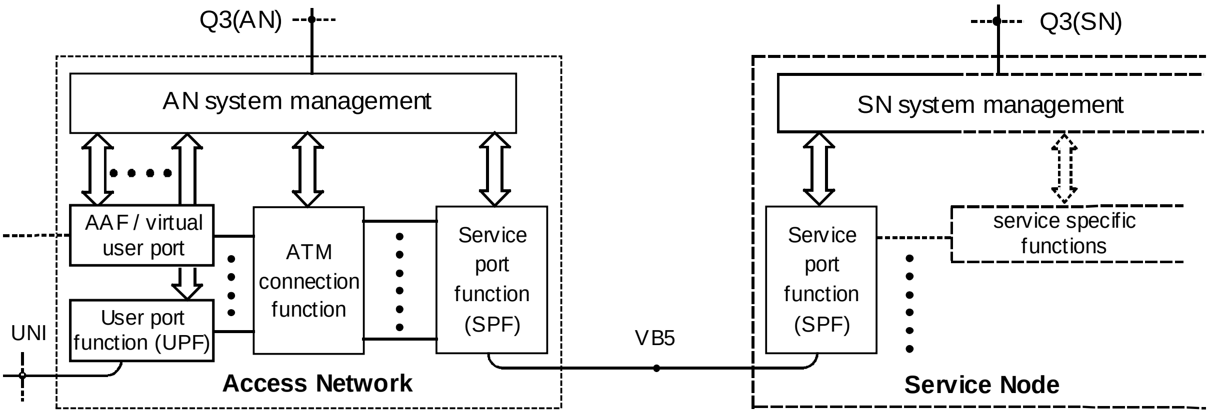


Figure 6. *Functional reference model for VB5 access network arrangement [14]*

IV.4. Protocol Architecture

A more detailed protocol architecture of a VB5-based AN arrangement is given in **Figure 7**.

IV.4.1. Physical Layer

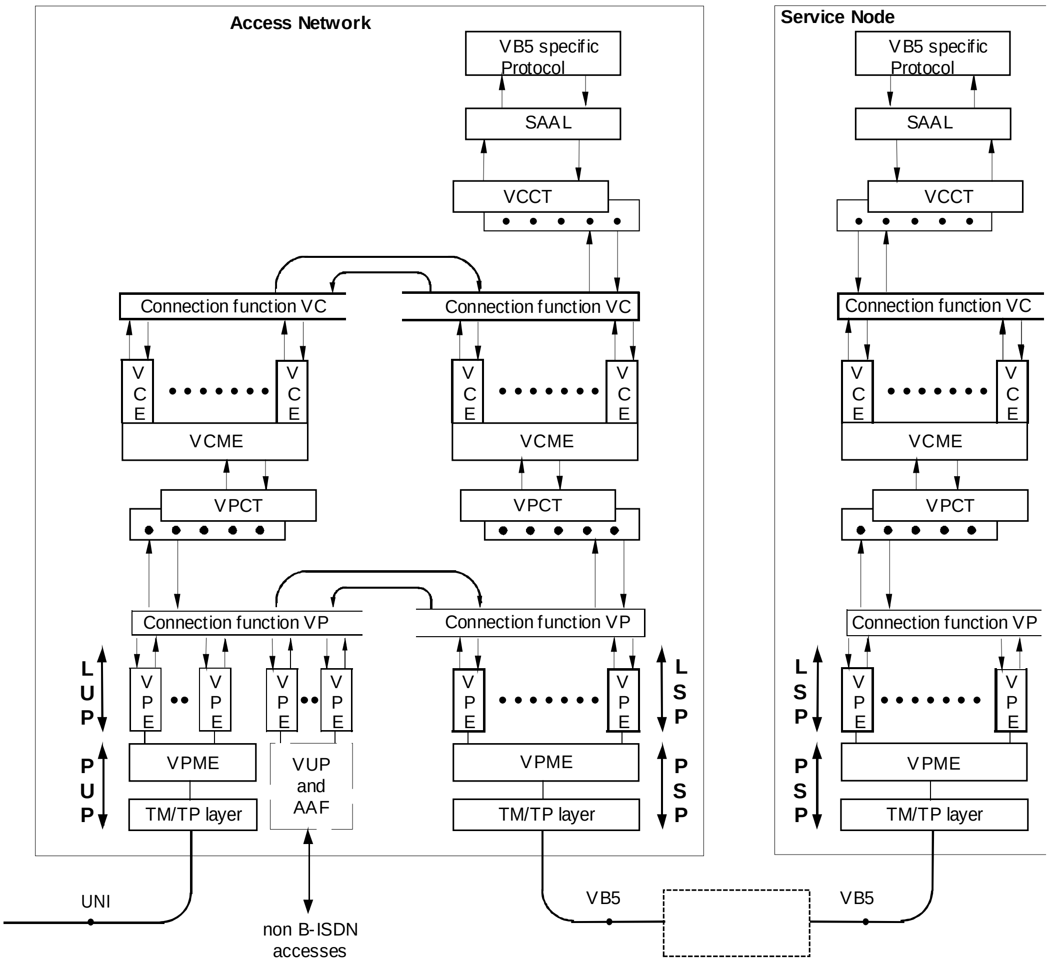
The transmission media and transmission path (TM/TP) layer represents the physical layer of the VB5 or User Network interface, respectively. Since ATM cell transfer is supported by various different physical layers, using e.g. SDH, PDH or cell relay techniques, the definition of the VB5 interface has been kept as far as possible independent of the physical layer. It is, however, expected that most implementations would use modern SDH technology (e.g. at 155 Mbit/s, 622 Mbit/s or 2.4 Gbit/s). SDH logy already provides advanced operation and maintenance functionality, like flexibile provisioning, path identification and protection switching, wich are important for the reliable and economic operation of SN and AN.

IV.4.2. ATM Layer

The formats and coding of the ATM cells at the VB5 interface are based on existing standard formats at the UNI and Network Network interface (NNI) [15]. The structure of the 5 octet cell header of the NNI is used, which provides 28 bits of routing information - 12 bits for the virtual path identifier (VPI) and 16 for the virtual channel identifier (VCI). This addressing range is considered large enough to cover all AN implementations, including those which support several thousand customers.

Existing mechanisms for operation and maintenance at the VP or VC level are re-used to provide information on the operational state of individual connections and to perform functions such as loop back, continuity check and performance monitoring [16].

Specific VPI and VCI values are pre-assigned for those VPs and VCs carrying the VB5 specific protocols. The individual messages of the VB5 specific protocols are carried by the signalling ATM adaptation layer (SAAL), which guarantees secure and reliable exchange of messages (see Figure 4).



AAF	ATM adaptation function	VCCT	virtual channel connection termination
LSP	logical service port	VCE	virtual channel entity
LUP	logical user port	VCME	virtual channel multiplex entity
PSP	physical service port	VPCT	virtual path connection termination
PUP	physical user port	VPE	virtual path entity
SAAL	signalling ATM adaptation layer	VPME	virtual path multiplex entity
TM/TP	transmission media/path	VUP	virtual user port

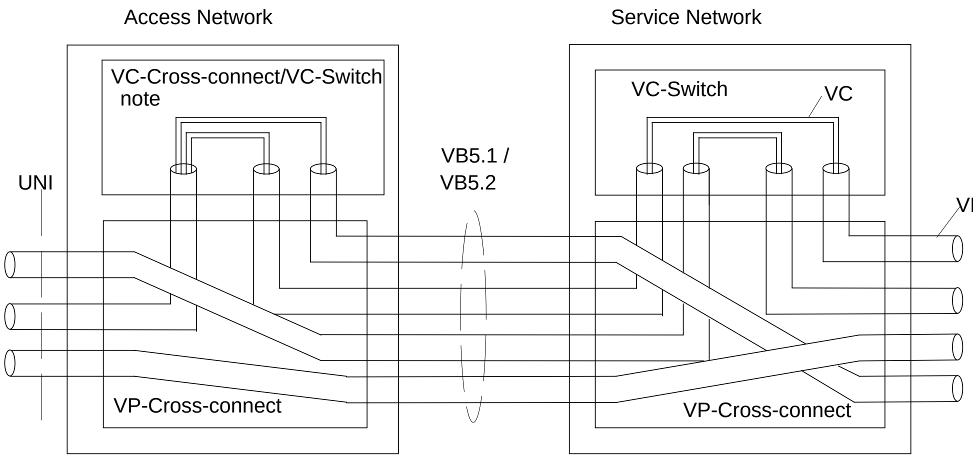
Figure 7. *Protocol architecture for VB5-based access network arrangements [14]*

IV.4.3 ATM connection types

As shown in Figure 3 the AN includes an ATM connection function. The ATM layer itself is composed of the virtual path (VP) layer and the virtual circuit (VC) layer. A single VP may carry a number of VCs.

With respect to the ATM layer the simple VB5.1 AN will mainly provide semi-permanent VP and VC cross-connect functionality. In addition, VB5.1 ANs must be able to terminate VCs for dedicated VB5 protocols and for supporting non-B-ISDN user ports (see e.g. Figure 4).

In case of the VB5.2 interface, VC switching functionality is required in the AN, which allows on-demand allocation of VCs to VPs in the AN under control of the SN.



Note: For VB5.1 only the VC cross-connect functionality is present at the ATM layer

Figure 8. *Virtual Path (VP) connections and Virtual Channel (VC) connections.*

V. 4.4 Real Time Management Co-ordination

As already mentioned, operation, administration and maintenance functions are typically performed through the Q3(AN) and Q3(SN) interfaces [13]. However, in some cases time critical co-ordination between AN and SN is required, in particular, when customer service is directly affected. In order to meet this requirement, a VB5-specific real time management co-ordination (RTMC) protocol has been defined, which provides direct communication between AN and SN.

The most important function of the RTMC protocol is to inform the SN about the availability of those resources in the AN, which are necessary to deliver the subscribed service. Since the SN is responsible for the service, this information has to be available in the SN on a real time basis, e.g. to stop charging in case of a failure in the AN. In addition, the RTMC protocol offers the AN operator the possibility to shut down gracefully user ports without interfering with ongoing services. This procedure may be applied, when non-urgent maintenance actions have to be performed inside the AN.

A set of further functions are supported by the RTMC protocol, such as the verification of the correct connection at physical level and ATM level between AN and SN, or the possibility to restart the whole VB5 interface.

IV.4.5 Broadband Bearer Connection Control

For VB5.2 it is foreseen that the AN may act as a VC switch, which establishes VC connections on demand. The VC switch in the AN is controlled by the SN, which has the full knowledge about the call states and the availability of resources. Since establishment of the VC connections in the AN has to be performed in real time, a dedicated protocol on the VB5 is required, the so-called Broadband Bearer Connection Control (B-BCC) protocol.

In the VB5.2 case the total sum of bandwidth permanently allocated at the UNIs is typically much higher than the bandwidth provisioned at the VB5.2 interface. Thus, the B-BCC protocol allows for concentration of traffic in the AN.

IV.4.5 Handling of Non-B-ISDN Access Types

Narrowband Access Types

Narrowband access types, like analogue PSTN accesses, ISDN basic access, or ISDN primary rate access, are connected to the broadband SN via narrowband V5.1 [18] or V5.2 [19] interfaces. For this purpose each 2048 kbit/s link of the V5.1 or the V5.2 interface, respectively, is carried transparently on the VB5 interface using circuit emulation. This approach provides the advantage that typical packetising delays can be avoided, simple separation of narrowband and broadband traffic is possible, and existing specifications are adopted.

Non-B-ISDN Access Types

Non-B-ISDN access types (apart from narrowband access types) can either be ATM based or not.

If they are ATM based, they can be connected to the SN via VB5 interfaces using a simple semi-permanent ATM connection (VP or VC). From a VB5 interface point of view these connections look like any other non-switched B-ISDN connection.

Non-ATM based access types need adaptation functionality in the AN, which provides conversion from the non-ATM transfer mode to ATM. The ATM connection carrying this type of traffic is terminated inside the AN, but may be treated from a VB5 interface point of view like an ATM connection of a virtual user port.

V. SUMMARY

The open V5 and VB5 interfaces enable network operators to connect Access Network equipment from different vendors independently to digital Local Exchanges. Both analogue and digital switched services as well as non-switched services for narrowband and broadband applications are supported in a flexible and forward looking way. A large variety of different physical architectures is considered for V5 and VB5 interfaces, among which are Digital Loop Carrier systems, Fibre In The Loop systems, Radio In The Loop systems and remote switching systems. International standardisation bodies such as ETSI and ITU-T have defined the standard specifications for the open V5 and VB5 interfaces.

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