ETSI TECHNICAL REPORT

ETR 248

January 1996

Source: ETSI TC-TM

Reference: DTR/TM-03057

ICS: 33.180

Key words: transmission, mux, monomode, fibre

Transmission and Multiplexing (TM); Use of single-mode fibre in the access network

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New presentation - see History box

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Foreword

This ETSI Technical Report (ETR) has been produced by the Transmission and Multiplexing (TM) Technical Committee of the European Telecommunications Standards Institute (ETSI).

ETRs are informative documents resulting from ETSI studies which are not appropriate for European Telecommunication Standard (ETS) or Interim European Telecommunication Standard (I-ETS) status. An ETR may be used to publish material which is either of an informative nature, relating to the use or the application of ETSs or I-ETSs, or which is immature and not yet suitable for formal adoption as an ETS or an I-ETS.

This ETR was originally published as an internal Technical Committee report (TM-TR 002) and was therefore only available with the TM Technical Committee. It is now published as an ETR, with its technical content unchanged, to allow the document to be made publicly available.

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1 Scope

This ETR describes the results of the studies of the use of single-mode fibre in the access network, referred to in this report as the Optical Access Network (OAN). It has identified a number of functions that are required and has begun to list those functions that require to be studied. There may even be a requirement not to define (standardize) some of the functions identified. Where it has been possible to provide a definition in suitable text for a function, it is given in this report. However where a definition requires further study, this is indicated accordingly.

As this network may carry analogue and digital signals, this ETR describes the characteristics of an access network using monomode fibre (single mode) between the user network and the local exchange, or head end, that allows evolution from the Plain Old Telephony Service (POTS) and similar bearer services to the Broadband Integrated Services Digital Network (B-ISDN) bearer service without the requirement to re-cable the installed fibre access.

It has also been identified that there may be studies in other standardisation bodies that could have an impact on the requirements of the access network. As there has not been any input from these bodies at this time, their requirements have not been considered.

2 References

This ETR incorporates by dated and undated reference, provisions from other publications. These references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this ETR only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

[1] ETS 300 007 (1991): "Integrated Services Digital Network (ISDN); Support of packet mode terminal equipment by an ISDN".

[2] ETS 300 011 (1992): "Integrated Services Digital Network (ISDN); Primary rate user-network interface; Layer 1 specification and test principles".

[3] ETS 300 012 (1992): "Integrated Services Digital Network (ISDN); Basic user-network interface; Layer 1 specification and test principles".

[4] ETS 300 166 (1993): "Transmission and Multiplexing (TM); Physical characteristics of hierarchical digital interfaces for equipment using the 2048 kbit/s-based plesiochronous or synchronous digital hierarchies".

[5] ETS 300 167 (1993): "Transmission and Multiplexing (TM); Functional characteristics of 2 048 kbit/s interfaces".

[6] ETSI 300 300 (1995): "Broadband Integrated Services Digital Network (B-ISDN); Synchronous Digital Hierarchy (SDH) based user network access; Physical layer interfaces for B-ISDN applications".

[7] ETS 300 324-1 (1994): "Signalling Protocols and Switching (SPS); V interfaces at the digital Local Exchange (LE); V5.1 interface for the support of Access Network (AN); Part 1: V5.1 interface specification".

[8] ITU Recommendation X.25 (1993): "Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit".

[9] ITU Recommendation G.652 (1993): "Characteristics of a single-mode optical fibre cable".

[10] EC SYN 287 (1990): "Proposal for the council directive concerning the protection of individuals in relation to the processing of personal data".

[11] EC SYN 288 (1990): "Proposal for the directive concerning the protection of personal data and privacy in the context of public digital telecommunication networks, in particular the integrated services digital network (ISDN) and public digital mobile networks".

[12] ETS 300 233 (1994): "Integrated Services Digital Network (ISDN); Access digital section for ISDN Primary rate".

[13] ETS 300 347-1 (1994): "Signalling Protocols and Switching (SPS); V interfaces at the digital Local Exchange (LE); V5.2 interface for the support of Access Network (AN); Part 1: V5.2 interface specification".

[14] ETS 300 418 (1995): "Business TeleCommunications (BTC); 2 048 kbit/s digital unstructured and structured leased lines (D2048U and D2048S); Network interface presentation".

[15] ETS 300 288 (1994): "Business TeleCommunications (BTC); 64 kbit/s digital unrestricted leased line with octet integrity (D64U); Network interface presentation".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of this ETR, the following definitions apply:

diplex working: Using a different wavelength for each direction of transmission over a single fibre.

duplex working: Using the same wavelength for both directions of transmission over a single fibre.

fibre: A medium used for the transport of optical signals according to ITU Recommendation G.652 [9].

filter: A device for the selection of optical signals at specific optical wavelengths.

head end: That part of the line terminal realisation that terminates the optical functions of the access (TV distribution).

multiplexing (static): A system of multiplexing where the relationship between the position of the tributaries to the multiplexed format (channels) is predetermined and fixed.

multiplexing (dynamic): A system of multiplexing where the relationship between the position of the tributaries to the multiplexed format (channels) is flexible. It also allows for tributaries to be aggregated where there are more tributaries than available channels and the possibility to vary the bandwidth to n times the capacity of the channels.

optical splitter: A device that has n inputs with k outputs, where $n \geq 2$ and $k \geq 2$.

passive component: A component part of the access that does not require external power and has reciprocal properties in both directions. i.e. fibre, splitter, filter.

point-to-multipoint: A transmission system which has one input at one end with multiple outputs at the other end.

R (Receive) reference point: point on the optical fibre just before the Optical Line Terminal (OLT) optical connection point (i.e. optical connector or optical splice).

S (Send) reference point: A point on the optical fibre just after the Optical Line Terminal (OLT) optical connection point (i.e. optical connector or optical splice).

simplex working: Using a different fibre for each direction of transmission.

3.2 Abbreviations

For the purposes of this ETR, the following abbreviations apply:

AC	Alternating Current
A/D	Analogue to Digital (conversion)
ATM	Asynchronous Transfer Mode
AU	Adaptation Unit
B-ISDN	Broadband Integrated Services Digital Network
CATV	CAble TeleVision
D/A	Digital to Analogue (conversion)
DC	Direct Current
DS	Distributive Services
DXC	Digital cross Connect
FITL	Fibre In The Loop
FTTA	Fibre To The Apartment
FTTB	Fibre To The Building
FTTC	Fibre To The Curb (Kerb)
FTTH	Fibre To The Home
FTTO	Fibre To The Office
ISDN	Integrated Services Digital Network
IS	Interactive Services
NE	Network Element
OAM	Operations, Administration and Management
OAN	Optical Access Network
ODN	Optical Distribution Network
OLT	Optical Line Terminal
ONU	Optical Network Unit
OSI	Open System Interconnection
OTDR	Optical Time Domain Reflectometer
PCN	Personal Communications Network
PON	Passive Optical Network
POTS	Plain Old Telephony Service
PSTN	Public Switched Telephone Network
TCM	Time Compression Multiplexing
TDM	Time Division Multiplexing
TV	Television
VCR	Video Cassette Recorder
VF	Voice Frequency
VSB/AM	Vestigial Side-Band/Amplitude Modulation
WDM	Wavelength Division Multiplexer

4 General

4.1 Bearer capabilities

As a guide some of the bearer capabilities identified are listed below:

- POTS;
- leased lines;
- packet data;
- Basic access Integrated Services Digital Network (ISDN);
- Primary rate access ISDN;
- n x 64 kbit/s;
- n x 2 Mbit/s;
- B-ISDN;
- Television (TV) distribution.

This list is not considered to be complete and requires further study.

4.2 Interfaces

4.2.1 Interfaces at the network-side

It has been identified that there is a requirement for a 2 Mbit/s exchange interface to enable the signalling requirements of POTS to be interfaced with the OAN. The new 2 Mbit/s interface has been defined in two stages:

1) an interface called V5.1, which enables POTS and Basic access ISDN to be offered via the optical access network, see ETS 300 324-1 [7];

2) an interface called V5.2 (evolved from the V5.1 interface) with additional functions that include the requirements for the Primary rate access ISDN and a concentration capability, see ETS 300 347-1 [13].

For packet type data the OAN will connect to data networks using existing defined interfaces, e.g. ITU Recommendation X.25 [8] and ETS 300 324 [7].

For leased line requirements the OAN will have the capability to either connect direct to leased line networks and private data networks via 2 Mbit/s interfaces, or, via the V5 interfaces for "semi-switched" or part time circuits.

4.2.2 Interfaces at the user-side

Existing defined Customer-network interfaces will be used at the user-side of the OAN and include:

- for Basic access ISDN (see ETS 300 012 [3]);
- for Primary rate access ISDN (see ETS 300 011 [2]);
- for packet data using rates up to 64 kbit/s channels (see ETS 300 007 [1]);
- for B-ISDN (see ETS 300 300 [6]);
- for n x 64 kbit/s services (see ETS 300 166 [4] and ETS 300 167 [5]);
- for 2 048 kbit/s digital leased lines (see ETS 300 418 [14]);
- for 64 kbit/s digital leased lines (see ETS 300 288 [15]);
- it has been agreed that for POTS, existing national interface specifications will used.

5 Configuration of an optical access network

5.1 Architectural configuration of an optical access network

The configuration of an OAN is shown in figure 1.

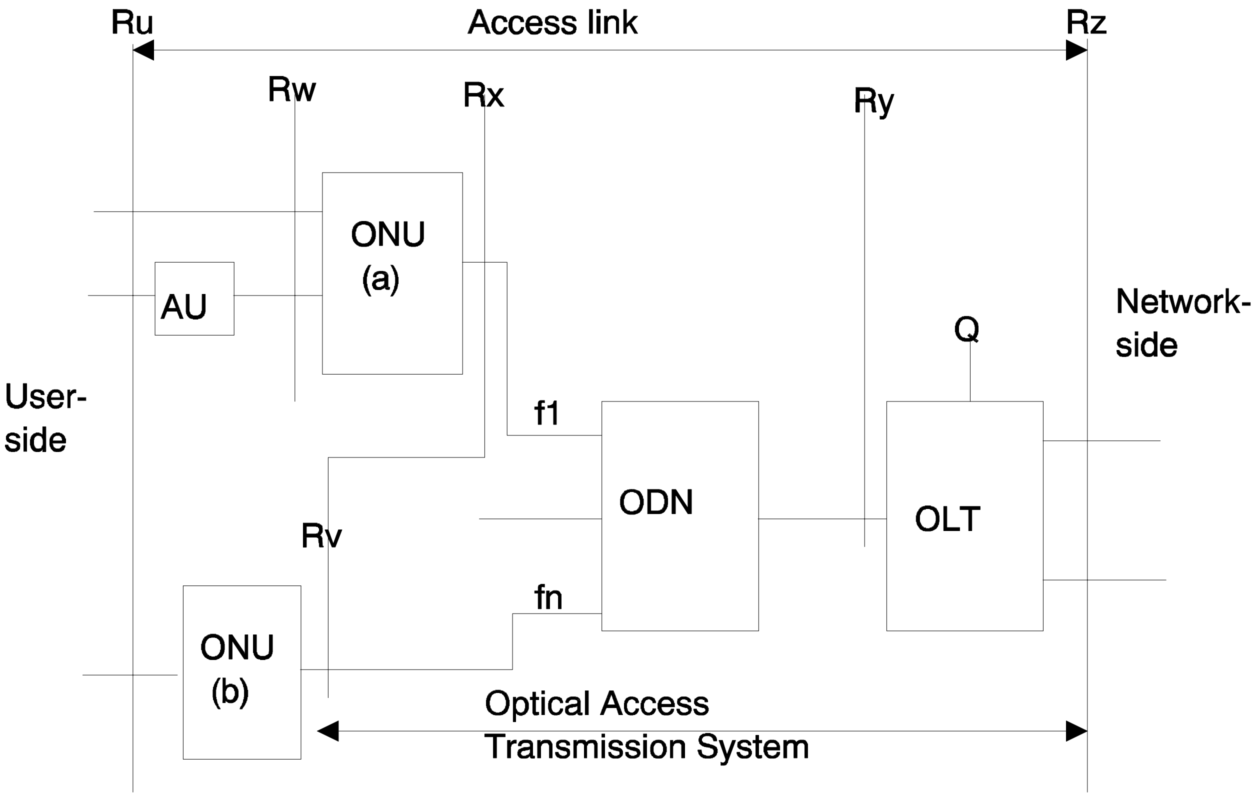


Figure 1: Provisional architectural configuration for the OAN

Figure 1 shows the boundaries of the access link in relation to the optical access transmission system definition.

The **access link** is defined as: "The whole of the transmission means between a given network interface and a single user interface".

The concept of access link is used in order to allow a functional and procedural description and a definition of the network requirements.

NOTE 1: The user-side and the network-side of the access link are not identical and therefore the access link is not symmetrical.

The **optical access transmission system** is defined as: "The whole of the transmission means, using optical fibre, between consecutive reference points inside an access link".

The concept of optical access transmission system is used in order to describe the characteristics of an implementation, using fibre, in support of the access link.

The OAN is defined as: "The set of access links sharing the same network-side interface and supported by optical access transmission systems".

NOTE 2: An OAN may include a number of Optical Distribution Networks (ODNs) connected to the same Optical Line Termination (OLT).

Figure 1 also shows the main functional blocks of an OAN, i.e. OLT, ODN, Optical Network Unit (ONU) and Adaptation Unit (AU).

The OLT provides the network-side interface of the OAN, and is connected to one or more ODNs.

The ODN provides the optical transmission means from the OLT towards the users, and vice versa.

The ONU provides (directly or remotely, see Note 3) the user-side interface of the OAN, and is connected to the ODN.

The AU provides adaptation functions between the ONU and the user side.

The reference points associated with the OAN reference model are:

- reference point Ru: located at the user-side interface of the OAN;
- reference point Rw: located at the interface between the ONU (case (a), see Note 3) and remote users;
- reference point Rx(Rv): located at the interface between the ONU and the optical access transmission system;
- reference point Ry: located at the interface between the OLT and the optical access transmission system;
- reference point Rz: located at the network-side interface of the OAN.

Examples of possible implementations of an OAN are given in annex A.

NOTE 3: The above reference model covers two possible cases. As fibre to an intermediate location as in the ONU(a), for example, Fibre To The Curb (FTTC), Fibre To The Apartment (FTTA), Fibre To The Building (FTTB) or as Fibre To The Home (FTTH) as in the ONU(b). This reference model is service and applications independent.

NOTE 4: Not all the above reference points (Rn) represent physical interfaces. The location of the reference points related to the definition of optical power levels is given in subclause 6.3.

NOTE 5: A number of bearer capabilities have been listed in subclause 4.1 from which a subset will be offered to the customer depending on its requirements.

Leased lines are considered to be included in the listed bearer capabilities and may include sub-64 kbit/s rates.

NOTE 6: The physical interface between ONU and customer can either be copper, fibre or cordless based.

The ONU can either be dedicated or shared amongst customers.

The ONU can either be sited at the kerb or at the customers premises.

n is a variable number of channels that could serve a variable number of customers.

NOTE 7: The ODN includes no optical to electrical conversion.

The OLT-ONU connection could be either point-to-multipoint or point-to-point. The network architecture could be a tree, bus or ring structure.

In the configuration the ODN can include the following optical elements: power splitters, fibre, couplers, filters, Wavelength Division Multiplexer (WDM) devices, connectors and in the case of point-to-multipoint optical amplifiers.

ODN optical elements may be collocated with the ONU.

The recommended fibre (f) is of the Single Mode type according to ITU Recommendation G.652 [9].

NOTE 8: The OLT may be co-located with the local exchange or deployed remotely.

Passive optical elements may be collocated with the OLT.

A "Q type" interface has been identified as required to handle Operations, Administration and Maintenance (OAM) requirements for the OAN and an embedded operation channel is identified for OAM requirements of the OLT. However for remote applications of an OAN the Q interface may not be physically present as it may be embedded within an OAM channel. This requires further study.

NOTE 9: The listed interfaces between the OLT and the network are considered to be possible open (i.e. multi-vendor) interfaces.

The network interface can be either metallic or optical.

5.2 Application of state machines to the architectural configuration

For ISDN applications it has been necessary to define state machines. This was to enable the relevant standards to identify and define the states between the customer equipment, the access digital section and systems, and the exchange termination.

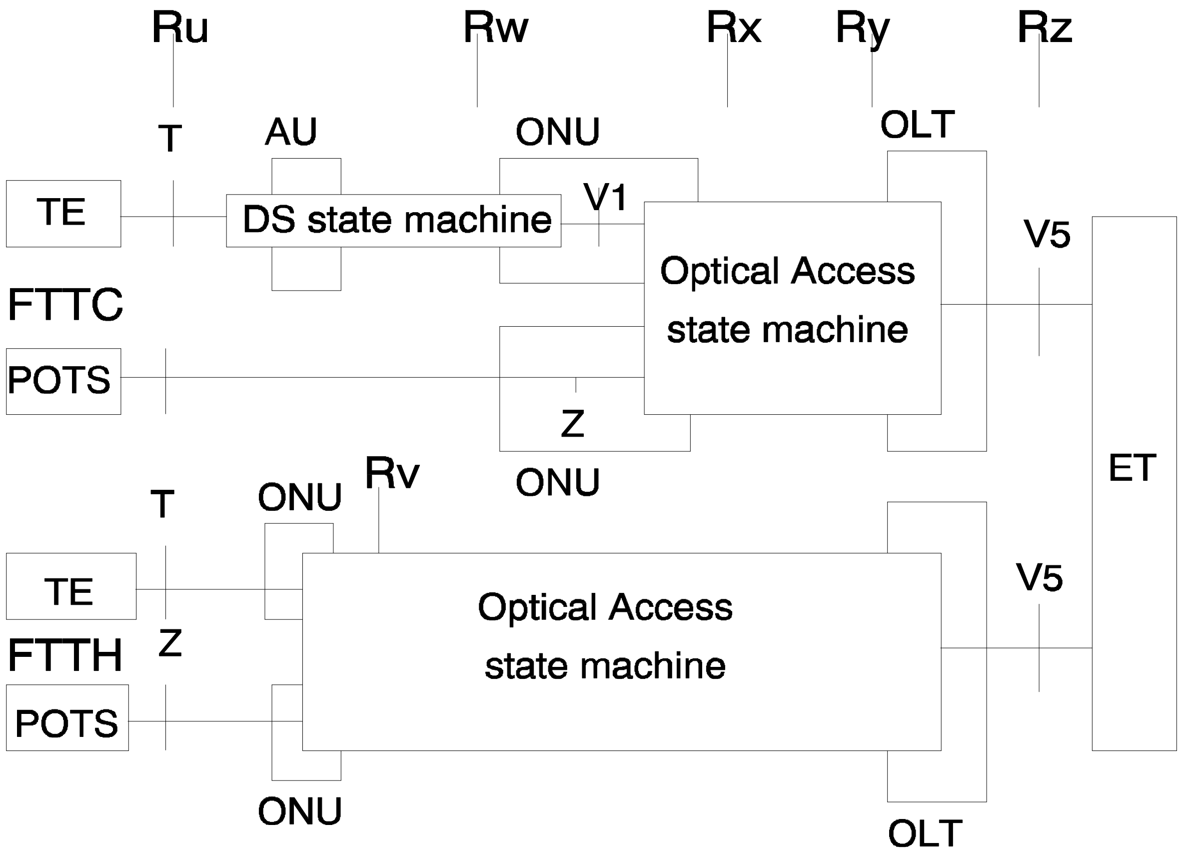
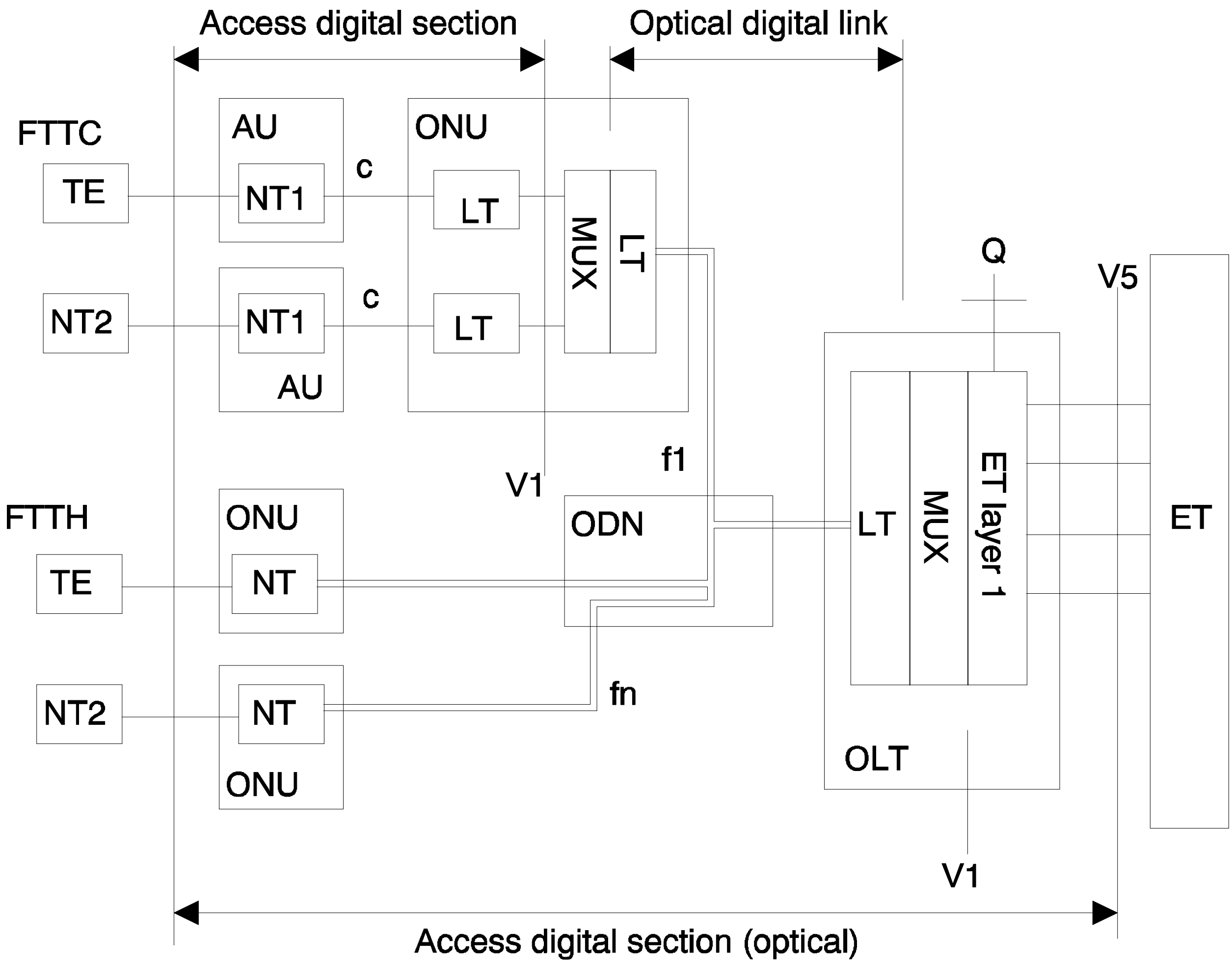


Figure 2: ISDN application of an OAN

Figure 2 shows ISDN applications (both FTTC and FTTH) of an OAN. The state machines are projected from figure 1.

5.3 Integration of the ISDN reference model onto the OAN architectural configuration

To assist with the understanding of possible implementations of Basic access ISDN and Primary rate access ISDN using an OAN, figure 3 has been developed. This confirmed that the existing or proposed defined ETSI access standards for the ISDN could be utilised without modification.



f: Optical fibre
c: Copper twisted pair
FTTH: FibreTo The Home
FTTC: Fibre To The Curb

Figure 3: Example of an OAN reference configuration for the ISDN

6 General requirements of an optical access network

The following items have been identified as requiring study and have been allocated a study point number. This list is not considered complete so that when new items are identified they can be allocated a study point number. Some of the items listed below have been considered and the results are given in the study item together with a status from the "living list procedure" as agreed in ETSI STC TM3.

6.1 Wavelength allocation

STUDY POINT 1

It has been proposed that at least for point-to-multipoint systems one method to reduce ONU component cost is to have an initial allocation of wavelength window to 1310 nm in the direction ONU to OLT.

Status: Agreed.

STUDY POINT 2

In the other direction (OLT to ONU), other service applications need to be defined before the wavelength allocation can be defined.

The entry strategy for TV distribution and other applications are to be defined.

Status: Under study.

Work to be done: Contributions required.

6.2 ONU functional definition

STUDY POINT 3

The ONU provides an optical interface towards the ODN and implements the interfaces at the customer side of the OAN. It can either be located on the customer's premises (FTTH, Fibre To The Office (FTTO)) or in the field as part of the optical access section (FTTC). It comprises the means necessary for delivering the different services that are to be handled by the system.

Figure 4 shows the functional decomposition of the ONU.

An ONU consists of:

- core shell including:
    - ODN interface function;
    - transmission multiplexing function;
    - customer and service multiplexer function;
- service shell including:
    - service interface functions;
- additional common functions including:
    - OAM function;
    - power supply function.

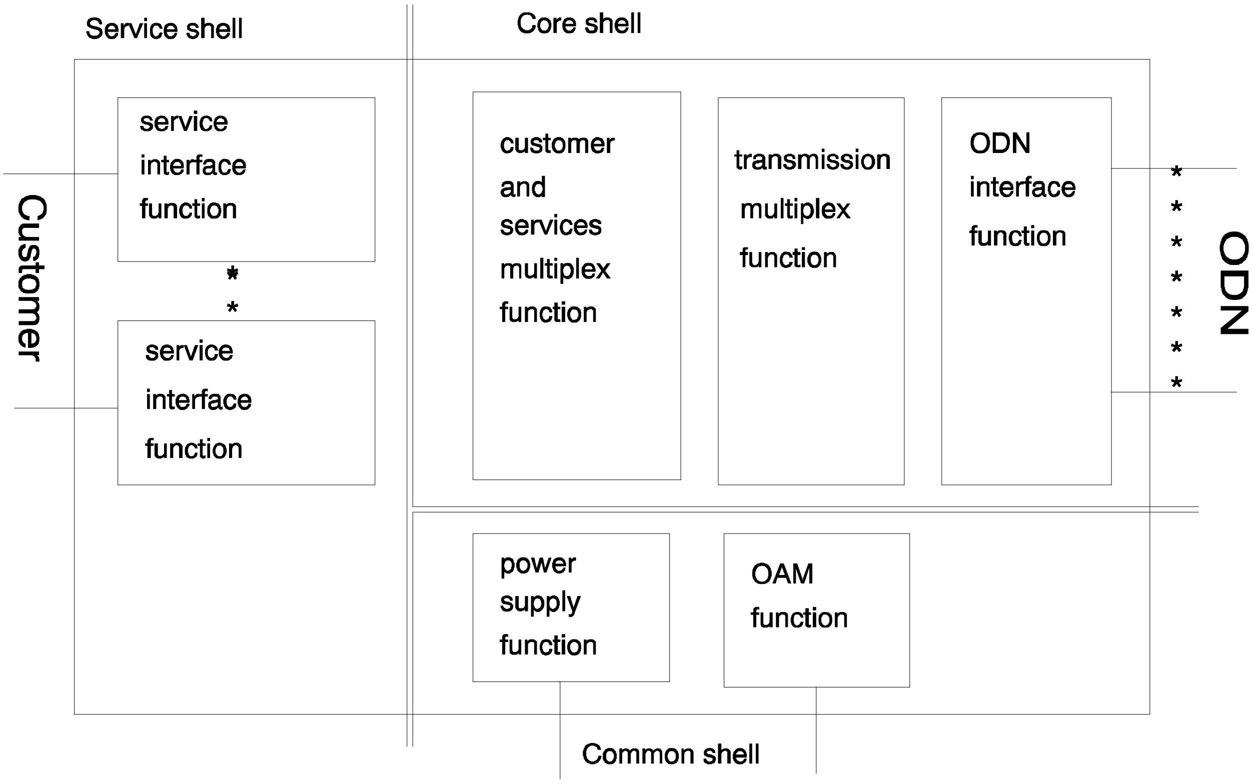


Figure 4: ONU functional blocks

6.2.1 Description of functions

ODN interface function:

This functional block provides a set of optical physical interface functions terminating the relevant set of optical fibres of the ODN. As an option also protective switching functions may be provided.

It may include a physical interface function for interactive and/or distributive signals using a suitable signal format terminating the appropriate set of optical fibres of the ODN. More than one physical interface may exist if more than one fibre is used per ONU, for instance for separation of transmission directions or of different types of services. It includes Optical/Electrical and Electrical/Optical conversion.

transmission multiplexing function:

For interactive services it provides the necessary functions for evaluation of the incoming signal from the ODN interface function extracting the information relevant to this ONU.

As an option security function (see subclause 6.6) may be provided.

For distributive services this function may not be necessary.

customer and service multiplexer function:

For interactive services it assembles/disassembles the information from/to the different subscribers and connects the individual service interface functions.

For distributive services this function may not be necessary.

service interface functions:

It provides the customer access for a service both interactive and distributive. The function can be provided for a single customer or a group of customers (e.g. for Cable Television (CATV)).

It also provides signalling conversion functions according to the physical interface (e.g. ringing, signalling, Analogue to Digital (A/D) and Digital to Analogue (D/A) conversions).

OAM function:

It provides OAM functions for all functional blocks of the ONU (e.g. control of loopbacks in the different blocks). Such functions can be extended to the subscribers connected to the ONU.

For local control an interface may be provided for testing purposes.

power supply:

Power may be provided locally (from mains) or remotely. Power supply can be shared by several ONUs.

Battery back-up may be provided.

Status: Under study.

Work to be done: Further contributions are requested to address these issues.

6.3 Optical power budget

STUDY POINT 4

The R and S reference points are shown in figure 5 and can be considered as the physical position after the first connection point to the equipment. Five cases of applications are considered but this is not an exhaustive list (e.g. the use of optical amplifiers as a booster within the equipment could be considered). Case 5 shows an example of the use of an optical amplifier within the network. It is recommended that for this case additional R and S reference points are included as shown, however further study is required.

It should be noted that maintenance WDMs could be included either within or outside the R and S region.

The maximum optical path allowance is initially described and the minimum value requires further study. It is recommended that within the maximum optical path loss allowance we include the following:

- optical loss of fibre cable and passive components;
- optical plant margin including:
    - future modifications to cable configuration (additional splices, increased cable lengths, changing splitters, etc.);
    - variations due to environmental factors;
    - degradation of any components between the S and R reference points.

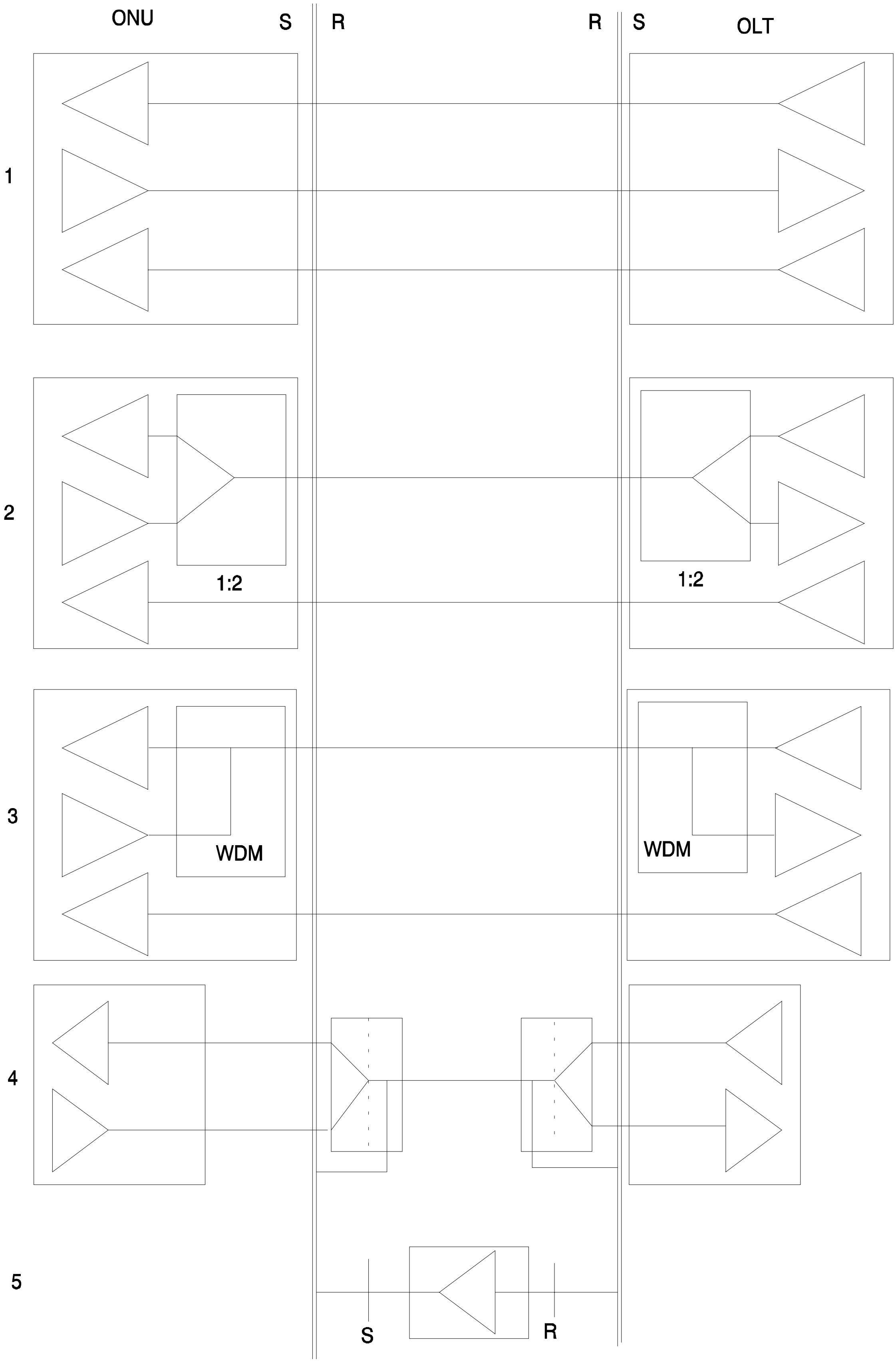


Figure 5: Reference configuration for the R and S reference points

The equipment margin is considered as outside of the R and S reference points (equipment margin includes the effect of time and environmental factors on equipment performance).

It is assumed that four maximum optical path loss allowances are required. Initially these maximum are suggested as up to 15 dB, 15 dB to 25 dB, 25 dB to 35 dB and 35 dB to 45 dB. These values should be used to stimulate further information.

It is recommended that the statistical calculation of optical path loss allowance is used by the network operator.

Status: Under study.

Work to be done: It is recommended that the subject of reflections and dispersion are studied for the identified cases of applications.

More inputs to define the cases of application are required in order to achieve the desired practical planning rule (e.g. analogue/digital transmission, wavelength ranges etc.).

6.4 Upgrade possibilities

STUDY POINT 5

It is anticipated that new services, (such as B-ISDN bearer capabilities), which are currently not cost-effective or not developed, will emerge, and should be supported by the OAN. The means for upgrading the OAN to transport these services should themselves be cost-effective and practical, and cause a minimum amount of disturbance to existing customers on the network, as they are implemented.

Some possible mechanisms include the principles in the following subclauses.

6.4.1 ODN Considerations

The basic and most cost intensive element of the Fibre In The Loop (FITL) system is the cable network. Therefore initial installation of spare fibres (or providing ducts for later fibre provisioning) in the distribution part of the network between optical splitting point and ONU, and even in the drop section, provides the largest flexibility for later upgrade of new services (e.g. B-ISDN) and for utilizing new technologies.

Upgrade to B-ISDN will be possible:

- in the drop section; by using the spare fibres or by installation of additional fibre cables in tubes/subducts or ducts;
- in the distribution/feeder section; by adding further optical wavelengths to the existing fibres;
- using spare fibres; by the installation of additional fibre cables in tubes/subducts or ducts.

The network for distributive services could allow to provide analogue and digital TV in parallel (e.g. analogue TV in 1310 nm range and digital TV in 1550 nm range) without influencing the evolution of the interactive services.

6.4.2 ONU Considerations

The OAN could be prepared in advance for future upgrading by inclusion of optical filtering in front of the optical receivers in the ONUs at the time of installation of the network. This filtering has to block selectively the wavelength region that is not in use by the transmission system for narrow band services. The narrowband service signals being passed remain virtually unaffected. The B-ISDN transmission system can occupy the wavelength window left unused.

In this way a smooth transition towards B-ISDN is made possible which may include an interim period of co-existence of narrow band and broadband service signals carried on the same OAN. It involves only a minor additional provision in the design of the narrow band ONUs to be implemented in the OAN.

6.4.3 Protocols

Some requirements for a common frame structure are to:

- define a flexible architecture independent of the services carried (POTS, leased lines, ISDN, etc.);
- define an architecture which will be compatible with future broadband services without defining as much different systems as evolutions;
- define an architecture independent of the transmission method; this frame must be supported either by a half duplex method, a full duplex method or a diplex method, or a simplex method;
- define a frame organization independent of the splitter ratio (fine granularity independent of any normalized interface).

Status: Under study.

Work to be done: Contributions are required.

6.5 Operations, Administration and Maintenance (OAM)

STUDY POINT 6

If OAM functions are identified in a random approach there is a danger that some requirements may be overlooked. To prevent this from happening, a framework has been used which consists of two axes along which the OAM functions can be classified. The first axis consists of the functional sub-system of the OAN to which the OAM function relates. The second axis is the OAM functional category to which the OAM function belongs.

This allows a number of OAM functions to be readily identified. The list which is generated is extensive, but not exhaustive as some functions may still have been overlooked. No attempt is made to prioritize the OAM functions at this stage.

OANs are already considered to be divided into an OLT and ONUs which are connected by optical fibre (ODN). The OLT interfaces to the exchange and the ONUs interface to the customer.

6.5.1 Analysis of OAM requirements by functional sub-systems

For the discussion of OAM, a logical division into functional sub-systems is more appropriate. The sub-systems described below provide a basis for the analysis of requirements.

Enclosures:

This sub-system includes the shelving and racking at the OLT and the ONUs. Enclosures also include any indicators (LEDs, lights, bells, etc.) which are not contained on the cards, and any fibre management equipment. Also included are the field-located housings for the optical splitters of a Passive Optical Network (PON) type OAN. The splitters themselves are not included as they are part of the optical sub-system.

Power:

This sub-system includes the powering of the shelves and racks at the OLT and at the ONUs. The ONUs are likely to contain a power supply unit. At the OLT there is likely to be a power unit per shelf and/or a power unit per rack. Power supplies may be duplicated for security.

Powering of the active electronics in remote ONUs is a significant challenge, particularly in the event of the failure of the primary supply.

Transmission:

This consists of transmit and receive electronics and opto-electronics at the OLT and at the ONUs. Fibre management equipment is deemed to be part of the Enclosures sub-system, and the optics (fibre cabling, filters, splitters, filters, etc.) are dealt with separately.

Optical sub-system:

This sub-system transcends the OAN as it has the ability to support other systems. It consists of fibre in all its forms, the splitters, filters, and any Optical Time Domain Reflectometer (OTDR) equipment or clip-on optical power meters. Enclosures are treated separately, and components which are specific to the OAN are not included as part of the optical sub-system. Fibre management which is specific to the OAN is included under the Enclosures sub-system.

Service sub-systems:

These consist of the sub-systems which tailor the generic core of the OAN to support different services. Two examples of services are Public Switched Telephone Network (PSTN) services and ISDN.

The PSTN line unit related OAM functions can be separated into:

1) line circuit configuration;
2) line circuit operation;
3) line circuit supervision;
4) line terminal supervision.

Line circuit configuration:

The configuration data of the line circuit are:

- mux address: the address of the line circuit in the multiplex section of the ODN;

- function selection: different parameters have to be set in order to put the line circuit into the correct configuration:

    - Voice Frequency (VF)-relative input level;
    - VF-relative output level;
    - VF-impedance;
    - metering pulse frequency;
    - metering pulse level.

Line circuit operation:

There are different operational states to be performed by the line circuit:

- normal operation;

- digital test loop. In case of a digital test loop the digital data dedicated for the line circuit is looped through the line circuit. The terminal is disconnected;

- analogue test loop. In the case of the analogue test loop the analogue VF-output signal is connected to the VF-analogue input. The terminal must be disconnected;

- copper line test. During copper testing the measurements described in line and terminal supervision below are executed;

- blocking. In the case of severe fault of the line (i.e. external voltage, short circuit) the line circuit interface has to be blocked.

Line circuit supervision:

Supervision of a POTS line circuit.

The line circuits will be supervised during normal operation. In the case of the specified values being exceeded an alarm will be set.

Supervision of feeding current conditions:

Direct Current (DC) voltage < 75 % U_{MIN} (where U is the minimum DC line feed voltage).

Supervision of ringing generator:

Alternating Current (AC) voltage < 75 % $U_{\sim MIN}$ (where $U_{\sim}$ is the minimum AC ringing generator voltage).

Supervision of metering pulse signal:

For further study.

Line and terminal supervision:

Supervision of a POTS a/b line and terminal: the a/b wire will be supervised against faults. This may happen as an automatic test. In the case of exceeding the defined maximum and minimum levels an alarm will be set. External voltages at the line will be identified by invalid current values.

Idle feeding current:

A fault will be detected if 0,1 mA < I_{Fpas} < 5 mA

Idle difference current:

A fault will be detected if 0,5 mA < I_{difpas}

Active feeding current:

A fault will be detected if 13 mA < I_F < $I_{Constant}$

Active difference current:

A fault will be detected if I_{dif} > 7 mA

Passive line termination:

A fault will be detected if the measured impedance exceeds (100k Ω < R < 500k Ω) + (Diode)Ω.

Idle terminal impedance:

The ringer impedance will be measured and if the impedance exceeds the value resulting from R < 10k Ω and C > 330 nF a fault will be detected.

NOTE: The values given above are one example and are for further study.

6.5.2 Analysis of OAM requirements by functional category

There are different ways in which OAM functions can be categorised. The categorisation used here is derived from the Open System Interconnection (OSI) management information service definition architecture. In addition, testing has been included in the performance management category in accordance with the other aspects of OSI fault management category.

The five categories used here are:

1) access & security management;
2) configuration & resource management;
3) performance management;
4) event (alarm) management;
5) financial (accounting) management.

The call and traffic statistics monitoring aspect of performance management and the entire category of financial management will not be discussed further. These are seen as out side the scope of this ETR.

6.5.2.1 Access and security

The access aspect of this category relates to who or what can gain access to the system and its resources. The security aspect relates to the integrity of the data in the system and the fall back arrangements, for instance in the event of loss of communication with higher level management. Functions for discussion in this category include:

1) enclosures:
   a) prevention of unauthorised physical access to enclosures;
   b) security of enclosures against deliberate or accidental damage.

2) power:
   a) possible duplication of power suppliers with transparent switch-over;
   b) back-up in the event of a primary supply failure.

3) transmission:
   a) detection of access to the system by unauthorised ONUs;
   b) security of transmission between the OLT and ONUs, including duplication where required;
   c) security of stored configuration data;
   d) fail-safe operation of lasers in remote ONUs to ensure these cannot transmit at random;
   e) security of any down-loadable transmission software.

4) optical sub-system:
   a) support of access by clip-on power meters if required;
   b) support of access by OTDRs if required;
   c) detection of unauthorised tapping of optical signals.

5) service sub-systems:
   a) security of service specific configuration data;
   b) security of any service specific down loadable software.

6.5.2.2 Configuration and resource management

Configuration management relates to the logical arrangement and topology of the resources within the OAN. Configuration management is responsible for the provision, modification and cessation of capabilities within the system. It also controls reconfiguration for traffic control and any reconfiguration which is required during and after testing.

Resource management relates to the physical organisation and detailed structure of the system. It is responsible for keeping an inventory of the components which make up the system, including their version numbers. Resource management is highly implementation dependant.

Functions for discussion in configuration and resource management include:

1) enclosures:
   a) support of simple and convenient working practices;
   b) simple indication, possibly visual, of configuration of internal components.

2) power:
   a) configuration of duplicated power supplies;
   b) support of system auditing.

3) transmission:
   a) configuration of bandwidth between the OLT and ONUs;
   b) initialisation of ONUs;
   c) maintenance of an inventory and status of ONUs and general support of system auditing.

4) optical sub-system:
   a) possible support of identification of OANs and their branches by clip-on power meters or OTDR through "finger-printing";
   b) switching of OTDRs between OANs if required;
   c) support of system auditing.

5) service sub-systems:
   a) reconfiguration for line test;
   b) reconfiguration for loopback tests;
   c) configuration of line cards in ONUs;
   d) upgrading of line cards in ONUs and of exchange interface at the OLT;
   e) support of system auditing;
   f) re-provisioning through the use of spare line circuits in ONUs.

6.5.2.3 Performance management

This category has two aspects. The first involves the collection of call and traffic statistics. This is likely to be the responsibility of the exchange for the immediate future, but could be off-loaded to an OAN plant controller element manager function in the long term.

The second aspect involves the on-going monitoring of the system. Since automatic routine testing of the system is included here, performance management is also taken to include testing which is initiated through human intervention or in response to an alarm. The passive monitoring of the system can act to supplement alarms by providing status information and can also initiate alarms.

The functions for discussion in performance management include:

1) enclosures:
   a) support of visual monitoring of enclosed components;
   b) environmental monitoring of enclosures.

2) power:
   a) operational status of power supplies;
   b) monitoring of degradation of power supplies;
   c) power supply testing.

3) transmission:
   a) block error rate monitoring for measurable error rates;
   b) monitoring of S/N for very low errors;
   c) monitoring of ranging delays and received power level where applicable;
   d) diagnostic testing of transmission.

4) optical sub-system:
   a) monitoring of OAN degradation;
   b) fault location on the OAN.

5) service sub-systems:
   a) monitoring of exchange interface at the OLT;
   b) monitoring of the lines at the ONUs;
   c) testing of the exchange interface at the OLT;
   d) testing of the line at the ONUs;
   e) loopback testing of service capability;
   f) installation testing of services.

6.5.2.4 Event (alarm) management

Alarms are raised to give notice of events which can jeopardise service. These events may be logged or correlated, and may be generated automatically or through an external agency. Alarms have different degrees of priority and urgency.

The most common response to an alarm will be an attempt to locate the fault through performance management functions. Ideally alarms should be incorporated into a strategy of scheduled preventative maintenance which should reduce the need for the crisis management associated with high priority alarms.

The issues of the alarm priority and the masking of alarms to prevent the swamping of the network management layer are relevant to all functional sub-systems. The other functions for discussion for event (alarm) management include:

1) enclosures:
   a) environmental alarms at the ONUs;
   b) fault location alarms at the OLT.

2) power:
   a) power unit failure;
   b) power source failure.

3) transmission:
   a) loss of communication with an ONU;
   b) failure of transmission system at the OLT;
   c) excessive errors;
   d) excessive variation in received signals.

4) optical sub-system:
   a) fault discovered by automatic testing.

5) service sub-systems:
   a) exchange interface alarms at the OLT;
   b) fault discovered by routine testing of lines at ONUs.

It has been agreed that the OAM of the OAN should be via a "Q" type interface. This will allow the access to develop independently of the switch development. However it has been recognised that there will be a need for the switch to have the knowledge of the availability of channels within the OAN. This will therefore require a "blocking" function to be indicated across the switch interface.

Status: Under study.

Work to be done: Contributions are required.

NOTE: ETSI STC SPS3 are defining "Objects" for the Q_{AN} interface related to the V5 interface and its associated user ports, and STC TM2 are defining the “Information Model" for an OAN. However, the physical aspects of the "Q" interface still need to be defined.

6.6 Security

STUDY POINT 7

Security of the equipment and of the data.

The council of EC has made a proposal (SYN 287 [10] & SYN 288 [11], Brussels September 1990) for a council directive concerning the protection of personal data and privacy of public network.

Also the directives of some European countries demands security measurements in public networks.

Due to the distribution characteristics of an OAN, data of one customer reaches in downstream directions all ONUs on that OAN. Therefore it is very important to consider the security aspects on this network.

The Scope of this section covers the security related aspects and functions of the access network.

This study item may eventually be included with the OAM study point. However from the discussions it has been agreed that the initial definition should use the security level of the copper network as a minimum basis for this work. The security at the physical layer can be defined and as an example the requirements of the mobile network could be considered as a basis for further studies. The use of network security functions requires further study whilst the use of end-to-end application security functions may be left to the customer.

In order to progress this work it is recommended that the security aspects referred to in the following subclauses are considered. However these aspects can also be used as a basis to stimulate further contributions.

6.6.1 Reasons for security

6.6.2 Reference model (functional model of OAN)

6.6.3 Threats

- e.g. impersonation, eavesdropping of data.

6.6.4 Requirements

- to reduce this threats;
- from EC SYN 287 [10] & EC SYN 288 [11] (privacy);
- from service providers.

6.6.5 Functions and mechanisms

- security architecture;
- realization of security mechanisms, algorithms, etc.

6.6.6 Integration of additional security

- integration of mechanisms;
- on which place encryption ?

6.6.7 Security management

- key management, e.g. for authentication; and
- encryption.

6.6.8 Security recommendations

- which security functions and mechanisms;
- and where, on which interface.

Status: Under study.

Work to be done: Contributions are required.

6.7 Safety

STUDY POINT 8

- to the customer;
- to the network operator.

This study item may eventually be included with the OAM study point.

Work to be done: Contributions are required.

6.8 Reliability and availability

STUDY POINT 9

6.8.1 Methodology steps

The Network Elements (NEs) as in figure 6 (reference configuration (based upon those elements which can be considered as autonomous or replaceable)) which affect the reliability between the points A and B (exchange and user side).

To establish the Time To Repair for each individual (TTRi) (repairable) network element.

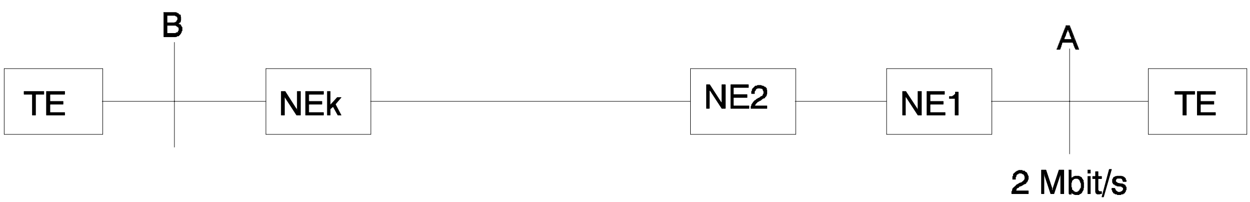


Figure 6: Reference configuration

To establish the failure rate objective per network element (Fi failures per year). A distinction must be made between service affecting failures and those failures requiring maintenance actions.

To establish the number (ni) of each type of NEi of the system.

6.8.2 Reliability related parameters

The above methodology allows the establishment of the technical data required for the evaluation of:

- the unavailability per line (minutes per year); and
  the number of repair actions (indicated as actions per year for a typical local exchange line).

$$\text{Unavailability} \leq U = \sum_{i=1}^{k} [\text{Fi (service affecting)} \times \text{TTRi}] \qquad \text{(minutes/year-line)}$$

$$\text{Repair action} = RA = \sum_{i=1}^{k} (n\,i \times Fi) \qquad \text{(per year and per system)}$$

Fi (all failures)

6.8.3 Availability

The reference configuration will allow the service availability to be related to the equipment reliability in a clearly defined way, aiding both network operators and equipment manufactures. The end to end channel unavailability is defined as existing between the customer and the network (e.g. local exchange). It is recognised that other transmission systems may exist in the access network which would have an effect on the service availability as seen by the user. Therefore these systems should be included in the reference configuration.

It is considered that OAN technology is too immature at this time to allocate actual values to the end to end unavailability objective to the different elements of the OAN.

This study item may be eventually be included with the OAM study point.

Status: Under study.

Work to be done: Contributions are required.

6.9 User-network interfaces and network interfaces

STUDY POINT 10

It has been identified for the PSTN that there is a requirement for a digital 2 Mbit/s exchange interface that enables POTS to be carried via an access digital link. This interface has been designated “V5", see ETS 300 324-1 [7] and ETS 300 347-1 [13].

Status: Completed.

6.10 Leased line bearer capabilities for n x 2 Mbit/s

STUDY POINT 11

There has been no input to this study item.

Status: Under study.

Work to be done: The use of n x 2 Mbit/s needs to be established and contributions are required.

6.11 Transfer signal delay

STUDY POINT 12

A minimum value for delay of 0,5 ms has been proposed. However it has been suggested that a maximum delay value should be defined.

It can be shown that a transfer delay exists between the subscriber and the local exchange, this will include the delay of the OAN and the delay of the feeder section. The delay of the feeder section is considered outside the scope of this ETR. The delay of the OAN has been identified as that existing between the user side of the ONU and the network side of the OLT.

In ETS 300 233 [12] the mean one way transfer delay between V and T for the Primary rate access digital section is as 1,25 ms that applies irrespective of the type of transmission.

However, for optical transmission system that need other requirements due to specific functions and techniques i.e. Time Division Multiplexing (TDM), Time Compression Multiplexing (TCM) or increased functionality in the OLT, excessive transfer delay figures have to be studied.

Status: Under study.

Work to be done: Network operators to identify if there is any regulatory limits on the permissible delay value. There may be a requirement to liaise with other STCs to agree the final value.

6.12 ODN functional definition

STUDY POINT 13

The functions that have been identified are:

- optical connection;
- optical distribution or branching;
- optical splitting/combining;
- optical de-multiplexing/multiplexing;
- change of an optical multi-customer signal function into n single-customer signal functions (point-to-multipoint) or vice versa;
- optical amplification;
- optical network maintenance;
- optical interfaces.

Status: Under study.

Work to be done: Contributions are requested to address these issues.

6.13 OLT functional definition

STUDY POINT 14

The OLT provides an optical interfaces towards the ODN and provides one or more network interfaces on the network side of the OAN. It can be either located within a network termination or at a remote location. It comprises the means necessary for delivering different services to the required ONUs.

Figure 7 shows the functional decomposition of the OLT.

An ONU consists of:

- Core shell including:
  - ODN interface function;
  - transmission multiplexing function;
  - subscriber and service cross-connect functions.

- Service shell including:
  - network tributary interface functions;
  - signal processing function.

- Common shell including:
  - power supply function;
  - OAM functions.

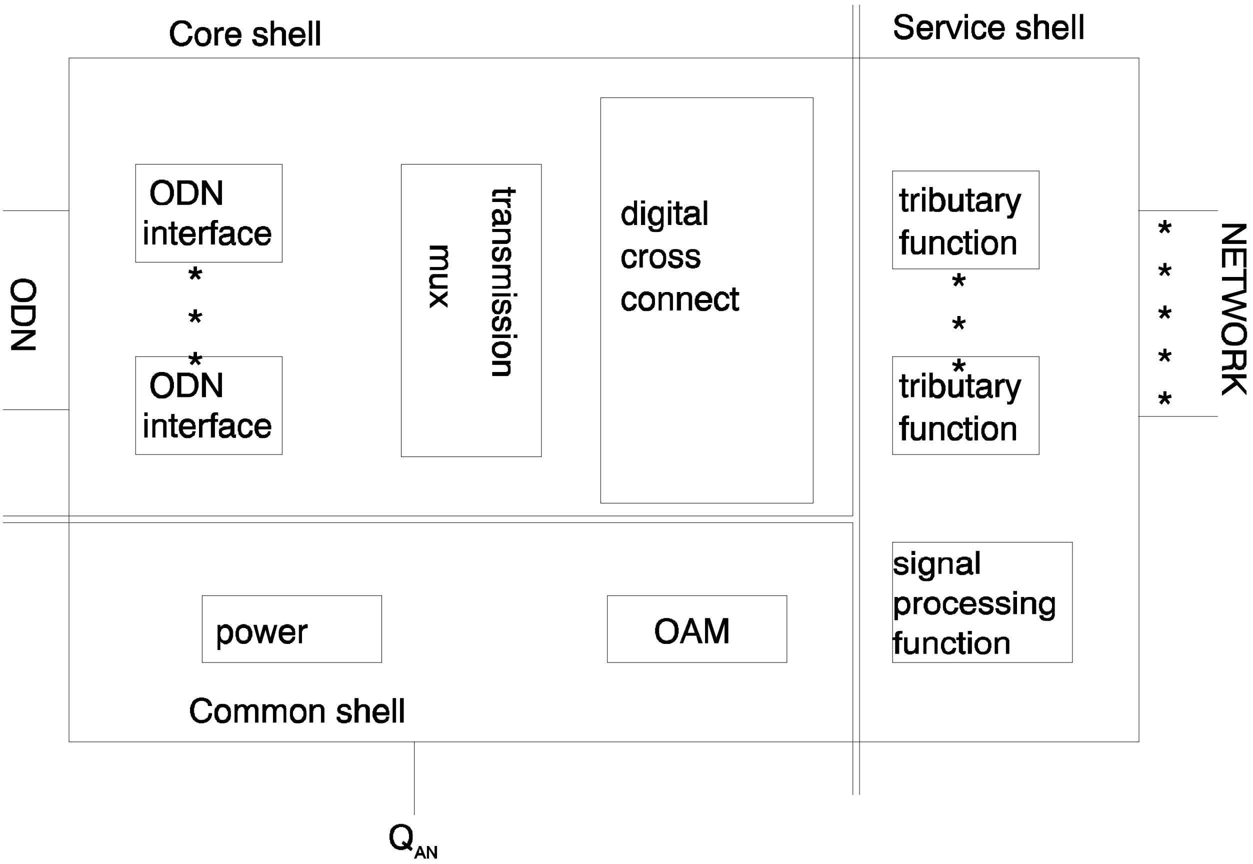


Figure 7: OLT functional blocks

6.13.1 Description of functions

ODN interface function:

This functional block provides a set of physical optical interface functions terminating the relevant set(s) of optical fibres of the ODN(s).

It may include a physical interface function for interactive and/or distributive signals using a suitable signal format terminating the appropriate set of optical fibres of the ODN. More than one physical interface may exist if more than one fibre or one ODN is used per OLT. It includes optical/electrical and electrical/optical conversion.

Protective switching functions may be incorporated in this function.

transmission multiplexing function:

For interactive services it provides the necessary functions for transmitting or receiving service channels over the ODN.

subscriber and service cross-connect function:

This provides connectivity between the available bandwidth at the ODN side and the network parts at the network side.

network tributary function:

This function adapts the network interfaces to other OLT functions and vice versa.

signalling processing functions:

This function comprises all the means necessary for handling signalling information through the OLT. However this function may not be required as further study is necessary.

OAM function:

It provides OAM functions for all functional blocks of the OLT. It also provides an interface function, for local control an interface may be provided for testing purposes, and Q interfaces.

power supply function:

This function converts an external power source to the required level.

Status: Under study.

Work to be done: Contributions are requested to address these issues.

7 Short-term solutions

7.1 Introduction

This example describes one possible point-to-multipoint (Personal Communications Network (PCN)) solution for a FITL system (which was introduced during 1993/94). Point-point (single star) solutions may also exist, but are not described here.

The system must cost-effectively satisfy today's customer needs. This can be reached by providing only a limited number of interactive services (mainly POTS and narrowband ISDN) and by being fully compatible with existing CATV distribution networks. The system has to be able to evolve, i.e. it must be upgradable to allow the support of B-ISDN and digital TV. The main cost driving factor is the installation of the cable network. Therefore the initial installation should allow later extension to future services without additional trenching.

7.2 Architectural configuration

Due to the fact that the electrical to optical converters for the 1310 nm wavelength region and higher will still be fairly expensive, a system supporting several users per ONU (FTTC or FTTB) combined with sharing of optical components may be considered for a short term solution, evolvable to FTTH. The discussed system consists of an OLT connected via an OAN to several ONUs. The OLT provides interfaces at the network side to a Local Exchange carrying switched interactive services (e.g. V5), to other network elements carrying non switched or non locally switched services (e.g. data services via leased lines) and to a TV head-end which provides distributive services. The OLTs for interactive services and distributive services may be located separately. The ODN may use separate fibres for interactive and distributive services (if possible within the same cable) and includes only passive optical components (with the exception of optical amplifiers which may be used in the ODN). The ONU provides at the user side symmetric pairs for interactive services and coaxial pairs for distributive services. The upstream OAM channel for distributive services may be routed via the interactive part of the system.

In the case where the separation of the interactive and the distributive part of the FITL system is provided independent technical evolution of both type of services is permitted which provides flexibility with regard to later upgradability to B-ISDN and to digital TV.

There are a number of possible implementation for the OAN. In figures 8 to 12: W stands for WDM, C for Coupler, T for Transmitter and R for receiver, IS for Interactive Services, DS for Distributive Services.

1) 1 fibre, 2 wavelengths:

L1 is used for Distributive Services, and L2 for Interactive Services. Suitable methods, e.g. ping-pong or sub-carrier multiplexing techniques may be used to avoid degradation of the Interactive Services due to reflections in the ODN. Spare fibres may be installed to cater for future upgrades (for example for Asynchronous Transfer Mode (ATM) services).

There might be another splitter inserted between OLT and the WDM to match the possibly different power budgets for the IS and DS services.

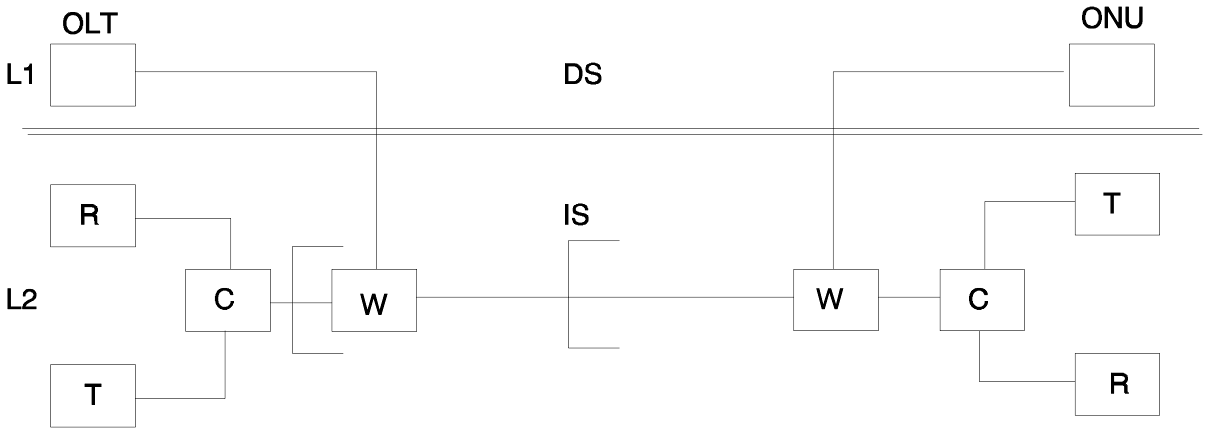


Figure 8: Implementation for the OAN (1 fibre, 2 wavelengths)

2) 2 fibres, 1 for upstream and 1 for downstream traffic:

Compared to the previous system implementation, a second fibre is used for upstream Interactive Services. The Distributive Service is still realized via WDM coupling. One window is free for future applications on the IS return fibre.

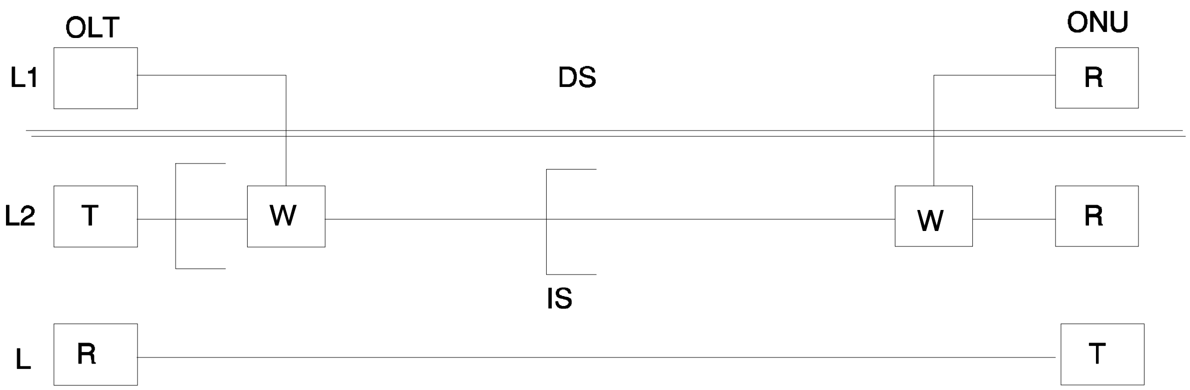


Figure 9: Implementation for the OAN (2 fibres)

3) 2 fibres, 1 for Interactive and 1 for Distributive Services:

In this case the Interactive and Distributive Services use separate fibres. Only 1 wavelength is used for each fibre. This leaves one window free in each fibre for future applications. On the Interactive Service fibre, e.g. a ping-pong technique can be used to avoid degradation due to reflections. The splitting factor of the DS and IS network can be different and optimized for the application.

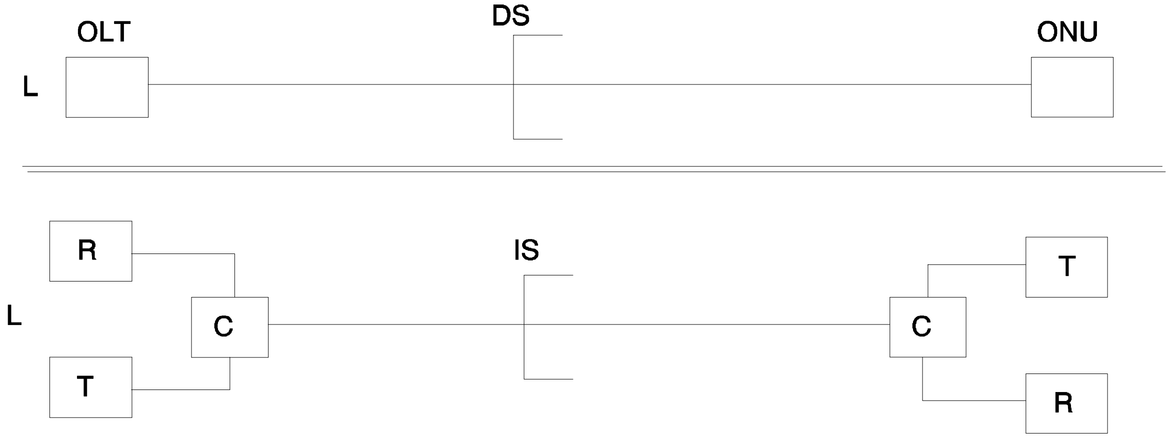


Figure 10: Implementation for the OAN (2 fibres, 1 for IS and 1 for DS)

4) 2 fibres, 1 for Interactive and 1 for Distributive Services:

The difference between this implementation and the previous one is that the Interactive Services fibre uses 2 wavelengths, 1 for upstream traffic and 1 for downstream traffic. The splitting factor for the DS and IS network is not necessarily the same. One window is free for upgrades.

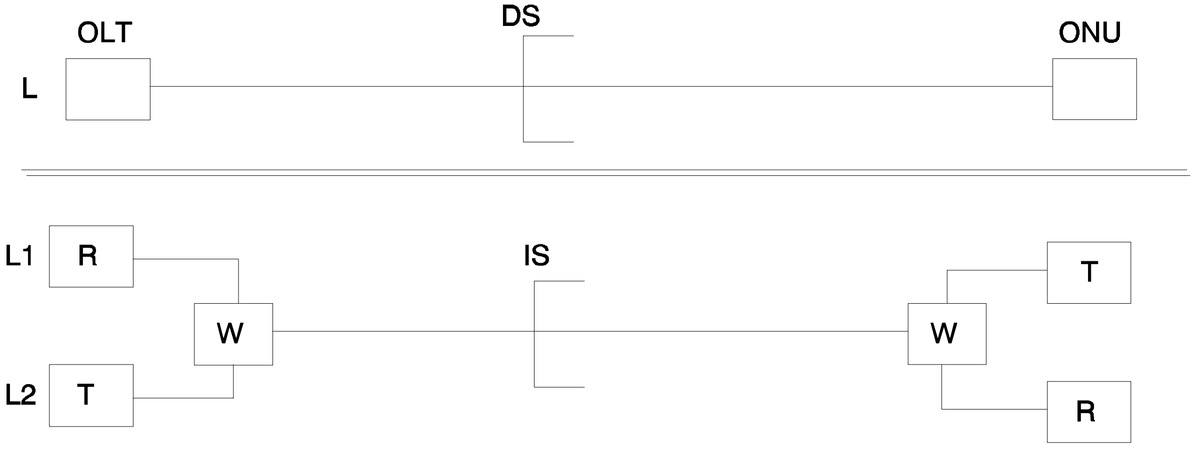


Figure 11: Implementation for the OAN (2 fibres, 1 for IS (2 wavelengths) and 1 for DS)

5) **3 fibres, 2 for Interactive and 1 for Distributive services:**

This solution is relatively easy to implement but requires a greater number of fibres. It also would be relatively simple to upgrade.

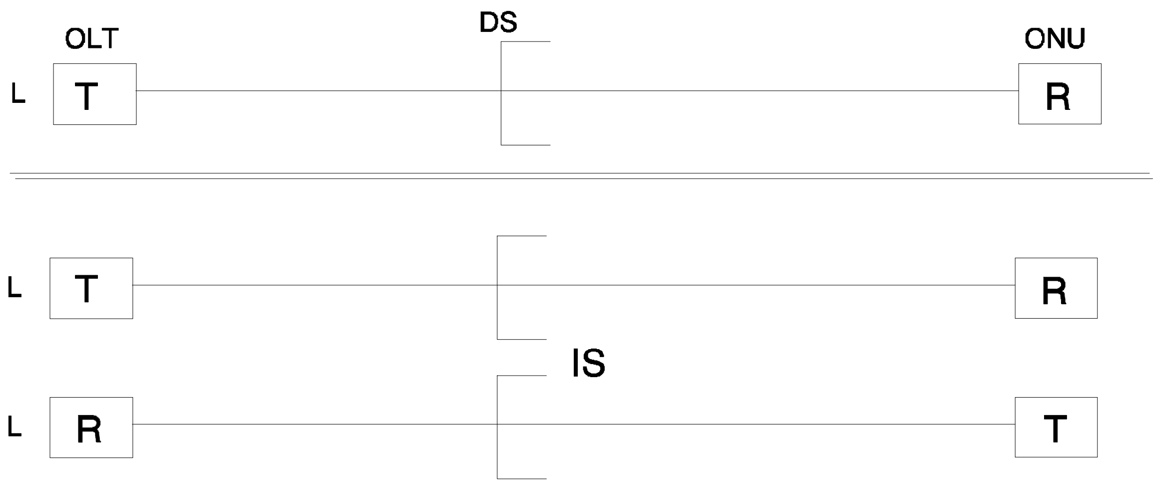


Figure 12: Implementation for the OAN (3 fibres, 2 for IS and 1 for DS)

More fibre solutions are also possible, but are not discussed here.

7.3 Interactive services

A short term solution provides existing services only. The supported services are POTS, Basic access ISDN, Primary rate access ISDN and data services (up to 64 kbit/s and 2 Mbit/s).

7.4 Distributive services

Distributive services (broadcast and audio/video signals) may be transmitted in the direction towards the subscriber on separate fibre or different wavelength. The upstream OAM channel may be carried by the interactive network. For TV distribution a VSB/AM signal format may be used as within today's coaxial CATV networks. This allows for simultaneous distribution of a fairly large number of programs without any need for changes in today's available coaxial home cabling networks, TV sets and Video Cassette Recorders (VCRs). Depending on the available power budget and the use of optical power amplifiers or external modulators this approach may require more than one fibre in the feeder part of the FITL system to supply TV signals to the same number of connected ONUs as in the interactive part of the system.

7.5 Exchange interface

The interface between OLT and local exchange will be preferably an open interface e.g. V5.

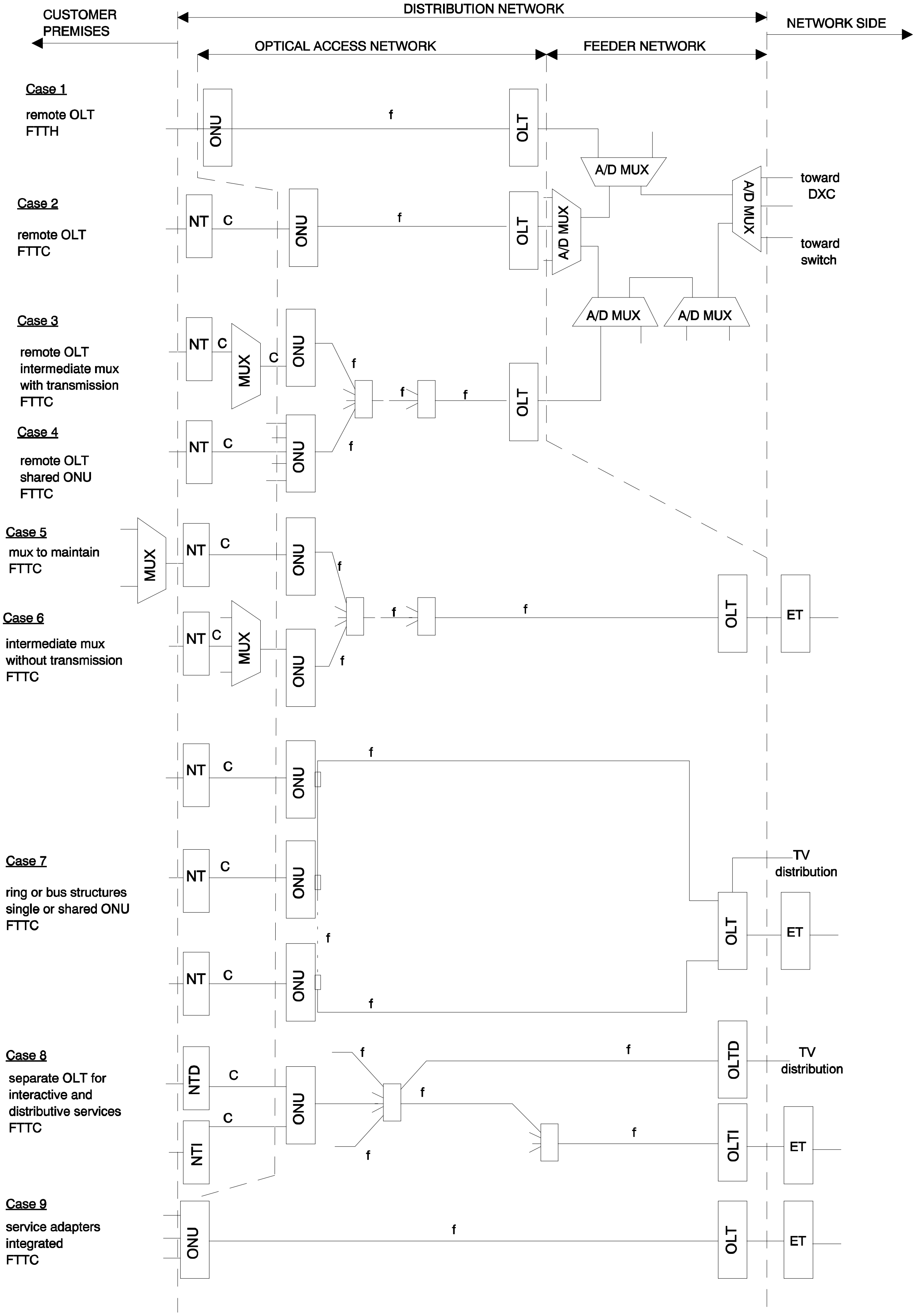
7.6 Operations, Administration and Maintenance (OAM)

The OLT provides an OAM interface for handling access network specific OAM functions. The splitting of the OAM functionality between the exchange and access network depends on the used interface between OLT and local exchange.

7.7 Powering

Powering of ONUs may be done locally at the subscriber site or at the kerb by the power utility. In both cases battery back-up can be provided to ensure operation in case of power supply failure. What kind of power supply of the ONUs is used depends mainly on the topology and ONU size (available space in the ONU housing for batteries).

Annex A: Examples of possible implementations of an OAN



History

Document history	
January 1996	First Edition
February 1996	Converted into Adobe Acrobat Portable Document Format (PDF)

ISBN 2-7437-0468-3
IDépôt légal : Janvier 1996