Technical Report
TR-022

The Operation of ADSL-based Networks

ABSTRACT:
This document describes the generic processes required for the operation of ADSL-based network in terms of Network Operational Reference Models (NORMs). It gives greater detail about the process components where this is required to understand how the capabilities of ADSL equipment, network management and testers may be used to plan and build the network, provision service, repair and maintain the network, and monitor network performance.

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The Operation of ADSL-based Networks

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1. Scope

This document describes generic processes required for ADSL-based service operations in terms of Network Operational Reference Models (NORMs). It gives greater detail about the process components where this is required to understand how the capabilities of ADSL equipment, network management and testers may be used. In the process diagrams components that require functionality in equipment, network management, or testers are indicated by shading and a tick.

1.1 Definitions

Generally, services over an ADSL access-based broadband network will be provided and supported by a number of different operational organisations. These organisations may be part of one company or more than one company. Leaving commercial issues aside, it is necessary to have a clear idea of the roles of the different organisations and how the functionality of equipment, network management and test equipment can support their ability to discharge their roles for the benefit of the end customers.

There is much confusion over the use of the words service and network and so it is proposed that a common terminology is described for clarification.

For the purposes of this document a service is an application that runs over an end-to-end connection supported by ADSL access technology. Thus, for example, a Service Provider may provide Internet Access, VOD, or Telephony. A Service Provider does not provide ADSL access.

Access is the digital connection of a customer’s terminal to DSLAM equipment at the local central office via an ADSL.

A regional network is a digital network that connects the DSLAM to a Service Provider’s equipment.

A loop is a metallic pair of wires running from the customer’s premises to the DSLAM.

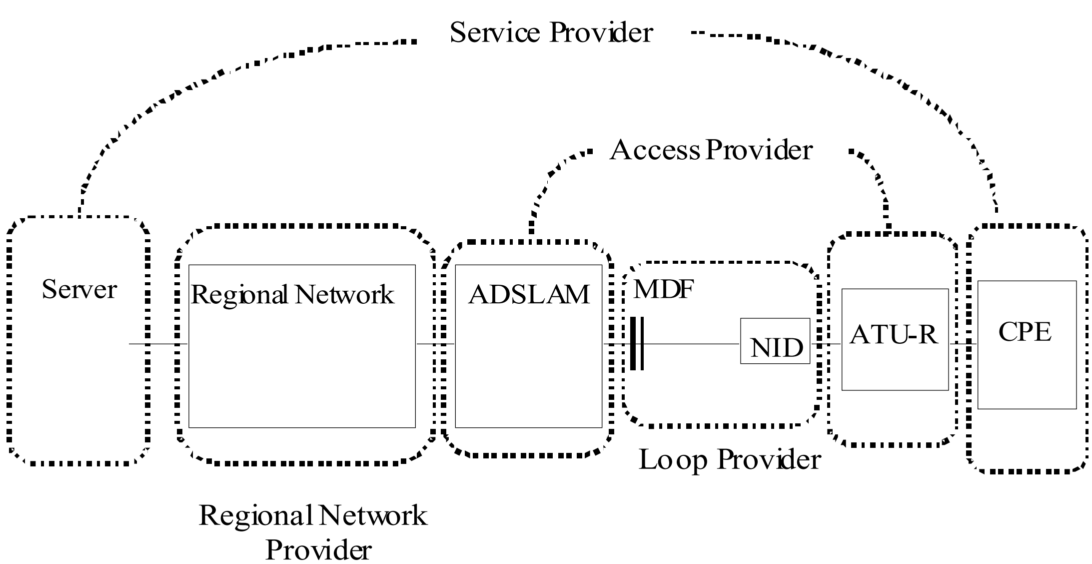


Fig. 1: Provider Architecture

Fig.1 shows the key components of an ADSL access-based broadband network. It indicates ownership of the components to different providing organisations. The role of these providers is as follows:

The Service Provider:
- provides service to the end customer,
- is responsible for overall service assurance and, in particular, the aspects of service that are independent of the network between the server and the customer,
- may provide CPE, or software to run on customer-owned CPE, to support a given service

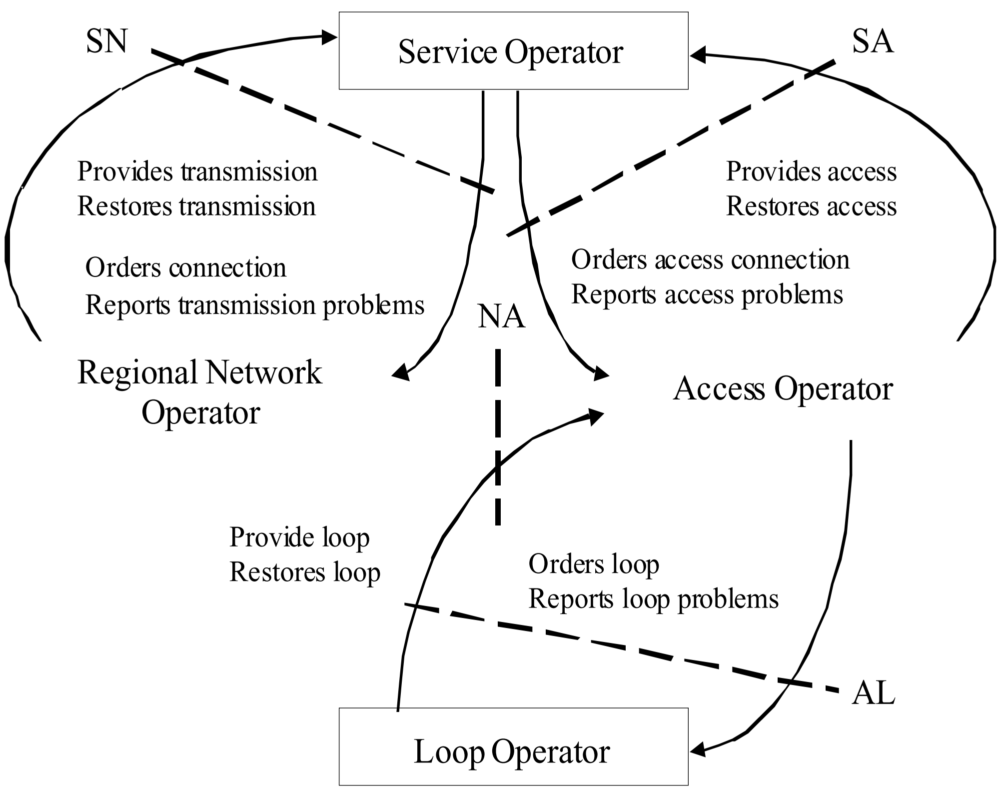
The Regional Network Provider:
- provides appropriate connectivity between the access network and the server.
- is responsible for regional network performance and repair.

The Access Network Provider:
- provides digital connectivity to the customer
- is responsible for the performance and repair of the access transmission equipment.

The Loop Provider:
- provides a metallic loop from the access network equipment to the customer's premises
- is responsible for the integrity of the metallic loop and its repair.

An illustrative relationship between the providers is shown in Fig. 2. To provide a seamless and possibly automated operational environment interfaces between the providers need to be defined.

Fig. 2: Relationship Between Operators



These are:

Service to Access Provider Interface	-	SA
Service to Regional Network Provider	-	SN
Regional Network to Access Provider	-	NA
Access to Loop Provider	-	AL

The definition of the flow of data across these interfaces will be an important enabler for operations and will be the subject of another ADSL Forum Document.

2. Planning & Building

Planning determines where and when equipment is deployed that has a significant lead time, eg central office racks, element manager communications. It has as its input geographical distribution of the potential customer base, equipment cost and, if on-line confirmation of service availability from records is required for the provisioning process, copper pair transmission coverage identification.

Building is the process of installing and testing long lead time equipment so that it is ready to provide service when provisioning is complete. It will require ADSL multiplexers to have automatic self-testing capability, the element manager to build its database and possibly test equipment to verify potential service ready status.

Fig. 3 show the top level steps involved in planning and building the network. The network is first designed taking into account the capabilities of the equipment used and the distribution of potential customers for services. In this step pre-qualification of loops may be carried out to determine which customers can receive service. Test equipment may be needed for this.

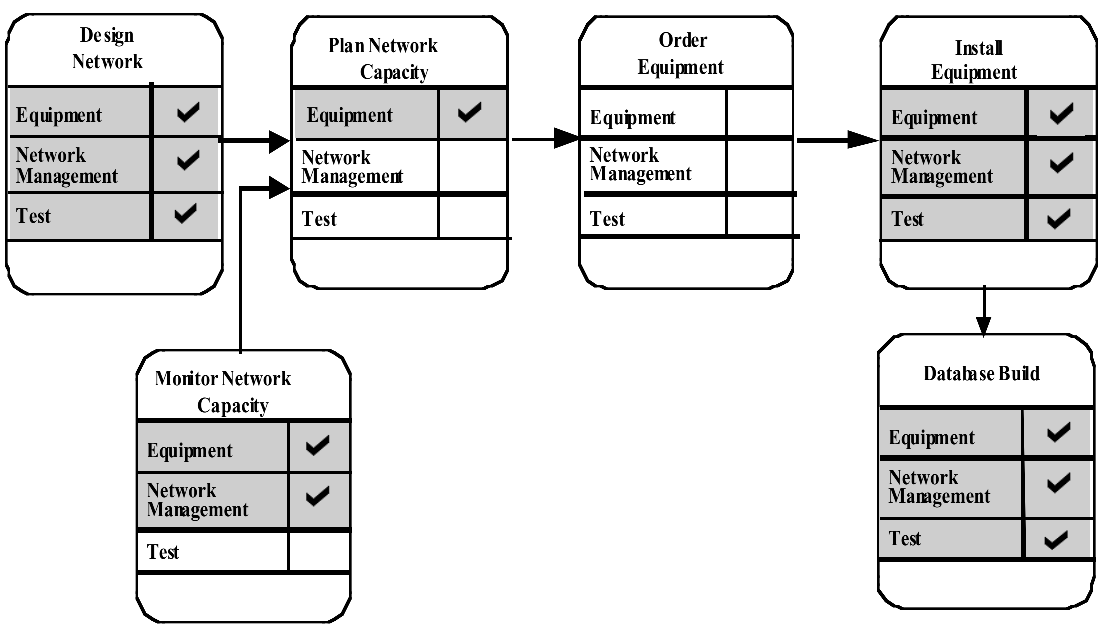


Fig. 3: Plan and Build NORM

Planning network capacity involves determining what quantities of equipment to pre-provide at various locations in the network to meet the initial demand and later to meet the growth. As a stimulus to capacity planning, monitoring network capacity is required to flag when spare capacity may be getting low. Ordering equipment involves either internal processes for getting equipment or commercial transactions with a supplier to provide more equipment. Installing equipment is the physical installation. It has potential impact on the equipment design, network management and test equipment. Database build is the process of ensuring that data about the equipment, its configuration and usage is correctly recorded or extracted from the equipment via its element manager.

2.1 Spectrum Management

A particular issue that needs to be addressed in the planning and building of ADSL-based access networks is that of spectrum management. The need is a result of the crosstalk interference generated by high-speed DSL technologies. The spectrum management process seeks to control use of the line plant so that best use is made of its potential capacity. The dominant source of the noise that limits ADSL system performance is crosstalk, so the potential capacity of the line plant is a shared resource. The spectrum management process has two parts:

- Limit transmitter levels
- Produce deployment rules

Limiting the levels of signals transmitted into the line plant is intended to control the crosstalk levels experienced by other users. This part of the process would be done by the owners of the line plant (Loop Providers), and the limits would apply to all equipment – ADSL and everything else. However, in the ADSL band the limits will be different in different locations, to support asymmetric service.

Once crosstalk is bounded the Access Providers can deduce what capacity a given line can support. They will then produce their own deployment rules.

2.1.1 Limiting Transmitter Levels

Limits on transmitter levels, expressed as rules that the transmitters must obey, will need to be created by a technically competent organisation, eg the Loop Provider, or a regulatory body. It is in the interests of all Access Providers that they keep to the rules and ensure that their equipment is conformant before any service commences. If they do not then considerable time, effort and cost will be wasted using highly specialised skills and tools to track down performance problems as part of the repair process.

The transmitter limits will apply to all new transmitters connected to the line plant, irrespective of the transmitter technology. For existing equipment the line plant owner will want the rules to be liberal enough to permit those systems already common in its network. If, however, existing systems create levels of crosstalk that are incompatible with ADSL then, if they are to remain in the network, local loop records must contain sufficient information that loops that are at risk can be identified during the service compatibility component of the service viability process. Existing systems that require protection from new transmitters will need to be identified so that the transmitter limits can be set accordingly.

The transmitter limits will in general vary with location, for example different signals are permitted at the two ends of an ADSL line.

The permissible levels will vary between local loop populations. Amongst the varying factors are:

- maximum cable fill permitted by the line plant owner - not all will permit 100% cable fill.
- demographic distribution of line lengths.
- RFI risk – includes the amount of line plant above ground, the national allocation of radio spectrum, and the balance quality of the line plant

Failure to limit transmitter levels will mean the loudest signals swamp everything else. In practice a failure to co-ordinate use is expected to mean that service providers may find useful ADSL capacity, but only on the shortest lines, and this is always at risk of being lost to new equipment with more powerful transmitters (power boosted ADSL, leakage from home networks, etc.).

One approach is the ‘frequency plan’, in which each location’s limit is a power spectral density (a ‘mask’). A transmitter is permissible at a particular location if and only if its power spectrum is at or below the mask, at each frequency separately. Masks generally differ at different locations, and in different directions along the cable at the same location.

One example of this is RADSL service, where transmitters are all limited to a common mask (different in each direction), and each system gets the best capacity it can in the resulting environment: capacity is not guaranteed, and operation implicitly relies on the absence of rogue systems.

In some networks “power back off” can extend service reach: for this the frequency plan would prescribe varying customer end masks, with lower power for short lines.

The frequency plan would need to define bandwidth, signal amplitude, time characteristics and the measurement technique for these parameters. The frequency plan will be country/network specific so no numbers are given in this document.

Ideally the crosstalk limiting rules should be designed explicitly to give

- best real use of the potential capacity
- a rational basis - to reduce the risk of the plan being challenged

2.1.2 Deployment Rules

The transmitter limits above allow some estimation of a given line’s capacity. Such estimation also requires knowledge of the line plant’s transmission properties, such as:

- typical attenuation factors of the cable types
- typical crosstalk coupling
- how long the line is, and what cable types it is constructed from
- unusual defects (aged cable, adjacent T1 system, etc.)
- RFI ingress expected (e.g. radio hot spots near TV transmitters).

An Access Provider will produce their own deployment rules, to enable the ‘service viability process’. These will necessarily be informed by the capacity estimate for a line, but may also be based on commercial considerations, such as the target proportion of ‘reworks’ (mistaken decisions to be expected from the service viability process), and the confidence in available information. Typically, uncertainty is absorbed by making planning rules more conservative.

ADSL equipment is available with *many* options. Therefore, separately, the service provider will also have to determine how to configure the ADSL equipment to meet the transmitter power limits.

2.2 Capacity Management

Capacity management is the process of ensuring that there is sufficient network capacity to meet demand but not too much that will add to cost unduly. It is divided into the two components of capacity monitoring and capacity planning. It is reliant upon records that are formed when equipment is installed and database build of the resource allocations of the equipment.

2.2.1 Database Build and Records

Some of the data resulting from network build has to be manually provided and recorded, eg location of a multiplexer. Much however can be extracted from the equipment itself. For example the status and availability of ATU-Cs in a multiplexer should be available from the element manager.

2.2.2 Monitoring Network Capacity (Capacity Alarms)

Capacity alarms require the definition of key resources and the setting of levels of spare resource below which an unacceptable ability to respond to customer demand will possibly occur.

3. Provisioning

Providing customer service is the process of installing the remaining equipment and configuring the existing equipment so as to provide service. Provisioning will impact existing POTS service and the nature and duration of the impact must be minimised. Fig. 4 shows a Provide Customer Service NORM (P-NORM). A service request is followed by a check to see if service is viable given that there are a number of reasons that ADSL may not work over a particular loop. If service is viable then the resources required to give service are reserved and a service offer made. If the offer is accepted then there follows a series of installation, configuration and validation steps before the order is finally closed. Installation and configuration steps will usually involve the updating of a database(s) that record the service implementation details. Each of the steps that involve equipment, network management or tester functionality are now described in more detail. The steps will involve one or more of the Loop, Access, Regional Network or Service Providers. Their involvement is indicated.

<u>3.1 Service Viability Process</u>

Service viability involves two issues: loop qualification and resource availability. Loop qualification is the process of determining if a loop will support ADSL transmission at a given rate. The resource availability involves establishing if equipment is already installed, and if not, if it is available for installation. Also, it involves establishing that there is technician resource available to install, and configure equipment and validate service in the desired time frame.

There are a number of factors that affect the ability of a loop to support ADSL:

- the age, condition and make-up of the loop, and the plant that it passes through
- including DLC and pair gain systems
- the transmission rate desired
- the ADSL technology employed (DMT, g.lite)
- the services carried on the loop already
- the loss introduced by the loop including customer premises wiring to the ADSL signals
- transmission impairments — crosstalk, radio interference, impulse noise

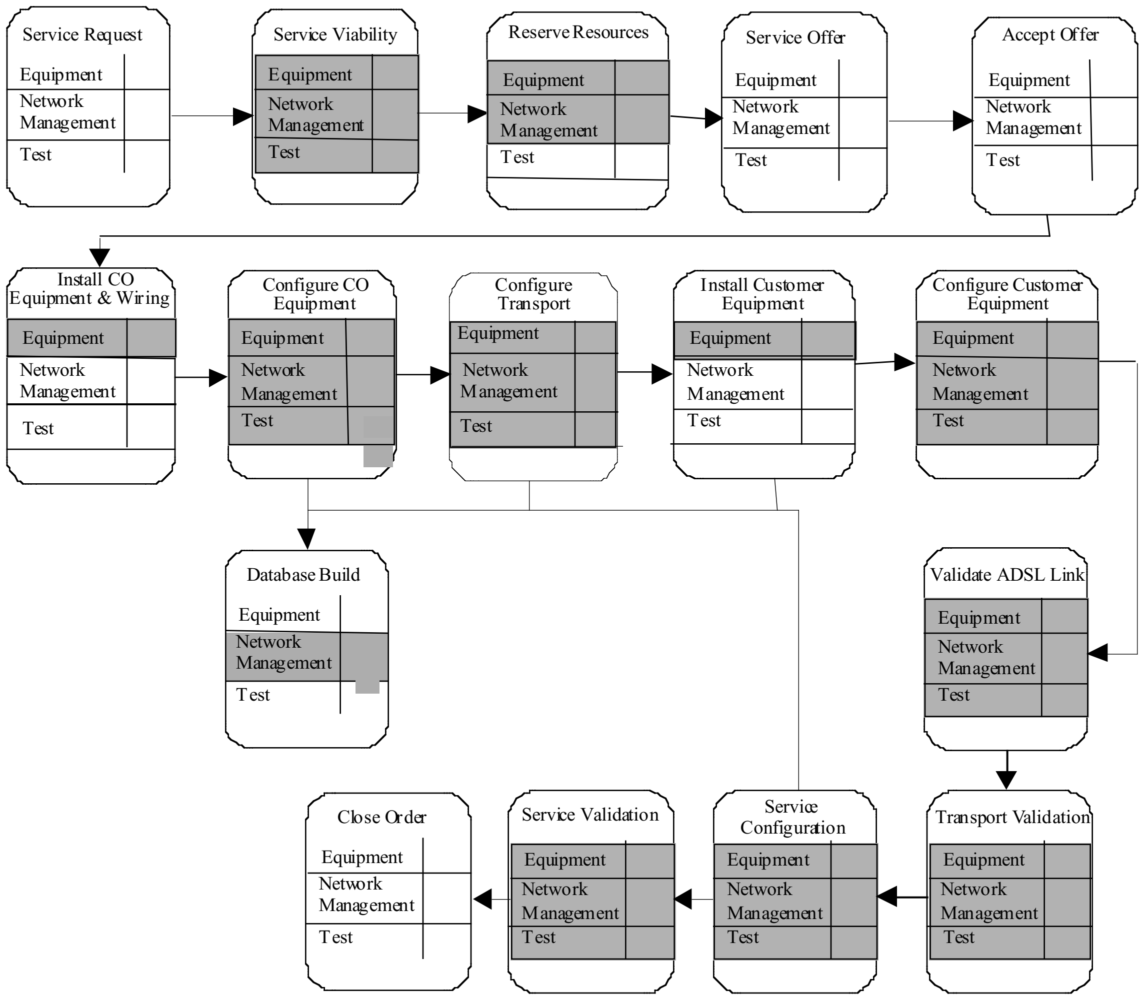


Fig. 4: Provide Customer Service NORM

There are a number of key facts required to determine the suitability of a loop for ADSL service. They are:

- loop loss at the transmission rate
- the presence of load coils
- the presence, length and location of bridge taps
- the presence of POTS loop faults
- the presence of crosstalk interferers

These may be determined from records or by measurements.

In addition it may be desirable to investigate:

- longitudinal balance
- wideband noise
- impulse noise

These would require measurement.

3.1.1 Plant Records (Loop and Access Providers)

The plant records including connectivity records allow the make-up of a given loop to be determined with some level of probability. Analysis of plant records allows for the elimination of loops that obviously exceed the loop length criteria for the desired service levels. This analysis also may or may not detail the presence of load coils and/or bridge taps. In conjunction with service records the crosstalk environment of the loop can be estimated. The records can also be used to compute for a transmission model the likely loss of a loop.

3.1.2 Service Records (Loop and Access Providers)

These record which services run over which loop. ADSL is incompatible with some *services* in the same or adjacent binder group, eg alarm circuits, and these records will need to be consulted to predict with some level of confidence if service is viable.

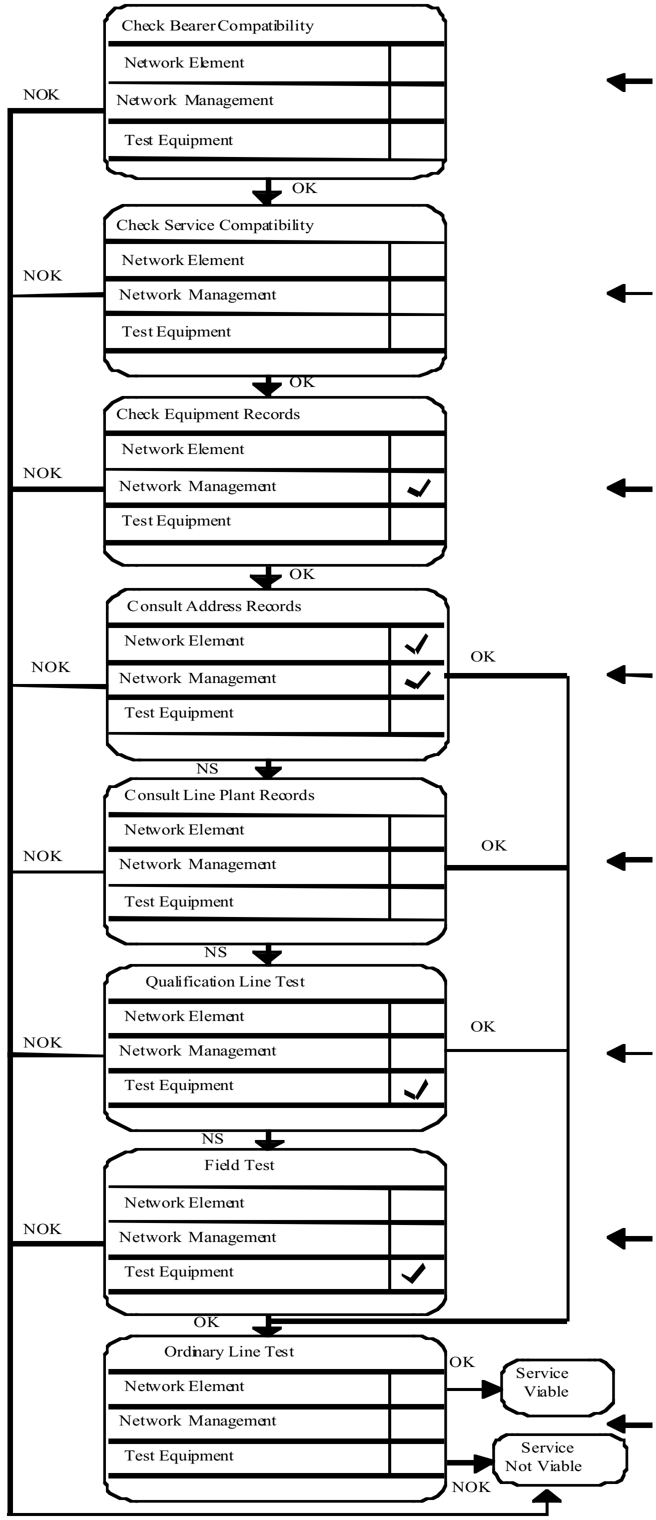
3.1.3 Measurement (Loop and/or Access Providers)

Pre-measurement of some or all of the loop parameters, as listed in above, by the loop provider and storage in a database is one method for determining the suitability of the loop for the desired ADSL service offering. Testing arrangements should be considered for existing POTS loops, for spare loops, and for some existing Special Services and Private Lines. Test access for each of these three categories may be different. The results of these tests and possible threshold analysis on the data, ideally could be stored in a database to allow loops to be identified from the Service Request process as suitable for ADSL service. However, pre-measurement of all loops may be too costly depending on the characteristics of the loop population. In this case measurement following a service request may be a better option.

Loss measurements should ideally be true end to end transmission loss measurements, but this requires a field visit. It is possible that single ended measurements can give adequate results in many cases. Similarly, if noise measurements are required, then they should be taken at the appropriate end of the loop.

3.1.4 Methodology (Loop and/or Access Providers)

Fig. 5 shows an expanded generic view of the Service Viability component of the P-NORM. The first three activities of records checking can give one of two outcomes: service is viable or service is not viable. The next three activities can give one of three outcomes: service viable, service not viable or unsure. The uncertainty may arise from inadequate records, or from the statistical variation of actual loop parameters (eg loss) from calculated or measured parameters. To eliminate the uncertainty the step of last resort is to measure a proposed loop in a field test. As the process shows an ordinary line test would be done to check for abnormal conditions that would degrade ADSL performance. In practice different access or loop providers may use all or only some of these steps and the order may vary. Fig. 5 assumes that ADSL-based service is required over an existing loop that is providing POTS service to the customer. If ADSL-based service is to be provided over a new loop then the same activities will be required to establish service viability, but there is greater freedom to select a viable loop from the available line plant. However, the use of ordinary line test or qualification line test will not be possible until the loop is jumpered to the line test system. If the loop provider and access provider are separate companies then there would need to be a clear definition of what constitutes a loop, eg specification of maximum loss vs frequency mask, maximum noise level. Alternatively, agreement is required on what information the loop provider would need to provide to the access provider to enable the latter to assess what ADSL-based service could be provided over the given loop, eg actual frequency response, loss, noise levels etc.



Records are checked to ensure that the service bearer is a copper pair and not a carrier system.

Records are checked to ensure that an existing service is not carried over the copper pair that is incompatible with ADSL operation. The records can also be checked, if necessary, for the presence of services operating over adjacent loops that may give rise to unacceptable crosstalk interference.

Equipment records are checked to ensure resources are available to serve the customer

The postal address of the premises to be served is checked to see if they are within a distance that can or cannot definitely be served. The equipment records are checked to see if equipment/capacity is available at the serving CO.

Line plant and connectivity records are consulted to enable an estimate of loop loss to be made and checked against ADSL planning rules.

An enhanced metallic line test is performed to measure loop loss and other relevant parameters and the result checked against ADSL planning rules.

A technician(s) are sent out to perform an end to end insertion loss measurement that is checked against ADSL planning rules.

An ordinary line test is done to check for fault conditions that may prevent acceptable ADSL performance.

Key: OK - will support ADSL
NOK - will not support ADSL
NS - not sure

Fig. 5: Service Viability Process

3.2 Reserve Resource (Assignment)

After service viability has been established the service provider would like to be able to provide a commitment date for service turnup. In order to make that commitment, information needs to be available about facilities and inventory as well as the standard work loads and flow through times. To obtain the current information about the circuit, an automated process could be used to query the ADSL Element Manager and take inventory of the equipment that is installed.

Additionally, beyond the appropriate hardwired equipment, the following items must be identified and assigned; plug in equipment identified and deployed, circuit numbers assigned, service level parameters assigned, billing arrangements, network level addressing assigned (gateway IP address, PVC, SVC, ATM VPI/VCI), and test access point identification assigned. This information ideally should be automatically generated and used to configure the Elements.

3.3 Installation

Installation is the physical installation of equipment or wiring at either the CO or the customer’s premises. These two stages are identified in Fig. 4 and are described below.

3.3.1 Install CO Equipment and Wiring (Loop and Access Providers)

For each installation the identification and location of all cross connections must be identified and recorded. These connections include running jumpers in the CO from the ADSL equipment to POTS Splitters or the CO side of the MDF, and connection of those jumpers to terminal blocks. This jumpering effort may require changes to in-service jumpers for the existing service. Also there is the potential of having to run new jumpers to the customer side of the MDF. In the outside plant, new jumpers or splices may be required at junction boxes if ADSL service is assigned to a spare pair. Ideally, all cross connection assignment and record keeping is accomplished using automated procedures consistent with existing Methods and Procedures

3.3.2 CO Equipment Test/Check (Access Provider)

After the CO equipment is installed and wiring completed, an optional test of the CO equipment can be performed. The following tests are possible:

- a POTS metallic line test
- if wideband test access is available, the full suite of tests identified in 3.1 should be performed. If any results are outside of the acceptable limits, dispatch and/or repair as necessary
- a “golden ATU-R may be connected at the MDF with appropriate pads inserted to verify that the modems will synchronise.

3.3.3 Customer Equipment Installation (Loop, or Access, or Service Providers or the Customer)

Depending on the service deployed, a technician may or may not be deployed to install the equipment and verify service.

If a technician is dispatched, a number of items need to be covered

- Pair assignment — use existing POTS pair, or a spare pair
- Customer wiring arrangement — home run or star configuration
- POTS splitter(s) installation locations (if required)
- New wiring installation (Category 5)
- ATU-R placement and powering
- Interconnection of ATU-C with the CPE
- Service turnup and acceptance procedures
- Troubleshooting procedures
- Centralised remote Network test capability
- Handheld test equipment

If the customer is performing the installation, or no technician is being dispatched, these items need to be covered:

- Customer equipment list — POTS splitters, ATU-C, cables, wiring diagrams, installation manual
- Installation and turnup check list
- Troubleshooting procedures
- Network help line
- Centralised remote Network test capability

3.4 Configure Elements

Configuration of the network elements during the provision process can be subdivided into four parts, which are illustrated in Fig. 1 and are described in the following paragraphs. Most configuration will be done automatically in response to the service order definition, but each configuration stage may require functionality in the equipment and the network management, and possibly in separate, portable test equipment that allows independent configuration and testing before connection to other network or service equipment.

3.4.1 Configure CO Equipment (Access Provider)

Once all the equipment required to provide service to a specific customer line is installed then it may need configuring. This would be done, preferably, by the ADSL element manager. Alternatively, configuration could be achieved by the setting of local switches either physically or by local portable test equipment (which may also perform some testing if necessary). In the latter two cases the configuration of the equipment would need to be automatically recorded by the element manager.

3.4.2 Configure Customer Equipment (Service and Access Provider)

Once the customer equipment is installed then it may need configuration. Note that this is the transmission equipment that is being configured. This may be a separate box or a card in a PC. Configuration of the ATU-R will result in train-up of the ADSL link.

3.4.3 Configure Transport (Service, Regional Network and Access Providers)

Once the ADSL Link has been validated the end to end transport can be configured. For example, ATM routing and performance parameters can be set.

3.4.4 Configure Service (Service Provider)

Finally, once valid transport is achieved, the specific service will be configured, eg Internet Access, VOD, etc. This may involve configuration of software in the customer's PC, for example, and the setting of service parameters within the service provider's domain.

3.5 Service Verification

Following loop qualification and installation of order-specific equipment, the service should be verified. For POTS, service verification is performed by running a metallic POTS test from the centralised test system and/or plugging in a telephone and making a call to a test number. For ADSL-based services the situation is more complicated. There are three aspects to consider, first the ADSL link, second the end-to-end transmission performance and third the service. In a mass deployment situation it is undesirable to have to train all field technicians in service-specific knowledge, or to equip them with transmission test sets. Mechanising the ADSL verification process in a consistent fashion with existing methods and procedures is highly desirable. Also, since a customer may not have CPE available at the time of installation of the ADSL network equipment, service testing will either require some sort of tester, or have to wait for the customer to acquire CPE. In the latter case co-ordination effort may be required to wait for the customer's CPE to verify the service.

Commissioning aspect	**Objective**
ADSL link	Does the ADSL link work satisfactorily?
Transmission	Is satisfactory end-to-end transmission performance achieved?
Service	Does the service work?

Table: 1

The responsibility for verification may lie with different parts of a telco organisation or with different companies, in the evolving competitive environment. A logical approach to commissioning is indicated in Table: 1. It recognises that establishing satisfactory working requires working upwards from the ADSL link, through end to end transmission to the service.

3.5.1 ADSL Link Validation (Access Provider)

Ideally, commissioning of the ADSL link should involve some form of testing between the interfaces on the exchange side of the exchange ADSL equipment and the customer side of the network termination. This is both for troubleshooting an ADSL link that does not turn up successfully, and to verify that the link is working properly when the modems do synchronise. This testing arrangement must also provide for the situations where there is no Network Technician at the customer site, such as in ADSL.lite installations. In all cases it is highly desirable for these tests to be accomplished remotely without the necessity of Network Technician involvement, by for example the use of the built-in self testing and monitoring capabilities of ADSL modems to validate the link. For installations where a Network Technician is available at the customer site, however, a test set may need to be provided to every field technician. The results of either type of test, should be capable of being displayed to the centralised test technician on a terminal, or to the technician in the field visually, eg by LEDs on the ADSL network termination, or via the ADSL Element Manager (EM) to an operations centre. For tracking purpose, it is desirable that initial link measurement results be archived in an operations database for future reference, to include results such as SNR, transmission rates upstream/downstream, and bits & gains. This information could prove valuable for future diagnostics of trouble reports on the link.

3.5.2 End to End Transport Validation (Service, Regional Network, or Access Provider)

Similarly, for end-to-end transmission testing, the use of a separate tester is undesirable. There are several options for end-to-end testing that are based on the use of loopbacks. These can be on the basis of classical intrusive bit-stream loopbacks or, utilising the fact that ATM transport is preferred for broadband networks, non-intrusive cell loopbacks. Bit-stream loopbacks are complicated by the asymmetric nature of the access link. Cell loopbacks, which are the subject of international standardisation, and provide a uniform methodology across the whole broadband network, are probably to be preferred. Loopbacks are discussed further in paragraph 4.2.2.

3.5.3 Service Validation (Service Provider)

Given that there could be a wide range of services offered over an ADSL link probably the only sensible means of commissioning at the service level is for the customer to plug in their CPE and for the service software to be smart enough to configure service automatically, with the use of a helpline for dealing with the small number of problem cases. The Network Operator should have procedures in place to ensure all services types are properly functioning and the customer accepts them, before billing begins and service is turned over to the customer.

3.6 Database Build

Information regarding ADSL service covers a broad range of parameters and possibly spans across a number of operations groups of the network operators. From a practical perspective, some information may reside in a centrally located database, while other data may logically reside in remote databases. Regardless of the physical location, all data should be logically accessible from all relevant points in the network. Information may include service parameters, billing information, assignment records. IP address, VCI/VPI, performance monitoring data, test access, link validation data. Ideally, this data should be automatically generated, assigned, and written to the database(s) without manual intervention.

4. Repairing and Maintaining

Repair is the process of restoring service following a customer reported fault and/or a network alarm. In the event of a customer-reported fault, repair service bureau personnel will be required to validate service remotely. This will involve the management systems of all the technologies used to provide end-to-end service, including the ADSL element manager. Such testing should enable demarcation between network, customer premise equipment and server equipment, and demarcation between different networks if more than one network operating company is involved. Testing will also help to diagnose a fault to a specific location in the access network, and enable a repair job to be assigned to the appropriate work stack. Because ADSL systems may share a copper pair with POTS, it should be possible to co-ordinate POTS and ADSL trouble reports, and to test the copper pair with normal line test systems. The ADSL sectionalisation and dispatch process will possibly interact with the POTS repair process. Repair will rely on database information, and may impact equipment functionality, network management functionality, and possibly involve a test set for use by the repair technician. Maintenance is the process of replacing or renewing equipment that is faulty or likely to become faulty, but is not currently service affecting. A generic repair NORM is shown in Fig. 6.

4.1 Fault Reporting

The initiation of a fault report nominally can originate from three sources, a customer fault report, secondly an autonomous network alarm, and thirdly, threshold crossing alerts from an ADSL Element Manager for performance monitoring reasons. The latter two are both network fault reports. Of these trouble reports, two types of trouble may exist: hard faults resulting in an out-of-service condition and intermittent or degradation of service fault. The ADSL support infrastructure must be capable of handling these faults, sectionalising them and resolving the problems.

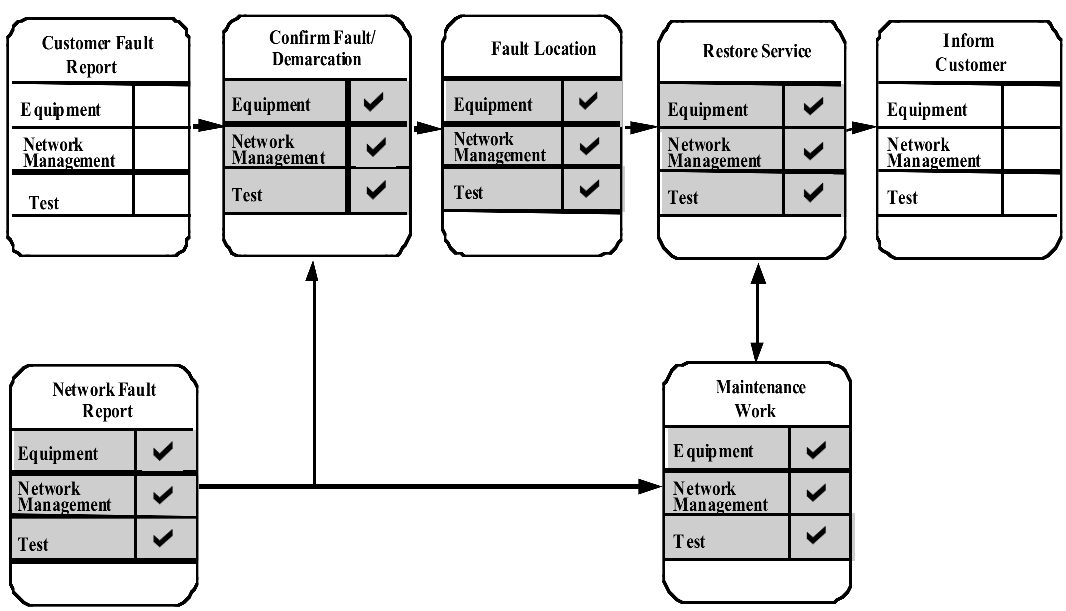


Fig. 6: Repair and Maintain NORM

4.1.1 Out-of-Service Faults (Service, Regional Network, Access or Loop Providers)

Assuming that most Network Elements will be alarmed, if one fails, an indication should be available to repair service personnel to alert them that multiple customers may be effected. If individual faults are reported, the following process in section 4.2 should enable restoration of service.

4.1.2 Degradation-of-Service Faults (Service, Regional Network, Access or Loop Providers)

If the customer complaint, or performance monitoring threshold indicates a service quality problem, the objective will be to determine the source of trouble, which of course could lay in a variety of places in the network including, CPE, ADSL link, CO equipment, ATM equipment, ATM network, the Internet, or the far end server. With multiple possible suspects, isolating the cause of degraded service may be more difficult than out of service conditions.

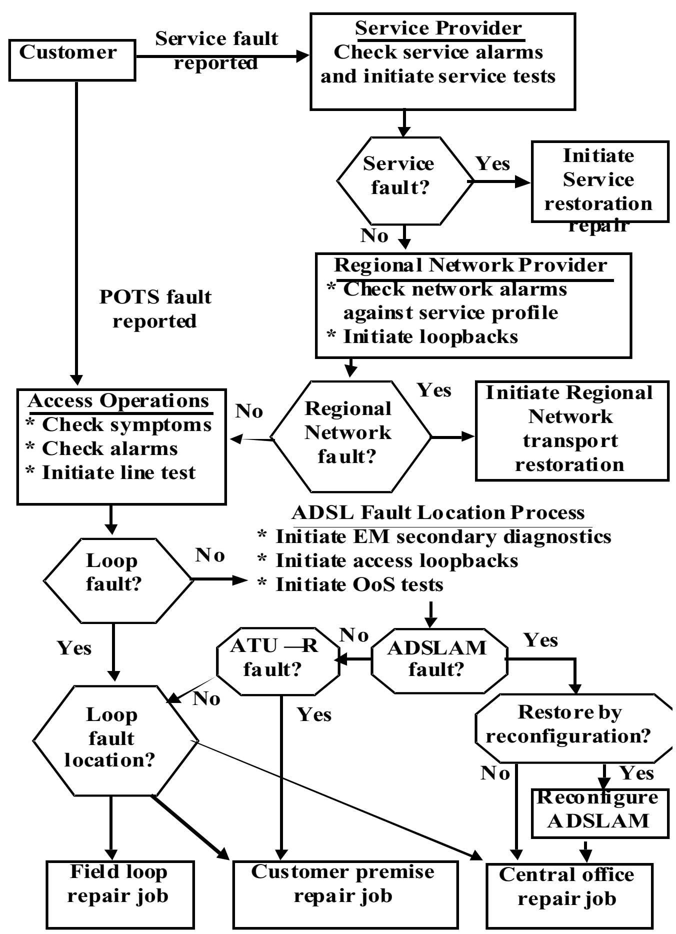
4.2 Fault Confirmation/Demarcation/Location

Although fault confirmation/demarcation and location are shown as two logical steps in a process in practice the two may overlap and may possibly be done by the same person. Both steps may rely on the use of equipment alarms, performance parameters, and/or out-of-service testing based on existing metallic line test capabilities, out-of-service test capabilities of the ADSL equipment, or test equipment. For out-of-service conditions, the ADSL Element Manager should be interrogated to determine the status of the link. If the link is down, a metallic line test should be performed to determine the integrity of the loop. Additionally, the service repair systems must be capable of co-ordinating simultaneous trouble reports on the same loop for POTS and ADSL as this can give an indication of where the fault may lie.

4.2.1 Sectionalisation (Service, Regional Network, Access or Loop Providers)

Sectionalisation is the traditional name given to the process of establishing the location and ownership of a fault. Traditionally for telephony this demarcation has been between the telco that owns the network and the customer who owns the CPE. For ADSL services there is also the service provider who owns the server for the service and possibly owners of different parts of the network. For telephony service a line test combined with dialogue with the customer by repair service personnel has been the means of establishing demarcation. As described below ADSL-based services will require additional methods and sophistication to determine the ownership of a fault.

Fig.7 shows a general process for sectionalisation. In the first instance a customer experiencing a fault will report



this to the service provider. The service provider tries to establish if the fault is in the customerÕs CPE or the server domain, ie it is not a network problem. If it is a network problem then it is passed to network operations to try to establish if the fault is in the transport network or in the access domain. If it is in the access domain then the problem is passed to access operations. Access operations first try to identify a loop fault. If it is a loop fault then there is a high probability that the customer will also report a POTS fault. Alarms and line test may also be used to prove if it is a loop fault or not, and also where in the loop the fault may be. Location to Central Office, field, or customer premises ensures the correct dispatch of an appropriately equipped and trained technician. If the fault is not thought to be in the loop then the problem passes into the ADSL fault location process that is described later in WT-026. This will give outcomes of reconfiguration followed by a CO repair job, an immediate CO repair job, a customer premise repair job, or a field loop repair job if further analysis shows a more subtle loop fault that was not determined in the previous step.

4.2.2 Loopbacks (Service, Regional Network and Access Providers)

Loopbacks are the traditional method of attempting to sectionalise a fault in digital transmission networks. They involve connecting the output of a transmission element to the input of the return path and detecting a correct sequence sent from the test point on the return path at the test point. ADSL transmission introduces a complication in that the two directions of transmission are not of the same rate. From the outline of sectionalisation above it can be deduced that a minimum set of loopbacks are required at the points shown in the generalised network shown in Fig. 8 which is based on the reference model of TR-001. Other loopbacks, especially within the regional network may be required. The loops and test signals are applied by the relevant Element Managers (EMs) co-ordinated through the Operational Support (OS) system. The test signals are introduced at test access points as shown. The test access point in the transport network can be at any convenient point

Loop 1 enables transport from the Service Provider to the customers CPE to be checked. Loop 2 enables transport to the service provider to be checked. Loop 3 enables transport to the ADSLAM to be checked. Loop 4 enables transmission to the ATU-C to be checked. Loop 5 enables transmission to the ATU-R to be checked.

The transport loops will need to be ATM cell or IP packet based. The transmission loops can be at a lower level if desirable. A loopback is a conceptual term from an operational point of view. Any test mechanism that gives the same result of checking continuity will suffice.

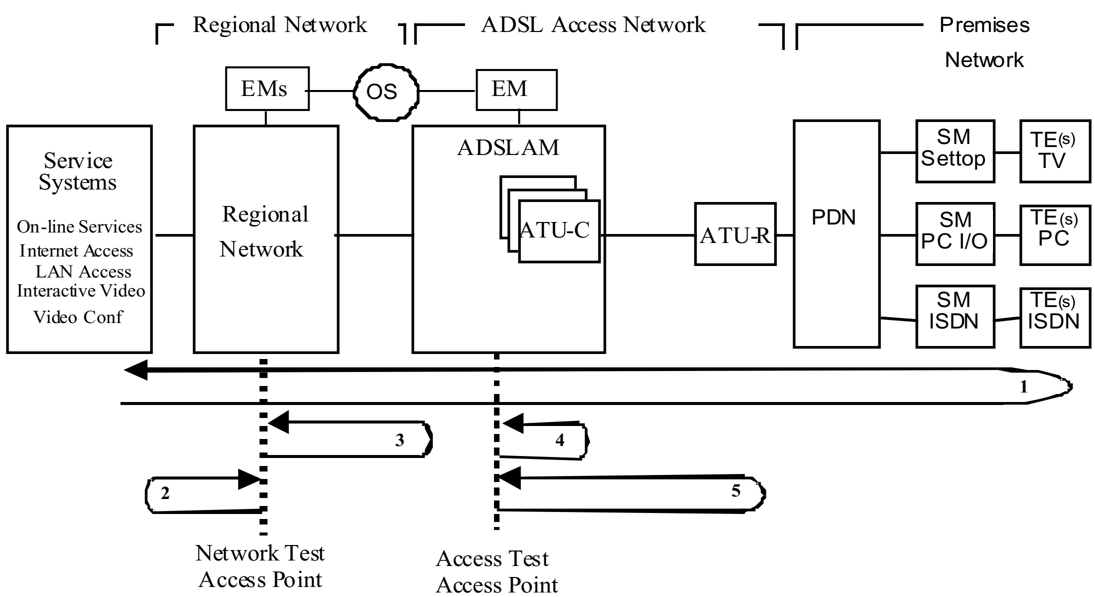


Fig. 8: Loopback Definitions

4.2.3 Line Test (Loop, or Access Provider)

The interpretation of metallic line test measurements to diagnose and locate faults has a long history and algorithms to interpret the measurements have been developed that are widely deployed. The metallic line test measurements are affect by the splitters at the CO and CustomerÕs premises. Decisions are made in the POTS repair process based on the output of LTS algorithms and it is possible that disruption of the repair process may occur resulting in extra costs and delays in restoring service. Ideally, POTS splitters would not add bothersome resistance and capacitance to the loop to effect the test algorithms, however if they do, a number of options for solution of this problem are possible:

1) Do not mix POTS and ADSL-based services on the same loop. This minimises interaction with POTS process but is expensive in loop plant.
2) Re-program the LTSs to factor out the splitters effects on diagnostics. Re-programming LTSs can be costly if a telco uses several different LTSs and the resulting performance is unknown.
3) Provide alternative LTS access after the splitter, perhaps built into the ADSL equipment. This will leave some exchange wiring untestable and require some additional exchange wiring.
4) Provide relay bypass of the splitter operated by detection of line test onset. It may not be possible to detect the onset fast enough to bypass the splitter before LTS measurements have started.
5) Provide relay bypass of the splitters operated from the ADSL EM. This requires co-ordination between the LTS operation and the EM operation.

An alternative approach is to accept that splitters will add impedances and to define the impedances to provide splitter signatures. These may then be used in the fault location process and other purposes.

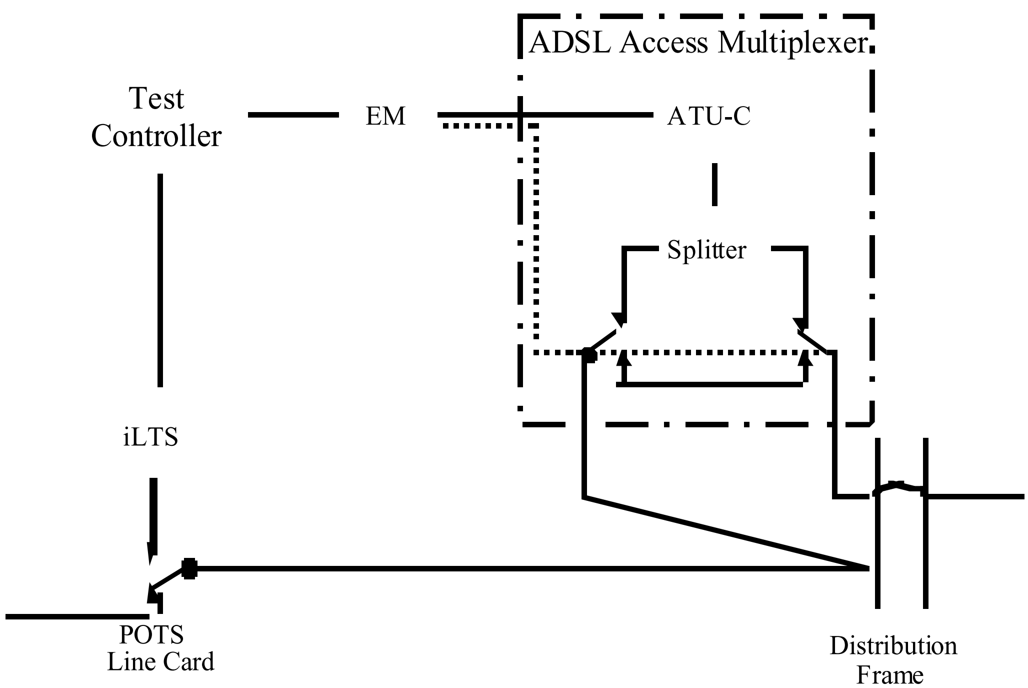
4.2.4 Splitter Bypass (Access Provider)

Fig. 9 illustrates splitter bypass at the central office. The element manager for the ADSL access multiplexer can operate relays that provide a metallic bypass of the splitter. The only components left in circuit may be protection components, but these do not normally cause significant impedance changes.

Fig. 9: CO Splitter Bypass

For the bypass function to be of use a test controller function is required that co-ordinates the application of the bypass and the measurements made by the incumbentÕs Line Test System (iLTS). This function may be manual, or incorporated into network management software.

It is also necessary for the splitter at the customerÕs premises to be bypassed. In this case the relay activation has to be communicated via the operations channel of the ADSL system. As the ADSL system is taken out of service by the bypass a timer function has to be included at the ATU-R to remove the bypass so the ADSL link can be established again after a test. The duration of this timer will depend on the time a particular line test system takes to perform its test measurements. It may be desirable that the duration can be set by the element manager, either during initial configuration of the ATU-R or as part of the relay bypass initiation.



4.2.5 Splitter Signatures (Access Provider)

The overall goal of deploying POTS splitters with testable signatures is to be able to identify the condition of the physical ADSL circuit even when the electronics are powered off or not present.

One of the main objectives of any service provider is providing the service to the customer at the lowest possible cost. One of the largest cost items in provisioning and maintaining lines is the cost to dispatch a repair person in a truck to the customer premises to just look at the problem. Single ended test systems that allow the service provider to locate, identify, test and provision lines without sending a truck to the customer site are desired.

To allow these test systems to obtain the appropriate information, the equipment that is deployed must contain features that interact with and provide information for the testing system. Single ended testing is possible and practical but the equipment being deployed needs to be capable of responding to the test system.

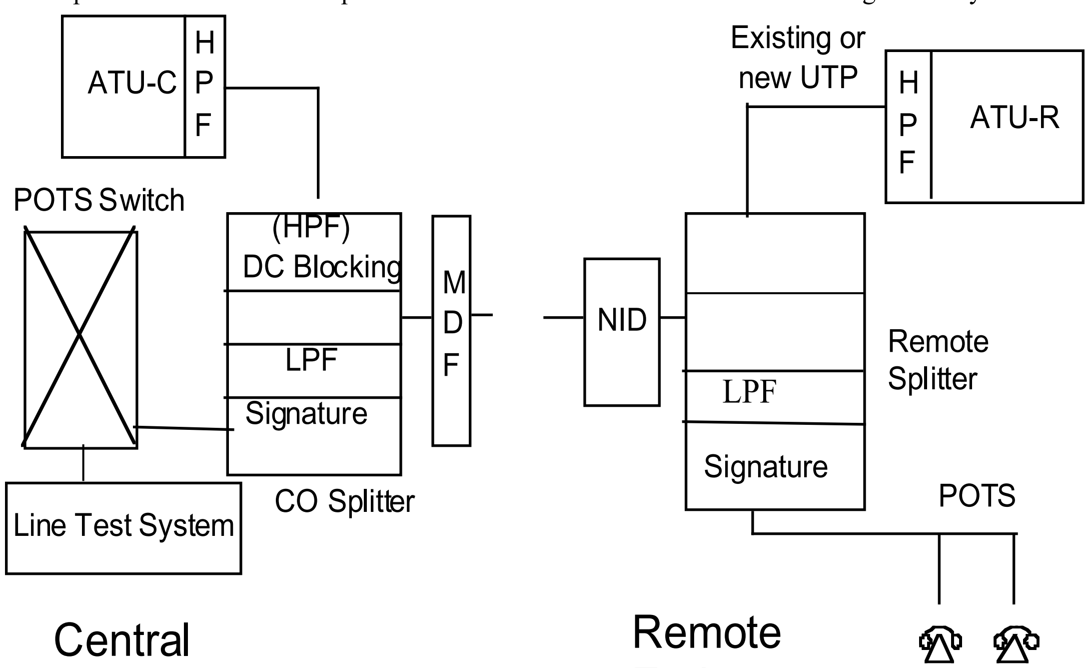
If each POTS splitter were to contain a “signature” as indicated in Fig. 10 that uniquely identified that splitter as either a CO splitter or a Remote splitter, a single-ended test system could identify the presence of the splitters without sending the truck to the premises, or to have to issue a work order to check for the presence of the CO unit. In the case of order entry, the test system could provide immediate feedback allowing the order taker to better predict a commitment date for turnup of the service. The signatures should be unique from other signatures defined or expected on the network.

Fig. 10: Signaturised ADSL System

A “signature” in this case would be a readily identifiable combination of DC and/or AC characteristics that distinguish the splitter from the network itself. This would include network faults such as crosses, grounds or open networks. The uniqueness of the signature would be standardised and would be identifiable by all test systems as either a CO end splitter or a Remote end splitter. An example of a signature in use today is the NT1 signature used in the ISDN network (reference T1.601 1988).

At the time the customer makes his initial request for service the service provider would like to be able to provide a commitment date for service turnup. In order to make that commitment, information needs to be available about facilities and inventory as well as the standard work loads and flow through times. To obtain the current information about the circuit, an automated, single ended test system could be used to query the circuit and take inventory of the equipment that is installed.

Information can be obtained from signaturised POTS splitters at the CO and the Remote ends of the circuit. ADSL testing could be done with the ATU-R if it is in place in the customer premises. If the ATU-R is not present or is powered off, the signature in the Remote POTS splitter identifies the continuity of the circuit and the presence of the Remote splitter. All this can be fed back to the flow through order system and can



be used to make a commitment to the customer for service turnup. If the equipment is not in place then the equipment can be ordered automatically. If the equipment is in place then provisioning can take place immediately.

When the circuit has been installed and is operational there are times that maintenance must be done on the circuit. When the physical copper line breaks, when components are unplugged or powered off or when there are faults on the circuit that interfere with the POTS or ADSL signals on the line it is necessary to provide accurate diagnosis of the line conditions.

With signaturised POTS splitters in the circuit the job of segmenting the circuit becomes much easier. In the case where a customer complains of no dial tone on the POTS circuit, a quick test to see if the network termination signature in the Remote splitter is still on-line would confirm that the copper pair is still intact all the way to the NID. If the network termination signature is not present (possibly a network open condition) the test system can check to see if the CO POTS splitter signature is in place which would confirm that the wiring is in place to the MDF. Then a length test could be made to find the distance to the fault. With this information the craft could be dispatched directly to the problem rather than driving to the customer premises first and working his way back.

4.2.6 Fault Location in the ADSL Link (Access and Loop Providers)

Fig. 11 shows the fault location component of the R-NORM. It is assumed by the time this part of the overall repair process is reached that in the preceding confirm fault/demarcation component sectionalisation of the fault has indicated an ADSL Link fault. It is also assumed that either evidence of an ADSL equipment fault has been found, or that no evidence of a fault on the copper pair has been found. In secondary diagnostics component loopbacks and other features of the ADSL element manager's fault management capability are used to try to pin point the fault. If no equipment fault is identifiable then it may be that there is a transmission problem arising from loop conditions that were not observable by the metallic line test performed earlier. Therefore, the out-of-service testing functions would be invoked in the ternary diagnostics component to try to get to the root cause of the problem.

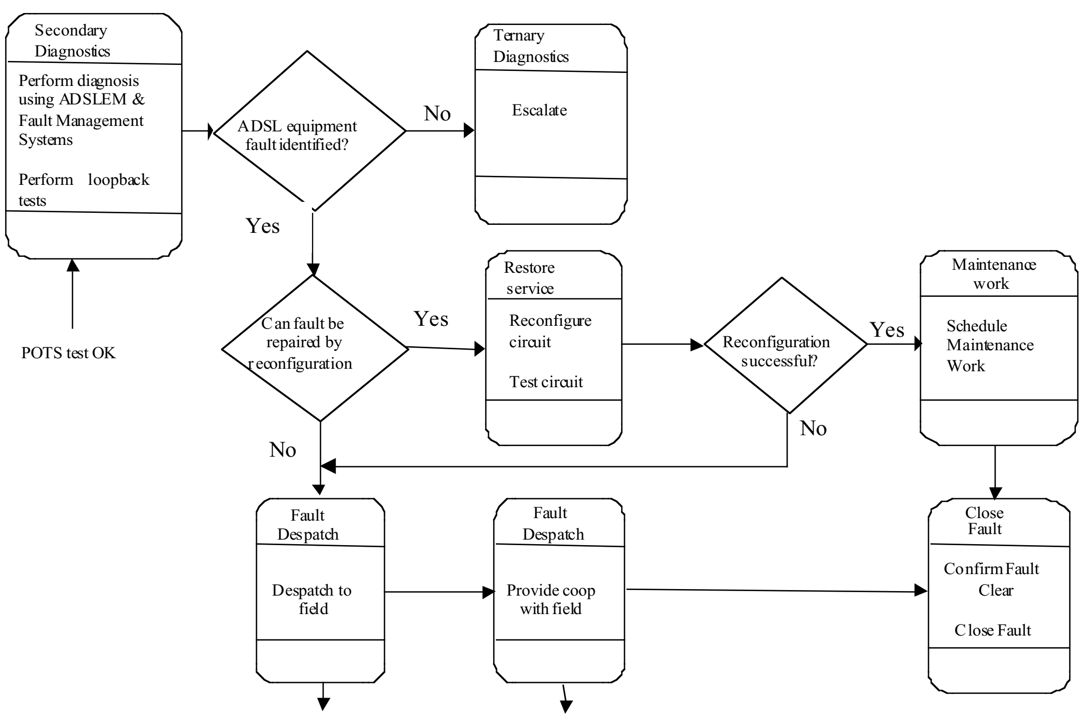


Fig. 11: Fault Location Process

4.2.7 Out-of-Service Testing (Access and Loop Providers)

To understand how any out-of-service test functions would be used it is necessary to expand the ternary diagnostics component to show the individual tests and the process outcomes that would result. However, there are three catch-all categories: tests that identify a loop transmission characteristic degradation, tests that identify crosstalk from other DSL systems, and tests that identify other interference. The first is likely to lead to action by the business as usual field operation people who would repair a loop or substitute another pair. The second is likely to involve planning personnel who would work out how to avoid the interference problem by re-routing one or more services and the last differently, and more highly skilled field personnel, who would track down the source of interference and seek a bespoke solution. Thus we can expand the ternary diagnostics component as indicated in Fig. 12.

In the early days of ADSL deployment it may be acceptable for there to be skilled personnel who can interpret information obtained from the out-of-service tests. However as deployment becomes widespread then automation of the interpretation of the test outputs is highly desirable. It is a point for discussion whether this automated function is implemented in the element manager or in some higher layer operational support system. This decision will impact the definition of the ADSL network management and MIB.

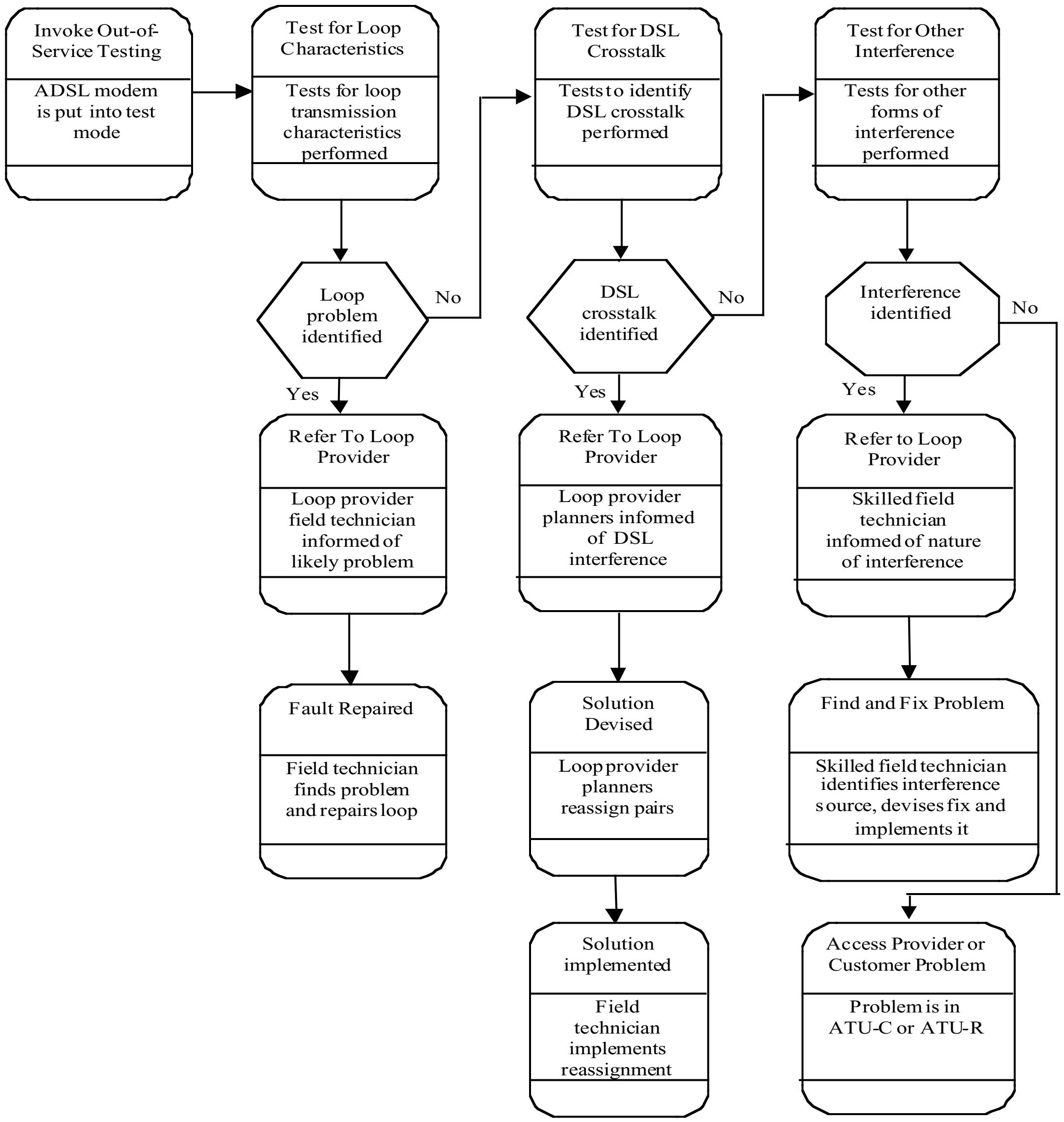


Fig. 12: Out-of-Service Test Process

4.2.8 Wideband Testing (Access or Loop Provider)

If the automated testing described above does not provide a definitive result, or only a general indication of the problem then further testing by CO based or field testers may be required. Tests that may be required are impulse noise detection, and wideband noise and/or crosstalk measurement including level and type of disturber.

4.3 Fault Correction

Regardless of the source of the trouble, the Repair Systems ideally should attempt to automatically sectionalise the problem, reconfigure equipment if possible and automatically dispatch the appropriate technician to repair the problem, and with as much mechanisation as possible, close out the trouble report.

4.3.1 Reconfiguration (Service, Regional Network, Access or Loop Provider)

Reconfiguration to automatically and rapidly restore service may be possible but this will need to be followed by planned maintenance activity to repair the faulty equipment or facilities.

Depending on the type of fault found either equipment or facilities might need to be reconfigured. The automated assignment tools may assign new ADSL equipment and/or a new cable pair and a technician will then be dispatched to carry out the reconfiguration. If new equipment or facilities are assigned, the service verification process needs to be followed again.

4.3.2 Dispatch (Service, Regional Network, Access or Loop Provider)

Dispatch is the sending of an appropriately trained technician equipped with the correct tools and equipment to the right place to carry out the repair.

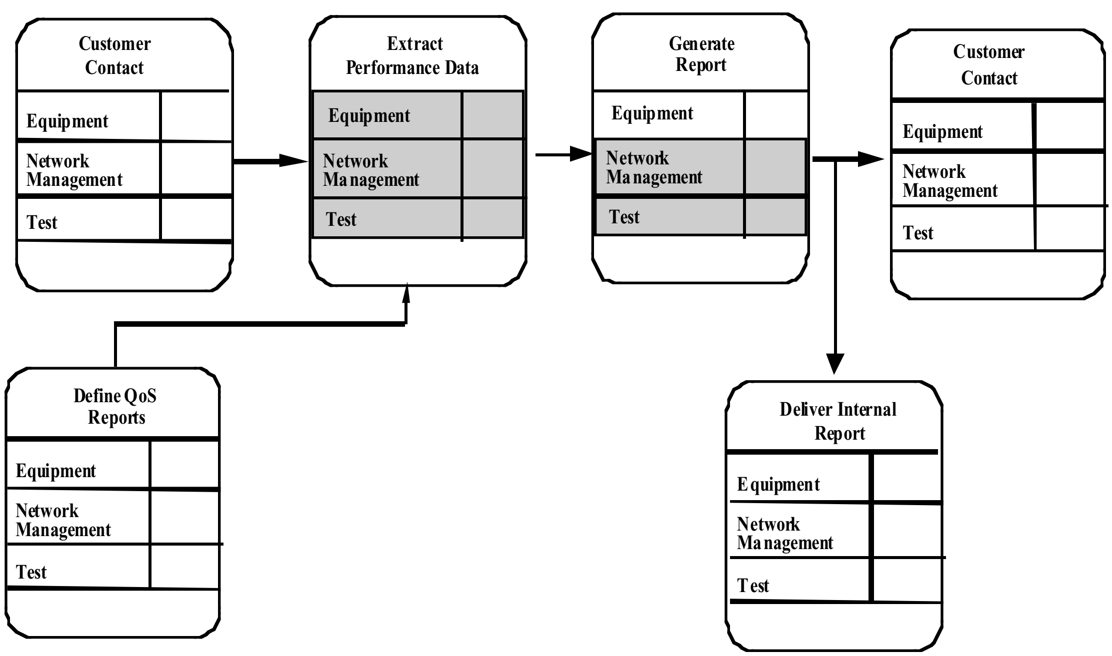
4.4 Re-Validation

Once service is restored for either an out-of-service condition or a degraded service condition, the procedures to validate the operation and quality of service need to be rerun as detailed in section 3.5.

5. Performance Monitoring

Monitor service performance is the process of determining performance parameters in order to inform customers or prepare reports for network providerÕs management purposes. It involves access to the element manager to extract data. It will impose requirements on the equipment to measure raw performance data. A Monitor Service Performance NORM is shown in Fig.13.

Fig. 13: Monitor Service Performance NORM



1. *Customer contact* receives the service order from the customer. Part of this order will specify the Service Level Agreement (SLA) detailing the service quality that the network provider will guarantee, together with any compensation payments payable if the service falls outside the quality envelope. A typical SLA will detail the end-to-end service network performance parameters, times when perceived faults can be reported, maximum time for the provider to respond to a fault report, times to fix a fault, maximum downtime per year/month/week/day, and the amount of pro-active monitoring. Higher order management systems determine from the SLA the information that the ADSL system needs to produce.

2. *Define QoS Reports* are the reports on the network which the provider wishes to see, in order to efficiently manage the network. The sort of information which might be needed includes fault rates on a per equipment type basis, fault rates on a geographic basis, performance of network connections, times to fix faults, numbers of repeat faults and times to provide circuits. Higher order systems determine what information the ADSL system needs to supply.

3. *Extract Data*: The ADSL hardware and NM need to instigate performance monitoring in response to the request, whether from the customer or the network provider. Higher level performance monitoring (such as average task times, analysis of equipment failures, etc) is not applicable to the ADSL system. Of more interest is information on the performance of circuits, including G.826 statistics of links, alarms if performance drops below thresholds, and ATM measures. These requirements have impacts upon the ADSL hardware and the NM.

4. *Generate Reports*: the higher level management system would take the information from the ADSL NM, other NMs, and other management systems and generate suitable reports for the customers and the network providers.

5. *Deliver Internal Reports*: the network QoS reports would be delivered to the correct points within the network provider's organisation, probably on a regular basis.

6. *Inform Customer*: depending upon the SLA reports will be sent to the customer. These reports could be either regularly scheduled or sent if an exception occurs.

Fig. 14 shows a more detailed analysis of the Extract Data process.

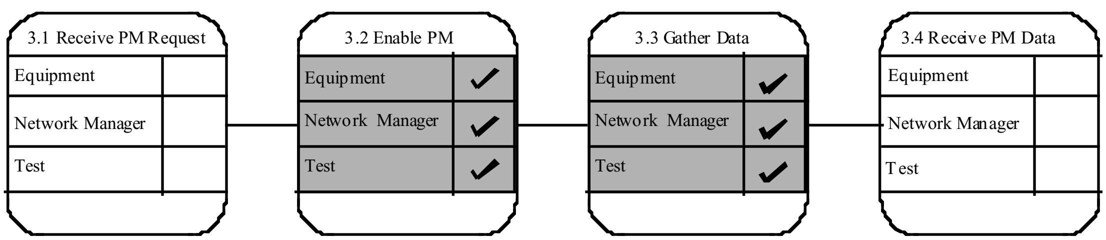


Fig. 14: Extract Data Process

1. *Receive Performance Monitoring Request*. The higher order management system or duty receive a request to instigate performance monitoring either as a result of a customer or internal request. The system determines what information it requires from which Element managers.

2. *Enable Performance Monitoring*. The NM is sent a request to enable performance monitoring. Depending upon the type of performance monitoring required this could include either the logging of service performance or the reporting of faults to this higher order system.

   The request needs to specify the circuits and/or equipment which the EM needs to monitor. If the monitoring requires reconfiguration of the ADSL hardware then the relevant commands are sent.

3. *Gather Data*. The ADSL hardware and NM gather the relevant information and either store it for later transmission to the higher order system or sends it immediately.

4. *Receive PM Data.* Higher order systems receive the data from the NM(s) and collate.

6. Document History

Version No.	Date	Reason for new version	Author
1	1/6/98	First draft.	Peter Adams
2	24/8/98	Minor editorial corrections.	Peter Adams
3	9/10/98	Incorporation of contributions 98-126,127, 137 and editing and reorganisation of material.	Peter Adams
4	7/1/99	Incorporation of contributions 188, 234, 235 and 240, and editing and reorganisation of material.	Peter Adams
5	25/3/99	Minor edits following last ADSL Forum meeting	Peter Adams
6	24/6/99	Alterations to address comments from straw ballot and editorial corrections.	Peter Adams