

# **An introduction to functional architecture**

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## **Introduction**

This paper is intended to introduce the concepts and constructs of functional modelling as described in ITU-T Recommendations G.805 and G.809. This paper is aimed at an audience that is familiar with general networking concepts and introduces the reader to G.805 and G.809 terminology and diagrammatic conventions by using examples to map concepts that the reader should be familiar with to their equivalent G.805 and G.809 terminology and diagrammatic conventions.

G.805 and G.809 provide useful generic methods for modelling and describing transport ‘layer networks’ from a functional and structural architecture perspective. The terminology defined is technology independent and can be used to describe the physical and logical components for any given network. This is particularly useful for network inventory and management as the complete network view can be modelled from the optical fibres in the duct right up to the services running over the top of them (including all the layer networks in between).

As noted in G.805, the term ‘layer’ (or ‘layer network’) is used by both G.805, G.809 and X.200 when describing and decomposing a given ‘layer network stack’. However, layer networks defined using functional modelling (as described by G.805 and G.809) should not be confused with the layers of the OSI Model (ITU-T Recommendation X.200). Each layer in the OSI model can only offer a specific service and the protocols defined at each layer perform a specific function corresponding to that layer. For example the OSI transport layer (Layer 4) accepts data from the OSI session layer, and passes it onto the OSI network layer providing an end-to-end delivery service. In contrast, each layer network in a functional model based on G.805 or G.809 offers the equivalent services to OSI layers 1, 2 and 3 (although one or more of OSI layers 1, 2 or 3 maybe non-existent for some layer network technologies), in other words functional models based on G.805 and G.809 provide the transport of information (bits/frames) between inputs and outputs. Abstraction is commonly used to hide detail and to focus on the layer networks and the components (in those layer networks) of interest. However layer networks can be modelled right down to their network elements, e.g. Ethernet switches, copper pairs, SDH cross connects, etc.

In addition to providing a model for describing layer networks (and their layering and interactions), the G.805/G.809 model can also be mapped into detailed equipment specifications using the set of generic atomic and compound functions and the set of rules on how to combine them specified in G.806, for example I.732 provides an ATM equipment specification and G.783 provides an SDH equipment specification. Detailed equipment specifications are considered important by equipment manufacturers as they provide a detailed formal specification of what components a piece of transport equipment should contain, how those components should interact and how the piece of equipment itself should behave.

As well as detailed equipment specifications, the G.805/G.809 model can be mapped into management information models using the equipment management functions specified in G.7710, for example TMF MTNM<sup>1</sup> specifications TMF 513, TMF 608, TMF 814 and TMF MTOSI<sup>2</sup> TMF 517, TMF 608 and TMF 854. Management information models are considered important by network operators (and management standardisation organisations such as the TMF) because they formally define and describe the reference points that the operator's OSS system must interact with in order to manage a piece of transport equipment (and ultimately the transport network itself).

Other ITU-T Recommendations related to the G.805 model include G.808.1 which defines the generic functional models, characteristics and processes associated with various linear protection schemes for connection-oriented layer networks and G.8080 which describes the reference architecture for the control plane of the Automatically Switched Optical Network (ASON).

Therefore there is a set of generic ITU-T Recommendations describing the different aspects of transport networks: functional architecture (G.805/G.809), equipment specification (G.806), equipment management functions (G.7710), protection (G.808.1) and control plane (G.8080). This paper will only deal with the first of these the G.805/G.809 architecture model.

Throughout this paper the reader should remember that the G.805 and G.809 models and their architectural components and functions can be viewed at any level of abstraction, so a single architectural component can represent several different 'real world' components depending on the level of abstraction that is used, which allows a small set of fundamental building blocks to be used to describe any layer network, while allowing the user to only have to describe the parts of a layer network that are of interest. This paper will try and introduce each architectural component at its lowest level of abstraction, as the lowest level of abstraction is thought to be the easiest for the reader to understand. Higher levels of abstraction will be introduced throughout this paper to further explain some concepts and constructs as required. The G.805 model will be introduced first and then the differences between the G.805 and G.809 models will be explained.

It should be noted that there is not always a direct correlation (or mapping) between a given networking concept that the reader is likely to be familiar with and a G.805 or G.809 construct. In these cases some 'artistic licence' or 'liberty' has been taken by the author in order to avoid introducing too much complexity at too early a stage in the paper. The cases where the author has taken a 'liberty' will be clearly highlighted within the text. In general the analogies drawn should not be taken too literally as they are intended to aid the reader to rapidly grasp the concepts and constructs of G.805 and G.809. The analogies drawn in this paper are not intended to be interpreted as rigorous mappings between different sets of terminology.

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<sup>1</sup> Multi-Technology Network Management.

<sup>2</sup> Multi-Technology Operations System Interface.

Throughout this paper any general networking concepts that the reader should be familiar with are written in inverted comments (for example ‘node’). Any G.805 architectural components or constructs are preceded by either the term “G.805” or “G.809” as appropriate. Within the diagrams used in the paper, G.805 or G.809 constructs are depicted in red if they are being used for the first time otherwise they are depicted in black. The G.805 and G.809 models do not attribute any special meanings to different colours and this convention is purely to aid the reader in identifying which G.805 and G.809 constructs have already been introduced and which constructs are new to the reader.

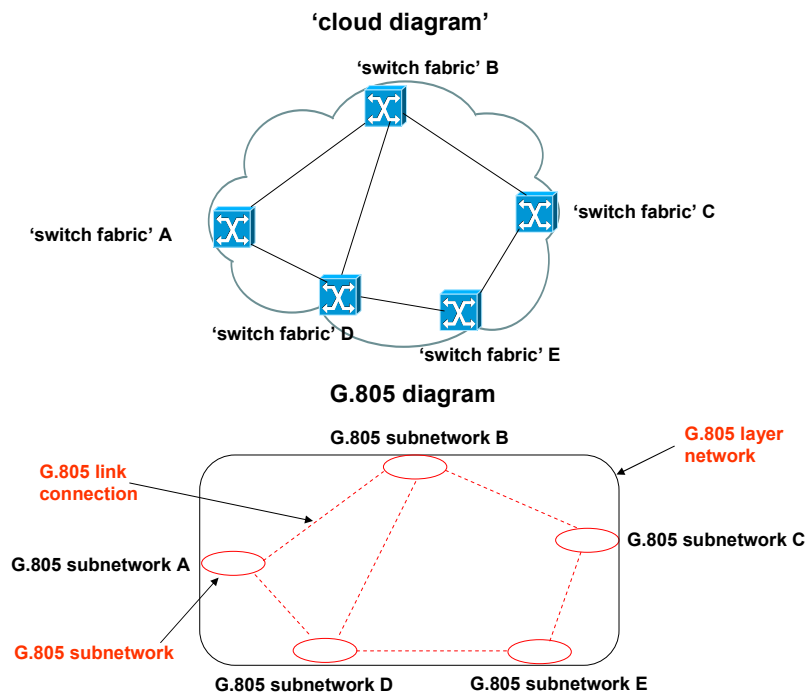
### **Basic G.805 concepts and constructs**

A transport network can be described and modelled using a small number of architectural components and functions. G.805 describes the architectural components and functions required to model connection-orientated networks (for example SDH or ATM) and G.809 describes the architectural components and functions required to model connectionless technologies (for example IP).

Readers should be familiar with the concept that a telecommunications network generally consists of a set of ‘nodes’ which are interconnected by ‘links’. Each ‘node’ can be decomposed into one or more ‘switching fabrics’ where a ‘switching fabric’ is used to interconnect a set of input ‘ports’ to a set of output ‘ports’.

At its lowest level of abstraction a G.805 subnetwork represents a 'switching fabric' within a 'node' within a layer network. The connectivity between two G.805 subnetworks is described by a G.805 link that represents a GMPLS 'link bundle'. A G.805 link contains one or more G.805 link connections that represent a 'link' between two G.805 subnetworks (between two 'switching fabrics').

Figure 1 below shows a layer network described using a ‘cloud diagram’ (assuming each ‘node’ only contains a single ‘switch fabric’) and underneath it the same layer network (with the same topology) is described in terms of G.805 subnetworks and G.805 link connections using the diagrammatic conventions of G.805.



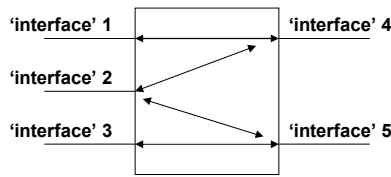
**Figure 1: Introducing G.805 subnetworks & G.805 link connections**

A subnetwork can be used to represent a higher level of abstraction in which case it represents a set of (contained) subnetworks and the G.805 links that interconnect them. At its highest level of abstraction a G.805 subnetwork represents an entire layer network (equivalent to a ‘network cloud’). In between its lowest and highest levels of abstraction a G.805 subnetwork can be used to represent the allowed connectivity without exposing the details of how that connectivity is achieved. This demonstrates one of the advantages to the G.805 and G.809 models, namely that they allow the user to model a transport network (or multiple transport networks) at whichever level of abstraction is required or most appropriate.

G.805 ports exist along the boundary (edge) of a G.805 subnetwork. A G.805 port is either the output of a G.805 link connection or the input to a G.805 link connection. A G.805 link connection transfers information between G.805 ports. At its lowest level of abstraction a G.805 port can be thought of as an ‘interface’ attached to a ‘switching fabric’ (a G.805 subnetwork). A G.805 subnetwork connection represents an information flow across a G.805 subnetwork between two G.805 ports within that G.805 subnetwork. At its lowest level of abstraction a G.805 subnetwork connection represents an internal information flow between two ‘interfaces’ attached to a ‘switching fabric’.

Figure 2 below shows a single ‘switching fabric’ and the allowed bi-directional connectivity between its different ‘ports’. Below it the same ‘switching fabric’ is described in terms of G.805 ports, G.805 subnetwork connections and G.805 subnetworks using the diagrammatic conventions of G.805.

### 'interface' connectivity within a 'switching fabric'



### G.805 equivalent using G.805 ports & G.805 subnetwork connections

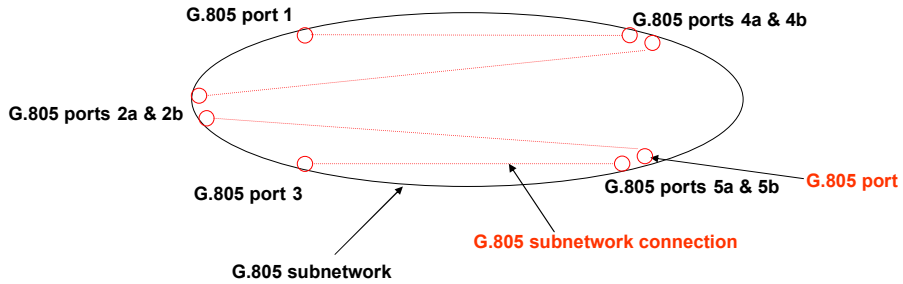


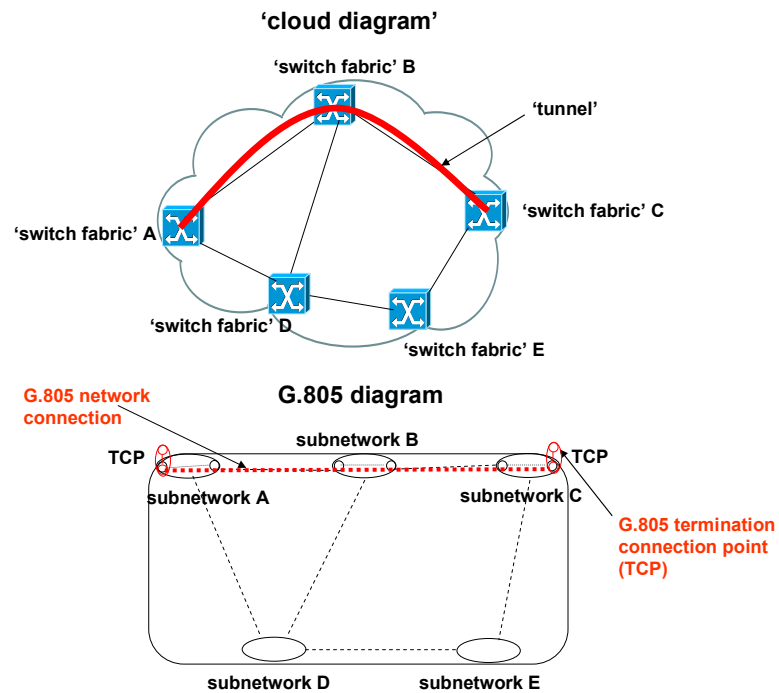
Figure 2: G.805 ports & G.805 subnetwork connections

*Note: A G.805 port must only be associated with a single G.805 link connection which, in turn, must only be associated with a single G.805 subnetwork connection, therefore an 'interface' may map to multiple G.805 ports as shown in Figure 2. There is no G.805 construct that can be directly mapped to the concept of an 'interface', however mapping an 'interface' to a G.805 port is a useful analogy in order to illustrate that G.805 subnetwork connections provide internal connectivity across G.805 subnetworks in the same way that internal 'switch fabric links' provide connectivity between 'switch fabric interfaces'.*

A G.805 reference point is an architectural construct which binds the inputs and outputs of G.805 processing functions. G.805 uses several types of reference point and each one is given a specific name depending on its function.

A G.805 network connection is formed from a concatenation of G.805 subnetwork connections and/or G.805 link connections. A G.805 network connection transparently transfers information across a layer network. It is delimited by a pair of G.805 reference points called G.805 Termination Connection Points (TCPs). A G.805 network connection can be thought of as a 'tunnel' (or a 'VC' or an 'LSP') across a layer network, where such a 'tunnel' (G.805 network connection) traverses a concatenation of G.805 subnetwork connections ('links' across G.805 subnetworks) and G.805 link connections ('links' between G.805 subnetworks) in order to traverse a layer network.

Figure 3 below shows a layer network consisting of several G.805 subnetworks interconnected by G.805 link connections. A G.805 network connection is shown including its component G.805 link connections and G.805 subnetwork connections. Above it, the same layer network (with the same topology) is also described using a 'cloud diagram'.

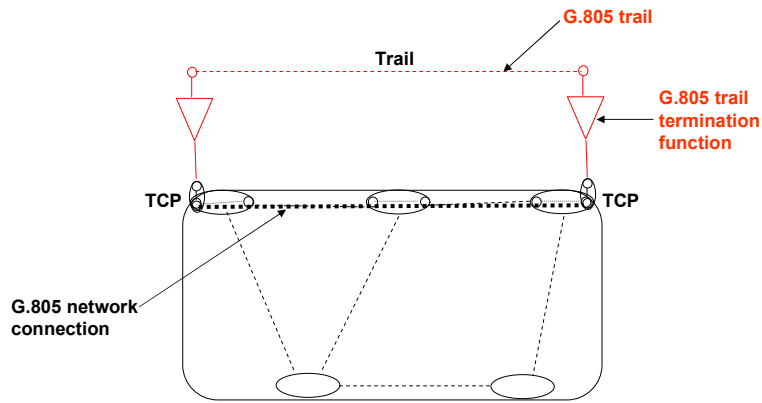


**Figure 3: G.805 network connections & G.805 termination connection points (TCPs)**

A G.805 trail is a construct that supports a monitored information flow between two G.805 termination connection points which are at either end of a G.805 network connection. A G.805 trail is delimited by a pair of G.805 trail termination functions. A G.805 trail represents the generic characteristics of a whole class of transport entities including transmission paths and transmission sections and is formed by associating a pair of G.805 trail termination functions with the G.805 termination connection points of a G.805 network connection.

A G.805 network connection transparently transfers information between a pair of G.805 termination connection points. A G.805 trail uses that G.805 network connection but also monitors the integrity and validity of the information flow from the input to the output of that G.805 network connection. A G.805 trail can be thought of as a G.805 network connection with OAM monitoring capabilities.

Figure 4 below shows the same layer network (with the same topology) as Figure 3 above with a G.805 trail formed by associating a pair of G.805 trail termination functions with the G.805 network connection shown in Figure 3.



**Figure 4: G.805 trails & G.805 trail termination functions**

### **Adaptation and Client/Server relationships**

G.805 Characteristic Information (CI) is a signal with a specific format, which is transferred on G.805 network connections. The specific formats of G.805 characteristic information depends on the network technology used.

A G.805 trail in one layer network (the server layer network) is used to support a G.805 link connection in a higher layer network (the client layer network). In order for this to be possible the G.805 characteristic information of the client layer network must be adapted ('encapsulated') in the format expected by the server layer network. This adaptation ('encapsulation') is performed by a G.805 adaptation function in the server layer. The reference point that binds a G.805 adaptation function to a G.805 trail termination function is known as a G.805 access point (AP).

Figure 5 below shows two ATM switches at either end of an ATM 'network cloud'. The 'link' between the two ATM switches is transported over a SDH layer network (for example a VC-4 layer network). Below this the same scenario is shown using the diagrammatic conventions of G.805.

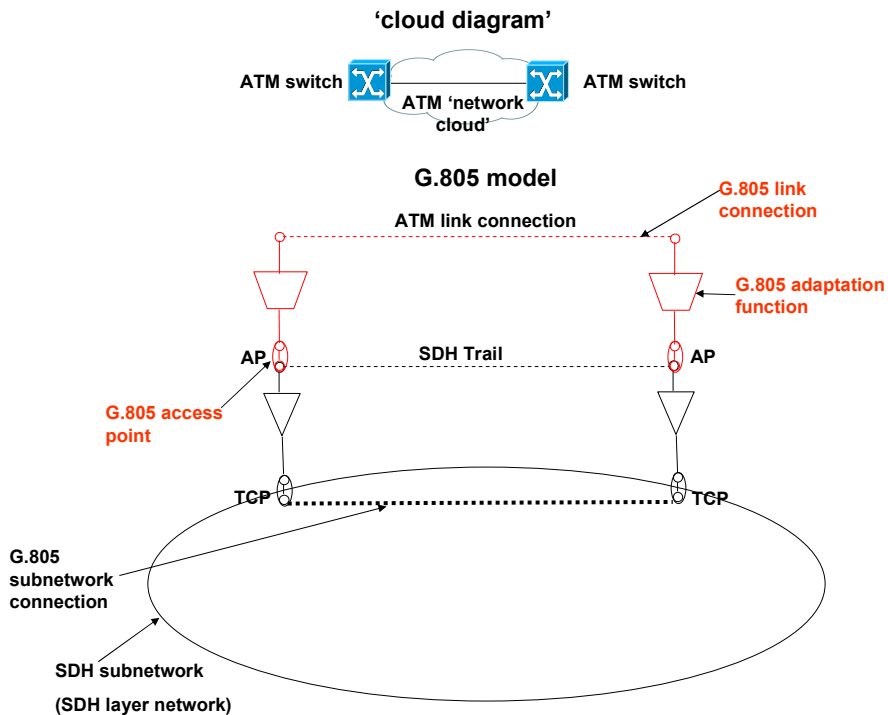


Figure 5: G.805 link connections, G.805 adaptation functions & G.805 access points (APs)

In Figure 5 above the SDH subnetwork (the SDH layer network) at the bottom of the G.805 diagram is shown at its highest level of abstraction (i.e. as a single subnetwork), and therefore at this level of abstraction what was previously shown as a G.805 network connection is now shown as a G.805 subnetwork connection. G.805 allows us to model the SDH layer network at a lower level of abstraction if we desire, and therefore also show the SDH 'switching fabrics' (as G.805 subnetworks), the G.805 link connections between SDH 'switches fabrics' and the G.805 subnetwork connections internal to each SDH 'switch fabric' as shown in Figure 6 below.

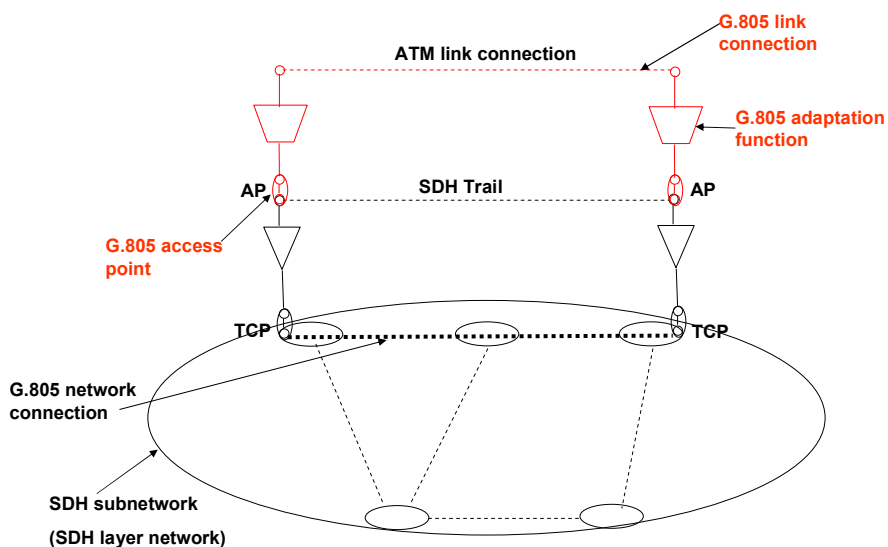


Figure 6: Figure 5 with the SDH layer network modelled at a lower level of abstraction

Again, this demonstrates how the G.805 model allows the user to model a transport network (or multiple transport networks) at whichever level of abstraction is required or most appropriate.

A G.805 client/server relationship is the association between layer networks that is performed by a G.805 adaptation function to allow the G.805 link connection in the client layer network to be supported by a G.805 trail in the server layer network.

A G.805 link represents a 'link bundle' and models the aggregation of several G.805 link connections that all share the same properties. For example all the G.805 link connections within a single G.805 link may terminate on the same G.805 subnetworks or they may belong to the same shared risk group, etc. A single G.805 link may contain one or more G.805 link connections. A single G.805 link is supported by one or more G.805 trails and a single G.805 trail may support one or more G.805 links.

A G.805 access point (AP) is the reference point at which the interlayer client/server relationship is defined and it is where the externally visible addresses of the server layer are located. From the server layer's viewpoint, a G.805 access point (AP) is a routing destination that may support a trail. From the client layer's viewpoint, a G.805 access point (AP) represents a point at which it is possible to procure link capacity. This means that the G.805 adaptation function of the G.805 client/server relationship sits in between the client and server layers, however it is conventionally considered to 'belong' to the server layer from a management and control viewpoint.

The G.805 (and the G.809) model includes the concept of client/server recursion i.e. one layer network can be the client of another layer network ad infinitum<sup>3</sup> in order to create a 'layer network stack'.

## **Multiplexing**

Often several client layer networks are multiplexed onto a single server layer trail. For example several ATM VCs may be multiplexed onto a single SDH trail.

Figure 7 below shows two ATM VP link connections being multiplexed onto a single SDH layer network (for example a VC-4 layer network) using the diagrammatic conventions of G.805.

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<sup>3</sup> In theory at least.

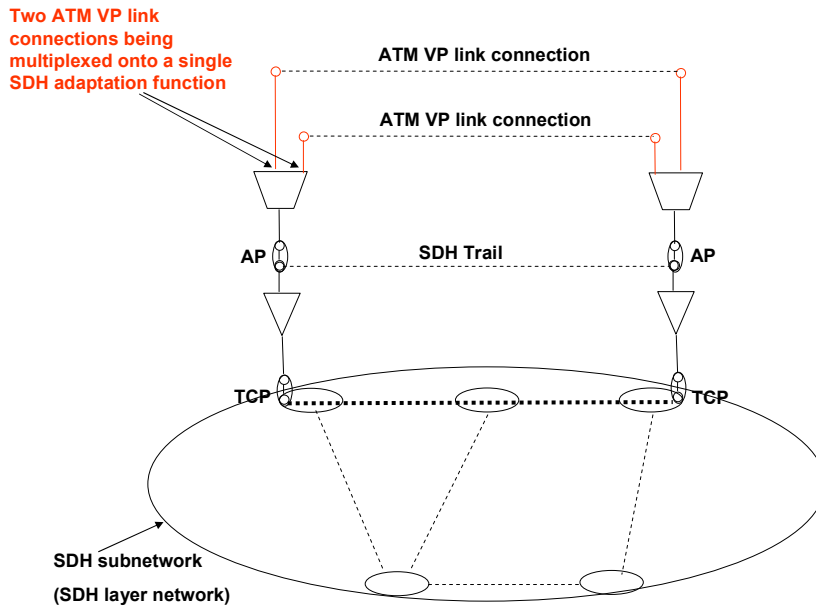


Figure 7: G.805 multiplexing

### More complex examples of G.805 models

G.805 allows any layer network topology to be modelled at any level of abstraction, and to illustrate this several examples are depicted in the figures below.

Figure 8 below shows three ATM switches interconnected by 'links' (G.805 link connections) across two ATM 'network clouds' (G.805 layer networks). The 'links' (G.805 link connections) between the ATM switches are transported over two different SDH layer networks (for example two VC-4 layer networks). Below this the same scenario is shown using the diagrammatic conventions of G.805.

*Note: Although Figure 8 below shows both ATM link connections being transported over SDH layer networks, in reality each ATM link connection could be transported over a different server layer network technology. So for example, the left hand ATM link connection could be transported over an SDH VC-4 layer network and the right hand ATM link connection could be transported over a PDH E4 layer network etc.*

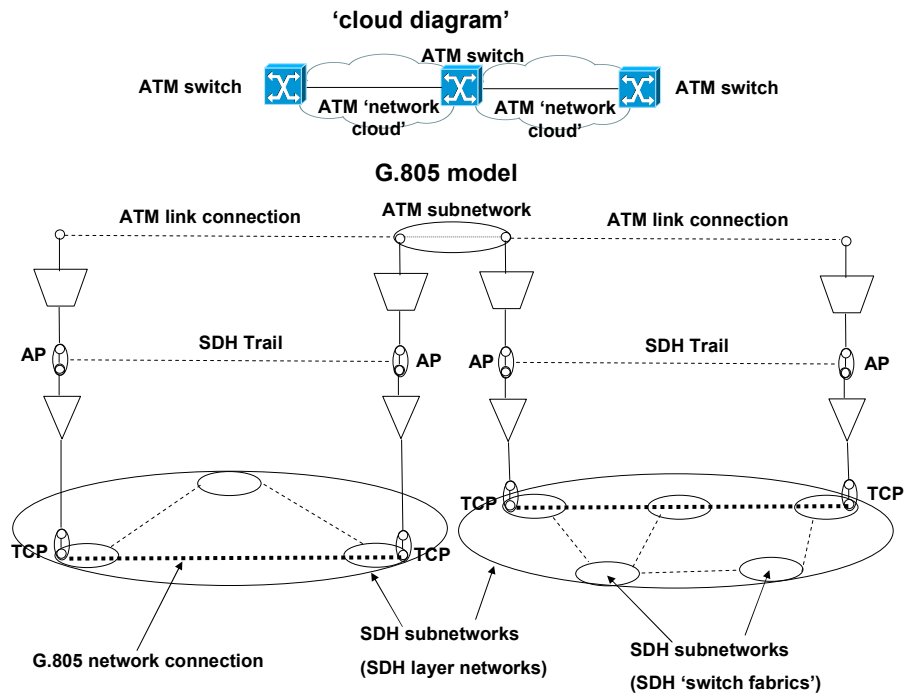


Figure 8: Two ATM link connections supported by two different SDH layer networks

Figure 9 below shows the same three ATM switches as Figure 8 above interconnected by 'links' across two ATM 'network clouds'. However, the 'links' between the ATM switches are transported over the same SDH layer network (for example a VC-4 layer network). Below this the same scenario is shown using the diagrammatic conventions of G.805.

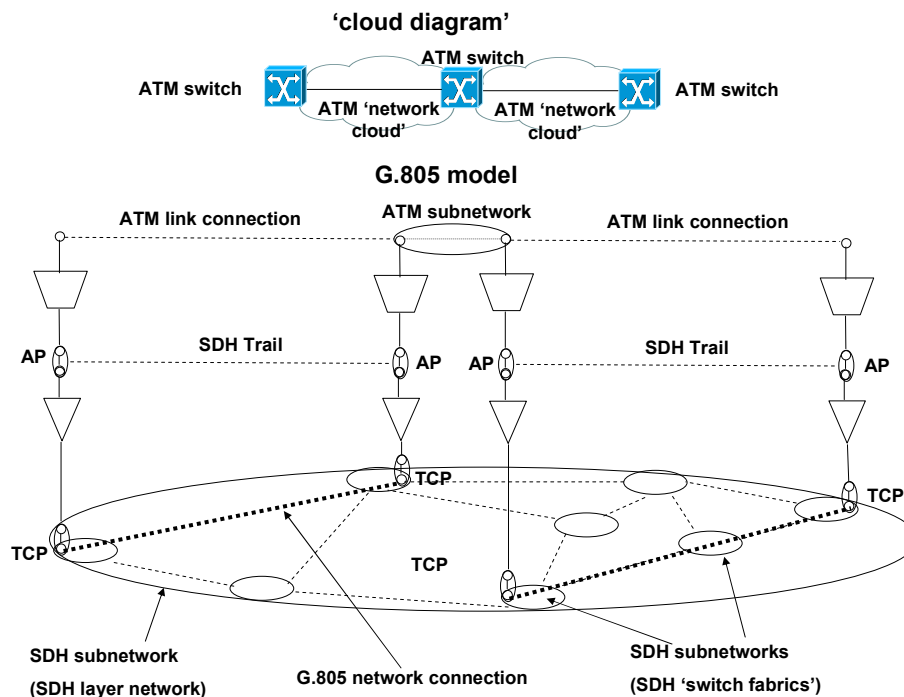
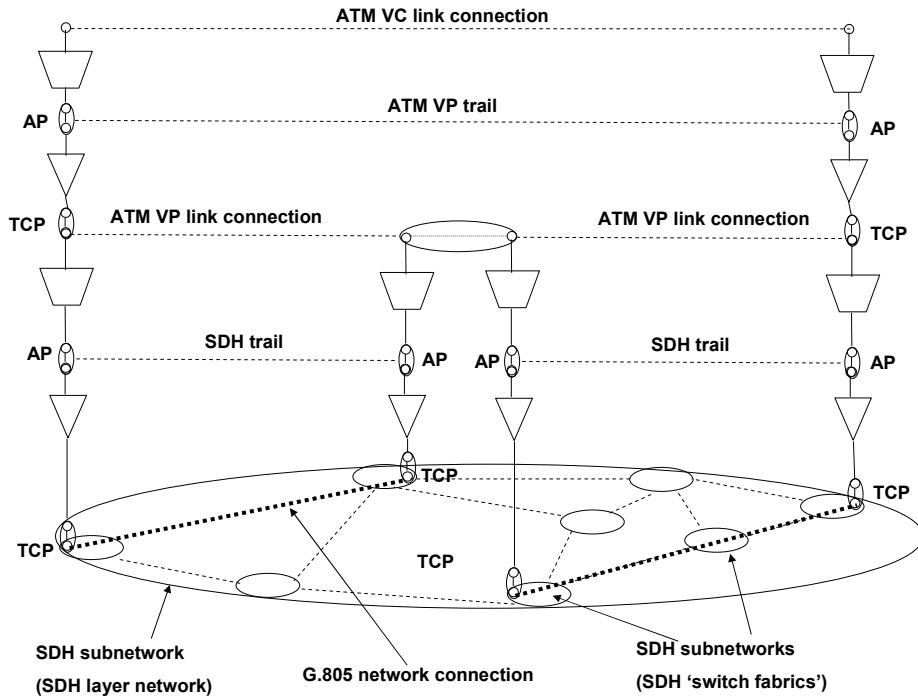


Figure 9: Two ATM link connections supported by the same SDH layer network

Figure 10 below shows the same ATM and SDH layer network topologies as Figure 9 above, however it shows how an ATM VC link connection is supported by an ATM VP trail which in turn is supported by the two ATM VP link connections shown in Figure 9 above.



**Figure 10: An ATM VC link connection supported by an ATM VP trail**

### Additional G.805 constructs and definitions

This section outlines and defines several G.805 terms that are not referenced directly in the sections above but are either commonly used or are more specific incarnations of terms used in the sections above.

G.805 Adapted Information (AI) is a signal with a specific format, which is transferred on G.805 trails. The specific formats of G.805 adapted information depends on the networking technology used.

A G.805 port represents either: the output of a G.805 link connection, the input to a G.805 link connection, the output of a G.805 trail termination source, or the input to a G.805 trail termination sink.

A G.805 trail termination source function is a G.805 trail termination function which accepts adapted G.805 characteristic information from a client layer network at its input, adds information to allow the G.805 trail to be monitored and presents the characteristic information of the (server) layer network at its output.

A G.805 trail termination sink function is a G.805 function which accepts the characteristic information of the (server) layer network at its input, removes the

information related G.805 trail monitoring and presents the remaining information at its output.

A G.805 adaptation source function is a G.805 adaptation function which accepts client layer network G.805 characteristic information at its input and processes it to allow transfer over a G.805 trail (in the server layer network).

G.805 adaptation sink function is a G.805 adaptation function which presents the client layer network G.805 characteristic information at its output by processing the information presented at its input by the server layer network G.805 trail.

A G.805 access point (AP) is a G.805 reference point where the output of a G.805 adaptation source function is bound to the input of a G.805 trail termination source function, or where the output of a G.805 trail termination sink function is bound to the input of a G.805 adaptation sink function.

G.805 connection is a G.805 construct which transfers information transparently from an input to an output. G.805 uses several types of connection and each one is given a specific name depending on its function. Examples include a G.805 network connection, a G.805 link connection and a G.805 subnetwork connection.

A G.805 connection point (CP) is a G.805 reference point where the output of one G.805 connection is bound to the input of another G.805 connection.

A G.805 termination connection point (TCP) is a G.805 reference point where the output of a G.805 trail termination source function is bound to the input of a G.805 connection, or where the output of a G.805 connection is bound to the input of a trail termination sink function.

A G.805 access group is a group of co-located G.805 trail termination functions that are connection to the same G.805 subnetwork or G.805 link.

A G.805 link is a construct which describes a fixed relationship between a G.805 subnetwork or G.805 access group and a different G.805 subnetwork or G.805 access group. A G.805 link is supported by one or more already instantiated G.805 trails in one or more lower (server) layer networks.

### **Unidirectional and bi-directional G.805 constructs**

This paper refers in places to G.805 connections, G.805 connection points (CPs), G.805 ports, G.805 termination connection points (TCPs) and G.805 trails. However the constructs referred to in this paper are, strictly speaking, unidirectional G.805 connections, unidirectional G.805 connection points (CPs), unidirectional G.805 ports, unidirectional G.805 termination connection points (TCPs) and unidirectional G.805 trails. The term unidirectional has been omitted to try and avoid unnecessary confusion and complexity when describing unfamiliar G.805 constructs and functions.

In general, a G.805 connection is bi-directional (and has common routing) and consists of an associated pair of unidirectional G.805 connections, a G.805 connection

point (CP) is bi-directional and consists of a pair of co-located unidirectional G.805 connection points (CPs), a G.805 port is bi-directional and consists of a pair of unidirectional G.805 ports, a G.805 termination connection point (TCP) is bi-directional and consists of pair of co-located unidirectional G.805 termination connection points (TCPs) and a G.805 trail is bi-directional and consists of an associated pair of unidirectional G.805 trails capable of simultaneously transferring information in opposite directions between their respective inputs and outputs.

### **G.809 constructs and their relationship to G.805 constructs**

G.805 provides useful generic methods for modelling and describing connection orientated transport layer networks from a functional and structural architecture perspective. Central to the description of connection orientated networks is the concept of a connection. However, such a construct is inappropriate for the description of a connectionless network. Consequently it is necessary to replace the concepts of a connection and a connection point as defined in G.805 with new architectural constructs. G.809 defines such architectural components for modelling and describing connectionless networks from a functional and structural architecture perspective.

The description of connection-orientated layer networks in G.805 assumes that the default for information transfer is bi-directional whereas information transfer in a connectionless layer network is always unidirectional.

Whereas G.805 uses the concept of a connection, G.809 introduces the concept of a flow. A G.809 flow is an aggregation of one or more traffic units with an element of common routing. A flow has the following properties:

- It is a unidirectional entity.
- A flow can contain another flow. This is recursive until, for example, the limit of a single traffic unit is reached.
- Flows can be multiplexed together in the same layer network.
- Flows can be multiplexed together as part of adaptation to a server layer network.
- A flow can be associated with one or more topological entities.
- A flow can be defined in terms of a parameter such as its characteristic information, the address to which traffic units are directed or the address the traffic units have come from.
- The aggregation of traffic units may be spatial or temporal.

Once the concept of a G.809 flow is understood G.805 architectural constructs can be easily mapped to their G.809 equivalents (when describing connectionless layer networks) according to the mappings provided in following table. Any G.805 constructs not listed in the following table remain the same for both G.805 and G.809 (i.e. they remain the same regardless of whether it is a connection-orientated or connectionless network that is being described).

<b>G.805 construct</b>	<b>Equivalent G.809 construct</b>
Unidirectional connection	Flow

Unidirectional connection point	Flow point (FP)
Link	Flow point pool link
Link connection	Link flow
Network connection	Network flow
Subnetwork	Flow domain
Subnetwork connection	Flow domain flow
Unidirectional termination connection point (TCP)	Termination flow point (TFP)
Trail	Connectionless trail
Trail termination	Flow termination
Trail termination sink	Flow termination sink
Trail termination source	Flow termination source

Figure 11 below shows two IP routers at either end of an IP ‘network cloud’. The ‘link’ (G.809 link flow) between the two IP routers is transported over a SDH layer network (for example a VC-4 layer network). Below this the same scenario is shown using the diagrammatic conventions of G.809 (for the connectionless IP layer network) and the diagrammatic conventions of G.805 (for the connection-orientated SDH layer network).

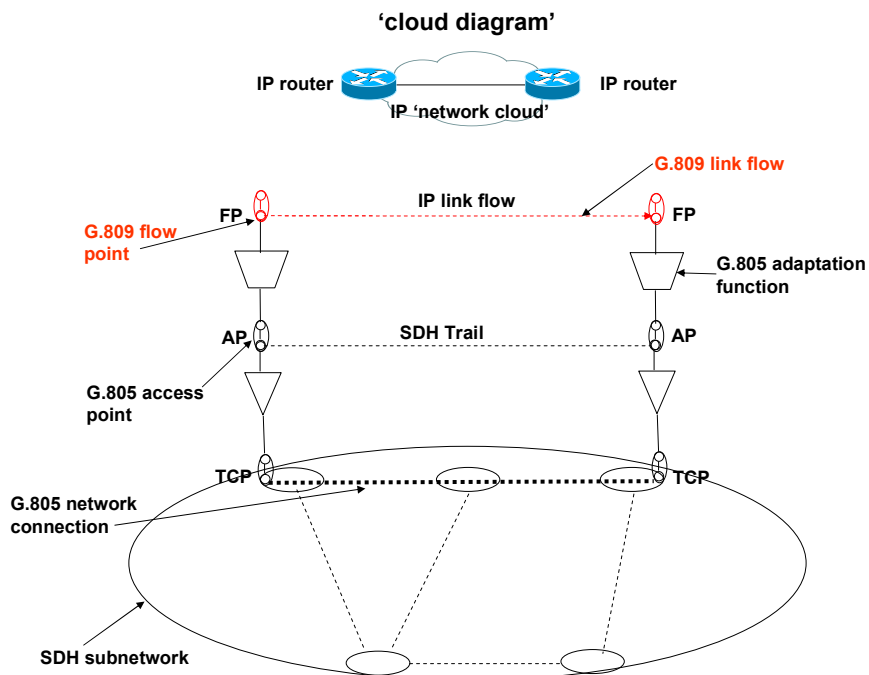


Figure 11: G.809 link flows & G.809 flow points

Figure 12 below shows three IP routers interconnected by ‘links’ (G.809 link flows) across two IP ‘network clouds’. The ‘links’ (G.809 link flows) between the IP routers are transported over the same SDH layer network (for example a VC-4 layer network). An IP ‘tunnel’ (a client layer G.809 link flow) is supported by the two IP link flows (i.e. the ‘network stack’ is IP in IP over SDH).

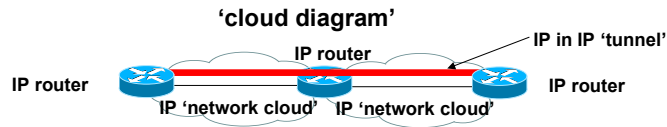


Figure 12: 'Cloud diagram' showing an IP in IP 'tunnel' across three IP routers

Figure 13 below shows the same scenario as Figure 12 but using the diagrammatic conventions of G.809 (for the connectionless IP layer networks) and G.805 (for the connection orientated SDH layer network).

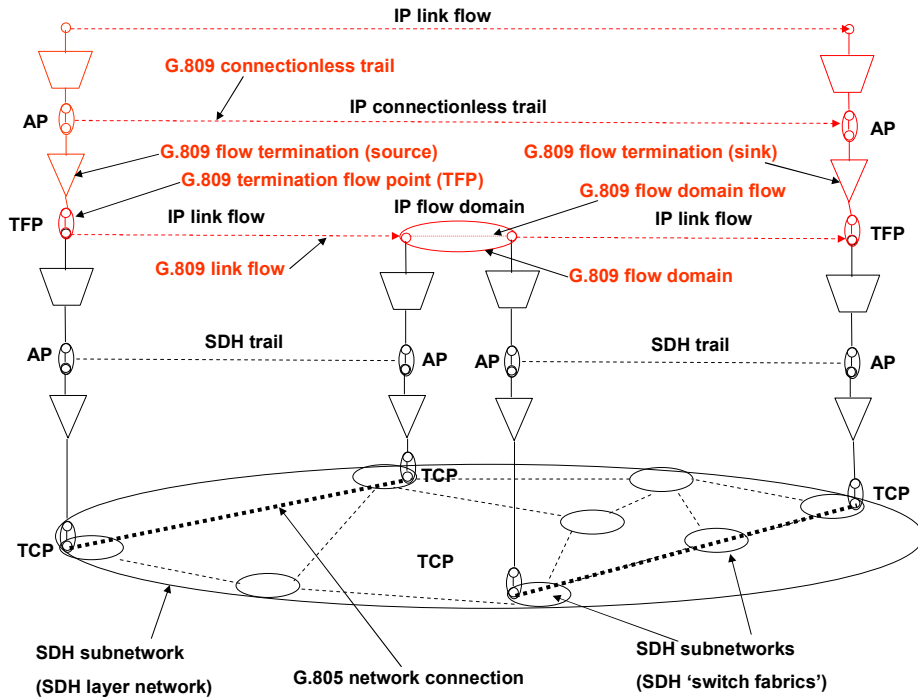


Figure 13: A G.805 & G.809 model of Figure 12

### Clarity through functional architecture

The previous sections of this paper have introduced various G.805 and G.809 constructs and shown how they can be used to describe and draw networks. This section will briefly show how functional architecture can also be used to describe and draw networks with a level of precision and clarity that is not possible using cloud diagrams alone. The example given in this section is not prescriptive, there are many examples of how functional architecture can be used to describe and draw networks with a precision and clarity that cannot be reproduced by other methods. In addition, the G.805 and G.809 models can also be mapped into detailed equipment specifications as well as management information models. Other methods of describing and drawing networks cannot easily be mapped into detailed equipment specifications and management information models in the way that G.805 and G.809 diagrams can.

Figure 14 shows a commonly depicted interworking scenario. Two ATM layer networks are separated by an MPLS layer network and PE1 and PE2 provide ATM-MPLS and MPLS-ATM interworking respectively.

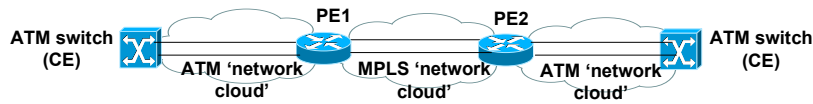


Figure 14: An ATM-MPLS interworking scenario

Figure 14 alone is not sufficient to precisely describe the interworking scenario that is taking place. For example it is not clear from Figure 14 alone whether the interworking scenario being depicted is ‘network interworking’ (i.e. a G.805 client/server relationship) or whether the interworking scenario being depicted is ‘service interworking’ (i.e. G.805 peer partition interworking). Figure 15 shows a G.805 functional model that describes the ‘network interworking’ scenario that Figure 14 may represent.

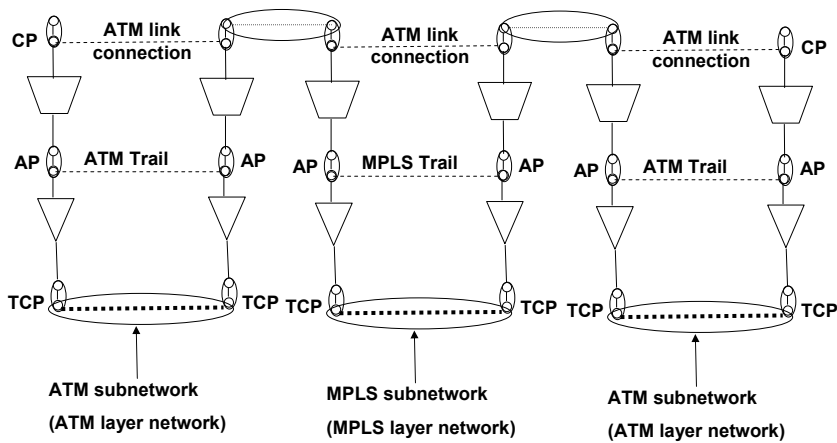


Figure 15: G.805 model of the ‘network interworking’ scenario that Figure 14 may represent

Figure 16 shows a G.805 functional model that describes the ‘service interworking’ scenario that Figure 14 may represent.

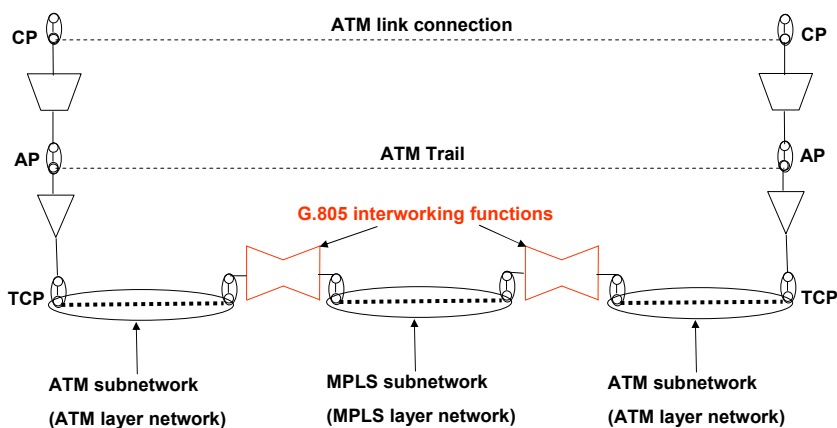


Figure 16: G.805 model of the ‘service interworking’ scenario that Figure 14 may represent

As can be clearly seen from comparing Figure 15 and Figure 16, the two possible scenarios that Figure 14 may represent are very different and the precision and clarity offered by the G.805 and the G.809 functional models clearly highlights the differences between the two possible interworking scenarios that Figure 14 may represent.

## **Conclusions**

Functional architecture in general and ITU-T Recommendations G.805 and G.809 in particular provide significant advantages over less formal and rigorous methods of modelling and describing layer networks. G.805 and G.809 are particularly useful for network inventory and management as the complete network view can be modelled from the optical fibres in the duct right up to the services running over the top of them (including all the layer networks in between).

In addition to providing a model for describing layer networks (and their layering and interactions), the G.805 and G.809 models can also be mapped into detailed equipment specifications as well as management information models. Detailed equipment specifications are considered important by equipment manufacturers as they provide a detailed formal specification of what components a piece of transport equipment should contain and how those components should interact and how the piece of equipment itself should behave. Management information models are considered important by network operators (and management standardisation organisations such as the TMF) because they formally define and describe the reference points that the operator's OSS system must interact with in order to manage a piece of transport equipment (and ultimately the transport network itself).

Finally, the author believes that a good understanding of functional modelling enables those working in the telecommunications industry to better architect layer networks, networking equipment and management systems. Functional modelling also enables those working in the telecommunications industry to better understand any possible consequences of architectural decisions and to more easily identify possible unintended architectural violations.

## **Bibliography**

Text from the following documents and books was used as the basis for some of the normative text in this paper.

*ITU-T Recommendation G.805 (2000), Generic functional architecture of transport networks*

*ITU-T Recommendation G.809 (2003), Functional architecture of connectionless layer networks*

*ITU-T Recommendation Y.1314 (2005), Virtual Private Network functional decomposition*

*Broadband Networking: ATM, SONET, and SDH, Mike Sexton & Andy Reid, Artech House, 1997, ISBN 0-89006-578-0*

The following ITU-T Recommendations contain the functional architecture for various networking technologies. Readers that are familiar with the details of these technologies may find that reading the relevant ITU-T Recommendation and comparing the functional models to their knowledge of that network technology may further aid their understanding of functional architecture.

*ITU-T Recommendation G.803 (2000), Architecture of transport networks based on the synchronous digital hierarchy (SDH)*

*ITU-T Recommendation G.8010/Y.1306 (2004), Architecture of Ethernet Layer Networks*

*ITU-T Recommendation G.8110/Y.1370 (2005), MPLS layer network architecture*

*ITU-T Recommendation I.326 (2003), Functional architecture of transport networks based on ATM*

The following ITU-T Recommendations contain examples of how functional modelling can be used to create detailed equipment specifications.

*ITU-T Recommendation G.806 (2004), Characteristics of transport equipment - Description methodology and generic functionality*

*ITU-T Recommendation G.763 (2004), Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks*

*ITU-T Recommendation I.732 (2000), Functional characteristics of ATM equipment*

The following ITU-T Recommendations and TMF specifications contain examples of how functional modelling can be used to create management information models.

*ITU-T Recommendation G.7710/Y.1701 (2001), Common equipment management function requirements*

*TMF513 V3.0, Multi-Technology Network Management Business Agreement, NML-EML Interface*

*TMF608 V3.0, Multi-Technology Network Management Information Agreement, NML-EML Interface*

*TMF814 V3.0, Multi-Technology Network Management Solution Set*

The following ITU-T Recommendations are related to the G.805 model

*ITU-T Recommendation G.808.1 (2003), Generic protection switching – Linear trail and subnetwork protection*

*ITU-T Recommendation G.8080/Y.1304 (2001), Architecture for the automatically switched optical network (ASON)*

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### **Biography**

Benjamin Niven-Jenkins is currently working for BT as a Network Architect. He graduated with a B.Sc (Hons.) in Computer Science and Software Engineering from the University of Birmingham, England. He is currently involved researching and standardising next generation network technologies and architectures.